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7. Abstract

Jumper connectors are used in the Hanford site for remotely connecting jumper pipe lines in the radioactive zones. The jumper pipes are used for transporting radioactive fluids and hazardous chemicals. This report evaluates the adequacy and the integrity of the 2-, 3-, and 4-in. single-port integral seal block (ISB) jumper connector assemblies, as well as the three-way 2-in. configuration. The evaluation considers limiting forces from the piping to the nozzle. A stress evaluation of the jumper components (hook, hook pin, operating screw, nozzle and nozzle flange, and block) under operational (pressure, thermal, dead weight, and axial torquing of the jumper) and seismic loading is addressed in the report.

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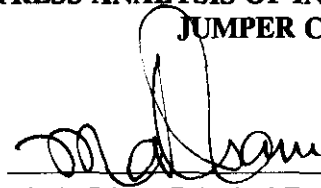
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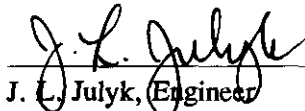
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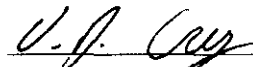
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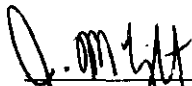
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TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Stress Analysis of ISB Jumper Connectors

Authors M. A. Islam, J. L. Jolyk, and E. O. Weiner

Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

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DESCRIPTION OF ANALYSIS:

The elastic static analysis performed on Dec. 1, 1994 was a system model of the jumper using BEAM4 elements for the components and MATRIX27 element for the interface element used in the interaction of the screw with the block top.

The elastic static analysis performed on Oct. 20, 1994 was a 2D model of the 2-in. hook using PLANE82 elements to determine the static deflection of the hook under axial loading.

The plastic static analysis performed on Jan. 12, 1995 was a axisymmetric screw/block interaction model using SOLID42 elements for the screw and block and CONTACT48 elements for the screw/block surfaces in contact.

The elastic static analysis performed on March 10, 1995 were 3D solid models of the Integral Seal Block (ISB) for the 2-, 3-, and 4-in. jumpers. SOLID72 elements were used for the block structure while BEAM4 elements were used to transfer loads to the block at the pipe opening.

The plastic static analysis performed on April 12, 1995 was an axisymmetric 3-way block/insert interaction model using SOLID42 elements for the screw and block and CONTACT12 elements for the surfaces in contact.

SIGNATURE OF ANALYSTS *E.O. Weiner & J.L. Julyk* DATE *5/18/95*

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STRESS ANALYSIS OF INTEGRAL SEAL BLOCK (ISB) JUMPER CONNECTORS

1.0 INTRODUCTION

This report evaluates the adequacy and the integrity of the 2-, 3-, and 4-in. standard (single-port) integral seal block (ISB) jumper connector assemblies, as well as the three-way 2-in. assembly when subjected to operating and various service conditions. The evaluation also determines and provides limiting loads from the piping to the nozzle. Jumper connectors are used in conjunction with the jumper piping to remotely connect nozzles in valve pits, hot cells etc. The jumper pipes are part of the systems used for transporting radioactive and hazardous wastes for storage or processing.

The jumper design currently in use at the Hanford site and other Department of Energy (DOE) sites is referred to as the Plutonium-Uranium Extraction Plant (PUREX) connector. The proposed connectors for the Multi-Function Waste Tank Facility (MWTF) will be similar to the design of the PUREX type connectors except for a change in the nozzle material and a redesign of the seal between the block and the nozzle. The change in the nozzle material is compatible with the operating environment and the radioactive and hazardous wastes being transported. The block and the nozzle of the jumper connector assembly are analyzed to the American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME 1989), Section VIII, Division 2 code, while the remaining components are analyzed to the American Institute of Steel Construction (AISC 1989) code.

The connector assemblies will be used in various piping systems for the MWTF project. The piping systems are classified as either safety class 2 or 3. The use of ASME Section VIII herein for the analysis of the block and nozzle in a safety class 2 assembly is appropriate. Of all the load categories used in this analysis, the seismic acceleration is the only one dependent on the safety classifications in Hanford Plant Standards SDC-4.1 (DOE-RL, 1993). As described in Section 5.4, the seismic load based on the self-weight of the assembly and the seismic acceleration for any safety class is insignificant. Seismic accelerations corresponding to safety classifications will have more influence in the reaction load values in the jumper piping system stress analysis. The reaction loads are called the external piping loads applied to the connector assembly. They are the combined applicable piping design loads in each of the six (6) basic loading components. Since the external loads used in this report do not distinguish the contributory seismic load with respect to safety class, specifying a safety class in this report may mislead some readers. Basically, this analysis can be used for any safety class as long as the acceptable piping reactions herein are satisfied. Additionally, if this analysis is used for safety class 1 assembly, the minor differences between ASME Section VIII and III with respect to materials and allowables shall be reconciled for the evaluation of the block and nozzle. However, there may be other functions to be maintained regardless of safety class, e.g., as required by the Functional Design Criteria, and they would have to be addressed. The MWTF/W236A project does not require the assembly for a no-leakage safety function during and after a Design Basis Earthquake (DBE.) Therefore, the no-leak function is not addressed in this evaluation. For other projects or DOE sites that plan to use the ISB design and require no leakage during and after a DBE, the connector assembly would have to be seismically qualified for operability and maintain a leak tight configuration.

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Two previous analyses (WHC, 1992) and (WHC, 1993) were conducted for PUREX standard connector assemblies with axial loading only. The first report considers a 2-in. assembly, and the second considers 3-in. and 4-in. assemblies as well. The current analysis covers 2-in., 3-in. and 4-in. connectors and includes non-axial loading. In particular, external piping moments are treated with proper consideration of load paths through the assembly into the nozzle. The three-way assembly is also considered. Finite-element analysis is the basis for the evaluation. Spreadsheet and general mathematical PC programs were used extensively for miscellaneous analysis, data reduction and presentation.

2.0 JUMPER CONNECTOR ASSEMBLY

2.1 DESCRIPTION OF THE CONNECTOR ASSEMBLY

Figure 1 shows the different components of a standard 2-in. jumper connector assembly. Details for 3-in. and 4-in. connectors are similar to those of 2-in. connector assembly. Drawings of the connector assemblies are shown in the references (WHC 1992abc). The assembly consists of following parts:

- Three hooks placed 120 degrees apart. The hook opposite the pipe entrance is in the plane of the pipe axis.
- One operating screw with a nut specially designed to hold the hooks with pins.
- A block, which is the prime fluid-flow path, has an internal configuration in the form of a 90° elbow. The block is connected to the jumper piping by a full-penetration weld.
- The nozzle is not an integral part of the assembly, however, the assembly is connected to the nozzle flange by means of three hooks.
- The guide serves to control the closing of the hooks around the nozzle as the screw is tightened. In addition, a skirt (not shown) is connected to the guide with three pairs of tie bolts to form a cage around the block. Together, the skirt and block constrain the hooks to axial planes for alignment and ease of jumper piping installation.
- The gasket is installed in a recess in the block seating surface.

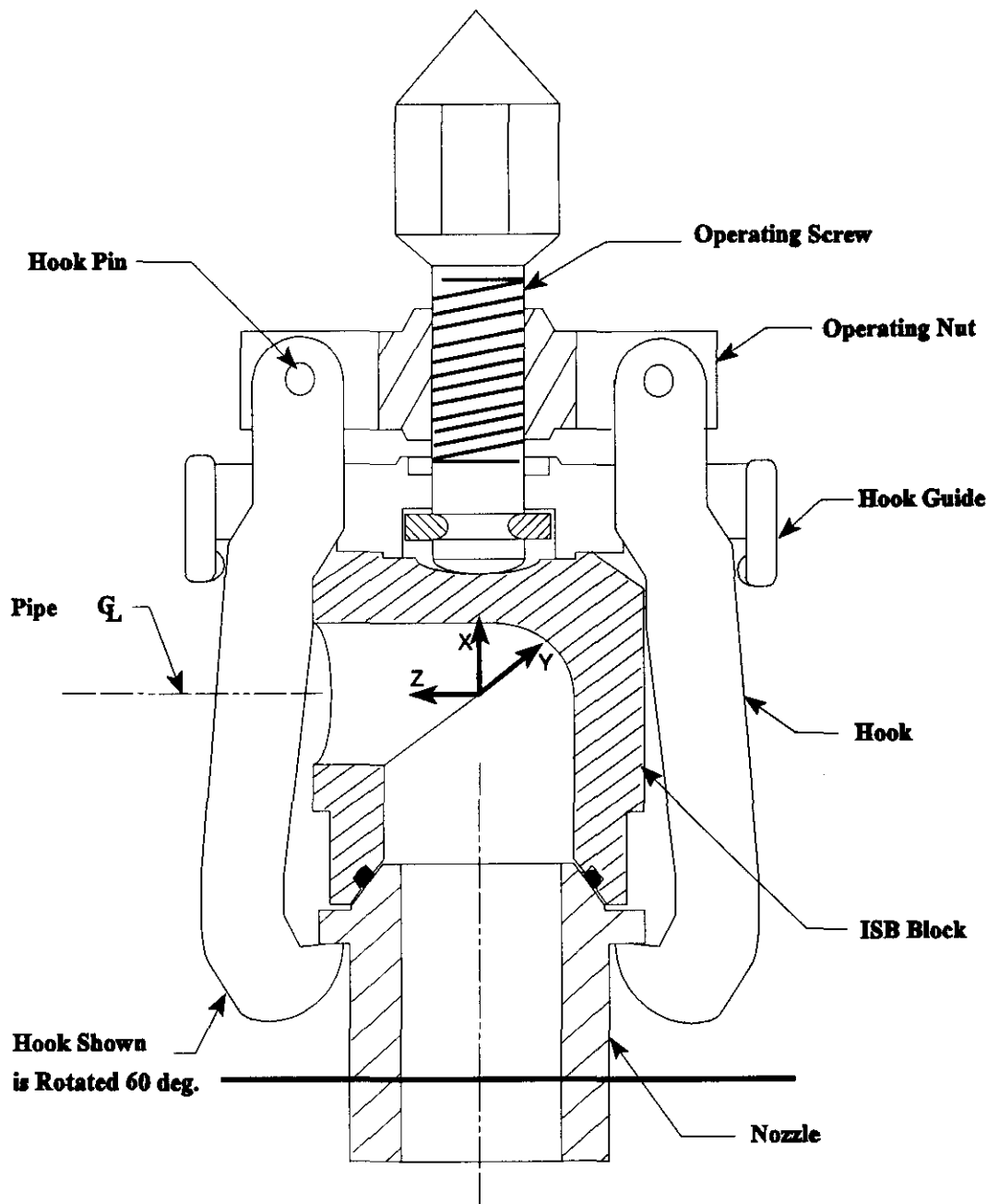
The three-way connector is similar to the standard 2-in. connector, except three 1/2 inch pipes are attached to the block, and three individual fluid flow paths in the block are connected to individual inserts in the nozzle. Each flow path has an insert-block interface consisting of a spherical contact surface and gasket configuration similar the nozzle-block interface of the standard configuration.

2.2 INSTALLATION OF THE CONNECTOR ASSEMBLY

The installation and operation of the connector assembly are as follows.

A full penetration weld connects the piping to the block. The whole assembly is then lifted and placed over the nozzle. Tightening the screw causes the hooks to close behind the flange of the nozzle. Once in this position, the operating screw is torqued further by means of a remotely operated torque wrench which is activated for a predetermined period of time. The torque wrench is rated for a specific maximum torque. By pulling back on the hooks, the torque produces a pre-load in the assembly serving as a seating force at the block-nozzle interface.

Figure 1. Standard Integral Seal Block (ISB) Jumper Connector Assembly.



3.0 SUMMARY OF RESULTS

With respect to pre-load torque loading, coverage of the integrity of all structural components extends only to the 50 ft-lbf pre-load torque. Other loadings consist of the design pressure of 400 lbf/in², the design temperature of 250 °F and external piping forces and moments. Acceptable piping forces and moments were determined in this analysis and should be checked with reactions from future jumper piping analyses. Maximum allowable torques were also considered for the block integrity and seating forces.

3.1 STANDARD CONFIGURATION

Piping

Nominal limiting forces at the interface of the piping and the block for all three jumper connector assemblies are provided in Table 3.1. These nominal loads are used to discuss the capacities of the connector assembly components treated in Appendix C. Except for the top region of the block with screw bearing effects, they do not pertain to the block. They do not reflect on the piping capacities; this analysis does not attest to the integrity of the piping. Components shown are with respect to a coordinate system with the Z-axis aligned with the pipe and the X-axis aligned with the connector axis. See Figure 1.

Block

Non-axial load analysis of the block showed that the balance of structural components essentially controlled with regard to all individual components of loading except axial force. Block stresses controlled the acceptable axial loads in Table 3.4. The analysis of the block is discussed in Section 5.5.1.

Nozzle Flange

Although the nozzle flanges cannot accept the full external piping loads of Table 3.1, they are stronger than the hooks unless the low carbon stainless steels are used. The calculations are given in Appendix B. Considerations of non-axial piping reactions are discussed below with the system model, and nozzle limitations are factored into Table 3.4.

Hook, Hook Pin, Operating Nut, and Screw

Capacities of the individual components are given in Table 3.2. These capacities apply only to axial loading on the connector and not to non-axial piping loads.

Seating forces for various pre-loads were obtained in Appendix B and are given in Table 3.3. These results include pressure and thermal loading effects in ideal conditions. They do not include external piping axial forces and cold springing due to misalignment and tolerance build-up from the jumper piping. Negative seating forces in the cold condition are the result of the pressure loading. Therefore, negative seating forces, attributable to pressurization, are found for some pre-loads. This might imply leakage. Testing should confirm or deny this.

System Model Results

A system model was developed to determine stresses in all structural components except the block from the non-axial external piping loads. These structural components include the block top region under the screw bearing point. Only the 50 lbf-ft pre-load torque was considered. Acceptable load components of the piping external forces and moments are factored into Table 3.4. In all cases, except for the axial force, the acceptable levels are limited by the strength of the hook eyes under the condition of tight clearances between the pin and hook which transmits lateral hook moments to the pin. Further discussion is provided in Section 5.5.5, and suggestions for further work that could increase the allowable loads is given in Section 6.1.

The system model also provides stiffnesses, given in Table 3.5, for the connector assemblies under the external piping load components. They could be used by the piping analyst to calculate spring stiffnesses for the piping model to provide relief in the calculation of actual reactions. It is recommended that the piping model have a rigid link from the piping attachment point to the center of the spherical block-nozzle interface, and that the stiffnesses be used at this point. In this case, the lateral stiffnesses K_{uy} and K_{uz} may be taken as rigid.

Acceptable External Piping Loads

Actual axial piping forces (with respect to the connector) should be checked against limits in Tables 3.3 and 3.4 for unseating and seating limits, respectively. Any combination of the remaining five components of loading is acceptable if the absolute sum of ratios of the applied force/moment components of shear, torsion and bending to the limit values of Table 3.4. is less than unity. The two components of shear force or bending moment should be combined with a circular interaction rule by forming the square root of the sum of the squares.

Acceptable loads of Table 3.4 do not reflect the 1/3 increase in allowable stresses permitted in Section 1.5.6 of (AISC, 1989) for wind and seismic loads. Thus, jumper piping analysis reactions based on seismic loading could be compared with values of Table 3.4 increased by 1/3 provided that analysis reactions based on the non-seismic loadings compare favorably with the table as shown.

An example is provided by the worst case in a preliminary study of MWTF jumper piping provided in Appendix F. At pressure and temperature and with forces referenced to the intersection of the pipe and block centerlines, the piping analysis force and moment components are:

$f_x = -114$ lbf $f_y = 419$ lbf $f_z = 237$ lbf
 $m_x = -7$ ft-lbf $m_y = -58$ ft-lbf $m_z = 173$ ft-lbf
Connector size = 2 in.
Pre-load torque = 50 ft-lbf.
Temperature = 250 °F

Figure 1 provides the coordinate system for interpretation of the components. Then the axial force is checked as follows:

Seating: $f_x = -114$ lbf, $F_x = 7,370$ lbf (Table 3.4), $-f_x < F_x$, OK
Unseat: $f_x < 0$, no check necessary.

The interaction of shear, torsion and bending is formed by comparing the applied values with the limits of Table 3.4 and summing:

Shear: $f_{yz} = \sqrt{f_y^2 + f_z^2} = \sqrt{419^2 + 237^2} = 482 \text{ ft-lbf}$

Torsion: $|m_x| = 7 \text{ ft-lbf}$

Bending: $m_{yz} = \sqrt{m_y^2 + m_z^2} = \sqrt{58^2 + 173^2} = 182 \text{ ft-lbf}$

$$I = f_{yz}/F_{yz} + |m_x|/M_x + m_{yz}/M_{yz} = 482/1330 + 7/260 + 182/365 = 0.90 \text{ OK}$$

Note that the unseating axial force limit is dependent on pre-load, pressure and temperature. For example, if the axial load is positive, it tends to unseat the block. At 4,000 lbf in a cold condition with a 2-in. connector, Table 3.3 shows a 3,390 lbf limit indicating that the condition is unacceptable. Such axial forces are unlikely under piping thermal expansion environments at temperature. Axial piping forces which tend to increase the seating force need not be checked against Table 3.3. All axial forces are to be checked against the limits of Table 3.4.

Table 3.1. Nominal System Model Piping Reaction Loads.

Connector Size	F _x (lbf)	F _y (lbf)	F _z (lbf)	M _x (ft-lbf)	M _y (ft-lbf)	M _z (ft-lbf)
2-in.	2,300	1,000	400	1,600	1,600	2,000
3-in.	15,000	2,000	2,000	7,000	7,000	4,000
4-in.	27,000	3,000	3,000	13,000	13,000	7,000

Table 3.2. Axial Load Capacities of the Supporting Components (One Hook).

Component	Material	2 in. (lbf)	3 in. (lbf)	4 in. (lbf)	Remarks
Hook	ASTM A 747 Grade CB7Cu-1 or CB7Cu-2, H1075 Ht. Tr.	5,943	8,750	12,717	See App. A
Hook Pin	As required by Table 4.1	14,420	24,930	35,400	See App. C
Operating Nut	ASTM A 148	9,705	14,669	27,580	See App. A
Operating Screw	ASTM A 193 Grade B7 C.S.	19,442	37,895	53,149	See App. A

Table 3.3. Seating Forces for Various Pre-loads ¹.

Connector Size	Torque (ft-lbf)	Cold (lbf)	Hot ² (lbf)
2-in.	50	3,390	9,160
	180	15,200	21,000
3-in.	50	-1,920	6,210
	490	20,600	28,700
4-in.	50	-4,310	6,310
	230	2,560	13,700

1. Internal pressure = 400 psi. Cold springing effects are not included.
2. Hot condition temperature = 250 °F

Table 3.4. Standard Connector Acceptable Piping Loads¹

Connector Size	Axial Force Fx ² (lbf)	Shear Fyz ⁴ (lbf)	Torsion Mx (ft-lbf)	Bending Myz (ft-lbf)
2-in.	7,370 ^{3,6}	1,330 ⁵	260	365 ⁵
3-in.	38,100 ^{3,7}	1,540	410	630
4-in.	42,100 ^{3,7}	2,220	780	1,170

1. Design pressure = 400 psi, temperature = 250 °F, pre-load torque = 50 ft-lbf. Acceptable loads do not reflect the 1/3 increase in allowable stresses permitted in Section 1.5.6 of (AISC, 1989) for wind and seismic loads.
2. To be limited by forces that would unseat the block nozzle interface per Table 3.3.
3. Limited by block analysis at the same design parameters.
4. Referenced to intersection of piping and connector centerlines.
5. Reduce by 25% for 304L/316L nozzle material.
6. Reduce by 35% for 304L/316L block material.
7. Reduce by 25% for 304L/316L block material.

Table 3.5. Connector Stiffnesses to Piping Reaction Loads (Standard Configuration).

Connector size ⁴	Kux ^{1,2} , lbf/in	Kuy ³ , lbf/in	Kuz ³ , lbf/in	Krotx, lbf-in/rad	Kroty, lbf-in/rad	Krotz, lbf-in/rad
2-in.	1.35e+7	2.78e+4	2.78e+4	7.38e+4	4.53e+5	4.53e+5
3-in.	1.90e+7	2.47e+4	2.47e+4	1.02e+5	9.16e+5	9.16e+5
4-in.	2.33e+7	2.52e+4	2.52e+4	2.09e+5	1.43e+6	1.43e+6

1. See ANSYS (1992) for notation. See Figure 1 for the coordinate system.
2. Applicable only for a positive seating force.
3. Kuy and Kuz should be taken as rigid provided that the piping model runs a rigid link from the pipe-block interface to the center of the spherical seating surface. This is the preferred modeling method.
4. Connector stiffnesses shown relate to flexibility between the pipe attachment and nozzle flange area. They do not account for the straight pipe flexibility from the nozzle flange area to the concrete or other anchor point. Applicable pre-load torque is 50 ft-lbf.

Conditions of Design

Since the hook-nozzle load application point was taken at the center of the flange overhang, validity of the analysis requires that a substantial majority, say 80%, of the maximum possible hook-flange contact area be achieved.

Connector Boundaries

Validity of the analysis herein extends from the pipe opening of the block to the flange of the nozzle. The applicable region of the analysis does not include the pipe and the weld attachment at the opening or the non-standard pipe between the nozzle flange and kick-plate or concrete embedment.

3.2 THREE-WAY CONFIGURATION

Acceptable Piping Reactions

As in the standard connector, acceptable piping reactions have been determined only for a pre-load torque of 50 lbf-ft.

Limits are placed on net piping loads to the block in order to guard against lift-off of the block from an insert. Such lift-off is characterized by pivoting of the block about the other two inserts or by sliding up an inclined plane. Net incoming piping moments and forces are limited by the equation

$$\frac{F_x + M_T/R}{F_{atm} - F_x} + \frac{M_o}{M_{olm} - F_x R/2} < 1$$

where

- F_{alm} = Limiting axial force = 7,330 lbf
- M_{olm} = Limiting overturning moment = 272 lbf-ft
- F_s = Net piping shear force referenced to nozzle pivot level at connector centerline
- M_T = Net torsional moment on connector from piping
- M_o = Net overturning (bending) moment on connector from piping
- F_x = Net axial load from piping, negative if tending to seat the block-insert interface
- R = Insert circle radius, = 0.75 inch = 0.0625 ft

Also,

$$M_T = |M_x| \quad F_s = \sqrt{F_y^2 + F_z^2} \quad M_o = \sqrt{M_y^2 + M_z^2}$$

$F_x, F_y, F_z, M_x, M_y, M_z$ = net forces and moments from piping. Each component is the algebraic sum of components from three pipes in the coordinate system of Figure 1.

The lift-off criterion implicitly places constraints on the axial piping force:

$$F_x < F_{alm} \quad F_x < 2M_{olm}/R$$

Additional limits are placed on net piping reactions considering stress limits on the connector inserts:

$$|F_x| < F_{xall} = 10,700 \text{ lbf} \quad F_s + M_T/R < 4,300 \text{ lbf}$$

Piping analyses should treat the three-way connector as rigid.

4.0 DESIGN ANALYSIS

4.1 DESIGN OBJECTIVES

The analysis of the 2-in., 3-in., and 4-in. jumper connector assemblies was performed to fulfill the following objectives:

- Determine the forces at the interface of the nozzle and the block for pre-determined pre-loads to the operating screw. The pre-load is the compressive force in the operating screw caused by the torque applied to the operating screw remotely by a pneumatic torque wrench.
- Demonstrate that the jumper connector assembly is adequate to withstand loads from torque, operating pressure, thermal expansion, and piping.

4.2 MATERIALS PROPERTIES AND ACCEPTANCE CRITERIA

The structural materials used for the Multi-Function Waste Tank Facility (MWTF) jumper connector assembly designs are similar to those used in the PUREX and HWVP type designs. The exception is the sealing device between the block and the nozzle. The PUREX type design uses a Teflon gasket installed with a retaining ring in the skirt. The MWTF type design uses an O-ring (see Figure 1 for details). The materials for each of the jumper connector assembly components are shown in Table 4.1 along with the associated structural properties at room temperature (70 °F) and at the elevated temperature of 250 °F if affected by the thermal gradient.

The analysis of the jumper assemblies herein does not include qualification with respect to material selection. None of the materials for the hook, pin and screw is found in the material section of the specifications in the AISC (1989) code.

Table 4.1. Material Properties of MWTF Jumper Connectors.

Component	Material	Yield strength (lbf/in ²)	Ultimate tensile strength (lbf/in ²)	% Elong.
Hook	ASTM A747, Grade CB7Cu-1 or CB7Cu-2, H1075 heat treat.	115,000. ¹	145,000	9
Hook Pin	Aermet 100 ⁴	110,000	124,000	12
Nozzle	ASTM A276, Grade 304 SS	30,000 24,000. ²	75,000 61,830. ²	40
Block	ASTM A276, Grade 304 SS	30,000. ³ 24,000. ²	75,000 61,830. ²	40
Operating screw	ASTM A193, Grade B7 CS	105,000	125,000	16
Operating nut	ASTM A148	60,000	90,000	20
Tie-bolts	ASTM A193, Grade B7 CS	105,000	125,000	16

1. Hanford Specification HSBP-0071, indicating a 132,000 lbf/in² ultimate tensile strength, implies a yield strength of 105,000 lbf/in² based on hardness. Results of the analysis herein is controlled by the yield strength of 115,000 lbf/in² shown above. Results for lower values should be scaled accordingly.
2. At temperature 250 °F (ORNL 1976).
3. Grade 316L and 304L material specifications show a yield strength of 25,000 lbf/in².
4. Ultimate and yield strengths shown are those used in the analysis. They are met by the Aermet 100 material. AerMet 100 alloy is produced by Carpenter Technology Corp., Reading , PA.

Attention is directed to the footnotes of Table 4.1 pointing out that applications with cast hooks or 316L and 304L blocks should use results herein scaled to the appropriate yield strength levels. Conclusions in this report should not be assumed applicable to these materials unless explicitly stated.

The pin material upon which this analysis is based has yet to be identified. The properties shown in Table 4.1 are based on a martensitic stainless steel tempered to the yield strength shown.

The American Institute of Steel Construction (AISC 1989) allowable stress criteria were used for analyzing components such as the hooks, hook pins, operating screw and nut, and tie-bolts. These allowables do not include the 1/3 increase permitted for wind and seismic loads. The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME 1989) Section VIII, Division 2, Appendix 1, Article 1-110 (design based on stress analysis), was used to analyze the pressure boundary components (nozzle and block). The ASME criteria utilizes allowable stresses based on the value of S_m , where S_m is defined in ASME Section VIII, Division 2, Appendix 4, Article 4-1 (ASME 1989) and is the least of the following:

- One-third of the specified minimum tensile strength at room temperature.
- One-third of the tensile strength at maximum temperature.

- Two-thirds of the specified minimum yield strength at room temperature.
- Two-thirds of the yield strength at maximum temperature, except for austenitic stainless steels and specific nonferrous materials, this factor may be as large as 90% of the yield strength at maximum temperature (but no to exceed 2/3 of the specified minimum yield strength at room temperature).

The 2/3 of the minimum yield strength value for 304 stainless steel controlled the S_m value used herein.

The allowable stresses for the hooks, hook pins, operating screw and nut, tie-bolt, block, and nozzle are shown in Table 4.2.

Table 4.2. Material Allowable Stresses Based on AISC and ASME Criteria.

Code:		ASME	AISC		
Component	Material	S_m (lb/in ²)	$0.75S_y$ (lb/in ²)	$0.60 S_y$ (lb/in ²)	$0.40 S_y$ (lb/in ²)
Hook	ASTM A747, Grade CB7Cu-1 or CB7Cu-2, H1075 Ht. Tr.	-	-	69,000	46,000
Hook Pins	Per min. yield/tensile strengths in Table 4.1	-	82,500	-	44,000
Nozzle	ASTM A276, Grade 304 SS	20,000	-	-	-
Block	ASTM A276, Grade 304 SS	20,000	-	-	-
Operating screw	ASTM A193, Grade B7 CS	-	-	63,000	42,000
Operating nut	ASTM A148	-	45,000	-	24000
Tie-bolts	ASTM A193, Grade B7 CS	-	-	63,000	42,000

4.3 DESIGN PARAMETERS

The following design parameters were considered in the structural analysis of the connector assembly. Pressure and temperature requirements are taken from MWTF Functional Design Criteria, Table 3 (WHC 1993a).

- Pressure:

Minimum = 20 psi
Maximum = 155 psi
Design = 400 psi

- **Temperature:**

Minimum = 70 °F
Maximum = 200 °F
Design = 250 °F
Rate of fluid temperature change = 50 °F/minute
Number of maximum temperature cycles = 3000.
- Torque versus force relationship was obtained from testing results (Squier 1993).
- All dimensions used in the analysis and ANSYS models were obtained from the drawings.

5.0 ANALYSIS OF CONNECTOR ASSEMBLY

This analysis does not include fatigue considerations nor does it include thermal shock effects. Both are considered negligible. Discussion herein is mainly devoted to the standard connector configuration. Discussion of the three-way connector is given in Section 5.6.

The jumper connector analysis is complex in nature, because of number of components, the gaps observed between components, friction considerations and the redundancy of load paths. The following sections describe the above items more in detail. Frequent references are made to the appendices in this section. The reader is cautioned that the coordinate systems used in the appendices differ from the one in the main body of this report shown in Figure 1.

5.1 LOAD PATH

Load sources include pre-load, internal pressure in the block, differential thermal expansion of the block and nozzle flange, and the piping reactions. Piping reactions from cold springing have not been included. While the block and nozzle are at operating temperature, the other components such as the hooks are assumed at room temperature. In the end, all the loads must be transmitted to the nozzle built in to the wall of the pit.

Axial loads (with respect to the connector axis) are transmitted to the nozzle in a rather simple way. The block is much stiffer than the hooks, so that most of the pressure load goes to relief of the seating force and little goes to the hooks. Pre-load and thermal expansion increase both the seating force and the hook loads.

The external piping loads present a much more complicated situation. Of course, the axial force is treated just like a pressure force. For the other components, two scenarios are considered.

- If the friction between the block and the nozzle is adequate, the block and the loading through the hooks is minimal. Almost all the loads from the piping are transferred to the nozzle directly as long as the pre-load in the block is not exceeded.
- If the friction between the block and the nozzle is not adequate, the block will rotate relative to the nozzle and screw in any combination of three directions. In this case, the load path on interest is through the hooks. There are two routes to the hooks: through the screw, nut and pins, and through the guide contacting the hooks.

Calculations in Appendix C show that no more than about 20% of the nominal (Table 3.1) piping reaction moments can be resisted by a typical 0.4 metal-to-metal friction coefficient at the block-nozzle interface. Consequently, it was considered improper to rely on friction for transmission of external piping moments from the block to the nozzle. The system model of Appendix C, with the kinematics of the hooks, pins, guide and screw-block interface, was developed to determine component stresses under the assumption of no block-nozzle friction. Neither of the two previous analyses (WHC 1992 and WHC 1993) appear to have considered non-axial loading. The only significant difference with the current configuration is that the previous ones employed Teflon seals which prevent metal-to-metal contact. They would be expected to have a substantially lower coefficient of friction at the interface as well as a lesser ability to transfer moment directly to the nozzle.

5.2 FRICTION

The static friction coefficient between the block and the nozzle (Type 304 SST to 304 SST) with a normal oxide film in air at 250 °F would be 0.4 or less. Substantially larger friction coefficients are achieved with true metal to metal contact. In general, debris and galling can break through the oxide giving true metal to metal contact. A wide range of friction coefficients should be expected. Considering piping bending moment loading, the bearing between the nozzle and the block might produce a sudden change in stiffness when static friction is overcome during load-up.

5.3 SEALING

Sealing between the nozzle and the connector assembly is primarily accomplished by maintaining compressive seating force at the block-nozzle interface which includes the O-ring gasket. The pre-load in the screw provides the initial compression for the O-ring gasket, and it is augmented by thermal expansion effects. This compression should not be overcome by internal pressure or axial loading from the piping. The axial piping force that would overcome seat compression is simply taken as the compressive force from pre-load torque and thermal effects. This is conservative and reasonable, because almost all the external axial piping force goes to the seating interface and not the hooks. Larger unseating axial forces would produce a net tensile force at the interface which invalidates the system model results and starts to open a gap between the nozzle and block. Although an O-ring seal may fill a small gap and still prevent leakage, a quantification of such effects was not attempted.

5.4 LOADS

- **Pre-load**

Pre-loads for all sizes of connectors are taken as those from (Squier, 1993) at a torque of 50 ft-lbf for consideration non-axial loading effects in Appendix C. Appendix B considers 50 ft-lbf and calculated maximum allowable torques for seating force calculations and certain block capacities. The piping load allowables shown in Table 3.4, however, are only valid for 50 ft-lbf pre-load torque.

- **Seismic loading**

The jumper connector assembly, when installed without piping and connected to a nozzle, has insignificant seismic forces compared to the piping reactions.

- **Thermal Loads**

The calculations are made with a temperature differential from 70 and 250 °F to include the effect of relative thermal expansion between the block and other structural paths such as the hooks.

- **Piping Loads**

These loads are developed as a result of pressure, dead load, differential thermal expansion of the jumper piping, and seismic motions. Cold springing effects are not considered.

- **Internal Pressure**

The design internal pressure was considered to be 400 psi in the analysis.

5.5 ANALYSIS

The block was analyzed with the ANSYS (1992) 5.0a finite element code using solids modelling tools. Details are given in Appendix B. All loadings were considered. Capacities of the hooks and nozzle flange with axial loading on the connector were evaluated with closed form solutions in Appendices A and B, respectively. Appendix G provides load stresses resulting from the nominal external piping load components. Here, a three-dimensional system model, consisting of beam elements, was developed with ANSYS for this purpose. Structural component capacities, including the block top region under the screw, were determined in Appendix C using capacity information from Appendix B. These capacities were compared with load stresses from all sources (Appendix G and B). Load stresses from the external piping loads came from the system model of Appendix G, while pre-load, thermal expansion and pressure stress information came from the closed form solutions of Appendix B. The analysis of each component is described separately in this section. All of the above-mentioned analyses are linear elastic.

5.5.1 Block

The analysis for the 2-, 3-, and 4-in. diameter Integral Seal Blocks (ISB) identified the stress levels of the block at different locations, as result of applied loading. The critical failure mode areas were:

- (1) The top of the block where the operating screw contacts the screw seat and causes plate bending in two directions.
- (2) The pipe connection opening where the pipe line and block connect causing localized yielding.
- (3) The bottom surface of the block where the block and nozzle interact causing the block to spread apart.

The requirement for acceptability of the block design is that the linearized stress intensities shall not exceed the specified allowable limits. These limits are based on the stress intensity classification found in ASME Section VIII, Division 2, Appendix 4, Table 4-120.1 (ASME 1989) and are given in Table 5.1 for the block analysis.

Table 5.1. Classification of Stress Intensities for Block Sections.

Location	Failure mode	Origin of Stress	Type of Stress	Classification	Stress Intensity Allowable Check
Top of block under operating screw	Punch Through of screw	Axial load from torque, thermal, internal pressure, and external load	General membrane and bending	P_m P_b	$P_m \leq S_m$ $P_m + P_b \leq 1.5S_m$
Near Pipe connection opening	Elastic yielding	External load, moment, and internal pressure	Local membrane and bending	P_L Q	$P_L \leq 1.5 S_m$ $P_L + P_b + Q \leq 3S_m$
Bottom of block at nozzle interface	Elastic yielding	External load, moment, and internal pressure	Local membrane, bending (outside), bending (inside), and General membrane (Hoop)	P_L P_b Q P_m	$P_L \leq 1.5 S_m$ $P_L + P_b \leq 1.5 S_m$ $P_L + P_b + Q \leq 3S_m$ $P_m < S_m$

A number of factors were considered that might affect the stress levels at the noted locations. It was determined that the full contact diameter of the operating screw should be used for the evaluation of the top of the block. The basis is a plastic analysis of the 2-in. block-top region using an axisymmetric model. The analysis found that the stresses in the top of the block, under the operating screw contact point, was sensitive to the footprint area. As the axial load increased, the footprint area increased to the diameter of the screw (see Appendix E). Under axial loading, a punch-through failure of the bottom surface of the top of the block would only occur when the entire screw was in contact with the block top surface. Therefore, the axial loads were applied to the top of the block/screw contact surface over the

diameter of the operating screw for the elastic analysis of the 2-, 3-, and 4-in. ISB block models (see Appendix B). The axial loading considered pre-load torques of 50 ft-lbf and maximum allowable torques, along with the forces required to resist axial thermal growth, and internal pressure loads.

Because jumpers typically do not experience a large number of severe thermal transients, the restrained thermal growth and internal pressure were conservatively considered as additive to the pre-load torques. Although temperature-dependent stresses, resulting from thermal expansion are normally classified as self-limiting and secondary, they are conservatively treated in this evaluation as load-controlled primary stresses.

The evaluation of the block at the pipe opening considered the influence of the axial loads (torque, thermal resistance, and internal pressure) along with the external piping loads. Assumed piping loads were considered as possible piping configurations under seismic, dead weight, and thermal expansion. Each external force and moment were applied separately in order to maximize the external loads applied to the block. Using the ASME criteria allowables, accounting for stressed conditions under pre-load torques and design condition loads, the maximum external piping loads were calculated at the pipe line opening from the linearized stress intensities found in Appendix B. The stresses induced into the block near the pipe connection are attributed to the discontinuities of the two surfaces, and the maximum linearized stress intensities were considered as localized and secondary stresses (ASME 1989).

The evaluation of the bottom section of the block under axial and external forces and moments considered that the stresses on the inner surface of the block were bearing stresses and treated them as localized and secondary stresses. However, the hoop component was considered as a generalized primary membrane stress.

The analysis shows stress levels of the block at the different locations as a result of various pre-load torque loadings. The areas of concern are located at the top of the block where the operating screw seats, at the pipe opening where the maximum external piping loads are applied, and at the bottom of the block where the block seats on the nozzle. The stress contours show some concentration around the locations of concern and were used as guidance for selecting paths through the thickness of the block for stress linearization and stress intensities. The linearized stress intensities were used with the ASME (1989) criteria, according to classification (see Table 5.1), to determine the maximum allowable piping loads that the block can withstand under operating conditions for external loads applied independently of each other. The applied forces and moments were scaled up or down with load fractions to accommodate the allowable stresses in the block. The maximum acceptable piping loads, applied individually, are derived and shown in Table 5.2 for the 50 ft-lbf pre-load torque case. The maximum acceptable piping loads at higher pre-load torques are contained in Appendix B. In terms of shear forces and moments, the loads of Table 5.2 are substantially higher than the acceptable loads to the remaining connector structural components. The axial force components of Table 5.2 control with respect to the overall connector. The interaction of this load with the other components is addressed in the system model effort of Appendix C. Maximum piping non-axial loads acceptable to the non-block structural components were assumed interacting with this load. The reduced acceptable axial load is thus considered independent of the other load components and entered into Table 3.4.

Table 5.2. Maximum Allowable External Piping Loads Acceptable to ISB Block.

Load Component	2-in. Connector	3-in. Connector	4-in. Connector
P_x , lbf	9,320	40,530	50,950
F_y , lbf	13,910	34,850	29,140
F_z , lbf	22,650	57,770	70,720
M_x , ft-lbf	1,320	6,440	8,440
M_y , ft-lbf	1,630	9,360	7,940
M_z , ft-lbf	2,440	11,210	13,920

The models of the ISB blocks consisted of tetrahedral solid elements (SOLID72) as the structural body and 3-D beams (BEAM4) which allow the external piping loads and moments to be transferred to the block structure from single point. The boundary conditions at the block and nozzle contact surface were considered as frictionless and constrained in the radial direction along the gasket line in the spherical block-nozzle interface. This allows the block to rotate in three directions about the center of the spherical seating surface. The surface at the top of the block and screw contact point was restrained against rotational motion around the X-axis. These restraints allow the block model to thermally expand axially with out restraint and expand radially at the bottom section of the block. The boundary conditions are valid for the axial loading effects in the top of the block under the operating screw. They do not reflect proper conditions for non-axial loading. Stresses in the block top region from non-axial loading were not evaluated in the block finite element analysis, and their effects are covered in Appendix C. It should be noted that the resistance to torsional loading on the block is entirely reacted in the model by the block-top boundary conditions. This does not imply that a realistically-rigid anchor is provided to the piping designer. The boundary condition served to demonstrate that the pipe entrance area could take almost all the remaining full nominal component values of external piping reaction. In reality, the block is likely to rotate considerably before building up resistance to torsion. The matter is dealt with in more detail in the system model.

A 2-D axisymmetric finite-element model was developed to determine the plastic behavior of the operating screw and block-top region under various axial loads. The model consisted of 2-D structural solids (PLANE42) as the structure of the block and screw and contact elements (CONTAC48) as the medium between the screw and the block. This model shows that the footprint area, for the applied axial loads, should be the full diameter of the operating screw. This full footprint was utilized in the evaluation of the top of the block for a punch-through failure mode. See Appendix E for details.

5.5.2 Nozzle Flange

The nozzle flange is stressed by the clamping forces in the hook. The analysis followed the procedure outlined in ASME Section VIII, Division 2, Appendix 3, Article 3-300 (ASME 1989). The results of the analysis indicate that the axial load capacities of the supporting components is not controlled by flange unless the low carbon stainless steels are used. Results of the analysis are included in

Appendix B. Since the load application point was taken at the center of the flange overhang, validity of the analysis requires that a substantial majority, say 80%, of the maximum possible hook-flange contact area be achieved.

5.5.3 Hook, Hook Pin, Operating Nut, Screw and Guide (Axial Loading)

A curved beam formula from Blake (1982) was used to obtain stresses in the hook for a given axial load to the connector. The method preserves the moment arm from the load line to the center of the hook section of interest. Appendix A has the details.

A standard four-point (Shigley, 1977) pin-clevis treatment of the pin produces overly conservative bending stresses in the pin, because deformation of the hook, pin and nut bearing surfaces result in significant shifting of opposite reactions toward one another. This leads to smaller moment arms and bending stresses. A procedure was found that accounts for the movement of the load points. Results in Appendix C show that the pins are stronger than the hooks under axial loading. Consideration of lateral bending moments developed in the hooks and transmitted to the pins required modification of the axial load capacities.

5.5.4 Piping

Nominal piping load are presented in Appendix F. They were derived by finite element analyses of piping systems and are likely to be substantially higher than what is expected from systems actually using the connectors.

5.5.5 System Model

A system model for the jumper clamp was constructed with ANSYS BEAM4 elements to determine how external pipe loads were carried to the nozzle and to provide load stresses for all components except the block sections already covered. Details of the system model are given in Appendix G. Load stresses from the system model are used in Appendix C to compare with capacities of the components.

The system model avoids gap and friction elements for expediency. Closing of gaps in the screw-nut-pin-hook and guide-hook interfaces is complex process for which simplifying assumptions are necessary. Given a pre-load, the load path through the screw, nut, pins and hooks is considered continuous except for rotations about the pin and screw axes. The hooks are assumed to slide in the radial guide slots without any restraint to rotation. With the pre-loads, the screw load path is considered active immediately. All results from the system model depend on a positive seating force at the block-nozzle interface.

The actual guide-hook interface has gaps such that the load path through that interface might activate at some point after external pipe loads are applied. Consequently, a model variation with two configurations, with and without the guide contacting the hook, was considered.

A MATRIX27 element was derived to provide lateral resistance between the screw and block top attributed to pre-load and the depression in which the screw bears. Both rolling (no-slip element) and free sliding (interface element with slip) conditions were derived and used as a second model variation. The

stresses from the pre-load itself not included in the system model, but it provides stability to the model by way of the interface element. A 5,000 lbf pre-load values was used with the element. This represents the 50 ft-lbf torque pre-load plus a little less than half of the thermal pre-load developed with all three sizes of connectors. The reduced thermal pre-load is conservative, since its effect is stabilizing. Full thermal pre-load need not be achieved, since the hooks could be at room temperature. The full thermal pre-load, however, is used conservatively in Appendix C to evaluate the structural component stresses.

Hook-pin moments were released for a third model variation to see if the high stresses developed in the pins could be relieved by increasing the pin-hook clearances. A moment based on eccentricity to the edge of the hook was still imposed on pins for capacity evaluation. At the nozzle, the hooks were pinned.

Loads of Table 3.1 are applied at the intersection of the pipe and block. They include gravity, thermal and seismic cases as given in Appendix F.

Appendix C distinguishes between the pin moment transmission and release variations in order to show the effects of clearances between the pin and hook. Otherwise, the worst stresses among the remaining two variations (guide active/inactive, block-screw rolling/slipping) were used for the capacity checks of Appendix C. The worst sign of loading is always used. Results for load components and model variations were dismissed if they produced very large displacements. Such displacements occur in some cases with the guide inactive. The large relative displacement between the guide and hook shows that the gap is taken up early in the loading process and that the guide-inactive case then has little meaning.

An initial effort, not reported herein, used a 77,000 lbf/in² yield stress for the pins along with an elastic section modulus for evaluation of bending stresses. This resulted in the pins controlling and producing very low acceptable loads. Since the pin bending moment capacity is less than the shear capacity, a plastic modulus was used in the currently reported effort. Additionally, a higher yield strength of 110,000 lbf/in² was employed. These improvements removed the pins from a controlling role.

Pin clearances, required to accept the full moment loads of Table 3.1 without binding the pin in the hook hole, are given in Table 5.4. The clearances are derived from relative rotations between the hook and pin given in Appendix G for the pin-moment-released variation. The clearances are clearly excessive for the connector design, since they form a significant part of the hook width or pin diameter. However, the full nominal loading is unlikely ever to be accepted. A reasonable moment load fraction, say 0.20, may result in an acceptable clearance as having an influence in the pin moment loading. Thus, in the actual configuration, the stresses in the pin are expected to be some mix of the two pin moment transmitted/released cases considered in Appendix G. Without further refinement, the worst case was considered for the summary of Table 3.4.

Table 5.3 gives the controlling load fractions from Appendix C for all components and each size connector and loading component along with the names of the associated structural components and controlling model variations. Along with the nominal loads of Table 3.1 and interaction considerations, these fractions (less the guide-block controlled values) were used to construct Table 3.4. The guide-block interface almost always controls, because of high bearing stresses that result from lateral loads being passed from the hooks to the guide and to the top of the block. The guide lip is typically only 0.02 in. high fitting into a 0.06-in. recess of the block top. Increases in the minimum step height are recommended in Section 6.2. This would probably eliminate the guide-block interface as a controlling source of stress. The guide-block interface, however, was dismissed as irrelevant to the acceptable loads of Table 3.4.

Reasons include the confinement of the bearing stresses, large friction forces that can be developed between the guide and block from thermal expansion effects, and a comparison of hook-guide clearances with travel noticed in guide-inactive model variations. For the tight-pin-clearance variation and all connector sizes, the hook eyes control the acceptable load fractions. The bending moment passed from the hook to the pin is largely responsible for the high stresses. For the case of loose pin clearances, the hook eye and pin generally fail to control, suggesting that a clearance can play an important role in the capacity of the connector to resist piping moments. After the guide-block interface and the hook eyes, various critical components such as the nozzle and hooks appear. The hook release condition (losing engagement force at the nozzle) appears as a contender in the 3-in. and 4-in. sizes, suggesting that larger pre-loads should be considered. In the case of the 2-in. connector, the nozzle flange strength becomes a contender. If 304L or 316L is used for the nozzle, it definitely controls as noted in Table 3.4. Being that the nozzle is probably the most difficult to replace, it is recommended that use of the low carbon stainless steels be carefully scrutinized.

Appendix C has capacity evaluations of the nut and screw which are substantially stronger than the pins, nozzle or hooks. Given lateral loads, the region of the block directly under the screw was analyzed in Appendix C as well as the guide-block interface which takes lateral loads transmitted from the hooks to the guide and block.

The AISC (1989) code was used for determining the allowable stresses in these components (aside from the block). Stresses from the system model were superimposed on the pre-load (for 50 ft-lbf torque), pressure and thermal stresses in Appendix C and compared with the capacities. The comparison was measured in terms of a load fraction defined as the acceptable fraction of each nominal external piping load component acting by itself in conjunction with the pre-load, pressure and thermal loads. The acceptable piping loads of Table 3.4 are obtained by multiplying the minimum load fractions, after consideration of interaction, with the load components of Table 3.1.

Interaction among the load fractions for the various load components is discussed in Appendix C along with interaction diagrams which provide a good picture of potentially controlling structural components. Basically, load components are divided into shear, bending and torsion, and the resultants interact linearly (the most conservative alternative). Within the shear and bending categories, the limits are chosen so that circular (SRSS) interaction of, say, the two bending components, produces a conservative result.

Considering each of the external piping load components, connector stiffnesses were determined from displacements taken directly from the stiffest kinematic variation in the system model. The stiffnesses are given in Table 3.5. If used in piping models, they would produce conservative piping reactions. Strictly speaking, the six stiffnesses are diagonal terms of a 6x6 stiffness matrix. The shear forces clearly produce rotations which indicate that the stiffness matrix has off-diagonal terms. These terms are not evaluated. It is recommended that the piping model employ a rigid link from the incoming-pipe end to the pivot center of the block-nozzle interface. Using the rotational stiffnesses between the pivot point and ground along with rigid translational restraints is considered appropriate for the pipe modeling.

Table 5.3. Component Load Fractions for Piping Loads

Connector Size: 2-in.

Fz	Cs Cmp	Fx	Cs Cmp	Fy	Cs Cmp	Mz	Cs Cmp	Mx	Cs Cmp	My	Cs Cmp
2.797	ASR GdBl	32.091	ANT BlTp	1.119	ASR GdBl	0.155	ASR GdBl	0.164	ANT HkC0	0.194	ASR GdBl
3.879	IST HkC1	58.069	ANT Noz1	1.395	IST HkC0	0.194	IST HkC0	0.164	ANT HkC1	0.269	IST HkC1
3.882	INR Scr	58.069	ANT Noz0	1.553	INR Scr	0.216	INR Scr	0.240	ANT HkB0	0.270	INR Scr
4.013	INR Noz0	92.896	ANT HkR1	1.854	INR Noz1	0.257	INR Noz1	0.240	ANT HkB1	0.279	INR Noz0
5.199	IST Pi1	92.896	ANT HkR0	2.057	IST Pi0	0.286	IST Pi0	0.242	ANT Pi0	0.361	IST Pi1
5.372	ASR HkB1	99.000	ANT HkA1	2.069	ASR HkB0	0.287	ASR HkB0	0.242	ANT Pi1	0.373	ASR HkB1
6.059	ASR BlTp	99.000	ANT HkB0	2.424	ASR BlTp	0.336	ASR BlTp	0.581	ANT HkA0	0.421	ASR BlTp
6.420	INR HkR0	99.000	ANT HkB1	2.503	IST HkC1	0.347	IST HkC1	0.581	ANT HkA1	0.446	INR HkR0
8.027	INR Noz1	99.000	ANT HkC0	2.885	IST Pi1	0.401	IST Pi1	99.000	ANT Noz0	0.557	INR Noz1
10.170	INR Pi0	99.000	ANT HkC1	2.965	INR HkR1	0.412	INR HkR1	99.000	ANT Noz1	0.706	INR Pi0
11.575	INR HkC0	99.000	ANT Pi0	3.099	ASR HkB1	0.430	ASR HkB1	99.000	ANT HkR0	0.804	INR HkC0
11.809	ASR HkA1	99.000	ANT Pi1	5.010	ASR HkA0	0.696	ASR HkA0	99.000	ANT HkR1	0.820	ASR HkA1
12.840	INR HkR1	99.000	ANT Scr	5.986	ASR HkA1	0.831	ASR HkA1	99.000	ANT Scr	0.891	INR HkR1
24.268	INR HkB0	99.000	ANT HkA0	99.000	ANT Noz0	99.000	ANT Noz0	99.000	ANT BlTp	1.685	INR HkB0
29.236	INR HkA0	99.000	ANT GdBl	99.000	ANT HkR0	99.000	ANT HkR0	99.000	ANT GdBl	2.030	INR HkA0

Components: HkRel Hook release from flange HkC0 Hook section C (at pin)
 HkA0 Hook section A (max. load offset) Pi0 Pin
 HkA1 0 = in-line with pipe Scr Screw
 HkB0 Hook section B (at guide) BlTp Block top
 HkB1 1 = 120 degr from pipe axis GdBl Guide-block lip
 Noz Nozzle flange

Coordinate systems: X - block/nozzle axis
 Z - pipe axis

Cases A Guide active N No-slip screw-block interface T Pin moments transmitted
 I Guide inactive S Slip screw-block interface R Pin moments released

Table 5.3. Component Load Fractions for Piping Loads (continued)

Connector Size: 3-in.

Fz	Cs Cmp	Fx	Cs Cmp	Fy	Cs Cmp	Mz	Cs Cmp	Mx	Cs Cmp	My	Cs Cmp
0.607	ASR GdBl	10.168	ANT BlTp	0.607	ASR GdBl	0.125	ASR GdBl	0.059	ANT HkCO	0.071	ASR GdBl
0.906	IST HkC1	21.427	ANT HkR1	0.810	IST HkCO	0.166	IST HkCO	0.059	ANT HkC1	0.106	IST HkC1
1.191	INR HkRO	21.427	ANT HkRO	1.375	INR HkR1	0.282	INR HkR1	0.108	ANT HkBO	0.140	INR HkRO
1.554	IST Pi1	32.495	ANT Noz1	1.478	IST HkC1	0.303	IST HkC1	0.108	ANT HkB1	0.182	IST Pi1
1.599	ASR BlTp	32.495	ANT Noz0	1.500	IST Pi0	0.308	IST Pi0	0.110	ANT Pi0	0.188	ASR BlTp
1.601	INR Scr	68.530	ANR HkC1	1.599	ASR BlTp	0.328	ASR BlTp	0.110	ANT Pi1	0.188	INR Scr
1.806	INR Noz0	68.532	ANR HkCO	1.601	INR Scr	0.329	INR Scr	0.323	ANT HkA0	0.212	INR Noz0
1.909	IST HkB1	73.757	ANR Pi1	1.867	IST HkBO	0.383	IST HkBO	0.323	ANT HkA1	0.224	IST HkB1
2.381	INR HkR1	73.759	ANR Pi0	2.085	INR Noz1	0.428	INR Noz1	99.000	ANT Noz0	0.279	INR HkR1
3.611	INR Noz1	99.000	ANT HkA1	2.232	IST Pi1	0.458	IST Pi1	99.000	ANT Noz1	0.424	INR Noz1
3.808	INR HkCO	99.000	ANT HkBO	2.693	IST HkB1	0.553	IST HkB1	99.000	ANT HkRO	0.447	INR HkCO
4.098	INR Pi0	99.000	ANT HkB1	5.571	IST HkA0	1.144	IST HkA0	99.000	ANT HkR1	0.481	INR Pi0
5.200	IST HkA1	99.000	ANT Scr	6.513	IST HkA1	1.337	IST HkA1	99.000	ANT Scr	0.610	IST HkA1
7.689	INR HkBO	99.000	ANT HkA0	99.000	ANT Noz0	99.000	ANT Noz0	99.000	ANT BlTp	0.902	INR HkBO
12.474	INR HkA0	99.000	ANT GdBl	99.000	ANT HkRO	99.000	ANT HkRO	99.000	ANT GdBl	1.464	INR HkA0

Components: HkRel Hook release from flange HkCO Hook section C (at pin)
HkA0 Hook section A (max. load offset) Pi0 Pin
HkA1 0 = in-line with pipe Scr Screw
HkBO Hook section B (at guide) BlTp Block top
HkB1 1 = 120 degr from pipe axis GdBl Guide-block lip
Noz Nozzle flange

Coordinate systems: X - block/nozzle axis
Z - pipe axis

Cases A Guide active N No-slip screw-block interface T Pin moments transmitted
I Guide inactive S Slip screw-block interface R Pin moments released

Table 5.3. Component Load Fractions for Piping Loads (continued)

Connector Size: 4-in.

Fz	Cs Cmp	Fx	Cs Cmp	Fy	Cs Cmp	Mz	Cs Cmp	Mx	Cs Cmp	My	Cs Cmp
0.401	ASR GdBl	7.605	ANT BLTp	0.401	ASR GdBl	0.090	ASR GdBl	0.060	ANT HkC0	0.049	ASR GdBl
0.872	IST HkC1	18.483	ANT HkR1	0.780	IST HkC0	0.176	IST HkC0	0.060	ANT HkC1	0.106	IST HkC1
0.960	INR HkR0	18.483	ANT HkR0	0.993	ASR BLTp	0.224	ASR BLTp	0.106	ANT Pi0	0.117	INR HkR0
0.993	ASR BLTp	33.599	ANT Noz1	1.109	INR HkR1	0.250	INR HkR1	0.106	ANT Pi1	0.121	ASR BLTp
1.387	INR Scr	33.599	ANT Noz0	1.387	INR Scr	0.313	INR Scr	0.108	ANT HkB0	0.168	INR Scr
1.443	IST Pi1	64.448	ANR HkC1	1.391	IST Pi0	0.314	IST Pi0	0.108	ANT HkB1	0.175	IST Pi1
1.578	ASR HkB1	64.449	ANR HkC0	1.420	IST HkC1	0.320	IST HkC1	0.372	ANT HkA0	0.192	ASR HkB1
1.746	INR Noz0	69.203	ANR Pi1	1.571	ASR HkB0	0.354	ASR HkB0	0.372	ANT HkA1	0.212	INR Noz0
1.920	INR HkR1	69.203	ANR Pi0	2.016	INR Noz1	0.455	INR Noz1	99.000	ANT Noz0	0.233	INR HkR1
3.348	INR HkC0	99.000	ANT HkA1	2.076	IST Pi1	0.468	IST Pi1	99.000	ANT Noz1	0.407	INR HkC0
3.491	INR Noz1	99.000	ANT HkB0	2.168	ASR HkB1	0.489	ASR HkB1	99.000	ANT HkR0	0.424	INR Noz1
3.595	INR Pi0	99.000	ANT HkB1	5.404	ASR HkA0	1.219	ASR HkA0	99.000	ANT HkR1	0.437	INR Pi0
4.958	ASR HkA1	99.000	ANT Scr	6.086	ASR HkA1	1.373	ASR HkA1	99.000	ANT Scr	0.602	ASR HkA1
5.292	INR HkB0	99.000	ANT HkA0	99.000	ANT Noz0	99.000	ANT Noz0	99.000	ANT BLTp	0.643	INR HkB0
10.545	INR HkA0	99.000	ANT GdBl	99.000	ANT HkR0	99.000	ANT HkR0	99.000	ANT GdBl	1.281	INR HkA0

Components: HkRel Hook release from flange HkC0 Hook section C (at pin)
 HkA0 Hook section A (max. load offset) Pi0 Pin
 HkA1 0 = in-line with pipe Scr Screw
 HkB0 Hook section B (at guide) BLTp Block top
 HkB1 1 = 120 degr from pipe axis GdBl Guide-block lip
 Noz Nozzle flange

Coordinate systems: X - block/nozzle axis
 Z - pipe axis

Cases A Guide active N No-slip screw-block interface T Pin moments transmitted
 I Guide inactive S Slip screw-block interface R Pin moments released

Table 5.4. Required Clearances for the Pin-Released Condition.

Connector Size	Max. Rel. Rotation, (rad)	Hook Thickness, (in)	Clearance Required on Pin Diameter, (in)
2 in.	0.11	0.81	0.09
3 in.	0.14	1.00	0.14
4 in.	0.25	1.18	0.30

5.6 THREE-WAY CONNECTOR ANALYSIS

The hooks, pins, nut and screw for the three-way connector are similar to the standard 2-in. connector, but the block and nozzle configurations differ considerably in the kinematics of deformation. In particular, there is no single pivot point for the block to rotate about. Instead, three inserts to the nozzle have spherical interfaces with the block which can rotate about one or two of them. Either way, the pre-load acts as a righting moment and any rotation must stretch the hooks. See the assembly drawing H-2-821874.

Appendix I provides details of the analysis of the connectors.

Consideration is given to lift-off of the block from one or more inserts as a result of piping forces. Such lift-off is characterized by pivoting of the block about two inserts as a result of an overturning moment or by sliding up an inclined plane as a result of shearing of the block relative to the nozzle. The criterion for lift-off is that the block does not separate more than 0.002 inch from the insert. This separation is considered acceptable from the viewpoint of the sealing ability of the O-ring, and places limits on the shear force and overturning moments which are combined with linear interaction rules.

Appendix I has an example which calculates upper bound piping moments from 1/2 inch schedule 40 piping based on allowable stresses. The acceptable overturning moment in Section 3.7 is about half this value, so moments are admitted up to half of the piping capacity. This is better than the situation of the standard connector. Furthermore, more opportunities of flexibility in thermal loading environments are expected from the 1/2 inch line as opposed to a 2 inch line. Consequently, the 3-way connector limiting loads are not expected to be overly restrictive to the designer.

It is acknowledged that the lift-off criteria could be quite conservative in some regards. Testing, for example, that would set an overturning moment to cause pivoting about one insert instead of two, would move the pivot point out from the center of the block and essentially double the acceptable moment. Furthermore, nominal dimensions result in block-insert contact coincident with block-nozzle body contact. Analysis herein conservatively assumes block-insert contact without any contact between the outer block bottom surface with the nozzle body. Tolerances allow the situation of block-nozzle contact before block-insert contact, and this would move the pivot point out even further from the line of righting forces and substantially increase the acceptable overturning moment. Neither directional consideration of the overturning moment nor refinement of tolerances is considered practical at this time.

The 3-way connector is expected to be stiffer than the standard connector to overturning moments, because rotation of the block does not occur until lift-off an insert takes place under the righting forces. The moment to start lift-off is a large majority of the acceptable moment. The block of the standard connector, on the other hand, can rotate immediately without friction. Additionally, 1/2 inch piping is expected to be quite flexible, so that relief of thermal load reactions by connector flexibility is expected to be minimal. Consequently, connector stiffnesses have not been evaluated, and piping analyses should consider the 3-way connector as rigid.

Block-insert interface stresses were evaluated for axial loading of the 3-way connector. Stacked tolerances are such that 0.021 in. of deformation could be imposed on the interface before the block body bottoms out on the nozzle body and limits further deformation. Finite element inelastic analysis of the interface including the gasket groove was carried out with gap-sliding elements and friction. The results show that the strains developed before bottoming out are acceptable. Plastic strains are largely limited to the downstream sidewall of the gasket groove. They are compressive, and a 10% strain could be achieved if the tolerances are stacked pessimistically. The piping axial force limitation of 10700 lbf in Section 3.7 is simply the capacity of two inserts adjusted for pre-load and thermal effects. It is quite large for 1/2 inch piping, and further refinement is considered unnecessary. Note that axial forces that tend to unseat the interface are involved with and limited by the lift-off criteria.

By drawing on the standard connector capacities given in Table 3.4, it is demonstrated in Appendix I that the 3-way lift-off criteria are more restrictive than the stress criteria in the hooks, pins and screw of the connector. As the standard connector demonstrates, these stresses are associated with block rotation. This does not occur in the 3-way connector until the righting forces are overcome and lift-off begins. Note, however, that such consideration is restricted to the 50 lbf-ft pre-load condition. Standard connector capacities at larger pre-loads were not considered, and consequently the 3-way criteria of Section 3.7 are restricted to the 50 lbf-ft pre-load.

Local block stresses at the piping attachment region are minor, because the block presents the equivalent of substantially thicker piping compared to the incoming 1/2 inch schedule 40 lines. After the flow path in the block turns toward the nozzle, there is a concern for stresses developed by piping bearing on the block surface much like a vehicle bearing on a tunnel cover. Two-dimensional finite element analysis shows that stresses developed with limit piping loads are small.. Consequently, block stresses do not enter in to the 3-way criteria of Section 3.2.

6.0 RECOMMENDATIONS

6.1 SUGGESTED FURTHER WORK

Standard connector piping reactions acceptable to this analysis effort might be found too small from the point of view of the piping designer. Although available test information has no reference or indication as to what safety factors were derived in the results, the information nevertheless suggests that the results of this analysis are too conservative. Future work to better define the reported capacities of the connectors is suggested as follows.

6.1.1 Testing

Testing for capacity, either on the component or system level requires that all environmental features of the clamp be addressed. If generic testing is to replace the role of analysis, then safety factors must be employed that reflect code factors of safety in addition to the fact that actual material strengths are higher than the minimum strengths specified in the codes. Typically, average yield strength is 1.25 time the minimum value. Also AISC design typically employs a safety factor of 1.67, although some components may traditionally have more. For example, fasteners typically have a 2.5 safety factor. This might bear directly on the pins in terms of code acceptance. A minimum factor for test acceptance of the AISC components is considered to be $1.67 \times 1.25 = 2.09$. Prudent procedures would even demand more.

6.1.2 Analysis Refinement

Pin, hook and nozzle capacities might be increased by testing or refined analysis. In particular, the strength of the pins and hook eye region under moment loading could be examined by finite element analysis as opposed to the simple treatment of Appendix C. Such an effort would require modelling with brick elements and gaps. As in the axial loading case, normal deformation is expected to move the reaction points. Since peaking of stresses are expected and fatigue is not a concern, the criteria for failure would be excessive inelastic deformation which requires inelastic analysis. The system appears similar to the block-top analysis of Appendix I which would not have been able to predict the failure load without inelastic analysis.

Load stresses might be limited by consideration of friction and gaps in a system model. The system model herein uses the worst results from open/closed gap cases and slip/no-slip friction considerations. In particular, high stresses in the screw, block top and perhaps the pins appear to be associated with screw-block frictional forces that are unlikely to be supported by any reasonable friction coefficient. Furthermore, the pin and hook eye components show substantially reduced stresses under the conditions of release of the pin moments. Actual values, somewhere between the released and transmitted conditions, have not been determined. Questions of this sort would have to be answered by models with gap and friction elements. Since such model would be nonlinear, reasonable upper bound piping loads would have to be established along with worst combinations of the components. Such a model is capable of demonstrating that loads to certain components are limited by slippage considerations. For example, hook contact at the nozzle might slip before significant moments accumulate in the pins. Such analyses, however, requires consideration of bounds to the frictions coefficient and clearance control. Skirt-hook interaction should also be considered in this model.

Evidence exists (WHC 1995) indicating that all sizes of connectors can survive non-axial moments upward of 1,200 lbf-ft compared with the currently acceptable end-over moment of 365 lbf-ft. Consequently, the acceptable loads obtained in this analysis appear overly conservative by a factor of two or more. As can be observed from Table 3.2, the pins are stronger than the hooks under axial loading. If it can be shown that the pins and hook eyes do not develop the moments of the current analysis or if the moment capacities are substantially larger than currently found, it appears the acceptable loads would increase substantially. Even then there are possibilities of improvement, because the axial analyses of the nozzle and hooks appear rudimentary and the analysis of the block top region with lateral screw loads is acknowledged to be very conservative. Granted that nonlinear considerations may be required as in Appendix E, it is believed that refined finite element analyses of the pins, nozzle, hooks and block-top region would show substantially higher capacities. Stabilization of the system model herein was provided by the interface element used at the screw-block interface. Full benefit of pre-load stabilization should be investigated with large displacement and stress stiffening effects. This requires a model reproducing the kinematics of the block-top depression and the screw bearing cap, as well as the fact that lateral hook rotation tends to separate the pre-load bearing points in a way that provides stabilization.

Previous analysis efforts (WHC 1992, WHC 1994) both show about the same axial hook capacities as this report. For the 2-in. connector, this is about 6,000 lbf. Testing by Squier (1993) shows that a 2-in. hook failed with a 9400 lbf loading. Material testing of the failed hook showed a 2 ft-lbf Charpy impact strength, whereas the ASTM specification for the material shows 12-15 ft-lbf. The hooks have the least elongation values among the connector components. It is the opinion of at least one of the authors that the hook should have a substantially higher test strength. The AISC acceptable load was estimated at about 10,000 to 11,000 lbf suggesting that the test failure load would be around 16,000 to 18,000 lbf. Examination of the pins in the same test revealed longitudinal cracks, while no unusual material findings were indicated. Previous analysis associated with but not reported in the current effort, have the pins controlling for all external piping loading except the axial force. In view of the cracked pins, this finding is not easily dismissed. The test and analysis findings discussed here clearly underscore the need for good material quality.

6.1.3 Consideration of Reaction Component Signs and Combinations

No effort was made in the current analysis to consider specific combinations of piping load components. The interaction recommendation for comparing actual and acceptable loads is conservative for the components. The effects of specific combinations, when known, could be evaluated with the system model developed herein.

6.1.4 Consideration of Safety Class

Basically, this analysis can be used for any safety class as long as the acceptable piping reactions herein are satisfied. Additionally, if this analysis is used for safety class 1 assemblies, the minor differences between ASME Section VIII and III with respect to materials and allowables shall be reconciled for the evaluation of the block and nozzle. There may be other functions to be maintained regardless of safety class, e.g., as required by the Functional Design Criteria, and they would have to be addressed. The MWTF/W236A project, which this analysis addresses, does not require the assemblies for a no-leakage safety function during and after a Design Basis Earthquake (DBE.) Therefore, the no-leak function is not addressed in this evaluation. For other projects or DOE sites that plan to use the ISB design and require no

leakage during and after a DBE, the connector assembly would have to be seismically qualified for operability and maintain a leak tight configuration.

6.2 DESIGN MODIFICATIONS

It is recommended that lip sizes be increased for the guide-block interface. As a result of piping loads on the connector, lateral forces from the hooks to the guide are transmitted through this interface to the block in bearing. Lip engagement heights are now about 0.02" to 0.03". It is recommended that the minimum engagement (not counting fillets) be increased to 0.04" for the 2" connector size, 0.06" for the 3" size, and 0.10" for the 4" size. These recommendations are based on an acceptable load fractions of about 0.20. Removal of material from the block to achieve this is not recommended. The preferred way would be to take it out of the guide and add to the ledge height of the block if necessary.

The block thickness under the screw is unusually small for the 4-in. connector size when compared to the 2-in. and 3-in. connectors. This, along with the large piping loads used in the analysis, results in the 4-in. block top region being identified as a weak component. A larger thickness consistent with the 2-in. and 3-in. sizes is recommended.

Hook eyes and pins represent some of the weakest components from the point of view of the analysis results. However, as discussed extensively in the report, there are possibilities of increased capacities, by analysis or test, not yet explored. If these possibilities do not materialize, the moments on the pins could be relieved by placing shims between the nut lugs and the hook so that the hook would bear against the lugs with moment loading. The hook hole clearance would have to be large enough to prevent cocking against the pin. Spreading of the lugs may have to be checked with additional lug thickness or simply with nuts on the ends of the pin. Increases in hook eye material or pin size, of course, would be desirable.

Hook release from the flange appears as a contender in Table 5.3 for controlling the acceptable load fractions for moment loading to a 4-in. connector. This condition is influenced by the pre-load, and consideration of and increase for the 3-in. and 4-in sizes is recommended.

7.0 REFERENCES

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- WHC, 1992b, *3" Horiz. and Vert. Purex Type/HWVP Connector Assembly*, Drawing No. H-2-815358, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
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APPENDIX A

HOOK, HOOK PIN, OPERATING NUT AND SCREW CALCULATIONS FOR AISC EVALUATION

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed APPENDIX "A" OF ISB JUMPER DOC.

Author M. A. ISLAM

Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number

N/A

Reviewer

O. Z. Kous

Date

1-30-95

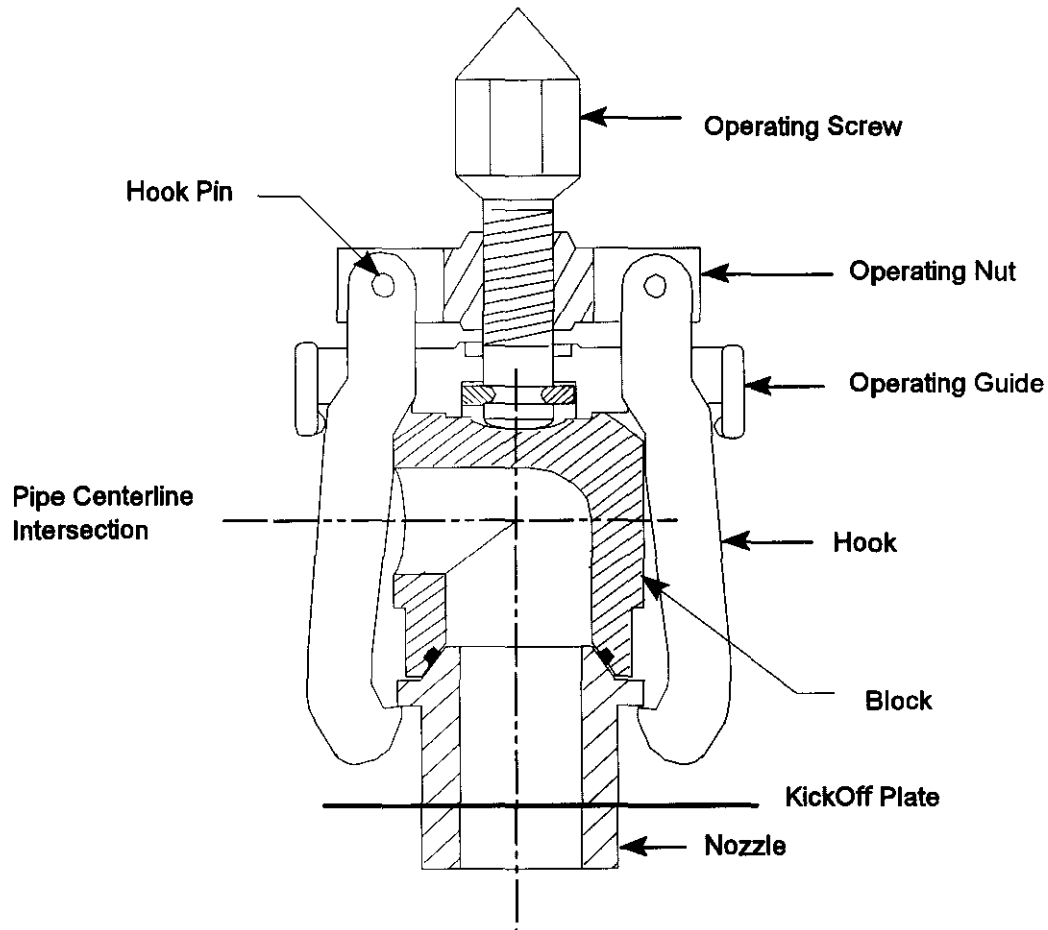
Subject Hook, Hook Pin, and Operating Nut Calculations for ISB Jumper Connector AssemblyOriginator M. A. Islam*MATE*Date 1/25/95Checker D. L. Kories*D. L. Kories*Date 1/25/95

Axial Capacity of 2-, 3-, and 4-in. Mechanical Jumper Hooks, Hook pins, Operating Nut, and Screw under Axial Loading Only

The analysis of the 2-in, 3-in, and 4-in hook, hook pin, operating nut and screw are analyzed in accordance with AISC 1989 for operational and seismic loading conditions. The axial capacities calculated for the 2-, 3-, and 4-in. jumpers in this appendix is used in appendix C to determine the allowable external piping loads for future jumper design.

These components are primarily used to maintain the seal between the block and the nozzle which are governed by the boiler and pressure vessel (BPV) codes (ASME, 1989, Section VIII, Division I). Because the jumper connection is performed remotely and it is located in a confined space, failure of the jumper connection will not release radio-logical dose to the environment or to the workers. Therefore, the jumper connection failure is not comparable to the risks associated with the failure of BPV components. The use of AISC allowables provides a more realistic loading capability for the hook, hook pin, nut, and the screw.

Figure A1. Typical Jumper Connector Assembly for 2-, 3-, and 4-in. ISB Connectors



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Subject Hook, Hook Pin, and Operating Nut Calculations for ISB Jumper Connector AssemblyOriginator M. A. IslamDate 1/25/95Checker D. L. KoriesDate 1/25/95**1.0 DESIGN PARAMETERS FOR MWTF PROJECT**

The following design parameters are considered in the structural analysis of the connector assembly. Pressure and temperature requirements are taken from the MWTF Functional Design Criteria (FDC) found in WHC-SD-W236A-FDC-001 (WHC 1993a)

$P_{\min} := -10 \cdot \frac{\text{lbf}}{\text{in}^2}$	minimum internal pressure applied to block and nozzle
$P_{\max} := 400 \cdot \frac{\text{lbf}}{\text{in}^2}$	maximum operation internal pressure applied to block and nozzle
$P_{\text{design}} := 400 \cdot \frac{\text{lbf}}{\text{in}^2}$	design internal pressure applied to block and nozzle
$P_{\text{test}} := 1000 \cdot \frac{\text{lbf}}{\text{in}^2}$	internal pressure applied to block and nozzle tested (Ruff 1994)
$T_{\min} := 70$	minimum temperature of block and nozzle (70 °F)
$T_{\max} := 200$	maximum operation temperature of block and nozzle (250 °F)
$T_{\text{design}} := 250$	design temperature of block and nozzle
$T_{\text{test}} := 400$	temperature of block and nozzle tested in the lab by Ruff (1994)

2.0 MATERIAL PROPERTIES OF JUMPERS (2-, 3-, and 4-in.)**2.1 Block and Nozzle Material Properties (@ 70 and 250 °F) for ASTM A 276 Grade 304 SST (Nuclear Systems Materials Handbook (ORNL 1976) and ASTM (1989))**

Minimum yield strength	Minimum tensile strength	Modulus of Elasticity for 304 SST
$S_{y70A276} := 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$S_{t70A276} := 75000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$E_{70A276} := 28.5 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$
$S_{y250A276} := 24000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$S_{t250A276} := 61830 \cdot \frac{\text{lbf}}{\text{in}^2}$	$E_{250A276} := 27.4 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$

mean coefficient of thermal expansion is $8.55\text{E-}6/^{\circ}\text{F}$ and $9.19\text{E-}6/^{\circ}\text{F}$ (ORNL 1976)

$$\alpha_{70A276} := 8.55 \cdot 10^{-6} \quad \alpha_{250A276} := 8.89 \cdot 10^{-6}$$

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2.2 Screw Material Properties @ 70 °F for ASTM A193 Grade B7 Carbon Steel, ASTM (1989) and AISC (1989)

Minimum yield strength

Minimum tensile strength

Modulus of Elasticity (assumed)

$$S_{yA193} := 105000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{tA193} := 125000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$E_{A193} := 29.7 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable shear stress per AISC 1989

Allowable bearing stress per AISC 1989

$$\sigma_{vA193} := 0.40 \cdot S_{yA193}$$

$$\sigma_{brA193} := 0.90 \cdot S_{yA193}$$

$$\sigma_{vA193} = 42000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{brA193} = 94500 \cdot \frac{\text{lbf}}{\text{in}^2}$$

2.3 Hook Material Properties (@ 70 °F) for ASTM A747 Grade CB7Cu-1 or CB7Cu-2, H1075 Heat Treated ASTM and AISC (1989)

Minimum yield strength

Minimum tensile strength

Modulus of Elasticity (assumed)

$$S_{yA747} := 115000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{uA747} := 145000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$E_{A747} := 29.0 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable bending stress based on AISC (1989)

Allowable shear stress based on AISC (1989)

$$\sigma_{bA747} := 0.60 \cdot S_{yA747}$$

$$\sigma_{vA747} := 0.40 \cdot S_{yA747}$$

$$\sigma_{bA747} = 69000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{vA747} = 46000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

2.4 Operating Pin Material Properties (@ 70 °F) for ASTM A108 Grade 1045 ASTM (1989) and AISC (1989)

Minimum yield strength

Minimum tensile strength

$$S_{yA108} := 77000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{uA108} := 91000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable shear per AISC 1989

Allowable bending per AISC 1989

$$\sigma_{vA108} := 0.40 \cdot S_{yA108}$$

$$\sigma_{bA108} := 0.75 \cdot S_{yA108}$$

$$\sigma_{vA108} = 30800 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{bA108} = 57750 \cdot \frac{\text{lbf}}{\text{in}^2}$$

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Subject Hook, Hook Pin, and Operating Nut Calculations for ISB Jumper Connector AssemblyOriginator M. A. IslamM.A.I.Date 1/30/95Checker D. L. KoriesD.L. KoriesDate 1/30/95**2.5 Operating Nut Material Properties (@ 70 °F) for ASTM A148 ASTM (1989) and AISC (1989)**

Minimum yield strength

Minimum tensile strength

$$S_{yA148} := 60000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{uA148} := 90000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable shear

Allowable bending stress

Allowable bearing stress

$$\sigma_{vA148} := 0.40 \cdot S_{yA148}$$

$$\sigma_{bA148} := 0.60 \cdot S_{yA148}$$

$$\sigma_{brA148} := 1.2 \cdot S_{uA148}$$

$$\sigma_{vA148} = 24000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{bA148} = 36000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{brA148} = 108000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

3.0 ANALYSIS OF 2-inch HOOK

Apply Curved Beam Formulas, Reference: Blake, Alexander, 1982, Practical Stress Analysis in Engineering Design, Marcel Dekker, Inc., New York, New York. Reference drawing H-2-90174, Rev. 7, sheet 1

3.1 Top Portion of the Hook

Following WHC-SD-HWV-DCR-002 Rev 0 Appendix A, the values of h and R are estimated by modelling the local area of concern with a 180 degree circular hook having the inner and outer radii equal to the distances of the inner and outer hook surfaces to the load line. These values are approximate and conservative because the inner radius is small and has the effect of overemphasizing the stress concentration.

$$c := \frac{1.25 \cdot \text{in} - 0.18 \cdot \text{in}}{2} \quad c = 0.535 \cdot \text{in}$$

radius of curvature

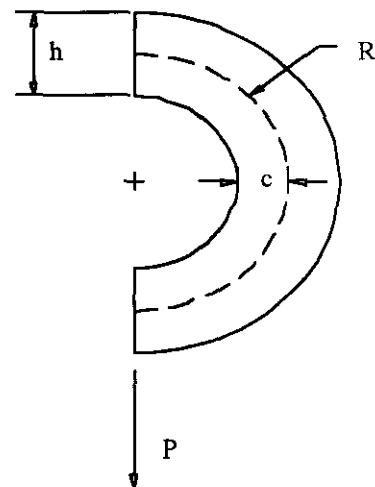
$$R(c) := 0.375 \cdot \text{in} + c \quad R(c) = 0.91 \cdot \text{in}$$

$$h(c) := 2 \cdot c \quad h(c) = 1.07 \cdot \text{in} \quad \text{width of top}$$

$$t := 0.78 \cdot \text{in} \quad \text{thickness or width of hook}$$

Area of Hook @ top portion of the hook

$$A := t \cdot h(c) \quad A = 0.835 \cdot \text{in}^2$$



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$$\lambda := 1 + \frac{R(c)}{h(c)} \cdot \left(\ln \left(\frac{R(c) + c}{R(c) - c} \right) \right) \quad \lambda = 0.147 \quad \text{Table 28.1, page 331, Rectangular section}$$

$$\frac{R(c)}{c} = 1.701 \quad I := \frac{t \cdot h(c)^3}{12} \quad I = 0.08 \cdot \text{in}^4 \quad \text{Moment of Inertia}$$

Tangential stress at the top section of the hook, $S_{ts} = \frac{P_{tst} \cdot c}{A \cdot \lambda \cdot (R - c)}$ Equation 28.12, where $S_{ts} := \sigma_{bA747}$

Therefore, $P_{tst} := \frac{S_{ts} \cdot A \cdot \lambda \cdot (R(c) - c)}{c}$ $P_{tst} = 5943 \cdot \text{lbf}$

Compressive stress at the top section of the hook, $S_{cs} = \frac{-P_{cst} \cdot (h - c)}{A \cdot \lambda \cdot (R + h - c)}$ Eqn. 28.13, where $S_{cs} := \sigma_{bA747}$

Therefore, $P_{cst} := \frac{-S_{cs} \cdot A \cdot \lambda \cdot (R(c) + h(c) - c)}{h(c) - c}$ $P_{cst} = -22900 \cdot \text{lbf}$

3.2 Bottom Portion of the hook

$$c := \frac{1.64 \cdot \text{in} - .5 \cdot \text{in}}{2} \quad c = 0.57 \cdot \text{in}$$

Hook Cross-Sectional Area @ bottom

$$A := t \cdot h(c) \quad A = 0.889 \cdot \text{in}^2$$

$$R(c) = 0.945 \cdot \text{in} \quad \text{radius of curvature}$$

$$h(c) = 1.14 \cdot \text{in} \quad \text{width of bottom}$$

$$\lambda := 1 + \frac{R(c)}{h(c)} \cdot \left(\ln \left(\frac{R(c) + c}{R(c) - c} \right) \right) \quad \lambda = 0.157 \quad \text{Table 28.1, Blake 1982, page 331 Rectangular section}$$

Tangential stress in the hook, $S_{ts} = \sigma_{bA747} = \frac{P_{tsb} \cdot c}{A \cdot \lambda \cdot (R - c)}$ Equation 28.12

$P_{tsb} := \frac{S_{ts} \cdot A \cdot \lambda \cdot (R(c) - c)}{c}$ $P_{tsb} = 6354 \cdot \text{lbf}$

Compressive stress in the hook, $S_{cs} = \sigma_{bA747} = \frac{-P_{csb} \cdot (h - c)}{A \cdot \lambda \cdot (R + h - c)}$ Equation 28.13

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$$P_{csb} := \frac{-S_{cs} \cdot A \cdot \lambda \cdot (R(c) + h(c) - c)}{h(c) - c}$$

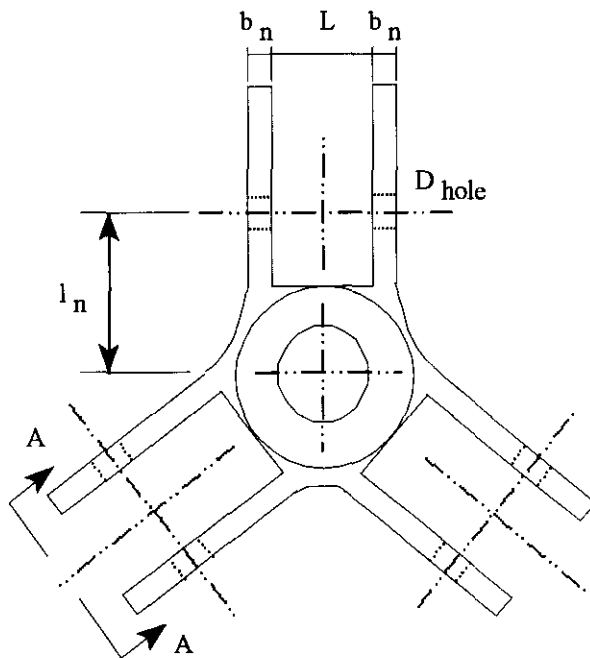
$$P_{csb} = -25670 \cdot \text{lbf}$$

The critical value for the hook axial capacity will be at the top portion of the hook.

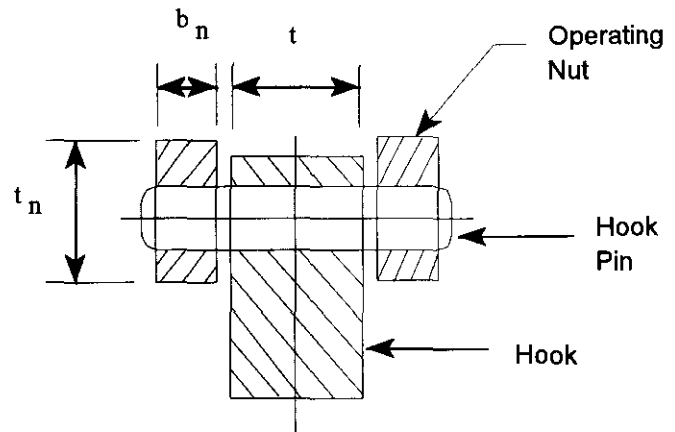
$$P_{\text{capacity}} := P_{\text{tst}}$$

$$P_{\text{capacity}} = 5943 \cdot \text{lbf}$$

3.3 Operating Nut and Pin, Reference drawing H-2-68209



Operating Nut (H-2-68209)



Section A-A

Where the pin and nut dimensions are:

$L := 0.91 \cdot \text{in}$ Hook pin span

$D_{\text{pin}} := 0.5625 \cdot \text{in}$ Hook pin diameter

$l_n := 1.563 \cdot \text{in}$ Nut span

$b_n := 0.47 \cdot \text{in}$ Nut width

$t_n := 1.64 \cdot \text{in}$ Nut depth

$D_{\text{hole}} := 0.565 \cdot \text{in}$ Hole in operating nut

Axial Capacity of Operating Nut

Allowable bending stress,

Moment of inertia, (for 2 nuts)

$$\sigma_{bA148} = 36000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$I_n := 2 \cdot \frac{b_n \cdot t_n^3}{12}$$

$$I_n = 0.346 \cdot \text{in}^4$$

$$c := \frac{t_n}{2}$$

$$c = 0.82 \cdot \text{in}$$

Max. bending moment, $M = P \cdot l_n$

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Calculating for the allowable moment, allowable stresses is used

$$\sigma_{bA148} = \frac{M \cdot c}{I_n} = \frac{P \cdot l_n \cdot c}{I_n} \quad \text{per WHC-SD-W028-DA-001, Rev. 0, page 11}$$

Therefore, the axial capacity of the operating nut is

$$P_{nut} := \frac{\sigma_{bA148} \cdot I_n}{l_n \cdot c} \quad P_{nut} = 9705 \cdot \text{lb}$$

The Axial Capacity of the hook pin

$W_b := 8564 \cdot \text{lb}$ Pin capacity is determined in Appendix C.

3.4 Determine the axial capacity of the operating screw (Drawing H-2-32421)

The operating screw will be under compression and its threads along with the threads of the operating nut will be under shearing and bearing stresses. The material of the ~~screw~~ ^{SCREW} is ASTM A193, Gr. B7, C.S.

Allowable shear stress,

Allowable bearing stress,

$$\sigma_{vA193} = 42000 \cdot \frac{\text{lb}}{\text{in}^2}$$

$$\sigma_{brA193} = 94500 \cdot \frac{\text{lb}}{\text{in}^2}$$

Per AISC 1980, section 1.5

Refer to Shigley, J. E., Mechanical Engineering Design, 3rd Ed., 1977, page 237

$d_s := 1.25 \cdot \text{in}$ Screw diameter

$h_n := 1.88 \cdot \text{in}$ Operating Nut Height

$d_r := 1.06 \cdot \text{in}$ Screw root diameter

Average screw-thread shear stress $\tau_{av} := \sigma_{vA193}$

$$\tau_{av} = \frac{2 \cdot F}{\pi \cdot d_r \cdot h_n} \quad \text{Equation (6-7)}$$

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$$\text{therefore, } F := \frac{\tau_{av} \cdot \pi \cdot d_r \cdot h_n}{2} \quad F = 131472 \cdot \text{lbf}$$

Similarly, the average nut-thread shear stress

$$\tau_{av} = \frac{2 \cdot F}{\pi \cdot d_s \cdot h_n} \quad \text{Equation (6-8)}$$

Because $d_s > d_r$, the value for F will be even larger than 131,472 lbf.

The bearing stress in the thread

$$\sigma_{bear} = \frac{4 \cdot p \cdot F}{\pi \cdot h_n \cdot (d_s^2 - d_r^2)} \quad \text{Equation (6-9) where, } p := \frac{1}{8} \cdot \text{in} \quad \text{and} \quad \sigma_{bear} := \sigma_{brA193}$$

$$\text{Therefore, } F := \frac{\sigma_{bear} \cdot \pi \cdot h_n \cdot (d_s^2 - d_r^2)}{4 \cdot p} \quad F = 489931 \cdot \text{lbf} \quad \text{which is } > \text{ than } 131,472 \text{ lbf}$$

Shear stress in threads controls over bearing stress

Check Contact Stress between screw and the block (Refer to Shigley 1977, page 75)

$$\text{contact radius, } a := \frac{1.03 \cdot \text{in}}{2} \quad \text{Drawing H-2-32421}$$

$$\text{Maximum contact pressure, } p_{max} = \frac{3 \cdot F}{2 \cdot \pi \cdot a^2}$$

Because contact pressure may cause some local deformation, p_{max} can be used as high as yield value

$$\text{Therefore, } F := \frac{S_{yA193} \cdot 2 \cdot \pi \cdot a^2}{3} \quad F = 58326 \cdot \text{lbf}$$

$$\text{Therefore, the capacity of the operating screw (based on per hook), is } P := \frac{F}{3} \quad P = 19442 \cdot \text{lbf}$$

After reviewing the capacities of the Hook, Hook Pin, and the Operating nut, we conclude that the axial capacity of ~~the~~ Hook controls. Therefore, the capacity of the supporting assembly, ~~the~~

$$P_{\text{capacity}} = 5943 \cdot \text{lbf}$$

Subject Hook, Hook Pin, and Operating Nut Calculations for ISB Jumper Connector AssemblyOriginator M. A. IslamDate 1/25/95Checker D. L. KoriesDate 1/30/95**4.0 ANALYSIS OF 3-inch HOOK**

Apply Curved Beam Formulas, Reference: Blake, Alexander, 1982, Practical Stress Analysis in Engineering Design, Marcel Dekker, Inc., New York, New York. Reference drawing H-2-90175, Rev. 6, sheet 1

4.1 Top Portion of the Hook, (Inside Curve)

Following WHC-SD-HWV-DCR-002 Rev 0 Appendix A, the values of h and R are estimated by modelling the local area of concern with a 180 degree circular hook having the inner and outer radii equal to the distances of the inner and outer hook surfaces to the load line. These values are approximate and conservative because the inner radius is small and has the effect of overemphasizing the stress concentration.

$$c := \frac{1.75 \cdot \text{in} - 0.375 \cdot \text{in}}{2} \quad c = 0.688 \cdot \text{in}$$

radius of curvature

$$R(c) := 0.812 \cdot \text{in} + c \quad R(c) = 1.5 \cdot \text{in}$$

$$h(c) := 2 \cdot c \quad h(c) = 1.375 \cdot \text{in} \quad \text{width of top}$$

$$t := 0.97 \cdot \text{in} \quad \text{thickness or width of hook}$$

$$A := t \cdot h(c) \quad A = 1.334 \cdot \text{in}^2 \quad \text{Area of Hook @ top portion}$$

$$\lambda := -1 + \frac{R(c)}{h(c)} \cdot \left(\ln \left(\frac{R(c) + c}{R(c) - c} \right) \right) \quad \lambda = 0.08 \quad \text{Table 28.1, page 331, Rectangular section}$$

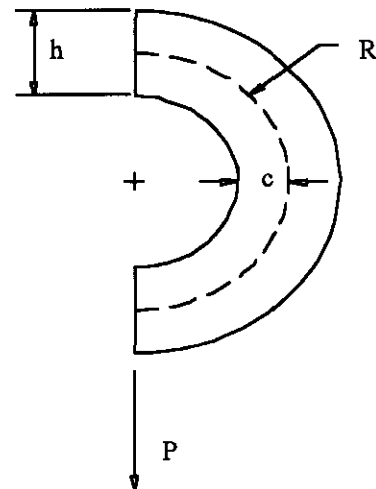
$$\frac{R(c)}{c} = 2.181 \quad \Phi_o := 1.48 \quad \text{per WHC-SD-HWV-DCR-002 rev. 0, p. 5 of 13}$$

$$I := \frac{t \cdot h(c)^3}{12} \quad I = 0.21 \cdot \text{in}^4 \quad \text{Moment of Inertia}$$

Tangential stress at the top section of the hook,

$$S_{ts} = \frac{P_{tst} \cdot c}{A \cdot \lambda \cdot (R - c)} \quad \text{Equation 28.12, where} \quad S_{ts} := \sigma_{bA747}$$

$$\text{Therefore,} \quad P_{tst} := \frac{S_{ts} \cdot A \cdot \lambda \cdot (R(c) - c)}{c} \quad P_{tst} = 8750 \cdot \text{lbf}$$



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Compressive stress at the top section of the hook,

$$S_{cs} = \frac{-P_{cst} \cdot (h - c)}{A \cdot \lambda \cdot (R + h - c)} \quad \text{Eqn. 28.13, where} \quad S_{cs} := \sigma_{bA747}$$

$$\text{Therefore, } P_{cst} := \frac{-S_{cs} \cdot A \cdot \lambda \cdot (R(c) + h(c) - c)}{h(c) - c} \quad P_{cst} = -23566 \cdot \text{lbf}$$

4.2 Bottom Portion of the hook

$$c := \frac{2.28 \cdot \text{in} - 0.78 \cdot \text{in}}{2} \quad c = 0.75 \cdot \text{in}$$

$$h(c) = 1.5 \cdot \text{in} \quad \text{width of hook}$$

$$R(c) := 0.375 \cdot \text{in} + c \quad \text{radius of curvature}$$

$$R(c) = 1.125 \cdot \text{in}$$

$$A := t \cdot h(c) \quad \text{Hook cross-sectional area @ bottom}$$

$$A = 1.455 \cdot \text{in}^2$$

$$\lambda := -1 + \frac{R(c)}{h(c)} \cdot \left(\ln \left(\frac{R(c) + c}{R(c) - c} \right) \right) \quad \lambda = 0.207 \quad \text{Table 28.1, Blake 1982, page 331}$$

Rectangular section

$$\text{Tangential stress in the hook, } S_{ts} = \sigma_a = \frac{P_{tsb} \cdot c}{A \cdot \lambda \cdot (R - c)} \quad \text{Equation 28.12}$$

$$P_{tsb} := \frac{S_{ts} \cdot A \cdot \lambda \cdot (R(c) - c)}{c} \quad P_{tsb} = 10395 \cdot \text{lbf}$$

$$\text{Compressive stress in the hook, } S_{cs} = \sigma_a = \frac{-P_{csb} \cdot (h - c)}{A \cdot \lambda \cdot (R + h - c)} \quad \text{Equation 28.13}$$

$$P_{csb} := \frac{-S_{cs} \cdot A \cdot \lambda \cdot (R(c) + h(c) - c)}{h(c) - c} \quad P_{csb} = -51974 \cdot \text{lbf}$$

The critical value for the hook axial capacity will be at the top portion of the hook.

$$P_{\text{capacity}} := P_{tst} \quad P_{\text{capacity}} = 8750 \cdot \text{lbf}$$

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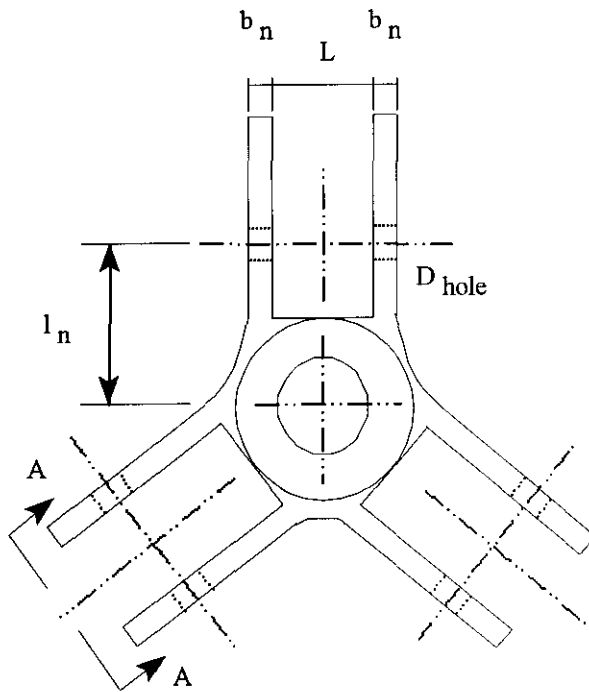
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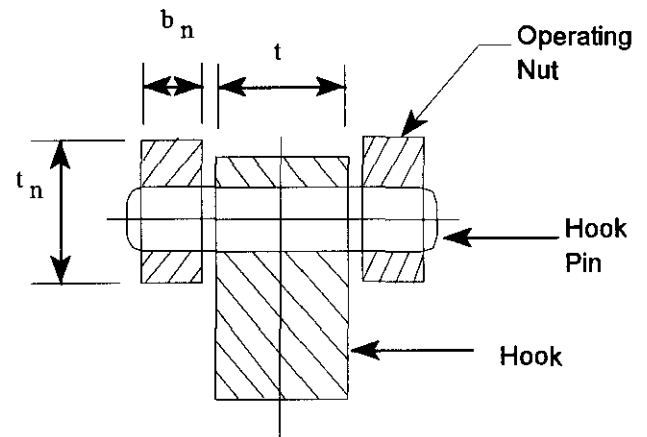
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4.3 Operating Nut and Pin, Reference drawing H-2-68210 and H-2-32431, Rev. 15



Operating Nut (H-2-68210)



Section A-A

Where the pin and nut dimensions are:

$L := 1.07 \cdot \text{in}$ Hook pin span

$D_{\text{pin}} := 0.75 \cdot \text{in}$ Hook pin diameter

$l_n := 2.25 \cdot \text{in}$ Nut span

$b_n := 0.77 \cdot \text{in}$ Nut width

$t_n := 1.89 \cdot \text{in}$ Nut depth

$D_{\text{hole}} := 0.753 \cdot \text{in}$ Hole in operating nut

Axial capacity of Operating Nut (Refer to drawing H-2-68210, Rev. 8)

Allowable bending stress

Moment of inertia (for 2 nuts)

$$\sigma_{bA148} = 36000 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

$$I_n = 2 \cdot \frac{b_n \cdot t_n^3}{12}$$

$$I_n = 0.866 \cdot \text{in}^4$$

$$c := \frac{t_n}{2}$$

$$c = 0.945 \cdot \text{in}$$

Max. bending moment, $M = P \cdot l_n$

Calculating for the allowable moment, allowable bending stress is used

$$\sigma_{bA148} = \frac{M \cdot c}{I_n} = \frac{P \cdot l_n \cdot c}{I_n}$$

per WHC-SD-W028-DA-001, Rev. 0, page 11

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Therefore, the axial capacity of the Operating nut is

$$P_{\text{nut}} := \frac{\sigma_{bA148} \cdot I_n}{I_n \cdot c} \quad P_{\text{nut}} = 14669 \cdot \text{lbf}$$

Axial capacity of the hook pin

$W_b := 15057 \cdot \text{lbf}$ Pin capacity is determined in Appendix C.

4.4 Determine the axial capacity of the operating screw (Drawing H-2-32431)

The operating screw will be under compression and its threads along with the threads of the operating nut will be under shearing and bearing stresses.

Allowable shear stress

Allowable bearing stress

$$\sigma_{vA193} = 42000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{brA193} = 94500 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Per AISC 1980, section 1.5

Refer to shigley, J. E., Mechanical Engineering Design, 3rd Ed., 1977, page 237

$d_s := 1.75 \cdot \text{in}$ Screw diameter

$h_n := 2.25 \cdot \text{in}$ Operating Nut Height

$d_r := 1.46 \cdot \text{in}$ Screw root diameter

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Average screw-thread shear stress $\tau_{av} := \sigma_{vA193}$

$$\tau_{av} = \frac{2 \cdot F}{\pi \cdot d_r \cdot h_n} \quad \text{Equation (6-7)}$$

Therefore, $F := \frac{\tau_{av} \cdot \pi \cdot d_r \cdot h_n}{2}$ $F = 216723 \cdot \text{lbf}$

Similarly, the average nut-thread shear stress,

$$\tau_{av} = \frac{2 \cdot F}{\pi \cdot d_s \cdot h_n} \quad \text{Equation (6-8)}$$

Because $d_s > d_r$, the value for F will be even larger then $F = 216723 \cdot \text{lbf}$

The bearing stress in the thread

$$\sigma_{bear} = \frac{4 \cdot p \cdot F}{\pi \cdot h_n \cdot (d_s^2 - d_r^2)} \quad \text{Equation (6-9) where, } p := \frac{1}{5} \cdot \text{in} \quad \text{and} \quad \sigma_{bear} := \sigma_{brA193}$$

Therefore, $F := \frac{\sigma_{bear} \cdot \pi \cdot h_n \cdot (d_s^2 - d_r^2)}{4 \cdot p}$ $F = 777280 \cdot \text{lbf}$ which is > than 216,723 lbf

Shear stress in the threads controls over bearing stress

Check Contact Stress between screw and the block (Refer to Shigley 1977, page 75)

contact radius, $a := \frac{1.438 \cdot \text{in}}{2}$ Drawing H-2-32431

Maximum contact pressure,

$$p_{max} = \frac{3 \cdot F}{2 \cdot \pi \cdot a^2}$$

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Because contact pressure may cause some local deformation, p_{max} can be used as high as yield value

$$\text{Therefore, } F := \frac{S_y A_{193} \cdot 2 \cdot \pi \cdot a^2}{3} \quad F = 113686 \cdot \text{lbf}$$

Therefore, the axial capacity of the operating screw (based on per hook), is

$$P := \frac{F}{3} \quad P = 37895 \cdot \text{lbf}$$

After reviewing the capacities of the Hook, Hook Pin, and the Operating nut, we conclude that the axial capacity of the Hook controls. Therefore, the capacity of the supporting assembly,

$$P_{\text{capacity}} = 8750 \cdot \text{lbf}$$

5.0 ANALYSIS OF 4-inch HOOK

Apply Curved Beam Formulas, Reference: Blake, Alexander, 1982, Practical Stress Analysis in Engineering Design, Marcel Dekker, Inc., New York, New York., Reference drawing H-2-90176, Rev. 4, sheet 1

5.1 Top Portion of the Hook, (Inside Curve)

Following WHC-SD-HWV-DCR-002 Rev 0 Appendix A, the values of h and R are estimated by modelling the local area of concern with a 180 degree circular hook having the inner and outer radii equal to the distances of the inner and outer hook surfaces to the load line. These values are approximate and conservative because the inner radius is small and has the effect of overemphasizing the stress concentration..

$$c := \frac{2.25 \cdot \text{in} - 0.625 \cdot \text{in}}{2} \quad c = 0.812 \cdot \text{in}$$

$$t := 1.15 \cdot \text{in} \quad \text{thickness or width of hook}$$

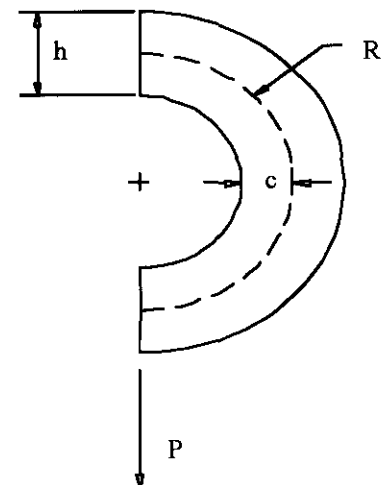
radius of curvature

$$R(c) := 0.812 \cdot \text{in} + c \quad R(c) = 1.624 \cdot \text{in}$$

$$h(c) := 2 \cdot c \quad h(c) = 1.625 \cdot \text{in} \quad \text{width of top}$$

Area of Hook @ top portion of hook

$$A := t \cdot h(c) \quad A = 1.869 \cdot \text{in}^2$$



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$$\text{Moment of Inertia} \quad I := \frac{t \cdot h(c)^3}{12} \quad I = 0.411 \cdot \text{in}^4$$

$$\lambda := -1 + \frac{R(c)}{h(c)} \cdot \left(\ln \left(\frac{R(c) + c}{R(c) - c} \right) \right) \quad \lambda = 0.099 \quad \text{Table 28.1, page 331, Rectangular section}$$

Tangential stress at the top section of the hook

$$S_{ts} = \frac{P_{tst} \cdot c}{A \cdot \lambda \cdot (R - c)} \quad \text{Equation 28.12, where} \quad S_{ts} := \sigma_{bA747}$$

$$\text{Therefore,} \quad P_{tst} := \frac{S_{ts} \cdot A \cdot \lambda \cdot (R(c) - c)}{c} \quad P_{tst} = 12717 \cdot \text{lbf}$$

Compressive stress at the top section of the hook

$$S_{cs} = \frac{-P_{cst} \cdot (h - c)}{A \cdot \lambda \cdot (R + h - c)} \quad \text{Eqn. 28.13, where} \quad S_{cs} := \sigma_{bA747}$$

$$\text{Therefore,} \quad P_{cst} := \frac{-S_{cs} \cdot A \cdot \lambda \cdot (R(c) + h(c) - c)}{h(c) - c} \quad P_{cst} = -38166 \cdot \text{lbf}$$

5.2 Bottom Portion of the hook

$$c := \frac{2.718 \cdot \text{in} - 1.0 \cdot \text{in}}{2} \quad c = 0.859 \cdot \text{in}$$

$$h(c) = 1.718 \cdot \text{in} \quad \text{width of hook @ bottom}$$

Radius of curvature

$$R(c) := 0.375 \cdot \text{in} + c \quad R(c) = 1.234 \cdot \text{in}$$

Hook cross-sectional area @ bottom

$$A := t \cdot h(c) \quad A = 1.976 \cdot \text{in}^2$$

$$\lambda := -1 + \frac{R(c)}{h(c)} \cdot \left(\ln \left(\frac{R(c) + c}{R(c) - c} \right) \right) \quad \lambda = 0.235 \quad \text{Table 28.1, Blake 1982, page 331 Rectangular section}$$

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Tangential stress in the hook, $S_{ts} = \sigma_a = \frac{P_{tsb} \cdot c}{A \cdot \lambda \cdot (R - c)}$ Equation 28.12

$$P_{tsb} := \frac{S_{ts} \cdot A \cdot \lambda \cdot (R(c) - c)}{c} \quad P_{tsb} = 13987 \cdot \text{lbf}$$

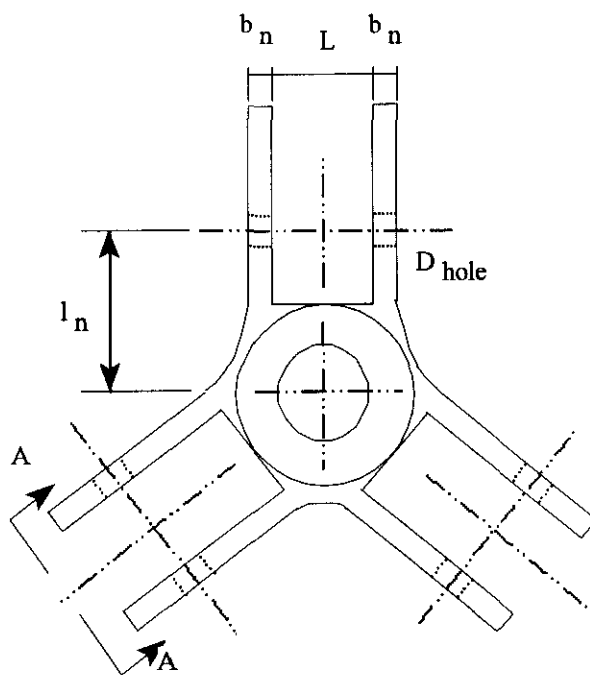
Compressive stress in the hook, $S_{cs} = \sigma_a = \frac{-P_{csb} \cdot (h - c)}{A \cdot \lambda \cdot (R + h - c)}$ Equation 28.13

$$P_{csb} := \frac{-S_{cs} \cdot A \cdot \lambda \cdot (R(c) + h(c) - c)}{h(c) - c} \quad P_{csb} = -78066 \cdot \text{lbf}$$

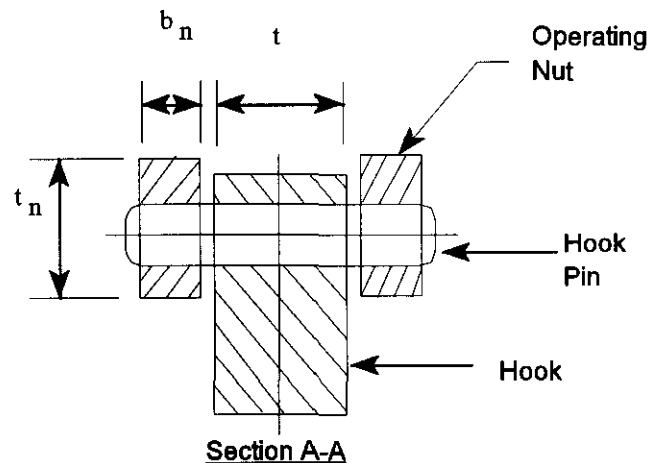
The critical value for the hook axial capacity will be at the top portion of the hook.

$$P_{\text{capacity}} := P_{\text{tst}} \quad P_{\text{capacity}} = 12717 \cdot \text{lbf}$$

5.3 Operating Nut and Pin, Reference drawing H-2-68211 and H-2-32441, Rev. 15



Operating Nut (H-2-68210)



Where the pin and nut dimensions are:

$L := 1.23 \cdot \text{in}$ Hook pin span

$D_{\text{pin}} := 0.874 \cdot \text{in}$ Hook pin diameter

$l_n := 2.688 \cdot \text{in}$ Nut span

$b_n := 0.90 \cdot \text{in}$ Nut width

$t_n := 2.62 \cdot \text{in}$ Nut depth

$D_{\text{hole}} := 0.878 \cdot \text{in}$ Hole in operating nut

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Date 1/25/95**Axial capacity of Operating Nut**

(Refer to drawing H-2-68211, Rev. 9)

Allowable bending stress

Moment of inertia for 2 nuts

$$\sigma_{bA148} = 36000 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

$$I_n = 2 \cdot \frac{b_n \cdot t_n^3}{12}$$

$$I_n = 2.698 \cdot \text{in}^4$$

$$c = \frac{t_n}{2}$$

$$c = 1.31 \cdot \text{in}$$

Max. bending moment, $M = P \cdot l_n$

Calculating for allowable moment, using allowable bending stress

$$\sigma_{bA148} = \frac{M \cdot c}{I_n} = \frac{P \cdot l_n \cdot c}{I_n}$$

per WHC-SD-W028-DA-001, Rev. 0, page 11

Therefore, the axial capacity of the operating nut is $P_{\text{nut}} := \frac{\sigma_{bA148} \cdot I_n}{l_n \cdot c}$ $P_{\text{nut}} = 27580 \cdot \text{lb} \cdot \text{f}$

Axial capacity of the hook pin $W_b := 21140 \cdot \text{lb} \cdot \text{f}$ Pin capacity is determined in Appendix C.**5.4 Determine the axial capacity of the operating screw (Drawing H-2-32441)**

The operating screw will be under compression and its threads along with the threads of the operating nut will be under shearing and bearing stresses.

Allowable shear stress

Allowable bearing stress

$$\sigma_{vA193} = 42000 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

$$\sigma_{brA193} = 94500 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

Per AISC 1980, section 1.5

Refer to shigley, J. E., Mechanical Engineering Design, 3rd Ed., 1977, page 237

 $d_s := 2.0 \cdot \text{in}$ Screw diameter $h_n := 3.0 \cdot \text{in}$ Operating Nut Height $d_r := 1.69 \cdot \text{in}$ Screw root diameter

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1-25/95Average screw-thread shear stress $\tau_{av} := \sigma_{vA193}$

$$\tau_{av} = \frac{2 \cdot F}{\pi \cdot d_r \cdot h_n} \quad \text{Equation (6-7)}$$

$$\text{Therefore, } F := \frac{\tau_{av} \cdot \pi \cdot d_r \cdot h_n}{2} \quad F = 334485 \cdot \text{lbf}$$

Similarly, the average nut-thread shear stress,

$$\tau_{av} = \frac{2 \cdot F}{\pi \cdot d_s \cdot h_n} \quad \text{Equation (6-8)}$$

Because $d_s > d_r$, the value for F will be even larger then $F = 334485 \cdot \text{lbf}$

The bearing stress in the thread

$$\sigma_{bear} = \frac{4 \cdot p \cdot F}{\pi \cdot h_n \cdot (d_s^2 - d_r^2)} \quad \text{Equation (6-9) where, } p := \frac{1}{4.5} \cdot \text{in} \quad \text{and} \quad \sigma_{bear} := \sigma_{brA193}$$

$$\text{Therefore, } F := \frac{\sigma_{bear} \cdot \pi \cdot h_n \cdot (d_s^2 - d_r^2)}{4 \cdot p} \quad F = 1146155 \cdot \text{lbf} \quad \text{which is } > \text{ than } 334,485 \text{ lbf.}$$

Check Contact Stress between screw and the block (Refer to Shigley 1977, page 75)

$$\text{contact radius, } a := \frac{1.703 \cdot \text{in}}{2} \quad \text{Drawing H-2-32441}$$

Maximum contact pressure,

$$p_{max} = \frac{3 \cdot F}{2 \cdot \pi \cdot a^2}$$

Because contact pressure may cause some local deformation, p_{max} can be used as high as yield value

$$\text{Therefore, } F := \frac{S_{yA193} \cdot 2 \cdot \pi \cdot a^2}{3} \quad F = 159447 \cdot \text{lbf}$$

Therefore, the axial capacity of the operating screw (based on per hook), is

$$P := \frac{F}{3} \quad P = 53149 \cdot \text{lbf}$$

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After reviewing the capacities of the Hook, Hook Pin, and the Operating nut, we conclude that the axial capacity of the Hook controls. Therefore, the capacity of the supporting assembly,

$$P_{\text{capacity}} = 12717 \cdot \text{lbf}$$

6.0 CONCLUSION

The axial capacity of the hooks, hook pins, operating nut, and screw are governed by the hook. The axial capacities for the 2-, 3-, and 4-in. hooks are 5943, 8750, and 12717 lbf, respectively. These axial capacities are used in the evaluation of the hook, hook pins, operating nut and screw under bending moments and forces from external loading and are discussed in appendix C.

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DL Kories

Date 1/30/95

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APPENDIX B

BLOCK AND NOZZLE EVALUATION OF 2-, 3-, AND 4-IN. ISB JUMPERS PER ASME CRITERIA

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Appendix "B" Block Evaluation of 2- 3-, and 4- in. jumpers per ASME criteria
Authors J. L. Julyk

Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☐	☒	☐	Computer codes and data files documented. <i>Data files are large and cannot be included with this documentation</i>
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number 95-002

Reviewer

L. P. Shrivastava

Date

3/30/95

Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)

Originator J. L. Julyk *JLJ* Date 3/28/95

Checker H. P. Shrivastava *HS* Date 3/30/95

Stress Evaluation of Integral Seal Blocks (ISB) and Nozzle Flanges

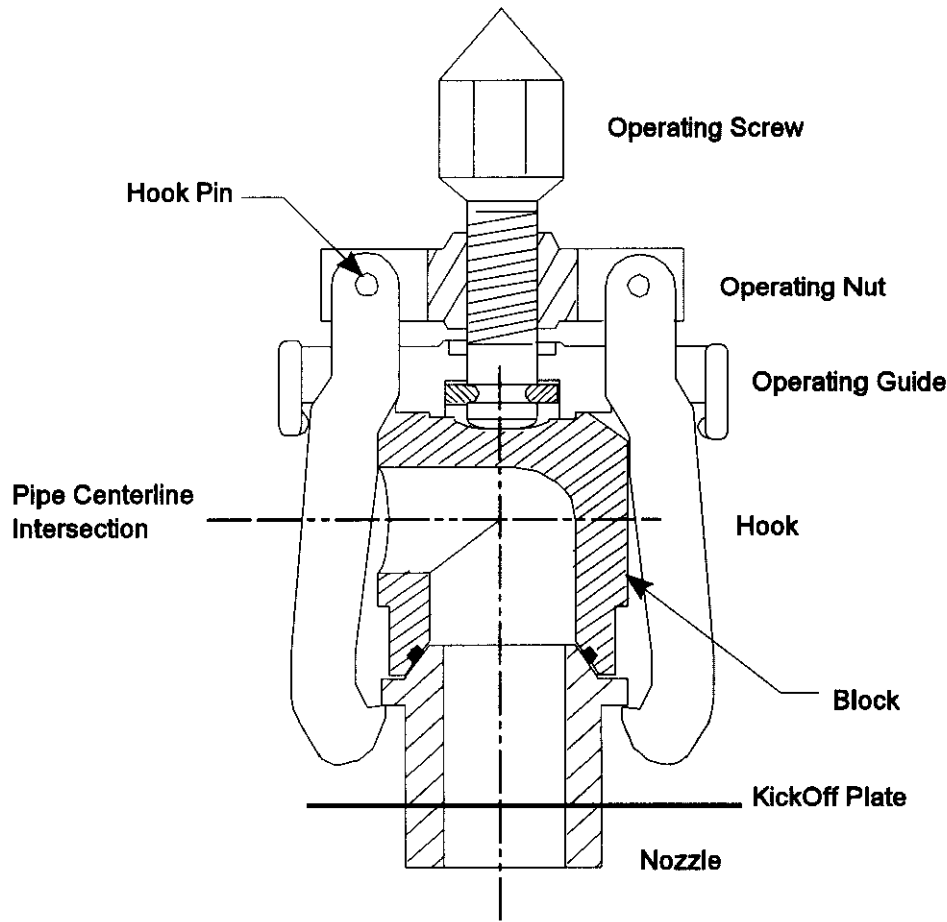
1.0 Introduction

The analysis of the 2-in., 3-in., and 4-in. jumper connector considers operational and seismic loading. The operational loading consists of an axial torque load, internal pressures in the block and nozzle, thermal expansion of block and nozzle, and pipe loads (dead weight and thermal expansion of pipe configurations). The seismic loading consists of loads that the pipe configurations may impose on the block connector during a Design Basis Earthquake.

Since the pipe configuration is not known, the maximum allowable external piping loads for the 2-, 3-, and 4-in. blocks are determined using the stress intensities through the thickness of the block finite-element model sections (top, pipe intersection, side sections, and bottom section) and evaluating them against the ASME (1989b) code allowables, according to failure modes. The results will determine if the assumed enveloping external loads, torque loads, pressure load, and thermal load meet ASME (1989b) code allowables. The maximum piping loads will be determined by increasing the assumed piping loads by calculated load fractions. The end product is a set of maximum allowable external piping loads that the ISB block can accommodate. The interaction of the external piping loads from appendix C is also discussed in this appendix and compared with Table 3.4 in the main report.

The nozzle flange is evaluated in according with ASME (1989c). The results will determine the axial capacity of the nozzle flange based on ASME (1989) code allowables.

Figure B1. Typical Jumper Connector Assembly for 2-, 3-, and 4-in. ISB Connectors



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Originator J. L. Julyk

Date 3/28/95

Checker H. P. Shrivastava

Date 3/30/95

1.1 DESIGN PARAMETERS FOR MWTF PROJECT

The following design parameters are considered in the structural analysis of the connector assembly. Pressure and temperature requirements are taken from the MWTF Functional Design Criteria (FDC) found in WHC-SD-W236A-FDC-001 (WHC 1993a)

$P_{\min} := -10 \cdot \frac{\text{lbf}}{\text{in}^2}$ minimum internal pressure applied to block and nozzle

$P_{\max} := 400 \cdot \frac{\text{lbf}}{\text{in}^2}$ maximum operation internal pressure applied to block and nozzle

$P_{\text{design}} := 400 \cdot \frac{\text{lbf}}{\text{in}^2}$ design internal pressure applied to block and nozzle

$P_{\text{test}} := 1000 \cdot \frac{\text{lbf}}{\text{in}^2}$ internal pressure applied to block and nozzle tested (Ruff 1994)

$T_{\min} := 70$ minimum temperature of block and nozzle (70 °F)

$T_{\max} := 200$ maximum operation temperature of block and nozzle (200 °F)

$T_{\text{design}} := 250$ design temperature of block and nozzle (250 °F)

$T_{\text{test}} := 400$ temperature of block and nozzle tested in the lab by Ruff (1994)

2.0 MATERIAL PROPERTIES OF JUMPERS (2-, 3-, and 4-in.)

The Integral Seal Block (ISB) and nozzles for the 2-, 3-, and 4-in. jumper connectors can be manufactured using four different materials. The materials called out in drawings H-2-821324, H-2-821325, and H-2-821326 are ASTM A276 (Grade 304 SST), ASTM A276 (Grade 316L SST), ASTM B574 (Hastelloy, C-22), and ASTM B166 (Inconel 690). According to ASTM (1989), Ulbricht (1994), ASME (1989a) and ORNL (1976) the minimum yield, tensile strength, Young's modulus, and thermal expansion at 70, 250, and 400 °F are tabulated in Table B1.

ANALYTICAL CALCULATIONS

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REVISION 0Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)Originator J. L. JulykDate 3/28/95Checker H. P. ShrivastavaDate 3/30/95**Table B1. Material Properties of Block and Nozzle**

	Temp	ASTM A276 (Gr. 304)	ASTM A276 (Gr. 316L)	ASTM B574 (C-22)	ASTM B166 (690)
Minimum yield strength (lb/in ²)	70 °F	30,000	25,000	40,000	35,000
	250 °F	24,000	20,417	40,000	31,800
	400 °F	20,000	17,761	39,850 (Est.)	29,900
Minimum tensile strength (lb/in ²)	70 °F	75,000	70,000	100,000	80,000
	250 °F	61,830	62,500	100,000	78,000
	400 °F	58,420	60,750	97,200 (Est.)	76,850
Modulus of Elasticity (lb/in ²)	70 °F	28,500,000	28,500,000	29,900,000	31,600,000
	250 °F	27,620,000	27,620,000	29,400,000	30,650,000
	400 °F	26,640,000	26,640,000	28,500,000	30,050,000
mean coefficient of thermal expansion 1.0E-6 /° F	70 °F	8.55	8.47	6.90	7.15
	250 °F	8.89	8.864	6.90	7.45
	400 °F	9.19	9.21	6.90	7.65

The ASTM A276 (Gr. 304) material is selected for the evaluation of the block at the specified design temperature (70 to 250 deg F) and pressure (400 psi). Based on the minimum yield, minimum tensile strength, and mean coefficient of thermal expansion for the possible materials used in the construction of the block.

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2.1 Block and Nozzle Material Properties (@ 70 and 250 °F) for ASTM A 276 Grade 304 SST (Nuclear Systems Materials Handbook (ORNL 1976) and ASTM (1989))

Minimum yield strength	Minimum tensile strength	Modulus of Elasticity for 304 SST
$S_{y70A276} := 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$S_{t70A276} := 75000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$E_{70A276} := 28.5 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$
$S_{y250A276} := 24000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$S_{t250A276} := 61830 \cdot \frac{\text{lbf}}{\text{in}^2}$	$E_{250A276} := 27.4 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$

mean coefficient of thermal expansion is $8.55\text{E-}6/^{\circ}\text{F}$ and $8.89\text{E-}6/^{\circ}\text{F}$
(ORNL 1976)

Poisson's Ratio

$$\alpha_{70A276} := 8.55 \cdot 10^{-6}$$

$$\nu_{70A276} := 0.266$$

$$\alpha_{250A276} := 8.89 \cdot 10^{-6}$$

$$\nu_{250A276} := 0.274$$

2.2 Screw Material Properties @ 70 °F for ASTM A193 Grade B7 Carbon Steel, ASTM (1989) and ASME (1989a)

Minimum yield strength	Minimum tensile strength	Modulus of Elasticity (assumed)
$S_{yA193} := 105000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$S_{tA193} := 125000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$E_{A193} := 29.7 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$

mean coefficient of thermal expansion is $5.6\text{E-}6/^{\circ}\text{F}$

$$\alpha_{A193} := 5.6 \cdot 10^{-6}$$

2.3 Hook Material Properties (@ 70 °F) for ASTM A747 Grade CB7Cu-1 or CB7Cu-2, H1075 Heat Treated ASTM (1989) and ASME (1989a)

Minimum yield strength	Minimum tensile strength	Modulus of Elasticity (assumed)
$S_{yA747} := 115000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$S_{tA747} := 145000 \cdot \frac{\text{lbf}}{\text{in}^2}$	$E_{A747} := 29.0 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$

mean coefficient of thermal expansion is $5.6\text{E-}6/^{\circ}\text{F}$ (assumed)

$$\alpha_{A747} := 5.6 \cdot 10^{-6}$$

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3.0 CODE ALLOWABLE STRESSES FOR THE 2-, 3-, and 4-in. BLOCK

The ASME (ASME 1989a) criteria is used for the evaluation of the structural limits of the pressure boundary components of the connector assembly (block). The ASME criteria utilizes allowable stresses based on the value on S_m , where S_m is defined in ASME Section VIII, Division 2, Appendix 1, Article 1-110 (ASME 1989a) and is the least of the following:

- (a) One-third of the specified minimum tensile strength at room temp (70 °F)
- (b) One-third of the tensile strength at maximum temperature (250 °F)
- (c) Two-thirds of the specified minimum yield strength at room temp (70 °F)
- (d) Two-thirds of the yield strength at maximum temperature (250 °F), except that for austenitic stainless steels and specific nonferrous materials, this factor may be as large as 90% of the yield strength at maximum temp (but not to exceed 2/3 of the specified minimum yield strength at room temp).

3.1 ASME (1989a) Criteria per stated above for steps (a) thru (d)

$$S_a := \frac{1}{3} \cdot S_{t70A276} \quad S_b := \frac{1}{3} \cdot S_{t250A276} \quad S_c := \frac{2}{3} \cdot S_{y70A276} \quad S_d := 0.90 \cdot (S_{y250A276})$$
$$S_a = 25000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad S_b = 20610 \cdot \frac{\text{lbf}}{\text{in}^2} \quad S_c = 20000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad S_d = 21600 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Therefore, the minimum allowable design stress intensity value for temperatures between 70 to 250 deg. F (based criteria (d) in the ASME (1989a), Appendix 1, Mandatory Design Stress Intensity Value) is shown below.

3.2 Design Stress Intensity value at 250 ° F for 304 SST (ASME 1989a)

$$S_m := S_c \quad S_m = 20000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{Material Allowable Stress per ASME (1989a) Criteria}$$

4.0 Evaluation of 2-in. ISB Single Port Connector (Block analysis)

4.1 Applied axial load on the 2-in. ISB jumper block for a 50 ft-lbf torque screw force

A series of experiment were conducted for MWTF project using a 2-in ISB jumper connector. The results were documented by Ruff (1994) and showed a 50 ft-lbf torque is required to seal up to 1000 lbf/in² of internal pressure. The design pressure for MWTF 2-, 3-, and 4-in. ISB jumpers is 400 lbf/in². This does not include thermal and operational loads.

The Squier (1993) report relates the applied pre-torque vs axial force on the block from the torque screw. From Squier (1993) the screw force for a 2-in. jumper connector (50 ft-lbf screw torque) is 5,000 lbf.

$$F_{\text{torque}} := 5000 \cdot \text{lbf} \quad \text{axial load for a 50 ft-lbf torque (Squier 1993)}$$

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2/20/95**4.2 Determine Equivalent Stiffnesses of Block, Nozzle, Screw, Operating Nut, and Hooks**
(used to determine the axial force to constrain thermal expansion of the block and nozzle) $T_{atm} := T_{min}$ ambient temperature of block and nozzle (70 °F) $T_{max} := T_{design}$ maximum design temperature of block and nozzle**4.2.1 Nozzle stiffness (approximate method):** (WHC 1993b, Drawing No. H-2-83572)

area of nozzle from flange, hook location, to top of nozzle SCH 40

$$A_{N1} := \frac{\pi}{4} \cdot [(3.25 \cdot \text{in})^2 - (2.06 \cdot \text{in})^2]$$

$$A_{N2} := \frac{\pi}{4} \cdot [(2.77 \cdot \text{in})^2 - (2.06 \cdot \text{in})^2]$$

$$A_{N1} = 4.963 \cdot \text{in}^2$$

$$A_{N2} = 2.693 \cdot \text{in}^2$$

 $\Delta T_N := T_{max} - T_{atm}$ temperature change in nozzle

original length of nozzle at hook interface @ 70 degrees F

$$L_{N1} := 0.50 \cdot \text{in}$$

$$L_{N2} := \frac{0.44 \cdot \text{in}}{2}$$

$$\alpha_N := \alpha_{250A276}$$

mean coefficient of thermal expansion for nozzle @ 250 deg. F

$$E_N := E_{250A276}$$

Young's modulus for ASTM A276 @ 250 deg. F (ASTM 1989)

$$K_{N1} := \frac{E_N \cdot A_{N1}}{L_{N1}}$$

$$K_{N2} := \frac{E_N \cdot A_{N2}}{L_{N2}}$$

$$K_{N1} = 2.72 \cdot 10^8 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}}$$

$$K_{N2} = 3.354 \cdot 10^8 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}}$$

approximate stiffness of nozzle section

4.2.2 Block stiffness (approximate method): (WHC 1994a, Drawing No. H-2-821324)

$$A_B := \frac{\pi}{4} \cdot [(3.375 \cdot \text{in})^2 - (2.06 \cdot \text{in})^2]$$

approximate area of block

$$A_B = 5.613 \cdot \text{in}^2$$

 $\Delta T_B := T_{max} - T_{atm}$ temperature change in block

$$L_B := 4.023 \cdot \text{in} - 0.183 \cdot \text{in} - \frac{0.356 \cdot \text{in}}{2}$$

original length of block at 70 degrees F

$$L_B = 3.662 \cdot \text{in}$$

$$\alpha_B := \alpha_{250A276}$$

mean coefficient of thermal expansion for block @ 250 deg. F

$$E_B := E_{250A276}$$

Young's modulus for ASTM A276 @ 250 deg. F (ASTM 1989)

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$$K_{Bapp} := \frac{E_B \cdot A_B}{L_B} \quad \text{estimated stiffness of block} \quad K_{Bapp} = 4.2 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}}$$

4.2.3 Block stiffness (based on Finite-Element Block model, ANSYS5.0a):

The stiffness of the block is determined using the 2-in. ANSYS5.0a block model data. By imposing a fictitious uniform load of 22,00 lbf (Load Case 3) to the top of the block model the UZ displacement, at the center of the uniform loading (node 1774), is 0.002964 in. A section of the output is shown below.

PRINT U NODAL SOLUTION PER NODE

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 3 SUBSTEP= 1
TIME= 3.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UZ
1740	-.21417E-02
1741	-.21539E-02
1742	-.22060E-02
1743	-.22709E-02
1744	-.23448E-02
1745	-.24098E-02
1746	-.22759E-02
1747	-.22757E-02
1748	-.23911E-02
1749	-.23880E-02
1750	-.21596E-02
1751	-.20806E-02
1752	-.20158E-02
1753	-.19839E-02
1754	-.19142E-02
1755	-.18820E-02
1756	-.18624E-02
1757	-.18493E-02
1758	-.18387E-02
1759	-.18345E-02
1760	-.18302E-02
1761	-.18364E-02
1762	-.18429E-02
1763	-.18517E-02
1764	-.18655E-02
1765	-.18836E-02

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1766 -.19142E-02
 1767 -.19831E-02
 1768 -.20138E-02
 1769 -.20714E-02
 1770 -.21256E-02
 1771 -.22186E-02
 1772 -.22600E-02
 1773 -.29271E-02
 1774 -.29637E-02
 1775 -.29569E-02
 1776 -.28919E-02

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 3 SUBSTEP= 1
 TIME= 3.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE UZ
 3849 -.13907E-02
 3850 -.14674E-02
 3851 -.12322E-02
 20000 -.13510E-02

MAXIMUM VALUES
 NODE 1774
 VALUE -.29637E-02

Therefore, the stiffness of the block is calculated below.

$UZ := 0.002964 \cdot \text{in}$ displacement of node in the axial direction (Z-axis)

$F_{Bfea} := 22000 \cdot \text{lbf}$ load applied to top of block model to determine the displacement

$K_{Bfea} := \frac{F_{Bfea}}{UZ}$ $K_{Bfea} = 7.422 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}}$ stiffness of hooks based on node 1774 UZ displacement in block model.

Therefore, the stiffness of the block is the finite-element model calculated stiffness $K_B := K_{Bfea}$

$K_B = 7.422 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}}$

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4.2.4 Screw stiffness (approximate method): (WHC 1982, Drawing No.H-2-32421)

$$A_S := \frac{\pi}{4} \cdot (1.06 \cdot \text{in})^2 \quad \text{aproximate area of block} \quad A_S = 0.882 \cdot \text{in}^2$$

$$L_S := 7.68 \cdot \text{in} - (L_B + L_{N1} + L_{N2}) \quad \text{original length of screw at @ 70 degrees F} \quad L_S = 3.298 \cdot \text{in}$$

$$E_S := E_{A193} \quad \text{Young's modulus for ASTM A193 @ 70 deg. F (ASTM 1989)}$$

$$K_S := \frac{E_S \cdot A_S}{L_S} \quad K_S = 7.947 \cdot 10^6 \cdot \frac{\text{lbF}}{\text{in}} \quad \text{estimated stiffness of screw}$$

4.2.5 Operating nut guide stiffness (approximate method): (WHC 1991a, Drawing No. H-2-68209)

$$I_{\text{nut}} := \frac{2}{12} \cdot \left(\frac{1.82 \cdot \text{in} - 0.83 \cdot \text{in}}{2} \right) \cdot (1.64 \cdot \text{in})^3 \quad \text{aproximate moment of inertia of operating nut guide} \quad I_{\text{nut}} = 0.364 \cdot \text{in}^4$$

$$L_{\text{nut}} := 1.56 \cdot \text{in} \quad \text{original length of operating nut guide at @ 70 degrees F}$$

$$E_{\text{nut}} := 29 \cdot 10^6 \cdot \frac{\text{lbF}}{\text{in}^2} \quad \text{Young's modulus of operating nut guide @ 70 deg. F (assumed)}$$

$$K_{\text{nut}} := \left(\frac{3 \cdot E_{\text{nut}} \cdot I_{\text{nut}}}{L_{\text{nut}}^3} \right) \quad K_{\text{nut}} = 8.339 \cdot 10^6 \cdot \frac{\text{lbF}}{\text{in}} \quad \text{estimated stiffness of operating nut guide}$$

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4.2.6 Hook pin stiffness (approximate method): (WHC 1991a, Drawing No. H-2-68209)

$$I_{pin} := \frac{\pi}{64} \cdot (0.5625 \cdot \text{in})^4 \quad \text{aproximate moment of inertia of hook pin} \quad I_{pin} = 0.005 \cdot \text{in}^4$$

$$L_{pin} := 0.78 \cdot \text{in} + 2 \cdot (0.05 \cdot \text{in}) + \frac{2 \cdot (0.47 \cdot \text{in})}{2} \quad \text{length of hook pin (WHC 1991a, H-2-68209)} \quad L_{pin} = 1.35 \cdot \text{in}$$

$$E_{pin} := 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{Young's modulus of hook pin @ 70 deg. F (assumed)}$$

$$\Delta_{pin} := \frac{1 \cdot \text{lbf} \cdot L_{pin}^3}{48 \cdot E_{pin} \cdot I_{pin}} \quad \text{deflection of pin per AISC 1989 case 7 for a simple beam with a 1 lbf concentrated load at the center (AISC 1989)} \quad \Delta_{pin} = 3.597 \cdot 10^{-7} \cdot \text{in}$$

$$K_{pin} := \left(\frac{1 \cdot \text{lbf}}{\Delta_{pin}} \right) \quad K_{pin} = 2.78 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{estimated stiffness of hook pin}$$

4.2.7 Hooks stiffness (based on Finite-Element Hook model, ANSYS5.0a):

The stiffness of the hooks is determined using the 2-in. ANSYS5.0a hook model found in appendix H. By imposing a fictitious uniform load of 17,000 lbf to the lip of the hook surface while fixing the nodes at the pin location the UY displacement, at the center of the uniform loading (node 79), is 0.04019 in. Therefore, the stiffness of the hook is calculated below.

$$UY := 0.04019 \cdot \text{in} \quad \text{displacement of node 79 in the axial direction (Y-axis)}$$

$$F_{fea} := 17000 \cdot \text{lbf} \quad \text{Fictitious uniform load applied to hook model to determine the displacement of the structure at the hook lip.}$$

$$K_{2fea} := \frac{F_{fea}}{UY} \quad K_{2fea} = 4.23 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{stiffness of hook based on node 79 UY displacement in hook model.}$$

$$\text{Therefore, the stiffness of the one hook is the finite-element model calculated stiffness} \quad K_H := K_{2fea}$$

$$K_H = 4.23 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

Note: The hook is assumed at a constant temperature of 70 deg. F. Therefore, the hook will not thermally expand like the nozzle and block.

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4.2.8 Hooks stiffness for 2-in. Hook (approximate method): (WHC 1993e, Drawing No. H-2-90174, rev. 7, sh 1)

The line joining the top and the bottom points of the hook is virtually parallel to the axis of the nozzle and the block, consider the hook as a crescent with the follow parameters.

$H := 7.68 \cdot \text{in}$ chord length

$$B := 1.64 \cdot \text{in} - \frac{1.14 \cdot \text{in}}{2} \quad B = 1.07 \cdot \text{in} \quad \text{rise}$$

$$\tan\left(\frac{A_{app}}{4}\right) = \frac{2 \cdot B}{H} \quad \text{Refer AISC, 1989, page 6-18}$$

Figure B2. Typical Hook of Jumper
(WHC 1993e, H-2-90174, rev. 7, sh 1)

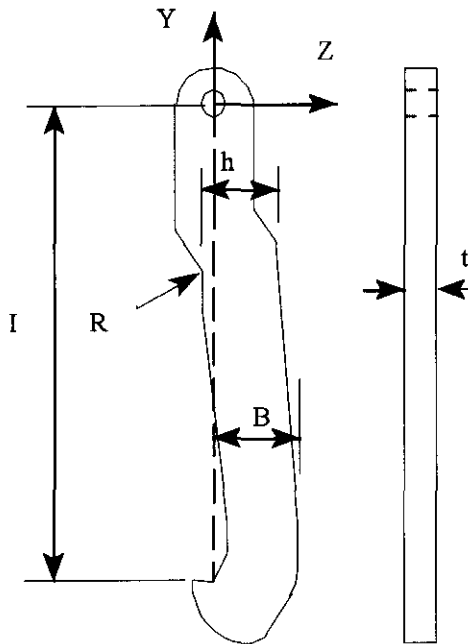
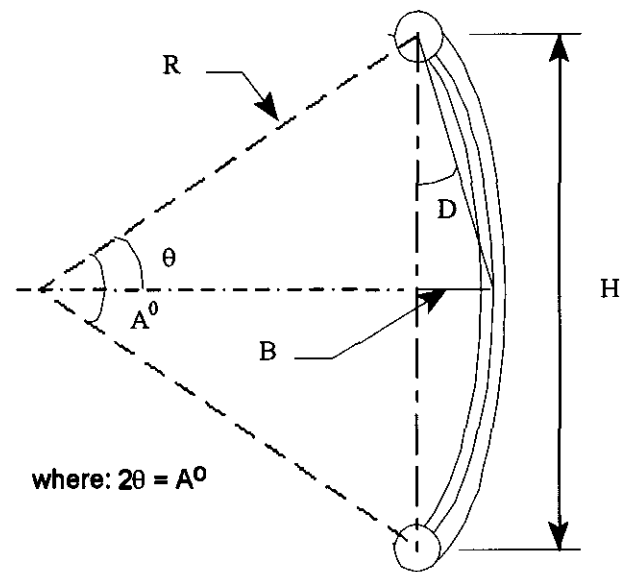


Figure B3. Hook shape for determining Hook Stiffness
(Assumed)



$$\tan(D) = \frac{2 \cdot B}{H} \quad D := \text{atan}\left(\frac{2 \cdot B}{H}\right) \quad D = 15.57 \cdot \text{deg}$$

$$\text{Therefore, } A := 4 \cdot D \quad A = 62.281 \cdot \text{deg} \quad \theta := \frac{A}{2} \quad \theta = 31.141 \cdot \text{deg}$$

$$R := \frac{H}{2 \cdot \sin(\theta)} \quad R = 7.425 \cdot \text{in}$$

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Because load is applied at top pin of the hook $\Phi := \theta$ $\Phi = 31.141 \cdot \text{deg}$ $\theta = 0.544 \cdot \text{rad}$

Refer Roark, 1989, Table 18, Case 3 (Roark 1989)

$$s := \sin(\theta) \quad s = 0.517$$

$$A_{app} := 1.14 \cdot \text{in} \cdot 0.78 \cdot \text{in}$$

$$A_{app} = 0.889 \cdot \text{in}^2$$

$$c := \cos(\theta) \quad c = 0.856$$

$$I_{app} := \frac{0.78 \cdot \text{in} \cdot (1.14 \cdot \text{in})^3}{12}$$

$$I_{app} = 0.096 \cdot \text{in}^4$$

$$n := \sin(\Phi) \quad n = 0.517$$

$$F := \frac{6}{5}$$

Shape Factor (Roark 1989)

$$e := \cos(\Phi) \quad e = 0.856$$

$$W := 1 \cdot \text{lbf} \quad \text{Assume load}$$

$$\mu := 0.30 \quad \text{Poisson ratio for A747 @ 70 deg. F (ASTM 1989)}$$

$$E_{app} := E_{A747}$$

Young's modulus for ASTM A747 @ 70 deg. F (ASTM 1989)

$$E_{A747} = 2.9 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$G := \frac{E_{app}}{2 \cdot (1 + \mu)}$$

Shear Modulus

$$G = 1.115 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\alpha := \frac{I_{app}}{A_{app} \cdot R^2} \quad \alpha = 0.002$$

$$\beta := \frac{F \cdot E_{app} \cdot I_{app}}{G \cdot A_{app} \cdot R^2}$$

$$\beta = 0.006$$

$$LP_H := W \cdot \left[\frac{\theta}{2} + \theta \cdot c^2 - \frac{3}{2} \cdot s \cdot c + \Phi \cdot c \cdot c + \frac{\Phi}{2} - \frac{n \cdot e}{2} - n \cdot c + (\alpha + \beta) \cdot \left(\frac{\theta + \Phi}{2} \right) + (\alpha - \beta) \cdot \left(\frac{s \cdot c + n \cdot e}{2} \right) \right]$$

$$LP_H = 0.015 \cdot \text{lbf}$$

Deformation along the axis of the hook

$$\delta H_A := - \frac{R^3}{E_{A747} \cdot I_{app}} \cdot LP_H$$

$$\delta H_A = -2.127 \cdot 10^{-6} \cdot \text{in}$$

Stiffness of the hook along its axis

$$K_{2app} := \frac{-W}{\delta H_A}$$

$$K_{2app} = 4.702 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

estimated stiffness of hook

$$K_{2fea} = 4.23 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

stiffness of hook based on node 79 UY displacement in hook model.

Therefore, the stiffness of the one hook is the finite-element model calculated stiffness $K_H = 4.23 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$

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$$\Delta L_N := [\alpha_N \cdot (L_{N1} + L_{N2})] \cdot \Delta T_N$$

thermal growth of nozzle @ 250 deg. F

$$\Delta L_N = 0.0012 \cdot \text{in}$$

$$\Delta L_B := (\alpha_B \cdot L_B) \cdot \Delta T_B$$

thermal growth of block @ 250 deg. F

$$\Delta L_B = 0.0059 \cdot \text{in}$$

$$\Delta L_{\text{total}} := \Delta L_N + \Delta L_B$$

thermal growth of block @ 250 deg. F

$$\Delta L_{\text{total}} = 0.007 \cdot \text{in}$$

4.2.10 Determine Equivalent Stiffness of the Jumper (with and without stiffness of the block included)

$$K_{EQ1} := \left(\frac{1}{K_{N1}} + \frac{1}{K_{N2}} + \frac{1}{K_B} + \frac{1}{K_S} + \frac{1}{3 \cdot K_H} + \frac{1}{3 \cdot K_{\text{nut}}} + \frac{1}{3 \cdot K_{\text{pin}}} \right)^{-1} \quad K_{EQ1} = 8.23 \cdot 10^5 \cdot \frac{\text{lb}}{\text{in}}$$

$$K_{EQ2} := \frac{1}{(K_{EQ1}^{-1} - K_B^{-1})} \quad K_{EQ2} = 9.256 \cdot 10^5 \cdot \frac{\text{lb}}{\text{in}} \quad \text{estimated equivalent stiffness of system without block included is due to thermal expansion}$$

4.3 Determining the total force F_{thermal} required to restrain nozzle and block to original length L

$$F_{\text{thermal}} := \frac{K_B \cdot K_{EQ2}}{K_B + K_{EQ2}} \cdot \Delta L_{\text{total}} \quad F_{\text{thermal}} = 5771 \cdot \text{lb} \quad \text{Compression force on Block}$$

Note: The stiffness of the screw, block, nozzle, operating nut guide, hook pins, and hooks are in series**4.4 Determine the applied axial load to account for the internal pressure of the 2-in. ISB jumper block**According to the MWTF Functional Design Criteria (FDC) found in WHC-SD-W236A-FDC-001 (WHC 1993a), the design pressure considered in the structural analysis of the connector assembly is 400 lbf/in².

$$F_{\text{calcap}} := P_{\text{design}} \cdot \frac{\pi}{4} \cdot \left(\frac{2.3 \cdot \text{in} + 2.508 \cdot \text{in}}{2} \right)^2 \quad F_{\text{calcap}} = 1816 \cdot \text{lb}$$

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The axial pressure load applied to resist the internal pressure @ the top of the block/screw interaction is the calculated axial pressure multiplied by the ratio stiffnesses.

$$F_{\text{pressure}} := F_{\text{calcap}} \cdot \left(\frac{K_{\text{EQ2}}}{K_{\text{EQ2}} + K_B} \right) \quad F_{\text{pressure}} = 201 \cdot \text{lbf} \quad \text{Compression force on block and tensile force on hooks}$$

$$F_{\text{Pseat}} := F_{\text{calcap}} - F_{\text{pressure}} \quad F_{\text{Pseat}} = 1614 \cdot \text{lbf} \quad \text{Pressure load that goes to reduce the seating torque load}$$

4.5 Total applied axial load for 2-in. ISB jumper block

$$F_{\text{total}} := F_{\text{torque}} + F_{\text{thermal}} + F_{\text{pressure}}$$

$$F_{\text{total}} = 10972 \cdot \text{lbf} \quad \text{applied axial load for a 50 ft-lbf torque, thermal, and pressure loading.}$$

The full diameter of the screw is used to apply the total axial loads for the 2-in ISB jumper block. The failure mode of the block, at the top section, is a punch-through failure. Therefore, the full diameter of the screw is used for this failure mode. The justification of using the full diameter is discussed in the axisymmetric model of the block/screw interaction found in appendix E. The total axial loads are applied over a circular radius of $b = 0.52$ in., in the 2-in. FEA model, to simulate the punch-through failure mode of the screw and block. The stresses at the top section of the block are then compared to the ASME (1989b) criteria established in sections 4.7.1 to 4.7.3.

4.6 Seating load with and without thermal effects (cold and hot conditions)

Excluding the effects of thermal and axial external loading

$$F_{\text{cold}} := F_{\text{torque}} - (F_{\text{Pseat}})$$

$$F_{\text{cold}} = 3386 \cdot \text{lbf} \quad \text{seating load for a 50 ft-lbf torque}$$

Excluding the effects of axial external loading

$$F_{\text{hot1}} := F_{\text{torque}} + F_{\text{thermal}} - (F_{\text{Pseat}})$$

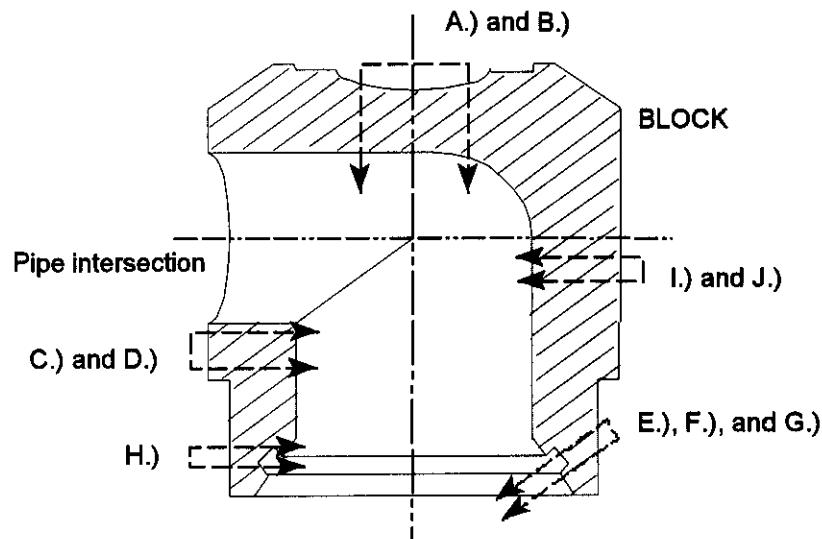
$$F_{\text{hot1}} = 9156 \cdot \text{lbf} \quad \text{seating load for a 50 ft-lbf torque}$$

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4.7 ASME (1989b) Stress Allowables for ISB connector block

Per the 1989 ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 4, Article 4-1, Mandatory Design Based on Stress Analysis (ASME 1989b), the stresses in the block due to the applied loads is defined for the following locations. See Table 4-120.1 in ASME 1989b for details.

Figure B4. Sketch of 2-in. ISB Block and ASME thru the thickness check locations (FEA block model that is checked per ASME 1989b stress criteria)



4.7.1 Stress Intensities through the top section of the block (under the torque screw for punch-through)

A.) $P_m \leq S_m = 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$ General Primary Membrane stress

B.) $P_L + P_b \leq 1.5 \cdot S_m = 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$ General primary membrane plus primary bending stress

4.7.2 Stress Intensities through the block thickness at pipe connection opening

C.) $P_L \leq 1.5 \cdot S_m = 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local primary membrane stress

D.) $P_L + P_b + Q \leq 3 \cdot S_m = 60000 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads (discontinuities in connection)

4.7.3 Stress Intensities through the bottom section of the block (at the nozzle/block interface)

E.) $P_L \leq 1.5 \cdot S_m = 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary Membrane stress

F.) $P_L + P_b \leq 1.5 \cdot S_m = 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary membrane plus primary bending plus bearing stress, outside surface

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$$G.) \quad P_L + P_b + Q \leq 3 \cdot S_m = 60000 \cdot \frac{\text{lb}f}{\text{in}^2}$$

Local Primary membrane plus primary bending plus bearing stress, inside surface (secondary stress)

$$H.) \quad P_m \leq S_m = 20000 \cdot \frac{\text{lb}f}{\text{in}^2}$$

General primary membrane stress (Hoop component)

where S_m is the allowable stress intensity, P_m is the membrane stress, P_b is the bending stress, P_L is the localized membrane, and Q is the bearing. The ASME stress criteria is used in determining the load fractions and maximum allowable forces and moments that the block can with stand all cases. A description of the ISB block Finite-Element Analysis model is discussed in section 10.0.

4.8 Calculation of Maximum Piping Loads using Linearized Stress Intensities through a section of the 2-in. ISB jumper connector block

The stress analysis is based on a linear-elastic material. The linearized stress intensity is taken from the 2-in. finite-element block model. The linearized stress intensities through the thickness of the block are from a 50 ft-lbf torque load case, thermal expansion from 70 to 250 deg. F, internal pressure of 400 lbf/in², and assumed external loads associated with the piping configuration. The assumed forces and moments are stated below.

4.8.1 Loads and Load Cases Applied to FEA 2-in. block model

$F_{Zlc1} := -11500 \cdot \text{lb}f$	Load Case 1 (LC1), axial load (Fz) applied at top of block/screw for 50 ft-lbf pre-load
$F_{Xlc5} := -12000 \cdot \text{lb}f$	Load Case 5 (LC5), horizontal force (Fx) applied at pipe intersection @ node 20,000
$F_{Ylc7} := -6000 \cdot \text{lb}f$	Load Case 7 (LC7), horizontal force (Fy) applied at pipe intersection @ node 20,000
$F_{Zlc9} := -4000 \cdot \text{lb}f$	Load Case 9 (LC9), axial force (Fz) applied at pipe intersection @ node 20,000
$M_{Xlc10} := 1128 \cdot \text{ft} \cdot \text{lb}f$	Load Case 10 (LC10), horizontal moment applied at pipe intersection @ node 20,000
$M_{Ylc13} := -1265 \cdot \text{ft} \cdot \text{lb}f$	Load Case 13 (LC13), horizontal moment applied at pipe intersection @ node 20,000
$M_{Zlc15} := -1265 \cdot \text{ft} \cdot \text{lb}f$	Load Case 15 (LC15), torsional moment applied at pipe intersection @ node 20,000

Load Case 16 (LC16), applied an internal pressure of 400 psi to the inside of the block.

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4.8.2 Maximum linearized stress intensities through the top section of the block from axial loading (See section 11, Table B9 for reference)

$$SI_{m50} := 9632 \cdot \frac{\text{lbf}}{\text{in}^2} \leq S_m = 20000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{General Primary Membrane stress for load case 1 (node 346 to 1833, path length 0.72 in.)}$$

$$SI_{mb50} := 11520 \cdot \frac{\text{lbf}}{\text{in}^2} \leq 1.5 \cdot S_m = 30000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{General Primary membrane plus primary bending stress for load case 1 (node 346 to 1833, path length 0.72 in.)}$$

Therefore, the top section of the block under axial loading (preload 50 + thermal expansion + pressure) meets the ASME (1989b) criteria established above for the top section of the block under the screw.

4.8.2.1 Maximum allowable pre-load the top section of the block can withstand

$$F_m := \frac{S_m}{SI_{m50}} \cdot F_{\text{total}} \quad F_m = 22782 \cdot \text{lbf} \quad \text{Total load based on membrane stress intensity}$$

$$F_{mb} := \frac{1.5 \cdot S_m}{SI_{mb50}} \cdot F_{\text{total}} \quad F_{mb} = 28573 \cdot \text{lbf} \quad \text{Total axial load based on membrane plus bending stress intensity}$$

$$F_{\text{preload}} := \text{if}(F_m \leq F_{mb}, F_m - F_{\text{pressure}} - F_{\text{thermal}}, F_{mb} - F_{\text{pressure}} - F_{\text{thermal}}) \quad F_{\text{preload}} = 16810 \cdot \text{lbf}$$

From the Squire (1993) test report the screw force of calculated is between 100 and 200 ft-lbf of torque. Therefore, by linearly interpolating the test data from the Squire (1993) report the maximum allowable preload torque is calculated.

$$\text{Torque}_{\text{max}} := \frac{1}{2} \cdot \left[\frac{\left(\frac{15421 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 19031 \cdot \text{lbf}} \right) \cdot 203.1 \cdot \text{ft} \cdot \text{lbf} + 150.6 \cdot \text{ft} \cdot \text{lbf}}{\frac{15421 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 19031 \cdot \text{lbf}} + 1} + \frac{\left(\frac{15663 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 17631 \cdot \text{lbf}} \right) \cdot 200.9 \cdot \text{ft} \cdot \text{lbf} + 176.1 \cdot \text{ft} \cdot \text{lbf}}{\frac{15663 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 17631 \cdot \text{lbf}} + 1} \right]$$

$$\text{Torque}_{\text{max}} = 181 \cdot \text{ft} \cdot \text{lbf}$$

Therefore, the maximum allowable preload torque is 180 ft-lbf at the current design conditions and material allowables based on a elastic linear analysis.

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4.8.3 Maximum External Forces and Moments @ the Pipe Intersection

(The Maximum linearized stress intensities through the block wall at the pipe entrance for external loading, 50 ft-lbf, thermal expansion, and pressure stresses are in section 11, Table B9)

$$SI_{L50} := 3926 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 1,
(node 505 to 541, path length of 0.681 in.)

$$SI_{LBQ50} := 8189 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress for load case 1, (node 505 to 541, path length of 0.681 in.)

$$SI_{EL180} := \frac{F_m}{F_{total}} \cdot SI_{L50}$$

Estimated Local Primary Membrane stress at the calculated maximum torque, (node 505 to 541, path length of 0.681 in.)

$$SI_{EL180} = 8152 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{ELBQ180} := \frac{F_m}{F_{total}} \cdot SI_{LBQ50}$$

Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, (node 55 to 496, path length of 0.656 in.)

$$SI_{ELBQ180} = 17004 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{Lpress} := 2653 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 16,
(node 55 to 496, path length of 0.656 in.)

$$SI_{LBQpress} := 3796 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress for load case 16, (node 55 to 496, path length of 0.656 in.)

4.8.3.1 The resultant of the initial stress intensity is stated as the following @ the pipe intersection:

$$SI_L := SI_{L50} + SI_{Lpress}$$

Local primary membrane stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_L = 6579 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ} := SI_{LBQ50} + SI_{LBQpress}$$

Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{LBQ} = 11985 \cdot \frac{\text{lbf}}{\text{in}^2}$$

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$$SI_{L180} := SI_{EL180} + SI_{Lpress}$$

Local primary membrane stress at maximum torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{L180} = 10805 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ180} := SI_{ELBQ180} + SI_{LBQpress}$$

Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{LBQ180} = 20800 \cdot \frac{\text{lbf}}{\text{in}^2}$$

4.8.3.2 Maximum allowable external forces and moments at the pipe intersection for 2-in ISB Block

The Local membrane and bending are compared to the allowable ASME stress, based on the criteria in section 4.7.2, minus the stress conditions due to torque, thermal expansion and internal pressure.

$$SI_{LFX} := 12410 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 5 (node 386 to 395, path length of 0.668 in.)

$$F_{Xm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm50} = -22647 \cdot \text{lbf}$$

$$F_{Xm180} = -18561 \cdot \text{lbf}$$

$$SI_{LBQFx} := 18710 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 386 to 395, path length of 0.668 in.)

$$F_{Xmb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQFx}} \cdot F_{Xlc5}$$

$$F_{Xmb180} := \frac{3 \cdot S_m - SI_{LBQ180}}{SI_{LBQFx}} \cdot F_{Xlc5}$$

$$F_{Xmb50} = -30795 \cdot \text{lbf}$$

$$F_{Xmb180} = -25142 \cdot \text{lbf}$$

$$SI_{LFy} := 10100 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 7 (node 1295 to 472, path length of 0.62 in.)

$$F_{Ym50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym50} = -13913 \cdot \text{lbf}$$

$$F_{Ym180} = -11403 \cdot \text{lbf}$$

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$SI_{LBQFy} := 16670 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 1295 to 472, path length of 0.62 in.)

$$F_{Ymb50} := \frac{3 \cdot S_m - SI_{LBQFy}}{SI_{LBQFy}} \cdot F_{Ylc7}$$

$$F_{Ymb180} := \frac{3 \cdot S_m - SI_{LBQ180}}{SI_{LBQFy}} \cdot F_{Ylc7}$$

$$F_{Ymb50} = -17282 \cdot \text{lbf}$$

$$F_{Ymb180} = -14109 \cdot \text{lbf}$$

$SI_{LFz} := 4097 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary Membrane stress for load case 9 (node 505 to 541, path length of 0.681 in.)

$$F_{Zm50} := \frac{1.5 \cdot S_m - SI_{LFz}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm50} = -22866 \cdot \text{lbf}$$

$$F_{Zm180} = -18741 \cdot \text{lbf}$$

$SI_{LBQFz} := 10810 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 505 to 541, path length of 0.681 in.)

$$F_{Zmb50} := \frac{3 \cdot S_m - SI_{LBQFz}}{SI_{LBQFz}} \cdot F_{Zlc9}$$

$$F_{Zmb180} := \frac{3 \cdot S_m - SI_{LBQ180}}{SI_{LBQFz}} \cdot F_{Zlc9}$$

$$F_{Zmb50} = -17767 \cdot \text{lbf}$$

$$F_{Zmb180} = -14505 \cdot \text{lbf}$$

$SI_{LMx} := 10780 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary Membrane stress for load case 10 (node 386 to 395, path length of 0.668 in.)

$$M_{Xm50} := \frac{1.5 \cdot S_m - SI_{LMx}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm50} = 2451 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xm180} = 2009 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{LBQMx} := 22228 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 386 to 395, path length of 0.668 in.)

$$M_{Xmb50} := \frac{3 \cdot S_m - SI_{LBQMx}}{SI_{LBQMx}} \cdot M_{Xlc10}$$

$$M_{Xmb180} := \frac{3 \cdot S_m - SI_{LBQ180}}{SI_{LFx}} \cdot M_{Xlc10}$$

$$M_{Xmb50} = 2437 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xmb180} = 3563 \cdot \text{ft} \cdot \text{lbf}$$

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$SI_{LMY} := 18160 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary Membrane stress for load case 13 (node 1295 to 472, path length of 0.62 in.)

$$M_{Ym50} := \frac{1.5 \cdot S_m - SI_{LMY}}{SI_{LMY}} \cdot M_{Ylc13} \quad M_{Ym180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LMY}} \cdot M_{Ylc13}$$

$$M_{Ym50} = -1631 \cdot \text{ft} \cdot \text{lbf} \quad M_{Ym180} = -1337 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{LBQMY} := 22271 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 1295 to 472, path length of 0.62 in.)

$$M_{Ymb50} := \frac{3 \cdot S_m - SI_{LBQMY}}{SI_{LBQMY}} \cdot M_{Ylc13} \quad M_{Ymb180} := \frac{3 \cdot S_m - SI_{LBQ180}}{SI_{LBQMY}} \cdot M_{Ylc13}$$

$$M_{Ymb50} = -2727 \cdot \text{ft} \cdot \text{lbf} \quad M_{Ymb180} = -2227 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{LMZ} := 22460 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary Membrane stress for load case 15 (node 386 to 395, path length of 0.668 in.)

$$M_{Zm50} := \frac{1.5 \cdot S_m - SI_{LMZ}}{SI_{LMZ}} \cdot M_{Zlc15} \quad M_{Zm180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LMZ}} \cdot M_{Zlc15}$$

$$M_{Zm50} = -1319 \cdot \text{ft} \cdot \text{lbf} \quad M_{Zm180} = -1081 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{LBQMZ} := 31610 \cdot \frac{\text{lbf}}{\text{in}^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 386 to 395, path length of 0.668 in.)

$$M_{Zmb50} := \frac{3 \cdot S_m - SI_{LBQMZ}}{SI_{LBQMZ}} \cdot M_{Zlc15} \quad M_{Zmb180} := \frac{3 \cdot S_m - SI_{LBQ180}}{SI_{LBQMZ}} \cdot M_{Zlc15}$$

$$M_{Zmb50} = -1922 \cdot \text{ft} \cdot \text{lbf} \quad M_{Zmb180} = -1569 \cdot \text{ft} \cdot \text{lbf}$$

The maximum allowable external forces and moments at the pipe section are summarized below for a 50 and 180 ft-lbf pre-load torques in Table B2.

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Table B2. The maximum allowable external forces and moments at the pipe section

<u>External Loads</u>	<u>50 ft-lbf Torque</u>	<u>180 ft-lbf Torque</u>
F _x (lbf)	22,647	18,561
F _y (lbf)	13,913	11,403
F _z (lbf)	17,767	14,505
M _x (ft-lbf)	2,437	2,009
M _y (ft-lbf)	1,631	1,337
M _z (ft-lbf)	1,319	1,081

4.8.4 Check Interaction with system model results for a 50 ft-lbf pre-load torque

From Table B2, the maximum allowable piping loads applied at the pipe opening were obtained. From Table 3.4 the acceptable piping loads were determined based on the other jumper components (hooks, pins, operating screw, guide lip with block lip, top of block, block bottom and pipe opening). The following is a linear interaction of Table 3.4 and Table B2 for the 50 ft-lbf pre-load case. See appendix C for interaction details.

Maximum Piping Loads from Table 3.4

$$f_x := 1330 \cdot \text{lbf} \quad m_x := 365 \cdot \text{ft} \cdot \text{lbf}$$

$$f_y := 1330 \cdot \text{lbf} \quad m_y := 365 \cdot \text{ft} \cdot \text{lbf}$$

$$f_z := 7370 \cdot \text{lbf} \quad m_z := 260 \cdot \text{ft} \cdot \text{lbf}$$

Maximum Piping loads from Table B2 @ 50 ft-lbf

$$F_x := 22647 \cdot \text{lbf} \quad M_x := 2437 \cdot \text{ft} \cdot \text{lbf}$$

$$F_y := 13913 \cdot \text{lbf} \quad M_y := 1631 \cdot \text{ft} \cdot \text{lbf}$$

$$F_z := 17767 \cdot \text{lbf} \quad M_z := 1319 \cdot \text{ft} \cdot \text{lbf}$$

$$I := \sqrt{\left(\frac{f_x}{F_x}\right)^2 + \left(\frac{f_y}{F_y}\right)^2 + \left(\frac{f_z}{F_z}\right)^2} + \sqrt{\left(\frac{m_x}{M_x}\right)^2 + \left(\frac{m_y}{M_y}\right)^2 + \left(\frac{m_z}{M_z}\right)^2}$$

The linear interaction (I) must be less than or equal to 1 in order to satisfy ASME criteria at the pipe intersection.

$$I = 0.76 \leq 1.0$$

Therefore, satisfied for above piping loads from Table 3.4.

See appendix C for details of the basis of the interaction.

4.8.5 Maximum External Forces and Moments @ Bottom section of the block

(The Maximum linearized stress intensities through the block wall at the nozzle /block interface external loading, 50 ft-lbf, thermal expansion, and pressure stresses are in section 11, Table B9)

$$SI_{L50} := 11170 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 1, (node 1253 to 1105, path length of 0.389 in.)

$$SI_{LBQ50I} := 14020 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress for load case 1, (node 1253 to 1105, path length of 0.389 in.)

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$SI_{LBQ500} := 8549 \cdot \frac{\text{lbf}}{\text{in}^2}$ **OUTSIDE Local Primary membrane plus primary bending plus secondary stress for load case 1, (node 1253 to 1105, path length of 0.389 in.)**

$SI_{H50} := 5796 \cdot \frac{\text{lbf}}{\text{in}^2}$ **General primary membrane stress compared to SY membrane stress for load case 1, Hoop component, (node 1253 to 1105, path length of 0.389 in.)**

$SI_{EL180} := \frac{F_m}{F_{total}} \cdot SI_{L50}$ **Estimated Local Primary Membrane stress at the calculated maximum torque, (node 1253 to 1105, path length of 0.389 in.)**
 $SI_{EL180} = 23194 \cdot \frac{\text{lbf}}{\text{in}^2}$

$SI_{ELBQ180I} := \frac{F_m}{F_{total}} \cdot SI_{LBQ50I}$ **INSIDE Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, (node 1253 to 1105, path length of 0.389 in.)**
 $SI_{ELBQ180I} = 29111 \cdot \frac{\text{lbf}}{\text{in}^2}$

$SI_{ELBQ180O} := \frac{F_m}{F_{total}} \cdot SI_{LBQ50O}$ **OUTSIDE Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, (node 1253 to 1105, path length of 0.389 in.)**
 $SI_{ELBQ180O} = 17751 \cdot \frac{\text{lbf}}{\text{in}^2}$

$SI_{EH180} := \frac{F_m}{F_{total}} \cdot SI_{H50}$ **Estimated General primary membrane stress compared to SY membrane stress for load case 1, Hoop component, (node 1253 to 1105, path length of 0.389 in.)**
 $SI_{EH180} = 12035 \cdot \frac{\text{lbf}}{\text{in}^2}$

$SI_{Lpress} := 4471 \cdot \frac{\text{lbf}}{\text{in}^2}$ **Local Primary Membrane stress for load case 16, (node 1215 to 1016, path length of 0.351 in.)**

$SI_{LBQpressI} := 6664 \cdot \frac{\text{lbf}}{\text{in}^2}$ **INSIDE Local Primary membrane plus primary bending plus secondary stress for load case 16, (node 1215 to 1016, path length of 0.351 in.)**

$SI_{LBQpressO} := 2618 \cdot \frac{\text{lbf}}{\text{in}^2}$ **OUTSIDE Local Primary membrane plus primary bending plus secondary stress for load case 16, (node 1215 to 1016, path length of 0.351 in.)**

ANALYTICAL CALCULATIONS

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Subject	<u>Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)</u>		
Originator	<u>J. L. Julyk</u> <i>JLJ</i>	Date	<u>3/28/95</u>
Checker	<u>H. P. Shrivastava</u> <i>HP</i>	Date	<u>3/30/95</u>

$$SI_{Hpress} := 295 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress compared to SY membrane stress for load case 16, Hoop component, (node 1215 to 1016, path length of 0.351 in.)

4.8.5.1 The resultant of the initial stress intensity is stated as the following @ the bottom section:

$$SI_L := SI_{L50} + SI_{Lpress}$$

Local primary membrane stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_L = 15641 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQI} := SI_{LBQ50I} + SI_{LBQpressI}$$

INSIDE Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQI} = 20684 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQO} := SI_{LBQ50O} + SI_{LBQpressO}$$

OUTSIDE Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQO} = 11167 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{HOOP50} := SI_{H50} + SI_{Hpress}$$

General primary membrane stress, SRSS of the in-plane SY membrane stress for Hoop component, @ bottom section.

$$SI_{HOOP50} = 6091 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{L180} := SI_{L180} + SI_{Lpress}$$

Local primary membrane stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{L180} = 15276 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ180I} := SI_{ELBQ180I} + SI_{LBQpressI}$$

INSIDE Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQ180I} = 35775 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ180O} := SI_{ELBQ180O} + SI_{LBQpressO}$$

OUTSIDE Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQ180O} = 20369 \cdot \frac{\text{lbf}}{\text{in}^2}$$

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 Originator J. L. Julyk *JLJ* Date 3/28/95
 Checker H. P. Shrivastava *HP* Date 2/20/95

$$SI_{HOOP180} := SI_{EH180} + SI_{Hpress}$$

General primary membrane stress, SY membrane stress for Hoop component, @ bottom section.

$$SI_{HOOP180} = 12330 \cdot \frac{\text{lb}}{\text{in}^2}$$

4.8.5.2 Maximum allowable external forces and moments at the bottom section for 2-in ISB Block

The Local membrane and bending are compared to the allowable ASME stress, based on the criteria in section 4.7.3, minus the stresses due to torque, thermal expansion and internal pressure.

$$SI_{LFX} := 6917 \cdot \frac{\text{lb}}{\text{in}^2}$$

Local Primary Membrane stress for load case 5 (node 1165 to 959, path length of 0.409 in.)

$$F_{Xm50} := \frac{1.5 \cdot S_m - SI_{LFX}}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm50} = -24911 \cdot \text{lb}$$

$$F_{Xm180} = -25544 \cdot \text{lb}$$

$$SI_{LBQFXI} := 11450 \cdot \frac{\text{lb}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 1165 to 959, path length of 0.409 in.)

$$F_{Xmb50I} := \frac{3 \cdot S_m - SI_{LBQFI}}{SI_{LBQFXI}} \cdot F_{Xlc5}$$

$$F_{Xmb180I} := \frac{3 \cdot S_m - SI_{LBQ180I}}{SI_{LBQFXI}} \cdot F_{Xlc5}$$

$$F_{Xmb50I} = -41205 \cdot \text{lb}$$

$$F_{Xmb180I} = -25388 \cdot \text{lb}$$

$$SI_{LBQFXO} := 2516 \cdot \frac{\text{lb}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 1165 to 959, path length of 0.409 in.)

$$F_{Xmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFXO}} \cdot F_{Xlc5}$$

$$F_{Xmb180O} := \frac{1.5 \cdot S_m - SI_{LBQ180O}}{SI_{LBQFXO}} \cdot F_{Xlc5}$$

$$F_{Xmb50O} = -89824 \cdot \text{lb}$$

$$F_{Xmb180O} = -45934 \cdot \text{lb}$$

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Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)
Originator J. L. Julyk *JLJ* Date 3/28/95
Checker H. P. Shrivastava *HP* Date 3/30/95

$$SI_{HOOP} := 2299 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress SY membrane stress for load case 5, Hoop component, (node 1165 to 959, path length of 0.409 in.)

$$F_{XHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Xlc5}$$

$$F_{XHOOP180} := \frac{S_m - SI_{HOOP180}}{SI_{HOOP}} \cdot F_{Xlc5}$$

$$F_{XHOOP50} = -72600 \cdot \text{lbf}$$

$$F_{XHOOP180} = -40035 \cdot \text{lbf}$$

$$SI_{LFy} := 3911 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 7 (node 1199 to 1010, path length of 0.395 in.)

$$F_{Ym50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym50} = -22029 \cdot \text{lbf}$$

$$F_{Ym180} = -22589 \cdot \text{lbf}$$

$$SI_{LBQFyI} := 4788 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 1199 to 1010, path length of 0.395 in.)

$$F_{Ymb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQFyI}} \cdot F_{Ylc7}$$

$$F_{Ymb180I} := \frac{3 \cdot S_m - SI_{LBQ180I}}{SI_{LBQFyI}} \cdot F_{Ylc7}$$

$$F_{Ymb50I} = -49268 \cdot \text{lbf}$$

$$F_{Ymb180I} = -30357 \cdot \text{lbf}$$

$$SI_{LBQFyO} := 3046 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 1199 to 1010, path length of 0.395 in.)

$$F_{Ymb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFyO}} \cdot F_{Ylc7}$$

$$F_{Ymb180O} := \frac{1.5 \cdot S_m - SI_{LBQ180O}}{SI_{LBQFyO}} \cdot F_{Ylc7}$$

$$F_{Ymb50O} = -37097 \cdot \text{lbf}$$

$$F_{Ymb180O} = -18971 \cdot \text{lbf}$$

ANALYTICAL CALCULATIONS

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Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)
 Originator J. L. Julyk *Julyk* Date 3/28/95
 Checker H. P. Shrivastava *HPs* Date 3/30/95

$$SI_{HOOP} := 1451 \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress SY membrane stress for load case 7, Hoop component, (node 1199 to 1010, path length of 0.395 in.)

$$F_{YHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Ylc7} \quad F_{YHOOP180} := \frac{S_m - SI_{HOOP180}}{SI_{HOOP}} \cdot F_{Ylc7}$$

$$F_{YHOOP50} = -57515 \cdot \text{lbf}$$

$$F_{YHOOP180} = -31717 \cdot \text{lbf}$$

$$SI_{LFz} := 6161 \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 9 (node 1165 to 959, path length of 0.409 in.)

$$F_{Zm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LFz}} \cdot F_{Zlc9} \quad F_{Zm180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm50} = -9323 \cdot \text{lbf}$$

$$F_{Zm180} = -9559 \cdot \text{lbf}$$

$$SI_{LBQFzI} := 8826 \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 1165 to 959, path length of 0.409 in.)

$$F_{Zmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQFzI}} \cdot F_{Zlc9} \quad F_{Zmb180I} := \frac{3 \cdot S_m - SI_{LBQ180I}}{SI_{LBQFzI}} \cdot F_{Zlc9}$$

$$F_{Zmb50I} = -17818 \cdot \text{lbf}$$

$$F_{Zmb180I} = -10979 \cdot \text{lbf}$$

$$SI_{LBQFzO} := 3559 \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 1165 to 959, path length of 0.409 in.)

$$F_{Zmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFzO}} \cdot F_{Zlc9} \quad F_{Zmb180O} := \frac{1.5 \cdot S_m - SI_{LBQ180O}}{SI_{LBQFzO}} \cdot F_{Zlc9}$$

$$F_{Zmb50O} = -29941 \cdot \text{lbf}$$

$$F_{Zmb180O} = -10824 \cdot \text{lbf}$$

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Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)
 Originator J. L. Julyk *JLJ* Date 3/28/95
 Checker H. P. Shrivastava *HP* Date 3/30/95

$$SI_{HOOP} := 2434 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress SY membrane stress for load case 9, Hoop component, (node 1165 to 959, path length of 0.409 in.)

$$F_{ZHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Zlc9}$$

$$F_{ZHOOP180} := \frac{S_m - SI_{HOOP180}}{SI_{HOOP}} \cdot F_{Zlc9}$$

$$F_{ZHOOP50} = -22858 \cdot \text{lbf}$$

$$F_{ZHOOP180} = -12605 \cdot \text{lbf}$$

$$SI_{LMx} := 5227 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 10 (node 1207 to 1007, path length of 0.35 in.)

$$M_{Xm50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm50} = 3099 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xm180} = 3177 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMxI} := 6624 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 1207 to 1007, path length of 0.35 in.)

$$M_{Xmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQMxI}} \cdot M_{Xlc10}$$

$$M_{Xmb180I} := \frac{3 \cdot S_m - SI_{LBQ180I}}{SI_{LBQMxI}} \cdot M_{Xlc10}$$

$$M_{Xmb50I} = 6695 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xmb180I} = 4125 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMxO} := 3904 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 1207 to 1007, path length of 0.35 in.)

$$M_{Xmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQMxO}} \cdot M_{Xlc10}$$

$$M_{Xmb180O} := \frac{1.5 \cdot S_m - SI_{LBQ180O}}{SI_{LBQMxO}} \cdot M_{Xlc10}$$

$$M_{Xmb50O} = 5442 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xmb180O} = 2783 \cdot \text{ft} \cdot \text{lbf}$$

ANALYTICAL CALCULATIONS

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Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)
 Originator J. L. Julyk *JLJ* Date 3/28/95
 Checker H. P. Shrivastava *hps* Date 3/29/95

$$SI_{HOOP} := 2183 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress SY membrane stress for load case 10, Hoop component, (node 1207 to 1007, path length of 0.35 in.)

$$M_{XHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Xlc10} \quad M_{XHOOP180} := \frac{S_m - SI_{HOOP180}}{SI_{HOOP}} \cdot M_{Xlc10}$$

$$M_{XHOOP50} = 7187 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{XHOOP180} = 3963 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LMY} := 7417 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 13 (node 1165 to 959, path length of 0.409 in.)

$$M_{Ym50} := \frac{1.5 \cdot S_m - SI_{LMY}}{SI_{LMY}} \cdot M_{Ylc13} \quad M_{Ym180} := \frac{1.5 \cdot S_m - SI_{LMY}}{SI_{LMY}} \cdot M_{Ylc13}$$

$$M_{Ym50} = -2449 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ym180} = -2511 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMyI} := 13510 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 1165 to 959, path length of 0.409 in.)

$$M_{Ymb50I} := \frac{3 \cdot S_m - SI_{LBQMyI}}{SI_{LBQMyI}} \cdot M_{Ylc13} \quad M_{Ymb180I} := \frac{3 \cdot S_m - SI_{LBQMyI}}{SI_{LBQMyI}} \cdot M_{Ylc13}$$

$$M_{Ymb50I} = -3681 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ymb180I} = -2268 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMyO} := 2482 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 1165 to 959, path length of 0.409 in.)

$$M_{Ymb50O} := \frac{1.5 \cdot S_m - SI_{LBQMyO}}{SI_{LBQMyO}} \cdot M_{Ylc13} \quad M_{Ymb180O} := \frac{1.5 \cdot S_m - SI_{LBQMyO}}{SI_{LBQMyO}} \cdot M_{Ylc13}$$

$$M_{Ymb50O} = -9599 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ymb180O} = -4909 \cdot \text{ft} \cdot \text{lbf}$$

ANALYTICAL CALCULATIONS

WHC-SD-W236A-DA-002
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Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)
 Originator J. L. Julyk *JLJ* Date 3/28/95
 Checker H. P. Shrivastava *hps* Date 3/30/95

$$SI_{HOOP} := 1919 \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress SY membrane stress for load case 13, Hoop component, (node 1165 to 959, path length of 0.409 in.)

$$M_{YHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Ylc13} \quad M_{YHOOP180} := \frac{S_m - SI_{HOOP180}}{SI_{HOOP}} \cdot M_{Ylc13}$$

$$M_{YHOOP50} = -9169 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{YHOOP180} = -5056 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LMz} := 579 \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 15 (node 1165 to 959, path length of 0.409 in.)

$$M_{Zm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMz}} \cdot M_{Zlc15} \quad M_{Zm180} := \frac{1.5 \cdot S_m - SI_{L180}}{SI_{LMz}} \cdot M_{Zlc15}$$

$$M_{Zm50} = -31372 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zm180} = -32169 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMzI} := 2777 \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 1165 to 959, path length of 0.409 in.)

$$M_{Zmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQMzI}} \cdot M_{Zlc15} \quad M_{Zmb180I} := \frac{3 \cdot S_m - SI_{LBQ180I}}{SI_{LBQMzI}} \cdot M_{Zlc15}$$

$$M_{Zmb50I} = -17910 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zmb180I} = -11035 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMzO} := 2966 \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 1165 to 959, path length of 0.409 in.)

$$M_{Zmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQMzO}} \cdot M_{Zlc15} \quad M_{Zmb180O} := \frac{1.5 \cdot S_m - SI_{LBQ180O}}{SI_{LBQMzO}} \cdot M_{Zlc15}$$

$$M_{Zmb50O} = -8032 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zmb180O} = -4108 \cdot \text{ft} \cdot \text{lbf}$$

ANALYTICAL CALCULATIONS

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Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)
 Originator J. L. Julyk Date 3/28/95
 Checker H. P. Shrivastava Date 4/5/95

$$SI_{HOOP} := 11 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress SY membrane stress for load case 15, Hoop component, (node 1165 to 959, path length of 0.409 in.)

$$M_{ZHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Zlc15} \quad M_{ZHOOP180} := \frac{S_m - SI_{HOOP180}}{SI_{HOOP}} \cdot M_{Zlc15}$$

$$M_{ZHOOP50} = -2 \cdot 10^6 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{ZHOOP180} = -9 \cdot 10^5 \cdot \text{ft} \cdot \text{lbf}$$

The maximum allowable external forces and moments at the bottom section are summarized below for a 50 and 180 ft-lbf pre-load torques in Table B3.

Table B3. The maximum allowable external forces and moments at the bottom section

<u>External Loads</u>	<u>50 ft-lbf Torque</u>	<u>180 ft-lbf Torque</u>
F _x (lbf)	24,911	25,388
F _y (lbf)	22,029	18,971
F _z (lbf)	9,323	9,559
M _x (ft-lbf)	3,099	2,783
M _y (ft-lbf)	2,449	2,269
M _z (ft-lbf)	8,032	4,108

4.8.6 Check Interaction with system model results for a 50 ft-lbf pre-load torque

From Table B3, the maximum allowable piping loads applied at the pipe opening were obtained. From Table 3.4 the acceptable piping loads were determined based on the other jumper components (hooks, pins, operating screw, guide lip with block lip, top of block, block bottom and pipe opening). The following is a linear interaction of Table 3.4 and Table B3 for the 50 ft-lbf pre-load case. See appendix C for interaction details.

Maximum Piping Loads from Table 3.4

$$f_x := 1330 \cdot \text{lbf} \quad m_x := 365 \cdot \text{ft} \cdot \text{lbf}$$

$$f_y := 1330 \cdot \text{lbf} \quad m_y := 365 \cdot \text{ft} \cdot \text{lbf}$$

$$f_z := 7370 \cdot \text{lbf} \quad m_z := 260 \cdot \text{ft} \cdot \text{lbf}$$

Maximum Piping loads from Table B3 @ 50 ft-lbf

$$F_x := 24911 \cdot \text{lbf} \quad M_x := 3099 \cdot \text{ft} \cdot \text{lbf}$$

$$F_y := 22029 \cdot \text{lbf} \quad M_y := 2449 \cdot \text{ft} \cdot \text{lbf}$$

$$F_z := 9323 \cdot \text{lbf} \quad M_z := 8032 \cdot \text{ft} \cdot \text{lbf}$$

$$I := \sqrt{\left(\frac{f_x}{F_x}\right)^2 + \left(\frac{f_y}{F_y}\right)^2} + \frac{f_z}{F_z} + \sqrt{\left(\frac{m_x}{M_x}\right)^2 + \left(\frac{m_y}{M_y}\right)^2 + \left(\frac{m_z}{M_z}\right)^2}$$

The linear interaction (I) must be less than or equal to 1 in order to satisfy ASME criteria at the bottom section.

$$I = 1 \leq 1.0$$

Therefore, satisfied for above piping loads from Table 3.4.
See appendix C for details of the basis of the interaction.

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Subject Structural Evaluation of Mechanical Jumpers for MWTF with Integral Seal Blocks (ISB)
 Originator J. L. Julyk *g2g* Date 3/28/95
 Checker H. P. Shrivastava *hps* Date 3/30/95

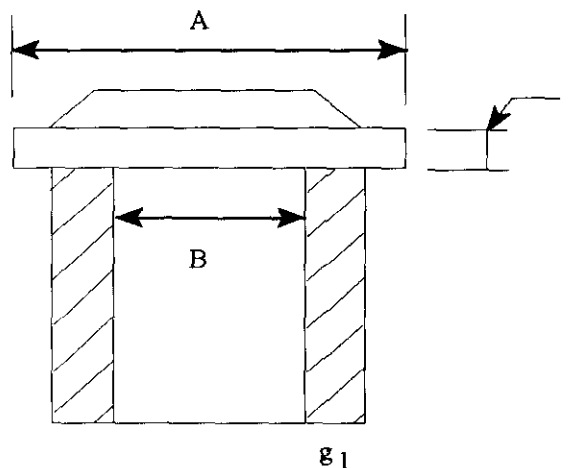
NOTE: The maximum allowable forces and moments are independent of sign, except for the axial loading condition (Fz). Where the above Fz is given as a compressive force. If the force is in tension then the Fz force is govern by the minimum seating force. In this case, for the 2-in. ISB jumper connector the minimum axial seating force is 9,156 lbf for a 50 ft-lbf pre-load (with thermal effects) and 3,386 lbf without thermal effect. The minimum axial seating force for the 180 ft-lbf preload, with and without thermal effects, is approximately 20,967 and 15,196 lbf, respectively.

5.0 Evaluation of 2-in. ISB Single Port Connector (Nozzle Flange Analysis)

Per ASME 1989 Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 3, Article 3-300, ASME Flange Design (ASME 1989c), the stresses in the flange due to the applied loading are evaluated in the following analysis.

$A := 3.25 \cdot \text{in}$ outside diameter of flange
 $B := 2.06 \cdot \text{in}$ inside diameter of flange
 $t := 0.5 \cdot \text{in}$ thickness of flange
 $g_1 := 0.28 \cdot \text{in}$ thickness of hub or nozzle wall
 $f := 1 \cdot \text{in}$ for uniform thickness of hub
 $K := \frac{A}{B}$ $K = 1.578$

Figure B5. Typical Nozzle for ISB Jumpers
(WHC 1993b, Drawing H-2-83572)



For $K = 1.578$, from Fig. 3-340.1 of ASME (1989c), the corresponding values are
(the units are only for consistence)

$T := 1.8 \cdot \text{in}$ $Y := 4.5 \cdot \text{in}$ $U := 5 \cdot \text{in}$ $Z := 2.5 \cdot \text{in}$

$h := 2.25 \cdot \text{in} - 0.5 \cdot \text{in}$ $h = 1.75 \cdot \text{in}$ (WHC 1993b, Drawing H-2-83572)

$h_o := \sqrt{B \cdot g_1}$ $h_o = 0.759 \cdot \text{in}$

For $\frac{h}{h_o} = 2.304$ from Fig. 3-340.2, in ASME 1989c $F := 0.91 \cdot \text{in}$

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$$e := \frac{F}{h_o} \quad e = 1.198 \quad \text{Again, from Fig. 3-340.3, in ASME 1989c} \quad V := 0.55 \cdot \text{in}$$

$$d := \frac{U}{V} \cdot h_o \cdot g_1^2 \quad d = 0.541 \cdot \text{in}^3$$

$$L_{\text{flange}} := \left(\frac{t \cdot e + 1 \cdot \text{in}}{T} + \frac{t^3}{d} \right) \cdot \text{in} \quad L_{\text{flange}} = 1.119 \cdot \text{in}$$

Axial capacity of hook according to appendix A

$$P_{\text{capacity}} := 5943 \cdot \text{lbf}$$

$$L := \frac{3.25 \cdot \text{in} - 2.06 \cdot \text{in}}{4} \quad \text{Moment arm at mid-flange to mid-pipe-wall (WHC 1993b, Drawing H-2-83572)} \\ L = 0.297 \cdot \text{in}$$

Moment due to torque load from the hook for 3 hooks

$$M_o := 3 \cdot P_{\text{capacity}} \cdot L \quad M_o = 5304 \cdot \text{lbf} \cdot \text{in}$$

5.1 Determine Flange stresses and compare with Allowable Flange Stress per ASME (1989c)

Per ASME 1989 Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 3, Article 3-300, ASME Flange Design (ASME 1989c), the stresses in the flange due to the applied loading are evaluated in the following analysis.

Longitudinal Hub Stress

Allowable Hub Stress

Conclusion

$$S_H := \frac{f M_o}{L_{\text{flange}} \cdot (g_1)^2 \cdot B}$$

$$S_{HA} := 1.5 \cdot S_m$$

$$S_H = 29341 \cdot \frac{\text{lbf}}{\text{in}^2} <$$

$$S_{HA} = 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Good (O. K.)

Radial Flange Stress

Allowable Radial Stress

Conclusion

$$S_R := \frac{(1.33 \cdot t \cdot e + 1 \cdot \text{in}) \cdot M_o}{L_{\text{flange}} \cdot t^2 \cdot B}$$

$$S_{RA} := S_m$$

$$S_R = 16533 \cdot \frac{\text{lbf}}{\text{in}^2} <$$

$$S_{RA} = 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Good (O. K.)

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Tangential Flange Stress

Allowable Tangential Stress

Conclusion

$$S_T := \left(\frac{Y \cdot M_o}{t^2 \cdot B} - Z \cdot S_R \right) \cdot \frac{1}{\text{in}}$$

$$S_{TA} := S_m$$

$$S_T = 5014 \cdot \frac{\text{lbf}}{\text{in}^2}$$

<

$$S_{TA} = 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Good (O.K.)

5.2 Determine the limiting value of axial load based on the capacity of the hooks

$$P_H := P_{\text{capacity}} \cdot \frac{S_{HA}}{S_H} \quad P_H = 6076 \cdot \text{lbf}$$

$$P_R := P_{\text{capacity}} \cdot \frac{S_{RA}}{S_R} \quad P_R = 7189 \cdot \text{lbf}$$

$$P_T := P_{\text{capacity}} \cdot \frac{S_{TA}}{S_T} \quad P_T = 23706 \cdot \text{lbf}$$

Therefore, the limiting axial load is

$$P_{HR} := \text{if}(P_H < P_R, P_H, P_R)$$

$$P_{\text{limit}} := \text{if}(P_{HR} < P_T, P_{HR}, P_T)$$

$P_{\text{limit}} = 6076 \cdot \text{lbf}$ which is greater than the 2-in. hook limit of 5,943 lbf found in appendix A.
 Therefore, the axial capacity of the 2-in. hook = 5,943 lbf governs.

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Following the methodology used for the 2-in. ISB single port connector block, the analysis of the 3-in. ISB single block connector is evaluated per ASME criteria

6.1 Applied axial load on the 3-in. ISB jumper block for a 50 ft-lbf torque screw force

A series of experiment were conducted for MWTF project using a 3-in ISB jumper connector. The results were documented by Ruff (1994) and showed a 50 ft-lbf torque is required to seal up to 1000 lbf/in² of internal pressure. The design pressure for MWTF 2-, 3-, and 4-in. ISB jumpers is 400 lbf/in². This does not include thermal and operational loads.

The Squier (1993) report related the applied pre-torque vs axial force on the block from the torque screw. From Squier (1993) the screw force for a 3-in. jumper connector (50 ft-lbf screw torque) is 2000 lbf.

$F_{\text{torque}} := 2000 \cdot \text{lbf}$ axial load for a 50 ft-lbf torque (Squier 1993)

6.2 Determine Equivalent Stiffnesses of Block, Nozzle, Screw and Hooks under thermal loading (used to determine the preload to constrain thermal expansion of the block and nozzle)**6.2.1 Nozzle stiffness (approximate method): (WHC 1993c, Drawing No. H-2-83573)**

area of nozzle from flange, hook location, to top of nozzle SCH 40

$$A_{N1} := \frac{\pi}{4} \cdot [(4.87 \cdot \text{in})^2 - (3.063 \cdot \text{in})^2]$$

$$A_{N2} := \frac{\pi}{4} \cdot [(4.43 \cdot \text{in})^2 - (3.063 \cdot \text{in})^2]$$

$$A_{N1} = 11.259 \cdot \text{in}^2$$

$$A_{N2} = 8.045 \cdot \text{in}^2$$

$$\Delta T_N := T_{\text{max}} - T_{\text{atm}} \quad \text{temperature change in nozzle}$$

original length of nozzle at hook interface @ 70 degrees F

$$L_{N1} := 0.625 \cdot \text{in}$$

$$L_{N2} := \frac{0.81 \cdot \text{in}}{2}$$

$$\alpha_N := \alpha_{250A276}$$

mean coefficient of thermal expansion for nozzle @ 250 deg. F

$$E_N := E_{250A276}$$

Young's modulus for ASTM A276 @ 250 deg. F (ASTM 1989)

$$K_{N1} := \frac{E_N \cdot A_{N1}}{L_{N1}}$$

$$K_{N2} := \frac{E_N \cdot A_{N2}}{L_{N2}}$$

$$K_{N1} = 4.936 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}}$$

$$K_{N2} = 5.443 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}}$$

approximate stiffness of nozzle section

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6.2.2 Block stiffness (approx. method using fea from 2-inch model): (WHC 1994b, Drawing No. H-2-821325)

The ratio hook stiffness based on the Finite-Element model vs approximate method is

$$R_B := \frac{K_{Bfea}}{K_{Bapp}} \quad R_B = 0.177$$

$$A_B := \frac{\pi}{4} \cdot [(5.0 \cdot \text{in})^2 - (3.06 \cdot \text{in})^2] \quad \text{aproximate area of block} \quad A_B = 12.281 \cdot \text{in}^2$$

$$\Delta T_B := T_{\max} - T_{\text{atm}} \quad \text{temperature change in block}$$

$$L_B := 6.217 \cdot \text{in} - 0.248 \cdot \text{in} - \frac{0.597 \cdot \text{in}}{2} \quad \text{original length of block at 70 degrees F} \quad L_B = 5.67 \cdot \text{in}$$

$$\alpha_B := \alpha_{250A276} \quad \text{mean coefficient of thermal expansion for block @ 250 deg. F}$$

$$E_B := E_{250A276} \quad \text{Young's modulus for ASTM A276 @ 250 deg. F (ASTM 1989)}$$

$$K_B := R_B \cdot \left(\frac{E_B \cdot A_B}{L_B} \right) \quad \text{estimated stiffness of block} \quad K_B = 1.049 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}}$$

6.2.3 Screw stiffness (approximate method): (WHC 1985a, Drawing No. H-2-32431)

$$A_S := \frac{\pi}{4} \cdot (1.438 \cdot \text{in})^2 \quad \text{aproximate area of screw} \quad A_S = 1.624 \cdot \text{in}^2$$

$$L_S := 11.259 \cdot \text{in} - (L_B + L_{N1} + L_{N2}) \quad \text{original length of screw at @ 70 degrees F} \quad L_S = 4.559 \cdot \text{in}$$

$$E_S := E_{A193} \quad \text{Young's modulus for ASTM A193 @ 70 deg. F}$$

$$K_S := \frac{E_S \cdot A_S}{L_S} \quad K_S = 1.058 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{estimated stiffness of screw}$$

6.2.4 Operating nut guide stiffness (approximate method): (WHC 1985b, Drawing No. H-2-68210)

$$I_{\text{nut}} := \frac{2}{12} \cdot \left(\frac{2.56 \cdot \text{in} - 1.02 \cdot \text{in}}{2} \right) \cdot (1.89 \cdot \text{in})^3 \quad \text{aproximate moment of inertia of operating nut guide} \\ I_{\text{nut}} = 0.866 \cdot \text{in}^4$$

$$L_{\text{nut}} := 2.25 \cdot \text{in} \quad \text{original length of operating nut guide at @ 70 degree F}$$

$$E_{\text{nut}} := 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{Young's modulus of operating nut guide @ 70 deg. F (assumed)}$$

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$$K_{\text{nut}} := \left(\frac{3 \cdot E_{\text{nut}} \cdot I_{\text{nut}}}{L_{\text{nut}}^3} \right) \quad K_{\text{nut}} = 6.618 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{estimated stiffness of operating nut guide}$$

6.2.5 Hook pin stiffness (approximate method): (WHC 1985b, Drawing No. H-2-68210)

$$I_{\text{pin}} := \frac{\pi}{64} \cdot (0.7505 \cdot \text{in})^4 \quad \text{aproximate moment of inertia of hook pin} \quad I_{\text{pin}} = 0.016 \cdot \text{in}^4$$

$$L_{\text{pin}} := \frac{1}{2} \cdot (2.56 \cdot \text{in} + 1.02 \cdot \text{in}) \quad \text{length of hook pin (WHC 1985b, Drawing H-2-68210)} \quad L_{\text{pin}} = 1.79 \cdot \text{in}$$

$$E_{\text{pin}} := 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{Young's modulus of hook pin @ 70 deg. F (assumed)}$$

$$\Delta_{\text{pin}} := \frac{1 \cdot \text{lbf} \cdot L_{\text{pin}}^3}{48 \cdot E_{\text{pin}} \cdot I_{\text{pin}}} \quad \text{deflection of pin per AISC 1989 case 7 for a simple beam with a 1 lbf concentrated load at the center (AISC 1989)} \quad \Delta_{\text{pin}} = 2.646 \cdot 10^{-7} \cdot \text{in}$$

$$K_{\text{pin}} := \left(\frac{1 \cdot \text{lbf}}{\Delta_{\text{pin}}} \right) \quad K_{\text{pin}} = 3.78 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{estimated stiffness of hook pinn}$$

6.2.6 Hooks stiffness (based on the ratio of the 2-in approximate method and FE Hook model stiffnesses):

The ratio hook stiffness based on the Finite-Element model vs approximate method is

$$R_H := \frac{K_{2\text{fea}}}{K_{2\text{app}}} \quad R_H = 0.9$$

The line joining the top and the bottom points of the hook is virtually parallel to the axis of the nozzle and the block, consider the hook as a crescent as before with the 2-in. hook.

$$H := 11.178 \cdot \text{in} \quad \text{chord length}$$

$$B := 2.28 \cdot \text{in} - \frac{1.5 \cdot \text{in}}{2} \quad B = 1.53 \cdot \text{in} \quad \text{rise}$$

$$\tan\left(\frac{A_{\text{app}}}{4}\right) = \frac{2 \cdot B}{H} \quad \text{Refer AISC, 1989, page 6-18}$$

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Figure B6. Typical Hook for ISB Jumpers
(WHC 1993f, H-2-90175, rev. 7, sh 2)

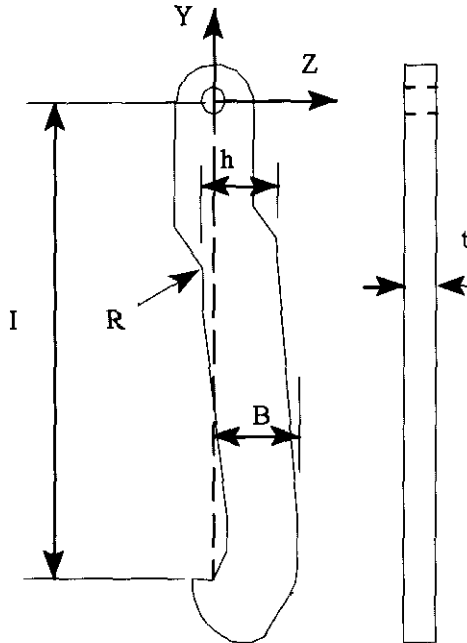
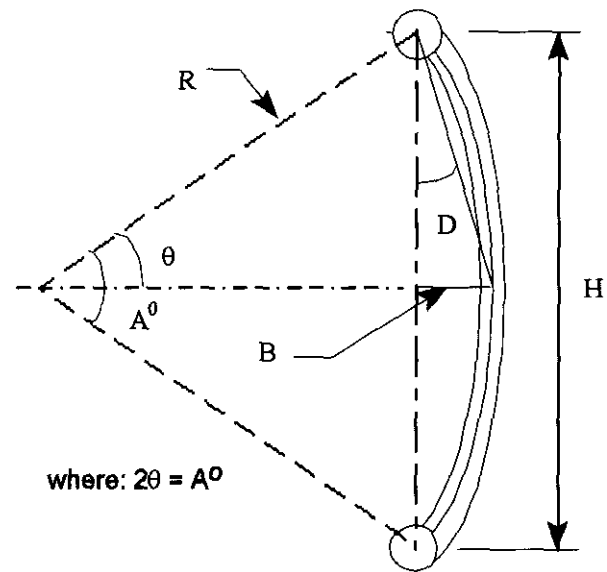


Figure B7. Hook shape for determining Hook Stiffness
(Assumed)



$$\tan(D) = \frac{2 \cdot B}{H} \quad D := \text{atan}\left(\frac{2 \cdot B}{H}\right) \quad D = 15.31 \cdot \text{deg}$$

Therefore, $A := 4 \cdot D \quad A = 61.239 \cdot \text{deg} \quad \theta := \frac{A}{2} \quad \theta = 30.62 \cdot \text{deg}$

$$R := \frac{H}{2 \cdot \sin(\theta)} \quad R = 10.973 \cdot \text{in}$$

Because load is applied at top pin of the hook $\Phi := \theta \quad \Phi = 30.62 \cdot \text{deg} \quad \theta = 0.534 \cdot \text{rad}$

Refer Roark, 1989, Table 18, Case 3 (Roark 1989)

$$s := \sin(\theta) \quad s = 0.509$$

$$c := \cos(\theta) \quad c = 0.861$$

$$n := \sin(\Phi) \quad n = 0.509$$

$$e := \cos(\Phi) \quad e = 0.861$$

$$W := 1 \cdot \text{lbf} \quad \text{Assume load}$$

$$A_{\text{app}} := 1.375 \cdot \text{in} \cdot 1.0 \cdot \text{in} \quad A_{\text{app}} = 1.375 \cdot \text{in}^2$$

$$I_{\text{app}} := \frac{1.0 \cdot \text{in} \cdot (1.375 \cdot \text{in})^3}{12} \quad I_{\text{app}} = 0.217 \cdot \text{in}^4$$

$$F := \frac{6}{5} \quad \text{Shape Factor (Roark 1989)}$$

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$\mu := 0.30$ Poisson ratio for A747 @ 70 deg. F (ASTM 1989)

$E_{app} := E_{A747}$ Young's modulus for ASTM A747 @ 70 deg. F (ASTM 1989) $E_{A747} = 2.9 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}^2}$

$G := \frac{E_{app}}{2 \cdot (1 + \mu)}$ Shear Modulus $G = 1.115 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}^2}$

$\alpha := \frac{I_{app}}{A_{app} \cdot R^2}$ $\alpha = 0.001$ $\beta := \frac{F \cdot E_{app} \cdot I_{app}}{G \cdot A_{app} \cdot R^2}$ $\beta = 0.004$

$$LP_H := W \cdot \left[\frac{\theta}{2} + \theta \cdot c^2 - \frac{3}{2} \cdot s \cdot c + \Phi \cdot e \cdot c + \frac{\Phi}{2} - \frac{n \cdot e}{2} - n \cdot c + (\alpha + \beta) \cdot \left(\frac{\theta + \Phi}{2} \right) + (\alpha - \beta) \cdot \left(\frac{s \cdot c + n \cdot e}{2} \right) \right]$$

$$LP_H = 0.013 \cdot \text{lbf}$$

Deformation along the axis of the hook

$$\delta H_A := - \frac{R^3}{E_{A747} \cdot I_{app}} \cdot LP_H \quad \delta H_A = -2.665 \cdot 10^{-6} \cdot \text{in}$$

Stiffness of the hook along its axis

$$K_H := R_H \cdot \frac{W}{\delta H_A} \quad K_H = 3.376 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{estimated stiffness of hook}$$

6.2.7 Determine the Thermal Expansion from nozzle to top of the block:

$$\Delta L_N := \left[\alpha_N \cdot (L_{N1} + L_{N2}) \right] \cdot \Delta T_N \quad \text{thermal growth of nozzle @ 250 deg. F}$$

$$\Delta L_N = 0.0016 \cdot \text{in}$$

$$\Delta L_B := \left(\alpha_B \cdot L_B \right) \cdot \Delta T_B \quad \text{thermal growth of block @ 250 deg. F}$$

$$\Delta L_B = 0.0091 \cdot \text{in}$$

$$\Delta L_{total} := \Delta L_N + \Delta L_B \quad \text{thermal growth of block @ 250 deg. F}$$

$$\Delta L_{total} = 0.0107 \cdot \text{in}$$

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6.2.8 Determine the Equivalent Stiffness of the Jumper (with and without stiffness of block included)

$$K_{EQ1} := \left(\frac{1}{K_{N1}} + \frac{1}{K_{N2}} + \frac{1}{K_B} + \frac{1}{K_S} + \frac{1}{3 \cdot K_H} + \frac{1}{3 \cdot K_{nut}} + \frac{1}{3 \cdot K_{pin}} \right)^{-1} \quad K_{EQ1} = 7.578 \cdot 10^5 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}}$$

$$K_{EQ2} := \frac{1}{(K_{EQ1}^{-1} - K_B^{-1})} \quad K_{EQ2} = 8.168 \cdot 10^5 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}} \quad \text{estimated equivalent stiffness of system without block, due to thermal expansion of the block}$$

6.3 Total force F_{thermal} required to restrain nozzle and block to original length L

$$F_{\text{thermal}} := \frac{K_B \cdot K_{EQ2}}{K_B + K_{EQ2}} \cdot \Delta L_{\text{total}} \quad F_{\text{thermal}} = 8125 \cdot \text{lb} \cdot \text{f} \quad \text{Compression force on Block}$$

Note: The stiffness of the screw, block, nozzle, and hooks are in series

6.4 Determine the applied axial load to account for the internal pressure of the 3-in. ISB jumper block

According to the MWTF Functional Design Criteria (FDC) found in WHC-SD-W236A-FDC-001 (WHC 1993a), the design pressure considered in the structural analysis of the connector assembly is 400 lb/f/in². The 2-in block methodology for determining the amount of axial pressure load applied to the jumper is used in the 3-in. ISB block.

$$F_{\text{calcap}} := P_{\text{design}} \cdot \frac{\pi}{4} \cdot \left(\frac{3.523 \cdot \text{in} + 3.807 \cdot \text{in}}{2} \right)^2 \quad F_{\text{calcap}} = 4220 \cdot \text{lb} \cdot \text{f}$$

The axial pressure load applied to resist the internal pressure @ the top of the block/screw interaction is the calculated axial pressure multiplied by the ratio estimated equivalent stiffnesses

$$F_{\text{pressure}} := F_{\text{calcap}} \cdot \left(\frac{K_{EQ2}}{K_{EQ2} + K_B} \right) \quad F_{\text{pressure}} = 305 \cdot \text{lb} \cdot \text{f} \quad \text{Compression force on block and tensile force on hooks}$$

$$F_{\text{Pseat}} := F_{\text{calcap}} - F_{\text{pressure}} \quad F_{\text{Pseat}} = 3915 \cdot \text{lb} \cdot \text{f} \quad \text{Pressure load that goes to reduce the seating torque load}$$

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6.5 Total applied axial load for 3-in. ISB jumper block

$$F_{\text{total}} := F_{\text{torque}} + F_{\text{thermal}} + F_{\text{pressure}}$$

$F_{\text{total}} = 10430 \cdot \text{lbf}$ applied axial load for a 50 ft-lbf torque, thermal, and pressure loading.

The total axial loads are applied over a circular radius of $b = 0.719 \text{ in.}$, in the 3-in. FEA model, to simulate the punch-through failure mode of the screw and block. The stresses at the top section of the block are then compared to the ASME (1989b) criteria established in sections 4.7.1 to 4.7.3.

6.6 Seating load with and without thermal effects (cold and hot conditions)

Excluding the effects of thermal and axial external loading

$$F_{\text{cold}} := F_{\text{torque}} - (F_{\text{Pseat}})$$

$F_{\text{cold}} = -1915 \cdot \text{lbf}$ seating load for a 50 ft-lbf torque

Excluding the effects of axial external loading

$$F_{\text{hot1}} := F_{\text{torque}} + F_{\text{thermal}} - (F_{\text{Pseat}})$$

$F_{\text{hot1}} = 6210 \cdot \text{lbf}$ seating load for a 50 ft-lbf torque

Therefore, it is possible that when the jumper is pressurized to 400 psi under cold conditions, no thermal expansion, the 3-in. jumper could leak at 50 ft-lbf pre-load torque. We recommend that a leak test of the jumper under the design conditions be performed before the jumper is used.

6.7 Calculation of Maximum Piping Loads using Linearized Stress Intensities through a section of the 3-in. ISB jumper connector block

The stress analysis is based on a linear-elastic material. The linearized stress intensity is taken from the 3-in. finite-element block model. The linearized stress intensities through the thickness of the block are from a 50 ft-lbf torque load case, thermal expansion from 70 to 250 deg. F, internal pressure of 400 lbf/in², and assumed external loads associated with the piping configuration. The assumed forces and moments are stated below.

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6.7.1 Loads and Load Cases Applied to FEA 3-in. block model

$F_{Zlc1} := -21167 \cdot \text{lbf}$ Load Case 1 (LC1), axial load (Fz) applied at top of block/screw for 50 ft-lbf pre-load
 $F_{Xlc5} := -22280 \cdot \text{lbf}$ Load Case 5 (LC5), horizontal force (Fx) applied at pipe intersection @ node 20,000
 $F_{Ylc7} := -18750 \cdot \text{lbf}$ Load Case 7 (LC7), horizontal force (Fy) applied at pipe intersection @ node 20,000
 $F_{Zlc9} := -8320 \cdot \text{lbf}$ Load Case 9 (LC9), axial force (Fz) applied at pipe intersection @ node 20,000
 $M_{Xlc10} := 1590 \cdot \text{ft} \cdot \text{lbf}$ Load Case 10 (LC10), horizontal moment applied at pipe intersection @ node 20,000
 $M_{Ylc13} := -1784 \cdot \text{ft} \cdot \text{lbf}$ Load Case 13 (LC13), horizontal moment applied at pipe intersection @ node 20,000
 $M_{Zlc15} := -1784 \cdot \text{ft} \cdot \text{lbf}$ Load Case 15 (LC15), torsional moment applied at pipe intersection @ node 20,000

Load Case 16 (LC16), applied an internal pressure of 400 psi to the inside of the block.

6.7.2 Maximum linearized stress intensities through the top section of the block from axial loading (See section 11, Table B10 for reference)

$SI_{m50} := 6337 \cdot \frac{\text{lbf}}{\text{in}^2} \leq S_m = 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$ General Primary Membrane stress for load case 1
(node 1039 to 1212, path length 1.05 in.)
 $SI_{mb50} := 7965 \cdot \frac{\text{lbf}}{\text{in}^2} \leq 1.5 \cdot S_m = 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$ General Primary membrane plus primary bending stress
for load case 1 (node 1039 to 1212, path length 1.05 in.)

Therefore, the top section of the block under axial loading (preload 50 + thermal expansion + pressure) meets the ASME (1989b) criteria established above for the top section of the block under the screw.

6.7.2.1 Maximum allowable pre-load the top section of the block can withstand

$F_m := \frac{S_m}{SI_{m50}} \cdot F_{\text{total}}$ $F_m = 32917 \cdot \text{lbf}$ Total load based on membrane stress intensity

$F_{mb} := \frac{1.5 \cdot S_m}{SI_{mb50}} \cdot F_{\text{total}}$ $F_{mb} = 39283 \cdot \text{lbf}$ Total axial load based on membrane plus bending stress intensity

$F_{\text{preload}} := \text{if}(F_m \leq F_{mb}, F_m - F_{\text{pressure}} - F_{\text{thermal}}, F_{mb} - F_{\text{pressure}} - F_{\text{thermal}})$ $F_{\text{preload}} = 24487 \cdot \text{lbf}$

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From the Squire (1993) test report the screw force of calculated is between 300 and 500 ft-lbf of torque. Therefore, by interpolating the test data from the Squire (1993) report the maximum allowable preload torque is calculated.

$$\text{Torque}_{\max} := \frac{1}{2} \left[\frac{\left(\frac{18930 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 21227 \cdot \text{lbf}} \right) \cdot 464 \cdot \text{ft} \cdot \text{lbf} + 420 \cdot \text{ft} \cdot \text{lbf}}{\frac{18930 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 21227 \cdot \text{lbf}} + 1} + \frac{\left(\frac{17725 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 20894 \cdot \text{lbf}} \right) \cdot 420 \cdot \text{ft} \cdot \text{lbf} + 380 \cdot \text{ft} \cdot \text{lbf}}{\frac{17725 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 20894 \cdot \text{lbf}} + 1} \right]$$

$\text{Torque}_{\max} = 496 \cdot \text{ft} \cdot \text{lbf}$ Therefore, the maximum allowable preload torque is 490 ft-lbf at the current design conditions and material allowables based on a elastic linear analysis.

6.7.3 Maximum External Forces and Moments @ the Pipe Intersection

(The Maximum linearized stress intensities through the block wall at the pipe entrance for external loading, 50 ft-lbf, thermal expansion, and pressure stresses are in section 11, Table B10)

$$SI_{L50} := 4708 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 1, (node 253 to 259, path length of 0.911 in.)

$$SI_{LBQ50} := 7094 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress for load case 1, (node 253 to 259, path length of 0.911 in.)

$$SI_{EL490} := \frac{F_m}{F_{\text{total}}} \cdot SI_{L50}$$

Estimated Local Primary Membrane stress at the calculated maximum torque, (node 253 to 259, path length of 0.911 in.)

$$SI_{EL490} = 14859 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{ELBQ490} := \frac{F_m}{F_{\text{total}}} \cdot SI_{LBQ50}$$

Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, (node 253 to 259, path length of 0.911 in.)

$$SI_{ELBQ490} = 22389 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{Lpress} := 1910 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 16, (node 36 to 714, path length of 1.026 in.)

$$SI_{LBQpress} := 3086 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress for load case 16, (node 36 to 714, path length of 1.026 in.)

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6.7.3.1 The resultant of the initial stress intensity is stated as the following @ the pipe intersection:

$$SI_L := SI_{L50} + SI_{Lpress}$$

Local primary membrane stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_L = 6618 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ} := SI_{LBQ50} + SI_{LBQpress}$$

Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{LBQ} = 10180 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{L490} := SI_{EL490} + SI_{Lpress}$$

Local primary membrane stress at maximum torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{L490} = 16769 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ490} := SI_{ELBQ490} + SI_{LBQpress}$$

Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{LBQ490} = 25475 \cdot \frac{\text{lbf}}{\text{in}^2}$$

6.7.3.2 Maximum allowable external forces and moments at the pipe intersection for 3-in ISB Block

The Local membrane and bending are compared to the allowable ASME stress, based on the criteria in section 4.7.2, minus the stresses due to torque, thermal expansion and internal pressure.

$$SI_{LFX} := 9017 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 5 (node 197 to 203, path length of 0.99 in.)

$$F_{Xm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm50} = -57774 \cdot \text{lbf}$$

$$F_{Xm490} = -32693 \cdot \text{lbf}$$

$$SI_{LBQFX} := 13430 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 197 to 203, path length of 0.99 in.)

$$F_{Xmb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQFX}} \cdot F_{Xlc5}$$

$$F_{Xmb490} := \frac{3 \cdot S_m - SI_{LBQ490}}{SI_{LBQFX}} \cdot F_{Xlc5}$$

$$F_{Xmb50} = -82650 \cdot \text{lbf}$$

$$F_{Xmb490} = -57276 \cdot \text{lbf}$$

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$$SI_{LFy} := 12580 \cdot \frac{\text{lb}}{\text{in}^2}$$

Local Primary Membrane stress for load case 7 (node 196 to 234, path length of 0.893 in.)

$$F_{Ym50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym50} = -34850 \cdot \text{lb}$$

$$F_{Ym490} = -19721 \cdot \text{lb}$$

$$SI_{LBQFy} := 20350 \cdot \frac{\text{lb}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 196 to 234, path length of 0.893 in.)

$$F_{Ymb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQFy}} \cdot F_{Ylc7}$$

$$F_{Ymb490} := \frac{3 \cdot S_m - SI_{LBQ490}}{SI_{LBQFy}} \cdot F_{Ylc7}$$

$$F_{Ymb50} = -45903 \cdot \text{lb}$$

$$F_{Ymb490} = -31810 \cdot \text{lb}$$

$$SI_{LFz} := 3742 \cdot \frac{\text{lb}}{\text{in}^2}$$

Local Primary Membrane stress for load case 9 (node 248 to 267, path length of 1.102 in.)

$$F_{Zm50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm50} = -51988 \cdot \text{lb}$$

$$F_{Zm490} = -29418 \cdot \text{lb}$$

$$SI_{LBQFz} := 9002 \cdot \frac{\text{lb}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 248 to 267, path length of 1.102 in.)

$$F_{Zmb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQFz}} \cdot F_{Zlc9}$$

$$F_{Zmb490} := \frac{3 \cdot S_m - SI_{LBQ490}}{SI_{LBQFz}} \cdot F_{Zlc9}$$

$$F_{Zmb50} = -46046 \cdot \text{lb}$$

$$F_{Zmb490} = -31909 \cdot \text{lb}$$

$$SI_{LMx} := 3316 \cdot \frac{\text{lb}}{\text{in}^2}$$

Local Primary Membrane stress for load case 10 (node 252 to 258, path length of 1.094 in.)

$$M_{Xm50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm50} = 11212 \cdot \text{ft} \cdot \text{lb}$$

$$M_{Xm490} = 6344 \cdot \text{ft} \cdot \text{lb}$$

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$$SI_{LBQMx} := 7001 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 252 to 258, path length of 1.094 in.)

$$M_{Xmb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQMx}} \cdot M_{Xlc10}$$

$$M_{Xmb490} := \frac{3 \cdot S_m - SI_{LBQ490}}{SI_{LFX}} \cdot M_{Xlc10}$$

$$M_{Xmb50} = 11315 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xmb490} = 6088 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LMY} := 4252 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 13 (node 714 to 36, path length of 1.026 in.)

$$M_{Ym50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMY}} \cdot M_{Ylc13}$$

$$M_{Ym490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LMY}} \cdot M_{Ylc13}$$

$$M_{Ym50} = -9810 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ym490} = -5551 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMy} := 9494 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 714 to 36, path length of 1.026 in.)

$$M_{Ymb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQMy}} \cdot M_{Ylc13}$$

$$M_{Ymb490} := \frac{3 \cdot S_m - SI_{LBQ490}}{SI_{LBQMy}} \cdot M_{Ylc13}$$

$$M_{Ymb50} = -9362 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ymb490} = -6488 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LMZ} := 6474 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 15 (node 248 to 267, path length of 1.102 in.)

$$M_{Zm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMZ}} \cdot M_{Zlc15}$$

$$M_{Zm490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LMZ}} \cdot M_{Zlc15}$$

$$M_{Zm50} = -6443 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zm490} = -3646 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMz} := 9780 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 248 to 267, path length of 1.102 in.)

$$M_{Zmb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQMz}} \cdot M_{Zlc15}$$

$$M_{Zmb490} := \frac{3 \cdot S_m - SI_{LBQ490}}{SI_{LBQMz}} \cdot M_{Zlc15}$$

$$M_{Zmb50} = -9088 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zmb490} = -6298 \cdot \text{ft} \cdot \text{lbf}$$

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The maximum allowable external forces and moments at the pipe section are summarized below for a 50 and 490 ft-lbf pre-load torques in Table B4.

Table B4. The maximum allowable external forces and moments at the pipe section

<u>External Loads</u>	<u>50 ft-lbf Torque</u>	<u>490 ft-lbf Torque</u>
F _x (lbf)	57,774	32,693
F _y (lbf)	34,850	19,721
F _z (lbf)	46,046	29,418
M _x (ft-lbf)	11,212	6,088
M _y (ft-lbf)	9,362	5,551
M _z (ft-lbf)	6,443	3,646

6.7.4 Check Interaction with system model results for a 50 ft-lbf pre-load torque

From Table B4, the maximum allowable piping loads applied at the pipe opening were obtained. From Table 3.4 the acceptable piping loads were determined based on the other jumper components (hooks, pins, operating screw, guide lip with block lip, top of block, block bottom and pipe opening). The following is a linear interaction of Table 3.4 and Table B4 for the 50 ft-lbf pre-load case. See appendix C for interaction details.

Maximum Piping Loads from Table 3.4

$$f_x := 1540 \cdot \text{lbf} \quad m_x := 630 \cdot \text{ft} \cdot \text{lbf}$$

$$f_y := 1540 \cdot \text{lbf} \quad m_y := 630 \cdot \text{ft} \cdot \text{lbf}$$

$$f_z := 38100 \cdot \text{lbf} \quad m_z := 410 \cdot \text{ft} \cdot \text{lbf}$$

Maximum Piping loads from Table B4 @ 50 ft-lbf

$$F_x := 57774 \cdot \text{lbf} \quad M_x := 11212 \cdot \text{ft} \cdot \text{lbf}$$

$$F_y := 34850 \cdot \text{lbf} \quad M_y := 9362 \cdot \text{ft} \cdot \text{lbf}$$

$$F_z := 46046 \cdot \text{lbf} \quad M_z := 6443 \cdot \text{ft} \cdot \text{lbf}$$

$$I := \sqrt{\left(\frac{f_x}{F_x}\right)^2 + \left(\frac{f_y}{F_y}\right)^2 + \left(\frac{f_z}{F_z}\right)^2} + \sqrt{\left(\frac{m_x}{M_x}\right)^2 + \left(\frac{m_y}{M_y}\right)^2 + \left(\frac{m_z}{M_z}\right)^2}$$

The linear interaction (I) must be less than or equal to 1 in order to satisfy ASME criteria at the pipe intersection.

$$I = 0.9 \leq 1.0$$

*Therefore, satisfied for above piping loads from Table 3.4.
See appendix C for details of the basis of the interaction.*

6.7.5 Maximum External Forces and Moments @ Bottom section of the block

(The Maximum linearized stress intensities through the block wall at the nozzle /block interface external loading, 50 ft-lbf, thermal expansion, and pressure stresses are in section 11, Table B10)

$$SI_{L50} := 7638 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 1,
(node 688 to 622, path length of 0.626 in.)

$$SI_{LBQ50I} := 9791 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress for
load case 1, (node 688 to 622, path length of 0.626 in.)

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$$SI_{LBQ500} := 5723 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress for load case 1, (node 688 to 622, path length of 0.626 in.)

$$SI_{H50} := 2721 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress compared to SY membrane stress for load case 1, Hoop component, (node 688 to 622, path length of 0.626 in.)

$$SI_{EL490} := \frac{F_m}{F_{total}} \cdot SI_{L50}$$

Estimated Local Primary Membrane stress at the calculated maximum torque, (node 688 to 622, path length of 0.626 in.)

$$SI_{EL490} = 24106 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{ELBQ490I} := \frac{F_m}{F_{total}} \cdot SI_{LBQ50I}$$

INSIDE Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, (node 688 to 622, path length of 0.626 in.)

$$SI_{ELBQ490I} = 30901 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{ELBQ490O} := \frac{F_m}{F_{total}} \cdot SI_{LBQ50O}$$

OUTSIDE Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, (node 688 to 622, path length of 0.626 in.)

$$SI_{ELBQ490O} = 18062 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{EH490} := \frac{F_m}{F_{total}} \cdot SI_{H50}$$

Estimated General primary membrane stress compared to SY membrane stress for load case 1, Hoop component, (node 688 to 622, path length of 0.626 in.)

$$SI_{EH490} = 8588 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{Lpress} := 2459 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 16, (node 652 to 520, path length of 0.732 in.)

$$SI_{LBQpressI} := 2058 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress for load case 16, (node 688 to 622, path length of 0.626 in.)

$$SI_{LBQpressO} := 3358 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress for load case 16, (node 688 to 622, path length of 0.626 in.)

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$$SI_{Hpress} := 57 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress compared to SY membrane stress for load case 16, Hoop component, (node 688 to 622, path length of 0.626 in.)

6.7.5.1 The resultant of the pre-stress intensity is stated as the following @ the bottom section:

$$SI_L := SI_{L50} + SI_{Lpress}$$

Local primary membrane stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_L = 10097 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQI} := SI_{LBQ50I} + SI_{LBQpressI}$$

INSIDE Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQI} = 11849 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQO} := SI_{LBQ50O} + SI_{LBQpressO}$$

OUTSIDE Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQO} = 9081 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{HOOP50} := SI_{H50} + SI_{Hpress}$$

General primary membrane stress, SY membrane stress for Hoop component, @ bottom section.

$$SI_{HOOP50} = 2778 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{L490} := SI_{EL490} + SI_{Lpress}$$

Local primary membrane stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{L490} = 26565 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ490I} := SI_{ELBQ490I} + SI_{LBQpressI}$$

INSIDE Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQ490I} = 32959 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ490O} := SI_{ELBQ490O} + SI_{LBQpressO}$$

OUTSIDE Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQ490O} = 21420 \cdot \frac{\text{lbf}}{\text{in}^2}$$

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$$SI_{HOOP490} := SI_{EH490} + SI_{Hpress}$$

General primary membrane stress, SY membrane stress for Hoop component, @ bottom section.

$$SI_{HOOP490} = 8645 \cdot \frac{\text{lbf}}{\text{in}^2}$$

6.7.5.2 Maximum allowable external forces and moments at the bottom section for 3-in ISB Block

The Local membrane and bending are compared to the allowable ASME stress, based on the criteria in section 4.7.3, minus the stresses due to torque, thermal expansion and internal pressure.

$$SI_{LFx} := 4549 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 5 (node 696 to 611, path length of 0.652 in.)

$$F_{Xm50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LFx}} \cdot F_{Xlc5}$$

$$F_{Xm490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LFx}} \cdot F_{Xlc5}$$

$$F_{Xm50} = -97481 \cdot \text{lbf}$$

$$F_{Xm490} = -16824 \cdot \text{lbf}$$

$$SI_{LBQFxI} := 6912 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 696 to 611, path length of 0.652 in.)

$$F_{Xmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQFxI}} \cdot F_{Xlc5}$$

$$F_{Xmb490I} := \frac{3 \cdot S_m - SI_{LBQ490I}}{SI_{LBQFxI}} \cdot F_{Xlc5}$$

$$F_{Xmb50I} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$F_{Xmb490I} = -87163 \cdot \text{lbf}$$

$$SI_{LBQFxO} := 3576 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 696 to 611, path length of 0.652 in.)

$$F_{Xmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFxO}} \cdot F_{Xlc5}$$

$$F_{Xmb490O} := \frac{1.5 \cdot S_m - SI_{LBQ490O}}{SI_{LBQFxO}} \cdot F_{Xlc5}$$

$$F_{Xmb50O} = -1 \cdot 10^5 \cdot \text{lbf}$$

$$F_{Xmb490O} = -53456 \cdot \text{lbf}$$

$$SI_{HOOP} := 1925 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 5, Hoop component, (node 696 to 611, path length of 0.652 in.)

$$F_{XHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Xlc5}$$

$$F_{XHOOP490} := \frac{S_m - SI_{HOOP490}}{SI_{HOOP}} \cdot F_{Xlc5}$$

$$F_{XHOOP50} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$F_{XHOOP490} = -1 \cdot 10^5 \cdot \text{lbf}$$

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$$SI_{LFy} := 5630 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 7 (node 669 to 559, path length of 0.651 in.)

$$F_{Ym50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym50} = -66284 \cdot \text{lbf}$$

$$F_{Ym490} = -11440 \cdot \text{lbf}$$

$$SI_{LBQFyI} := 6467 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 669 to 559, path length of 0.651 in.)

$$F_{Ymb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQFyI}} \cdot F_{Ylc7}$$

$$F_{Ymb490I} := \frac{3 \cdot S_m - SI_{LBQ490I}}{SI_{LBQFyI}} \cdot F_{Ylc7}$$

$$F_{Ymb50I} = -1 \cdot 10^5 \cdot \text{lbf}$$

$$F_{Ymb490I} = -78401 \cdot \text{lbf}$$

$$SI_{LBQFyO} := 5027 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 669 to 559, path length of 0.651 in.)

$$F_{Ymb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFyO}} \cdot F_{Ylc7}$$

$$F_{Ymb490O} := \frac{1.5 \cdot S_m - SI_{LBQ490O}}{SI_{LBQFyO}} \cdot F_{Ylc7}$$

$$F_{Ymb50O} = -78025 \cdot \text{lbf}$$

$$F_{Ymb490O} = -32002 \cdot \text{lbf}$$

$$SI_{HOOP} := 1177 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 7, Hoop component, (node 669 to 559, path length of 0.651 in.)

$$F_{YHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Ylc7}$$

$$F_{YHOOP490} := \frac{S_m - SI_{HOOP490}}{SI_{HOOP}} \cdot F_{Ylc7}$$

$$F_{YHOOP50} = -3 \cdot 10^5 \cdot \text{lbf}$$

$$F_{YHOOP490} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$SI_{LFz} := 4086 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 9 (node 688 to 622, path length of 0.626 in.)

$$F_{Zm50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm50} = -40527 \cdot \text{lbf}$$

$$F_{Zm490} = -6994 \cdot \text{lbf}$$

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$SI_{LBQFzI} := 5489 \cdot \frac{\text{lbf}}{\text{in}^2}$ **INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 688 to 622, path length of 0.626 in.)**

$$F_{Zmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQFzI}} \cdot F_{Zlc9}$$

$$F_{Zmb490I} := \frac{3 \cdot S_m - SI_{LBQ490I}}{SI_{LBQFzI}} \cdot F_{Zlc9}$$

$$F_{Zmb50I} = -72985 \cdot \text{lbf}$$

$$F_{Zmb490I} = -40988 \cdot \text{lbf}$$

$SI_{LBQFzO} := 2787 \cdot \frac{\text{lbf}}{\text{in}^2}$ **OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 688 to 622, path length of 0.626 in.)**

$$F_{Zmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFzO}} \cdot F_{Zlc9}$$

$$F_{Zmb490O} := \frac{1.5 \cdot S_m - SI_{LBQ490O}}{SI_{LBQFzO}} \cdot F_{Zlc9}$$

$$F_{Zmb50O} = -48671 \cdot \text{lbf}$$

$$F_{Zmb490O} = -25613 \cdot \text{lbf}$$

$SI_{HOOP} := 1641 \cdot \frac{\text{lbf}}{\text{in}^2}$ **General primary membrane stress, SY membrane stress for load case 9, Hoop component, (node 688 to 622, path length of 0.626 in.)**

$$F_{ZHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Zlc9}$$

$$F_{ZHOOP490} := \frac{S_m - SI_{HOOP490}}{SI_{HOOP}} \cdot F_{Zlc9}$$

$$F_{ZHOOP50} = -87317 \cdot \text{lbf}$$

$$F_{ZHOOP490} = -57572 \cdot \text{lbf}$$

$SI_{LMx} := 1841 \cdot \frac{\text{lbf}}{\text{in}^2}$ **Local Primary Membrane stress for load case 10 (node 688 to 622, path length of 0.626 in.)**

$$M_{Xm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm50} = 17189 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xm490} = 2967 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{LBQMxI} := 2421 \cdot \frac{\text{lbf}}{\text{in}^2}$ **INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 688 to 622, path length of 0.626 in.)**

$$M_{Xmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQMxI}} \cdot M_{Xlc10}$$

$$M_{Xmb490I} := \frac{3 \cdot S_m - SI_{LBQ490I}}{SI_{LBQMxI}} \cdot M_{Xlc10}$$

$$M_{Xmb50I} = 31623 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xmb490I} = 17759 \cdot \text{ft} \cdot \text{lbf}$$

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$SI_{LBQMxO} := 1339 \frac{\text{lb}}{\text{in}^2}$ **OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 688 to 622, path length of 0.626 in.)**

$$M_{Xmb500} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQMxO}} \cdot M_{Xlc10} \quad M_{Xmb4900} := \frac{1.5 \cdot S_m - SI_{LBQ4900}}{SI_{LBQMxO}} \cdot M_{Xlc1}$$

$$M_{Xmb500} = 24840 \cdot \text{ft} \cdot \text{lb}$$

$$M_{Xmb4900} = 10188 \cdot \text{ft} \cdot \text{lb}$$

$$SI_{HOOP} := 407 \frac{\text{lb}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 10, Hoop component, (node 688 to 622, path length of 0.626 in.)

$$M_{XHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Xlc10} \quad M_{XHOOP490} := \frac{S_m - SI_{HOOP490}}{SI_{HOOP}} \cdot M_{Xlc10}$$

$$M_{XHOOP50} = 67280 \cdot \text{ft} \cdot \text{lb}$$

$$M_{XHOOP490} = 44361 \cdot \text{ft} \cdot \text{lb}$$

$$SI_{LMY} := 1965 \frac{\text{lb}}{\text{in}^2}$$

Local Primary Membrane stress for load case 13 (node 676 to 607, path length of 0.574 in.)

$$M_{Ym50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMY}} \cdot M_{Ylc13} \quad M_{Ym490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LMY}} \cdot M_{Ylc13}$$

$$M_{Ym50} = -18070 \cdot \text{ft} \cdot \text{lb}$$

$$M_{Ym490} = -3119 \cdot \text{ft} \cdot \text{lb}$$

$$SI_{LBQMyI} := 3318 \frac{\text{lb}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 676 to 607, path length of 0.574 in.)

$$M_{Ymb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQMyI}} \cdot M_{Ylc13} \quad M_{Ymb490I} := \frac{3 \cdot S_m - SI_{LBQ490I}}{SI_{LBQMyI}} \cdot M_{Ylc13}$$

$$M_{Ymb50I} = -25890 \cdot \text{ft} \cdot \text{lb}$$

$$M_{Ymb490I} = -14539 \cdot \text{ft} \cdot \text{lb}$$

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$SI_{LBQMyO} := 1259 \frac{\text{lbf}}{\text{in}^2}$ OUSTIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 676 to 607, path length of 0.574 in.)

$$M_{Ymb500} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQMyO}} \cdot M_{Ylc13} \quad M_{Ymb4900} := \frac{1.5 \cdot S_m - SI_{LBQ4900}}{SI_{LBQMyO}} \cdot M_{Ylc13}$$

$$M_{Ymb500} = -29642 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ymb4900} = -12158 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{HOOP} := 820 \frac{\text{lbf}}{\text{in}^2}$ General primary membrane stress, SY membrane stress for load case 13, Hoop component, (node 676 to 607, path length of 0.574 in.)

$$M_{YHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Ylc13} \quad M_{YHOOP490} := \frac{S_m - SI_{HOOP490}}{SI_{HOOP}} \cdot M_{Ylc13}$$

$$M_{YHOOP50} = -37468 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{YHOOP490} = -24705 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{LMz} := 1127 \frac{\text{lbf}}{\text{in}^2}$ Local Primary Membrane stress for load case 15 (node 688 to 622, path length of 0.626 in.)

$$M_{Zm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMz}} \cdot M_{Zlc15} \quad M_{Zm490} := \frac{1.5 \cdot S_m - SI_{L490}}{SI_{LMz}} \cdot M_{Zlc15}$$

$$M_{Zm50} = -31506 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zm490} = -5437 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{LBQMzI} := 1877 \frac{\text{lbf}}{\text{in}^2}$ INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 688 to 622, path length of 0.626 in.)

$$M_{Zmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQMzI}} \cdot M_{Zlc15} \quad M_{Zmb490I} := \frac{3 \cdot S_m - SI_{LBQ490I}}{SI_{LBQMzI}} \cdot M_{Zlc15}$$

$$M_{Zmb50I} = -45765 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zmb490I} = -25701 \cdot \text{ft} \cdot \text{lbf}$$

$SI_{LBQMzO} := 728 \frac{\text{lbf}}{\text{in}^2}$ OUSTIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 688 to 622, path length of 0.626 in.)

$$M_{Zmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQMzO}} \cdot M_{Zlc15} \quad M_{Zmb490O} := \frac{1.5 \cdot S_m - SI_{LBQ490O}}{SI_{LBQMzO}} \cdot M_{Zlc15}$$

$$M_{Zmb50O} = -51263 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zmb490O} = -21025 \cdot \text{ft} \cdot \text{lbf}$$

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$$SI_{HOOP} := 299 \cdot \frac{\text{lb}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 15, Hoop component, (node 688 to 622, path length of 0.626 in.)

$$M_{ZHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Zlc15} \quad M_{ZHOOP490} := \frac{S_m - SI_{HOOP490}}{SI_{HOOP}} \cdot M_{Zlc15}$$

$$M_{ZHOOP50} = -1 \cdot 10^5 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{ZHOOP490} = -67752 \cdot \text{ft} \cdot \text{lbf}$$

The maximum allowable external forces and moments at the bottom section are summarized below for a 50 and 490 ft-lbf pre-load torques in Table B5.

Table B5. The maximum allowable external forces and moments at the bottom section

<u>External Loads</u>	<u>50 ft-lbf Torque</u>	<u>490 ft-lbf Torque</u>
F _x (lbf)	97,481	16,824
F _y (lbf)	66,284	11,440
F _z (lbf)	40,527	6,994
M _x (ft-lbf)	17,189	2,967
M _y (ft-lbf)	18,070	3,119
M _z (ft-lbf)	31,506	5,437

6.7.6 Check Interaction with system model results for a 50 ft-lbf pre-load torque

From Table B5, the maximum allowable piping loads applied at the pipe opening were obtained. From Table 3.4 the acceptable piping loads were determined based on the other jumper components (hooks, pins, operating screw, guide lip with block lip, top of block, block bottom and pipe opening). The following is a linear interaction of Table 3.4 and Table B5 for the 50 ft-lbf pre-load case. See appendix C for interaction details.

Maximum Piping Loads from Table 3.4

$$f_x := 1540 \cdot \text{lbf} \quad m_x := 630 \cdot \text{ft} \cdot \text{lbf}$$

$$f_y := 1540 \cdot \text{lbf} \quad m_y := 630 \cdot \text{ft} \cdot \text{lbf}$$

$$f_z := 38100 \cdot \text{lbf} \quad m_z := 410 \cdot \text{ft} \cdot \text{lbf}$$

Maximum Piping loads from Table B3 @ 50 ft-lbf

$$F_x := 97481 \cdot \text{lbf} \quad M_x := 17189 \cdot \text{ft} \cdot \text{lbf}$$

$$F_y := 66284 \cdot \text{lbf} \quad M_y := 18070 \cdot \text{ft} \cdot \text{lbf}$$

$$F_z := 40527 \cdot \text{lbf} \quad M_z := 31506 \cdot \text{ft} \cdot \text{lbf}$$

$$I := \sqrt{\left(\frac{f_x}{F_x}\right)^2 + \left(\frac{f_y}{F_y}\right)^2} + \frac{f_z}{F_z} + \sqrt{\left(\frac{m_x}{M_x}\right)^2 + \left(\frac{m_y}{M_y}\right)^2 + \left(\frac{m_z}{M_z}\right)^2}$$

The linear interaction (I) must be less than or equal to 1 in order to satisfy ASME criteria at the bottom section.

$$I = 1 \leq 1.0$$

Therefore, satisfied for above piping loads from Table 3.4.
See appendix C for details of the basis of the interaction.

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NOTE: The maximum allowable forces and moments are independent of sign, except for the axial loading condition (Fz). Where the above Fz is given as a compressive force. If the force is in tension then the Fz force is govern by the minimum seating force. In this case, for the 3-in. ISB jumper connector the minimum axial seating force is 6,210 lbf for a 50 ft-lbf pre-load (with thermal effects) and according to the calculations will not seat without the thermal effects at 50 ft-lbf of preload. The maximum axial seating force for a 490 ft-lbf pre-load, with and without thermal effects is approximately 28,697 and 20,572 lbf, respectively.

7.0 Evaluation of 3-in. ISB Single Port Connector (Nozzle Flange Analysis)

The analysis of the 3-in. nozzle flange is evaluated in the same manner that the 2-in. nozzle flange were evaluated above in section 5.0.

Per ASME 1989 Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 3, Article 3-300, ASME Flange Design (ASME 1989c), the stresses in the flange due to the applied loading are evaluated in the same manner that the 2-in. nozzle flange in section 5.3 was. See Figure B5 of nozzle in section 5.3 for details and see drawing H-2-83573 for dimensions.

$A := 4.87 \cdot \text{in}$ outside diameter of flange

$B := 3.063 \cdot \text{in}$ inside diameter of flange

$t := 0.625 \cdot \text{in}$ thickness of flange

$g_1 := 0.344 \cdot \text{in}$ thickness of hub or nozzle wall

$f := 1 \cdot \text{in}$ for uniform thickness of hub

$K := \frac{A}{B}$ $K = 1.59$

For $K = 1.59$, from Fig. 3-340.1, the corresponding values of

$T := 1.75 \cdot \text{in}$ $Y := 4.5 \cdot \text{in}$ $U := 5 \cdot \text{in}$ $Z := 2.5 \cdot \text{in}$

$h := 3 \cdot \text{in} - 0.625 \cdot \text{in}$ $h = 2.375 \cdot \text{in}$ (Drawing H-2-83573)

$h_o := \sqrt{B \cdot g_1}$ $h_o = 1.026 \cdot \text{in}$

For $\frac{h}{h_o} = 2.314$ from Fig. 3-340.2, in ASME (1989c) $F := 0.91 \cdot \text{in}$

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$$e := \frac{F}{h_o} \quad e = 0.887 \quad \text{Again, from Fig. 3-340.3, in ASME (1989c)} \quad V := 0.55 \cdot \text{in}$$

$$d := \frac{U}{V} \cdot h_o \cdot g_1^2 \quad d = 1.1043 \cdot \text{in}^3$$

$$L_{\text{flange}} := \left(\frac{t \cdot e + 1 \cdot \text{in}}{T} + \frac{t^3}{d} \right) \cdot \text{in} \quad L_{\text{flange}} = 1.1091 \cdot \text{in}$$

$$P_{\text{capacity}} := 8750 \cdot \text{lb} \cdot \text{f} \quad \text{Axial capacity of hook according appendix A}$$

$$L := \frac{4.87 \cdot \text{in} - 3.063 \cdot \text{in}}{4} \quad \text{Moment arm at mid-flange to mid-pipe-wall (Drawing H-2-83573)} \\ L = 0.452 \cdot \text{in}$$

Moment due to torque load from the hook for 3 hooks

$$M_o := 3 \cdot P_{\text{capacity}} \cdot L \quad M_o = 11858 \cdot \text{lb} \cdot \text{f} \cdot \text{in}$$

7.1 Determine Flange stresses and compare with Allowable Flange Stress per ASME (1989e)

Per ASME 1989 Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 3, Article 3-300, ASME Flange Design (ASME 1989c), the stresses in the flange due to the applied loading are evaluated in the same manner that the 2-in. nozzle flange in section 5.3.1 was. See figure B5 of nozzle in section 5.3 for details and see drawing H-2-83573 for dimensions.

Longitudinal Hub Stress

$$S_H := \frac{f M_o}{L_{\text{flange}} \cdot g_1^2 \cdot B}$$

$$S_H = 29497 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

<

Allowable Hub Stress

$$S_{HA} := 1.5 \cdot S_m$$

$$S_{HA} = 30000 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

Conclusion

Good (O. K.)

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Radial Flange Stress

Allowable Radial Stress

Conclusion

$$S_R := \frac{(1.33 \cdot t \cdot e + 1 \cdot \text{in}) \cdot M_o}{L_{\text{flange}} \cdot t^2 \cdot B}$$

$$S_{RA} := S_m$$

$$S_R = 15521 \cdot \frac{\text{lbf}}{\text{in}^2}$$

<

$$S_{RA} = 20000 \cdot \text{psi}$$

Good (O.K.)

Tangential Flange Stress

Allowable Tangential Stress

Conclusion

$$S_T := \left(\frac{Y \cdot M_o}{t^2 \cdot B} - Z \cdot S_R \right) \cdot \frac{1}{\text{in}}$$

$$S_{TA} := S_m$$

$$S_T = 5797 \cdot \frac{\text{lbf}}{\text{in}^2}$$

<

$$S_{TA} = 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Good (O.K.)

7.2 Determine the limiting value of axial load based on the capacity of the hooks

$$P_H := P_{\text{capacity}} \cdot \frac{S_{HA}}{S_H}$$

$$P_H = 8899 \cdot \text{lbf}$$

$$P_R := P_{\text{capacity}} \cdot \frac{S_{RA}}{S_R}$$

$$P_R = 11275 \cdot \text{lbf}$$

$$P_T := P_{\text{capacity}} \cdot \frac{S_{TA}}{S_T}$$

$$P_T = 30186 \cdot \text{lbf}$$

Therefore, the limiting axial load is

$$P_{HR} := \text{if}(P_H < P_R, P_H, P_R)$$

$$P_{\text{limit}} := \text{if}(P_{HR} < P_T, P_{HR}, P_T)$$

$$P_{\text{limit}} = 8899 \cdot \text{lbf}$$

which is greater than the 3-in. hook limit of 8,750 lbf found in appendix A.
Therefore, the axial capacity of the 3-in. hook = 8,750 lbf governs.

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8.0 Evaluation of 4-in. ISB Single Port Connector (Block Analysis)

Following the methodology used for the 2-in. and 3-in. ISB single port connector block, the analysis of the 4-in. ISB single block connector is evaluated per ASME criteria

8.1 Applied axial load on the 4-in. ISB jumper block for a 50 ft-lbf torque screw force

A series of experiments were conducted for MWTF project using a 4-in ISB jumper connector. The results were documented by Ruff (1994) and showed a 50 ft-lbf torque is required to seal up to 1000 lbf/in² of internal pressure. The design pressure for MWTF 2-, 3-, and 4-in. ISB jumpers is 500 lbf/in². This does not include thermal and operational loads.

The Squier (1993) report related the applied pre-torque vs axial force on the block from the torque screw. From Squier (1993) the screw force for a 4-in. jumper connector (50 ft-lbf screw torque) is approximately.

$$F_{\text{torque}} := 2000 \cdot \text{lbf} \quad \text{axial load for a 50 ft-lbf torque (Squier 1993)}$$

8.2 Determine Equivalent Stiffnesses of Block, Nozzle, Screw and Hooks under thermal loading (used to determine the preload to constrain thermal expansion of the block and nozzle)

8.2.1 Nozzle stiffness (approximate method): (WHC 1993d, Drawing No. H-2-83574)

area of nozzle from flange, hook location, to top of nozzle SCH 40

$$A_{N1} := \frac{\pi}{4} \cdot [(6.06 \cdot \text{in})^2 - (4.031 \cdot \text{in})^2] \quad A_{N2} := \frac{\pi}{4} \cdot [(5.50 \cdot \text{in})^2 - (4.031 \cdot \text{in})^2]$$

$$A_{N1} = 16.081 \cdot \text{in}^2 \quad A_{N2} = 10.996 \cdot \text{in}^2$$

$$\Delta T_N := T_{\text{max}} - T_{\text{atm}} \quad \text{temperature change in nozzle}$$

original length of nozzle at hook interface @ 70 degrees F

$$L_{N1} := 0.75 \cdot \text{in} \quad L_{N2} := \frac{0.84 \cdot \text{in}}{2}$$

$$\alpha_N := \alpha_{250A276} \quad \text{mean coefficient of thermal expansion for nozzle @ 250 deg. F}$$

$$E_N := E_{250A276} \quad \text{Young's modulus for ASTM A276 @ 250 deg. F}$$

$$K_{N1} := \frac{E_N \cdot A_{N1}}{L_{N1}} \quad K_{N2} := \frac{E_N \cdot A_{N2}}{L_{N2}}$$

$$K_{N1} = 5.875 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}} \quad K_{N2} = 7.174 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{approximate stiffness of nozzle section}$$

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8.2.2 Block stiffness (approx. method using fea from 2-inch model): (WHC 1994c, Drawing No. H-2-821326)

The ratio hook stiffness based on the Finite-Element model vs approximate method is

$$R_B := \frac{K_{Bfea}}{K_{Bapp}} \quad R_B = 0.177$$

$$A_B := \frac{\pi}{4} \cdot [(6.37 \cdot \text{in})^2 - (4.03 \cdot \text{in})^2] \quad \text{approximate area of block} \quad A_B = 19.113 \cdot \text{in}^2$$

$$\Delta T_B := T_{\max} - T_{\text{atm}} \quad \text{temperature change in block}$$

$$L_B := 7.141 \cdot \text{in} - 0.248 \cdot \text{in} - \frac{0.606 \cdot \text{in}}{2} \quad \text{original length of block at 70 degrees F} \quad L_B = 6.59 \cdot \text{in}$$

$$\alpha_B := \alpha_{250A276} \quad \text{mean coefficient of thermal expansion for block @ 250 deg. F}$$

$$E_B := E_{250A276} \quad \text{Young's modulus for ASTM A276 @ 250 deg. F}$$

$$K_B := R_B \cdot \left(\frac{E_B \cdot A_B}{L_B} \right) \quad \text{estimated stiffness of block} \quad K_B = 1.404 \cdot 10^7 \cdot \frac{\text{lbF}}{\text{in}}$$

8.2.3 Screw stiffness (approximate method):

(WHC 1988 , Drawing No. H-2-32441)

$$A_S := \frac{\pi}{4} \cdot (1.69 \cdot \text{in})^2 \quad \text{approximate area of screw} \quad A_S = 2.243 \cdot \text{in}^2$$

$$L_S := 12.578 \cdot \text{in} - (L_B + L_{N1} + L_{N2}) \quad \text{original length of screw at @ 70 degrees F} \quad L_S = 4.818 \cdot \text{in}$$

$$E_S := E_{A193} \quad \text{Young's modulus for ASTM A193 @ 70 deg. F}$$

$$K_S := \frac{E_S \cdot A_S}{L_S} \quad K_S = 1.383 \cdot 10^7 \cdot \frac{\text{lbF}}{\text{in}} \quad \text{estimated stiffness of screw}$$

8.2.4 Operating nut guide stiffness (approximate method): (WHC 1986b, Drawing No. H-2-68211)

$$I_{\text{nut}} := \frac{2}{12} \cdot \left(\frac{3.0 \cdot \text{in} - 1.20 \cdot \text{in}}{2} \right) \cdot (2.62 \cdot \text{in})^3 \quad \text{approximate moment of inertia of operating nut guide} \quad I_{\text{nut}} = 2.698 \cdot \text{in}^4$$

$$L_{\text{nut}} := 2.69 \cdot \text{in} \quad \text{original length of operating nut guide at @ 70 degrees F}$$

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Originator J. L. Julyk

Date 3/28/95

Checker H. P. Shrivastava

Date 3/30/95

$$E_{\text{nut}} := 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Young's modulus of operating nut guide @ 70 deg. F (assumed)

$$K_{\text{nut}} := \left(\frac{3 \cdot E_{\text{nut}} \cdot I_{\text{nut}}}{L_{\text{nut}}^3} \right)$$

$$K_{\text{nut}} = 1.206 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{estimated stiffness of operating nut guide}$$

8.2.5 Hook pin stiffness (approximate method): (WHC 1986b, Drawing No. H-2-68211)

$$I_{\text{pin}} := \frac{\pi}{64} \cdot (0.8755 \cdot \text{in})^4$$

aproximate moment of inertia of hook pin $I_{\text{pin}} = 0.029 \cdot \text{in}^4$

$$L_{\text{pin}} := \frac{3.0 \cdot \text{in} + 1.2 \cdot \text{in}}{2}$$

length of hook pin (WHC 1986b, Drawing H-2-68211) $L_{\text{pin}} = 2.1 \cdot \text{in}$

$$E_{\text{pin}} := 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Young's modulus of hook pin @ 70 deg. F (assumed)

$$\Delta_{\text{pin}} := \frac{1 \cdot \text{lbf} \cdot L_{\text{pin}}^3}{48 \cdot E_{\text{pin}} \cdot I_{\text{pin}}}$$

deflection of pin per AISC 1989 case 7 for a simple beam with a 1 lbf concentrated load at the center (AISC 1989)

$$\Delta_{\text{pin}} = 2.307 \cdot 10^{-7} \cdot \text{in}$$

$$K_{\text{pin}} := \left(\frac{1 \cdot \text{lbf}}{\Delta_{\text{pin}}} \right)$$

$$K_{\text{pin}} = 4.335 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}}$$

estimated stiffness of hook pin

8.2.6 Hooks stiffness (based on the ratio of the 2-in approximate method and FE Hook model stiffnesses): (WHC 1993g, Drawing H-2-90176, rev. 4, sh 1)

$$R_H := \frac{K_{2\text{fea}}}{K_{2\text{app}}}$$

The ratio hook stiffness based on the Finite-Element model vs approximate method

$$R_H = 0.9$$

The line joining the top and the bottom points of the hook is virtually parallel to the axis of the nozzle and the block, consider the hook as a crescent as previously assumed for the 2- and 3-in. hook stiffness calculations

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Figure B8. Typical Hook for ISB Jumper
(WHC 1993g, H-2-90176, rev. 4, sh 1)

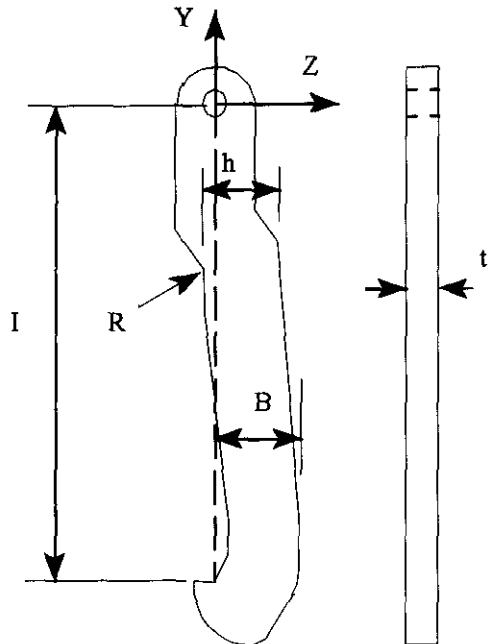
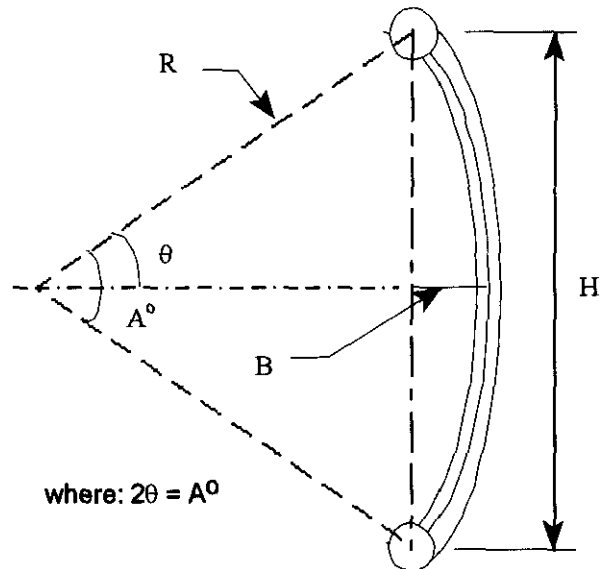


Figure B9. Hook Shape for determining the Hook Stiffness
(Assumed)



Refer AISC, 1989, page 6-18

$H := 12.486 \cdot \text{in}$ chord length

$B := 2.718 \cdot \text{in} - \frac{1.718 \cdot \text{in}}{2}$ $B = 1.859 \cdot \text{in}$ rise

$$\tan\left(\frac{A_{\text{app}}}{4}\right) = \frac{2 \cdot B}{H}$$

$\tan(D) = \frac{2 \cdot B}{H}$ $D := \text{atan}\left(\frac{2 \cdot B}{H}\right)$ $D = 16.582 \cdot \text{deg}$

Therefore, $A := 4 \cdot D$ $A = 66.329 \cdot \text{deg}$ $\theta := \frac{A}{2}$ $\theta = 33.164 \cdot \text{deg}$

$R := \frac{H}{2 \cdot \sin(\theta)}$ $R = 11.412 \cdot \text{in}$

Because load is applied at top pin of the hook $\Phi := \theta$ $\Phi = 33.164 \cdot \text{deg}$ $\theta = 0.579 \cdot \text{rad}$

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Refer Roark, 1989, Table 18, Case 3 (Roark 1989)

$$s := \sin(\theta) \quad s = 0.547$$

$$c := \cos(\theta) \quad c = 0.837$$

$$A_{app} := 1.36 \cdot \text{in} \cdot 1.18 \cdot \text{in}$$

$$A_{app} = 1.605 \cdot \text{in}^2$$

$$n := \sin(\Phi) \quad n = 0.547$$

$$I_{app} := \frac{1.18 \cdot \text{in} \cdot (1.62 \cdot \text{in})^3}{12}$$

$$I_{app} = 0.418 \cdot \text{in}^4$$

$$e := \cos(\Phi) \quad e = 0.837$$

$$F := \frac{6}{5}$$

Shape Factor (Roark 1989)

$$W := 1 \cdot \text{lbf} \quad \text{Assume load}$$

$$\mu := 0.30 \quad \text{Poisson ratio for A747 @ 70 deg. F (ASTM 1989)}$$

$$E_{app} := E_{A747}$$

Young's modulus for ASTM A747 @ 70 deg. F (ASTM 1989)

$$E_{A747} = 2.9 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$G := \frac{E_{app}}{2 \cdot (1 + \mu)}$$

Shear Modulus

$$G = 1.115 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\alpha := \frac{I_{app}}{A_{app} \cdot R^2} \quad \alpha = 0.002$$

$$\beta := \frac{F \cdot E_{app} \cdot I_{app}}{G \cdot A_{app} \cdot R^2} \quad \beta = 0.006$$

$$LP_H := W \cdot \left[\frac{\theta}{2} + \theta \cdot c^2 - \frac{3}{2} \cdot s \cdot c + \Phi \cdot e \cdot c + \frac{\Phi}{2} - \frac{n \cdot e}{2} - n \cdot c + (\alpha + \beta) \cdot \left(\frac{\theta + \Phi}{2} \right) + (\alpha - \beta) \cdot \left(\frac{s \cdot c + n \cdot e}{2} \right) \right]$$

$$LP_H = 0.019 \cdot \text{lbf}$$

Deformation along the axis of the hook

$$\delta H_A := - \frac{R^3}{E_{A747} \cdot I_{app}} \cdot LP_H$$

$$\delta H_A = -2.339 \cdot 10^{-6} \cdot \text{in}$$

Stiffness of the hook along its axis

$$K_H := R_H \cdot \frac{-W}{\delta H_A}$$

$$K_H = 3.846 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

estimated stiffness of hook

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8.2.7 Determine the Thermal Expansion from nozzle to top of the block:

$$\Delta L_N := [\alpha_N (L_{N1} + L_{N2})] \cdot \Delta T_N$$

thermal growth of nozzle @ 250 deg. F

$$\Delta L_N = 0.0019 \cdot \text{in}$$

$$\Delta L_B := (\alpha_B \cdot L_B) \cdot \Delta T_B$$

thermal growth of block @ 250 deg. F

$$\Delta L_B = 0.0105 \cdot \text{in}$$

$$\Delta L_{\text{total}} := \Delta L_N + \Delta L_B$$

thermal growth of block @ 250 deg. F

$$\Delta L_{\text{total}} = 0.0124 \cdot \text{in}$$

8.2.8 Determine Equivalent Stiffness of the Jumper (with and without the block stiffness included)

$$K_{EQ1} := \left(\frac{1}{K_{N1}} + \frac{1}{K_{N2}} + \frac{1}{K_B} + \frac{1}{K_S} + \frac{1}{3 \cdot K_H} + \frac{1}{3 \cdot K_{\text{nut}}} + \frac{1}{3 \cdot K_{\text{pin}}} \right)^{-1} \quad K_{EQ1} = 8.946 \cdot 10^5 \cdot \frac{\text{lb}}{\text{in}}$$

$$K_{EQ2} := \frac{1}{(K_{EQ1}^{-1} - K_B^{-1})} \quad K_{EQ2} = 9.555 \cdot 10^5 \cdot \frac{\text{lb}}{\text{in}} \quad \text{estimated equivalent stiffness of system excluding the block stiffness due to thermal expansion of the block}$$

8.3 Determine the total force F_{thermal} required to restrain nozzle and block to original length L

$$F_{\text{thermal}} := \frac{K_B \cdot K_{EQ2}}{K_B + K_{EQ2}} \cdot \Delta L_{\text{total}} \quad F_{\text{thermal}} = 11109 \cdot \text{lb} \quad \text{Compression force on Block}$$

Note: The stiffness of the screw, block, nozzle, and hooks are in series

8.4 Determine the applied axial load to account for the internal pressure of the 4-in. ISB jumper block

According to the MWTF Functional Design Criteria (FDC) found in WHC-SD-W236A-FDC-001 (WHC 1993a), the design pressure considered in the structural analysis of the connector assembly is 400 lb/in². The 2-in block methodology for determining the amount of axial pressure load applied to the jumper is used in the 4-in. ISB block.

$$F_{\text{calcap}} := P_{\text{design}} \cdot \frac{\pi}{4} \cdot \left(\frac{4.835 \cdot \text{in} + 4.425 \cdot \text{in}}{2} \right)^2 \quad F_{\text{calcap}} = 6735 \cdot \text{lb}$$

The axial pressure load applied to resist the internal pressure @ the top of the block/screw interaction is the calculated axial pressure multiplied by the ratio estimated equivalent stiffnesses.

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$$F_{\text{pressure}} := F_{\text{calcap}} \cdot \left(\frac{K_{\text{EQ2}}}{K_{\text{EQ2}} + K_{\text{B}}} \right)$$

$$F_{\text{pressure}} = 429 \cdot \text{lbf}$$

Compression force on block
and tensile force on hooks

$$F_{\text{Pseat}} := F_{\text{calcap}} - F_{\text{pressure}}$$

$$F_{\text{Pseat}} = 6306 \cdot \text{lbf}$$

Pressure load that goes to
reduce the seating torque load

8.5 Total applied axial load for 4-in. ISB jumper block

$$F_{\text{total}} := F_{\text{torque}} + F_{\text{thermal}} + F_{\text{pressure}}$$

$$F_{\text{total}} = 13538 \cdot \text{lbf} \quad \text{applied axial load for a 50 ft-lbf torque, thermal, and internal pressure}$$

The total axial loads are applied over a circular radius of $b = 0.852$ in., in the 4-in. FEA model, to simulate the punch-through failure mode of the screw and block. The stresses at the top section of the block are then compared to the ASME (1989b) criteria established in sections 4.7.1 to 4.7.3.

8.6 Seating load with and without thermal effects (cold and hot conditions)

Excluding the effects of thermal and axial external loading

$$F_{\text{cold}} := F_{\text{torque}} - (F_{\text{Pseat}})$$

$$F_{\text{cold}} = -4306 \cdot \text{lbf} \quad \text{seating load for a 50 ft-lbf torque}$$

Excluding the effects of axial external loading

$$F_{\text{hot}} := F_{\text{torque}} + F_{\text{thermal}} - (F_{\text{Pseat}})$$

$$F_{\text{hot}} = 6803 \cdot \text{lbf} \quad \text{seating load for a 50 ft-lbf torque}$$

8.7 Calculation of Maximum Piping Loads using Linearized Stress Intensities through a section of the 4-in. ISB jumper connector block

The stress analysis is based on a linear-elastic material. The linearized stress intensity is taken from the 4-in. finite-element block model. The linearized stress intensities through the thickness of the block are from a 50 ft-lbf torque load case, thermal expansion from 70 to 250 deg. F, internal pressure of 400 lbf/in², and assumed external loads associated with the piping configuration. The assumed forces and moments are stated below.

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8.7.1 Loads and Load Cases applied to FEA 4-in. Block Model

$F_{Zlc1} := -34013 \cdot \text{lbf}$ Load Case 1 (LC1), axial load (Fz) applied at top of block/screw for 50 ft-lbf pre-load
 $F_{Xlc5} := -30000 \cdot \text{lbf}$ Load Case 5 (LC5), horizontal force (Fx) applied at pipe intersection @ node 20,000
 $F_{Ylc7} := -25000 \cdot \text{lbf}$ Load Case 7 (LC7), horizontal force (Fy) applied at pipe intersection @ node 20,000
 $F_{Zlc9} := -11100 \cdot \text{lbf}$ Load Case 9 (LC9), axial force (Fz) applied at pipe intersection @ node 20,000
 $M_{Xlc10} := 2120 \cdot \text{ft} \cdot \text{lbf}$ Load Case 10 (LC10), horizontal moment applied at pipe intersection @ node 20,000
 $M_{Ylc13} := -2378 \cdot \text{ft} \cdot \text{lbf}$ Load Case 13 (LC13), horizontal moment applied at pipe intersection @ node 20,000
 $M_{Zlc15} := -2378 \cdot \text{ft} \cdot \text{lbf}$ Load Case 15 (LC15), torsional moment applied at pipe intersection @ node 20,000

Load Case 16 (LC16), was applied as in internal pressure of 400 psi to the inside of the block.

8.7.2 Maximum linearized stress intensities through the top section of the block from axial loading (See section 11, Table B5 for reference)

$SI_{m50} := 13270 \cdot \frac{\text{lbf}}{\text{in}^2} \leq S_m = 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$ General Primary Membrane stress for load case 1
(node 1703 to 1997, path length 0.591 in.)
 $SI_{mb50} := 15950 \cdot \frac{\text{lbf}}{\text{in}^2} \leq 1.5 \cdot S_m = 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$ General Primary membrane plus primary bending stress
for load case 1 (node 1703 to 1997, path length 0.591 in.)

Therefore, the top section of the block under axial loading (preload 50 + thermal expansion + pressure) meets the ASME (1989b) criteria established above for the top section of the block under the screw.

8.7.2.1 Maximum allowable pre-load the top section of the block can withstand

$F_m := \frac{S_m}{SI_{m50}} \cdot F_{\text{total}}$ $F_m = 20404 \cdot \text{lbf}$ Total load based on membrane stress intensity

$F_{mb} := \frac{1.5 \cdot S_m}{SI_{mb50}} \cdot F_{\text{total}}$ $F_{mb} = 25463 \cdot \text{lbf}$ Total axial load based on membrane plus bending stress intensity

$F_{\text{preload}} := \text{if}(F_m \leq F_{mb}, F_m - F_{\text{pressure}} - F_{\text{thermal}}, F_{mb} - F_{\text{pressure}} - F_{\text{thermal}})$ $F_{\text{preload}} = 8866 \cdot \text{lbf}$

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From the Squire (1993) test report the screw force of calculated is between 200 and 300 ft-lbf of torque. Therefore, by interpolating the test data from the Squire (1993) report the maximum allowable preload torque is calculated.

$$\text{Torque}_{\max} := \frac{1}{2} \left[\frac{\left(\frac{7968 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 9437 \cdot \text{lbf}} \right) \cdot 251.1 \cdot \text{ft} \cdot \text{lbf} + 198.5 \cdot \text{ft} \cdot \text{lbf}}{\frac{7968 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 9437 \cdot \text{lbf}} + 1} + \frac{\left(\frac{7572 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 9638 \cdot \text{lbf}} \right) \cdot 250.9 \cdot \text{ft} \cdot \text{lbf} + 201.9 \cdot \text{ft} \cdot \text{lbf}}{\frac{7572 \cdot \text{lbf} - F_{\text{preload}}}{F_{\text{preload}} - 9638 \cdot \text{lbf}} + 1} \right]$$

$\text{Torque}_{\max} = 232 \cdot \text{ft} \cdot \text{lbf}$ Therefore, the maximum allowable preload torque is 230 ft-lbf at the current design conditions and material allowables based on a elastic linear analysis.

8.7.3 Maximum External Forces and Moments @ the Pipe Intersection

(The Maximum linearized stress intensities through the block wall at the pipe entrance for external loading, 50 ft-lbf, thermal expansion, and pressure stresses are in section 11, Table B11)

$$\text{SI}_{\text{L50}} := 6987 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 1, (node 454 to 350, path length of 1.45 in.)

$$\text{SI}_{\text{LBQ50}} := 10170 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress for load case 1, (node 454 to 350, path length of 1.45 in.)

$$\text{SI}_{\text{EL230}} := \frac{F_m}{F_{\text{total}}} \cdot \text{SI}_{\text{L50}}$$

Estimated Local Primary Membrane stress at the calculated maximum torque, (node 454 to 350, path length of 1.45 in.)

$$\text{SI}_{\text{EL230}} = 10531 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\text{SI}_{\text{ELBQ230}} := \frac{F_m}{F_{\text{total}}} \cdot \text{SI}_{\text{LBQ50}}$$

Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, (node 454 to 350, path length of 1.45 in.)

$$\text{SI}_{\text{ELBQ230}} = 15328 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\text{SI}_{\text{Lpress}} := 2245 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 16, (node 55 to 458, path length of 1.17 in.)

$$\text{SI}_{\text{LBQpress}} := 3416 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress for load case 16, (node 55 to 458, path length of 1.17 in.)

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8.7.3.1 The resultant of the pre-stress intensity is stated as the following @ the pipe intersection:

$$SI_L := SI_{L50} + SI_{Lpress}$$

Local primary membrane stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_L = 9232 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ} := SI_{LBQ50} + SI_{LBQpress}$$

Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{LBQ} = 13586 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{L230} := SI_{EL230} + SI_{Lpress}$$

Local primary membrane stress at maximum torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{L230} = 12776 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ230} := SI_{ELBQ230} + SI_{LBQpress}$$

Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ pipe intersection.

$$SI_{ELBQ230} = 15328 \cdot \frac{\text{lbf}}{\text{in}^2}$$

8.7.3.2 Maximum allowable external forces and moments at the pipe intersection for 4-in ISB Block

The Local membrane and bending are compared to the allowable ASME stress, based on the criteria in section 4.7.2, minus the pre-stress condition due to torque, thermal expansion and internal pressure.

$$SI_{LFX} := 8810 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 5 (node 356 to 437, path length of 1.146 in.)

$$F_{Xm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm50} = -70720 \cdot \text{lbf}$$

$$F_{Xm230} = -58653 \cdot \text{lbf}$$

$$SI_{LBQFX} := 13240 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 356 to 437, path length of 1.146 in.)

$$F_{Xmb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQFX}} \cdot F_{Xlc5}$$

$$F_{Xmb230} := \frac{3 \cdot S_m - SI_{LBQ230}}{SI_{LBQFX}} \cdot F_{Xlc5}$$

$$F_{Xmb50} = -1 \cdot 10^5 \cdot \text{lbf}$$

$$F_{Xmb230} = -93481 \cdot \text{lbf}$$

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$$SI_{LFy} := 17820 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 7 (node 356 to 437, path length of 1.146 in.)

$$F_{Ym50} := \frac{1.5 \cdot S_m - SI_{LFy}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym50} = -29136 \cdot \text{lbf}$$

$$F_{Ym230} = -24165 \cdot \text{lbf}$$

$$SI_{LBQFy} := 31730 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 356 to 437, path length of 1.146 in.)

$$F_{Ymb50} := \frac{3 \cdot S_m - SI_{LBQy}}{SI_{LBQFy}} \cdot F_{Ylc7}$$

$$F_{Ymb230} := \frac{3 \cdot S_m - SI_{LBQ230}}{SI_{LBQFy}} \cdot F_{Ylc7}$$

$$F_{Ymb50} = -36569 \cdot \text{lbf}$$

$$F_{Ymb230} = -32506 \cdot \text{lbf}$$

$$SI_{LFz} := 4525 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 9 (node 465 to 515, path length of 0.9988 in.)

$$F_{Zm50} := \frac{1.5 \cdot S_m - SI_{LFz}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm50} = -50945 \cdot \text{lbf}$$

$$F_{Zm230} = -42252 \cdot \text{lbf}$$

$$SI_{LBQFz} := 9918 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 465 to 515, path length of 0.9988 in.)

$$F_{Zmb50} := \frac{3 \cdot S_m - SI_{LBQz}}{SI_{LBQFz}} \cdot F_{Zlc9}$$

$$F_{Zmb230} := \frac{3 \cdot S_m - SI_{LBQ230}}{SI_{LBQFz}} \cdot F_{Zlc9}$$

$$F_{Zmb50} = -51945 \cdot \text{lbf}$$

$$F_{Zmb230} = -46173 \cdot \text{lbf}$$

$$SI_{LMx} := 3163 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 10 (node 465 to 515, path length of 0.9988 in.)

$$M_{Xm50} := \frac{1.5 \cdot S_m - SI_{LMx}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm50} = 13920 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xm230} = 11545 \cdot \text{ft} \cdot \text{lbf}$$

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$SI_{LBQMx} := 6273 \cdot \frac{lbf}{in^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 465 to 515, path length of 0.9988 in.)

$$M_{Xmb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQMx}} \cdot M_{Xlc10}$$

$$M_{Xmb230} := \frac{3 \cdot S_m - SI_{LBQ230}}{SI_{LFX}} \cdot M_{Xlc10}$$

$$M_{Xmb50} = 15686 \cdot ft \cdot lbf$$

$$M_{Xmb230} = 9928 \cdot ft \cdot lbf$$

$SI_{LMY} := 6222 \cdot \frac{lbf}{in^2}$ Local Primary Membrane stress for load case 13 (node 356 to 437, path length of 1.146 in.)

$$M_{Ym50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMY}} \cdot M_{Ylc13}$$

$$M_{Ym230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LMY}} \cdot M_{Ylc13}$$

$$M_{Ym50} = -7937 \cdot ft \cdot lbf$$

$$M_{Ym230} = -6583 \cdot ft \cdot lbf$$

$SI_{LBQMy} := 10410 \cdot \frac{lbf}{in^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 356 to 437, path length of 1.146 in.)

$$M_{Ymb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQMy}} \cdot M_{Ylc13}$$

$$M_{Ymb230} := \frac{3 \cdot S_m - SI_{LBQ230}}{SI_{LBQMy}} \cdot M_{Ylc13}$$

$$M_{Ymb50} = -10603 \cdot ft \cdot lbf$$

$$M_{Ymb230} = -9424 \cdot ft \cdot lbf$$

$SI_{LMZ} := 5851 \cdot \frac{lbf}{in^2}$ Local Primary Membrane stress for load case 15 (node 465 to 515, path length of 0.9988 in.)

$$M_{Zm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMZ}} \cdot M_{Zlc15}$$

$$M_{Zm230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LMZ}} \cdot M_{Zlc15}$$

$$M_{Zm50} = -8441 \cdot ft \cdot lbf$$

$$M_{Zm230} = -7000 \cdot ft \cdot lbf$$

$SI_{LBQMz} := 8839 \cdot \frac{lbf}{in^2}$ Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 465 to 515, path length of 0.9988 in.)

$$M_{Zmb50} := \frac{3 \cdot S_m - SI_{LBQ}}{SI_{LBQMz}} \cdot M_{Zlc15}$$

$$M_{Zmb230} := \frac{3 \cdot S_m - SI_{LBQ230}}{SI_{LBQMz}} \cdot M_{Zlc15}$$

$$M_{Zmb50} = -12487 \cdot ft \cdot lbf$$

$$M_{Zmb230} = -11099 \cdot ft \cdot lbf$$

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The maximum allowable external forces and moments at the pipe section are summarized below for a 50 and 230 ft-lbf pre-load torques in Table B6.

Table B6. The maximum allowable external forces and moments at the pipe section

<u>External Loads</u>	<u>50 ft-lbf Torque</u>	<u>230 ft-lbf Torque</u>
F _x (lbf)	70,720	58,653
F _y (lbf)	29,136	24,165
F _z (lbf)	50,945	42,251
M _x (ft-lbf)	13,920	9,928
M _y (ft-lbf)	7,937	6,583
M _z (ft-lbf)	8,441	7,000

8.7.4 Check Interaction with system model results for a 50 ft-lbf pre-load torque

From Table B6, the maximum allowable piping loads applied at the pipe opening were obtained. From Table 3.4 the acceptable piping loads were determined based on the other jumper components (hooks, pins, operating screw, guide lip with block lip, top of block, block bottom and pipe opening). The following is a linear interaction of Table 3.4 and Table B6 for the 50 ft-lbf pre-load case. See appendix C for interaction details.

Maximum Piping Loads from Table 3.4

$$\begin{aligned} f_x &:= 2220 \cdot \text{lbf} & m_x &:= 1170 \cdot \text{ft} \cdot \text{lbf} \\ f_y &:= 2220 \cdot \text{lbf} & m_y &:= 1170 \cdot \text{ft} \cdot \text{lbf} \\ f_z &:= 42100 \cdot \text{lbf} & m_z &:= 780 \cdot \text{ft} \cdot \text{lbf} \end{aligned}$$

Maximum Piping loads from Table B2 @ 50 ft-lbf

$$\begin{aligned} F_x &:= 70720 \cdot \text{lbf} & M_x &:= 13920 \cdot \text{ft} \cdot \text{lbf} \\ F_y &:= 29136 \cdot \text{lbf} & M_y &:= 7937 \cdot \text{ft} \cdot \text{lbf} \\ F_z &:= 50945 \cdot \text{lbf} & M_z &:= 8441 \cdot \text{ft} \cdot \text{lbf} \end{aligned}$$

$$I := \sqrt{\left(\frac{f_x}{F_x}\right)^2 + \left(\frac{f_y}{F_y}\right)^2 + \left(\frac{f_z}{F_z}\right)^2} + \sqrt{\left(\frac{m_x}{M_x}\right)^2 + \left(\frac{m_y}{M_y}\right)^2 + \left(\frac{m_z}{M_z}\right)^2}$$

The linear interaction (I) must be less than or equal to 1 in order to satisfy ASME criteria at the pipe intersection.

$$I = 1 \leq 1.0$$

Therefore, satisfied for above piping loads from Table 3.4.
See appendix C for details of the basis of the interaction.

8.7.5 Maximum External Forces and Moments @ Bottom section of the block

(The Maximum linearized stress intensities through the block wall at the nozzle /block interface external loading, 50 ft-lbf, thermal expansion, and pressure stresses are in section 11, Table B11)

$$SI_{L50} := 7925 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 1,
(node 1070 to 886, path length of 0.6893 in.)

$$SI_{LBQ50I} := 11440 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress for
load case 1, (node 1070 to 886, path length of 0.6893 in.)

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$$SI_{LBQ500} := 5888 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress for load case 1, (node 1070 to 886, path length of 0.6893 in.)

$$SI_{H50} := 4455 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress compared to SY membrane stress for load case 1, Hoop component, (node 1070 to 886, path length of 0.6893 in.)

$$SI_{EL230} := \frac{F_m}{F_{total}} \cdot SI_{L50}$$

Estimated Local Primary Membrane stress at the calculated maximum torque, (node 1070 to 886, path length of 0.6893 in.)

$$SI_{EL230} = 11944 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{ELBQ230I} := \frac{F_m}{F_{total}} \cdot SI_{LBQ50I}$$

INSIDE Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, pre-stressed condition (node 1070 to 886, path length of 0.6893 in.)

$$SI_{ELBQ230I} = 17242 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{ELBQ230O} := \frac{F_m}{F_{total}} \cdot SI_{LBQ500}$$

OUTSIDE Estimated Local Primary membrane plus primary bending plus secondary stress at the calculated maximum torque, pre-stressed condition (node 1070 to 886, path length of 0.6893 in.)

$$SI_{ELBQ230O} = 8874 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{EH230} := \frac{F_m}{F_{total}} \cdot SI_{H50}$$

Estimated General primary membrane stress compared to the SY membrane stress for load case 1, Hoop component, (node 1070 to 886, path length of 0.6893 in.)

$$SI_{EH230} = 6714 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{Lpress} := 2636 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 16, (node 1046 to 878, path length of 0.7709 in.)

$$SI_{LBQpressI} := 3111 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress for load case 16, (node 1046 to 878, path length of 0.7709 in.)

$$SI_{LBQpressO} := 3313 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress for load case 16, node 1046 to 878, path length of 0.7709 in.)

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$$SI_{Hpress} := 678 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress compared to SY membrane stress for load case 16, Hoop component, (node 1046 to 878, path length of 0.7709 in.)

8.7.5.1 The resultant of the pre-stress intensity is stated as the following @ the bottom section:

$$SI_L := SI_{L50} + SI_{Lpress}$$

Local primary membrane stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_L = 10561 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQI} := SI_{LBQ50I} + SI_{LBQpressI}$$

INSIDE Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQI} = 14551 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQO} := SI_{LBQ50O} + SI_{LBQpressO}$$

OUTSIDE Local primary membrane plus bending plus secondary stress at 50 ft-lbf torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQO} = 9201 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{HOOP50} := SI_{H50} + SI_{Hpress}$$

General primary membrane stress, SY membrane stress for Hoop component, @ bottom section.

$$SI_{HOOP50} = 5133 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{L230} := SI_{EL230} + SI_{Lpress}$$

Local primary membrane stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{L230} = 14580 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ230I} := SI_{ELBQ230I} + SI_{LBQpressI}$$

INSIDE Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQ230I} = 20353 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$SI_{LBQ230O} := SI_{ELBQ230O} + SI_{LBQpressO}$$

OUTSIDE Local primary membrane plus bending plus secondary stress at maximum torque, thermal expansion, and pressure conditions @ bottom section.

$$SI_{LBQ230O} = 12187 \cdot \frac{\text{lbf}}{\text{in}^2}$$

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$$SI_{HOOP230} := SI_{EH230} + SI_{Hpress}$$

General primary membrane stress, SY membrane stress for Hoop component, @ bottom section.

$$SI_{HOOP230} = 7392 \cdot \frac{\text{lbf}}{\text{in}^2}$$

8.7.5.2 Maximum allowable external forces and moments at the bottom section for 4-in ISB Block

The Local membrane and bending are compared to the allowable ASME stress, based on the criteria in section 4.7.3, minus the pre-stress condition due to torque, thermal expansion and internal pressure.

$$SI_{LFX} := 4185 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 5 (node 1106 to 993, path length of 0.6969 in.)

$$F_{Xm50} := \frac{1.5 \cdot S_m - SI_{LFX}}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LFX}} \cdot F_{Xlc5}$$

$$F_{Xm50} = -139348 \cdot \text{lbf}$$

$$F_{Xm230} = -1 \cdot 10^5 \cdot \text{lbf}$$

$$SI_{LBQFXI} := 6503 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 1106 to 993, path length of 0.6969 in.)

$$F_{Xmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQFXI}} \cdot F_{Xlc5}$$

$$F_{Xmb230I} := \frac{3 \cdot S_m - SI_{LBQ230I}}{SI_{LBQFXI}} \cdot F_{Xlc5}$$

$$F_{Xmb50I} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$F_{Xmb230I} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$SI_{LBQFXO} := 2714 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 5 (node 1106 to 993, path length of 0.6969 in.)

$$F_{Xmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFXO}} \cdot F_{Xlc5}$$

$$F_{Xmb230O} := \frac{1.5 \cdot S_m - SI_{LBQ230O}}{SI_{LBQFXO}} \cdot F_{Xlc5}$$

$$F_{Xmb50O} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$F_{Xmb230O} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$SI_{HOOP} := 1932 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 5, Hoop component, (node 1106 to 993, path length of 0.6869 in.)

$$F_{XHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Xlc5}$$

$$F_{XHOOP230} := \frac{S_m - SI_{HOOP230}}{SI_{HOOP}} \cdot F_{Xlc5}$$

$$F_{XHOOP50} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$F_{XHOOP230} = -2 \cdot 10^5 \cdot \text{lbf}$$

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$$SI_{LFy} := 3119 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 7 (node 1069 to 888, path length of 0.6875 in.)

$$F_{Ym50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LFy}} \cdot F_{Ylc7}$$

$$F_{Ym50} = -155811 \cdot \text{lbf}$$

$$F_{Ym230} = -123595 \cdot \text{lbf}$$

$$SI_{LBQFyI} := 4417 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 1069 to 888, path length of 0.6875 in.)

$$F_{Ymb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQFyI}} \cdot F_{Ylc7}$$

$$F_{Ymb230I} := \frac{3 \cdot S_m - SI_{LBQ230I}}{SI_{LBQFyI}} \cdot F_{Ylc7}$$

$$F_{Ymb50I} = -3 \cdot 10^5 \cdot \text{lbf}$$

$$F_{Ymb230I} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$SI_{LBQFyO} := 2277 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 7 (node 1069 to 888, path length of 0.6875 in.)

$$F_{Ymb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFyO}} \cdot F_{Ylc7}$$

$$F_{Ymb230O} := \frac{1.5 \cdot S_m - SI_{LBQ230O}}{SI_{LBQFyO}} \cdot F_{Ylc7}$$

$$F_{Ymb50O} = -2 \cdot 10^5 \cdot \text{lbf}$$

$$F_{Ymb230O} = -195574 \cdot \text{lbf}$$

$$SI_{HOOP} := 1453 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 7, Hoop component, (node 1069 to 888, path length of 0.6875 in.)

$$F_{YHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Ylc7}$$

$$F_{YHOOP230} := \frac{S_m - SI_{HOOP230}}{SI_{HOOP}} \cdot F_{Ylc7}$$

$$F_{YHOOP50} = -3 \cdot 10^5 \cdot \text{lbf}$$

$$F_{YHOOP230} = -216924 \cdot \text{lbf}$$

$$SI_{LFz} := 4110 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 9 (node 1106 to 993, path length of 0.6969 in.)

$$F_{Zm50} := \frac{1.5 \cdot S_m - SI_{L}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LFz}} \cdot F_{Zlc9}$$

$$F_{Zm50} = -52499 \cdot \text{lbf}$$

$$F_{Zm230} = -41645 \cdot \text{lbf}$$

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$$SI_{LBQFzI} := 5901 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 1106 to 993, path length of 0.6969 in.)

$$F_{Zmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQFzI}} \cdot F_{Zlc9}$$

$$F_{Zmb230I} := \frac{3 \cdot S_m - SI_{LBQ230I}}{SI_{LBQFzI}} \cdot F_{Zlc9}$$

$$F_{Zmb50I} = -85491 \cdot \text{lbf}$$

$$F_{Zmb230I} = -74578 \cdot \text{lbf}$$

$$SI_{LBQFzO} := 2595 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 9 (node 1106 to 993, path length of 0.6969 in.)

$$F_{Zmb50O} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQFzO}} \cdot F_{Zlc9}$$

$$F_{Zmb230O} := \frac{1.5 \cdot S_m - SI_{LBQ230O}}{SI_{LBQFzO}} \cdot F_{Zlc9}$$

$$F_{Zmb50O} = -85066 \cdot \text{lbf}$$

$$F_{Zmb230O} = -76194 \cdot \text{lbf}$$

$$SI_{HOOP} := 1978 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 9, Hoop component, (node 1105 to 993, path length of 0.6969 in.)

$$F_{ZHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot F_{Zlc9}$$

$$F_{ZHOOP230} := \frac{S_m - SI_{HOOP230}}{SI_{HOOP}} \cdot F_{Zlc9}$$

$$F_{ZHOOP50} = -83430 \cdot \text{lbf}$$

$$F_{ZHOOP230} = -70750 \cdot \text{lbf}$$

$$SI_{LMx} := 1284 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 10 (node 1071 to 885, path length of 0.6751 in.)

$$M_{Xm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LMx}} \cdot M_{Xlc10}$$

$$M_{Xm50} = 32096 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xm230} = 25459 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMxI} := 2023 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 1071 to 885, path length of 0.6751 in.)

$$M_{Xmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQMxI}} \cdot M_{Xlc10}$$

$$M_{Xmb230I} := \frac{3 \cdot S_m - SI_{LBQ230I}}{SI_{LBQMxI}} \cdot M_{Xlc10}$$

$$M_{Xmb50I} = 47628 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xmb230I} = 41548 \cdot \text{ft} \cdot \text{lbf}$$

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$$SI_{LBQMxO} := 775 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUSTIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 10 (node 1071 to 885, path length of 0.6751 in.)

$$M_{Xmb500} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQMxO}} \cdot M_{Xlc10}$$

$$M_{Xmb2300} := \frac{1.5 \cdot S_m - SI_{LBQ2300}}{SI_{LBQMxO}} \cdot M_{Xlc1}$$

$$M_{Xmb500} = 56895 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Xmb2300} = 48727 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{HOOP} := 603 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 10, Hoop component, (node 1071 to 885, path length of 0.6751 in.)

$$M_{XHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Xlc10}$$

$$M_{XHOOP230} := \frac{S_m - SI_{HOOP230}}{SI_{HOOP}} \cdot M_{Xlc10}$$

$$M_{XHOOP50} = 52269 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{XHOOP230} = 44325 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LMy} := 1962 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 13 (node 1106 to 993, path length of 0.6969 in.)

$$M_{Ym50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMy}} \cdot M_{Ylc13}$$

$$M_{Ym230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LMy}} \cdot M_{Ylc13}$$

$$M_{Ym50} = -23561 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ym230} = -18689 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMyl} := 3228 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 1106 to 993, path length of 0.6969 in.)

$$M_{Ymb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQMyl}} \cdot M_{Ylc13}$$

$$M_{Ymb230I} := \frac{3 \cdot S_m - SI_{LBQ230I}}{SI_{LBQMyl}} \cdot M_{Ylc13}$$

$$M_{Ymb50I} = -33481 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ymb230I} = -29207 \cdot \text{ft} \cdot \text{lbf}$$

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$$SI_{LBQMyO} := 1377 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 13 (node 1106 to 993, path length of 0.6969 in.)

$$M_{Ymb500} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQMyO}} \cdot M_{Ylc13} \quad M_{Ymb2300} := \frac{1.5 \cdot S_m - SI_{LBQ2300}}{SI_{LBQMyO}} \cdot M_{Ylc13}$$

$$M_{Ymb500} = -35919 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Ymb2300} = -30762 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{HOOP} := 833 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 13, Hoop component, (node 1106 to 993, path length of 0.6969 in.)

$$M_{YHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Ylc13} \quad M_{YHOOP230} := \frac{S_m - SI_{HOOP230}}{SI_{HOOP}} \cdot M_{Ylc13}$$

$$M_{YHOOP50} = -42441 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{YHOOP230} = -35991 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LMz} := 522 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Local Primary Membrane stress for load case 15 (node 1105 to 993, path length of 0.6969 in.)

$$M_{Zm50} := \frac{1.5 \cdot S_m - SI_L}{SI_{LMz}} \cdot M_{Zlc15} \quad M_{Zm230} := \frac{1.5 \cdot S_m - SI_{L230}}{SI_{LMz}} \cdot M_{Zlc15}$$

$$M_{Zm50} = -88555 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zm230} = -70246 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{LBQMzI} := 1290 \cdot \frac{\text{lbf}}{\text{in}^2}$$

INSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 1106 to 993, path length of 0.6969 in.)

$$M_{Zmb50I} := \frac{3 \cdot S_m - SI_{LBQI}}{SI_{LBQMzI}} \cdot M_{Zlc15} \quad M_{Zmb230I} := \frac{3 \cdot S_m - SI_{LBQ230I}}{SI_{LBQMzI}} \cdot M_{Zlc15}$$

$$M_{Zmb50I} = -83781 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zmb230I} = -73086 \cdot \text{ft} \cdot \text{lbf}$$

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$$SI_{LBQMzO} := 461 \cdot \frac{\text{lbf}}{\text{in}^2}$$

OUTSIDE Local Primary membrane plus primary bending plus secondary stress due to external loads for load case 15 (node 1106 to 993, path length of 0.6969 in.)

$$M_{Zmb500} := \frac{1.5 \cdot S_m - SI_{LBQO}}{SI_{LBQMzO}} \cdot M_{Zlc15}$$

$$M_{Zmb2300} := \frac{1.5 \cdot S_m - SI_{LBQ2300}}{SI_{LBQMzO}} \cdot M_{Zlc15}$$

$$M_{Zmb500} = -1 \cdot 10^5 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{Zmb2300} = -91885 \cdot \text{ft} \cdot \text{lbf}$$

$$SI_{HOOP} := 132 \cdot \frac{\text{lbf}}{\text{in}^2}$$

General primary membrane stress, SY membrane stress for load case 15, Hoop component, (node 1106 to 993, path length of 0.6969 in.)

$$M_{ZHOOP50} := \frac{S_m - SI_{HOOP50}}{SI_{HOOP}} \cdot M_{Zlc15}$$

$$M_{ZHOOP230} := \frac{S_m - SI_{HOOP230}}{SI_{HOOP}} \cdot M_{Zlc15}$$

$$M_{ZHOOP50} = -3 \cdot 10^5 \cdot \text{ft} \cdot \text{lbf}$$

$$M_{ZHOOP230} = -2 \cdot 10^5 \cdot \text{ft} \cdot \text{lbf}$$

The maximum allowable external forces and moments at the pipe section are summarized below for a 50 and 230 ft-lbf pre-load torques in Table B7.

Table B7. The maximum allowable external forces and moments at the bottom section

<u>External Loads</u>	<u>50 ft-lbf Torque</u>	<u>230 ft-lbf Torque</u>
F _x (lbf)	139,348	100,000
F _y (lbf)	155,811	123,595
F _z (lbf)	52,499	41,645
M _x (ft-lbf)	32,096	25,459
M _y (ft-lbf)	23,561	18,689
M _z (ft-lbf)	83,781	70,246

8.7.6 Check Interaction with system model results for a 50 ft-lbf pre-load torque

From Table B7, the maximum allowable piping loads applied at the pipe opening were obtained. From Table 3.4 the acceptable piping loads were determined based on the other jumper components (hooks, pins, operating screw, guide lip with block lip, top of block, block bottom and pipe opening). The following is a linear interaction of Table 3.4 and Table B7 for the 50 ft-lbf pre-load case. See appendix C for interaction details.

Maximum Piping Loads from Table 3.4

$$f_x := 2220 \cdot \text{lbf} \quad m_x := 1170 \cdot \text{ft} \cdot \text{lbf}$$

$$f_y := 2220 \cdot \text{lbf} \quad m_y := 1170 \cdot \text{ft} \cdot \text{lbf}$$

$$f_z := 42100 \cdot \text{lbf} \quad m_z := 780 \cdot \text{ft} \cdot \text{lbf}$$

Maximum Piping loads from Table B2 @ 50 ft-lbf

$$F_x := 139348 \cdot \text{lbf} \quad M_x := 32096 \cdot \text{ft} \cdot \text{lbf}$$

$$F_y := 155811 \cdot \text{lbf} \quad M_y := 23561 \cdot \text{ft} \cdot \text{lbf}$$

$$F_z := 52499 \cdot \text{lbf} \quad M_z := 83781 \cdot \text{ft} \cdot \text{lbf}$$

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$$I := \sqrt{\left(\frac{f_x}{F_x}\right)^2 + \left(\frac{f_y}{F_y}\right)^2} + \frac{f_z}{F_z} + \sqrt{\left(\frac{m_x}{M_x}\right)^2 + \left(\frac{m_y}{M_y}\right)^2 + \left(\frac{m_z}{M_z}\right)^2}$$

The linear interaction (I) must be less than or equal to 1 in order to satisfy ASME criteria at the bottom section.

$$I = 0.9 \leq 1.0$$

Therefore, satisfied for above piping loads from Table 3.4.

See appendix C for details of the basis of the interaction.

NOTE: The maximum allowable forces and moments are independent of sign, except for the axial loading condition (Fz). Where the above Fz is given as a compressive force. If the force is in tension then the Fz force is govern by the minimum seating force. In this case, for the 4-in. ISB jumper connector the minimum axial seating force is 6,306 lbf for a 50 ft-lbf pre-load (with thermal effects) and according to the calculations will not seat without the thermal effects at 50 ft-lbf of preload. The maximum axial seating force for a 230 ft-lbf pre-load, with and without thermal effects is approximately 13,669 and 2,560 lbf, respectively.

9.0 Evaluation of 4-in. ISB Single Port Connector (Nozzle Flange Analysis)

The analysis of the 3-in. nozzle flange is evaluated in the same manner that the 2-and 3-in. nozzle flange were evaluated above in sections 5.0 and 7.0.

Per ASME 1989 Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 3, Article 3-300, ASME Flange Design (ASME 1989c), the stresses in the flange due to the applied loading are evaluated in the same manner that the 2-in. nozzle flange in section 5.3 was. See Figure B5 of nozzle in section 5.3 for details.

A := 6.06-in outside diameter of flange f := 1-in for uniform thickness of hub

B := 4.031-in inside diameter of flange

t := 0.75-in thickness of flange

g₁ := 0.39-in thickness of hub or nozzle wall

$$K := \frac{A}{B} \quad K = 1.503$$

For K = 1.503, from Fig. 3-340.1, the corresponding values of

T := 1.8-in Y := 5-in U := 5.6-in Z := 2.7-in

h := 3.38-in - t h = 2.63-in (Drawing H-2-83574)

ANALYTICAL CALCULATIONS

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Date 3/30/95

$$h_o := \sqrt{B \cdot g_1} \quad h_o = 1.254 \cdot \text{in}$$

$$\text{For } \frac{h}{h_o} = 2.098 \quad \text{from Fig. 3-340.2, ASME (1989d)} \quad F := 0.91 \cdot \text{in}$$

$$e := \frac{F}{h_o} \quad e = 0.726 \quad \text{from Fig. 3-340.3, ASME (1989d)} \quad V := 0.55 \cdot \text{in}$$

$$d := \frac{U}{V} \cdot h_o \cdot g_1^2 \quad d = 1.942 \cdot \text{in}^3$$

$$L_{\text{flange}} := \left(\frac{t \cdot e + 1 \cdot \text{in}}{T} + \frac{t^3}{d} \right) \cdot \text{in} \quad L_{\text{flange}} = 1.075 \cdot \text{in}$$

$$P_{\text{capacity}} := 12720 \cdot \text{lbf} \quad \text{Axial capacity of hooks according to appendix A}$$

$$L := \frac{0.3895 \cdot \text{in} + 0.625 \cdot \text{in}}{2} \quad \text{Moment arm (Drawing H-2-83574)}$$

$$L = 0.507 \cdot \text{in}$$

Moment due to torque load from the hook for 3 hooks

$$M_o := 3 \cdot P_{\text{capacity}} \cdot L \quad M_o = 19357 \cdot \text{lbf} \cdot \text{in}$$

9.1 Determine Flange stresses and compare with Allowable Flange Stress per ASME (1989c)

Material ASTM A276 Grade 304 ; Allowable values are same as in 2 and 3-inch connectors

Longitudinal Hub Stress

$$S_H := \frac{f M_o}{L_{\text{flange}} \cdot g_1^2 \cdot B}$$

Allowable Hub Stress

$$S_{HA} := 1.5 \cdot S_m$$

Conclusion

$$S_H = 29362 \cdot \frac{\text{lbf}}{\text{in}^2}$$

<

$$S_{HA} = 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Good (O. K.)

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Radial Flange Stress

Allowable Radial Stress

Conclusion

$$S_R := \frac{(1.33 \cdot t \cdot e + 1 \cdot \text{in}) \cdot M_o}{L_{\text{flange}} \cdot t^2 \cdot B}$$

$$S_{RA} := S_m$$

$$S_R = 13687 \cdot \frac{\text{lbf}}{\text{in}^2} <$$

$$S_{RA} = 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Good (O.K.)

Tangential Flange Stress

Allowable Tangential Stress

Conclusion

$$S_T := \left(\frac{Y \cdot M_o}{t^2 \cdot B} - Z \cdot S_R \right) \cdot \frac{1}{\text{in}}$$

$$S_{TA} := S_m$$

$$S_T = 5728 \cdot \frac{\text{lbf}}{\text{in}^2} <$$

$$S_{TA} = 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Good (O.K.)

9.2 Determine the limiting value of axial load based on the capacity of the hooks

$$P_H := P_{\text{capacity}} \cdot \frac{S_{HA}}{S_H}$$

$$P_H = 12996 \cdot \text{lbf}$$

$$P_R := P_{\text{capacity}} \cdot \frac{S_{RA}}{S_R}$$

$$P_R = 18586 \cdot \text{lbf}$$

$$P_T := P_{\text{capacity}} \cdot \frac{S_{TA}}{S_T}$$

$$P_T = 44414 \cdot \text{lbf}$$

Therefore, the limiting axial load is

$$P_{HR} := \text{if}(P_H < P_R, P_H, P_R)$$

$$P_{\text{limit}} := \text{if}(P_{HR} < P_T, P_{HR}, P_T)$$

$P_{\text{limit}} = 12996 \cdot \text{lbf}$ which is greater than the 4-in. hook limit of 12,720 lbf found in appendix A.
Therefore, the axial capacity of the 4-in. hook = 12,720 lbf governs.

10.0 DESCRIPTION OF BLOCK FINITE-ELEMENT-ANALYSIS MODEL

The Finite-Element Analysis (FEA) code used in the evaluation of the 2-, 3-, and 4-in. Integral Seal Blocks (ISB) was ANSYS version 5.0a. The 2-, 3-, and 4-in. blocks were modeled using four node Tetrahedral Structural Solids (SOLID72) elements. To account for the pipe welded to the side of the block 3-D beams (BEAM4) were used to transfer external loads and moments to the block structure (see Figure B10). The calculations to determine the beam sizing are found in section 15 of this appendix.

The material properties used for the 2-, 3-, and 4-in. block model is ASTM 276 Grade 304 SS at temperatures of 70 and 250 deg. F. The initial condition of the ISB block is that the blocks are pressurized at a design pressure of 400 psi and heated to a uniform temperature of 250 deg. F. per MWTF Functional Design Criteria. The material properties for ASTM A276 304 SS at 70 and 250 degrees F, used in the 2-, 3-, and 4-in. block models, is found in Table B1 and section 2.0.

The boundary conditions used on the block models are stated as follows. When an external torsion is applied on the block, the only torsional resistance in the system is due to friction at the screw/block and nozzle/block interface. However, as these machined surfaces have low coefficients of friction, frictional resistance would be broken by a small applied torsional moment. The block would then rotate until the pipe connection comes into contact with one of the tie-bolts and/or hooks. As the hooks are not included in the model, a group of nodes at the screw/block interface are fixed with respect to the torsion, to prevent instability under torsional loading. Additionally, nodes on the surface of the block at the nozzle/block interface are restrained radially. This boundary condition does not affect the stresses at the top of the block, for the axial loading cases. For the remainder of the block and the external loading, which include the piping forces and moments, this is conservative as it forces the block to resist torsional moments applied by the attached pipe. See Figure B11 for a illustration of where the boundary conditions are applied.

The axial loading considered an assumed pre-load torque of 50 ft-lbf along with the forces required to resist axial thermal expansion, and axial internal pressure loads. The total axial load was applied to the top of the block for the 2-, 3-, and 4-in. block models are found in this appendix and tabulized in Table B8. The total axial loads were applied over the screw diameter at the top of the block, see appendix E for justification of using a full screw diameter loading as the punch through failure mode.

The external loading condition considers assumed forces and moments, independent of each other, applied at the center of a spoke configuration of BEAM4 elements at node 20,000 so that the external piping forces and moments are transferred to the block (see Figure E13). The load cases considered for the 2-, 3-, and 4-in. block models are summarized in Table B8 for the top section (TS), bottom section (BS), and pipe opening section (POS) of the block.

Table B8. Load Cases applied to the 2-, 3-, and 4-in. ISB blocks

Description of Assumed Load Cases	ISB Block Jumper Connectors Load Cases (Forces and Moments)			Block section
	2-in.	3-in.	4-in.	
LC1: Axial Loads for 50 ft-lbf pre-load	Fz = -11,500 lbf	Fz = -21,167 lbf	Fz = -34,013 lbf	Top Section (TS)
LC5: External Piping Force applied @ node 20,000	Fx = -12,000 lbf	Fx = -22,280 lbf	Fx = -30,000 lbf	Sections (BS and POS)
LC7: External Piping Force applied @ node 20,000	Fy = -6,000 lbf	Fy = -18,750 lbf	Fy = -25,000 lbf	Sections (BS and POS)
LC9: External Piping Force applied @ node 20,000	Fz = -4,000 lbf	Fz = -8,320 lbf	Fz = -11,100 lbf	Sections (BS and POS)
LC10: External Piping Moment applied @ node 20,000	Mx = 1,128 ft-lbf	Mx = 1,590 ft-lbf	Mx = 2,210 ft-lbf	Sections (BS and POS)
LC13: External Piping Moment applied @ node 20,000	My = -1,265 ft-lbf	My = -1,784 ft-lbf	My = -2,378 ft-lbf	Sections (BS and POS)
LC15: External Piping Moment applied @ node 20,000	Mz = -1,265 ft-lbf	Mz = -1,784 ft-lbf	Mz = -2,378 ft-lbf	Sections (BS and POS)
LC16: Pressure and Temperature Loading	Press = 400 psi Temp = 250 deg. F	Press = 400 psi Temp = 250 deg. F	Press = 400 psi Temp = 250 deg. F	Sections (BS and POS)

The evaluation of the top of the block under axial loading is addressed in this appendix, while for the external loading conditions the top of the block is discussed in the system models of the 2-, 3-, and 4-in. jumper assembly in appendix C and G. The evaluation of the pipe connection opening and the bottom sections of block are addressed in this appendix. Sketches of the finite-element models are shown in Figures B10, B11, and B12.

Figure B10. Sketch of Finite-Element ISB Block Model (Geometry)

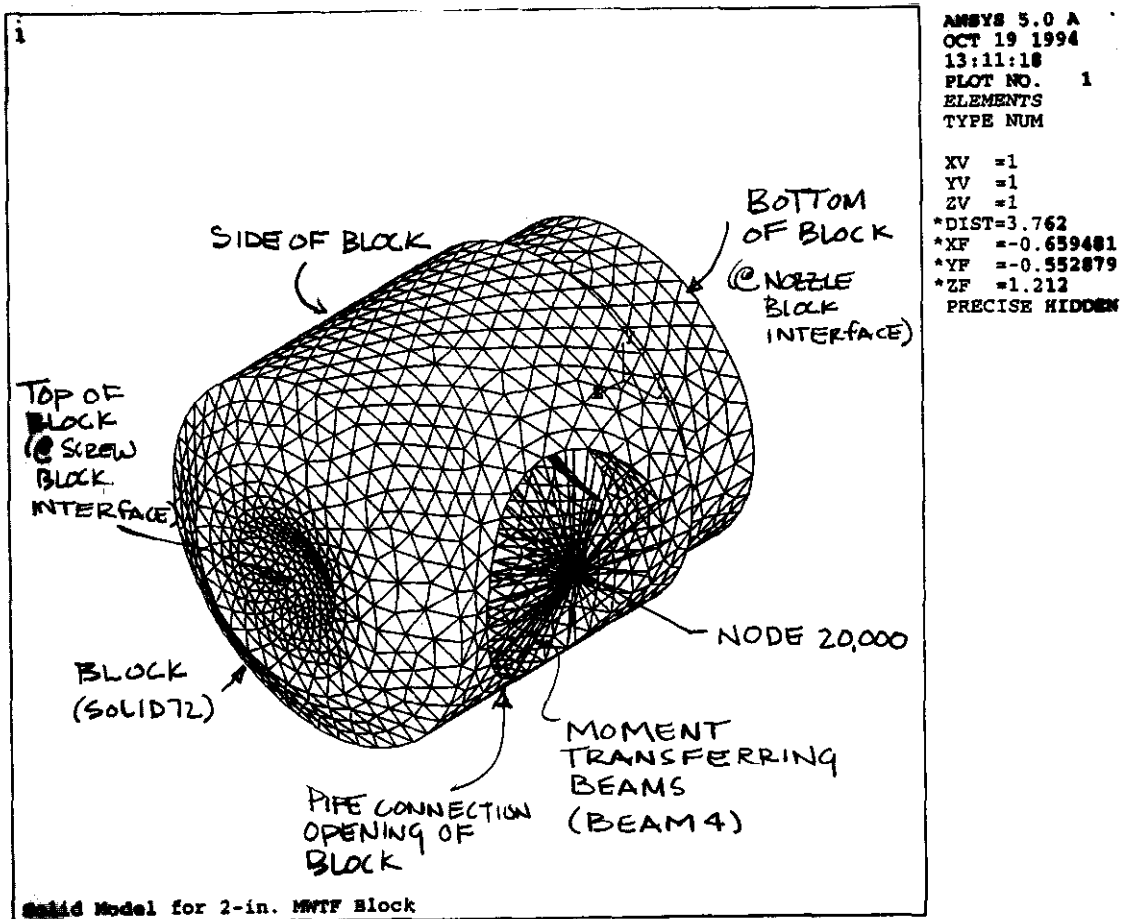


Figure B11. Sketch of Finite-Element ISB Block Model (Boundary Conditions)

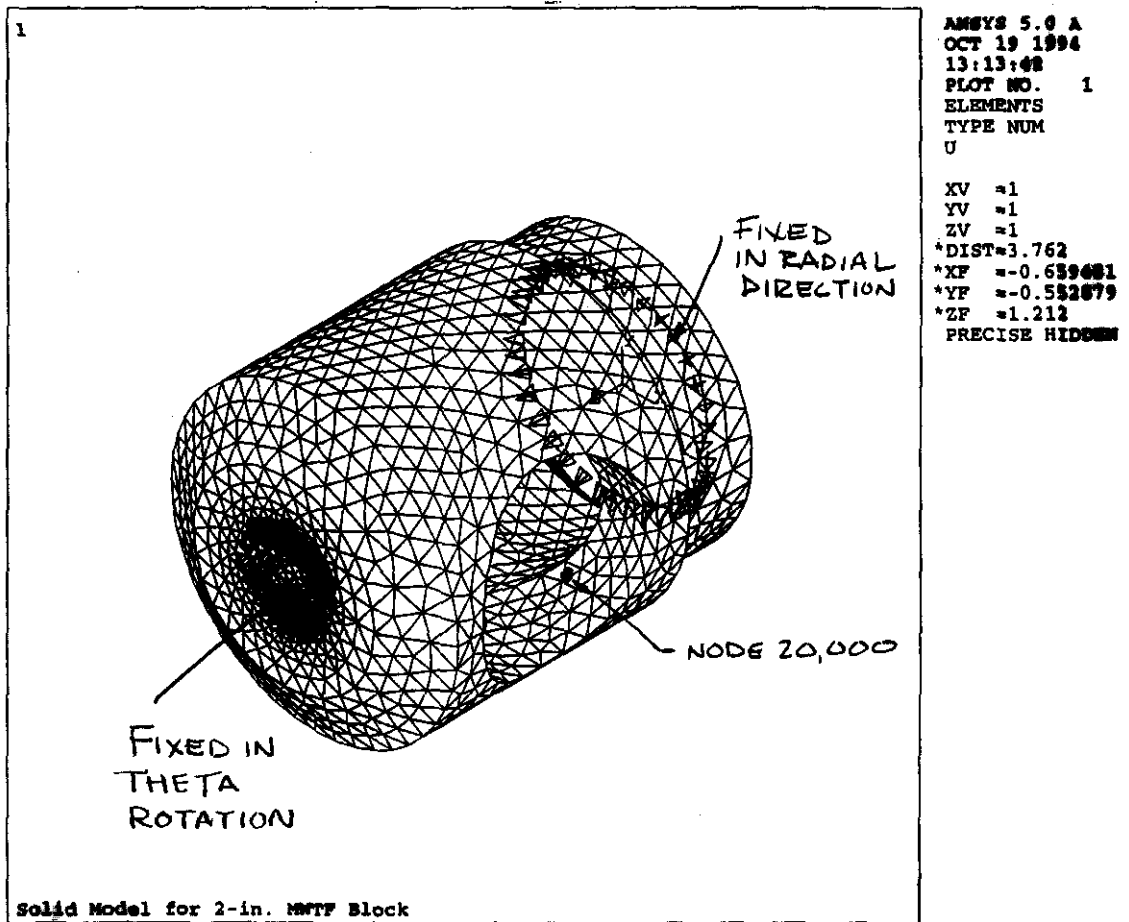
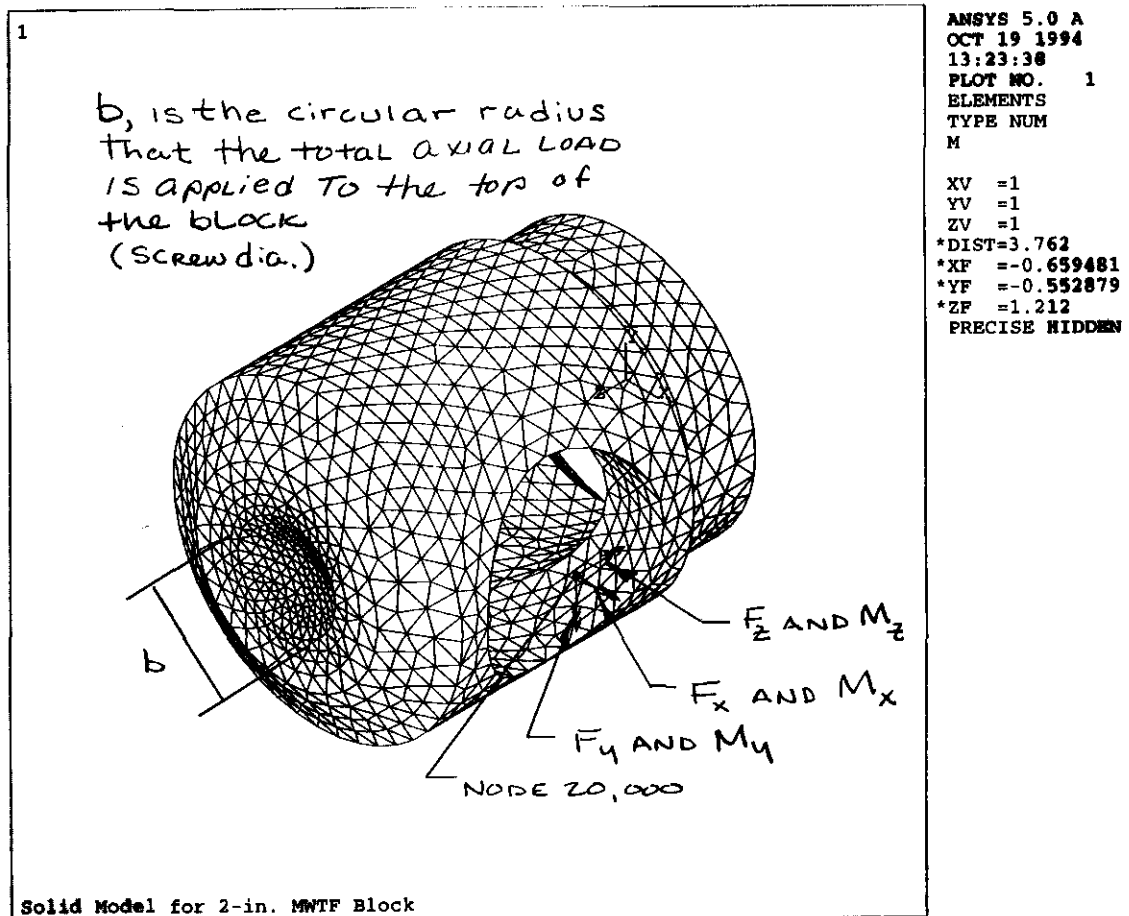


Figure B12. Sketch of Finite-Element ISB Block Model (applied load locations)



11.0 EVALUATION OF FEA BLOCK MODEL

The evaluation of the 2-, 3-, and 4-in. ISB is based on an ASME criteria established in section 4.7, where the membrane and membrane plus bending are evaluated for localized and generalized stress intensities. Using the ANSYS LPATH command, the best path length was used to determine the linearized stress intensity through the thickness of the block. The two nodes used for the path length were based on the maximum peak stress intensity at the section being evaluated. Using the ANSYS command PLSECT a linear plot of the path between the two nodes graphically illustrated the path length between the two selected nodes. This path length was compared to the drawing dimensions in determining the best path through the thickness to take. An illustration of the block sections evaluated is shown in Figure B4 and the ASME criteria is for a design stress intensity of 20,000 psi found in section 4.7.

The maximum linearized stress intensities are tabulated in Tables B9, B10, and B11 for the 2-, 3-, and 4-in. block finite-element models, respectively. The actual data is found in sections 12, 13, and 14 of this appendix.

Table B9. Maximum linearized stress intensities through 2-in. ISB block model sections

ISB Block Sections	Load Case	Nodes	Path Length (in)	Membrane Stress Intensity (psi)	Membrane Stress, S _y (psi)	Membrane + Bending Stress Intensity (psi)
TOP (TS)	LC1	346 and 1833	0.72	9632	-	11520 (I)
	LC2	346 and 1833	0.72	13820	-	16530 (I)
	LC3	346 and 1833	0.72	18430	-	22040 (I)
Pipe Connection Opening (POS)	LC1	505 and 541	0.681	3926	-	8189 (I)
	LC5	386 and 395	0.668	12410	-	18710 (I)
	LC7	1295 and 472	0.62	10100	-	16670 (I)
	LC9	505 and 541	0.681	4097	-	10810 (I)
	LC10	386 and 395	0.668	10780	-	22280 (I)
	LC13	1295 and 472	0.62	18160	-	22710 (I)
	LC15	386 and 395	0.668	22460	-	31610 (I)
	LC16	55 and 496	0.656	2653	-	3796 (I)
Bottom (BS)	LC1	1253 and 1105	0.389	11170	5796	14020 (I) and 8549 (O)
	LC5	1165 and 959	0.409	6917	2299	11450 (I) and 2516 (O)
	LC7	1199 and 1010	0.395	3911	1451	4788 (I) and 3046 (O)
	LC9	1165 and 959	0.409	6161	2434	8826 (I) and 3559 (O)
	LC10	1207 and 1007	0.35	5227	-2183	6624 (I) and 3904 (O)
	LC13	1165 and 959	0.409	7417	-1919	13510 (I) and 2482 (O)
	LC15	1165 and 959	0.409	579	11	2777 (I) and 2966 (O)
	LC16	1215 and 1016	0.351	4471	-295	6664 (I) and 2618 (O)

NOTE: The (I) and (O) stand for the Inside and Outside membrane plus bending stress intensities (See section 12 for the actual data obtained from the ANSYS Finite-Element analysis of the 2-in. ISB block).

Table B10. Maximum linearized stress intensities through 3-in. ISB block model sections

ISB Block Sections	Load Case	Nodes	Path Length (in)	Membrane Stress Intensity (psi)	Membrane Stress, SY (psi)	Membrane + Bending Stress Intensity (psi)
TOP (TS)	LC1	1039 and 1212	1.05	6337	-	7965 (I)
	LC2	1039 and 1212	1.05	7235	-	9093 (I)
	LC3	1039 and 1212	1.05	7998	-	10050 (I)
Pipe Connection Opening (POS)	LC1	253 and 259	0.911	4708	-	7094 (I)
	LC5	197 and 203	0.99	9017	-	13430 (I)
	LC7	196 and 234	0.893	12580	-	20350 (I)
	LC9	248 and 267	1.102	3742	-	9002 (I)
	LC10	252 and 258	1.094	3316	-	7001 (I)
	LC13	714 and 36	1.026	4252	-	9494 (I)
	LC15	248 and 267	1.102	6474	-	9780 (I)
	LC16	36 and 714	1.026	1910	-	3086 (I)
Bottom (BS)	LC1	688 and 622	0.626	7638	2721	9791 (I) and 5723 (O)
	LC5	696 and 611	0.652	4549	1925	6912 (I) and 3576 (O)
	LC7	669 and 559	0.651	5630	1177	6467 (I) and 5027 (O)
	LC9	688 and 622	0.626	4086	1641	5489 (I) and 2787 (O)
	LC10	688 and 622	0.626	1841	407	2421 (I) and 1339 (O)
	LC13	676 and 607	0.574	1965	-820	3318 (I) and 1259 (O)
	LC15	688 and 622	0.626	1127	299	1877 (I) and 728 (O)
	LC16	652 and 520	0.732	2459	-57	2058 (I) and 3358 (O)

NOTE: The (I) and (O) stand for the Inside and Outside membrane plus bending stress intensities (See section 13 for the actual data obtained from the ANSYS Finite-Element analysis of the 3-in. ISB block).

Table B11. Maximum linearized stress intensities through 4-in. ISB block model sections

ISB Block Sections	Load Case	Nodes	Path Length (in)	Membrane Stress Intensity (psi)	Membrane Stress, SY (psi)	Membrane + Bending Stress Intensity (psi)
TOP (TS)	LC1	1703 and 1997	0.591	13270	-	15950 (O)
	LC2	1703 and 1997	0.591	14050	-	16890 (O)
	LC3	1703 and 1997	0.591	14830	-	17830 (O)
Pipe Connection Opening (POS)	LC1	454 and 350	1.45	6987	-	10170 (I)
	LC5	356 and 437	1.146	8810	-	13240 (I)
	LC7	356 and 437	1.146	17820	-	31730 (I)
	LC9	465 and 515	0.9988	4525	-	9918 (I)
	LC10	465 and 515	0.9988	3163	-	6273 (I)
	LC13	356 and 437	1.146	6222	-	10410 (I)
	LC15	465 and 515	0.9988	5851	-	8839 (I)
	LC16	55 and 458	1.17	2245	-	3416 (I)
Bottom (BS)	LC1	1070 and 886	0.6893	7925	4455	11440 (I) and 5888 (O)
	LC5	1106 and 993	0.6969	4185	1932	6503 (I) and 2714 (O)
	LC7	1069 and 888	0.6875	3119	1453	4417 (I) and 2277 (O)
	LC9	1106 and 993	0.6969	4110	1978	5901 (I) and 2595 (O)
	LC10	1071 and 885	0.6751	1284	-603	2023 (I) and 775 (O)
	LC13	1106 and 993	0.6969	1962	-833	3228 (I) and 1377 (O)
	LC15	1106 and 993	0.6969	522	132	1290 (I) and 461 (O)
	LC16	1046 and 878	0.7709	2636	678	3111 (I) and 3313 (O)

NOTE: The (I) and (O) stand for the Inside and Outside membrane plus bending stress intensities (See section 14 for the actual data obtained from the ANSYS Finite-Element analysis of the 4-in. ISB block).

The data collected in Tables B9, B10, and B11 is from the finite-element analysis and is used to evaluate the 2-, 3-, and 4-in. block models per the established ASME (1989) criteria and determining the maximum allowable single force and moment loads that the block can accommodate. See section 12, 13, and 14 for print outs of the linearized stresses and input files for the 2-, 3-, and 4-in. ISB block models.

12.0 2-IN. ANSYS INPUT FILES FOR BLOCK MODEL

12.1 2-IN. ISB BLOCK GEOMETRY INPUT (block2g.inp)

```

/BATCH
/CONFIG,NRES,50000
/CONFIG,NCONT,10000
/TITLE,Solid Model for 2-in. MWTF Block
C*** Load Case (Preload, Pressure, Thermal, and External) **
/UNITS,BIN
/PREP7
/OUTPUT,block2,out
C*** 2-in. ISB Block **
ET, 1,SOLID72
TYPE,1
REAL,1
MAT,1
KEYO, 1, 5, 2
R, 1
MPTEMP,,70,250
MPDATA,EX,1,,28.5E6,27.4E6
MPDATA,NUXY,1,,0.266,0.274
MPDATA,ALPX,1,,8.50E-6,8.89E-6
MPDATA,DENS,1,,0.000734,0.000734
C*** Pipe Connection **
ET, 2,BEAM4
TYPE,2
REAL,2
MAT,2
KEYO, 2, 6,0
KEYO, 2, 7,0
KEYO, 2, 10,0
R, 2
RMOD, 2, 1,0.000356
RMOD, 2, 2,0.0029
RMOD, 2, 3,0.0064
RMOD, 2, 4,0.018866
RMOD, 2, 5,0.018866
RMOD, 2, 6,0
RMOD, 2, 7,0
RMOD, 2, 8,0.0006
RMOD, 2, 9,0
RMOD, 2, 10,0
RMOD, 2, 11,0
RMOD, 2, 12,0
RMOD, 2, 13,0
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MPDATA,NUXY,2,,0.274,0.274
MPDATA,ALPX,2,,8.89E-6,8.89E-6
MPDATA,DENS,2,,1.0E-10,1.0E-10
BOPT,NUMB,OFF
BOPTN,NO,1
C*** Block Geometry **
CSYS,0
CYLIND,,1.6875,0,4.023,0,360
K,10,,,2.28
K,11,4,,2.28
L,10,11
LWPLAN,,11
CYLIND,1.03,,0,4,0,360
VSBV,1,2
K,100
K,101,,,5.21
L,100,101
LWPLAN,,10
CYLIND,1.4985,1.6875,0,0.903,0,360
VSBV,3,1
CONE,1.392,1.03,0,0.356,0,360
VSBV,2,1
CYLIND,,1.03,0.356,1.924,0,360
VSBV,3,1

```

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L,10,101
LWPLAN,,12
SPHERE,,1.03,0,360
VSBV,2,1
K,200,,,10
L,101,200
LWPLAN,,13
SPHERE,,1.37,0,360
VSBV,3,1
K,210,,,3.6
L,210,200
LWPLAN,,40
CONE,2,1,0,2,0,360
CONE,1.6875,1.06,0,0.363,0,360
VSBV,1,3
VSBV,2,4
LWPLAN,,10
CYLIND,,1.03,,2.28,0,360
VSBV,1,2
C*** Mesh Density **
ESHAPE,2
ESIZE,0.25
C*** Refine mesh **
LESIZE,85,0.125
LESIZE,86,0.125
LESIZE,87,0.125
LESIZE,88,0.125
C*** Meshing of Block **
VATT,1,1,1
VMESH,ALL
N,20000,1.6875,0,2.28
TYPE,2
REAL,2
MAT,2
E,20000,386
E,20000,387
E,20000,388
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E,20000,504
E,20000,505
E,20000,506
E,20000,507
E,20000,508
E,20000,496
E,20000,502
E,20000,501
E,20000,500
E,20000,499
E,20000,498
E,20000,497
E,20000,1335
E,20000,1334
E,20000,1333
E,20000,1332
E,20000,1331
E,20000,1354
E,20000,1295
E,20000,601
E,20000,646

```

```

E,20000,702
E,20000,665
E,20000,664
E,20000,663
E,20000,662
E,20000,661
E,20000,660
E,20000,659
E,20000,658
E,20000,657
E,20000,656
E,20000,701
E,20000,645
E,20000,599
E,20000,1296
E,20000,1356
E,20000,1340
E,20000,1339
E,20000,1338
E,20000,1337
E,20000,1336
NSEL,ALL
ESEL,ALL
CSYS,0
ASEL,S,AREA,,6,7,1,1
NSEL,R,LOC,Z,.161,.26
LOCAL,11,2,,,-1.0522
CSYS,11
NROTAT,ALL
CSYS,0
ASEL,S,AREA,,1,23,22,1
NSEL,R,LOC,Z,3.84,3.963
CSYS,1
NSEL,R,LOC,X,-0.52,0.52
LOCAL,12,1,,3.84
CSYS,12
NROTAT,ALL
CSYS,0
ALLSEL,ALL,VOLU
ALLSEL,BELOW,VOLU
NSEL,ALL
ESEL,ALL
WSORT,ALL
C*** Reference Temperature **
TREF,70
SAVE,block2g,db
FINISH
/EXIT

```

12.2 2-IN. ISB BLOCK APPLIED LOADING AND BOUNDARY CONDITIONS INPUT (block2s.inp)

```

/PREP7
RESUME,block2g,db
FINISH
/SOLU
ANTYPE,STAT
C*** Defining Boundary Conditions **
ASEL,S,AREA,,6,7,1,1
NSEL,R,LOC,Z,.161,.26
CSYS,11
D,ALL,UX,0,0
CSYS,0
ASEL,S,AREA,,1,23,22,1
NSEL,R,LOC,Z,3.84,3.963
CSYS,1
NSEL,R,LOC,X,-0.52,0.52
CSYS,12
D,ALL,UY,0,0
CSYS,0
C*** Combined applied axial load (Preload + pressure + thermal + external) **

```

```

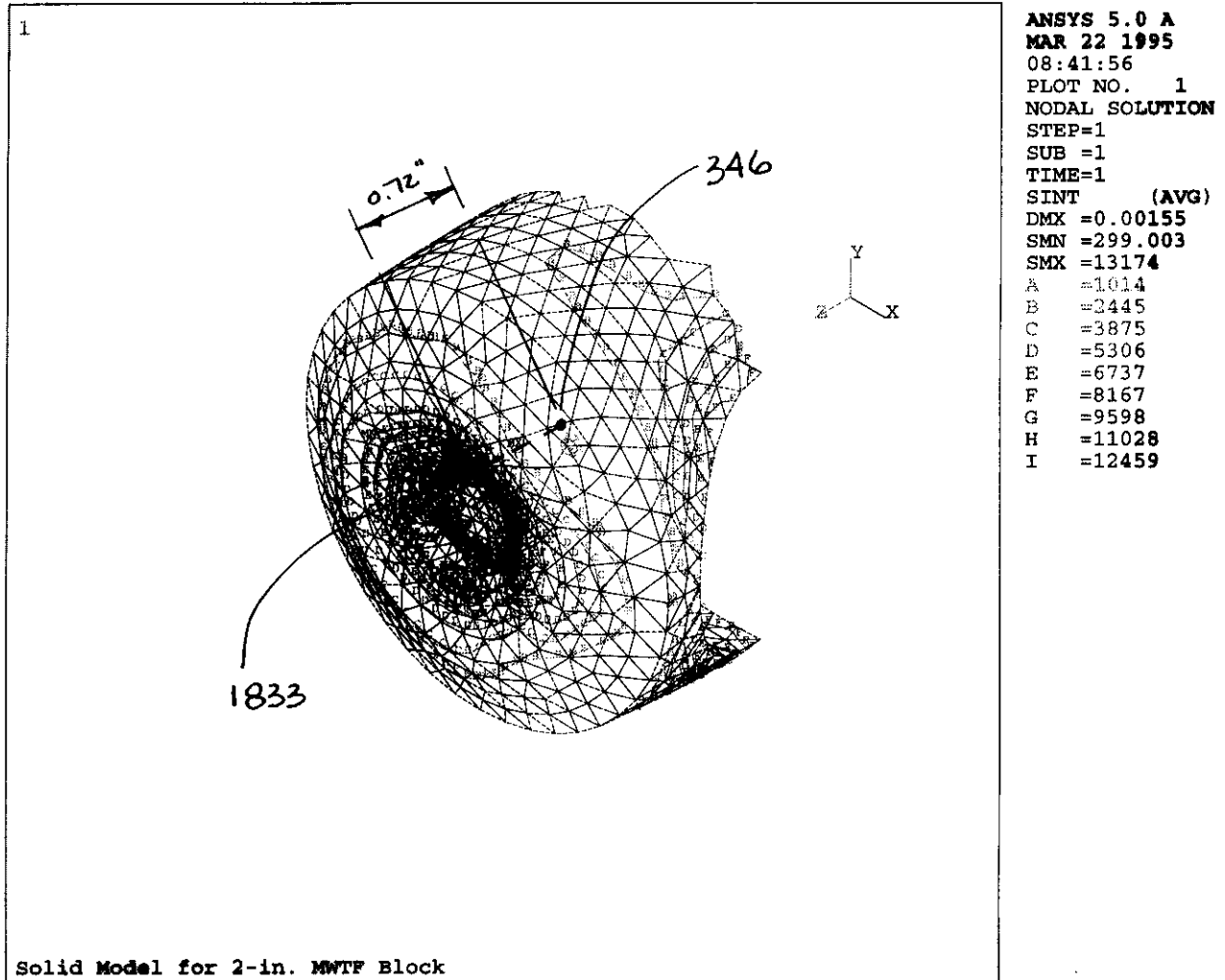
C*** used to determine the punch through failure mode and block stiffness **
ASEL,S,AREA,,1,23,22,1
NSEL,R,LOC,Z,3.84,3.963
CSYS,1
NSEL,R,LOC,X,-0.52,0.52
CSYS,0
*GET,HCTA,MODE,,COUNT
C*** 50 ft-lbf preload (LC1) **
AXIAL50=-11500/HCTA
F,ALL,FZ,AXIAL50
NSEL,ALL
ESEL,ALL
SOLVE
C*** 100 ft-lbf preload (LC2) **
FDELE,ALL,FZ
ASEL,S,AREA,,1,23,22,1
NSEL,R,LOC,Z,3.84,3.963
CSYS,1
NSEL,R,LOC,X,-0.52,0.52
CSYS,0
AXIAL100=-16500/HCTA
F,ALL,FZ,AXIAL100
NSEL,ALL
ESEL,ALL
SOLVE
C*** 150 ft-lbf preload (LC3) **
FDELE,ALL,FZ
ASEL,S,AREA,,1,23,22,1
NSEL,R,LOC,Z,3.84,3.963
CSYS,1
NSEL,R,LOC,X,-0.52,0.52
CSYS,0
AXIAL150=-22000/HCTA
F,ALL,FZ,AXIAL150
ALLSEL,ALL,VOLU
ALLSEL,BELOW,VOLU
NSEL,ALL
ESEL,ALL
SOLVE
FDELE,ALL,FZ
C*** Extrenal loading at pipe connection **
FORCEX=4000
FORCEY=6000
FORCEZ=12000
MOMENTX=(1265)*12
MOMENTY=(1265)*12
MOMENTZ=(1128)*12
C*** X Direction Loading (Force) **
FDELE,ALL,FZ
F,20000,FX,FORCEZ,,20000,1
SOLVE
FDELE,ALL,FX
F,20000,FX,-FORCEZ,,20000,1
SOLVE
C*** Y Direction Loading (Force) **
FDELE,ALL,FX
F,20000,FY,FORCEY,,20000,1
SOLVE
FDELE,ALL,FY
F,20000,FY,-FORCEY,,20000,1
SOLVE
C*** Z Direction Loading (Force) **
FDELE,ALL,FY
F,20000,FZ,FORCEX,,20000,1
SOLVE
FDELE,ALL,FZ
F,20000,FZ,-FORCEX,,20000,1
SOLVE
C*** X Direction Loading (Moment) **
FDELE,ALL,FZ
F,20000,MX,MOMENTZ,,20000,1

```

```
SOLVE
FDELE,ALL,MX
F,20000,MX,-MOMENTZ,,20000,1
SOLVE
C*** Y Direction Loading (Moment) **
FDELE,ALL,MX
F,20000,MY,MOMENTY,,20000,1
SOLVE
FDELE,ALL,MY
F,20000,MY,-MOMENTY,,20000,1
SOLVE
C*** Z Direction Loading (Moment) **
FDELE,ALL,MY
F,20000,MZ,MOMENTX,,20000,1
SOLVE
FDELE,ALL,MZ
F,20000,MZ,-MOMENTX,,20000,1
SOLVE
FDELE,ALL,MZ
NSEL,ALL
ESEL,ALL
TUNIF,70
BF,ALL,TEMP,250,250
C*** Internal pressure **
SFA,10,,PRES,400
SFA,16,,PRES,400
SFA,17,,PRES,400
SFA,18,,PRES,400
SFA,19,,PRES,400
SFA,20,,PRES,400
SFA,21,,PRES,400
SFA,24,,PRES,400
SFTRAN
NSEL,ALL
ESEL,ALL
SOLVE
SAVE,block2b.db
FINISH
/EXIT
```

12.3 LINEARIZED STRESS INTENSITIES THROUGH SECTIONS OF 2-IN. BLOCK MODEL

12.3.1 ISB TOP SECTION OF ISB BLOCK AT SCREW/ BLOCK INTERFACE



Applied Loading (Assumed axial loading for pre-load, thermal expansion, and internal pressure)

LC1 11,500 lbf/ number of nodes
LC2 16,500 lbf/ number of nodes
LC3 22,000 lbf/ number of nodes

Nodes used for stress linearization: 346 and 1833 with a path length of 0.72 in.

12.3.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.72 in. UNDER 50 FT-LBF TORQUE AND
COMBINED AXIAL EXTERNAL LOADS (filename SINTLC1.TP2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 346 OUTSIDE NODE = 1833

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -2790.    -2401.    -6767.    -71.87    4255.    -547.4
C      S1      S2      S3      SINT      SEQV
O 237.8    -2802.    -9394.     9632.     8528.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 9623.     5648.     4942.     343.3    217.5    -485.3
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O -9623.    -5648.    -4942.    -343.3    -217.5     485.3
C      S1      S2      S3      SINT      SEQV
I 9698.     5701.     4815.     4883.     4506.
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O -4815.    -5701.    -9698.     4883.     4506.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 6833.     3247.    -1825.     271.5    4472.    -1033.
C -2790.    -2401.    -6767.    -71.87    4255.    -547.4
O -.1241E+05 -8049.    -.1171E+05 -415.2    4037.    -62.13
C      S1      S2      S3      SINT      SEQV
I 6997.     5782.    -4523.    .1152E+05 .1096E+05
C 237.8    -2802.    -9394.     9632.     8528.
O -5426.    -.1242E+05 -.1433E+05 8902.     8118.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1832.    -2267.    -336.9     749.3    -1335.     164.8
C 1648.     1131.     274.8    -384.3    1587.    -11.00
O -1608.     1565.     2031.     939.9    -549.1     56.84
C      S1      S2      S3      SINT      SEQV
I 363.6    -1478.    -3321.     3685.     3191.
C 2467.     1547.    -960.6     3428.     3073.
O 2458.     1407.    -1876.     4334.     3916.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 5000.     980.1    -2162.     1021.     3138.    -867.9
C -1142.    -1270.    -6492.    -456.2     5842.    -558.4
O -.1402E+05 -6484.    -9678.     524.7     3488.    -5.288
C      S1      S2      S3      SINT      SEQV      TEMP
I 5247.     2847.    -4275.     9523.     8578.     70.00
C 2642.    -1262.    -.1029E+05 .1293E+05 .1148E+05
O -4225.    -.1188E+05 -.1408E+05 9855.     8960.     70.00

```


12.3.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.72 in. UNDER 100 FT-LBF TORQUE AND COMBINED AXIAL EXTERNAL LOADS (filename SINTLC2.TP2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 346 OUTSIDE NODE = 1833

LOAD STEP 2 SUBSTEP= 1
TIME= 2.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -4003.    -3445.    -9709.    -103.1    6104.    -785.5
C      S1      S2      S3      SINT      SEQV
O 341.3    -4021.    -.1348E+05    .1382E+05    .1224E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I .1381E+05  8104.    7091.    492.6    312.1    -696.3
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O -.1381E+05 -8104.    -7091.    -492.6    -312.1    696.3
      S1      S2      S3      SINT      SEQV
I .1391E+05  8179.    6908.    7007.    6466.
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O -6908.    -8179.    -.1391E+05  7007.    6466.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 9804.    4659.    -2618.    389.5    6417.    -1482.
C -4003.    -3445.    -9709.    -103.1    6104.    -785.5
O -.1781E+05 -.1155E+05 -.1680E+05 -.595.7  5792.    -89.14
      S1      S2      S3      SINT      SEQV
I .1004E+05  8295.    -6490.    .1653E+05 .1573E+05
C 341.3    -4021.    -.1348E+05 .1382E+05 .1224E+05
O -7785.    -.1782E+05 -.2056E+05 .1277E+05 .1165E+05

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -2629.    -3252.    -483.3    1075.    -1915.    236.5
C 2365.    1623.    394.2    -551.4    2277.    -15.78
O -2308.    2246.    2915.    1349.    -787.8    81.56
      S1      S2      S3      SINT      SEQV
I 521.7    -2121.    -4765.    5287.    4579.
C 3540.    2219.    -1378.    4918.    4409.
O 3526.    2019.    -2692.    6218.    5618.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 7175.    1406.    -3102.    1465.    4502.    -1245.
C -1639.    -1822.    -9315.    -654.5    8382.    -801.2
O -.2012E+05 -9303.    -.1389E+05 752.9    5005.    -7.587
      S1      S2      S3      SINT      SEQV      TEMP
I 7529.    4084.    -6134.    .1366E+05 .1231E+05 70.00
C 3791.    -1810.    -.1476E+05 .1855E+05 .1648E+05
O -6062.    -.1704E+05 -.2020E+05 .1414E+05 .1285E+05 70.00

```

12.3.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.72 in. UNDER 150 FT-LBF TORQUE AND COMBINED AXIAL EXTERNAL LOADS (filename SINTLC3.TP2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 346 OUTSIDE NODE = 1833

LOAD STEP 3 SUBSTEP= 1
TIME= 3.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
-5338.    -4593.    -.1295E+05    -137.5    8139.    -1047.
S1        S2        S3        SINT      SEQV
455.0     -5361.    -.1797E+05    .1843E+05    .1632E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I .1841E+05 .1080E+05 9455.    656.8    416.1    -928.4
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O -.1841E+05 -.1080E+05 -9455.    -656.8    -416.1    928.4
S1        S2        S3        SINT      SEQV
I .1855E+05 .1091E+05 9211.    9342.    8621.
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O -9211.    -.1091E+05 -.1855E+05 9342.    8621.

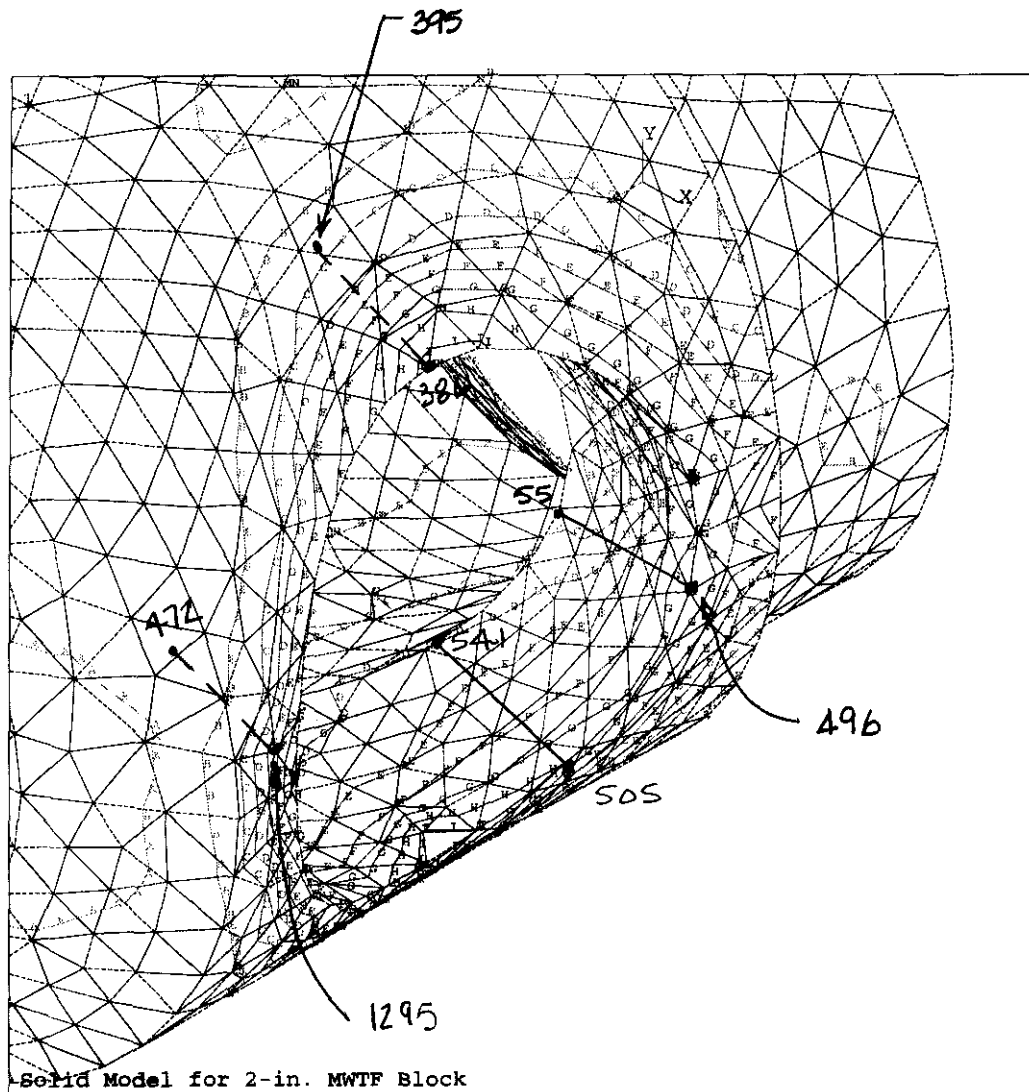
** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I .1307E+05 6212.    -3491.    519.3    8555.    -1976.
C -5338.    -4593.    -.1295E+05    -137.5    8139.    -1047.
O -.2375E+05 -.1540E+05 -.2240E+05    -794.3    7723.    -118.9
S1        S2        S3        SINT      SEQV
I .1338E+05 .1106E+05 -8653.    .2204E+05 .2097E+05
C 455.0     -5361.    -.1797E+05    .1843E+05 .1632E+05
O -.1038E+05 -.2376E+05 -.2741E+05    .1703E+05 .1553E+05

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -3505.    -4337.    -644.4    1433.    -2553.    315.3
C 3153.    2164.    525.6    -735.2    3036.    -21.04
O -3077.    2995.    3886.    1798.    -1050.    108.7
S1        S2        S3        SINT      SEQV
I 695.6     -2828.    -6354.    7049.    6105.
C 4720.    2959.    -1838.    6558.    5879.
O 4702.    2692.    -3589.    8291.    7491.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 9566.    1875.    -4136.    1953.    6002.    -1660.
C -2185.    -2430.    -.1242E+05    -872.7    .1118E+05    -1068.
O -.2682E+05 -.1240E+05 -.1851E+05    1004.    6673.    -10.12
S1        S2        S3        SINT      SEQV      TEMP
I .1004E+05 5446.    -8179.    .1822E+05 .1641E+05    70.00
C 5055.    -2413.    -.1968E+05    .2473E+05 .2197E+05
O -8082.    -.2272E+05 -.2693E+05    .1885E+05 .1714E+05    70.00

```

12.4 ISB PIPE CONNECTION SECTION OF BLOCK



ANSYS 5.0 A
MAR 22 1995
08:57:40
PLOT NO. 1
NODAL SOLUTION
STEP=5
SUB =1
TIME=5
SINT (AVG)
DMX =0.002211
SMN =618.134
SMX =20638
A =1730
B =3955
C =6179
D =8404
E =10628
F =12852
G =15077
H =17301
I =19525

Applied Loading (individual loading for pre-load, thermal expansion, internal pressure, and external forces and moments at pipe intersection)

- LC1 Fz = -11,500 lbf /number of nodes, applied @ top of block to account for 50 ft-lbf of pre-load torque, axial thermal expansion, and internal pressure (nodes 505 and 541, path length of 0.681 in.)
- LC5 Fx = -12,000 lbf applied at node 20,000 (nodes 386 and 395, with a path length of 0.668 in.)
- LC7 Fy = -6,000 lbf applied at node 20,000 (nodes 1295 and 472, with a path length of 0.62 in.)
- LC9 Fz = -4,000 lbf applied at node 20,000 (nodes 505 and 541, with a path length of 0.681 in.)
- LC10 Mx = 1128 ft-lbf applied at node 20,000 (nodes 386 and 395, with a path length of 0.668 in.)
- LC13 My = -1265 ft-lbf applied at node 20,000 (nodes 1295 and 472, with a path length of 0.62 in.)
- LC15 Mz = -1265 ft-lbf applied at node 20,000 (nodes 386 and 395, with a path length of 0.62 in.)
- LC16 Internal Pressure of 400 psi and uniform temperature @ 250 deg. F is applied to block model (nodes 55 and 496, path length 0.656 in.)

12.4.1 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.681 in. UNDER 50 FT-LBF TORQUE, AXIAL INTERNAL PRESSURE, AND AXIAL THERMAL EXPANSION LOADS (filenames SINTLC1.PS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 505 OUTSIDE NODE = 541

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
-566.6    -212.3    -3486.    202.4    974.8    277.3
      S1      S2      S3      SINT      SEQV
157.3     -653.6    -3769.    3926.    3590.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 1281.    -59.82    -2258.    1269.    664.2    -1110.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -1281.     59.82     2258.    -1269.    -664.2     1110.
      S1      S2      S3      SINT      SEQV
I 2139.    -229.6    -2946.    5085.    4407.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 2946.     229.6    -2139.    5085.    4407.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 714.3     -272.1    -5744.    1471.    1639.    -832.2
C -566.6    -212.3    -3486.    202.4    974.8    277.3
O -1848.    -152.5    -1228.    -1067.    310.6    1387.
      S1      S2      S3      SINT      SEQV
I 1785.    -682.9    -6404.    8189.    7276.
C 157.3     -653.6    -3769.    3926.    3590.
O 465.1     -393.5    -3300.    3765.    3418.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 709.7     139.4    -1007.    496.9    289.0    -188.0
C -402.5    -127.9     451.6    -366.6    -182.9     224.8
O 529.2     155.6    -780.7     493.1     328.2    -279.0
      S1      S2      S3      SINT      SEQV
I 997.6    -27.43    -1128.    2126.    1841.
C 615.2    -30.94    -663.1     1278.    1107.
O 870.9     38.61    -1006.    1876.    1629.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 1424.    -132.7    -6751.    1968.    1928.    -1020.
C -969.1    -340.2    -3034.    -164.3     791.9     502.2
O -1318.     3.107    -2009.    -573.5     638.8     1108.
      S1      S2      S3      SINT      SEQV      TEMP
I 2769.    -696.8    -7532.    0.1030E+05 9079.     70.00
C -123.8    -853.9    -3366.    3242.     2946.
O 249.8    -511.6    -3062.    3312.     3005.     70.00

```

12.4.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.668 in. WITH AN EXTERNAL FORCE OF
Fx = -12,000 lbf, APPLIED AT NODE 20,000 (filenames SINTLC5.PS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 386 OUTSIDE NODE = 395

LOAD STEP 5 SUBSTEP= 1
TIME= 5.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
-0.1238E+05 -2051.    -0.1354E+05  183.6    84.82    1381.
      S1      S2      S3      SINT     SEQV
-2047.    -0.1147E+05 -0.1446E+05  0.1241E+05  0.1122E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -3573.    -204.0    -7089.    -1353.    376.6    -391.8
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 3573.     204.0     7089.     1353.    -376.6    391.8
      S1      S2      S3      SINT     SEQV
I 304.2     -4030.    -7140.    7444.     6476.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 7140.     4030.    -304.2    7444.     6476.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.1595E+05 -2255.    -0.2063E+05 -1170.    461.5    989.1
C -0.1238E+05 -2051.    -0.1354E+05  183.6    84.82    1381.
O -8808.     -1847.    -6453.    1537.    -291.8    1773.
      S1      S2      S3      SINT     SEQV
I -2148.    -0.1583E+05 -0.2086E+05 0.1871E+05 0.1677E+05
C -2047.    -0.1147E+05 -0.1446E+05 0.1241E+05 0.1122E+05
O -1522.     -5555.    -0.1003E+05 8511.     7374.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 438.4     -286.4    -2083.    -520.4    240.0    191.0
C -154.5     21.60    848.6     314.4    -116.2    -19.96
O 179.6     200.0    -1311.    -737.1    224.8    -111.1
      S1      S2      S3      SINT     SEQV
I 711.3     -501.0    -2142.    2853.     2480.
C 868.9     242.1    -395.3     1264.     1095.
O 952.1     -539.7    -1344.    2296.     2018.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.1552E+05 -2542.    -0.2271E+05 -1690.     701.4    1180.
C -0.1254E+05 -2030.    -0.1269E+05 497.9     -31.38    1361.
O -8628.     -1647.    -7765.     799.7     -66.99    1662.
      S1      S2      S3      SINT     SEQV     TEMP
I -2310.    -0.1551E+05 -0.2295E+05 0.2064E+05 0.1810E+05 70.00
C -2006.    -0.1126E+05 -0.1399E+05 0.1198E+05 0.1088E+05
O -1554.     -6518.    -9968.     8414.     7326.     70.00

```

12.4.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.62 in. WITH AN EXTERNAL FORCE OF
Fy = -6,000 lbf, APPLIED AT NODEL 20,000 (filenames SINTLC7.PS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1295 OUTSIDE NODE = 472

LOAD STEP 7 SUBSTEP= 1
TIME= 7.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  207.4    -1208.    -1224.    -4126.    2762.    573.1
C      S1      S2      S3      SINT      SEQV
O  4078.    -281.0    -6022.    0.1010E+05  8774.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  139.0     1267.    -479.9    -2360.    2317.    12.24
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  -139.0    -1267.     479.9     2360.    -2317.    -12.24
C      S1      S2      S3      SINT      SEQV
I  3940.    -151.5    -2862.     6802.    5931.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  2862.     151.5    -3940.     6802.    5931.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  346.4     58.81    -1704.    -6487.    5080.    585.3
C  207.4    -1208.    -1224.    -4126.    2762.    573.1
O  68.42    -2475.    -744.3    -1766.    444.9    560.8
C      S1      S2      S3      SINT      SEQV
I  7859.    -348.7    -8809.    0.1667E+05 0.1443E+05
C  4078.    -281.0    -6022.    0.1010E+05 8774.
O  1026.    -643.4    -3533.     4558.    3995.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -447.0    -1006.    -623.9    -86.39    1148.    -134.5
C  102.0     264.5     210.1     244.6    -462.1     59.37
O  -88.10    -498.5    -288.9    -417.2     940.2    -116.5
C      S1      S2      S3      SINT      SEQV
I  378.9    -477.1    -1979.    2358.    2067.
C  732.4     176.7    -332.5    1065.    922.6
O  722.2    -213.7    -1384.    2106.    1828.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -100.6    -947.1    -2328.    -6573.    6227.    450.8
C  309.4    -943.4    -1014.    -3882.    2300.    632.4
O  -19.67    -2973.    -1033.    -2183.    1385.    444.3
C      S1      S2      S3      SINT      SEQV      TEMP
I  7857.    -826.1    -0.1041E+05 0.1826E+05 0.1582E+05 70.00
C  3853.    -146.6    -5354.     9207.    7996.
O  1176.    -507.8    -4694.     5870.    5235.    70.00

```

12.4.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.681 in. WITH AN EXTERNAL FORCE OF
Fz = -4,000 lbf, APPLIED AT NODE 20,000 (filenames SINTLC9.PS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 505 OUTSIDE NODE = 541

LOAD STEP 9 SUBSTEP= 1
TIME= 9.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  -954.2    -903.4    -3598.    622.2    1204.    -838.5
C      S1      S2      S3      SINT      SEQV
O  -258.5    -840.9    -4356.    4097.    3840.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   664.4    -857.1    -4145.    1482.    1426.    -1372.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  -664.4     857.1     4145.    -1482.    -1426.     1372.
C      S1      S2      S3      SINT      SEQV
I   1609.    -702.4    -5244.    6853.    6039.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O   5244.     702.4    -1609.    6853.    6039.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -289.8    -1760.    -7743.    2104.    2630.    -2211.
C  -954.2    -903.4    -3598.    622.2    1204.    -838.5
O  -1619.    -46.30     547.3    -859.8    -222.5     533.8
C      S1      S2      S3      SINT      SEQV
I   1216.    -1411.    -9598.    0.1081E+05  9769.
C  -258.5    -840.9    -4356.    4097.    3840.
O   907.3     35.33    -2060.    2968.    2642.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   590.2     32.10    -1894.    684.4    623.8    -162.1
C  -386.9    -121.3     940.3    -451.2    -273.9     305.4
O   449.4     25.06    -1350.    605.2    471.3    -383.5
C      S1      S2      S3      SINT      SEQV
I   1067.    -212.6    -2126.    3193.    2783.
C   1122.     38.48    -728.8    1851.    1611.
O   879.4    -108.4    -1646.    2526.    2205.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   300.4    -1728.    -9637.    2789.    3254.    -2373.
C  -1341.    -1025.    -2657.    171.0    929.7    -533.1
O  -1169.    -21.23    -802.7    -254.5    248.8    150.3
C      S1      S2      S3      SINT      SEQV      TEMP
I   2254.    -1652.    -0.1167E+05  0.1392E+05  0.1244E+05  70.00
C  -597.2    -1185.    -3241.    2644.    2405.
O   85.21    -771.4    -1307.    1392.    1216.    70.00

```

12.4.5 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.668 in. WITH AN EXTERNAL MOMENT OF
Mx = 1128 ft-lbf, APPLIED AT NODE 20,000 (filename: SINTLC10.PS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 386 OUTSIDE NODE = 395

LOAD STEP 10 SUBSTEP= 1
TIME= 10.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  144.4    -195.5    1549.    3.249    -2055.    4926.
C      S1      S2      S3      SINT      SEQV
O  6208.    -141.9    -4568.    0.1078E+05    9382.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -347.9    -687.4    -172.0    40.23    -1709.    5520.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O   347.9     687.4     172.0    -40.23     1709.    -5520.
C      S1      S2      S3      SINT      SEQV
I   5495.    -634.8    -6067.    0.1156E+05  0.1002E+05
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O   6067.     634.8    -5495.    0.1156E+05  0.1002E+05

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -203.5    -882.9    1377.    43.48    -3763.    0.1045E+05
C   144.4    -195.5    1549.    3.249    -2055.    4926.
O   492.3     491.9    1721.    -36.98    -346.0    -593.9
C      S1      S2      S3      SINT      SEQV
I  0.1167E+05 -776.0    -0.1060E+05  0.2228E+05  0.1934E+05
C   6208.    -141.9    -4568.    0.1078E+05    9382.
O   2023.     524.9     157.1     1866.     1712.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   545.3    -160.4     139.0     11.12    -219.5     1258.
C  -127.0     118.2     -6.499     -2.681     154.6    -680.0
O  -37.27    -312.4    -113.0    -0.3963    -398.9     1462.
C      S1      S2      S3      SINT      SEQV
I   1627.    -132.7    -970.1     2597.     2296.
C   641.9     104.3    -761.5     1403.     1226.
O   1433.    -293.2    -1602.     3035.     2636.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   341.8    -1043.    1516.     54.60    -3983.    0.1170E+05
C   17.42    -77.25     1543.     0.5682    -1900.     4246.
O   455.0     179.5     1608.    -37.38    -744.9     868.1
C      S1      S2      S3      SINT      SEQV      TEMP
I  0.1323E+05 -862.8    -0.1155E+05  0.2478E+05  0.2153E+05    70.00
C   5487.    -60.94    -3943.     9430.     8209.
O   2293.     278.6    -329.2     2623.     2378.     70.00

```


12.4.6 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.62 in. WITH AN EXTERNAL MOMENT OF
My = -1265 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC13.PS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1295 OUTSIDE NODE = 472

LOAD STEP 13 SUBSTEP= 1
TIME= 13.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
-0.1889E+05 -0.1066E+05 -1953.      2366.      1486.      1688.
      S1      S2      S3      SINT      SEQV
-1458.      -0.1043E+05 -0.1961E+05 0.1816E+05 0.1572E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -3022.      -6078.      617.0      867.9      892.6      -59.32
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 3022.      6078.      -617.0      -867.9      -892.6      59.32
      S1      S2      S3      SINT      SEQV
I 734.8      -2800.      -6417.      7152.      6194.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 6417.      2800.      -734.8      7152.      6194.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.2191E+05 -0.1674E+05 -1336.      3234.      2379.      1629.
C -0.1889E+05 -0.1066E+05 -1953.      2366.      1486.      1688.
O -0.1587E+05 -4579.      -2570.      1498.      593.5      1748.
      S1      S2      S3      SINT      SEQV
I -764.6      -0.1574E+05 -0.2348E+05 0.2271E+05 0.2000E+05
C -1458.      -0.1043E+05 -0.1961E+05 0.1816E+05 0.1572E+05
O -2085.      -4667.      -0.1627E+05 0.1418E+05 0.1308E+05

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 1359.      -1652.      984.2      753.5      479.2      -181.2
C 495.4      857.3      -341.0      -121.3      -131.8      163.4
O 943.3      -980.9      1159.      73.52      346.8      -451.3
      S1      S2      S3      SINT      SEQV
I 1546.      1064.      -1919.      3464.      3250.
C 918.7      474.2      -381.2      1300.      1144.
O 1536.      631.7      -1046.      2583.      2270.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.2056E+05 -0.1839E+05 -352.0      3987.      2858.      1448.
C -0.1840E+05 -9800.      -2294.      2245.      1354.      1852.
O -0.1493E+05 -5560.      -1411.      1572.      940.3      1296.
      S1      S2      S3      SINT      SEQV      TEMP
I 296.8      -0.1597E+05 -0.2362E+05 0.2392E+05 0.2116E+05 70.00
C -1756.      -9655.      -0.1908E+05 0.1732E+05 0.1502E+05
O -1019.      -5602.      -0.1528E+05 0.1426E+05 0.1261E+05 70.00

```

12.4.7 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.668 in. WITH AN EXTERNAL MOMENT OF
Mz = -1265 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC15.PS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 386 OUTSIDE NODE = 395

LOAD STEP 15 SUBSTEP= 1
TIME= 15.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I 0.2435E+05 2681.    0.1692E+05 -217.1    483.3    -2506.
C      S1      S2      S3      SINT      SEQV
O 0.2512E+05 0.1617E+05 2664.    0.2246E+05 0.1958E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 8021.    1144.    0.1472E+05 2088.    393.7    -708.8
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -8021.    -1144.    -0.1472E+05 -2088.    -393.7    708.8
C      S1      S2      S3      SINT      SEQV
I 0.1480E+05 8552.    536.8    0.1426E+05 0.1239E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -536.8    -8552.    -0.1480E+05 0.1426E+05 0.1239E+05

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 0.3237E+05 3825.    0.3165E+05 1871.    877.1    -3215.
C 0.2435E+05 2681.    0.1692E+05 -217.1    483.3    -2506.
O 0.1633E+05 1537.    2196.    -2305.    89.60    -1797.
C      S1      S2      S3      SINT      SEQV
I 0.3527E+05 0.2892E+05 3660.    0.3161E+05 0.2896E+05
C 0.2512E+05 0.1617E+05 2664.    0.2246E+05 0.1958E+05
O 0.1690E+05 2017.    1147.    0.1575E+05 0.1534E+05

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -510.9    1841.    5399.    344.5    2.253    -702.4
C 270.8    -594.4    -2394.    -352.8    1.603    253.9
O -572.2    536.5    4178.    1067.    -8.665    -313.3
C      S1      S2      S3      SINT      SEQV
I 5482.    1888.    -640.5    6122.    5329.
C 416.7    -715.7    -2419.    2836.    2472.
O 4200.    1175.    -1233.    5433.    4716.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 0.3186E+05 5666.    0.3705E+05 2215.    879.3    -3917.
C 0.2462E+05 2086.    0.1453E+05 -569.9    484.9    -2252.
O 0.1576E+05 2073.    6374.    -1238.    80.93    -2110.
C      S1      S2      S3      SINT      SEQV      TEMP
I 0.3915E+05 0.2999E+05 5433.    0.3372E+05 0.3020E+05 70.00
C 0.2512E+05 0.1406E+05 2057.    0.2307E+05 0.1998E+05
O 0.1632E+05 5930.    1959.    0.1436E+05 0.1284E+05 70.00

```

12.4.8 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.656 in. UNDER UNIFORM TEMPERATURE AND PRESSURE OF 250 deg. F AND 400 psi (filenames SINTLC16.PS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 55 OUTSIDE NODE = 496

LOAD STEP 16 SUBSTEP= 1
TIME= 16.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  169.3    2544.    -87.29   -41.59    19.35   -76.03
C      S1      S2      S3      SINT      SEQV
I  2545.    189.3   -108.1    2653.    2518.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -119.8   1220.    83.31   -48.03    16.73    32.17
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O   119.8  -1220.   -83.31    48.03   -16.73   -32.17
C      S1      S2      S3      SINT      SEQV
I  1222.    88.21   -126.6   1349.    1255.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O   126.6   -88.21  -1222.    1349.    1255.

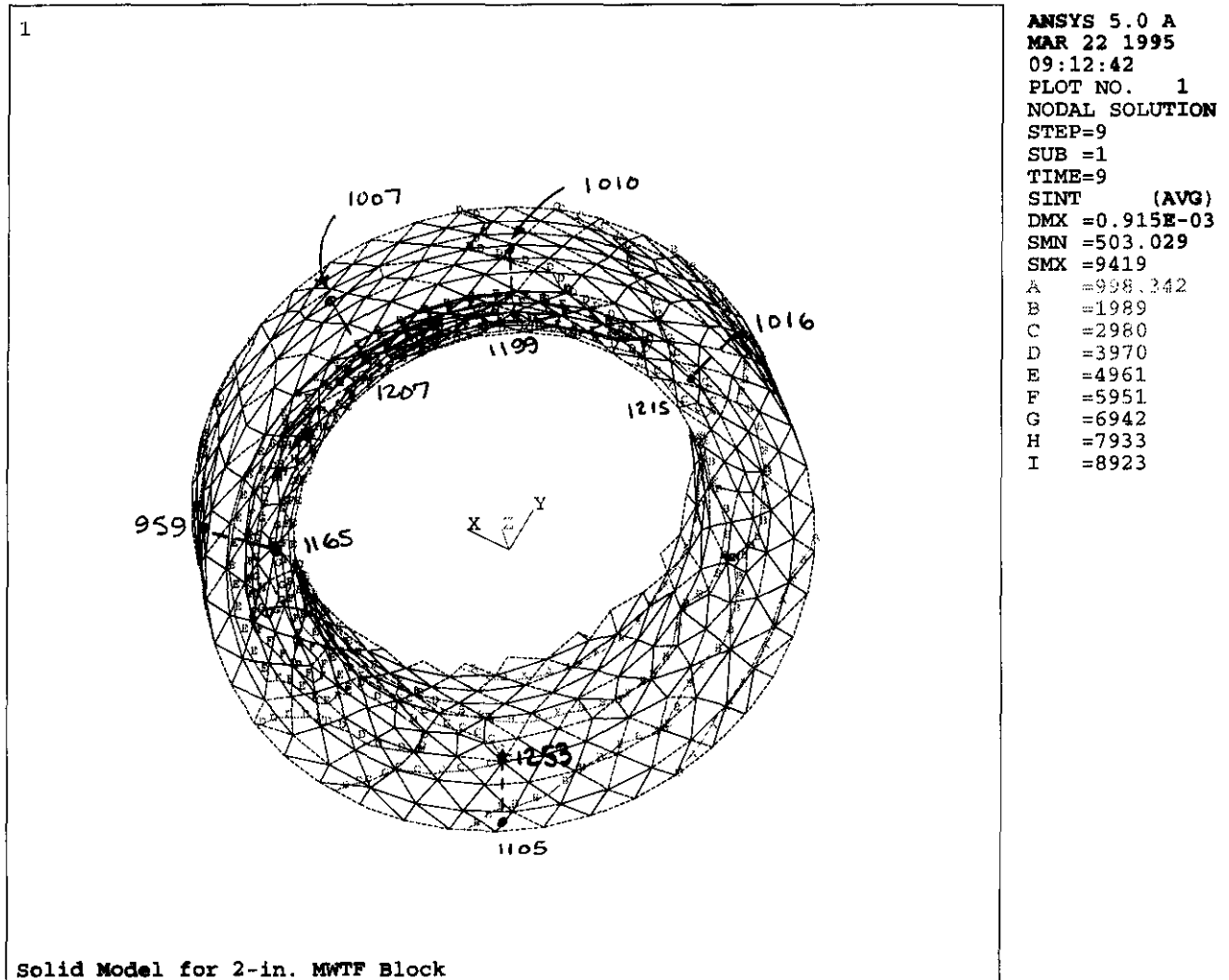
** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   49.52   3765.    -3.978   -89.63    36.07   -43.86
C  169.3    2544.    -87.29   -41.59    19.35   -76.03
O  289.1   1324.   -170.6    6.437    2.620   -108.2
C      S1      S2      S3      SINT      SEQV
I  3767.    71.65   -28.64   3796.    3747.
C  2545.    189.3   -108.1    2653.    2518.
O  1324.    313.3   -194.8    1519.    1339.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -4.839   18.67    15.09    38.40   -47.25    2.024
C   7.869  -8.427    77.70   -2.981    5.654   -9.282
O  -57.28   22.26   -111.6    7.225   -11.15   16.44
C      S1      S2      S3      SINT      SEQV
I   73.86    5.438   -50.38   124.2   107.8
C   79.32    6.967   -9.147    88.47    81.61
O   23.62   -52.89  -117.3   141.0   122.2

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   44.68   3783.    11.11   -51.22   -11.18   -41.83
C  177.2    2536.   -9.587   -44.57    25.00   -85.31
O  231.8    1346.  -282.2    13.66   -8.527   -91.76
C      S1      S2      S3      SINT      SEQV      TEMP
I  3784.    72.62   -17.56   3801.    3757.    250.0
C  2537.    209.2   -42.71   2580.    2463.
O  1346.    247.5   -298.1   1644.    1451.    250.0

```

12.5 ISB BOTTOM SECTION OF BLOCK



Applied Loading (individual loading for pre-load, thermal expansion, internal pressure, and external forces and moments at pipe intersection)

- LC1 Fz = -11,500 lbf /number of nodes, applied @ top of block to account for 50 ft-lbf of pre-load torque, axial thermal expansion, and internal pressure (nodes 1253 and 1105, path length of 0.389 in.)
- LC5 Fx = -12,000 lbf applied at node 20,000 (nodes 1165 and 959, with a path length of 0.409 in.)
- LC7 Fy = -6,000 lbf applied at node 20,000 (nodes 1199 and 1010, with a path length of 0.395 in.)
- LC9 Fz = -4,000 lbf applied at node 20,000 (nodes 1165 and 959, with a path length of 0.409 in.)
- LC10 Mx = 1128 ft-lbf applied at node 20,000 (nodes 1207 and 1007, with a path length of 0.35 in.)
- LC13 My = -1265 ft-lbf applied at node 20,000 (nodes 1165 and 959, with a path length of 0.409 in.)
- LC15 Mz = -1265 ft-lbf applied at node 20,000 (nodes 1165 and 959, with a path length of 0.409 in.)
- LC16 Internal Pressure of 400 psi and uniform temperature @ 250 deg. F is applied to block model (nodes 1215 and 1016, path length of 0.351 in.)

12.5.1 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.389 in. UNDER 50 FT-LBF TORQUE, AXIAL INTERNAL PRESSURE, AND AXIAL THERMAL EXPANSION LOADS (filenames SINTLC1.BS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1253 OUTSIDE NODE = 1105

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  5144.    -1499.    -4101.    1798.    1941.    -594.5
C      S1      S2      S3      SINT      SEQV
O  5601.    -734.1    -5322.    0.1092E+05    9500.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  175.5    -3054.    -3720.    -1370.    182.7    175.6
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  -175.5     3054.     3720.     1370.    -182.7    -175.6
C      S1      S2      S3      SINT      SEQV
I  680.8    -3394.    -3886.     4567.     4342.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  3886.     3394.    -680.8     4567.     4342.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  5320.    -4553.    -7821.     428.0    2124.    -418.9
C  5144.    -1499.    -4101.     1798.     1941.    -594.5
O  4969.     1555.    -380.3     3168.     1758.    -770.2
C      S1      S2      S3      SINT      SEQV
I  5347.    -3512.    -8889.    0.1424E+05  0.1245E+05
C  5601.    -734.1    -5322.    0.1092E+05    9500.
O  6869.     1541.    -2266.     9136.     7948.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -2837.    -3402.    -3674.    -794.6    1493.     339.9
C  347.3     491.2     184.6     58.89    418.5     74.53
O  -568.0    -404.7    -506.4    -346.5    -228.3    154.2
C      S1      S2      S3      SINT      SEQV
I  -1873.    -2747.    -5293.     3420.     3078.
C  801.8     330.8    -109.5     911.3     789.3
O  14.68     -649.5    -844.2     858.9     780.0

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  2483.    -7956.    -0.1150E+05  -366.6    3616.    -78.99
C  5492.    -1008.    -3916.     1857.    2359.    -520.0
O  4401.     1150.    -886.7     2822.    1530.    -616.0
C      S1      S2      S3      SINT      SEQV      TEMP
I  2499.    -5714.    -0.1375E+05  0.1625E+05  0.1408E+05    70.00
C  5986.    -10.06    -5408.    0.1139E+05    9872.
O  6040.     957.0    -2333.     8373.     7306.     70.00

```

12.5.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.409 in. WITH AN EXTERNAL FORCE OF
Fx = -12,000 lbf, APPLIED AT NODE 20,000 (filenames SINTLC5.BS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1165 OUTSIDE NODE = 959

LOAD STEP 5 SUBSTEP= 1
TIME= 5.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -1807.    2269.   -3311.    85.04   -2.063   -1893.
C      S1      S2      S3      SINT      SEQV
O 2272.   -523.3   -4597.    6868.    5982.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -2273.    1180.   -2682.   -101.9   -7.627   -861.7
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 2273.   -1180.    2682.    101.9    7.627    861.7
      S1      S2      S3      SINT      SEQV
I 1183.   -1593.   -3364.    4547.    3970.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 3364.    1593.   -1183.    4547.    3970.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -4079.    3450.   -5993.   -16.87   -9.690   -2755.
C -1807.    2269.   -3311.    85.04   -2.063   -1893.
O 466.0    1089.   -629.6    186.9    5.564   -1032.
      S1      S2      S3      SINT      SEQV
I 3450.   -2119.   -7952.    0.1140E+05 9876.
C 2272.   -523.3   -4597.    6868.    5982.
O 1247.    932.6   -1254.    2501.    2360.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -555.9   -561.9   -1419.    116.7    56.54   -96.79
C 450.1    414.8    1153.   -32.22   -23.14    96.99
O -659.0   -454.3   -1249.   -46.02   -9.516   -180.8
      S1      S2      S3      SINT      SEQV
I -441.2   -660.3   -1436.    994.4    905.0
C 1167.    456.4    394.3    772.7    743.6
O -443.2   -618.6   -1301.    857.5    784.6

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -4635.    2888.   -7412.    99.80    46.85   -2852.
C -1356.    2684.   -2158.    52.81   -25.20   -1796.
O -192.9    634.7   -1879.    140.9   -3.952   -1212.
      S1      S2      S3      SINT      SEQV      TEMP
I 2889.   -2852.   -9196.    0.1209E+05 0.1047E+05 70.00
C 2685.    81.97   -3598.    6283.    5468.
O 698.2    378.4   -2514.    3212.    3065.    70.00

```

12.5.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.395 in. WITH AN EXTERNAL FORCE OF
Fy = -6,000 lbf, APPLIED AT MODEL 20,000 (filenames SINTLC7.BS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1199 OUTSIDE NODE = 1010

LOAD STEP 7 SUBSTEP= 1
TIME= 7.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
1446.    -1048.    -1756.    -31.63    -988.9    92.41
      S1      S2      S3      SINT      SEQV
1451.    -354.9    -2453.    3904.    3384.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -586.3    -1019.    -1357.    -29.48    -230.3    -62.51
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O   586.3     1019.     1357.     29.48     230.3     62.51
      S1      S2      S3      SINT      SEQV
I  -580.9    -902.0    -1479.     897.9     788.1
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O   1479.     902.0     580.9     897.9     788.1

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   860.2    -2066.    -3113.    -61.10    -1219.    29.89
C   1446.    -1048.    -1756.    -31.63    -988.9    92.41
O   2033.    -29.03    -399.3    -2.150    -758.6    154.9
      S1      S2      S3      SINT      SEQV
I   862.4    -1265.    -3917.     4779.     4147.
C   1451.    -354.9    -2453.     3904.     3384.
O   2044.     560.3    -999.8     3044.     2636.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -339.0    -111.4    -681.8    -31.17     53.97    -13.38
C   203.0     172.8     419.3     18.86    -34.37     2.061
O  -236.4    -166.9    -484.4    -22.24     38.09    -4.403
      S1      S2      S3      SINT      SEQV
I  -101.9    -343.1    -687.1     585.2     509.4
C   424.0     211.4     159.8     264.2     242.6
O  -156.1    -242.8    -488.9     332.9     299.1

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   521.2    -2178.    -3795.    -92.28    -1165.    16.52
C   1650.    -874.9    -1337.    -12.77    -1023.    94.47
O   1796.    -196.0    -883.7    -24.39    -720.5    150.5
      S1      S2      S3      SINT      SEQV      TEMP
I   525.2    -1572.    -4405.     4930.     4285.    70.00
C   1653.    -59.59    -2156.     3810.     3305.
O   1807.     252.0    -1342.     3149.     2728.    70.00

```

12.5.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.409 in. WITH AN EXTERNAL FORCE OF
Fz = -4,000 (lbf, APPLIED AT NODE 20,000 (filenames SINTLC9.BS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1165 OUTSIDE NODE = 959

LOAD STEP 9 SUBSTEP= 1
TIME= 9.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -1450.    2412.    -2781.    63.05    -3.710   -1455.
C      S1      S2      S3      SINT      SEQV
O 2413.    -515.9   -3716.    6129.    5309.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1694.    428.1   -1634.    -65.99   -21.92   -623.2
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 1694.    -428.1    1634.     65.99    21.92    623.2
C      S1      S2      S3      SINT      SEQV
I 430.2   -1040.    -2289.     2719.    2358.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 2289.     1040.    -430.2     2719.    2358.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -3143.    2840.    -4415.    -2.938   -25.63   -2079.
C -1450.    2412.    -2781.    63.05    -3.710   -1455.
O 244.1    1984.    -1147.    129.0    18.21   -832.2
C      S1      S2      S3      SINT      SEQV
I 2840.    -1605.    -5953.     8793.    7615.
C 2413.    -515.9   -3716.     6129.    5309.
O 1994.     624.4   -1537.     3531.    3084.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -355.6   -309.6   -1123.     76.14    47.39   -59.56
C 294.0    231.9    926.5    -18.11   -16.04    64.64
O -455.2   -253.2   -1023.    -35.57   -7.367   -126.6
C      S1      S2      S3      SINT      SEQV
I -253.0   -404.1   -1131.     878.1    813.2
C 933.5    292.0    227.1     706.4    676.3
O -246.8   -434.3   -1050.     803.6    728.1

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -3499.    2530.    -5538.     73.20    21.76   -2138.
C -1156.    2644.    -1854.     44.94   -19.75   -1391.
O -211.1    1730.    -2170.     93.47    10.84   -958.8
C      S1      S2      S3      SINT      SEQV      TEMP
I 2531.    -2150.    -6887.     9419.    8157.    70.00
C 2645.    -71.80   -2939.     5584.    4836.
O 1735.     175.7   -2562.     4297.    3768.    70.00

```


12.5.5 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.35 in. WITH AN EXTERNAL MOMENT OF
Mx = 1128 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC10.BS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1207 OUTSIDE NODE = 1007

LOAD STEP 10 SUBSTEP= 1
TIME= 10.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -1335.    477.3    2101.    1498.    1201.    419.6
C      S1      S2      S3      SINT      SEQV
O 3029.    407.1    -2192.    5221.    4522.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 321.9    1169.    1164.    487.2    181.0    245.6
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -321.9   -1169.   -1164.   -487.2   -181.0   -245.6
C      S1      S2      S3      SINT      SEQV
I 1572.    1005.    78.51    1493.    1306.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -78.51   -1005.   -1572.    1493.    1306.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1013.    1646.    3265.    1985.    1382.    665.2
C -1335.    477.3    2101.    1498.    1201.    419.6
O -1656.   -691.8    937.4    1011.    1020.    174.1
C      S1      S2      S3      SINT      SEQV
I 4543.    1429.   -2073.    6617.    5733.
C 3029.    407.1   -2192.    5221.    4522.
O 1548.   -610.4   -2348.    3896.    3381.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 391.4    919.5    962.3    119.8    211.3    110.9
C -183.1   -428.0   -457.4   -62.04   -96.88   -52.01
O 230.3    538.7    572.3    75.65    122.5    65.28
C      S1      S2      S3      SINT      SEQV
I 1187.    729.0    357.6    829.0    719.2
C -165.2   -345.6   -557.7    392.6    340.3
O 700.1    432.7    208.6    491.5    426.2

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -621.3    2566.    4228.    2105.    1593.    776.1
C -1518.    49.37    1644.    1436.    1104.    367.6
O -1426.   -153.0    1510.    1086.    1142.    239.4
C      S1      S2      S3      SINT      SEQV      TEMP
I 5718.    2122.   -1668.    7386.    6397.    70.00
C 2477.    85.28   -2387.    4864.    4212.
O 2237.   -216.4   -2090.    4327.    3759.    70.00

```

12.5.6 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.409 in. WITH AN EXTERNAL MOMENT OF
My = -1265 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC13.BS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1165 OUTSIDE NODE = 959

LOAD STEP 13 SUBSTEP= 1
TIME= 13.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

** MEMBRANE **

	SX	SY	SZ	SXY	SYZ	SXZ
2075.	-1884.	3896.	-99.80	4.536	2313.	
S1	S2	S3	SINT	SEQV		
5471.	502.8	-1888.	7359.	6502.		

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I 2745.	-1949.	3398.	141.5	-0.9639E-01	1033.	
C 0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	
O -2745.	1949.	-3398.	-141.5	0.9639E-01	-1033.	
S1	S2	S3	SINT	SEQV		
I 4156.	1992.	-1954.	6110.	5366.		
C 0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00		
O 1954.	-1992.	-4156.	6110.	5366.		

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I 4820.	-3834.	7294.	41.67	4.440	3346.	
C 2075.	-1884.	3896.	-99.80	4.536	2313.	
O -670.5	64.86	497.3	-241.3	4.632	1280.	
S1	S2	S3	SINT	SEQV		
I 9624.	2491.	-3834.	0.1346E+05	0.1166E+05		
C 5471.	502.8	-1888.	7359.	6502.		
O 1333.	78.80	-1520.	2854.	2477.		

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I 692.0	688.5	1657.	-156.2	-67.40	132.5	
C -552.8	-505.8	-1330.	51.08	35.51	-123.1	
O 798.6	562.3	1428.	47.41	3.672	222.6	
S1	S2	S3	SINT	SEQV		
I 1683.	822.7	532.1	1151.	1037.		
C -471.2	-566.2	-1351.	879.7	836.3		
O 1499.	738.8	551.0	948.4	869.8		

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I 5512.	-3145.	8952.	-114.6	-62.96	3478.	
C 1522.	-2390.	2566.	-48.72	40.05	2190.	
O 128.1	627.1	1926.	-193.9	8.304	1503.	
S1	S2	S3	SINT	SEQV	TEMP	
I 0.1111E+05	3353.	-3147.	0.1426E+05	0.1237E+05	70.00	
C 4295.	-205.2	-2392.	6687.	5906.		
O 2782.	645.3	-746.0	3528.	3078.	70.00	

12.5.7 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.409 in. WITH AN EXTERNAL MOMENT OF
Mz = -1265 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC15.BS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1165 OUTSIDE NODE = 959

LOAD STEP 15 SUBSTEP= 1
TIME= 15.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
25.99    14.14    -5.725    -252.8    -132.8    14.05
      S1      S2      S3      SINT      SEQV
308.1    -10.43    -263.3     571.4     496.0

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  83.56    -21.74     61.42    -451.7    1331.    19.93
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O -83.56     21.74    -61.42     451.7    -1331.    -19.93
      S1      S2      S3      SINT      SEQV
I  1421.     93.40    -1391.    2812.    2436.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  1391.    -93.40    -1421.    2812.    2436.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  109.5     -7.604     55.69    -704.6    1198.    33.98
C  25.99     14.14    -5.725    -252.8    -132.8    14.05
O -57.57     35.88    -67.14     198.9    -1463.    -5.886
      S1      S2      S3      SINT      SEQV
I  1406.     125.4    -1374.    2780.    2410.
C  308.1    -10.43    -263.3     571.4     496.0
O  1463.    -59.31    -1493.    2956.    2560.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  41.88     85.90     42.90    -70.03    -90.01    -8.939
C -37.10    -30.99    -54.36     61.50     54.49    -2.766
O  58.67     10.07     63.97    -85.67    -63.17     28.76
      S1      S2      S3      SINT      SEQV
I  176.9     50.95    -57.14     234.0     202.9
C  43.77    -43.87    -122.3     166.1     143.9
O  163.0     34.40    -64.72     227.7     197.8

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  151.4     78.30     98.59    -774.6    1108.    25.04
C -11.11    -16.85    -60.08    -191.3    -78.26     11.28
O  1.101     45.95    -3.172     113.3    -1527.    22.87
      S1      S2      S3      SINT      SEQV      TEMP
I  1437.     157.6    -1267.    2704.    2343.    70.00
C  193.4    -60.88    -220.5     413.9     361.6
O  1551.     4.461    -1512.    3062.    2652.    70.00

```

12.5.8 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.351 in. UNDER UNIFORM TEMPERATURE AND PRESSURE OF 250 deg. F AND 400 psi (filenames SINTLC16.BS2)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1215 OUTSIDE NODE = 1016

LOAD STEP 16 SUBSTEP= 1
TIME= 16.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  817.8    209.7    3452.    -739.7    941.1   -1053.
C  4150.    630.0    -301.0    4451.    4067.
O

** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  1895.    1622.    2673.    -277.0    972.9   -642.4
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  -1895.   -1622.   -2673.    277.0   -972.9    642.4
      S1      S2      S3      SINT      SEQV
I  3545.    1616.    1029.    2516.    2280.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  -1029.   -1616.   -3545.    2516.    2280.

** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  2713.    1832.    6125.    -1017.    1914.   -1696.
C  817.8    209.7    3452.    -739.7    941.1   -1053.
O  -1077.   -1413.    778.8    -462.7   -31.82   -411.0
      S1      S2      S3      SINT      SEQV
I  7628.    2051.    991.3    6637.    6176.
C  4150.    630.0    -301.0    4451.    4067.
O  867.6    -813.7   -1765.    2633.    2309.

** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  886.4    1051.    2716.    241.4    628.9   -557.3
C  -478.6   -614.6   -760.4    80.62   -227.5    189.6
O  614.9    753.2    1118.   -46.93    307.8   -262.0
      S1      S2      S3      SINT      SEQV
I  3026.    1211.    416.2    2609.    2316.
C  -375.7   -474.2   -1004.    627.9    584.9
O  1377.    641.8    467.3    910.0    836.5

** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  3599.    2883.    8841.   -775.3    2543.   -2253.
C  339.2   -404.9    2691.   -659.1    713.6   -863.8
O  -462.5   -659.6    1897.   -509.6    276.0   -672.9
      S1      S2      S3      SINT      SEQV      TEMP
I  0.1059E+05 2791.    1942.    8648.    8256.    250.0
C  3195.    233.0   -801.8    3996.    3593.
O  2133.   -260.0   -1098.    3232.    2905.    250.0

```

13.0 3-IN. ANSYS INPUT FILES FOR BLOCK MODEL

13.1 3-IN. ISB BLOCK GEOMETRY INPUT (block3g.inp)

```

/BATCH
/CONFIG,NRES,50000
/CONFIG,NCONT,10000
/TITLE,Solid Model for 3-in. MMTF Block
C*** Load Case (Preload, Pressure, Thermal, and External) **
/UNITS,BIN
/PREP7
/OUTPUT,block3.out
C*** 3-in. ISB Block **
ET, 1,SOLID72
TYPE,1
REAL,1
MAT,1
KEYO, 1, 5, 2
R, 1
MPTEMP,,70,250
MPDATA,EX,1,,28.5E6,27.4E6
MPDATA,NUXY,1,,0.266,0.274
MPDATA,ALPX,1,,8.50E-6,8.89E-6
MPDATA,DENS,1,,0.000734,0.000734
C*** Pipe Connection **
ET, 2,BEAM4
TYPE,2
REAL,2
MAT,2
KEYO, 2, 6,0
KEYO, 2, 7,0
KEYO, 2, 10,0
R, 2
RMOD, 2, 1,0.0011
RMOD, 2, 2,0.0219
RMOD, 2, 3,0.042
RMOD, 2, 4,0.0332
RMOD, 2, 5,0.0332
RMOD, 2, 6,0
RMOD, 2, 7,0
RMOD, 2, 8,0.004
RMOD, 2, 9,0
RMOD, 2, 10,0
RMOD, 2, 11,0
RMOD, 2, 12,0
RMOD, 2, 13,0
MPDATA,EX,2,,27.4E6,27.4E6
MPDATA,NUXY,2,,0.274,0.274
MPDATA,ALPX,2,,8.89E-6,8.89E-6
MPDATA,DENS,2,,1.0E-10,1.0E-10
BOPT,NUMB,OFF
BOPT,NO,1
C*** Block Geometry **
CYLIND,,2.50,0,6.217,0,360
K,10,,,3.36
K,11,4,,3.36
L,10,11
LWPLAN,,11
CYLIND,1.53,,0,4,0,360
VSBV,1,2
K,100
K,101,,,7.589
L,100,101
LWPLAN,,10
CYLIND,2.311,2.50,0,1.28,0,360
VSBV,3,1
CONE,2.138,1.53,0,0.597,0,360
VSBV,2,1
CYLIND,,1.53,0.597,2.763,0,360
VSBV,3,1
L,10,101

```

```
LWPLAN,,12
SPHERE,,1.53,0,360
VSBV,2,1
K,200,,,15
L,101,200
LWPLAN,,13
SPHERE,,1.62,0,360
VSBV,3,1
K,210,,,5.563
L,210,200
LWPLAN,,40
CONE,3,1,0,3,0,360
CONE,2.50,1.75,0,0.654,0,360
VSBV,1,3
VSBV,2,4
LWPLAN,,10
CYLIND,,1.53,,3.36,0,360
VSBV,1,2
ALLSEL,ALL,VOLU
C*** Mesh Density **
ESHAPE,2
ESIZE,0.5
C*** Refine mesh **
LESIZE,56,0.25
LESIZE,65,0.25
LESIZE,66,0.25
LESIZE,67,0.25
C*** Meshing of Block **
VATT,1,1,1
VMESH,ALL
N,20000,2.5,0,3.36
TYPE,2
REAL,2
MAT,2
E,20000,197
E,20000,198
E,20000,199
E,20000,200
E,20000,201
E,20000,192
E,20000,196
E,20000,195
E,20000,194
E,20000,193
E,20000,188
E,20000,252
E,20000,253
E,20000,254
E,20000,255
E,20000,247
E,20000,251
E,20000,250
E,20000,249
E,20000,248
E,20000,740
E,20000,739
E,20000,738
E,20000,755
E,20000,713
E,20000,294
E,20000,328
E,20000,366
E,20000,340
E,20000,339
E,20000,338
E,20000,337
E,20000,336
E,20000,335
E,20000,364
E,20000,327
E,20000,292
```

```
E,20000,714
E,20000,756
E,20000,743
E,20000,742
E,20000,741
NSEL,ALL
ESEL,ALL
CSYS,0
ASEL,S,AREA,,6,7,1,1
NSEL,R,LOC,Z,-.277,.413
LOCAL,11,2,,, -1.5681
CSYS,11
NROTAT,ALL
CSYS,0
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,5.969,6.157
CSYS,1
NSEL,R,LOC,X,-0.719,0.719
LOCAL,12,1,,,5.969
CSYS,12
NROTAT,ALL
CSYS,0
ALLSEL,ALL,VOLU
ALLSEL,BELOW,VOLU
NSEL,ALL
ESEL,ALL
WSORT,ALL
C*** Reference Temperature **
TREF,70
SAVE,block3g,db
FINISH
/EXIT
```

13.2 3-IN. ISB BLOCK APPLIED LOADING AND BOUNDARY CONDITIONS INPUT (block3s.inp)

```
/PREP7
RESUME,block3g,db
FINISH
/SOLU
ANTYPE,STAT
C*** Defining Boundary Conditions **
ASEL,S,AREA,,6,7,1,1
NSEL,R,LOC,Z,-.277,.413
CSYS,11
D,ALL,UX,0,0
CSYS,0
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,5.969,6.157
CSYS,1
NSEL,R,LOC,X,-0.719,0.719
CSYS,12
D,ALL,UY,0,0
CSYS,0
C*** Combined applied axial load (Preload + pressure + thermal + external) **
C*** used to determine the punch through failure mode and block stiffness **
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,5.969,6.157
CSYS,1
NSEL,R,LOC,X,-0.719,0.719
CSYS,0
*GET,HCTA,NODE,,COUNT
C*** 50 ft-lbf preload (LC1) **
AXIAL50=-21167/HCTA
F,ALL,FZ,AXIAL50
NSEL,ALL
ESEL,ALL
SOLVE
C*** 100 ft-lbf preload (LC2) **
FDELE,ALL,FZ
ASEL,S,AREA,,14,17,3,1
```

```

NSEL,R,LOC,Z,5.969,6.157
CSYS,1
NSEL,R,LOC,X,-0.719,0.719
CSYS,0
AXIAL100=-24167/HCTA
F,ALL,FZ,AXIAL100
NSEL,ALL
ESEL,ALL
SOLVE
C*** 150 ft-lbf preload (LC3) **
FDELE,ALL,FZ
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,5.969,6.157
CSYS,1
NSEL,R,LOC,X,-0.719,0.719
CSYS,0
AXIAL150=-26717/HCTA
F,ALL,FZ,AXIAL150
ALLSEL,ALL,VOLU
ALLSEL,BELOW,VOLU
NSEL,ALL
ESEL,ALL
SOLVE
FDELE,ALL,FZ
C*** Extrenal loading at pipe connection **
FORCEX=8320
FORCEY=18750
FORCEZ=22280
MOMENTX=(1784)*12
MOMENTY=(1784)*12
MOMENTZ=(1590)*12
C*** X Direction Loading (Force) **
FDELE,ALL,FZ
F,20000,FX,FORCEZ,,20000,1
SOLVE
FDELE,ALL,FX
F,20000,FX,-FORCEZ,,20000,1
SOLVE
C*** Y Direction Loading (Force) **
FDELE,ALL,FX
F,20000,FY,FORCEY,,20000,1
SOLVE
FDELE,ALL,FY
F,20000,FY,-FORCEY,,20000,1
SOLVE
C*** Z Direction Loading (Force) **
FDELE,ALL,FY
F,20000,FZ,FORCEX,,20000,1
SOLVE
FDELE,ALL,FZ
F,20000,FZ,-FORCEX,,20000,1
SOLVE
C*** X Direction Loading (Moment) **
FDELE,ALL,FZ
F,20000,MX,MOMENTZ,,20000,1
SOLVE
FDELE,ALL,MX
F,20000,MX,-MOMENTZ,,20000,1
SOLVE
C*** Y Direction Loading (Moment) **
FDELE,ALL,MX
F,20000,MY,MOMENTY,,20000,1
SOLVE
FDELE,ALL,MY
F,20000,MY,-MOMENTY,,20000,1
SOLVE
C*** Z Direction Loading (Moment) **
FDELE,ALL,MY
F,20000,MZ,MOMENTX,,20000,1
SOLVE
FDELE,ALL,MZ

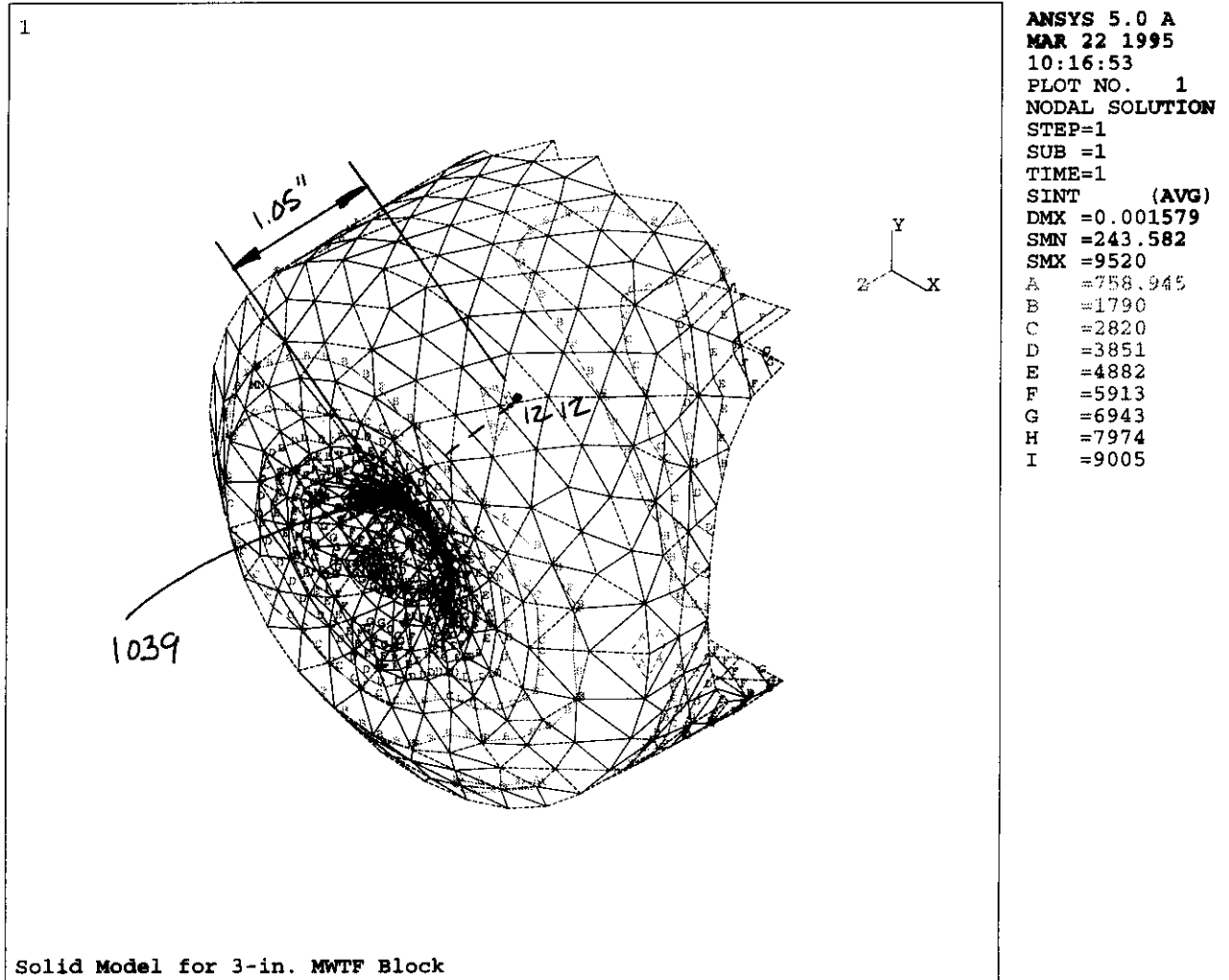
```



```
F,20000,MZ,-MOMENTX,,20000,1
SOLVE
FDELE,ALL,MZ
NSEL,ALL
ESEL,ALL
C*** Thermal Expansion **
TUNIF,70
BF,ALL,TEMP,250,250
C*** Internal pressure **
SFA,10,,PRES,400
SFA,18,,PRES,400
SFA,19,,PRES,400
SFA,20,,PRES,400
SFA,21,,PRES,400
SFA,24,,PRES,400
SFA,27,,PRES,400
SFA,29,,PRES,400
SFTRAN
NSEL,ALL
ESEL,ALL
SOLVE
SAVE,block3b.db
FINISH
/EXIT
```

13.3 LINEARIZED STRESS INTENSITIES THROUGH SECTIONS OF 3-IN. BLOCK MODEL

13.3.1 ISB TOP SECTION OF ISB BLOCK



Applied Loading (Axial loading for pre-load, thermal expansion, internal pressure, and axial external)

LC1 21,167 lbf/ number of nodes
LC2 24,167 lbf/ number of nodes
LC3 26,167 lbf/ number of nodes

Nodes used for stress linearization: 1039 and 1212 with a path length of 1.05 in.

13.3.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.05 in. UNDER 50 FT-LBF TORQUE AND COMBINED AXIAL EXTERNAL LOADS (filename SINTLC1.TP3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1039 OUTSIDE NODE = 1212

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -1979.    -2460.    -5944.    -224.3    1160.    -2143.
C      S1      S2      S3      SINT      SEQV
O -752.5    -2542.    -7089.     6337.    5658.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -3696.    -5043.    -5961.    -703.3    -320.0     93.30
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O 3696.     5043.     5961.     703.3     320.0    -93.30
      S1      S2      S3      SINT      SEQV
I -3379.    -5253.    -6069.     2690.    2389.
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O 6069.     5253.     3379.     2690.    2389.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -5675.    -7504.    -.1191E+05 -927.5    840.2    -2050.
C -1979.    -2460.    -5944.    -224.3    1160.    -2143.
O 1718.     2583.     16.21     479.0    1480.    -2236.
      S1      S2      S3      SINT      SEQV
I -4614.    -7892.    -.1258E+05 7965.     6933.
C -752.5    -2542.    -7089.     6337.    5658.
O 3600.     2730.    -2013.     5613.    5233.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -2069.    -3117.    -4229.    -145.0    -119.2     312.0
C 827.6     1116.     1473.     101.8    -14.00    -241.6
O -1224.    -1686.    -2314.    -109.5     8.545     324.9
      S1      S2      S3      SINT      SEQV
I -2002.    -3132.    -4281.     2279.    1974.
C 1559.     1133.     725.3     833.2     721.7
O -1116.    -1703.    -2405.     1289.    1118.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -7744.    -.1062E+05 -.1613E+05 -1073.     721.0    -1738.
C -1151.    -1345.    -4471.    -122.5     1146.    -2385.
O 493.9     896.9    -2297.     369.4     1489.    -1912.
      S1      S2      S3      SINT      SEQV      TEMP
I -7003.    -.1097E+05 -.1652E+05 9520.     8282.     70.00
C 358.0     -1404.    -5921.     6279.     5609.
O 1754.     1091.    -3751.     5505.     5206.     70.00

```

13.3.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.05 in. UNDER 100 FT-LBF TORQUE AND
COMBINED AXIAL EXTERNAL LOADS (filename SINTLC2.TP3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1039 OUTSIDE NODE = 1212

LOAD STEP 2 SUBSTEP= 1
TIME= 2.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -2259.    -2809.    -6787.    -256.1    1325.    -2447.
C      S1      S2      S3      SINT      SEQV
O -859.2    -2902.    -8094.     7235.    6460.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -4220.    -5758.    -6806.    -802.9    -365.3    106.5
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O 4220.     5758.     6806.     802.9     365.3    -106.5
      S1      S2      S3      SINT      SEQV
I -3857.    -5997.    -6929.    3072.    2728.
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O 6929.     5997.     3857.     3072.    2728.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -6479.    -8567.    -.1359E+05 -1059.    959.3    -2340.
C -2259.    -2809.    -6787.    -256.1    1325.    -2447.
O 1961.     2949.     18.51     546.8    1690.    -2553.
      S1      S2      S3      SINT      SEQV
I -5268.    -9010.    -.1436E+05 9093.    7916.
C -859.2    -2902.    -8094.     7235.    6460.
O 4111.     3117.    -2298.     6409.    5974.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -2363.    -3559.    -4828.    -165.5    -136.1    356.2
C 944.9     1274.     1682.     116.2    -15.98    -275.8
O -1397.    -1925.    -2641.    -125.1     9.756    370.9
      S1      S2      S3      SINT      SEQV
I -2286.    -3576.    -4888.     2602.    2254.
C 1779.     1293.     828.1     951.3    824.0
O -1274.    -1944.    -2746.     1472.    1277.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -8842.    -.1213E+05 -.1842E+05 -1225.    823.2    -1984.
C -1314.    -1535.    -5105.    -139.9    1309.    -2723.
O 563.9     1024.    -2623.     421.8    1700.    -2183.
      S1      S2      S3      SINT      SEQV      TEMP
I -7995.    -.1253E+05 -.1886E+05 .1087E+05 9456.     70.00
C 408.8     -1603.    -6760.     7169.    6404.
O 2002.     1246.    -4283.     6286.    5943.     70.00

```

13.3.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.05 in. UNDER 150 FT-LBF TORQUE AND COMBINED AXIAL EXTERNAL LOADS (filename SINTLC3.TP3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1039 OUTSIDE NODE = 1212

LOAD STEP 3 SUBSTEP= 1
TIME= 3.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -2497.    -3105.    -7503.    -283.1    1464.    -2705.
C      S1      S2      S3      SINT      SEQV
O -949.9    -3208.    -8948.     7998.     7142.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -4666.    -6366.    -7524.    -887.6    -403.9    117.8
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O 4666.     6366.     7524.     887.6     403.9    -117.8
      S1      S2      S3      SINT      SEQV
I -4265.    -6630.    -7660.    3396.     3016.
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O 7660.     6630.     4265.     3396.     3016.

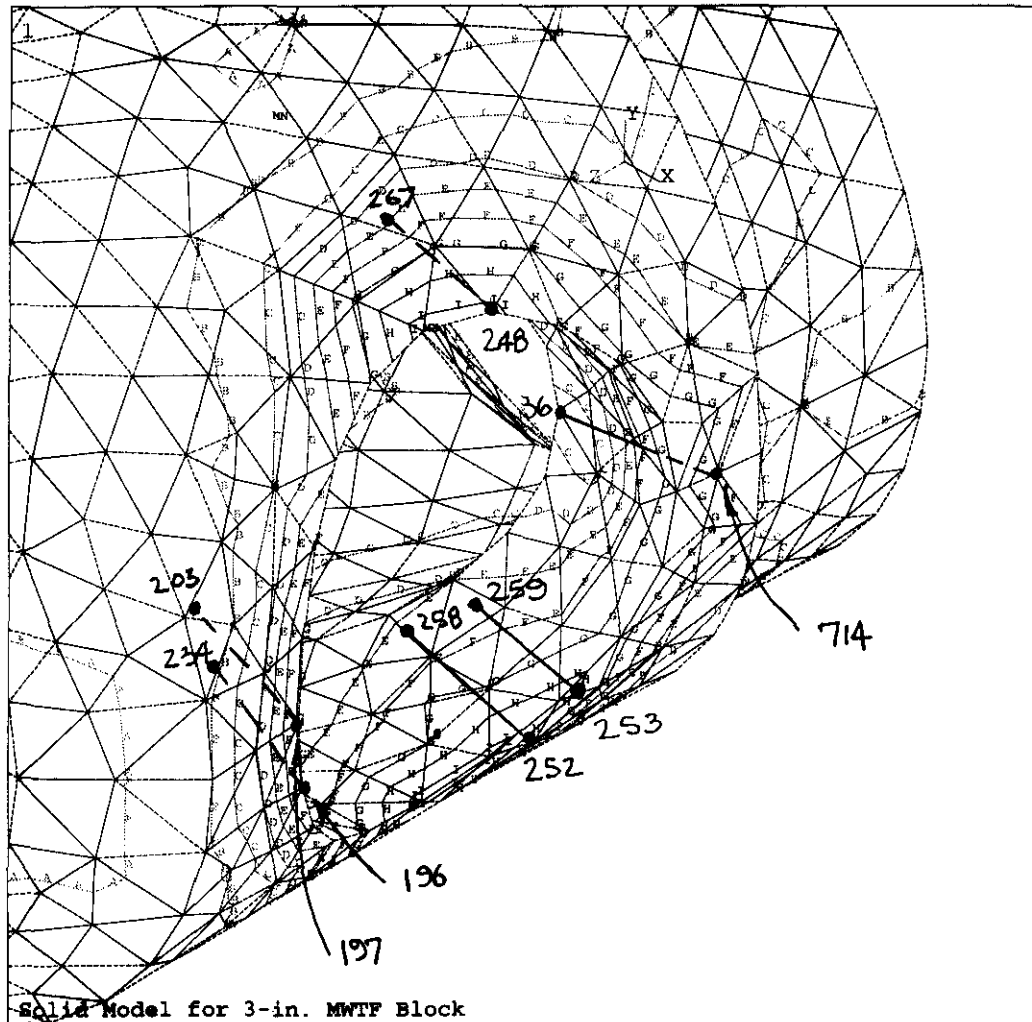
** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -7163.    -9471.    -.1503E+05 -1171.    1061.    -2587.
C -2497.    -3105.    -7503.    -283.1    1464.    -2705.
O 2168.     3260.     20.47     604.5    1868.    -2823.
      S1      S2      S3      SINT      SEQV
I -5824.    -9961.    -.1588E+05 .1005E+05 8751.
C -949.9    -3208.    -8948.     7998.     7142.
O 4544.     3446.    -2541.     7085.     6605.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -2612.    -3935.    -5337.    -183.0    -150.4    393.8
C 1045.     1408.     1860.     128.4    -17.67    -304.9
O -1545.    -2128.    -2920.    -138.3    10.79     410.0
      S1      S2      S3      SINT      SEQV
I -2527.    -3953.    -5404.     2877.     2491.
C 1967.     1430.     915.5     1052.     910.9
O -1408.    -2150.    -3036.     1627.     1411.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -9775.    -.1341E+05 -.2036E+05 -1354.     910.1    -2194.
C -1453.    -1697.    -5643.    -154.7     1447.    -3010.
O 623.4     1132.    -2900.     466.3     1879.    -2413.
      S1      S2      S3      SINT      SEQV      TEMP
I -8839.    -.1385E+05 -.2086E+05 .1202E+05 .1045E+05 70.00
C 451.9     -1772.    -7473.     7925.     7080.
O 2214.     1377.    -4735.     6949.     6571.     70.00

```

13.4 ISB PIPE CONNECTION SECTION OF BLOCK



ANSYS 5.0 A
MAR 22 1995
10:19:06
PLOT NO. 1
NODAL SOLUTION
STEP=5
SUB =1
TIME=5
SINT (AVG)
DMX =0.002575
SMN =513.718
SMX =13751
A =1249
B =2720
C =4191
D =5661
E =7132
F =8603
G =10074
H =11544
I =13015

Applied Loading (individual loading for pre-load, thermal expansion, internal pressure, and external forces and moments at pipe intersection)

- LC1 Fz = -21,167 lbf /number of nodes, applied @ top of block to account for 50 ft-lbf of pre-load torque, axial thermal expansion, and internal pressure (nodes 253 and 259, path length of 0.911 in.)
- LC5 Fx = -22,280 lbf applied at node 20,000 (nodes 197 and 203, with a path length of 0.99 in.)
- LC7 Fy = -18,750 lbf applied at node 20,000 (nodes 196 and 234, with a path length of 0.893 in.)
- LC9 Fz = -8,320 lbf applied at node 20,000 (nodes 248 and 267, with a path length of 1.102 in.)
- LC10 Mx = 1590 ft-lbf applied at node 20,000 (nodes 252 and 258, with a path length of 1.094 in.)
- LC13 My = -1784 ft-lbf applied at node 20,000 (nodes 714 and 36, with a path length of 1.026 in.)
- LC15 Mz = -1784 ft-lbf applied at node 20,000 (nodes 248 and 267, with a path length of 1.102 in.)
- LC16 Internal Pressure of 400 psi and uniform temperature @ 250 deg. F is applied to block model (nodes 36 and 714, path length 1.026 in.)

13.4.1 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.911 in. UNDER 50 FT-LBF TORQUE, AXIAL INTERNAL PRESSURE, AND AXIAL THERMAL EXPANSION LOADS (filenames SINTLC1.PS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 253 OUTSIDE NODE = 259

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -12.03    -60.14   -4022.    256.5    986.1    368.1
C      S1      S2      S3      SINT     SEQV
O 433.4    -252.5   -4275.    4708.    4406.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 686.3    -88.12   -1314.    575.1    585.5   -360.8
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -686.3     88.12    1314.   -575.1   -585.5    360.8
C      S1      S2      S3      SINT     SEQV
I 993.3    -28.30   -1681.    2674.    2337.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 1681.     28.30   -993.3    2674.    2337.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 674.2    -148.3   -5336.    831.6    1572.    7.338
C -12.03    -60.14   -4022.    256.5    986.1    368.1
O -698.3     27.98   -2708.   -318.6    400.6    728.9
C      S1      S2      S3      SINT     SEQV
I 1312.    -339.8   -5782.    7094.    6429.
C 433.4    -252.5   -4275.    4708.    4406.
O 154.4    -512.5   -3021.    3175.    2900.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -181.0    -3.658   -319.9    62.75    43.42    4.645
C 173.6     8.718    307.5   -50.00   -55.68   -5.635
O -185.1    -15.97   -346.5    53.90    64.30    9.204
C      S1      S2      S3      SINT     SEQV
I 21.66    -200.4   -325.8    347.5    304.8
C 317.6    186.9   -14.70    332.3    290.0
O 11.32    -200.3   -358.6    369.9    321.4

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 493.2    -151.9   -5656.    894.4    1615.    11.98
C 161.6    -51.43   -3715.    206.5    930.4    362.5
O -883.4    12.01   -3055.   -264.7    464.9    738.1
C      S1      S2      S3      SINT     SEQV      TEMP
I 1266.    -478.4   -6102.    7368.    6669.    70.00
C 462.3    -106.8   -3960.    4422.    4167.
O 110.0    -673.4   -3363.    3473.    3155.    70.00

```

13.4.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.99 in. WITH AN EXTERNAL FORCE OF
Fx = -22,280 lbf, APPLIED AT NODE 20,000 (filenames SINTLC5.PS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 197 OUTSIDE NODE = 203

LOAD STEP 5 SUBSTEP= 1
TIME= 5.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
-8859.    -1956.    -0.1052E+05    -89.51    115.3    968.9
S1        S2        S3        SINT      SEQV
-1954.    -8414.    -0.1097E+05    9017.    8049.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -2301.    -1042.    -5578.    -873.5    282.1    5.283
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 2301.    1042.    5578.    873.5    -282.1    -5.283
S1        S2        S3        SINT      SEQV
I -582.8    -2742.    -5597.    5014.    4356.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 5597.    2742.    582.8    5014.    4356.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.1116E+05 -2999.    -0.1610E+05    -963.0    397.4    974.1
C -8859.    -1956.    -0.1052E+05    -89.51    115.3    968.9
O -6557.    -914.0    -4945.    784.0    -166.8    963.6
S1        S2        S3        SINT      SEQV
I -2881.    -0.1107E+05 -0.1631E+05 0.1343E+05 0.1172E+05
C -1954.    -8414.    -0.1097E+05    9017.    8049.
O -806.8    -4504.    -7106.    6299.    5483.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -51.79    -795.2    -1076.    -135.2    36.38    61.24
C 50.79    794.7    1073.    134.8    -36.26    -61.23
O -49.79    -794.2    -1071.    -134.4    36.14    61.23
S1        S2        S3        SINT      SEQV
I -25.18    -810.9    -1087.    1061.    953.9
C 1084.    810.3    24.32    1060.    952.9
O -23.46    -809.7    -1082.    1058.    951.9

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.1121E+05 -3794.    -0.1718E+05    -1098.    433.8    1035.
C -8808.    -1162.    -9450.    45.32    79.04    907.6
O -6607.    -1708.    -6016.    649.5    -130.7    1025.
S1        S2        S3        SINT      SEQV      TEMP
I -3629.    -0.1117E+05 -0.1738E+05 0.1375E+05 0.1193E+05 70.00
C -1161.    -8167.    -0.1009E+05    8931.    8141.
O -1624.    -5267.    -7441.    5817.    5091.    70.00

```


13.4.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.893 in. WITH AN EXTERNAL FORCE OF
Fy = -18,750 lbf, APPLIED AT NODE 20,000 (filenames SINTLC7.PS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 196 OUTSIDE NODE = 234

LOAD STEP 7 SUBSTEP= 1
TIME= 7.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I 239.7    2078.    2474.    -4856.    3778.    -755.3
C      S1      S2      S3      SINT      SEQV
O 8209.    948.8    -4366.    0.1258E+05  0.1093E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -196.9    7.715    1972.    -2860.    2392.    -386.1
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 196.9    -7.715    -1972.    2860.    -2392.    386.1
C      S1      S2      S3      SINT      SEQV
I 4505.    641.9    -3364.    7870.    6816.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 3364.    -641.9    -4505.    7870.    6816.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 42.88    2086.    4446.    -7717.    6170.    -1141.
C 239.7    2078.    2474.    -4856.    3778.    -755.3
O 436.6    2070.    501.8    -1996.    1387.    -369.2
C      S1      S2      S3      SINT      SEQV
I 0.1264E+05 1642.    -7709.    0.2035E+05 0.1764E+05
C 8209.    948.8    -4366.    0.1258E+05 0.1093E+05
O 3951.    145.2    -1088.    5039.    4550.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 210.6    322.6    752.9    -290.0    372.1    11.45
C -203.8    -312.5    -746.2    299.2    -362.2    -10.57
O 226.4    345.5    764.4    -264.0    390.3    14.17
C      S1      S2      S3      SINT      SEQV
I 993.3    402.5    -109.7    1103.    956.1
C 121.8    -405.2    -979.0    1101.    953.6
O 1019.    394.7    -76.99    1096.    951.9

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 253.5    2408.    5199.    -8007.    6542.    -1130.
C 35.93    1765.    1728.    -4557.    3416.    -765.8
O 663.0    2416.    1266.    -2260.    1777.    -355.0
C      S1      S2      S3      SINT      SEQV      TEMP
I 0.1355E+05 2130.    -7819.    0.2137E+05 0.1852E+05 70.00
C 7345.    429.3    -4245.    0.1159E+05 0.1010E+05
O 4776.    723.4    -1154.    5930.    5249.    70.00

```

13.4.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.102 in. WITH AN EXTERNAL FORCE OF
Fz = -8,320 lbf, APPLIED AT NODE 20,000 (filenames SINTLC9.PS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 248 OUTSIDE NODE = 267

LOAD STEP 9 SUBSTEP= 1
TIME= 9.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  -432.7    -395.3    -3349.    -297.2    -64.94    -1037.
C      S1      S2      S3      SINT      SEQV
O  54.87    -544.4    -3687.    3742.    3481.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   763.5    -293.3    -3040.    -713.1    214.4    -1623.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  -763.5     293.3     3040.     713.1    -214.4     1623.
C      S1      S2      S3      SINT      SEQV
I  1647.    -577.4    -3639.    5286.    4597.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  3639.     577.4    -1647.    5286.    4597.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   330.8    -688.5    -6389.    -1010.    149.4    -2660.
C  -432.7    -395.3    -3349.    -297.2    -64.94    -1037.
O  -1196.    -102.0    -308.8     415.9    -279.3     585.6
C      S1      S2      S3      SINT      SEQV
I  1682.    -1108.    -7320.    9002.    7981.
C   54.87    -544.4    -3687.    3742.    3481.
O   92.55    -52.36    -1647.    1740.    1672.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   308.8     184.1    -710.0    -214.6    181.9    -405.7
C  -91.39    -98.76     406.1     80.14    -9.289     202.5
O   290.6    -10.78    -779.3    -203.7     70.95    -350.8
C      S1      S2      S3      SINT      SEQV
I   613.8     31.15    -862.1     1476.    1288.
C   478.7    -46.49    -216.2     694.9     627.5
O   488.4    -103.7    -884.2     1373.    1192.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   639.6    -504.5    -7099.    -1225.    331.3    -3066.
C  -524.1    -494.0    -2943.    -217.1    -74.23    -834.9
O  -905.6    -112.8    -1088.     212.3    -208.4     234.9
C      S1      S2      S3      SINT      SEQV      TEMP
I  2282.    -1079.    -8167.    0.1045E+05  9240.     70.00
C  -159.5    -591.6    -3210.     3050.    2859.
O  -37.76    -749.0    -1320.     1282.    1112.     70.00

```

13.4.5 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.094 in. WITH AN EXTERNAL MOMENT OF
Mx = 1590 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC10.PS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSY= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 252 OUTSIDE NODE = 258

LOAD STEP 10 SUBSTEP= 1
TIME= 10.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

** MEMBRANE **

	SX	SY	SZ	SXY	SYZ	SXZ
	534.1	429.8	-618.4	516.6	-580.2	-1320.
	S1	S2	S3	SINT	SEQV	
	1810.	41.91	-1506.	3316.	2874.	

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	506.8	0.2630	-1804.	430.5	-266.0	-1372.
C	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
O	-506.8	-0.2630	1804.	-430.5	266.0	1372.
	S1	S2	S3	SINT	SEQV	
I	1335.	-187.6	-2444.	3779.	3293.	
C	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	
O	2444.	187.6	-1335.	3779.	3293.	

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	1041.	430.0	-2422.	947.1	-846.2	-2693.
C	534.1	429.8	-618.4	516.6	-580.2	-1320.
O	27.32	429.5	1185.	86.17	-314.1	52.26
	S1	S2	S3	SINT	SEQV	
I	3089.	-127.6	-3912.	7001.	6069.	
C	1810.	41.91	-1506.	3316.	2874.	
O	1299.	346.5	-3.539	1303.	1168.	

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	271.8	157.2	-602.0	183.1	-5.964	-293.2
C	-187.2	4.786	446.9	-127.8	-39.90	154.6
O	149.4	-33.12	-704.6	154.3	-7.433	-338.9
	S1	S2	S3	SINT	SEQV	
I	463.8	57.26	-694.0	1158.	1017.	
C	492.3	44.34	-272.2	764.6	665.4	
O	328.5	-91.64	-825.2	1154.	1011.	

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE

	SX	SY	SZ	SXY	SYZ	SXZ
I	1313.	587.2	-3024.	1130.	-852.2	-2986.
C	346.9	434.5	-171.5	388.8	-620.1	-1166.
O	176.7	396.4	480.8	240.5	-321.5	-286.6
	S1	S2	S3	SINT	SEQV	TEMP
I	3503.	-68.57	-4558.	8061.	6996.	70.00
C	1674.	84.09	-1148.	2822.	2450.	
O	945.0	114.7	-5.872	950.9	896.7	70.00

13.4.6 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.026 in. WITH AN EXTERNAL MOMENT OF
My = -1784 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC13.PS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 714 OUTSIDE NODE = 36

LOAD STEP 13 SUBSTEP= 1
TIME= 13.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I 3532.    3868.    801.1   -1022.    564.3    612.2
C      S1      S2      S3      SINT      SEQV
O 4736.    2982.    483.5    4252.    3701.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 3279.    6125.    1249.   -856.4    994.3    164.2
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -3279.   -6125.   -1249.    856.4   -994.3   -164.2
C      S1      S2      S3      SINT      SEQV
I 6522.    3126.    1005.    5517.    4821.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -1005.   -3126.   -6522.    5517.    4821.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 6811.    9992.    2050.   -1878.    1559.    776.3
C 3532.    3868.    801.1   -1022.    564.3    612.2
O 253.3   -2257.   -448.3   -165.3   -430.0    448.0
C      S1      S2      S3      SINT      SEQV
I 0.1100E+05 6346.    1507.    9494.    8222.
C 4736.    2982.    483.5    4252.    3701.
O 513.8   -610.1   -2356.    2869.    2504.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -788.6   -320.5    199.5    48.65    228.9   -102.6
C 612.5    401.2   -18.72   -125.5   -157.3    82.47
O -720.2   -699.1   -249.1    112.2    346.1   -129.4
C      S1      S2      S3      SINT      SEQV
I 291.7   -390.5   -810.8    1102.    963.7
C 699.9    368.5   -73.40    773.3    672.0
O -55.53   -627.5   -985.3    929.8    812.3

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 6023.    9672.    2250.   -1829.    1787.    673.7
C 4145.    4269.    782.3   -1147.    407.0    694.7
O -466.8   -2956.   -697.3   -53.11   -83.86    318.6
C      S1      S2      S3      SINT      SEQV      TEMP
I 0.1067E+05 5706.    1568.    9102.    7893.    70.00
C 5363.    3301.    532.0    4831.    4199.
O -240.2   -920.2   -2960.    2720.    2451.    70.00

```

13.4.7 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.102 in. WITH AN EXTERNAL MOMENT OF
Mz = -1784 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC15.PS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 248 OUTSIDE NODE = 267

LOAD STEP 15 SUBSTEP= 1
TIME= 15.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
7242.    1462.    4556.    -345.9    1432.    -434.5
      S1      S2      S3      SINT      SEQV
7371.    4993.    896.6     6474.    5672.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 2375.    1822.    3858.     59.54    1989.    -1024.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -2375.    -1822.    -3858.    -59.54    -1989.     1024.
      S1      S2      S3      SINT      SEQV
I 5322.    2318.     416.2     4906.    4284.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -416.2    -2318.    -5322.     4906.    4284.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 9617.    3284.     8415.    -286.3    3422.    -1458.
C 7242.    1462.     4556.    -345.9    1432.    -434.5
O 4867.    -359.9     698.0    -405.4    -556.8     589.2
      S1      S2      S3      SINT      SEQV
I 0.1133E+05 8430.    1553.     9780.    8700.
C 7371.    4993.     896.6     6474.    5672.
O 4992.     816.0    -602.7     5594.    5037.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -549.4    1051.     1030.    -29.28    305.9    -166.7
C 531.4    -142.7    -53.80     9.897    -142.6     144.9
O -330.3    190.3     379.5    110.7     456.6    -239.7
      S1      S2      S3      SINT      SEQV
I 1357.     742.0    -566.8     1923.    1701.
C 566.1     28.22    -259.3     825.4     725.7
O 764.2    -13.25    -511.4     1276.    1114.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 9068.     4336.    9445.    -315.6    3728.    -1625.
C 7773.     1320.    4503.    -336.0    1290.    -289.7
O 4536.    -169.6     1077.    -294.7    -100.2     349.5
      S1      S2      S3      SINT      SEQV      TEMP
I 0.1221E+05 8299.    2336.     9878.    8616.     70.00
C 7832.     4908.    855.5     6976.    6068.
O 4591.     1047.    -192.9     4784.    4300.     70.00

```

13.4.8 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.026 in. UNDER UNIFORM TEMPERATURE AND PRESSURE OF 250 deg. F AND 400 psi (filenames SINTLC16.PS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 36 OUTSIDE NODE = 714

LOAD STEP 16 SUBSTEP= 1
TIME= 16.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  60.81    1807.    -1.845   -99.23    214.0   -87.41
C      S1      S2      S3      SINT      SEQV
I 1839.    99.06   -71.73    1910.    1831.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  68.04    1292.    68.74   -0.6874   -132.2    14.49
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -68.04   -1292.   -68.74    0.6874    132.2   -14.49
C      S1      S2      S3      SINT      SEQV
I 1306.    77.16    45.49    1260.    1245.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -45.49   -77.16   -1306.    1260.    1245.

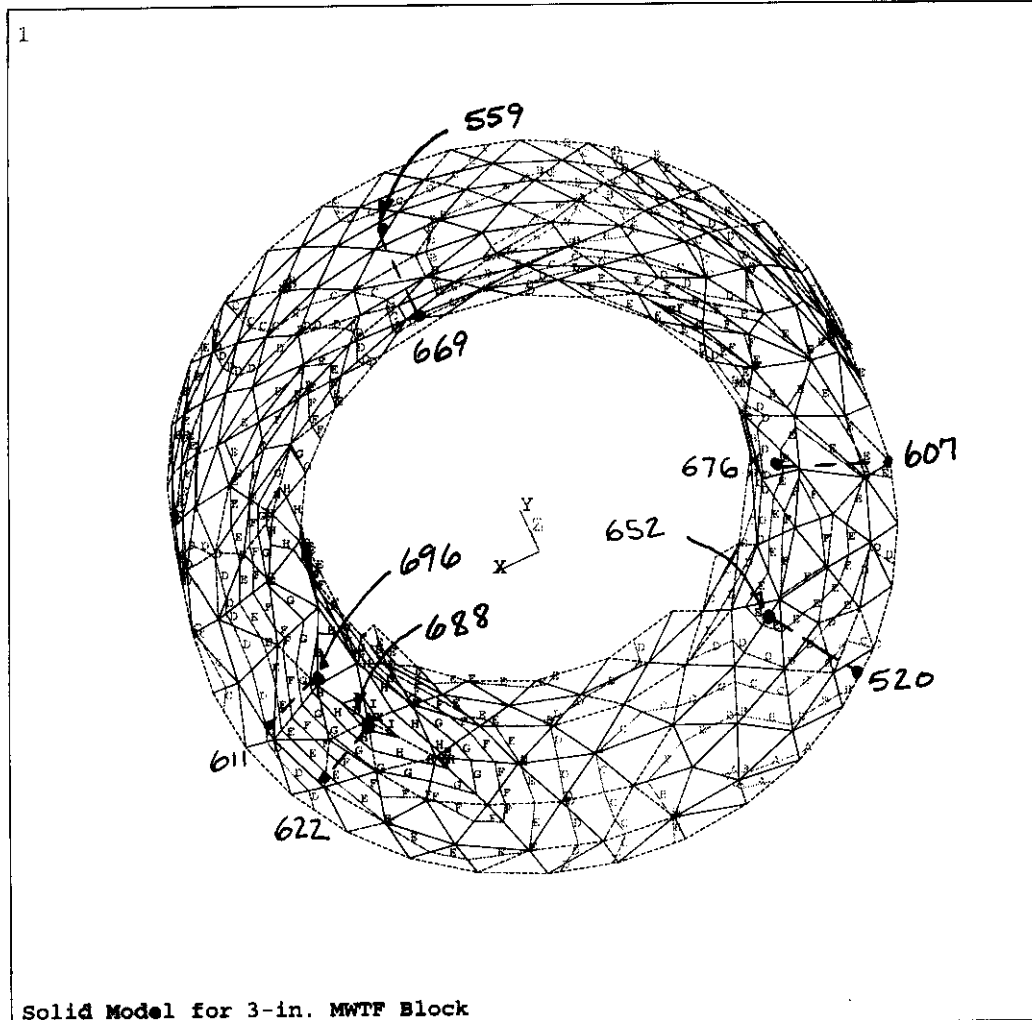
** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 128.9    3099.    66.90   -99.92    81.80   -72.92
C  60.81    1807.    -1.845   -99.23    214.0   -87.41
O -7.238    515.4   -70.59   -98.54    346.2   -101.9
C      S1      S2      S3      SINT      SEQV
I 3104.    171.5    18.59    3086.    3012.
C 1839.    99.06   -71.73    1910.    1831.
O 700.8    -20.06   -243.1    943.9    854.5

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  99.70    274.8    19.45    47.04   -26.09    47.91
C -39.21   -139.4   -39.91   -30.02    26.32   -21.34
O  40.63    232.8    36.74    11.59   -28.94    35.06
C      S1      S2      S3      SINT      SEQV
I 287.4    116.3   -9.762    297.1    258.3
C -6.270   -60.85   -151.4    145.1    126.9
O 237.2    73.04   -0.6599E-01 237.3    210.5

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 228.6    3373.    86.35   -52.87    55.70   -25.01
C 21.60    1668.   -41.75   -129.3    240.3   -108.8
O 33.39    748.2   -33.85   -86.95    317.3   -66.85
C      S1      S2      S3      SINT      SEQV      TEMP
I 3375.    231.6    81.43    3294.    3221.    250.0
C 1713.    66.49   -131.9    1845.    1754.
O 873.7    26.99   -152.9    1027.    949.5    250.0

```

13.5 ISB BOTTOM SECTION OF BLOCK



ANSYS 5.0 A
MAR 22 1995
10:23:48
PLOT NO. 1
NODAL SOLUTION
STEP=5
SUB =1
TIME=5
SINT (AVG)
DMX =0.002575
SMN =513.718
SMX =7932
A =925.822
B =1750
C =2574
D =3398
E =4223
F =5047
G =5871
H =6695
I =7519

Applied Loading (individual loading for pre-load, thermal expansion, internal pressure, and external forces and moments at pipe intersection)

- LC1 Fz = -21,167 lbf /number of nodes, applied @ top of block to account for 50 ft-lbf of pre-load torque, axial thermal expansion, and internal pressure (nodes 688 and 622, path length of 0.626 in.)
- LC5 Fx = -22,280 lbf applied at node 20,000 (nodes 696 and 611, with a path length of 0.652 in.)
- LC7 Fy = -18,750 lbf applied at node 20,000 (nodes 669 and 559, with a path length of 0.651 in.)
- LC9 Fz = -8,320 lbf applied at node 20,000 (nodes 688 and 622, with a path length of 0.626 in.)
- LC10 Mx = 1590 ft-lbf applied at node 20,000 (nodes 688 and 622, with a path length of 0.626 in.)
- LC13 My = -1784 ft-lbf applied at node 20,000 (nodes 676 and 607, with a path length of 0.574 in.)
- LC15 Mz = -1784 ft-lbf applied at node 20,000 (nodes 688 and 622, with a path length of 0.626 in.)
- LC16 Internal Pressure of 400 psi and uniform temperature @ 250 deg. F is applied to block model (nodes 652 and 520, path length 0.732 in.)

13.5.1 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.626 in. UNDER 50 FT-LBF TORQUE, AXIAL INTERNAL PRESSURE, AND AXIAL THERMAL EXPANSION LOADS (filenames SINTLC1.BS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 688 OUTSIDE NODE = 622

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  901.7    -410.2    -3386.    2424.    1626.    -985.1
C      S1      S2      S3      SINT      SEQV
O  2764.    -858.7    -4800.    7564.    6553.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -2870.    -2939.    -3888.    415.4    442.0    -1109.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  2870.     2939.     3888.    -415.4    -442.0    1109.
C      S1      S2      S3      SINT      SEQV
I  -2140.    -2765.    -4792.    2651.    2401.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  4792.     2765.     2140.    2651.    2401.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -1968.    -3349.    -7274.    2839.    2068.    -2094.
C  901.7     -410.2    -3386.    2424.    1626.    -985.1
O  3772.     2528.     502.9    2008.    1184.    123.6
C      S1      S2      S3      SINT      SEQV
I  285.4     -3401.    -9476.    9761.    8538.
C  2764.     -858.7    -4800.    7564.    6553.
O  5389.     1637.    -222.9    5612.    4951.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -1503.    -1011.    -2513.    281.5    572.4    -902.1
C  1155.     746.4    1476.    -224.3    -420.0    541.9
O  -1320.    -857.7    -1766.    255.0    483.6    -645.8
C      S1      S2      S3      SINT      SEQV
I  -815.2    -986.6    -3225.    2410.    2329.
C  2051.     773.1    553.4    1498.    1401.
O  -646.7    -881.9    -2415.    1768.    1663.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -3471.    -4359.    -9787.    3121.    2640.    -2996.
C  2057.     336.1    -1909.    2199.    1206.    -443.2
O  2452.     1671.    -1263.    2263.    1667.    -522.1
C      S1      S2      S3      SINT      SEQV      TEMP
I  -720.2    -4270.    -0.1263E+05  0.1191E+05  0.1059E+05  70.00
C  3577.     -246.5    -2847.    6424.    5597.
O  4446.     897.5    -2484.    6930.    6002.    70.00

```


13.5.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.652 in. WITH AN EXTERNAL FORCE OF
Fx = -22,280 lbf, APPLIED AT NODE 20,000 (filenames SINTLC5.BS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 696 OUTSIDE NODE = 611

LOAD STEP 5 SUBSTEP= 1
TIME= 5.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -399.6    1198.    -1722.    1281.    787.2    -834.0
C      S1      S2      S3      SINT      SEQV
O 1934.    -277.2    -2580.    4514.    3910.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -814.7    -948.0    -2218.    785.7    -665.7    -917.7
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 814.7     948.0     2218.    -785.7    665.7     917.7
C      S1      S2      S3      SINT      SEQV
I 394.1     -1657.    -2718.    3112.    2740.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 2718.     1657.    -394.1    3112.    2740.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1214.    250.2     -3940.    2067.    121.6     -1752.
C -399.6    1198.    -1722.    1281.    787.2     -834.0
O 415.1     2146.    496.6     495.8    1453.     83.67
C      S1      S2      S3      SINT      SEQV
I 1867.    -1749.    -5023.    6890.    5970.
C 1934.    -277.2    -2580.    4514.    3910.
O 3076.     373.9    -391.6     3467.    3155.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -536.0    -820.5    -1105.    358.2    200.7     -336.9
C 328.9     426.8     584.4    -175.0    15.50     224.0
O -478.7    -658.0    -755.7     257.4    15.79     -280.9
C      S1      S2      S3      SINT      SEQV
I -253.3    -755.3    -1453.    1200.    1044.
C 735.7     489.3     115.1     620.6    541.3
O -200.5    -683.9    -1008.     807.5    703.8

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1750.    -570.3    -5045.    2425.    322.2     -2089.
C -70.69    1625.    -1137.    1106.    802.7     -610.0
O -63.56    1488.    -259.1     753.2    1469.     -197.2
C      S1      S2      S3      SINT      SEQV      TEMP
I 1518.    -2470.    -6414.    7932.    6869.     70.00
C 2237.     28.94    -1849.    4085.    3542.
O 2451.     56.40    -1342.    3793.    3323.     70.00

```

13.5.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.651 in. WITH AN EXTERNAL FORCE OF
Fy = -18,750 lbf, APPLIED AT NODE 20,000 (filenames SINTLC7.BS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 669 OUTSIDE NODE = 559

LOAD STEP 7 SUBSTEP= 1
TIME= 7.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  961.3    -1807.    -2864.    -728.5    -1905.    -146.4
C      S1      S2      S3      SINT      SEQV
O  1175.    -513.9    -4372.    5547.    4925.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -932.7    -1832.    -1100.    338.0    -537.2    115.6
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O   932.7     1832.     1100.    -338.0     537.2    -115.6
C      S1      S2      S3      SINT      SEQV
I  -771.1    -880.5    -2213.    1442.    1391.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O   2213.     880.5     771.1    1442.    1391.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   28.60    -3639.    -3965.    -390.5    -2442.    -30.78
C   961.3    -1807.    -2864.    -728.5    -1905.    -146.4
O  1894.     24.55    -1764.    -1067.    -1368.    -262.1
C      S1      S2      S3      SINT      SEQV
I   90.09    -1403.    -6263.    6353.    5754.
C  1175.    -513.9    -4372.    5547.    4925.
O  2408.     376.7    -2630.    5037.    4390.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -213.0    -97.50    -672.6    514.1    169.9    123.6
C   82.02    -3.899    248.5    -241.4    -82.45    -58.61
O  -108.3    -10.04    -332.9    302.9    102.9    73.34
C      S1      S2      S3      SINT      SEQV
I   402.7    -663.9    -721.9    1125.    1097.
C   287.7    266.4    -227.5    515.2    504.9
O   273.8    -351.4    -373.7    647.6    636.7

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -184.4    -3737.    -4637.    123.6    -2272.    92.77
C  1043.    -1811.    -2616.    -969.9    -1987.    -205.0
O  1786.     14.51    -2097.    -763.7    -1265.    -188.7
C      S1      S2      S3      SINT      SEQV      TEMP
I  -180.0    -1871.    -6507.    6327.    5674.    70.00
C  1393.    -423.4    -4354.    5747.    5088.
O  2089.     358.2    -2744.    4833.    4242.    70.00

```

13.5.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.626 in. WITH AN EXTERNAL FORCE OF
Fz = -8,320 lbf, APPLIED AT NODE 20,000 (filenames SINTLC9.BS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 688 OUTSIDE NODE = 622

LOAD STEP 9 SUBSTEP= 1
TIME= 9.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  620.2    -128.0    -1713.    1370.    618.2    -657.7
C      S1      S2      S3      SINT      SEQV
O  1674.    -517.1    -2378.    4051.    3512.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -1260.    -1449.    -2023.    308.1    177.4    -579.4
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  1260.     1449.     2023.    -308.1    -177.4    579.4
C      S1      S2      S3      SINT      SEQV
I  -878.8    -1423.    -2431.    1552.    1364.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  2431.     1423.     878.8    1552.    1364.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -639.7    -1577.    -3737.    1679.    795.6    -1237.
C  620.2     -128.0    -1713.    1370.    618.2    -657.7
O  1880.     1321.     310.0    1062.    440.8    -78.33
C      S1      S2      S3      SINT      SEQV
I  699.6     -1877.    -4776.    5475.    4744.
C  1674.     -517.1    -2378.    4051.    3512.
O  2717.     805.9     -12.12    2729.    2426.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -647.3    -475.8    -1261.    200.3    344.2    -443.9
C  519.0     368.6     729.4    -130.6    -219.5    269.5
O  -589.4    -420.4    -874.9    153.4    258.8    -320.5
C      S1      S2      S3      SINT      SEQV
I  -335.3    -418.0    -1631.    1296.    1256.
C  1014.     338.0     264.7    749.5    715.7
O  -302.7    -383.0    -1199.    896.4    859.1

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -1287.    -2053.    -4998.    1879.    1140.    -1681.
C  1139.     240.6    -984.0    1240.    398.6    -388.2
O  1291.     900.5    -564.9    1216.    699.6    -398.8
C      S1      S2      S3      SINT      SEQV      TEMP
I  325.0     -2266.    -6397.    6722.    5872.    70.00
C  2011.     -230.3    -1385.    3396.    2991.
O  2335.     465.1     -1174.    3509.    3041.    70.00

```

13.5.5 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.626 in. WITH AN EXTERNAL MOMENT OF
Mx = 1590 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC10.BS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 688 OUTSIDE NODE = 622

LOAD STEP 10 SUBSTEP= 1
TIME= 10.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SKY      SYZ      SXZ
I  34.27    -233.0    -947.8    494.1    530.3    -286.8
C      S1      S2      S3      SINT      SEQV
O  421.2    -166.3    -1401.    1823.    1611.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SKY      SYZ      SXZ
I  -741.8    -686.9    -993.2    109.3    145.1    -300.4
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  741.8     686.9     993.2    -109.3    -145.1    300.4
      S1      S2      S3      SINT      SEQV
I  -540.7    -629.7    -1251.    710.7    670.6
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  1251.     629.7     540.7     710.7    670.6

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SKY      SYZ      SXZ
I  -707.6    -919.9    -1941.    603.4    675.4    -587.2
C  34.27    -233.0    -947.8    494.1    530.3    -286.8
O  776.1     453.9     45.41    384.8    385.2    13.56
      S1      S2      S3      SINT      SEQV
I  -200.8    -752.7    -2615.    2414.    2191.
C  421.2    -166.3    -1401.    1823.    1611.
O  1086.     415.0    -226.1    1313.    1137.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SKY      SYZ      SXZ
I  -434.4    -243.6    -693.4    77.26    152.0    -234.3
C  336.7     185.9     421.6    -67.61    -120.7    147.3
O  -384.4    -212.6    -501.1    75.82    137.3    -174.1
      S1      S2      S3      SINT      SEQV
I  -196.8    -297.3    -877.4    680.5    636.2
C  580.3     229.1     134.8    445.4    406.6
O  -157.4    -262.1    -678.5    521.0    477.4

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SKY      SYZ      SXZ
I  -1142.    -1163.    -2634.    680.7    827.5    -821.5
C  371.0     -47.10    -526.2    426.5    409.6    -139.5
O  391.7     241.3    -455.7    460.6    522.5    -160.5
      S1      S2      S3      SINT      SEQV      TEMP
I  -471.9    -1001.    -3467.    2995.    2768.    70.00
C  646.7     9.305    -858.3    1505.    1308.
O  828.7     195.0    -846.4    1675.    1465.    70.00

```

13.5.6 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.574 in. WITH AN EXTERNAL MOMENT OF
My = -1784 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC13.BS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 676 OUTSIDE NODE = 607

LOAD STEP 13 SUBSTEP= 1
TIME= 13.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  284.4    -756.1     721.5    -236.6    -226.3     524.8
C      S1      S2      S3      SINT     SEQV
O  1126.    -58.99    -816.9     1943.     1696.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I   92.61    -437.8     806.2    -204.4     292.6     288.7
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  -92.61     437.8    -806.2     204.4    -292.6    -288.7
C      S1      S2      S3      SINT     SEQV
I   941.8     126.5    -607.3     1549.     1342.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O   607.3    -126.5    -941.8     1549.     1342.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  377.1    -1194.     1528.    -441.1     66.36     813.5
C  284.4    -756.1     721.5    -236.6    -226.3     524.8
O  191.8    -318.3    -84.71    -32.17    -518.9     236.1
C      S1      S2      S3      SINT     SEQV
I  1956.     93.35    -1338.     3293.     2860.
C  1126.    -58.99    -816.9     1943.     1696.
O  481.2     57.56    -749.9     1231.     1083.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  259.3    -3.051     391.3    -31.09     117.5     209.1
C  -118.5     1.308    -178.7     14.17    -53.66    -95.50
O  150.0    -1.465     225.9    -17.85     67.79     120.8
C      S1      S2      S3      SINT     SEQV
I  555.4     157.1    -64.90     620.3     544.4
C  29.55    -71.78    -253.7     283.3     248.6
O  320.8     90.77    -37.15     357.9     314.1

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  636.4    -1197.     1919.    -472.1     183.9     1023.
C  165.9    -754.8     542.8    -222.4    -279.9     429.3
O  341.8    -319.8     141.2    -50.01    -451.1     356.8
C      S1      S2      S3      SINT     SEQV     TEMP
I  2486.     245.3    -1373.     3859.     3356.     70.00
C  899.8    -113.0    -832.8     1733.     1508.
O  719.2     63.97    -619.9     1339.     1160.     70.00

```

13.5.7 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.626 in. WITH AN EXTERNAL MOMENT OF
Mz = -1784 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC15.BS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 688 OUTSIDE NODE = 622

LOAD STEP 15 SUBSTEP= 1
TIME= 15.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
45.08    -49.93    -568.0    297.7    336.4    -98.25
      S1      S2      S3      SINT      SEQV
327.2    -105.1    -795.0    1122.    980.4

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -202.5    -132.0    -670.3    217.8    25.34    -239.8
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 202.5     132.0     670.3    -217.8    -25.34    239.8
      S1      S2      S3      SINT      SEQV
I 81.14    -295.4    -790.6    871.7    757.3
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 790.6     295.4    -81.14    871.7    757.3

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -157.5    -181.9    -1238.    515.5    361.8    -338.0
C 45.08     -49.93    -568.0    297.7    336.4    -98.25
O 247.6     82.08     102.2     79.92    311.1    141.5
      S1      S2      S3      SINT      SEQV
I 346.1    -394.9    -1529.    1875.    1636.
C 327.2    -105.1    -795.0    1122.    980.4
O 501.7     153.3    -223.0    724.7    627.7

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -193.3    -50.58    -332.9    63.27    143.7    -109.7
C 197.4     82.66     220.1    -42.82    -98.42    61.93
O -217.2    -86.88    -257.5    49.85    114.7    -74.62
      S1      S2      S3      SINT      SEQV
I 11.20    -134.1    -453.9    465.1    412.2
C 317.8     151.5     30.72    287.1    249.7
O -28.51    -165.2    -367.9    339.4    295.8

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -350.8    -232.5    -1571.    578.8    505.5    -447.8
C 242.5     32.73    -348.0    254.9    238.0    -36.32
O 30.42     -4.803    -155.3    129.8    425.8    66.91
      S1      S2      S3      SINT      SEQV      TEMP
I 294.0    -468.0    -1981.    2275.    2005.    70.00
C 428.3     -7.877    -493.2    921.6    798.5
O 406.4     -21.71    -514.4    920.8    798.1    70.00

```

13.5.8 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.732 in. UNDER UNIFORM TEMPERATURE AND PRESSURE OF 250 deg. F AND 400 psi (filenames SINTLC16.BS3)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 652 OUTSIDE NODE = 520

LOAD STEP 16 SUBSTEP= 1
TIME= 16.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  623.2    -26.19    2058.    -57.40    60.15   -753.1
C      S1      S2      S3      SINT      SEQV
O  2383.    303.0    -31.26    2414.    2266.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  546.7    975.3    -121.7    18.15   -51.81   -194.1
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -546.7   -975.3     121.7   -18.15    51.81    194.1
C      S1      S2      S3      SINT      SEQV
O  979.6    596.4   -175.8    1155.    1019.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  175.8   -596.4   -979.6    1155.    1019.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  1170.    949.1    1936.    -39.25    8.335   -947.2
C  623.2    -26.19    2058.    -57.40    60.15   -753.1
O  76.44   -1002.    2180.    -75.56    112.0   -559.1
C      S1      S2      S3      SINT      SEQV
O  2575.    950.5    529.4    2046.    1871.
C  2383.    303.0    -31.26    2414.    2266.
O  2324.   -60.67   -1009.    3333.    2974.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  265.3    650.4    724.2    88.86   -51.42   -6.814
C -132.2   -522.0   -561.7   -75.09    3.992    8.878
O  158.7    573.9    621.3    81.98   -10.58   -9.104
C      S1      S2      S3      SINT      SEQV
O  755.5    638.7    245.8    509.7    462.5
C -118.1   -534.8   -563.0    444.9    431.5
O  625.5    585.4    143.0    482.5    463.8

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  1435.    1600.    2660.    49.61   -43.09   -954.0
C  490.9   -548.2    1496.   -132.5    64.14   -744.3
O  235.1   -427.7    2801.    6.425    101.4   -568.2
C      S1      S2      S3      SINT      SEQV      TEMP
O  3184.    1598.    913.3    2271.    2017.    250.0
C  1897.    106.9   -565.4    2463.    2205.
O  2924.    116.3   -431.9    3356.    3118.    250.0

```

14.0 4-IN. ANSYS INPUT FILES FOR BLOCK MODEL

14.1 4-IN. ISB BLOCK GEOMETRY INPUT (block4g.inp)

```

/BATCH
/CONFIG,NRES,50000
/CONFIG,NCONT,10000
/TITLE,Solid Model for 4-in. MWTF Block
C*** Load Case (Preload, Pressure, Thermal, and External) **
/UNITS,BIN
/PREP7
/OUTPUT,block4,out
C*** 4-in. ISB Block **
ET, 1,SOLID72
TYPE,1
REAL,1
MAT,1
KEYO, 1, 5, 2
R, 1
MPTEMP,,70,250
MPDATA,EX,1,,28.5E6,27.4E6
MPDATA,NUXY,1,,0.266,0.274
MPDATA,ALPX,1,,8.50E-6,8.89E-6
MPDATA,DENS,1,,0.000734,0.000734
C*** Pipe Connection **
ET, 2,BEAM4
TYPE,2
REAL,2
MAT,2
KEYO, 2, 6,0
KEYO, 2, 7,0
KEYO, 2, 10,0
R, 2
RMOD, 2, 1,0.0014
RMOD, 2, 2,0.049
RMOD, 2, 3,0.080
RMOD, 2, 4,0.0378
RMOD, 2, 5,0.0378
RMOD, 2, 6,0
RMOD, 2, 7,0
RMOD, 2, 8,0.008
RMOD, 2, 9,0
RMOD, 2, 10,0
RMOD, 2, 11,0
RMOD, 2, 12,0
RMOD, 2, 13,0
MPDATA,EX,2,,27.4E6,27.4E6
MPDATA,NUXY,2,,0.274,0.274
MPDATA,ALPX,2,,8.89E-6,8.89E-6
MPDATA,DENS,2,,1.0E-10,1.0E-10
BOPT,NUMB,OFF
BOPTN,NO,1
C*** Block Geometry **
CSYS,0
CYLIND,,3.185,0,7.141,0,360
K,10,,,4.26
K,11,4,,4.26
L,10,11
LWPLAN,,11
CYLIND,2.015,,0,4,0,360
VSBV,1,2
K,100
K,101,,,8.893
L,100,101
LWPLAN,,10
CYLIND,2.873,3.185,0,1.264,0,360
VSBV,3,1
CONE,2.63,2.015,0,0.606,0,360
VSBV,2,1
CYLIND,,2.015,0.606,3.654,0,360
VSBV,3,1

```


L,10,101
LWPLAN,,12
SPHERE,,2.015,0,360
VSBV,2,1
K,200,,,10
L,101,200
LWPLAN,,13
SPHERE,,2.0,0,360
VSBV,3,1
K,210,,,6.39
L,210,200
LWPLAN,,40
CONE,4,3,0,4,0,360
CONE,3.185,2.31,0,0.751,0,360
VSBV,1,3
VSBV,2,4
LWPLAN,,10
CYLIND,,2.015,,4.26,0,360
VSBV,1,2
C*** Mesh Density **
ESHAPE,2
ESIZE,0.5
C*** Refine mesh **
LESIZE,56,0.25
LESIZE,65,0.25
LESIZE,66,0.25
LESIZE,67,0.25
C*** Meshing of Block **
VATT,1,1,1
VMESH,ALL
N,20000,3.185,0,4.26
TYPE,2
REAL,2
MAT,2
E,20000,357
E,20000,358
E,20000,359
E,20000,360
E,20000,361
E,20000,362
E,20000,363
E,20000,350
E,20000,356
E,20000,355
E,20000,354
E,20000,353
E,20000,352
E,20000,351
E,20000,345
E,20000,465
E,20000,466
E,20000,467
E,20000,468
E,20000,469
E,20000,470
E,20000,458
E,20000,464
E,20000,463
E,20000,462
E,20000,461
E,20000,460
E,20000,459
E,20000,1172
E,20000,1171
E,20000,1170
E,20000,1185
E,20000,1163
E,20000,593
E,20000,592
E,20000,591
E,20000,590

```

E,20000,589
E,20000,588
E,20000,587
E,20000,586
E,20000,585
E,20000,584
E,20000,596
E,20000,574
E,20000,1129
E,20000,1169
E,20000,1186
E,20000,1176
E,20000,1175
E,20000,1174
E,20000,1173
NSEL,ALL
ESEL,ALL
CSYS,0
ASEL,S,AREA,,6,7,1,1
NSEL,R,LOC,Z,.246,.444
LOCAL,11,2,,,-2.0569
CSYS,11
NROTAT,ALL
CSYS,0
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,6.893,7.081
CSYS,1
NSEL,R,LOC,X,-0.852,0.852
LOCAL,12,1,,6.893
CSYS,12
NROTAT,ALL
CSYS,0
ALLSEL,ALL,VOLU
ALLSEL,BELOW,VOLU
NSEL,ALL
ESEL,ALL
WSORT,ALL
C*** Reference Temperature **
TREF,70
SAVE,block4g,db
FINISH
/EXIT

```

14.2 4-IN. ISB BLOCK APPLIED LOADING AND BOUNDARY CONDITIONS INPUT (block4s.inp)

```

/PREP7
RESUME,block4g,db
FINISH
/SOLU
ANTYPE,STAT
C*** Defining Boundary Conditions **
ASEL,S,AREA,,6,7,1,1
NSEL,R,LOC,Z,.246,.444
CSYS,11
D,ALL,UX,0,0
CSYS,0
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,6.893,7.081
CSYS,1
NSEL,R,LOC,X,-0.852,0.852
CSYS,12
D,ALL,UY,0,0
CSYS,0
C*** Combined applied axial load (Preload + pressure + thermal + external) **
C*** used to determine the punch through failure mode and block stiffness **
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,6.893,7.081
CSYS,1
NSEL,R,LOC,X,-0.852,0.852
CSYS,0

```

```

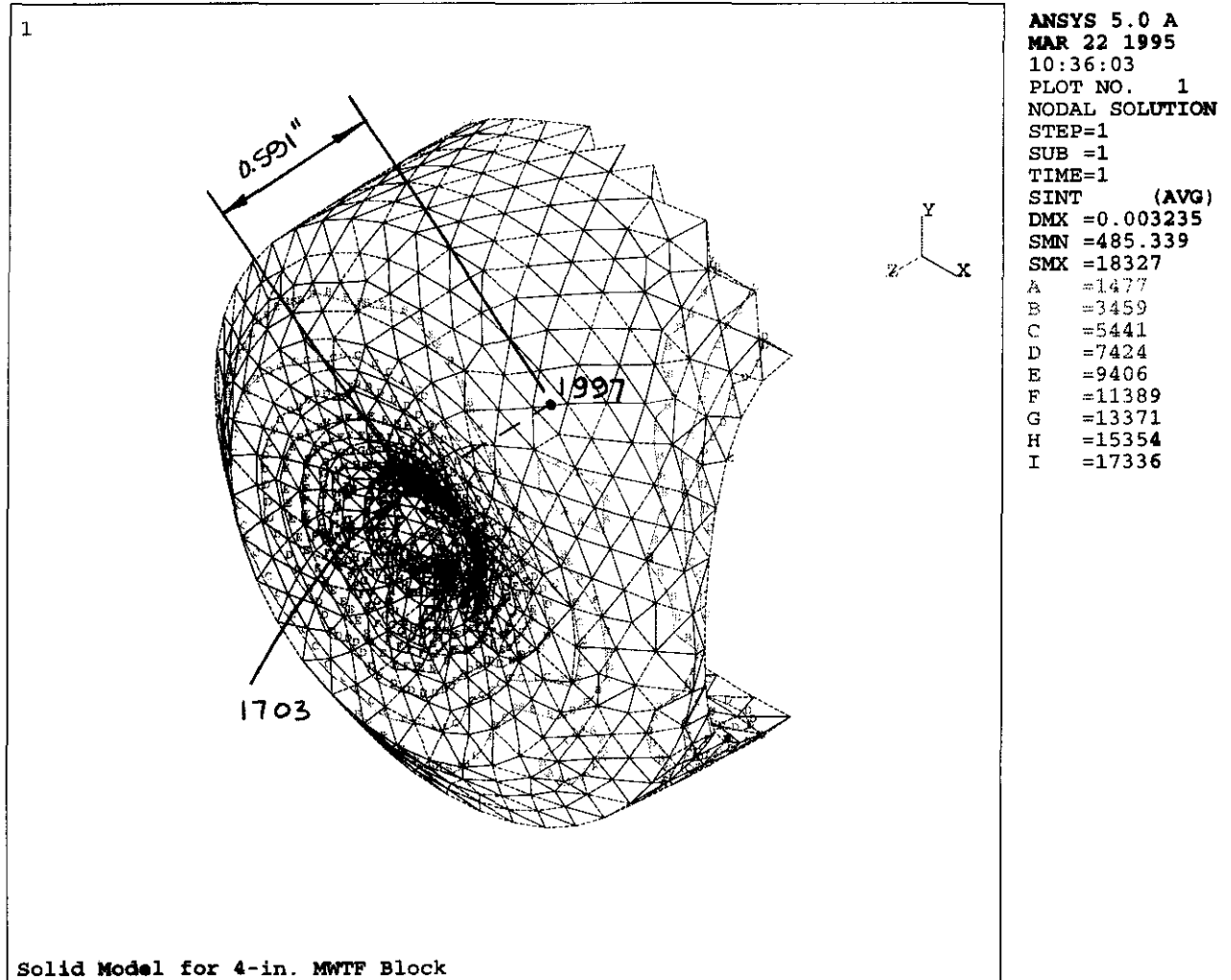
*GET,HCTA,NODE,,COUNT
C*** 50 ft-lbf preload (LC1) **
AXIAL50=-34013/HCTA
F,ALL,FZ,AXIAL50
NSEL,ALL
ESEL,ALL
SOLVE
C*** 100 ft-lbf preload (LC2) **
FDELE,ALL,FZ
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,6.893,7.081
CSYS,1
NSEL,R,LOC,X,-0.852,0.852
CSYS,0
AXIAL100=-36013/HCTA
F,ALL,FZ,AXIAL100
NSEL,ALL
ESEL,ALL
SOLVE
C*** 150 ft-lbf preload (LC3) **
FDELE,ALL,FZ
ASEL,S,AREA,,14,17,3,1
NSEL,R,LOC,Z,6.893,7.081
CSYS,1
NSEL,R,LOC,X,-0.852,0.852
CSYS,0
AXIAL150=-38013/HCTA
F,ALL,FZ,AXIAL150
ALLSEL,ALL,VOLU
ALLSEL,BELOW,VOLU
NSEL,ALL
ESEL,ALL
SOLVE
FDELE,ALL,FZ
C*** Extrenal loading at pipe connection **
FORCEX=11100
FORCEY=25000
FORCEZ=30000
MOMENTX=(2378)*12
MOMENTY=(2378)*12
MOMENTZ=(2120)*12
C*** X Direction Loading (Force) **
FDELE,ALL,FZ
F,20000,FX,FORCEZ,,20000,1
SOLVE
FDELE,ALL,FX
F,20000,FX,-FORCEZ,,20000,1
SOLVE
C*** Y Direction Loading (Force) **
FDELE,ALL,FX
F,20000,FY,FORCEY,,20000,1
SOLVE
FDELE,ALL,FY
F,20000,FY,-FORCEY,,20000,1
SOLVE
C*** Z Direction Loading (Force) **
FDELE,ALL,FY
F,20000,FZ,FORCEX,,20000,1
SOLVE
FDELE,ALL,FZ
F,20000,FZ,-FORCEX,,20000,1
SOLVE
C*** X Direction Loading (Moment) **
FDELE,ALL,FZ
F,20000,MX,MOMENTZ,,20000,1
SOLVE
FDELE,ALL,MX
F,20000,MX,-MOMENTZ,,20000,1
SOLVE
C*** Y Direction Loading (Moment) **
FDELE,ALL,MX

```

```
F,20000,MY,MOMENTY,,20000,1
SOLVE
FDELE,ALL,MY
F,20000,MY,-MOMENTY,,20000,1
SOLVE
C*** Z Direction Loading (Moment) **
FDELE,ALL,MY
F,20000,MZ,MOMENTX,,20000,1
SOLVE
FDELE,ALL,MZ
F,20000,MZ,-MOMENTX,,20000,1
SOLVE
FDELE,ALL,MZ
NSEL,ALL
ESEL,ALL
C*** Thermal Expansion **
TUNIF,70
BF,ALL,TEMP,250,250
C*** Internal pressure **
SFA,10,,PRES,400
SFA,18,,PRES,400
SFA,19,,PRES,400
SFA,20,,PRES,400
SFA,21,,PRES,400
SFA,24,,PRES,400
SFA,27,,PRES,400
SFA,29,,PRES,400
SFTRAN
NSEL,ALL
ESEL,ALL
SOLVE
SAVE,block4b.db
FINISH
/EXIT
```

14.3 LINEARIZED STRESS INTENSITIES THROUGH SECTIONS OF 4-IN. BLOCK MODEL

14.3.1 ISB TOP SECTION OF ISB BLOCK



Applied Loading (Axial loading for pre-load, thermal expansion, internal pressure, and axial external)

LC1 34,013 lbf/ number of nodes
LC2 36,013 lbf/ number of nodes
LC3 38,013 lbf/ number of nodes

Nodes used for stress linearization: 1703 and 1997 with a path length of 0.591 in.

14.3.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.591 in. UNDER 50 FT-LBF TORQUE AND
COMBINED AXIAL EXTERNAL LOADS (filename SINTLC1.TP4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1703 OUTSIDE NODE = 1997

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  -6858.    -3350.    -7887.    -2202.    5650.    -2030.
C      S1      S2      S3      SINT      SEQV
O  1518.    -7858.    -.1175E+05    .1327E+05    .1182E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -9588.    -4558.    -2798.    -2573.    -1082.    853.7
C  .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O  9588.     4558.     2798.     2573.     1082.    -853.7
      S1      S2      S3      SINT      SEQV
I  -1756.    -4499.    -.1069E+05    8933.     7926.
C  .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O  .1069E+05  4499.     1756.     8933.     7926.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -.1645E+05 -7908.    -.1068E+05 -4775.     4567.    -1176.
C  -6858.    -3350.    -7887.    -2202.     5650.    -2030.
O  2730.     1208.    -5089.     371.7     6732.    -2883.
      S1      S2      S3      SINT      SEQV
I  -2959.    -.1340E+05 -.1868E+05 .1572E+05 .1386E+05
C  1518.     -7858.    -.1175E+05 .1327E+05 .1182E+05
O  6027.     2747.    -9924.     .1595E+05 .1459E+05

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  1076.     3241.     2882.    -929.3     15.75     220.0
C  1622.     1243.     1112.    -55.35    -180.5     -86.77
O  -2669.    -1975.    -1654.    -193.8     51.55     57.60
      S1      S2      S3      SINT      SEQV
I  3591.     2897.     711.3     2880.     2603.
C  1638.     1370.     969.6     668.2     582.4
O  -1645.    -1929.    -2724.     1079.     968.4

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -.1537E+05 -4667.    -7803.    -5704.     4583.    -955.8
C  -5236.    -2107.    -6774.    -2257.     5469.    -2116.
O  60.69     -766.8    -6743.     177.9     6783.    -2826.
      S1      S2      S3      SINT      SEQV      TEMP
I  386.4     -.1028E+05 -.1794E+05 .1833E+05 .1594E+05  70.00
C  2683.     -6353.    -.1045E+05 .1313E+05 .1164E+05
O  4180.     60.65     -.1169E+05 .1587E+05 .1426E+05  70.00

```

14.3.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.591 in. UNDER 100 FT-LBF TORQUE AND COMBINED AXIAL EXTERNAL LOADS (filename SINTLC2.TP4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1703 OUTSIDE NODE = 1997

LOAD STEP 2 SUBSTEP= 1
TIME= 2.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  -7261.    -3547.    -8350.    -2331.    5982.    -2149.
C      S1      S2      S3      SINT     SEQV
O  1607.    -8320.    -.1245E+05  .1405E+05  .1251E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -.1015E+05 -4826.    -2963.    -2725.    -1146.    903.9
C  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
O  .1015E+05  4826.    2963.    2725.    1146.    -903.9
C      S1      S2      S3      SINT     SEQV
O  -1859.    -4764.    -.1132E+05  9458.    8392.
C  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
O  .1132E+05  4764.    1859.    9458.    8392.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -.1741E+05 -8373.    -.1131E+05 -5056.    4836.    -1245.
C  -7261.    -3547.    -8350.    -2331.    5982.    -2149.
O  2890.    1279.    -5388.    393.5    7128.    -3053.
C      S1      S2      S3      SINT     SEQV
O  -3133.    -.1419E+05 -.1978E+05 .1665E+05 .1467E+05
C  1607.    -8320.    -.1245E+05 .1405E+05 .1251E+05
O  6381.    2908.    -.1051E+05 .1689E+05 .1545E+05

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  1139.    3432.    3051.    -983.9    16.68    232.9
C  1717.    1316.    1178.    -58.60    -191.1    -91.87
O  -2826.    -2091.    -1752.    -205.1    54.58    60.99
C      S1      S2      S3      SINT     SEQV
O  3802.    3068.    753.1    3049.    2756.
C  1734.    1450.    1027.    707.5    616.7
O  -1742.    -2042.    -2884.    1142.    1025.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -.1627E+05 -4941.    -8261.    -6040.    4852.    -1012.
C  -5544.    -2231.    -7173.    -2390.    5791.    -2241.
O  64.26    -811.9    -7139.    188.4    7182.    -2992.
C      S1      S2      S3      SINT     SEQV      TEMP
O  409.1    -.1089E+05 -.1900E+05 .1941E+05 .1688E+05  70.00
C  2841.    -6726.    -.1106E+05 .1390E+05 .1232E+05
O  4426.    64.21    -.1238E+05 .1680E+05 .1510E+05  70.00

```

14.3.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.591 in. UNDER 150 FT-LBF TORQUE AND COMBINED AXIAL EXTERNAL LOADS (filename SINTLC3.TP4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1703 OUTSIDE NODE = 1997

LOAD STEP 3 SUBSTEP= 1
TIME= 3.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -7665.    -3744.    -8814.    -2461.    6314.    -2268.
C      S1      S2      S3      SINT      SEQV
O 1696.    -8783.    -.1314E+05 .1483E+05 .1321E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -.1072E+05 -5094.    -3127.    -2876.    -1210.    954.1
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O .1072E+05 5094.    3127.    2876.    1210.    -954.1
C      S1      S2      S3      SINT      SEQV
I -1962.    -5029.    -.1195E+05 9983.    8858.
C .0000E+00 .0000E+00 .0000E+00 .0000E+00 .0000E+00
O .1195E+05 5029.    1962.    9983.    8858.

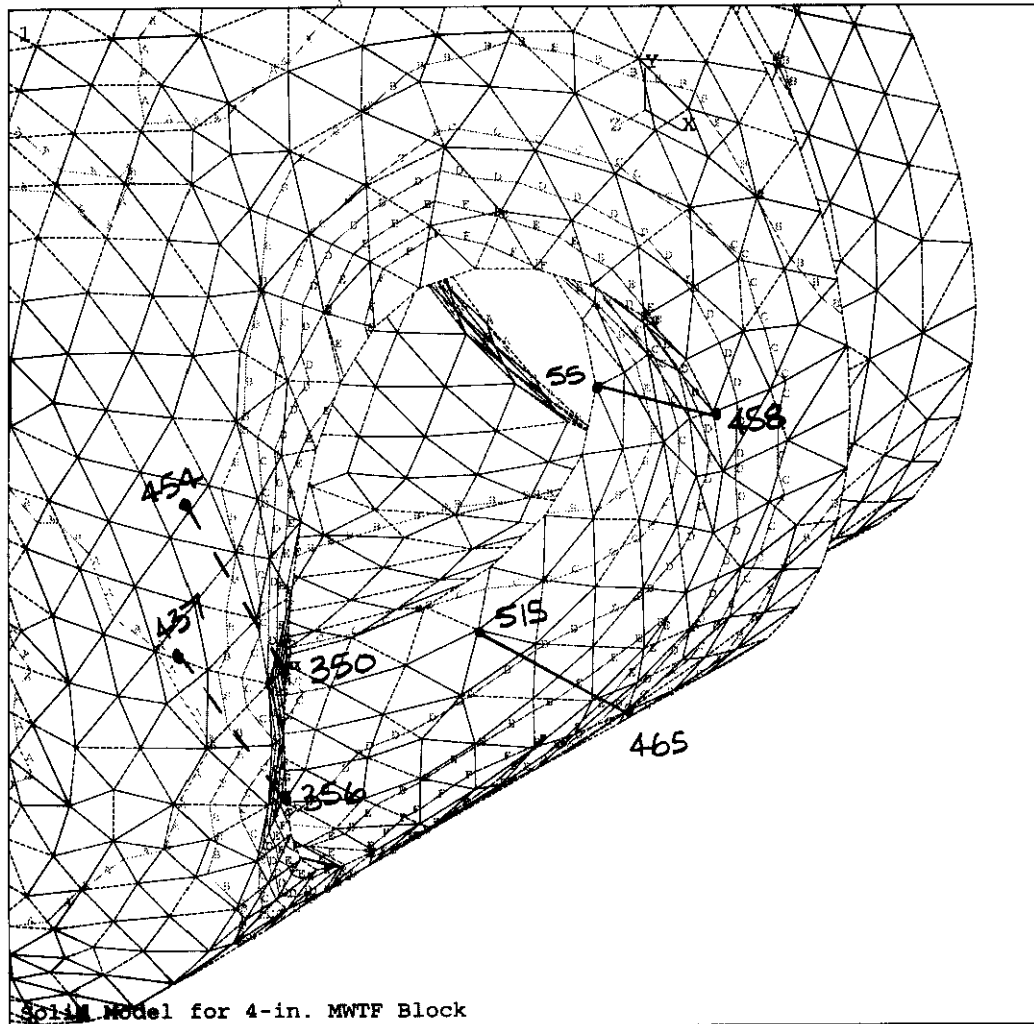
** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -.1838E+05 -8838.    -.1194E+05 -5337.    5104.    -1314.
C -7665.    -3744.    -8814.    -2461.    6314.    -2268.
O 3051.    1350.    -5687.    415.4    7524.    -3222.
C      S1      S2      S3      SINT      SEQV
I -3307.    -.1497E+05 -.2088E+05 .1757E+05 .1549E+05
C 1696.    -8783.    -.1314E+05 .1483E+05 .1321E+05
O 6735.    3070.    -.1109E+05 .1783E+05 .1631E+05

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 1203.    3623.    3221.    -1039.    17.61    245.9
C 1812.    1389.    1243.    -61.86    -201.7    -96.97
O -2983.    -2207.    -1849.    -216.5    57.61    64.38
C      S1      S2      S3      SINT      SEQV
I 4013.    3238.    794.9    3218.    2909.
C 1830.    1531.    1084.    746.8    650.9
O -1839.    -2156.    -3044.    1205.    1082.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -.1718E+05 -5216.    -8720.    -6375.    5122.    -1068.
C -5852.    -2355.    -7571.    -2522.    6112.    -2365.
O 67.83    -857.0    -7536.    198.8    7581.    -3158.
C      S1      S2      S3      SINT      SEQV      TEMP
I 431.8    -.1149E+05 -.2005E+05 .2048E+05 .1782E+05 70.00
C 2999.    -7100.    -.1168E+05 .1468E+05 .1301E+05
O 4671.    67.78    -.1306E+05 .1774E+05 .1594E+05 70.00

```


14.4 ISB PIPE CONNECTION SECTION OF BLOCK



ANSYS 5.0 A
MAR 24 1995
08:30:49
PLOT NO. 1
NODAL SOLUTION
STEP=5
SUB =1
TIME=5
SINT (AVG)
DMX =0.002918
SMN =352.629
SMX =20156
A =1453
B =3653
C =5854
D =8054
E =10255
F =12455
G =14655
H =16856
I =19056

Applied Loading (individual loading for pre-load, thermal expansion, internal pressure, and external forces and moments at pipe intersection)

- LC1 Fz = -34,013 lbf /number of nodes, applied @ top of block to account for 50 ft-lbf of pre-load torque, axial thermal expansion, and internal pressure (nodes 454 and 350, path length of 1.45 in.)
- LC5 Fx = -30,000 lbf applied at node 20,000 (nodes 356 and 437, with a path length of 1.146 in.)
- LC7 Fy = -25,000 lbf applied at node 20,000 (nodes 356 and 437, with a path length of 1.146 in.)
- LC9 Fz = -11,100 lbf applied at node 20,000 (nodes 465 and 515, with a path length of 0.9988 in.)
- LC10 Mx = 2,210 ft-lbf applied at node 20,000 (nodes 465 and 515, with a path length of 0.9988 in.)
- LC13 My = -2,378 ft-lbf applied at node 20,000 (nodes 356 and 437, with a path length of 1.146 in.)
- LC15 Mz = -2,378 ft-lbf applied at node 20,000 (nodes 465 and 515, with a path length of 0.9988 in.)
- LC16 Internal Pressure of 400 psi and uniform temperature @ 250 deg. F is applied to block model (nodes 55 and 458, path length of 1.17 in.)

14.4.1 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.45 in. UNDER 50 FT-LBF TORQUE, AXIAL INTERNAL PRESSURE, AND AXIAL THERMAL EXPANSION LOADS (filenames SINTLC1.PS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 454 OUTSIDE NODE = 350

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -684.7    6169.    323.6    101.0    56.89   385.4
C      S1      S2      S3      SINT      SEQV
O 6171.    452.7    -816.0    6987.    6447.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -227.4    2998.    1364.    131.4    36.54   85.42
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 227.4    -2998.    -1364.    -131.4    -36.54   -85.42
C      S1      S2      S3      SINT      SEQV
I 3004.    1367.    -237.1    3241.    2807.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 237.1    -1367.    -3004.    3241.    2807.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -912.1    9167.    1687.    232.3    93.43   470.8
C -684.7    6169.    323.6    101.0    56.89   385.4
O -457.4    3172.    -1040.    -30.36    20.35   299.9
C      S1      S2      S3      SINT      SEQV
I 9173.    1767.    -999.2    0.1017E+05 9110.
C 6171.    452.7    -816.0    6987.    6447.
O 3172.    -330.7    -1167.    4339.    3987.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -291.6    -730.9    -166.9    -140.7    2.794   398.0
C 218.0    283.4    330.0    -25.11    -26.17   -221.4
O -281.0    -216.0    -334.7    8.484    5.105   251.1
C      S1      S2      S3      SINT      SEQV
I 182.5    -565.2    -806.7    989.2    893.3
C 502.4    288.6    40.34    462.1    400.6
O -54.80    -216.6    -560.4    505.6    447.2

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1204.    8436.    1520.    91.69    96.22   868.8
C -466.8    6453.    653.5    75.88    30.72   164.0
O -738.4    2956.    -1375.    -21.87    25.45   551.0
C      S1      S2      S3      SINT      SEQV      TEMP
I 8438.    1772.    -1458.    9896.    8741.    70.00
C 6454.    676.7    -491.0    6945.    6441.
O 2956.    -420.3    -1693.    4649.    4161.    70.00

```

14.4.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.146 in. WITH AN EXTERNAL FORCE OF
Fx = -30,000 lbf, APPLIED AT NODE 20,000 (filenames SINTLC5.PS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 356 OUTSIDE NODE = 437

LOAD STEP 5 SUBSTEP= 1
TIME= 5.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
-9666.    -3241.    -1467.    276.9    -747.9    1232.
      S1      S2      S3      SINT      SEQV
-1059.    -3445.    -9869.    8810.    7892.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -4469.    -3701.    -309.9    -540.5    -802.2    462.1
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 4469.     3701.     309.9     540.5     802.2    -462.1
      S1      S2      S3      SINT      SEQV
I -55.48    -3676.    -4748.    4693.    4259.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 4748.     3676.     55.48     4693.    4259.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.1413E+05 -6942.    -1777.    -263.6    -1550.    1694.
C -9666.     -3241.    -1467.    276.9    -747.9    1232.
O -5197.     459.8    -1157.    817.4     54.34    769.8
      S1      S2      S3      SINT      SEQV
I -1124.     -7366.    -0.1436E+05 0.1324E+05 0.1147E+05
C -1059.     -3445.    -9869.    8810.    7892.
O 591.3      -1040.    -5446.    6037.    5409.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -2280.     -455.5    923.6     98.50    -408.8    670.4
C 987.7      126.2    -523.0    -49.97    160.9    -331.6
O -943.0     -323.3    672.1     44.44    -245.2    237.5
      S1      S2      S3      SINT      SEQV
I 1149.     -530.4    -2430.    3580.    3102.
C 1065.     148.1    -621.7    1686.    1462.
O 758.1     -365.2    -987.1    1745.    1532.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.1641E+05 -7397.    -853.0    -165.1    -1959.    2364.
C -8678.     -3115.    -1990.    227.0    -587.0    900.3
O -6140.     136.5    -484.6     861.9    -190.9    1007.
      S1      S2      S3      SINT      SEQV      TEMP
I 17.51      -7915.    -0.1677E+05 0.1678E+05 0.1454E+05 70.00
C -1659.     -3310.    -8813.    7154.    6488.
O 257.8      -313.5    -6433.    6690.    6424.    70.00

```

14.4.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.146 in. WITH AN EXTERNAL FORCE OF
Fy = -25,000 (bf, APPLIED AT NODE 20,000 (filenames SINTLC7.PS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 356 OUTSIDE NODE = 437

LOAD STEP 7 SUBSTEP= 1
TIME= 7.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
      357.8    4437.    3584.    -6643.    5571.    -1062.
      S1      S2      S3      SINT     SEQV
      0.1243E+05 1343.    -5390.    0.1782E+05 0.1558E+05

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 614.3    -2705.    1566.    -4845.    5064.    -485.6
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -614.3    2705.    -1566.    4845.    -5064.    485.6
      S1      S2      S3      SINT     SEQV
I 6798.    570.9    -7894.    0.1469E+05 0.1277E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 7894.    -570.9    -6798.    0.1469E+05 0.1277E+05

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 972.0    1733.    5149.    -0.1149E+05 0.1064E+05 -1548.
C 357.8    4437.    3584.    -6643.    5571.    -1062.
O -256.5    7142.    2018.    -1799.    506.9    -576.5
      S1      S2      S3      SINT     SEQV
I 0.1895E+05 1679.    -0.1278E+05 0.3173E+05 0.2752E+05
C 0.1243E+05 1343.    -5390.    0.1782E+05 0.1558E+05
O 7626.    2022.    -744.6    8370.    7386.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 820.0    -425.2    327.5    -1781.    2901.    -89.91
C -384.1    304.6    -151.8    868.7    -1417.    27.62
O 459.7    -316.8    643.3    -1728.    2304.    -1.816
      S1      S2      S3      SINT     SEQV
I 3510.    599.0    -3387.    6897.    5997.
C 1719.    -293.1    -1658.    3377.    2942.
O 3047.    523.3    -2784.    5832.    5066.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 1792.    1308.    5477.    -0.1327E+05 0.1354E+05 -1638.
C -26.38    4742.    3432.    -5775.    4154.    -1034.
O 203.2    6825.    2661.    -3527.    2811.    -578.3
      S1      S2      S3      SINT     SEQV      TEMP
I 0.2246E+05 1955.    -0.1584E+05 0.3829E+05 0.3319E+05 70.00
C 0.1084E+05 1528.    -4219.    0.1506E+05 0.1316E+05
O 9509.    1608.    -1428.    0.1094E+05 9779.    70.00

```

14.4.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.9988 in. WITH AN EXTERNAL FORCE OF
Fz = -11,110 lbf, APPLIED AT NODE 20,000 (filenames SINTLC9.PS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 465 OUTSIDE NODE = 515

LOAD STEP 9 SUBSTEP= 1
TIME= 9.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  -466.5    -292.5    -3377.  405.7    -323.1    -1516.
C      S1      S2      S3      SINT      SEQV
O  497.5    -605.3    -4028.  4525.    4087.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  609.9    -48.85    -2368.  701.8    -713.1    -1987.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  -609.9     48.85     2368.  -701.8     713.1     1987.
      S1      S2      S3      SINT      SEQV
I  2037.    -449.3    -3395.  5432.    4710.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O  3395.     449.3    -2037.  5432.    4710.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  143.5    -341.4    -5744.  1107.    -1036.    -3503.
C  -466.5    -292.5    -3377.  405.7    -323.1    -1516.
O  -1076.    -243.7    -1009.  -296.1    390.0     471.2
      S1      S2      S3      SINT      SEQV
I  2509.    -1043.    -7408.  9918.    8703.
C  497.5    -605.3    -4028.  4525.    4087.
O  -68.77    -582.2    -1678.  1609.    1424.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  86.12    -84.44    -666.0    191.8    -186.7    -392.9
C  -100.6    -10.16    321.2    -119.6    104.1     239.9
O  201.3     64.74    -487.3    210.5    -252.7    -525.1
      S1      S2      S3      SINT      SEQV
I  388.0    -205.4    -847.0    1235.    1070.
C  434.8     67.48    -291.8    726.6    629.3
O  647.8    -78.98    -790.1    1438.    1245.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  229.6    -425.8    -6411.  1299.    -1223.    -3895.
C  -567.1    -302.7    -3055.  286.1    -219.0    -1276.
O  -875.1    -179.0    -1496.  -85.56    137.3    -53.88
      S1      S2      S3      SINT      SEQV      TEMP
I  2897.    -1253.    -8251.  0.1115E+05  9759.    70.00
C  209.2    -538.7    -3596.  3805.    3492.
O  -153.4    -883.3    -1514.  1360.    1179.    70.00

```

14.4.5 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.9988 in. WITH AN EXTERNAL MOMENT OF
Mx = 2,120 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC10.PS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 465 OUTSIDE NODE = 515

LOAD STEP 10 SUBSTEP= 1
TIME= 10.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  335.0    152.3   -1008.    334.7   -444.5   -1293.
C      S1      S2      S3      SINT     SEQV
O  1346.    -51.34   -1816.    3163.    2745.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  283.6    -94.35   -1367.    259.0   -337.4   -1240.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -283.6     94.35    1367.    -259.0    337.4    1240.
C      S1      S2      S3      SINT     SEQV
I  1077.    -207.6   -2047.    3124.    2720.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  2047.     207.6   -1077.    3124.    2720.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  618.6     57.93   -2375.    593.7   -781.9   -2532.
C  335.0     152.3   -1008.    334.7   -444.5   -1293.
O  51.43     246.6    358.8     75.72   -107.2   -53.08
C      S1      S2      S3      SINT     SEQV
I  2413.    -252.7   -3859.    6273.    5453.
C  1346.    -51.34   -1816.    3163.    2745.
O  442.2     190.0    24.64    417.6    364.2

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -27.36    -36.87   -364.9     71.57   -14.06   -206.6
C  8.401     23.11    207.9    -36.00    19.12    128.8
O -23.90    -38.44   -370.3     45.69   -83.53   -292.7
C      S1      S2      S3      SINT     SEQV
I  105.8    -71.26   -463.7     569.5    504.8
C  271.1     40.52   -72.18     343.3    303.1
O  174.4    -64.79   -542.3     716.7    632.0

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  591.2     21.06   -2740.    665.3   -796.0   -2739.
C  343.4     175.4   -800.3    298.7   -425.4   -1164.
O  27.53     208.2   -11.54    121.4   -190.7   -345.8
C      S1      S2      S3      SINT     SEQV      TEMP
I  2512.    -327.4   -4313.    6825.    5938.    70.00
C  1279.     -9.725   -1551.    2829.    2453.
O  513.6     55.26   -344.7    858.3    743.9    70.00

```

14.4.6 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.146 in. WITH AN EXTERNAL MOMENT OF
My = -2,378 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC13.PS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 356 OUTSIDE NODE = 437

LOAD STEP 13 SUBSTEP= 1
TIME= 13.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -7022.    -4462.    -1156.    -303.1    -633.2    796.2
C      S1      S2      S3      SINT      SEQV
O -923.7    -4570.    -7146.     6222.     5415.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -3832.    -2504.     62.02    -351.9    -640.4     422.5
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 3832.     2504.    -62.02     351.9     640.4    -422.5
      S1      S2      S3      SINT      SEQV
I 272.3     -2609.    -3938.     4210.     3728.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 3938.     2609.    -272.3     4210.     3728.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.1085E+05 -6966.    -1094.    -655.0    -1274.     1219.
C -7022.    -4462.    -1156.    -303.1    -633.2     796.2
O -3190.    -1958.    -1218.     48.82     7.195     373.7
      S1      S2      S3      SINT      SEQV
I -656.8    -7191.    -0.1107E+05 0.1041E+05 9112.
C -923.7    -4570.    -7146.     6222.     5415.
O -1149.    -1957.    -3260.     2110.     1844.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1616.    -352.1     967.0    -12.06    -429.9     455.3
C 700.0     68.81    -527.8    -2.221     173.1    -218.6
O -691.6    -216.7     635.0    -0.7912    -261.1     134.8
      S1      S2      S3      SINT      SEQV
I 1165.     -468.9    -1697.     2862.     2486.
C 739.3     110.1    -608.4     1348.     1168.
O 720.6     -287.3    -706.6     1427.     1271.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -0.1247E+05 -7318.    -127.2    -667.1    -1704.     1674.
C -6322.    -4393.    -1684.    -305.3    -460.2     577.6
O -3881.    -2175.    -583.2     48.03    -253.9     508.5
      S1      S2      S3      SINT      SEQV      TEMP
I 500.4     -7686.    -0.1273E+05 0.1323E+05 0.1157E+05 70.00
C -1528.    -4448.    -6423.     4896.     4266.
O -471.7     -2206.    -3962.     3490.     3023.     70.00

```

14.4.7 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.9988 in. WITH AN EXTERNAL MOMENT OF
Mz = -2,378 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC15.PS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 465 OUTSIDE NODE = 515

LOAD STEP 15 SUBSTEP= 1
TIME= 15.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -6415.    -1078.    -4974.    -150.9    1286.    359.7
C      S1      S2      S3      SINT      SEQV
O -691.4    -5233.    -6542.    5851.    5319.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1090.    -454.0    -2926.    361.7    1279.    845.2
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 1090.     454.0     2926.    -361.7    -1279.    -845.2
C      S1      S2      S3      SINT      SEQV
I 405.1     -1239.    -3635.    4041.    3519.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 3635.     1239.    -405.1    4041.    3519.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -7505.    -1532.    -7900.    210.8    2565.    1205.
C -6415.    -1078.    -4974.    -150.9    1286.    359.7
O -5325.    -624.0    -2048.    -512.7    7.047    -485.5
C      S1      S2      S3      SINT      SEQV
I -574.2    -6949.    -9413.    8839.    7901.
C -691.4    -5233.    -6542.    5851.    5319.
O -566.3    -1982.    -5448.    4882.    4350.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -323.9    -751.6    -831.9    -26.09    230.6    81.68
C -57.94    200.3     295.0    -24.35    -141.8    -127.9
O 565.5     13.97    -343.0    131.1    251.8    327.5
C      S1      S2      S3      SINT      SEQV
I -310.8    -562.0    -1035.    723.9    636.6
C 415.1     137.6     -115.4    530.5    459.6
O 731.1     32.57    -527.1    1258.    1092.

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -7829.    -2284.    -8732.    184.7    2796.    1287.
C -6473.    -877.7    -4679.    -175.3    1144.    231.8
O -4759.    -610.1    -2391.    -381.6    258.8    -158.0
C      S1      S2      S3      SINT      SEQV      TEMP
I -1180.    -7355.    -0.1031E+05 9129.    8068.    70.00
C -557.8    -4949.    -6523.    5965.    5354.
O -535.3    -2424.    -4801.    4266.    3703.    70.00

```


14.4.8 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 1.17 in. UNDER UNIFORM TEMPERATURE AND PRESSURE OF 250 deg. F AND 400 psi (filenames SINTLC16.PS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 55 OUTSIDE NODE = 458

LOAD STEP 16 SUBSTEP= 1
TIME= 16.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I 117.5    2167.    -65.50    -13.07    2.818    -50.14
C      S1      S2      S3      SINT      SEQV
I 2167.    130.2    -78.33    2245.    2148.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -35.71    1236.    95.82    -11.74    10.39    -14.09
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 35.71    -1236.    -95.82    11.74    -10.39    14.09
C      S1      S2      S3      SINT      SEQV
I 1236.    97.19    -37.29    1273.    1212.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 37.29    -97.19    -1236.    1273.    1212.

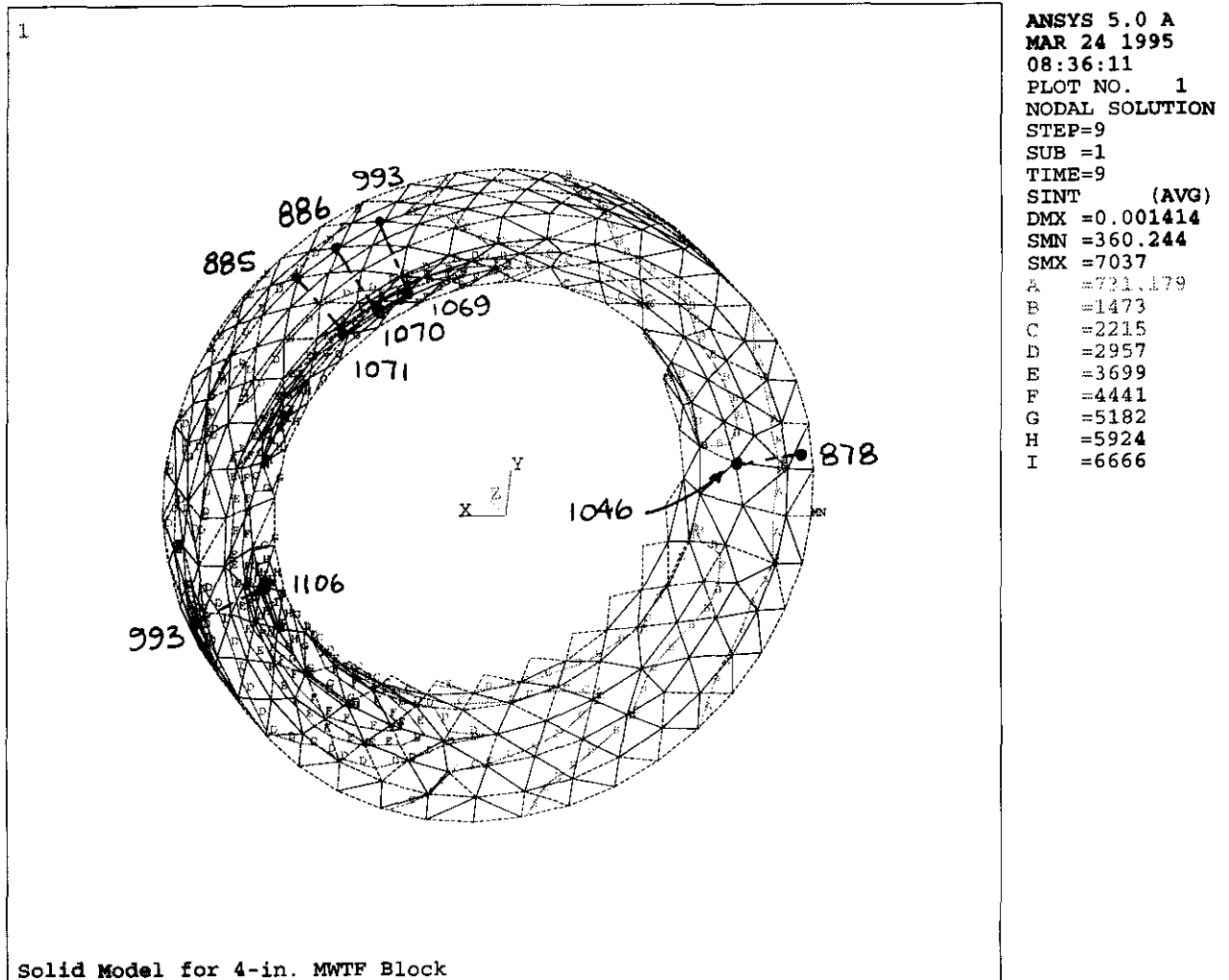
** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 81.78    3402.    30.32    -24.82    13.21    -64.23
C 117.5    2167.    -65.50    -13.07    2.818    -50.14
O 153.2    930.9    -161.3    -1.326    -7.571    -36.04
C      S1      S2      S3      SINT      SEQV
I 3403.    125.0    -13.14    3416.    3349.
C 2167.    130.2    -78.33    2245.    2148.
O 930.9    157.3    -165.4    1096.    975.9

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 107.6    232.9    75.77    13.26    -23.24    51.36
C -30.42    -52.66    -39.20    -5.046    -4.593    -18.68
O -19.66    17.86    -17.88    -6.772    2.018    23.91
C      S1      S2      S3      SINT      SEQV
I 236.6    145.3    34.35    202.2    175.4
C -15.59    -46.58    -60.11    44.52    39.53
O 19.25    4.417    -43.34    62.59    56.65

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 189.4    3635.    106.1    -11.56    -10.04    -12.87
C 87.08    2114.    -104.7    -18.12    -1.776    -68.82
O 133.5    948.7    -179.2    -8.098    -5.554    -12.13
C      S1      S2      S3      SINT      SEQV      TEMP
I 3635.    191.3    104.1    3531.    3489.    250.0
C 2114.    109.1    -126.9    2241.    2133.
O 948.9    133.9    -179.7    1129.    1009.    250.0

```

14.5 ISB BOTTOM SECTION OF BLOCK



Applied Loading (individual loading for pre-load, thermal expansion, internal pressure, and external forces and moments at pipe intersection)

- LC1 Fz = -34,013 lbf /number of nodes, applied @ top of block to account for 50 ft-lbf of pre-load torque, axial thermal expansion, and internal pressure (nodes 1070 and 886, path length of 0.6893 in.)
- LC5 Fx = -30,000 lbf applied at node 20,000 (nodes 1106 and 993, with a path length of 0.6969 in.)
- LC7 Fy = -25,000 lbf applied at node 20,000 (nodes 1069 and 888, with a path length of 0.6875 in.)
- LC9 Fz = -11,100 lbf applied at node 20,000 (nodes 1106 and 993, with a path length of 0.6969 in.)
- LC10 Mx = 2,210 ft-lbf applied at node 20,000 (nodes 1071 and 885, with a path length of 0.6751 in.)
- LC13 My = -2,378 ft-lbf applied at node 20,000 (nodes 1106 and 993, with a path length of 0.6969 in.)
- LC15 Mz = -2,378 ft-lbf applied at node 20,000 (nodes 1106 and 993, with a path length of 0.6969 in.)
- LC16 Internal Pressure of 400 psi and uniform temperature @ 250 deg. F is applied to block model (nodes 1046 and 878, path length of 0.7709 in.)

14.5.1 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.6893 in. UNDER 50 FT-LBF TORQUE, AXIAL INTERNAL PRESSURE, AND AXIAL THERMAL EXPANSION LOADS (filenames SINTLC1.BS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1070 OUTSIDE NODE = 886

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
3589.    -1633.    -2049.    -2271.    -1120.    -352.1
      S1      S2      S3      SINT      SEQV
4439.    -1074.    -3458.      7897.      7016.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1359.    -2417.    -4350.    -207.8    -1302.    -482.3
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 1359.      2417.      4350.      207.8      1302.      482.3
      S1      S2      S3      SINT      SEQV
I -1283.    -1764.    -5079.      3796.      3579.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 5079.      1764.      1283.      3796.      3579.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 2230.     -4049.    -6399.    -2479.    -2421.    -834.4
C 3589.     -1633.    -2049.    -2271.    -1120.    -352.1
O 4948.      784.4     2301.    -2064.     182.1     130.2
      S1      S2      S3      SINT      SEQV
I 3091.     -2988.    -8322.    0.1141E+05 9890.
C 4439.     -1074.    -3458.      7897.      7016.
O 5798.      2320.     -85.05    5883.      5123.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -545.5    -979.1    -2642.    -16.25    -349.7    -78.73
C 125.1     184.7     829.5     11.89     131.5     28.06
O -188.9    -300.7    -1130.    -11.22    -170.7    -36.47
      S1      S2      S3      SINT      SEQV
I -542.5    -908.6    -2716.     2173.     2015.
C 856.5     160.0     122.8     733.7     715.8
O -187.2    -267.1    -1165.     977.8     940.4

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I 1684.     -5029.    -9042.    -2495.    -2771.    -913.1
C 3714.     -1448.    -1220.    -2259.    -988.1    -324.0
O 4759.      483.7     1171.    -2075.     11.35     93.72
      S1      S2      S3      SINT      SEQV      TEMP
I 2510.     -4124.    -0.1077E+05 0.1328E+05 0.1150E+05 70.00
C 4564.     -588.5    -2929.      7492.      6639.
O 5602.      1171.    -359.1     5961.      5362.      70.00

```

14.5.2 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.6969 in. WITH AN EXTERNAL FORCE OF
Fx = -30,000 lbf, APPLIED AT NODE 20,000 (filenames SINTLC5.BS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1106 OUTSIDE NODE = 993

LOAD STEP 5 SUBSTEP= 1
TIME= 5.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -742.1    1481.    -1415.    1100.    444.1    -822.5
C      S1      S2      S3      SINT      SEQV
O 1937.    -370.8    -2243.    4179.    3626.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -917.3    -396.1    -2334.    522.3    -441.8    -614.8
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 917.3     396.1     2334.    -522.3    441.8     614.8
C      S1      S2      S3      SINT      SEQV
I 130.5     -1187.    -2590.    2721.    2357.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 2590.     1187.     -130.5    2721.    2357.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -1659.    1085.    -3749.    1623.    2.340    -1437.
C -742.1    1481.    -1415.    1100.    444.1    -822.5
O 175.1     1877.    918.3     578.1    885.9    -207.7
C      S1      S2      S3      SINT      SEQV
I 1907.    -1643.    -4588.    6495.    5633.
C 1937.    -370.8    -2243.    4179.    3626.
O 2474.     735.6    -239.7    2714.    2381.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -669.3    -415.8    -1515.    201.2    -23.98    -335.2
C 189.5     59.86    563.1    -90.49    124.4     120.8
O -262.6    -114.4    -725.6    110.5    -119.0    -158.3
C      S1      S2      S3      SINT      SEQV
I -273.9    -692.8    -1633.    1359.    1206.
C 615.5     230.4    -33.50    649.0    565.3
O -9.028    -308.7    -784.9    775.9    677.7

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -2329.    668.9    -5264.    1824.    -21.64    -1773.
C -552.6    1541.    -852.4    1010.    568.5    -701.6
O -87.47    1762.    192.7     688.6    767.0    -366.0
C      S1      S2      S3      SINT      SEQV      TEMP
I 1626.    -2361.    -6189.    7815.    6768.    70.00
C 1976.    -59.63    -1780.    3756.    3257.
O 2192.     422.6    -747.3    2940.    2564.    70.00

```

14.5.3 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.6875 in. WITH AN EXTERNAL FORCE OF
Fy = -25,000 (lbf, APPLIED AT NODE 20,000 (filenames SINTLC7.BS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1069 OUTSIDE NODE = 888

LOAD STEP 7 SUBSTEP= 1
TIME= 7.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
1407.    -1017.    -970.5    -323.7    -641.7    100.6
      S1      S2      S3      SINT      SEQV
1464.    -399.8    -1645.    3109.    2710.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -705.0    -925.2    -1733.    -128.4    -584.8    -128.0
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O   705.0     925.2     1733.     128.4     584.8     128.0
      S1      S2      S3      SINT      SEQV
I  -587.8    -713.3    -2062.     1474.     1415.
C  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
O   2062.     713.3     587.8     1474.     1415.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  702.1    -1942.    -2703.    -452.1    -1227.    -27.46
C  1407.    -1017.    -970.5    -323.7    -641.7    100.6
O  2112.    -91.71     762.0    -195.3    -56.90    228.6
      S1      S2      S3      SINT      SEQV
I  787.5    -1104.    -3626.     4414.     3836.
C  1464.    -399.8    -1645.     3109.     2710.
O  2168.     725.1    -110.5     2278.     1996.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -404.0    -539.3    -1286.    -23.85    -193.9    -16.65
C   120.4     54.58     391.6     6.304     3.168     17.29
O  -168.2    -123.5    -541.2    -9.024    -29.70    -18.67
      S1      S2      S3      SINT      SEQV
I  -399.5    -496.0    -1334.     934.4     890.1
C   392.7     119.9     53.97     338.8     311.1
O  -120.2    -168.5    -544.3     424.1     402.1

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  298.1    -2481.    -3989.    -476.0    -1420.    -44.11
C  1528.    -962.3    -578.9    -317.4    -638.6    117.9
O  1944.    -215.2     220.8    -204.4    -86.60    210.0
      S1      S2      S3      SINT      SEQV      TEMP
I  387.1    -1700.    -4859.     5246.     4575.     70.00
C  1587.    -151.2    -1449.     3035.     2638.
O  1990.     204.2    -244.4     2234.     2047.     70.00

```

14.5.4 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.6969 in. WITH AN EXTERNAL FORCE OF
Fz = -11,110 lbf, APPLIED AT NODE 20,000 (filenames SINTLC9.BS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1106 OUTSIDE NODE = 993

LOAD STEP 9 SUBSTEP= 1
TIME= 9.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  -722.1    1572.    -1334.    1048.    301.4    -840.2
C      S1      S2      S3      SINT      SEQV
O  1979.    -333.1    -2130.    4109.    3568.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -902.8    -432.7    -1941.    372.2    -113.3    -458.2
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  902.8     432.7     1941.    -372.2    113.3     458.2
C      S1      S2      S3      SINT      SEQV
I  -165.2    -996.5    -2114.    1949.    1694.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  2114.     996.5     165.2     1949.    1694.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -1625.    1139.    -3274.    1421.    188.1    -1298.
C  -722.1    1572.    -1334.    1048.    301.4    -840.2
O  180.8     2005.    607.2     676.1    414.7    -382.0
C      S1      S2      S3      SINT      SEQV
I  1763.    -1387.    -4136.    5899.    5113.
C  1979.    -333.1    -2130.    4109.    3568.
O  2276.     831.4    -314.7    2591.    2249.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -652.8    -404.1    -1432.    135.6    -16.98    -282.3
C  180.3     70.03    507.5    -50.62    60.40     77.05
O  -252.7    -120.9    -663.3    64.72    -58.46    -110.3
C      S1      S2      S3      SINT      SEQV
I  -326.8    -638.0    -1524.    1197.    1076.
C  529.8     193.2     34.81    495.0    437.9
O  -77.87    -265.0    -694.0    616.2    547.1

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -2278.    735.3    -4706.    1556.    171.1    -1581.
C  -541.8    1642.    -826.0    997.7    361.8    -763.2
O  -71.89    1884.    -56.08    740.9    356.3    -492.3
C      S1      S2      S3      SINT      SEQV      TEMP
I  1432.    -2076.    -5605.    7037.    6094.    70.00
C  2031.    -34.50    -1722.    3753.    3255.
O  2149.    395.2    -787.9    2937.    2559.    70.00

```

14.5.5 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.6751 in. WITH AN EXTERNAL MOMENT OF
Mx = 2,120 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC10.BS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1071 OUTSIDE NODE = 885

LOAD STEP 10 SUBSTEP= 1
TIME= 10.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  -331.3    150.9    417.5    447.1    242.8    97.39
C      S1      S2      S3      SINT      SEQV
O  676.7    160.3   -599.9    1277.    1112.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  281.0    433.4    802.2    108.7    233.3    185.0
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -281.0   -433.4   -802.2   -108.7   -233.3   -185.0
C      S1      S2      S3      SINT      SEQV
O  980.6    322.9    213.0    767.6    718.9
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -213.0   -322.9   -980.6    767.6    718.9

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  -50.31    584.3    1220.    555.8    476.1    282.4
C  -331.3    150.9    417.5    447.1    242.8    97.39
O -612.2   -282.5   -384.7    338.4    9.529   -87.64
C      S1      S2      S3      SINT      SEQV
O  1639.    488.1   -373.0    2012.    1748.
C  676.7    160.3   -599.9    1277.    1112.
O -66.25   -375.5   -837.7    771.5    672.5

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  99.90    163.6    531.5    5.532    62.93    56.50
C -70.83   -101.4   -201.6   -35.63   -46.03   -42.16
O  73.97    102.4    258.0    31.92    51.85    47.50
C      S1      S2      S3      SINT      SEQV
O  549.1    153.4    92.52    456.6    429.4
C -46.44   -91.20   -236.3    189.8    171.9
O  287.8    94.33    52.27    235.5    217.6

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  49.59    747.9    1751.    561.3    539.0    338.9
C -402.1    49.41    215.9    411.4    196.8    55.23
O -538.3   -180.1   -126.6    370.3    61.38   -40.14
C      S1      S2      S3      SINT      SEQV      TEMP
O  2130.    682.1   -263.0    2393.    2087.    70.00
C  456.6    55.57   -649.0    1106.    969.5
O  57.37   -125.1   -777.3    834.7    760.1    70.00

```

14.5.6 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.6969 in. WITH AN EXTERNAL MOMENT OF
My = -2,378 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC13.BS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1106 OUTSIDE NODE = 993

LOAD STEP 13 SUBSTEP= 1
TIME= 13.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  353.6    -608.6    702.1    -521.6    -215.5    425.1
C      S1      S2      S3      SINT      SEQV
O  1122.    162.8    -837.6    1959.    1697.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  377.3    129.5    1164.    -288.3    322.7    324.7
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -377.3    -129.5    -1164.    288.3    -322.7    -324.7
C      S1      S2      S3      SINT      SEQV
O  1321.    557.8    -207.9    1529.    1324.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  207.9    -557.8    -1321.    1529.    1324.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  730.9    -479.1    1866.    -809.8    107.2    749.8
C  353.6    -608.6    702.1    -521.6    -215.5    425.1
O -23.64    -738.1    -462.2    -233.3    -538.2    100.4
C      S1      S2      S3      SINT      SEQV
O  2268.    806.0    -955.7    3224.    2796.
C  1122.    162.8    -837.6    1959.    1697.
O  194.3    -248.9    -1169.    1364.    1205.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  338.2    242.3    758.2    -107.7    3.532    165.9
C -108.3    -41.54    -279.6    48.32    -83.35    -61.83
O  144.3    72.74    361.3    -58.79    78.00    80.36
C      S1      S2      S3      SINT      SEQV
O  817.7    365.2    155.8    661.9    585.9
C  19.19    -132.6    -316.1    335.3    290.8
O  398.1    173.7    6.652    391.4    340.2

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  1069.    -236.8    2625.    -917.6    110.8    915.7
C  245.3    -650.2    422.6    -473.2    -298.8    363.3
O  120.7    -665.4    -100.9    -292.1    -460.2    180.7
C      S1      S2      S3      SINT      SEQV      TEMP
O  3075.    1176.    -794.7    3870.    3352.    70.00
C  892.6    -5.932    -868.9    1762.    1526.
O  449.3    -143.8    -951.0    1400.    1217.    70.00

```


14.5.7 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.6969 in. WITH AN EXTERNAL MOMENT OF
Mz = -2,378 ft-lbf, APPLIED AT NODE 20,000 (filenames SINTLC15.BS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1106 OUTSIDE NODE = 993

LOAD STEP 15 SUBSTEP= 1
TIME= 15.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I -191.1    159.4   -193.3    15.66    107.3   -114.4
C      S1      S2      S3      SINT    SEQV
O 190.2   -92.22   -323.0    513.2    445.2

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -212.7    212.0   -446.0    46.13    247.8   -17.48
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 212.7   -212.0    446.0   -46.13   -247.8    17.48
C      S1      S2      S3      SINT    SEQV
I 297.7   -212.5   -532.0    829.7    724.9
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 532.0    212.5   -297.7    829.7    724.9

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -403.7    371.4   -639.4    61.80    355.1   -131.9
C -191.1    159.4   -193.3    15.66    107.3   -114.4
O 21.63   -52.52    252.7   -30.47   -140.6   -96.91
C      S1      S2      S3      SINT    SEQV
I 484.1   -352.0   -803.8    1288.    1132.
C 190.2   -92.22   -323.0    513.2    445.2
O 328.6    28.84   -135.7    464.3    407.7

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -136.7    17.52   -245.6    1.227   -10.37   -51.63
C 41.43   -32.52    93.54   -7.559   -43.50    11.22
O -56.73    31.37   -119.5    7.397    38.99   -17.65
C      S1      S2      S3      SINT    SEQV
I 18.00   -116.3   -266.5    284.5    246.5
C 109.6    39.14   -46.25    155.8    135.1
O 40.95   -52.18   -133.6    174.5    151.3

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -540.4    388.9   -885.0    63.02    344.7   -183.5
C -149.6    126.9   -99.80    8.103    63.78   -103.2
O -35.11   -21.15    133.2   -23.08   -101.6   -114.6
C      S1      S2      S3      SINT    SEQV    TEMP
I 476.5   -466.7   -1046.    1523.    1331.    70.00
C 144.9   -30.67   -236.8    381.7    330.9
O 219.6   -4.304   -138.3    357.9    313.2    70.00

```

14.5.8 LINEARIZED STRESS THROUGH SECTION DEFINED BY PATH LENGTH = 0.7709 in. UNDER UNIFORM TEMPERATURE AND PRESSURE OF 250 deg. F AND 400 psi (filenames SINTLC16.BS4)

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1046 OUTSIDE NODE = 878

LOAD STEP 16 SUBSTEP= 1
TIME= 16.000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
I  647.0    29.49    2077.    32.54    -17.59    -1029.
C      S1      S2      S3      SINT      SEQV
O  2616.    113.8     24.07    2592.    2548.

** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  394.6    1145.    107.9    103.3    -89.26    -402.7
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -394.6    -1145.    -107.9    -103.3    89.26     402.7
C      S1      S2      S3      SINT      SEQV
I  1181.    642.0    -176.3    1358.    1184.
C  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  176.3    -642.0    -1181.    1358.    1184.

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  1042.    1174.    2185.    135.8    -106.9    -1432.
C  647.0    29.49    2077.    32.54    -17.59    -1029.
O  252.4    -1115.    1969.    -70.73    71.67    -626.6
C      S1      S2      S3      SINT      SEQV
I  3169.    1163.    68.80    3100.    2723.
C  2616.    113.8     24.07    2592.    2548.
O  2176.    49.77    -1119.    3295.    2894.

** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  146.4    642.3    983.6    -80.62    0.6802    -262.6
C -134.4    -439.7    -628.5    -37.74    31.41     137.8
O  120.1    579.6    785.2    19.77     6.686    -164.3
C      S1      S2      S3      SINT      SEQV
I  1060.    651.3    60.54    999.8    870.6
C -96.12    -435.2    -671.3    575.1    500.7
O  823.5    580.4    80.84    742.7    655.9

** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  1188.    1816.    3169.    55.19    -106.2    -1695.
C  512.6    -410.2    1449.    -5.199    13.82    -891.5
O  372.5    -535.6    2754.    -50.96    78.36    -790.9
C      S1      S2      S3      SINT      SEQV      TEMP
I  4147.    1810.    215.4    3932.    3425.    250.0
C  1988.    -26.27    -410.3    2398.    2231.
O  2995.    134.8    -538.9    3534.    3250.    250.0

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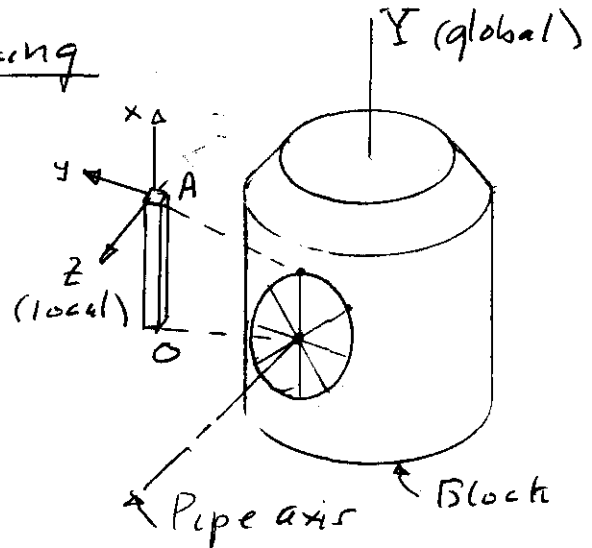
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 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator EP Weiner Date 1/17/95
 (9) Checker H. P. Soderstrom Date 1/26/95

(10)

15.0 CALCULATIONS FOR BLOCK-PIPE BEAM SIZING (BEAMS)

Block-pipe beam sizing

Pipe influence on the block is accomplished by applying moments and forces at the hub of an array of 60 beams running out to the two first circles of nodes on the outer surface of the block. Transmission of the gross forces and moments to the block is of primary importance. That is achieved by the spoke arrangement itself. Beam sizing is carried out to provide reasonable local effects



The local beam z -axis is assumed parallel to the pipe axis.

I_{yy} (out-of-hole-plane bending)

Through-wall moment flexibility of the pipe.

Ansys SHELL61 is used to obtain the stiffness



DESIGN CALCULATION

WHC-SD-W236A-DA-002

REVISION 0-

(1) Drawing _____ (2) Doc. No. _____ (3) _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator E.O. Weiner Date 1/17/95
 (9) Checker J.P. Stronatan Date 1/24/95

(10)

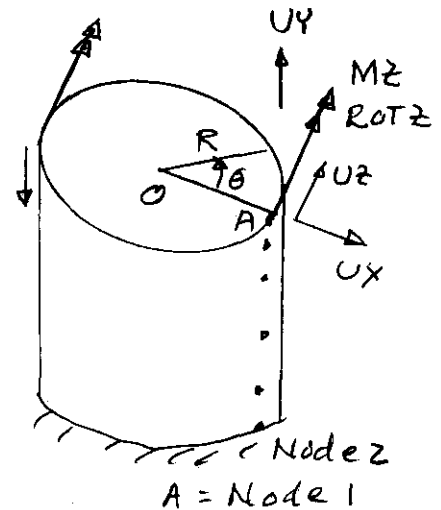
for a moment distribution

$$\frac{M_z}{2\pi R} \cos \theta$$

around the pipe edge giving
a local rotation

$$\phi = ROT_z - R \cdot U_y$$

Use $U_x = U_z = 0$ at the edge
since the block is very stiff.



$$k_b = \frac{M_b}{\phi} = \frac{3EI_y}{R}$$

$$M_b = \frac{M_z}{2\pi R} R \Delta \theta \quad \Delta \theta = \frac{2\pi}{N}$$

$N \equiv$ number of beams attaching to the block

Beam matches pipe flexibility when $\phi = ROT_z - R \cdot U_y$:

$$\frac{3EI_y}{R} = \frac{M_b}{\phi} = \frac{\frac{M_z}{2\pi R} R \frac{2\pi}{N}}{ROT_z - R \cdot U_y}$$

$$I_y = \frac{M_z}{ROT_z - R \cdot U_y} \cdot \frac{R}{3EN}$$

Use

$$M_z = 1000$$

$$E = 27 \times 10^6 \text{ psi}$$

$$N = 60, 42 \text{ \& } 52 \text{ for } 2", 3", 4" \text{ connectors}$$

$$R = \bar{R}, \text{ sched 40 pipe } \bar{D} = 2\bar{R}$$

$$t = \text{wall thickness, sched 40}$$

$$B-174$$

$$\text{Pipe length} = 3\sqrt{Rt}$$

Build-in at far end

DESIGN CALCULATION

WHC-SD-W236A-DA-002

REVISION 0

(1) Drawing _____ (2) Doc. No. _____ (3) _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator Ed Weiner Date 1/17/95
 (9) Checker H. P. Schroeder Date 1/26/95

(10)

Size	$\bar{R}$, in	t , in	ROTZ	UY	I_y , in ⁴
2"	1.10	.154	.263-2	.25-4	.87-4
3"	1.64	.216	.925-3	.13-4	.53-3
4"	2.14	.237	.640-3	.10-4	.82-3

I_{yy} (second consideration): I_{yy} might be chosen to reproduce the ability of the pipe to maintain plane sections. Use a $\cos 2\theta$ distribution with F_y on the pipe and compare with the cross scheme shown below

$$\frac{1}{UY} \cdot \frac{F_y}{2\pi R} R \Delta\theta = \frac{3EI_y}{R^3}$$

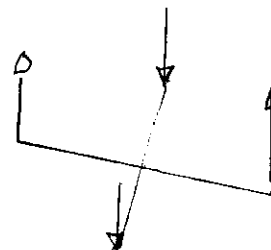
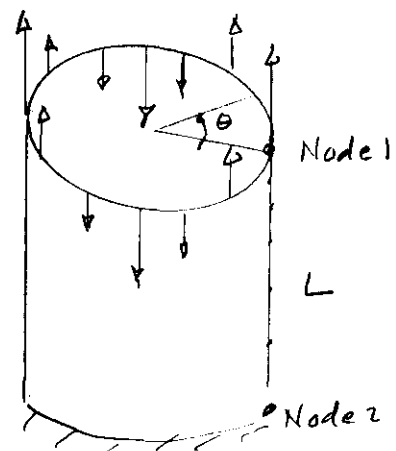
$$\Delta\theta = \frac{2\pi}{N}$$

$$\therefore I_y = \frac{F_y}{UY} \cdot \frac{1}{N} \cdot \frac{R^3}{3E}$$

Use $F_y = 1000$
 $L = 4R$

Size	UY, in	I_y , in ⁴
2"	.431-4	.0064
3"	.310-4	.042
4"	.291-4	.080

USE



(1) Drawing _____ (2) Doc. No. _____ (3) _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator EO Weiner Date 1/17/95
 (9) Checker J. P. Shannahan Date 1/24/95

(10)

There is a one to two order of magnitude difference with the moment (M_z) consideration. F_y is considered important for membrane stresses in the block. M_z is considered important for bending stresses in the block. Choosing I_y based on F_z gives a stiffness higher than that based on M_z . This results in accurate membrane stresses and conservative bending stresses.

A (beam area) Use a beam area that gives 1% volume of material cut from the block to form the hole

$$A \times R \leq 0.01 \pi R^2 t_b \quad \therefore A \leq \frac{\pi R t_b}{100 N}$$

R = hole radius

A = beam area

t_b = thickness of the block

I_z (bending in the plane of the hole). This is used to pass piping shear into the block. The piping shear should not be transmitted by a beam direct stress through area A .

DESIGN CALCULATION

WHC-SD-W236A-DA-0025

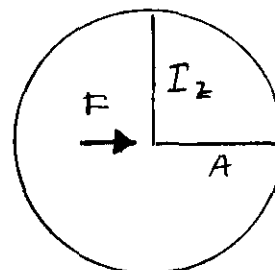
(1) Drawing _____ (2) Doc. No. _____ (3) REVISION 05A
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator EO Weiner Date 1/17/95
 (9) Checker H. P. Shroeder Date 1/26/95

(10)

$$\delta_A = \frac{F}{EA/R} \quad \delta_{I_z} = \frac{F}{12EI_z/R^3}$$

$$\delta_{I_z} \leq 0.01 \delta_A$$

$$\frac{F}{12EI_z/R^3} \leq 0.01 \frac{F}{EA/R}$$



$$I_z \geq \frac{100}{12} AR^2$$

Size	R, in	t _b , in	A _{max} , in ²	I _{z min} , in ⁴
2"	1.03	.66	.00036	.0029
3"	1.53	.98	.0011	.0219
4"	2.02	1.17	.0014	.049

J (beam torsion) Avoid transmitting out-of-plane moments by torsion (prefer I_y)

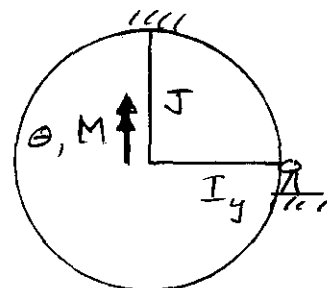
$$\theta_J = \frac{M}{GJ/R}$$

$$\theta_{I_y} = \frac{M}{3EI_y/R}$$

$$\theta_{I_y} \ll \theta_J$$

$$\frac{3EI_y}{R} \gg \frac{GJ}{R}$$

$$J \ll \frac{3E}{G} I_y$$



$$\frac{3E}{G} \approx 8$$

$$\text{Use } J_{\max} = 0.1 I_y$$

Size	I _y , in ⁴	J _{max} , in ⁴
2"	.0064	.0006
3"	.042	.004
4"	.080	.008

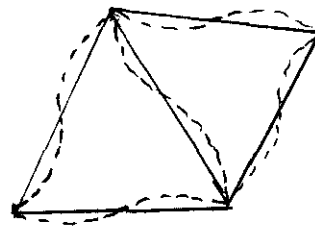
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(1) Drawing _____ (2) Doc. No. _____ (3) _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator EO Werner Date 1/17/95
 (9) Checker J. P. Sherrington Date 1/26/95

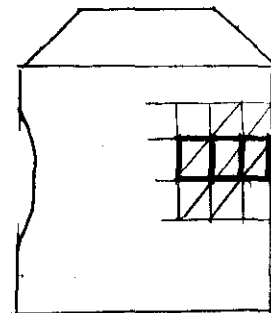
(10)

Rotational DOF Restraints

SOLID72 user instructions suggest the restraint of rotational dofs to avoid mechanisms involving uniform rotations of all nodes without translation. Rotational springs to ground are not considered acceptable since there is no built-in boundary condition area on the block. The beam-spokes used to model the pipe attachment effect will serve to restrain the mechanism, since uniform nodal rotations at the hole's edge will clearly deform the spokes.



Another way to do this would be to attach SHELL63 elements over a small low-stressed area. Use about 10% of the block wall thickness for the shell thickness. The coverage should span $\sim 10^\circ$ around the circumference, since the shell is known to have a weak dof associated with rotation about the surface normal.



DESIGN CALCULATION

WHC-SD-W236A-DA-002

REVISION 0

(1) Drawing _____ (2) Doc. No. _____ (3) _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator EO Weiner Date 1/17/95
 (9) Checker J. P. Sherrington Date 1/26/95

(10)

Since the beam-spokes represent the restraint of the pipe to block deformations, they are considered better than the 10% thickness shell element restraint

Note also; using rotational springs to ground could produce ill conditioning if they are too flexible. $\therefore$ the beam-spoke presence is considered the best restraint,

Subject _____

Originator EO Weiner Date 1/17/95Checker L. P. Shroeder Date 1/26/95

Block pipe-beam sizing calculations

Out-of-plane moment of inertia based on local pipe wall bending:

 $j := 1..3$ (2", 3", and 4" connectors) $MZ := 1000$ $E := 27 \cdot 10^6$

$N_j :=$	$t_j :=$	$R_j :=$	$ROTZ_j :=$	$UY_j :=$
60	.154	1.1	.00263	.000025
42	.216	1.64	.000925	.000013
52	.237	2.14	.000640	.000010

$$I_{y_j} := \frac{MZ}{ROTZ_j - R_j \cdot UY_j} \cdot \frac{R_j}{3 \cdot E \cdot N_j}$$

I_{y_j}
$8.697 \cdot 10^{-5}$
$5.335 \cdot 10^{-4}$
$8.213 \cdot 10^{-4}$

Out-of-plane moment of inertia based on pipe plane sections:

$FY := 1000$	$UY_j :=$	$I_{y_j} := \frac{FY}{UY_j} \cdot \frac{(R_j)^3}{3 \cdot E \cdot N_j}$	I_{y_j}
	$.431 \cdot 10^{-4}$		$6.354 \cdot 10^{-3}$
	$.310 \cdot 10^{-4}$		0.042
	$.291 \cdot 10^{-4}$		0.080

Beam area, in-plane moment of inertia and polar moment of inertia:

$tb_j :=$	$R_j :=$	$A_j := \frac{\pi R_j \cdot tb_j}{100 \cdot N_j}$	A_j
.66	1.02		$3.525 \cdot 10^{-4}$
.98	1.53		$1.122 \cdot 10^{-3}$
1.17	2.02		$1.428 \cdot 10^{-3}$

$$I_{z_j} := \frac{100}{12} \cdot A_j \cdot (R_j)^2$$

I_{z_j}
$3.056 \cdot 10^{-3}$
0.022
0.049

$$J_j := 0.1 \cdot I_{y_j}$$

J_j
$6.354 \cdot 10^{-4}$
$4.182 \cdot 10^{-3}$
$7.996 \cdot 10^{-3}$

ANSYS Input Listing

```

/batch
/title, Pipe flexibility for beam representation, 2"
/prep7
rbar=2.21/2      ! ave radius, pipe
thk=.154         ! thicknes
lc=3*sqrt(rbar*thk)
ET, 1,61
R, 1
RMOD, 1, 1,thk
MP,EX,1,27e6
k,1,rbar
k,,rbar,lc
l,1,2
LESIZE,P50X,,,10,3
↑
LMESH,ALL
FINISH
/SOLU
MODE,1,1
d,1,ux
d,1,uz
D,2,ALL
F,1,MZ,1000
SOLVE
FINISH
/POST1
SET
*status
PRNSOL,U
PRNSOL,ROT
fini
/clear
/batch
/title, Pipe flexibility for beam representation, 3"
/prep7
rbar=3.28/2      ! ave radius, pipe
thk=.216         ! thicknes
lc=3*sqrt(rbar*thk)
ET, 1,61
R, 1
RMOD, 1, 1,thk
MP,EX,1,27e6
k,1,rbar
k,,rbar,lc
l,1,2
LESIZE,P50X,,,10,3
↑
LMESH,ALL
FINISH
/SOLU
MODE,1,1
d,1,ux
d,1,uz
D,2,ALL
F,1,MZ,1000
SOLVE
FINISH
/POST1
SET
*status
PRNSOL,U
PRNSOL,ROT
fini
/clear
/batch
/title, Pipe flexibility for beam representation, 4"
/prep7
rbar=4.27/2      ! ave radius, pipe
thk=.237         ! thicknes
lc=3*sqrt(rbar*thk)
ET, 1,61
R, 1
RMOD, 1, 1,thk
MP,EX,1,27e6
k,1,rbar

```

k,,rbar,lc
l,1,2
LESIZE,P50X,,,10,3
1
LMESH,ALL
FINISH
/SOLU
MODE,1,1
d,1,ux
d,1,uz
D,2,ALL
F,1,MZ,1000
SOLVE
FINISH
/POST1
SET
*status
PRNSOL,U
PRNSOL,ROT
fini
/exit

ANSYS Output Listing

Running ANSYS 5.0a on workstation: cea8 on: Fri Jan 13 13:48:14 PST 1995

USE LOAD STEP 1 SUBSTEP 0 FOR LOAD CASE 0
SET COMMAND GOT LOAD STEP= 1 SUBSTEP= 1 CUMULATIVE ITERATION= 1
TIME/FREQUENCY= 1.0000

PARAMETER STATUS- (3 PARAMETERS DEFINED)

NAME	VALUE	TYPE	DIMENSIONS
LC	1.23755000	SCALAR	
RBAR	1.10500000	SCALAR	
THK	0.154000000	SCALAR	

PRINT U NODAL SOLUTION PER NODE 1

Pipe flexibility for beam representation, 2"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	USUM
1	0.00000E+00	-0.25354E-04	0.00000E+00	0.25354E-04
2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.14335E-03	-0.22495E-04	0.00000E+00	0.14510E-03
4	-0.23715E-03	-0.17879E-04	0.00000E+00	0.23783E-03
5	-0.27974E-03	-0.12233E-04	0.00000E+00	0.28001E-03
6	-0.27533E-03	-0.64745E-05	0.00000E+00	0.27541E-03
7	-0.23437E-03	-0.15599E-05	0.00000E+00	0.23438E-03
8	-0.17214E-03	0.17407E-05	0.00000E+00	0.17215E-03
9	-0.10562E-03	0.30693E-05	0.00000E+00	0.10566E-03
10	-0.49413E-04	0.26273E-05	0.00000E+00	0.49483E-04
11	-0.12789E-04	0.11822E-05	0.00000E+00	0.12844E-04

...

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A *****

Pipe flexibility for beam representation, 2"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	ROTZ
1	0.26310E-02
2	0.00000E+00
3	0.16701E-02
4	0.84281E-03
5	0.19581E-03
6	-0.24173E-03
7	-0.46751E-03
8	-0.51062E-03
9	-0.42679E-03
10	-0.28269E-03
11	-0.13265E-03

...

PARAMETER STATUS- (3 PARAMETERS DEFINED)

NAME	VALUE	TYPE	DIMENSIONS
LC	1.78554193	SCALAR	
RBAR	1.64000000	SCALAR	
THK	0.216000000	SCALAR	

PRINT U NODAL SOLUTION PER NODE

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1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A *****

... Pipe flexibility for beam representation, 3"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	USUM
1	0.00000E+00	-0.12803E-04	0.00000E+00	0.12803E-04
2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.72720E-04	-0.11431E-04	0.00000E+00	0.73613E-04
4	-0.12024E-03	-0.91713E-05	0.00000E+00	0.12059E-03
5	-0.14171E-03	-0.63783E-05	0.00000E+00	0.14186E-03
6	-0.13930E-03	-0.35060E-05	0.00000E+00	0.13934E-03
7	-0.11834E-03	-0.10298E-05	0.00000E+00	0.11834E-03
8	-0.86649E-04	0.66263E-06	0.00000E+00	0.86652E-04
9	-0.52906E-04	0.13848E-05	0.00000E+00	0.52924E-04
10	-0.24567E-04	0.12267E-05	0.00000E+00	0.24598E-04
11	-0.62860E-05	0.55983E-06	0.00000E+00	0.63109E-05

MAXIMUM VALUES

NODE	5	1	0	5
VALUE	-0.14171E-03	-0.12803E-04	0.00000E+00	0.14186E-03

PRINT ROT NODAL SOLUTION PER NODE

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A *****

... Pipe flexibility for beam representation, 3"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	ROTZ
1	0.92541E-03
2	0.00000E+00
3	0.58690E-03
4	0.29547E-03
5	0.67627E-04
6	-0.86260E-04
7	-0.16534E-03
8	-0.17989E-03
9	-0.14966E-03
10	-0.98354E-04
11	-0.45507E-04

...

PARAMETER STATUS- (3 PARAMETERS DEFINED)

NAME	VALUE	TYPE	DIMENSIONS
LC	2.13399977	SCALAR	
RBAR	2.13500000	SCALAR	
THK	0.237000000	SCALAR	

PRINT U NODAL SOLUTION PER NODE 1

...

Pipe flexibility for beam representation, 4"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

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THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	USUM
1	0.00000E+00	-0.10355E-04	0.00000E+00	0.10355E-04
2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.60079E-04	-0.93929E-05	0.00000E+00	0.60809E-04
4	-0.99190E-04	-0.77122E-05	0.00000E+00	0.99489E-04
5	-0.11663E-03	-0.55759E-05	0.00000E+00	0.11676E-03
6	-0.11424E-03	-0.33286E-05	0.00000E+00	0.11428E-03
7	-0.96513E-04	-0.13397E-05	0.00000E+00	0.96522E-04
8	-0.70058E-04	0.80762E-07	0.00000E+00	0.70059E-04
9	-0.42194E-04	0.77092E-06	0.00000E+00	0.42201E-04
10	-0.19169E-04	0.77946E-06	0.00000E+00	0.19185E-04
11	-0.47383E-05	0.37304E-06	0.00000E+00	0.47529E-05

MAXIMUM VALUES

NODE	5	1	0	5
VALUE	-0.11663E-03	-0.10355E-04	0.00000E+00	0.11676E-03

PRINT ROT NODAL SOLUTION PER NODE 1

... Pipe flexibility for beam representation, 4"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	ROTZ
1	0.64034E-03
2	0.00000E+00
3	0.40512E-03
4	0.20261E-03
5	0.44448E-04
6	-0.62019E-04
7	-0.11612E-03
8	-0.12503E-03
9	-0.10269E-03
10	-0.66022E-04
11	-0.29321E-04

```

/batch
/title, Pipe flexibility for plane sections, 2"
/prep7
rbar=2.21/2      ! ave radius, pipe
thk=.154         ! thicknes
lc=4*rbar
ET, 1,61
R, 1
RMOD, 1, 1,thk
MP,EX,1,27e6
k,1,rbar
k,,rbar,lc
l,1,2
LESIZE,P50X,,,10,3
1
LMESH,ALL
FINISH
/SOLU
mode,2,1
d,1,ux
d,1,uz
D,2,ALL
F,1,fy,1000
SOLVE
FINISH
/POST1
SET
*status
PRNSOL,U
fini
/clear
/batch
/title, Pipe flexibility for plane sections, 3"
/prep7
rbar=3.28/2      ! ave radius, pipe
thk=.216         ! thicknes
lc=4*rbar
ET, 1,61
R, 1
RMOD, 1, 1,thk
MP,EX,1,27e6
k,1,rbar
k,,rbar,lc
l,1,2
LESIZE,P50X,,,10,3
1
LMESH,ALL
FINISH
/SOLU
mode,2,1
d,1,ux
d,1,uz
D,2,ALL
F,1,fy,1000
SOLVE
FINISH
/POST1
SET
*status
PRNSOL,U
fini
/clear
/batch
/title, Pipe flexibility for plane sections, 4"
/prep7
rbar=4.27/2      ! ave radius, pipe
thk=.237         ! thicknes
lc=4*rbar
ET, 1,61
R, 1
RMOD, 1, 1,thk
MP,EX,1,27e6
k,1,rbar
k,,rbar,lc
l,1,2

```



```
LESIZE,P50X,,,10,3
1
LMESH,ALL
FINISH
/SOLU
mode,2,1
d,1,ux
d,1,uz
D,2,ALL
F,1,fy,1000
SOLVE
FINISH
/POST1
SET
*status
PRNSOL,U
fini
/exit
```

...
 PARAMETER STATUS- (3 PARAMETERS DEFINED)

NAME	VALUE	TYPE	DIMENSIONS
LC	4.42000000	SCALAR	
RBAR	1.10500000	SCALAR	
THK	0.15400000	SCALAR	

...
 Pipe flexibility for plane sections, 2"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
 TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	USUM
1	0.00000E+00	0.43051E-04	0.00000E+00	0.43051E-04
2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.14039E-04	0.35500E-04	0.00000E+00	0.38175E-04
4	-0.30307E-04	0.27650E-04	0.00000E+00	0.41025E-04
5	-0.45082E-04	0.20088E-04	0.00000E+00	0.49355E-04
6	-0.54945E-04	0.13139E-04	0.00000E+00	0.56494E-04
7	-0.58290E-04	0.70409E-05	0.00000E+00	0.58713E-04
8	-0.54880E-04	0.20578E-05	0.00000E+00	0.54919E-04
9	-0.45253E-04	-0.15023E-05	0.00000E+00	0.45278E-04
10	-0.30770E-04	-0.32903E-05	0.00000E+00	0.30946E-04
11	-0.13862E-04	-0.28598E-05	0.00000E+00	0.14154E-04

...
 PARAMETER STATUS- (3 PARAMETERS DEFINED)

NAME	VALUE	TYPE	DIMENSIONS
LC	6.56000000	SCALAR	
RBAR	1.64000000	SCALAR	
THK	0.21600000	SCALAR	

...
 Pipe flexibility for plane sections, 3"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
 TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	USUM
1	0.00000E+00	0.31012E-04	0.00000E+00	0.31012E-04
2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.10450E-04	0.25621E-04	0.00000E+00	0.27670E-04
4	-0.22586E-04	0.20000E-04	0.00000E+00	0.30168E-04
5	-0.33609E-04	0.14565E-04	0.00000E+00	0.36629E-04
6	-0.40986E-04	0.95459E-05	0.00000E+00	0.42083E-04
7	-0.43551E-04	0.51148E-05	0.00000E+00	0.43850E-04
8	-0.41108E-04	0.14713E-05	0.00000E+00	0.41134E-04
9	-0.34000E-04	-0.11485E-05	0.00000E+00	0.34020E-04
10	-0.23198E-04	-0.24728E-05	0.00000E+00	0.23329E-04
11	-0.10537E-04	-0.21509E-05	0.00000E+00	0.10755E-04

...
 PARAMETER STATUS- (3 PARAMETERS DEFINED)

NAME	VALUE	TYPE	DIMENSIONS
LC	8.54000000	SCALAR	
RBAR	2.13500000	SCALAR	
THK	0.23700000	SCALAR	

...
 Pipe flexibility for plane sections, 4"

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
 TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	USUM
1	0.00000E+00	0.29104E-04	0.00000E+00	0.29104E-04
2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.10651E-04	0.24171E-04	0.00000E+00	0.26413E-04
4	-0.23139E-04	0.18985E-04	0.00000E+00	0.29931E-04
5	-0.34477E-04	0.13919E-04	0.00000E+00	0.37181E-04
6	-0.42109E-04	0.91752E-05	0.00000E+00	0.43097E-04
7	-0.44943E-04	0.49187E-05	0.00000E+00	0.45211E-04
8	-0.42720E-04	0.13591E-05	0.00000E+00	0.42742E-04
9	-0.35625E-04-0.12456E-05	0.00000E+00	0.00000E+00	0.35647E-04
10	-0.24526E-04-0.25869E-05	0.00000E+00	0.00000E+00	0.24662E-04
11	-0.11406E-04-0.22587E-05	0.00000E+00	0.00000E+00	0.11627E-04

...

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16.0 CONCLUSION

16.1 ISB Block Conclusion

The 2-, 3-, and 4-in. Integral Seal Block (ISB) were analyzed and evaluated in this appendix in accordance with ASME (1989a and 1989b) criteria. The loading applied to the blocks was comprised of assumed axial loading, which comprised of torques, thermal expansion, and internal pressure applied to the blocks. The blocks were evaluated with the criteria established in section 4.7 of this appendix. The failure modes of the blocks were used to determine the appropriate ASME (1989b) criteria. The evaluation of the 2-, 3-, and 4-in. blocks considered the following possible failure modes. A punch-through at the top of the block (block/screw interface), failure at the pipe connection where the external loads were applied, and failure at the bottom of the block (nozzle/block interface)

The evaluation consisted of comparing general and local primary membrane, general and local primary membrane plus bending, and local primary membrane plus bending plus secondary stresses occurring from the discontinuities or bearing type stresses on the surface of the blocks.

The evaluation of the top of the blocks, for a punch-through effect, used the full diameter of the screw to apply the axial loads at the top of the 2-, 3-, and 4-in. blocks. The full diameter is justified in appendix E, where the plasticity of the block and screw is considered. The 50 ft-lbf and the maximum torque was determined based on the linearized stress intensities through the thickness of the top section of the block, at the screw interface, in accordance with the ASME (1989a and 1989b) criteria established in section 4.7.1. The stress intensities for a 50 ft-lbf pre-load torque, through the top of the block, is found in section 11, Tables B8, B9, and B10. The maximum pre-load torques calculated, based on linear elastic theory, are 180, 490, and 230 ft-lbf for the 2-, 3-, and 4-in. ISB blocks respectively. This is only for A276 grade 304 SST material. There are uncertainties which effect the conclusion stated, namely the boundary conditions used in the evaluation at the top of the section under external loading. The punch-through is valid for axial loading. However, the influence of the screw and guide under external forces and moments is more complicated. To address the interaction of the components and the block, system models of the 2-, 3-, and 4-in. jumpers were developed to determine the interaction of the block, torque screw, nozzle, hooks, and operating guide under external forces and moments. The system models are discussed in appendix C and G of this report. The acceptability of the acceptable piping loads from Table 3.4 was linearly compared to the block maximum allowable piping loads based in the section. The loads obtained from Table 3.4 were found to be acceptable for linear interaction.

The results of the ISB block evaluation, to determine maximum allowable external piping forces and moments under design temperature (250 deg. F) and pressure (400 psi), at 50 ft-lbf for the 2-, 3-, and 4-in. is tabulated in Table B12 for A276 grade 304 SST material.

Table B12. Maximum external piping forces and moments applied to ISB block for A276 Grade 304 SST material @ 50 ft-lbf pre-load torque.

External Piping Loads	2-in. ISB Block		3-in. ISB Block		4-in. ISB Block	
	POS	BS	POS	BS	POS	BS
Fx (lbf)	22,647	24,911	57,774	97,481	70,720	139,348
Fy (lbf)	13,913	22,029	34,850	66,284	29,136	155,811
Fz (lbf)	17,767	9,323	46,046	40,527	50,945	52,499
Mx (ft-lbf)	2,437	3,099	11,212	17,189	13,920	32,096
My (ft-lbf)	1,631	2,449	9,362	18,070	7,937	23,561
Mz (ft-lbf)	1,319	8,032	6,443	31,506	8,441	83,781

Note: POS is defined as the pipe opening section and BS is defined as the bottom section.

The maximum allowable external piping loads are independent of sign, except for the axial loading (Fz). Where the above Fz is given as a compressive force. If the force is in tension then the Fz force is govern by the minimum seating forces.

In this case, for the 2-, 3-, and 4-in. ISB jumper connectors, the minimum axial seating force with and without thermal effects and at 50 ft-lbf pre-load torque are as follows: 9,156 and 3,386 lbf, 6,210 and -1,915 lbf, 6,306 and -4,306, respectively. In this case, if the seating force is negative a possible leak could occur. See Table 3.3 for seating forces at various pre-load torques.

The seating force for the 2-, 3-, and 4-in. at the maximum calculated torques of 180, 490, and 230 ft-lbf, respectively are stated as the following (with and without thermal effects): 20,967 and 15,196 lbf, 28,697 and 20,572 lbf, 13,669 and 2,560 lbf. In order to insure that the jumpers do not leak in the field, leak testing should be done. Where the minimum torques are at 50 ft-lbf and the maximum torques are 180, 490, and 230 ft-lbf for the 2-, 3-, and 4-in. ISB blocks. However, the conclusions in appendix A and C may restrict these higher torque values. In the main report is Table 3.4 which states the acceptable piping loads for the 2-, 3-, and 4-in. ISB jumper connectors.

16.2 ISB Nozzle Flange Conclusion

The 2-, 3-, and 4-in. nozzle flange of the ISB jumper was analyzed in accordance with ASME (1989b and 1989c) criteria. Using ASME (1989b) flange design the longitudinal hub, radial flange, and tangential flange stresses were compared to the allowable hub, radial, and tangential stresses per ASME (1989c). The evaluation of the nozzle flanges meet the ASME (1989c) criteria allowables established in sections 5.3.1, 7.3.1 and 9.3.1 for the 2-, 3-, and 4-in. ISB jumpers. The system model evaluation of the nozzle flange is discussed in appendix C.

To better understand the behavior of the jumpers under external loading multiple test should be completed with strain gauges on critical components.

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APPENDIX C

SYSTEM MODEL CALCULATIONS FOR THE EVALUATION OF ALL COMPONENTS

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Appendix "C" System Model Calculations for the Evaluation of All Components
Authors E. O. Weiner

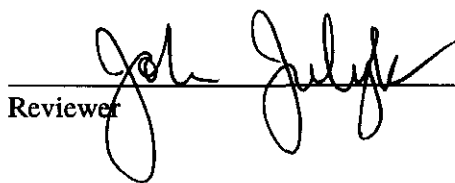
Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☐	☐	☒	Computer codes and data files documented. (IN APPENDIX G)
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☐	☐	☒	Models appropriate and used within range of validity or use outside range of established validity justified. (IN APPENDIX G)
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation. (IN APPENDIX G)
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation. (IN APPENDIX G)
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number 95-002

Reviewer



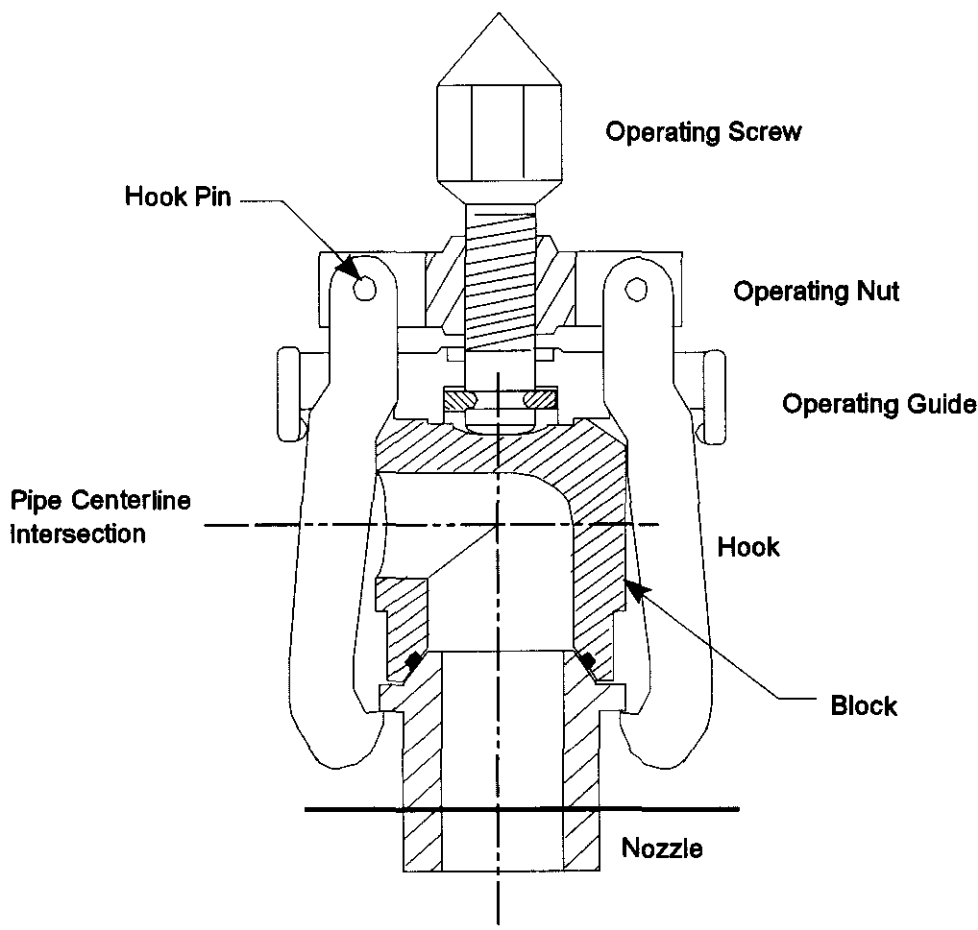
Date

4/10/95

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner *EOW*Date 3/29/95Checker J. L. Julyk *JLJ*Date 3/30/95**2-, 3-, and 4-in. ISB Jumper Connector System Model Evaluations**

The purpose of the following calculations is to describe the system models used for the pin and interface, with and without the guide engaged conditions. The maximum forces, moments and stresses output from the system models are used to evaluate the nozzle, hooks, hook pins, operating nut, guide, operating screw, top of block, and guide-block interface (see appendix G). Both the interface, pinned, and pinned released (pin allowed to rotate) system model results are used in the evaluation. The end product is a set of load fractions to be used with the nominal piping loads provided in appendix F, Table F1.

Figure C1. Typical Jumper Connector Assembly for 2-, 3-, and 4-in. ISB Connectors

**1.0 MATERIAL PROPERTIES**

The material allowables are calculated in accordance with AISC (1989) guidelines or ASME (1989) criteria, based on ASTM (1989) yield and tensile strength of each material.

ANALYTICAL CALCULATIONS

WHC-SD-W236A-DA-002
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Subject System Model Evaluation for ISB Jumper Clamp

Originator E. O. Weiner *EOW*

Date 3/29/95

Checker J. L. Julyk *JLJ*

Date 3/30/95

1.1 Hook Material Properties (@ 70 °F) for ASTM A747 Grade CB7Cu-1 or CB7Cu-2, H1075 Heat Treated ASTM (1989) and AISC (1989)

Minimum yield strength Minimum tensile strength

$$S_{yA747} := 115000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{uA747} := 145000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable bending stress based on AISC (1989)

Allowable shear stress based on AISC (1989)

$$\sigma_{bA747} := 0.60 \cdot S_{yA747}$$

$$\sigma_{vA747} := 0.40 \cdot S_{yA747}$$

$$\sigma_{bA747} = 69000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{vA747} = 46000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

1.2 Block Material Properties (@ 250 °F) for ASTM A276 Grade 304, ASTM (1989) and ASME (1989)

Minimum yield strength

Material allowable stress per ASME (1989) criteria for block, appendix B.

$$S_{yA276} := 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{mA276} := 20000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable shear stress based on ASME (1989)

Allowable bearing stress based on ASME (1989)

$$\sigma_{vA276} := 0.60 \cdot S_{mA276}$$

$$\sigma_{brA276} := 1.5 \cdot S_{yA276}$$

$$\sigma_{vA276} = 12000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{brA276} = 45000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

1.3 Operating Pin Material Properties (@ 70 °F): Replace ASTM A108 Grade 1045

ASTM (1989) and AISC (1989) with material having minimum yield and tensile strengths shown.

Minimum yield strength

Minimum tensile strength

$$S_{yA108} := 110000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{uA108} := 124000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable shear per AISC (1989)

Allowable bending per AISC (1989)

$$\sigma_{vA108} := 0.40 \cdot S_{yA108}$$

$$\sigma_{bA108} := 0.75 \cdot S_{yA108}$$

$$\sigma_{vA108} = 44000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{bA108} = 82500 \cdot \frac{\text{lbf}}{\text{in}^2}$$

ANALYTICAL CALCULATIONS

WHC-SD-W236A-DA-002
REVISION 0Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner *EOW*Date 3/29/95Checker J. L. Julyk *JLJ*Date 3/30/95**1.4 Guide Material Properties (@ 70 °F) for ASTM A743 Grade CF8 (McLusky 1988) and AISC (1989)**

Minimum yield strength

Minimum tensile strength

$$S_{yA743} := 30000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{uA743} := 70000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable bearing stress per AISC (1989)

Allowable shear stress based on AISC (1989)

$$\sigma_{brA743} := 1.2 \cdot S_{uA743}$$

$$\sigma_{vA743} := 0.25 \cdot S_{uA743}$$

$$\sigma_{brA743} = 84000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{vA743} = 17500 \cdot \frac{\text{lbf}}{\text{in}^2}$$

1.5 Operating Nut Material Properties (@ 70 °F) for ASTM A148 ASTM (1989) and AISC (1989)

Minimum yield strength

Minimum tensile strength

$$S_{yA148} := 60000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{uA148} := 90000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable shear
per AISC (1989)Allowable bending stress
per AISC (1989)Allowable bearing stress
per AISC (1989)

$$\sigma_{vA148} := 0.40 \cdot S_{yA148}$$

$$\sigma_{bA148} := 0.75 \cdot S_{yA148}$$

$$\sigma_{brA148} := 1.2 \cdot S_{uA148}$$

$$\sigma_{vA148} = 24000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{bA148} = 45000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{brA148} = 108000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

**1.6 Operating Screw Material Properties (@ 70 °F) for ASTM A193 Grade B7 Carbon Steel
ASTM (1989) and AISC (1989)**

Minimum yield strength

Minimum tensile strength

$$S_{yA193} := 105000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$S_{uA193} := 125000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable bending stress per AISC (1989)

$$\sigma_{bA193} := 0.60 \cdot S_{yA193}$$

$$\sigma_{bA193} = 63000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner EOWDate 3/29/95Checker J. L. JulvikDate 3/30/95**2.0 2-in. ISB Jumper Connector System Model Calculations****2.1 NOZZLE ANALYSIS** $P_{\text{limit}} := 5943 \cdot \text{lbf}$ Total Axial Capacity for one hook (appendix A) $P_{\text{thermal}} := 5771 \cdot \text{lbf}$ Thermal expansion resistance load (appendix B, section 4.3) $P_{\text{pressure}} := 201 \cdot \text{lbf}$ Pressure resistance load (appendix B, section 4.4) $P_{\text{preload}} := 5000 \cdot \text{lbf}$ Preload for 50 ft-lbf torque (Squier 1993)
$$P_{\text{nom}} := \frac{1}{3} (P_{\text{thermal}} + P_{\text{pressure}} + P_{\text{preload}})$$

$$P_{\text{nom}} = 3657 \cdot \text{lbf} \quad \text{Nominal load}$$

Net load after thermal expansion, pressure, and the pre-load are deducted from the limit load
(see appendix B for thermal, pressure, and pre-load axial values)

$$P_{\text{net}} := P_{\text{limit}} - P_{\text{nom}} \quad P_{\text{net}} = 2286 \cdot \text{lbf}$$
2.2 Determine the load fractions to use in the nozzle evaluation for the interface, pinned, and pin released system models.**2.2.1 Interface and pinned system model**

Load	ΔF (lbf)	LF	where: ΔF is the maximum axial hook load from system models (appendix G)
$F_x = 400 \text{ lbf}$	500	4.57	$LF = \frac{P_{\text{net}}}{\Delta F}$ is the Load fraction
$F_y = 2300 \text{ lbf}$	100	10.00	
$F_z = 1000 \text{ lbf}$	1,200	1.91	
$M_x = 2000 \text{ lbf-ft}$	8,300	0.28	
$M_y = 1600 \text{ lbf-ft}$	-	10.00	
$M_z = 1600 \text{ lbf-ft}$	7,700	0.30	

Full release of the hook from the nozzle is not acceptable as it invalidates the model.

Pro-rate absolute hook-nozzle reactions to the existing load.

$$P_{\text{pre}} := P_{\text{nom}}$$

Load	ΔF (lbf)	LF	where: ΔF is the maximum axial hook load from system models (appendix G)
$F_x = 400 \text{ lbf}$	500	7.31	$LF = \frac{P_{\text{pre}}}{\Delta F}$ is the Load fraction
$F_y = 2300 \text{ lbf}$	100	10.00	
$F_z = 1000 \text{ lbf}$	1,200	3.05	
$M_x = 2000 \text{ lbf-ft}$	8,300	0.44	
$M_y = 1600 \text{ lbf-ft}$	-	10.00	
$M_z = 1600 \text{ lbf-ft}$	7,700	0.47	

ANALYTICAL CALCULATIONS

WHC-SD-W236A-DA-002
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Subject System Model Evaluation for ISB Jumper Clamp

Originator E. O. Weiner *EOW*

Date 3/29/95

Checker J. L. Julyk *JK*

Date 3/30/95

2.2.2 Pin Released or allowed to rotate @ hook/operating nut location

Load	ΔF (lbf)	LF
$F_x = 400$ lbf	600	3.81
$F_y = 2300$ lbf	100	10.00
$F_z = 1000$ lbf	1,200	1.91
$M_x = 2000$ lbf-ft	8,900	0.26
$M_y = 1600$ lbf-ft	-	10.00
$M_z = 1600$ lbf-ft	8,200	0.28

where: ΔF is the maximum axial hook load from system models (appendix G)

$$LF = \frac{P_{net}}{\Delta F} \quad \text{is the Load fraction}$$

Full release of the hook from the nozzle is not acceptable as it invalidateds the model.

Pro-rate absolute hook-nozzle reactions to the existing load. $P_{pre} := P_{nom}$

Load	ΔF (lbf)	LF
$F_x = 400$ lbf	600	6.10
$F_y = 2300$ lbf	100	10.00
$F_z = 1000$ lbf	1,200	3.05
$M_x = 2000$ lbf-ft	8,900	0.41
$M_y = 1600$ lbf-ft	-	10.00
$M_z = 1600$ lbf-ft	8,200	0.45

where: ΔF is the maximum axial hook load from system models (appendix G)

$$LF = \frac{P_{pre}}{\Delta F} \quad \text{is the Load fraction}$$

Figure C2. Typical 2-in. Hook
(WHC 1993b, H-2-90174, rev. 7, sh 2)

3.0 HOOK ANALYSIS

3.1 Section (A) of the Hook (nozzle flange location)

Use β as the fraction of hook-guide bending stresses.

$$\beta := \frac{1.4 \cdot \text{in}}{5.26 \cdot \text{in}} \quad \beta = 0.266$$

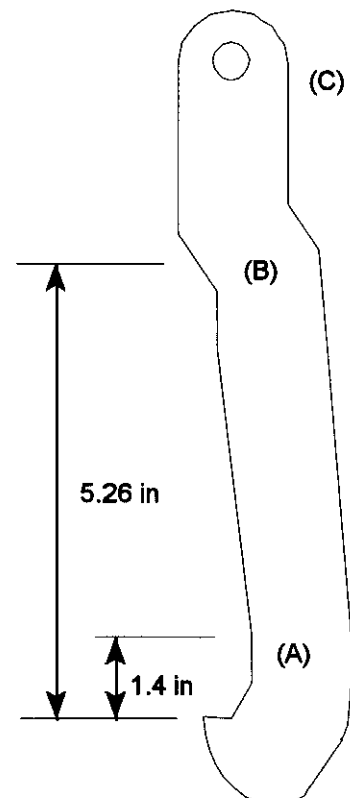
$$P_{limit} = 5943 \cdot \text{lbf}$$

Total capacity, axial, for one ASTM A747 hook (appendix A)

Net load after thermal expansion, pressure, and the pre-load are deducted from the limit load (see appendix B for thermal, pressure, and pre-load axial values)

$$P_{net} := P_{limit} - P_{nom}$$

$$P_{net} = 2286 \cdot \text{lbf}$$



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Checker J. L. Julyk *JLJ*

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The pipe loads produce both membrane and bending stresses in the hook. To account for the bending and membrane stresses re-calculate the P_{limit} and P_{net} in terms of stresses

$$\sigma_{\text{limit}} = \sigma_{\text{bA747}}$$

$$\sigma_{\text{limit}} = 69000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{\text{net}} = \frac{P_{\text{net}}}{P_{\text{limit}}} \cdot \sigma_{\text{limit}}$$

$$\sigma_{\text{net}} = 26537 \cdot \frac{\text{lbf}}{\text{in}^2}$$

3.1.1 Interface and pinned system models

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 400 lbf	600	-	1,000	10.00
	Fy = 2300 lbf	100	-	-	10.00
	Fz = 1000 lbf	-	16,600	-	6.01
	Mx = 2000 lbf-ft	-	119,800	-	0.83
	My = 1600 lbf-ft	-	171,429	-	0.58
	Mz = 1600 lbf-ft	8,400	-	14,500	2.17
Hook @ 120-deg.	Fx = 400 lbf	300	5,800	376	10.00
	Fy = 2300 lbf	100	-	-	10.00
	Fz = 1000 lbf	1,200	8,300	2,200	6.65
	Mx = 2000 lbf-ft	9,000	60,000	15,500	0.91
	My = 1600 lbf-ft	-	171,429	-	0.58
	Mz = 1600 lbf-ft	4,200	83,000	7,200	0.94

3.1.2 Pin released or allowed to rotate at hook/nut location

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 400 lbf	600	-	1,100	10.00
	Fy = 2300 lbf	100	-	-	10.00
	Fz = 1000 lbf	-	19,900	-	5.01
	Mx = 2000 lbf-ft	-	143,000	-	0.70
	My = 1600 lbf-ft	-	19,000	-	5.25
	Mz = 1600 lbf-ft	9,000	-	15,500	2.02
Hook @ 120-deg.	Fx = 400 lbf	300	6,906	500	10.00
	Fy = 2300 lbf	100	-	-	10.00
	Fz = 1000 lbf	1,300	10,000	2,100	5.87
	Mx = 2000 lbf-ft	8,800	71,700	15,200	0.83
	My = 1600 lbf-ft	-	18,700	-	5.33
	Mz = 1600 lbf-ft	4,200	99,400	7,300	0.81

where: $LF = \frac{\sigma_{\text{net}}}{Sd + \beta \cdot (Sby + Sbz)}$

Note: The stresses are from appendix G and are the maximum stresses at location (A) on the hook, from the Jumper clamp system model data.

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner EOWDate 3/29/95Checker J. L. JulykDate 3/30/95**3.2 Section (b) of the Hook (Guide location)**

Using the system model bending and direct stresses section (B) is considered. Section (B) is closer to the load axis. Therefore, adjust section (A) limit using the beam membrane plus bending stress formula.

$$\sigma = \frac{P}{A} + \frac{P \cdot L}{S} \quad \text{Axial and bending stress}$$

@ section (A) per drawing H-2-90174 (WHC 1993b)

$$w_{\text{hook}} := 1.64 \cdot \text{in} - 0.5 \cdot \text{in} \quad \text{Width of hook} \quad w_{\text{hook}} = 1.14 \cdot \text{in}$$

$$t_{\text{hook}} := 0.78 \cdot \text{in} \quad \text{Thickness of hook}$$

$$A_{\text{hook}} := w_{\text{hook}} \cdot t_{\text{hook}} \quad \text{area of hook} \quad A_{\text{hook}} = 0.889 \cdot \text{in}^2$$

$$S_{\text{hook}} := \frac{1}{6} \cdot (t_{\text{hook}} \cdot w_{\text{hook}}^2) \quad \text{Section modulus of hook} \quad S_{\text{hook}} = 0.169 \cdot \text{in}^3$$

$$L_{\text{effective}} := S_{\text{hook}} \cdot \left(\frac{\sigma_{\text{limit}}}{P_{\text{limit}}} - \frac{1}{A_{\text{hook}}} \right) \quad L_{\text{effective}} = 1.772 \cdot \text{in}$$

$$L_o := \frac{w_{\text{hook}}}{2} + 0.5 \cdot \text{in} - 0.06 \cdot \text{in} + \frac{0.31 \cdot \text{in}}{2} \quad L_o = 1.165 \cdot \text{in}$$

Figure C3. Sketch of 2-in. Hook section (WHC 1993b, H-2-90174)

$$\text{Scale by } \Omega := \frac{L_{\text{effective}}}{L_o} \quad \text{on section (B)}$$

$$L_o := \frac{1}{2} \cdot (0.18 \cdot \text{in} + 1.25 \cdot \text{in}) \quad L_o = 0.715 \cdot \text{in}$$

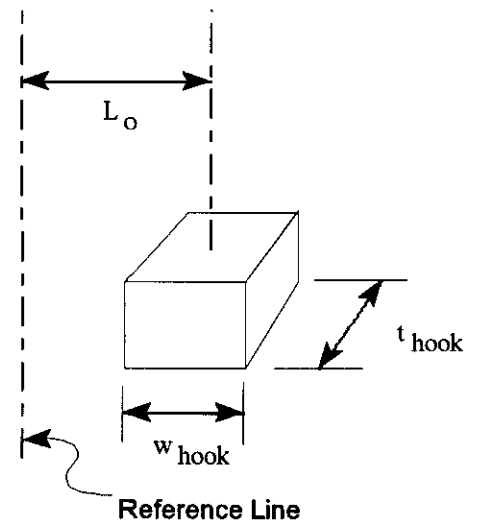
$$L_{\text{effective}} := L_o \cdot \Omega \quad L_{\text{effective}} = 1.087 \cdot \text{in}$$

Determine the combined axial and bending stress at the limit load P_{limit}

$$\sigma := P_{\text{limit}} \cdot \left(\frac{1}{A_{\text{hook}}} + \frac{L_{\text{effective}}}{S_{\text{hook}}} \right) \quad \sigma = 44929 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Adjust section (A) σ_{net} for (B)

$$\sigma_{\text{net}} := \sigma_{\text{limit}} - \frac{P_{\text{nom}}}{P_{\text{limit}}} \cdot \sigma \quad \sigma_{\text{net}} = 41350 \cdot \frac{\text{lbf}}{\text{in}^2}$$



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3.2.1 Interface and pinned system models

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 400 lbf	600	-	1,000	10.00
	Fy = 2300 lbf	100	-	-	10.00
	Fz = 1000 lbf	-	16,600	-	2.49
	Mx = 2000 lbf-ft	-	119,800	-	0.35
	My = 1600 lbf-ft	-	171,429	-	0.24
	Mz = 1600 lbf-ft	8,400	-	14,500	1.81
Hook @ 120-deg.	Fx = 400 lbf	300	5,800	376	6.39
	Fy = 2300 lbf	100	-	-	10.00
	Fz = 1000 lbf	1,200	8,300	2,200	3.53
	Mx = 2000 lbf-ft	9,000	60,000	15,500	0.49
	My = 1600 lbf-ft	-	171,429	-	0.24
	Mz = 1600 lbf-ft	4,200	83,000	7,200	0.44

where: $LF = \frac{\sigma_{net}}{Sd + Sby + Sbz}$

Note: The stresses are from appendix G and are the maximum stresses at location (B) on the hook, from the Jumper clamp system model data.

3.2.2 Pin released or allowed to rotate at hook/nut location

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 400 lbf	600	-	1,100	10.00
	Fy = 2300 lbf	100	-	-	10.00
	Fz = 1000 lbf	-	19,900	-	2.08
	Mx = 2000 lbf-ft	-	143,000	-	0.29
	My = 1600 lbf-ft	-	19,000	-	2.18
	Mz = 1600 lbf-ft	9,000	-	15,500	1.69
Hook @ 120-deg.	Fx = 400 lbf	300	6,906	500	5.37
	Fy = 2300 lbf	100	-	-	10.00
	Fz = 1000 lbf	1,300	10,000	2,100	3.09
	Mx = 2000 lbf-ft	8,800	71,700	15,200	0.43
	My = 1600 lbf-ft	-	18,700	-	2.21
	Mz = 1600 lbf-ft	4,200	99,400	7,300	0.37

where: $LF = \frac{\sigma_{net}}{Sd + Sby + Sbz}$

Note: The stresses are from appendix G and are the maximum stresses at location (B) on the hook, from the Jumper clamp system model data.

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REVISION 0Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 3/29/95Checker J. L. JulykDate 3/30/95**3.3 Section (C) of the Hook (for the Pin Hole)**Use the system model stresses with a k_c factor for the hook pin hole.**3.3.1 Interface and pinned system models**

	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 400 lbf	600	-	10.00
	Fy = 2300 lbf	100	-	10.00
	Fz = 1000 lbf	-	22,000	1.37
	Mx = 2000 lbf-ft	-	157,000	0.19
	My = 1600 lbf-ft	-	185,250	0.16
	Mz = 1600 lbf-ft	8,500	-	3.55
Hook @ 120-deg.	Fx = 400 lbf	300	7,500	3.86
	Fy = 2300 lbf	100	-	10.00
	Fz = 1000 lbf	1,300	11,000	2.45
	Mx = 2000 lbf-ft	9,100	78,000	0.35
	My = 1600 lbf-ft	-	185,250	0.16
	Mz = 1600 lbf-ft	4,100	109,000	0.27

$$\text{where: } LF = \frac{\sigma_{\text{limit}} - k_c \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}}{k_c \cdot (S_d + S_{by})}$$

Note: The stresses are from appendix G and are the maximum stresses at location (C) on the hook, from the Jumper clamp system model data.

$$k_c = \frac{2 \cdot 0.56}{2 \cdot 56 - .564} \quad k_c = 2.014$$

3.3.2 Pin released or allowed to rotate at hook/nut locationThe moments in the hook of section (C) are admitted to the extent of the eccentricity $t_{\text{hook}}/2$ to the edge of the hook at the pin.

$$\sigma_{\text{limit}} = k_c \cdot \frac{(P_{\text{nom}} + LF \cdot S_d \cdot A_{\text{hook}}) \cdot \frac{t_{\text{hook}}}{2}}{S_{\text{hook}}} + k_c \cdot \left(\frac{P_{\text{nom}}}{A_{\text{hook}}} + LF \cdot S_d \right) \quad \sigma_{\text{limit}} = 69000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\text{where: } LF = \frac{\sigma_{\text{limit}} - k_c \cdot \frac{P_{\text{nom}} \cdot \frac{t_{\text{hook}}}{2}}{S_{\text{hook}}} - k_c \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}}{k_c \cdot S_d + k_c \cdot \left[S_d \cdot A_{\text{hook}} \cdot \frac{t_{\text{hook}}}{2} \right]}$$

Note: The stresses are from appendix G and are the maximum stresses at location (C) on the hook, from the Jumper clamp system model data.

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	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 400 lbf	690	-	10.00
	Fy = 2300 lbf	100	-	10.00
	Fz = 1000 lbf	-	-	10.00
	Mx = 2000 lbf-ft	-	-	10.00
	My = 1600 lbf-ft	-	-	10.00
	Mz = 1600 lbf-ft	8,950	-	0.80
Hook @ 120-deg.	Fx = 400 lbf	300	-	10.00
	Fy = 2300 lbf	100	-	10.00
	Fz = 1000 lbf	1,300	-	5.53
	Mx = 2000 lbf-ft	9,700	-	0.74
	My = 1600 lbf-ft	-	-	10.00
	Mz = 1600 lbf-ft	4,500	-	1.60

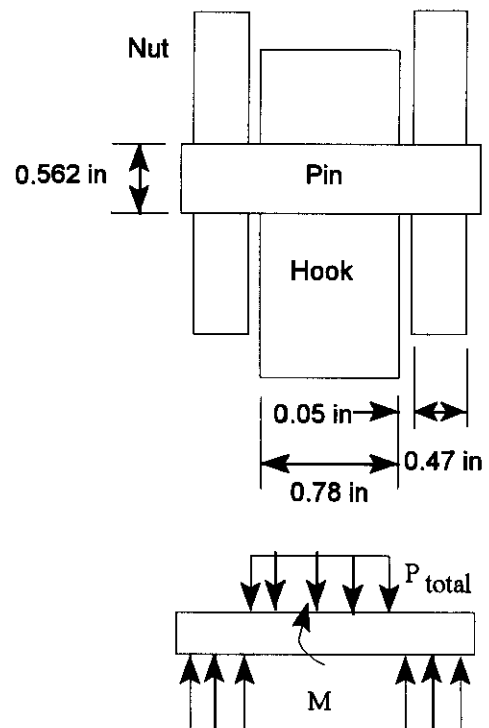
4.0 PIN ANALYSIS

Considerable latitude in pin allowables can be obtained with different assumptions for the bearing load distribution. The most common and conservative is the 4-point assumption is equivalent to a uniform bearing load (Shigley 1989). This is consistent with other assumptions used with the hook and nut.

Figure C4. Sketch of 2-in. Hook, Hook pin and Nut
(four point axial loading condition)

4.1 Dimensions (WHC, 1982, 1991a, 1993b)

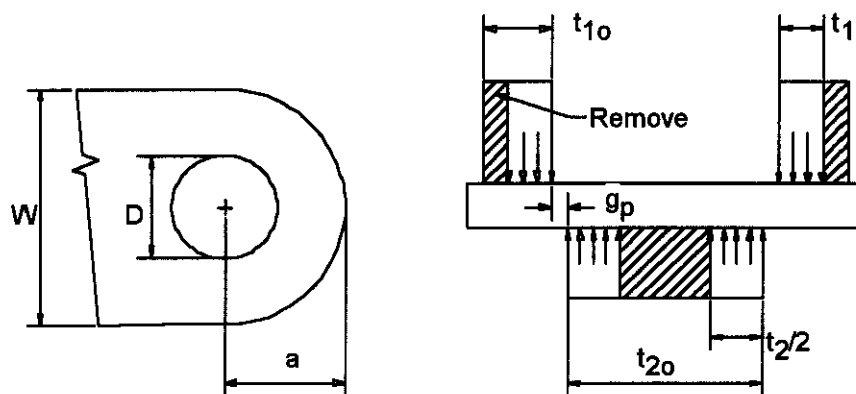
$d_{pin} := 0.562 \cdot \text{in}$	Pin diameter (H-2-32421)
$t_{nut} := 0.47 \cdot \text{in}$	Operating nut thickness (H-2-68209)
$\Delta_{tol} := 0.05 \cdot \text{in}$	tolerance between hook and operating nut (H-2-68209)
$t_{hook} = 0.78 \cdot \text{in}$	hook thickness (H-2-90174)
$A_{pin} := \frac{\pi \cdot d_{pin}^2}{4}$	Area of pin
	$A_{pin} = 0.248 \cdot \text{in}^2$
$S_{pin} := \frac{\pi \cdot d_{pin}^3}{32}$	Section modulus for pin
	$S_{pin} = 0.017 \cdot \text{in}^3$



Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner F045Date 3/29/95Checker J. L. JulykDate 3/30/95**4.2 Pin analysis with bearing considerations**

Pin-lug capacity estimates should consider the movement of hook and nut bearing forces toward one another thus reducing the lever arm causing bending moments in the pin. The method herein removes lug material away from the bearing areas until margins of the lugs and pin are nearly equal. A weakened lug system that increases the normally calculated pin strength is satisfactory as long as the lugs are as strong as the pin.

Figure C5. Sketch of Pin and Operating Nut for bearing type loading



Ref: Northrup Structural Design manual, ca 1967, Section 204.4 (section 28, of appendix C)

Derived Units: kip = 1000 · lbf ksi = 1000 · $\frac{\text{lbf}}{\text{in}^2}$

Connector size: 2 inch

Drawings: Pin: H-2-32421 (WHC 1982)
Nut: H-2-68209 (WHC 1991a)
Hook: H-2-90174 (WHC1993b)

Common:

$$t_{10} := 0.47 \cdot \text{in} \quad t_{20} := .78 \cdot \text{in} \quad t_1 := t_{10} \quad t_2 := t_{20}$$

4.2.1 Nut: (symmetric)

$$F_{tu} := S_u A_{148} \quad F_{ty} := S_y A_{148}$$

$$a := 2.31 \cdot \text{in} - 1.563 \cdot \text{in} \quad a = 0.747 \cdot \text{in}$$

$$D := 0.56 \cdot \text{in} \quad W := 1.64 \cdot \text{in} \quad \frac{W}{D} = 2.929$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_1 \quad A_t = 0.508 \cdot \text{in}^2 \quad K_t := 0.92 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{tu} := K_t F_{tu} A_t \quad P'_{tu} = 42.029 \cdot \text{kip}$$

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b. Shear tear-out

$$\frac{a}{D} = 1.334$$

$$\frac{D}{t_1} = 1.191$$

$$K_{br} := 1.25$$

(curve 1, Fig 204.4-3)

$$A_{br} := D \cdot t_1$$

$$A_{br} = 0.263 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br}$$

$$P'_{bru} = 29.61 \cdot \text{kip}$$

c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru}$$

$$\frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 1.25$$

$$C := 1.10$$

(Fig. 204.4-4)

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin}$$

$$P'_y = 21.714 \cdot \text{kip}$$

204.44 Transverse curve. Use curve at 90 deg

$$f := .75$$

(Fig. 204.4-5)

$$P'_{lug} := f \cdot P'_y$$

$$P'_{lug} = 16.286 \cdot \text{kip}$$

4.2.2 Hook

$$F_{tu} := S_u A_{747}$$

$$F_{ty} := S_y A_{747}$$

$$a := .56 \cdot \text{in}$$

$$D := 0.567 \cdot \text{in}$$

$$W := 1.12 \cdot \text{in}$$

$$\frac{W}{D} = 1.975$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_2$$

$$A_t = 0.431 \cdot \text{in}^2$$

$$K_t := 0.97$$

(curve 1, Fig 204.4-2)

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t$$

$$P'_{tu} = 60.668 \cdot \text{kip}$$

b. Shear tear-out

$$\frac{a}{D} = 0.988$$

$$\frac{D}{t_2} = 0.727$$

$$K_{br} := .83$$

(curve 1, Fig 204.4-3)

$$A_{br} := D \cdot t_2$$

$$A_{br} = 0.442 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br}$$

$$P'_{bru} = 53.226 \cdot \text{kip}$$

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c. Lug yield. Use min of P'tu, P'bru.

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 0.83 \quad C := 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 46.435 \cdot \text{kip} \quad P'_{hook} := P'_y$$

$$P'_{hook} = 46.435 \cdot \text{kip}$$

4.2.3 Operating Pin

204.45 Account for pin bending

$$F_{ty} := S_y A_{108} \quad F_{tu} := S_u A_{108}$$

$$g_p := .05 \cdot \text{in} \quad R := \frac{.56}{2} \cdot \text{in}$$

a. Pin capacity

$$b := .5 \cdot t_1 + g_p + 0.25 \cdot t_2 \quad b = 0.48 \cdot \text{in}$$

$$Z := \pi \cdot R^2 \cdot 0.4244 \cdot R \quad Z = 0.029 \cdot \text{in}^3$$

$$S := \frac{\pi}{4} \cdot R^3 \quad S = 0.017 \cdot \text{in}^3 \quad f_{shape} := \frac{Z}{S} \quad f_{shape} = 1.698$$

$$P'_{pin} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{pin} = 13.415 \cdot \text{kip}$$

b. Peaking effect

$$r := \frac{a - \frac{D}{2}}{t_2} \quad r = 0.354 \quad K_{br} = 0.83 \quad (\text{min: } P'tu \text{ or } P'bru)$$

$$\gamma := 0.62 \quad (\text{Fig. 204.4-8}) \quad b := 0.5 \cdot t_1 + g_p + \gamma \cdot \frac{t_2}{4} \quad b = 0.406 \cdot \text{in}$$

$$P'_{pin} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{pin} = 15.864 \cdot \text{kip}$$

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$$P'_{\text{nut}} := 2 \cdot P'_{\text{lug}} \quad P'_{\text{nut}} = 32.571 \cdot \text{kip}$$

$$P'_{\text{hook}} = 46.435 \cdot \text{kip}$$

$$P'_{\text{pin}} = 15.864 \cdot \text{kip}$$

4.3 Estimate f_1 and f_2 factors to reduce t_{10} and t_{20} for nearly equal limits

For a first cut, estimate the new pin limit by averaging the nut and hook limits and then forming the geometric mean with the old pin limit. Compare this with the old nut and hook limits for f_1 and f_2 .

$$f_1 := 0.74 \quad f_2 := 0.53 \quad (\text{after iteration})$$

$$t_1 := f_1 \cdot t_{10} \quad t_2 := f_2 \cdot t_{20}$$

$$t_1 = 0.348 \cdot \text{in} \quad t_2 = 0.413 \cdot \text{in}$$

4.3.1 Nut: (symmetric)

$$F_{\text{tu}} := S_{\text{uA148}} \quad F_{\text{ty}} := S_{\text{yA148}}$$

$$a := 2.31 \cdot \text{in} - 1.563 \cdot \text{in} \quad a = 0.747 \cdot \text{in}$$

$$D := 0.56 \cdot \text{in} \quad W := 1.64 \cdot \text{in} \quad \frac{W}{D} = 2.929$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_1 \quad A_t = 0.376 \cdot \text{in}^2 \quad K_t := 0.92 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{\text{tu}} := K_t \cdot F_{\text{tu}} \cdot A_t \quad P'_{\text{tu}} = 31.102 \cdot \text{kip}$$

b. Shear tear-out

$$\frac{a}{D} = 1.334 \quad \frac{D}{t_1} = 1.61 \quad K_{\text{br}} := 1.28 \quad (\text{curve 1, Fig 204.4-3})$$

$$A_{\text{br}} := D \cdot t_1 \quad A_{\text{br}} = 0.195 \cdot \text{in}^2$$

$$P'_{\text{bru}} := K_{\text{br}} \cdot F_{\text{tu}} \cdot A_{\text{br}} \quad P'_{\text{bru}} = 22.437 \cdot \text{kip}$$

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c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 1.28 \quad C := 1.09 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 16.304 \cdot \text{kip}$$

204.44 Transverse curve. Use curve at 90 deg $f := .75$ (Fig. 204.4-5)

$$P'_{lug} := f \cdot P'_y \quad P'_{lug} = 12.228 \cdot \text{kip}$$

4.3.2 Hook

$$F_{tu} := S_u A_{747} \quad F_{ty} := S_y A_{747}$$

$$a := .56 \cdot \text{in}$$

$$D := 0.567 \cdot \text{in} \quad W := 1.12 \cdot \text{in} \quad \frac{W}{D} = 1.975$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_2 \quad A_t = 0.229 \cdot \text{in}^2 \quad K_t := 0.97 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t \quad P'_{tu} = 32.154 \cdot \text{kip}$$

b. Shear tear-out

$$\frac{a}{D} = 0.988 \quad \frac{D}{t_2} = 1.372 \quad K_{br} := .82 \quad (\text{curve 1, Fig 204.4-3})$$

$$A_{br} := D \cdot t_2 \quad A_{br} = 0.234 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br} \quad P'_{bru} = 27.87 \cdot \text{kip}$$

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c. Lug yield. Use min of P'tu, P'bru.

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 0.82 \quad C := 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 24.314 \cdot \text{kip} \quad P'_{hook} := P'_y$$

$$P'_{hook} = 24.314 \cdot \text{kip}$$

4.3.3 Operating Pin

204.45 Account for pin bending

$$F_{ty} := S_y A_{108} \quad F_{tu} := S_u A_{108}$$

$$g_p := .05 \cdot \text{in} \quad R := \frac{.56}{2} \cdot \text{in}$$

a. Pin capacity

$$b := .5 \cdot t_1 + g_p + 0.25 \cdot t_2 \quad b = 0.327 \cdot \text{in}$$

$$Z := \pi \cdot R^2 \cdot 0.4244 \cdot R \quad Z = 0.029 \cdot \text{in}^3$$

$$S := \frac{\pi}{4} \cdot R^3 \quad S = 0.017 \cdot \text{in}^3 \quad f_{\text{shape}} := \frac{Z}{S} \quad f_{\text{shape}} = 1.698$$

$$P'_{\text{pin}} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{\text{pin}} = 19.676 \cdot \text{kip}$$

b. Peaking effect

$$r := \frac{a - \frac{D}{2}}{t_2} \quad r = 0.669 \quad K_{br} = 0.82 \quad (\text{min: } P'tu \text{ or } P'bru)$$

$$\gamma := 0.42 \quad (\text{Fig. 204.4-8}) \quad b := .5 \cdot t_1 + g_p + \gamma \cdot \frac{t_2}{4} \quad b = 0.267 \cdot \text{in}$$

$$P'_{\text{pin}} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{\text{pin}} = 24.089 \cdot \text{kip}$$

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4.4 Check shear

$$A_{pin} := \frac{\pi \cdot D^2}{4} \quad P'_{shr} := 0.6 \cdot F_{tu} \cdot A_{pin} \cdot 2 \quad P'_{shr} = 37.572 \cdot \text{kip}$$

Pin bending is treated as a yield type limit reflecting a shape factor of 1.70 which is applicable in plastic design. With the usual AISC safety factor of 1.67:

$$P_{b.all} := \frac{P'_{pin}}{1.67} \quad P_{b.all} = 14.424 \cdot \text{kip} \quad (\text{Use})$$

Shear safety factor of 2.5:

$$P_{s.all} := \frac{P'_{shr}}{2.5} \quad P_{s.all} = 15.029 \cdot \text{kip}$$

Therefore, Bending governs

4.5 Calculated Limit Load

$$P_{limit} := P_{b.all} \quad P_{limit} = 14424 \cdot \text{lbf} \quad \text{which governs}$$

4.6 Shear limit

$$\tau_{limit} := P_{s.all} \quad \tau_{limit} = 15029 \cdot \text{lbf} \quad \text{Which does not govern}$$

4.7 External Loads

$$P_{net} := P_{limit} - P_{nom} \quad P_{net} = 10767 \cdot \text{lbf}$$

$$\sigma_{net} := \frac{P_{net}}{P_{limit}} \cdot \sigma_{bA108} \quad \sigma_{net} = 61582 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Pin bending stress σ_{pm} caused by hook membrane stress σ_{hm}

$$\sigma_{pm}(\sigma_{hm}) := \frac{\sigma_{hm} \cdot A_{hook}}{P_{limit}} \cdot \sigma_{bA108} \quad \sigma_{pm} \left(1 \cdot \frac{\text{lbf}}{\text{in}^2} \right) = 5.086 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \sigma_{hm} \quad \text{gives } a_{hm}$$

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner EOWDate 3/29/95Checker [Signature]Date 3/30/95**4.7.1 Determine the pin bending stress σ_{pb} caused by hook bending stress σ_{hb} .**

Use the distribution shown on half the pin (Figure C6).

$$M_{hook} := 1 \cdot \text{lbf} \cdot \text{in}$$

assumed hook moment equal to 1

$$P_1 := \frac{M_{hook}}{2 \cdot \frac{2}{3} \cdot \frac{t_{hook}}{2}}$$

$$P_1 = 1.923 \cdot \text{lbf}$$

$$P_2 := \frac{M_{hook}}{2 \cdot \left(\frac{t_{hook}}{2} + \Delta_{tol} + \frac{t_{nut}}{2} \right)}$$

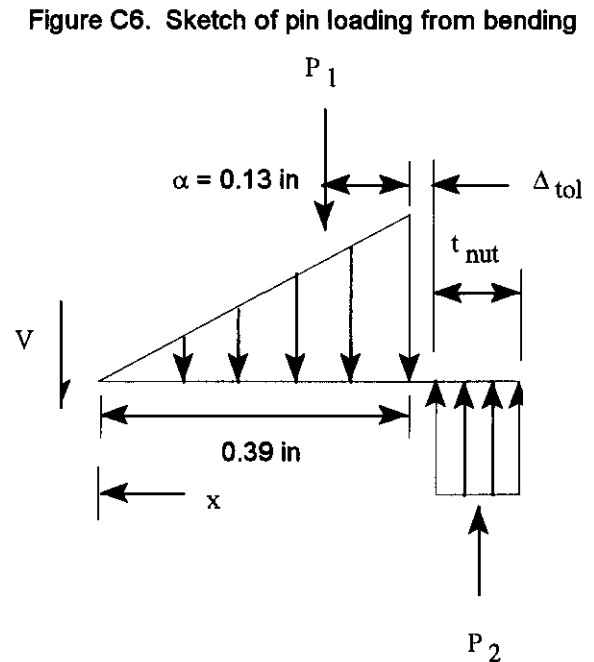
$$P_2 = 0.741 \cdot \text{lbf}$$

shear force

$$V := P_1 - P_2 \quad V = 1.182 \cdot \text{lbf}$$

The maximum displacement is determined as the following

$$M_h(x) := V \cdot x - P_1 \cdot \frac{t_{hook}}{6} \cdot \left[\frac{x}{\left(\frac{t_{hook}}{2} \right)} \right]^3$$



Taking the derivative of both sides of the equation, to determine the maximum displacement, the equation simplifies to

$$x_{max} := \sqrt{\frac{V}{P_1 \cdot 4 \cdot \frac{t_{hook}}{2}}} \quad x_{max} = 0.306 \cdot \text{in}$$

Therefore, the maximum moment in the pin is

$$M_{max} := V \cdot x_{max} - P_1 \cdot \frac{t_{hook}}{6} \cdot \left[\frac{x_{max}}{\left(\frac{t_{hook}}{2} \right)} \right]^3$$

$$\text{maximum moment in pin} \quad M_{max} = 0.241 \cdot \text{lbf} \cdot \text{in}$$

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4.8 Interface and Pinned system model

The pin bending stress σ_{pb} is a function of the hook bending stress σ_{hb} $Z_{pin} := 1.70 \cdot S_{pin}$

$$\sigma_{pb}(\sigma_{hb}) := \frac{M_{max} \cdot \sigma_{hb} \cdot S_{hook}}{M_{hook} \cdot Z_{pin}} \quad \sigma_{pb} \left(1 \cdot \frac{\text{lbf}}{\text{in}^2} \right) = 1.375 \cdot \frac{\text{lbf}}{\text{in}^2} \sigma_{hb} \quad \text{gives } a_{hbt}$$

Add σ_{pb} and σ_{pm} directly using the hook stresses at the nut and compare with σ_{net} $\sigma_{net} = 61582 \cdot \frac{\text{lbf}}{\text{in}^2}$

	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 400 lbf	600	-	10.00
	Fy = 2300 lbf	-	-	10.00
	Fz = 1000 lbf	-	22,000	2.04
	Mx = 2000 lbf-ft	-	157,000	0.29
	My = 1600 lbf-ft	-	185,000	0.24
	Mz = 1600 lbf-ft	8,400	-	1.44
Hook @ 120-deg.	Fx = 400 lbf	300	7,500	5.20
	Fy = 2300 lbf	-	-	10.00
	Fz = 1000 lbf	1,300	11,000	2.83
	Mx = 2000 lbf-ft	9,000	78,000	0.40
	My = 1600 lbf-ft	-	185,000	0.24
	Mz = 1600 lbf-ft	4,100	109,000	0.36

where: $LF = \frac{\sigma_{net}}{a_{hm} \cdot Sd + a_{hbt} \cdot Sby}$

Note: The stresses are maximum stresses from appendix G.

4.9 Pin Released or Pin allowed to rotate @ hook/nut location

The hook moments are admitted to this extent of the eccentricity to the edge of the hook ($t_{hook}/2$) at the pin.

The pin bending stress σ_{pb} is a function of the hook membrane stress σ_{hm}

$$\sigma_{pb} = \frac{M_{max} \cdot (\sigma_{hm} \cdot A_{hook} + P_{nom}) \cdot \frac{t_{hook}}{2}}{M_{hook} \cdot S_{pin}} = \frac{M_{max} \cdot A_{hook} \cdot \frac{t_{hook}}{2}}{M_{hook} \cdot S_{pin}} \left(\sigma_{hm} + \frac{P_{nom}}{A_{hook}} \right)$$

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$$\frac{M_{\max} \cdot A_{\text{hook}} \cdot \frac{t_{\text{hook}}}{2}}{M_{\text{hook}} \cdot Z_{\text{pin}}} = 2.822 \quad \text{gives } a_{\text{hbr}}$$

$$\sigma_{\text{net}} = \text{LF} \cdot \left(a_{\text{hm}} \cdot \sigma_{\text{hm}} + a_{\text{hbr}} \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}} \right) + a_{\text{hbr}} \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}$$

$$\text{where: } \text{LF} = \frac{\sigma_{\text{net}} - a_{\text{hbr}} \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}}{(a_{\text{hm}} + a_{\text{hbr}}) \cdot \sigma_{\text{hm}}}$$

and σ_{hm} and σ_{hb} are defined as S_d and S_{by} in the table below.

	Load	S_d (psi)	S_{by} (psi)	LF
Hook @ 0-deg.	$F_x = 400 \text{ lbf}$	620	-	10.00
	$F_y = 2300 \text{ lbf}$	100	-	10.00
	$F_z = 1000 \text{ lbf}$	-	-	10.00
	$M_x = 2000 \text{ lbf-ft}$	-	-	10.00
	$M_y = 1600 \text{ lbf-ft}$	-	-	10.00
	$M_z = 1600 \text{ lbf-ft}$	8,920	-	0.71
Hook @ 120-deg.	$F_x = 400 \text{ lbf}$	300	-	10.00
	$F_y = 2300 \text{ lbf}$	-	-	10.00
	$F_z = 1000 \text{ lbf}$	1,350	-	4.68
	$M_x = 2000 \text{ lbf-ft}$	9,700	-	0.65
	$M_y = 1600 \text{ lbf-ft}$	-	-	10.00
	$M_z = 1600 \text{ lbf-ft}$	4,500	-	1.40

5.0 OPERATING NUT

The nut is quite strong compared to the pin. Consider a 30,000 lbf axial loading with three hooks, which is more than the pins can take. We will demonstrate that the nut is stronger than the pins, so that the piping load limitations are derived from the pins analysis that was discussed in section 4.0.

$d_{\text{hole}} := 0.56 \text{ in}$

diameter of nut hole @ pin location
(WHC 1982)

$L_{\text{nut}} := 1.64 \text{ in}$

length of nut
(WHC 1991a)

$P_{\text{axial}} := 30000 \text{ lbf}$

assumed axial loading on operating nut
(applied to three hooks)

$t_{\text{nut}} := 0.47 \text{ in}$

thickness of nut
(WHC 1991a)

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner *apw*Date 3/29/95Checker J. L. Julyk *JLJ*Date 3/30/95**5.1 Bearing stress @ 30,000 lbf for 3 hooks**Figure C7. Sketch of Operating Nut
(WHC 1991a, H-2-68209)

$$\sigma_{brg} := \frac{\frac{2}{3} \cdot P_{axial}}{d_{hole} \cdot t_{nut}}$$

$$\sigma_{brg} = 75988 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{brA148} = 108000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{O.K.}$$

$$\text{The edge distance/diameter is } \frac{L_{nut}}{2 \cdot (d_{hole})} = 1.464 \quad \text{O.K.}$$

5.2 Bending stress (one ear)

$$\sigma_b(M_{nut}, S_{nut}) := \frac{M_{nut}}{S_{nut}}$$

Moment on one ear of operating nut

$$M_{nut} := \frac{P_{axial}}{6} \cdot (1.56 \cdot \text{in} - 0.94 \cdot \text{in}) \quad M_{nut} = 3100 \cdot \text{lbf} \cdot \text{in}$$

Section modulus on operating nut

$$S_{nut} := \frac{1}{6} \cdot (t_{nut} \cdot L_{nut}^2) \quad S_{nut} = 0.211 \cdot \text{in}^3$$

$$\sigma_b(M_{nut}, S_{nut}) = 14714 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{bA148} = 45000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Therefore, O.K.

5.3 Ring Stress

$$\sigma_{ring}(M_{tot}, R, C, S) := \frac{M_{tot} \cdot R}{C(R) \cdot S}$$

where

$$b := 0.94 \cdot \text{in} - \frac{1.25 \cdot \text{in}}{2}$$

$$b = 0.315 \cdot \text{in}$$

$$C(R) := 2 \cdot \pi \cdot R$$

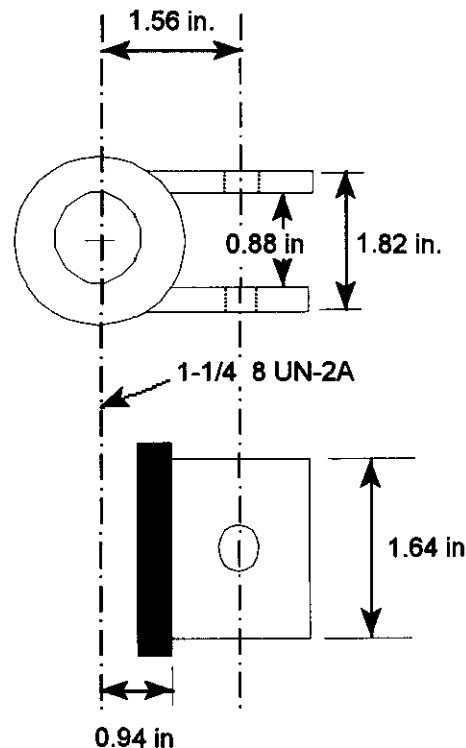
$$S := b \cdot \frac{L_{nut}^2}{6}$$

$$S = 0.141 \cdot \text{in}^3$$

$$M_{tot} := P_{axial} \cdot \left(1.56 \cdot \text{in} - 0.94 \cdot \text{in} + \frac{b}{2} \right)$$

$$M_{tot} = 23325 \cdot \text{lbf} \cdot \text{in}$$

moment applied to nut ring



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Bending ring stress

$$\sigma_{\text{ring}}(M_{\text{tot}}, R, C, S) = 26290 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{\text{bA148}} = 45000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{Therefore, O.K.}$$

5.4 Shear stress (one ear)

$$\tau := \frac{P_{\text{preload}}}{t_{\text{nut}} \cdot L_{\text{nut}}} \quad \tau = 6487 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{\text{vA148}} = 24000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{O.K.}$$

6.0 OPERATING SCREW

$$d_{\text{min}} := 1.10 \cdot \text{in}$$

Minimum thread diameter of screw
(WHC 1982, H-2-32421)

Figure C8. Sketch of Operating Screw
(WHC 1982, H-2-32421)

$$A_{\text{screw}} := \frac{\pi}{4} \cdot d_{\text{min}}^2$$

Area of screw

$$A_{\text{screw}} = 0.95 \cdot \text{in}^2$$

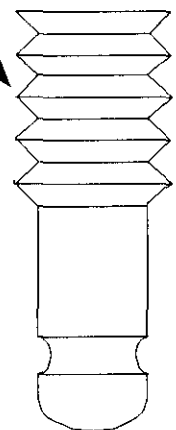
Calculation of membrane stress in screw

$$\sigma_m := \frac{P_{\text{thermal}} + P_{\text{pressure}} + P_{\text{preload}}}{A_{\text{screw}}} \quad \sigma_m = 11545 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Calculation of bending stress in screw

$$\sigma_b := \sigma_{\text{bA193}} - \sigma_m \quad \sigma_b = 51455 \cdot \frac{\text{lbf}}{\text{in}^2}$$

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6.1 Determination of adjustment factor used for screw bending

System model output for screw bending stresses at the nut are based on a lever arm from the top of the block of the mid-height location in the nut. In the no-slip screw-block model, the lever arm should be taken from the block top to the base of the nut. In the interface element model, the lever arm should be taken from center of the sphere defining the screw bearing surface to the lower edge of the nut.

$$h_{\text{pin}} := (7.06 - 4.02 + 0.18) \cdot \text{in}$$

$$h_{\text{pin}} = 3.22 \cdot \text{in}$$

block-top to mid-nut height

$$W_{\text{lug}} := 1.64 \cdot \text{in}$$

nut length (WHC 1991a)

$$d_{\text{scr}} := 1.03 \cdot \text{in}$$

diameter of the operating screw
(WHC 1982)

$$R_{\text{cap}} := 1.31 \cdot \text{in}$$

screw bearing radius
(WHC 1982)

$$S_{\text{scr}} := \frac{\pi}{32} \cdot d_{\text{scr}}^3$$

section modulus of the screw

$$S_{\text{scr}} = 0.107 \cdot \text{in}^3$$

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In the no-slip model, the end load bending contribution from $w_{lug}/2$ is subtracted.

$$S_{by} = S_{bANSYS} - \frac{W_{lug}}{2} \cdot \frac{F_{yANSYS}}{S_{pin}}$$

Note: That S_{bANSYS} and F_{yANSYS} , at the nut end, should have the same sign.

In the interface model, multiply the ANSYS output bending stresses by β_{iface} .

$$\beta_{iface} = 1 - \frac{W_{lug} + 2 \cdot R_{cap}}{2 \cdot h_{pin}} \quad \beta_{iface} = 0.339 \quad (\text{interface model})$$

The adjustments are applied before entering the data in the table below.

6.2 Interface and Pinned system model

Load	Sd (psi)	Sby (psi)	LF
Fx = 400 lbf	-	6,100	7.94
Fy = 2300 lbf	100	-	10.00
Fz = 1000 lbf	-	15,200	3.19
Mx = 2000 lbf-ft	-	110,000	0.44
My = 1600 lbf-ft	-	-	10.00
Mz = 1600 lbf-ft	-	87,600	0.55

Where: $LF = \frac{\sigma_b}{Sd + Sby}$

Note: That the high bending stresses are from the pin model (screw pinned to block) and they might not be supported by friction forces at the block top. The interface element model shows less than half these moments

6.3 Pin Released or Pin allowed to rotate @ hook/nut location

Load	Sd (psi)	Sby (psi)	LF
Fx = 400 lbf	-	12,500	3.88
Fy = 2300 lbf	100	-	10.00
Fz = 1000 lbf	-	31,200	1.55
Mx = 2000 lbf-ft	-	224,700	0.22
My = 1600 lbf-ft	-	-	10.00
Mz = 1600 lbf-ft	-	180,000	0.27

Where: $LF = \frac{\sigma_b}{Sd + Sby}$

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The top of the block was evaluated in appendix B.
The assumed axial load is also in appendix B

$$F := 11500 \cdot \text{lbf}$$

Assumed axial load obtained
from appendix B

$$P_m := 9632 \cdot \frac{\text{lbf}}{\text{in}^2}$$

membrane stresses from
appendix B (@ assumed load)

Calculation of the limit load

$$F_{\text{limit}} := F \cdot \frac{S_{mA276}}{P_m} \quad F_{\text{limit}} = 23879 \cdot \text{lbf}$$

To obtain a lateral load criterion, compare this
with a shear plug using the diameter of the screw

$$P_{\text{limit}} := \pi \cdot d_s \cdot t \cdot \sigma_{vA276}$$

$$P_{\text{limit}} = 27958 \cdot \text{lbf}$$

Use the shear plug concept with a factor

$$f_p := \frac{F_{\text{limit}}}{P_{\text{limit}}} \quad f_p = 0.854$$

with lateral loading H

$$V := P_{\text{thermal}} + P_{\text{preload}} \quad V = 10771 \cdot \text{lbf}$$

N is carried over circle with radius r.

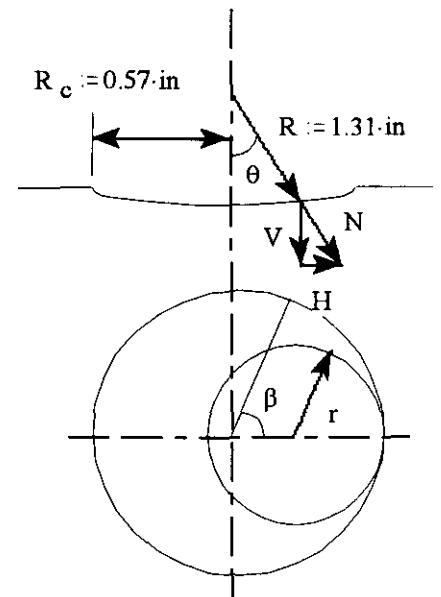
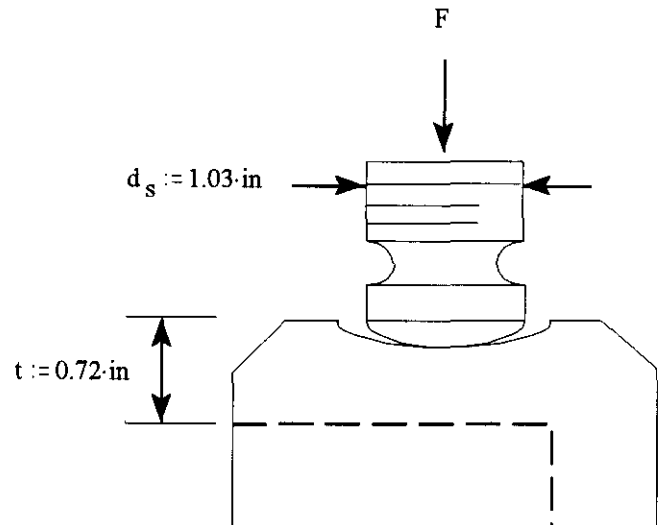
$$\tan(\theta) = \frac{H}{V} \quad (\text{no friction})$$

$$\cos(\beta) = \frac{R \cdot \tan(\theta)}{R_c} = \frac{R \cdot H}{R_c \cdot V}$$

$$r = R_c \cdot (1 - \cos(\beta)) = R_c \cdot \left(1 - \frac{R \cdot H}{R_c \cdot V}\right)$$

$$P_{\text{limit}}(r) := 2 \cdot \pi \cdot r \cdot t \cdot \sigma_{vA276} \cdot f_p$$

Figure C9. Sketch of Screw/Block interaction at top of block.
(WHC 1994a, H-2-821324 and WHC 1982, H-2-32421)



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$$N(r) := P_{\text{limit}}(r)$$

$$H(r) := V \cdot \frac{R_c}{R} \cdot \left(1 - \frac{N(r)}{P_{\text{limit}}(R_c)} \right)$$

Estimate $r := 0.24 \cdot \text{in}$

Therefore, $N(r) = 11128 \cdot \text{lbf}$ and $H(r) = 2713 \cdot \text{lbf}$

Check that the vector sum of $(V + H)$ is less than N

$$\sqrt{V^2 + H(r)^2} = 11107 \cdot \text{lbf} \quad \text{YES (O.K.)}$$

Using a minimum coefficient of friction of $\mu := 0.1$

$$\Delta H := \mu \cdot V \quad \Delta H = 1077 \cdot \text{lbf}$$

$$H_{\text{limit}}(r) := H(r) + \Delta H \quad H_{\text{limit}}(r) = 3790 \cdot \text{lbf}$$

V is limited by F_{limit} less the existing V .

The load fraction is the minimum of: $LF(r) = \frac{H_{\text{limit}}(r)}{H}$ or $LF = \frac{F_{\text{limit}} - V}{\Delta V}$

since H and ΔV do not occur together. As data, they are found at the base of the screw element in the system models

7.1 Interface and Pinned system model

Load	ΔV (lbf)	H (lbf)	LF
$F_x = 400 \text{ lbf}$	-	200	10.00
$F_y = 2300 \text{ lbf}$	100	-	10.00
$F_z = 1000 \text{ lbf}$	-	600	6.32
$M_x = 2000 \text{ lbf-ft}$	-	4,400	0.86
$M_y = 1600 \text{ lbf-ft}$	-	-	10.00
$M_z = 1600 \text{ lbf-ft}$	-	3,500	1.08

where: $LF = \frac{H_{\text{limit}}}{\Delta V + H}$ is conservative

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3/30/95**7.2 Pin Released or Pin allowed to rotate @ hook/nut location**

Load	ΔV (lbf)	H (lbf)	LF
$F_x = 400$ lbf	-	600	6.32
$F_y = 2300$ lbf	100	-	10.00
$F_z = 1000$ lbf	-	1,500	2.53
$M_x = 2000$ lbf-ft	-	11,300	0.34
$M_y = 1600$ lbf-ft	-	-	10.00
$M_z = 1600$ lbf-ft	-	9,000	0.42

where: $LF = \frac{H_{\text{limit}}}{\Delta V + H}$ is conservative

Figure C10. Sketch of Block and Guide lip interaction

8.0 GUIDE-BLOCK INTERFACE

Height of block lip (WHC 1994a, H-2-821324)

$$h_B := 0.06 \cdot \text{in}$$

outside diameter for block lip (WHC 1994a, H-2-821324)

$$d_{Bo} := 2.12 \cdot \text{in}$$

inside diameter for block lip (WHC 1994a, H-2-821324)

$$d_{Bi} := 1.882 \cdot \text{in}$$

8.1 Block Lip**8.1.1 Allowable Shear Force**

$$A_{vBL} := 0.12 \cdot \text{in} \cdot d_{Bi} \quad A_{vBL} = 0.226 \cdot \text{in}^2 \quad \text{Shear area}$$

$$H_{vBL} := \sigma_{vA276} \cdot A_{vBL} \quad H_{vBL} = 2710 \cdot \text{lbf} \quad \text{Shear limit at top of lip}$$

8.1.2 Allowable Bearing Force

$$A_{bBL} := 0.03 \cdot \text{in} \cdot d_{Bi} \quad A_{bBL} = 0.056 \cdot \text{in}^2 \quad \text{Bearing area}$$

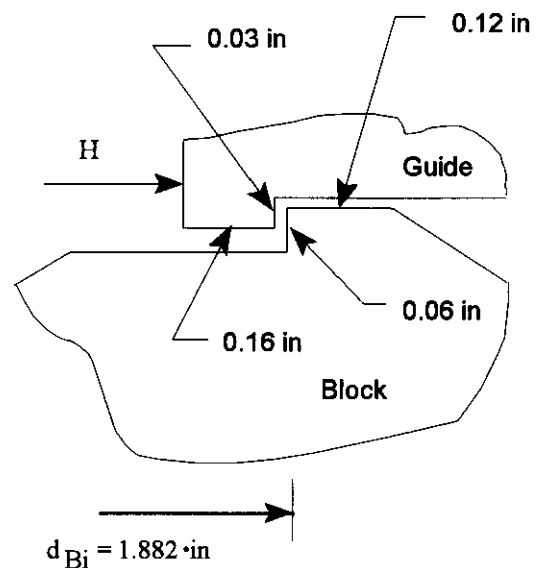
$$H_{bBL} := \sigma_{brA276} \cdot A_{bBL} \quad H_{bBL} = 2541 \cdot \text{lbf} \quad \text{Bearing limit at top lip}$$

8.2 Guide Lip

$$h_G := 0.030 \cdot \text{in} \quad \text{Height of guide lip (WHC 1985c, H-2-68205)}$$

$$d_{Go} := 1.877 \cdot \text{in} \quad \text{outside diameter for hook guide lip (WHC 1985c, H-2-68205)}$$

$$d_{Gi} := 1.55 \cdot \text{in} \quad \text{inside diameter for hook guide lip (WHC 1985c, H-2-68205)}$$



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8.2.1 Allowable Shear Force

$$A_{vGL} := 0.16 \cdot \text{in} \cdot d_{Go}$$

$$A_{vGL} = 0.3 \cdot \text{in}^2$$

Shear area

$$H_{vGL} := \sigma_{vA743} \cdot A_{vGL}$$

$$H_{vGL} = 5256 \cdot \text{lbf}$$

Shear limit at top of lip

8.2.2 Allowable Bearing Force

$$A_{bGL} := 0.03 \cdot \text{in} \cdot d_{Go}$$

$$A_{bGL} = 0.056 \cdot \text{in}^2$$

Bearing area

$$H_{bGL} := \sigma_{brA743} \cdot A_{bGL}$$

$$H_{bGL} = 4730 \cdot \text{lbf}$$

Bearing limit at top lip

8.2.3 Determine the allowable for bearing and shear that the block and guide lip can accomdate

$$H_{allBL} := \text{if}(H_{vBL} < H_{bBL}, H_{vBL}, H_{bBL})$$

$$H_{allBL} = 2541 \cdot \text{lbf}$$

$$H_{allGL} := \text{if}(H_{vGL} < H_{bGL}, H_{vGL}, H_{bGL})$$

$$H_{allGL} = 4730 \cdot \text{lbf}$$

$$H_{allow} := \text{if}(H_{allBL} < H_{allGL}, H_{allBL}, H_{allGL})$$

$$H_{allow} = 2541 \cdot \text{lbf}$$

8.2.4 Interface and Pinned system model results

Load	H (lbf)	LF
Fx = 400 lbf	400	6.35
Fy = 2300 lbf	-	10.00
Fz = 1000 lbf	1,100	2.31
Mx = 2000 lbf-ft	7,700	0.33
My = 1600 lbf-ft	-	10.00
Mz = 1600 lbf-ft	6,200	0.41

$$\text{where: } LF = \frac{H_{allow}}{H}$$

8.2.5 Pin Released or Pin allowed to rotate @ hook/nut location

Load	H (lbf)	LF
Fx = 400 lbf	900	2.82
Fy = 2300 lbf	-	10.00
Fz = 1000 lbf	2,270	1.12
Mx = 2000 lbf-ft	16,400	0.15
My = 1600 lbf-ft	-	10.00
Mz = 1600 lbf-ft	13,100	0.19

$$\text{where: } LF = \frac{H_{allow}}{H}$$

Note: The Load Fractions are controlled by the no-slip model assumption, which are difficult to support by friction between the screw and block.

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Date

3/30/95

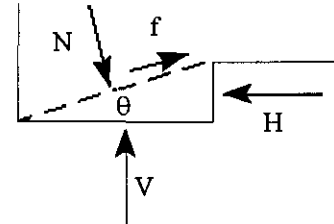
8.3 Check for Lift-Out

Figure C11. Sketch of guide lift-off from top of block

Consider that $f = 0$, no friction

$$\frac{H}{V} = \tan(\theta) = \frac{0.03 \cdot \text{in}}{0.16 \cdot \text{in}}$$

If the skirt-bolt-guide system has sufficient stiffness to provide V for $\delta = 0.03$ in. deflection, lift-out can not occur



$$\delta := 0.03 \cdot \text{in}$$

$$H_{\text{lift}} = \frac{0.03 \cdot \text{in}}{0.16 \cdot \text{in}} \cdot V \quad V = k_{\text{sbg}} \cdot \delta$$

8.3.1 Bolt Stiffness (WHC 1991d, H-2-3808)

$N_{\text{bolts}} := 6$ Number of bolts, at least 2 participate directly

$d_{\text{bolt}} := \frac{1}{2} \cdot \text{in}$ diameter of bolts

$l_{\text{bolt}} := 5 \cdot \text{in}$ length of bolts

$E_{\text{bolt}} := 28 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$ modulus of elastic for bolts

$A_{\text{bolt}} := \frac{\pi}{4} \cdot d_{\text{bolt}}^2$ cross-sectional area of bolt $A_{\text{bolt}} = 0.196 \cdot \text{in}^2$

$k_{\text{bolt}} := 2 \cdot E_{\text{bolt}} \cdot \frac{A_{\text{bolt}}}{l_{\text{bolt}}}$ stiffness of bolts $k_{\text{bolt}} = 2.199 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}}$

8.3.2 Guide Stiffness as 2 cantilevers (WHC 1985c, H-2-68205)

$b_{\text{guide}} := 0.96 \cdot \text{in}$ width of guide

$h_{\text{guide}} := 1.0 \cdot \text{in}$ height of guide

$l_{\text{guide}} := 0.98 \cdot \text{in}$ length of guide or span

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$$E_{\text{guide}} := 28 \cdot 10^6 \frac{\text{lbf}}{\text{in}^2} \quad \text{modulus of elasticity for guide}$$

$$I_{\text{guide}} := \frac{2 \cdot b_{\text{guide}} \cdot h_{\text{guide}}^3}{12} \quad \text{moment of inertia for guide} \quad I_{\text{guide}} = 0.16 \cdot \text{in}^4$$

$$k_{\text{guide}} := \frac{3 \cdot E_{\text{guide}} \cdot I_{\text{guide}}}{l_{\text{guide}}^3} \quad \text{stiffness of guide} \quad k_{\text{guide}} = 14279764 \frac{\text{lbf}}{\text{in}}$$

$$\text{Therefore let, } k_{\text{sbg}} := k_{\text{bolt}}$$

$$H_{\text{limit}} := \frac{0.03 \cdot \text{in}}{0.16 \cdot \text{in}} \cdot k_{\text{bolt}} \cdot \delta \quad H_{\text{limit}} = 12370 \cdot \text{lbf}$$

Therefore, the block controls with the H_{bearing} limit.

9.0 Block-Nozzle Moment Transfer ISB jumper

From Roger Evanson, for 304/304 metal to metal contact, the coefficient of friction can range from 0.2 to 0.7. Assuming a coefficient of friction of 0.40 the frictional force under a normal pre-load torque force (5000 lbf) is determined.

$$\mu := 0.40 \quad \text{coefficient of friction for 304/304 metal to metal contact}$$

$$P := P_{\text{preload}} \quad P = 5000 \cdot \text{lbf} \quad \text{Pre-load for a 50 ft-lbf torque screw load (Squier 1993)}$$

$$N := \sqrt{2} \cdot P \quad N = 7071 \cdot \text{lbf} \quad \text{Normal force acting of surface}$$

$$F := \mu \cdot N \quad F = 2828 \cdot \text{lbf} \quad \text{friction force}$$

The Breakaway friction for a bending moment and torsional load under a pre-load of F are calculated below

$$R_s := 1.745 \cdot \text{in} \quad \text{Radius of Block/Nozzle cone (WHC,1994a, H-2-821324)}$$

$$c := 2 \cdot \pi \quad \text{contact circle}$$

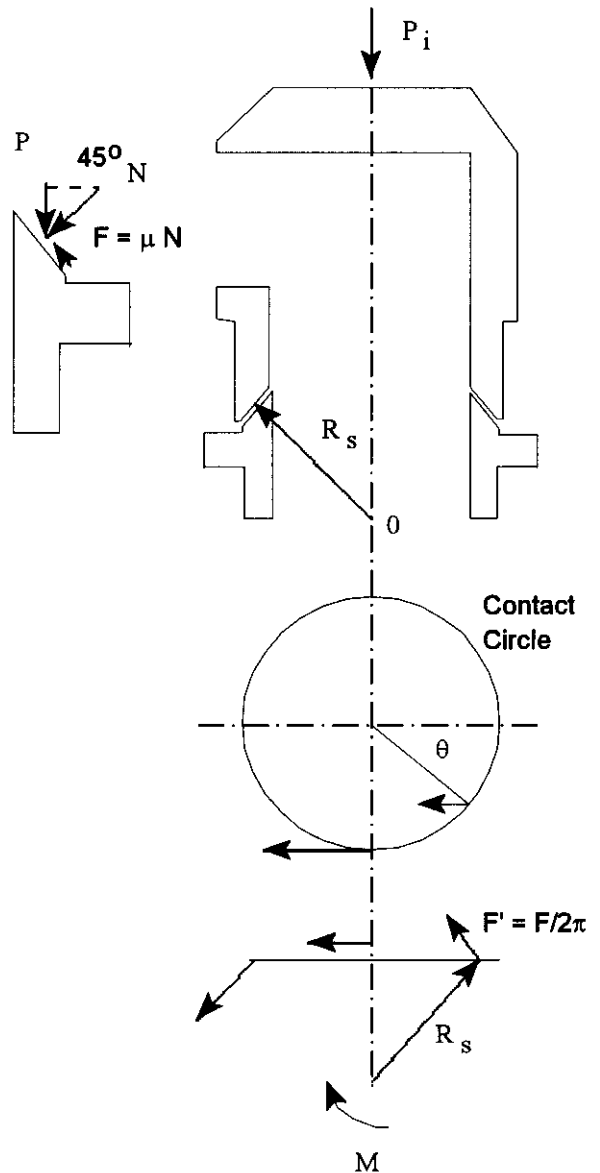
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$$M := \frac{F \cdot R_s}{2 \cdot \pi} \int_0^c \sqrt{\frac{\cos(\theta) \cdot \cos(\theta)}{2} + \frac{1}{2}} d\theta$$

$M = 354 \cdot \text{ft} \cdot \text{lbf}$ for a 50 ft-lbf torque screw load

Therefore, based on the assumed coefficient of friction of 0.40 the block/nozzle allowable moment that the friction could withstand for pre-load screw torque of 50 ft-lbf is 354 ft-lbf. This is compared to the external moments of 2000, 1600, and 1600 ft-lbf in the x, y, and z-directions, respectively. Since a 50 ft-lbf torque is plausible, and the friction coefficient may be smaller, was recommended that friction be ignored in the above evaluation.

Figure C12. Sketch of Block-Nozzle Moment Transfer



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3/30/95**10.0 3-in. Jumper Connector System Model Calculations****10.1 NOZZLE ANALYSIS** $P_{\text{limit}} := 8750 \cdot \text{lbf}$ Total Axial Capacity for one hook (appendix A) $P_{\text{thermal}} := 8125 \cdot \text{lbf}$ Thermal expansion resistance load (appendix B, section 6.3) $P_{\text{pressure}} := 305 \cdot \text{lbf}$ Pressure resistance load (appendix B, section 6.4) $P_{\text{preload}} := 2000 \cdot \text{lbf}$ Preload for a 50 ft-lbf toqure (Squier 1993)

$$P_{\text{nom}} := \frac{1}{3} (P_{\text{thermal}} + P_{\text{pressure}} + P_{\text{preload}}) \quad P_{\text{nom}} = 3477 \cdot \text{lbf} \quad \text{Nominal load}$$

Net load after thermal expansion, pressure, and the pre-load are deducted from the limit load
(see appendix B for thermal, pressure, and pre-load axial values)

$$P_{\text{net}} := P_{\text{limit}} - P_{\text{nom}} \quad P_{\text{net}} = 5273 \cdot \text{lbf}$$

10.2 Determine the load fractions to use in the nozzle evaluation for the interface, pinned, and pin released system models.**10.2.1 Interface and pinned system model**

Load	ΔF (lbf)	LF
$F_x = 2000 \text{ lbf}$	2,800	1.88
$F_y = 15000 \text{ lbf}$	200	10.00
$F_z = 2000 \text{ lbf}$	2,400	2.20
$M_x = 7000 \text{ lbf-ft}$	11,700	0.45
$M_y = 7000 \text{ lbf-ft}$	-	10.00
$M_z = 7000 \text{ lbf-ft}$	23,600	0.22

where: ΔF is the maximum axial hook load from system models (appendix G)

$$LF = \frac{P_{\text{net}}}{\Delta F} \quad \text{is the Load fraction}$$

Full release of the hook from the nozzle is not acceptable as it invalidates the model.

Pro-rate absolute hook-nozzle reactions to the existing load. $P_{\text{pre}} := P_{\text{nom}}$

Load	ΔF (lbf)	LF
$F_x = 2000 \text{ lbf}$	2,800	1.24
$F_y = 15000 \text{ lbf}$	200	10.00
$F_z = 2000 \text{ lbf}$	2,400	1.45
$M_x = 7000 \text{ lbf-ft}$	11,700	0.30
$M_y = 7000 \text{ lbf-ft}$	-	10.00
$M_z = 7000 \text{ lbf-ft}$	23,600	0.15

where: ΔF is the maximum axial hook load from system models (appendix G)

$$LF = \frac{P_{\text{pre}}}{\Delta F} \quad \text{is the Load fraction}$$

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10.2.2 Pin Released or allowed to rotate @ hook/operating nut location

Load	ΔF (lbf)	LF
$F_x = 2000$ lbf	2,920	1.81
$F_y = 15000$ lbf	160	10.00
$F_z = 2000$ lbf	2,530	2.08
$M_x = 7000$ lbf-ft	12,310	0.43
$M_y = 7000$ lbf-ft	-	10.00
$M_z = 7000$ lbf-ft	24,890	0.21

where: ΔF is the maximum axial hook load from system models (appendix G)

$$LF = \frac{P_{net}}{\Delta F} \quad \text{is the Load fraction}$$

Full release of the hook from the nozzle is not acceptable as it invalidateds the model.

Pro-rate absolute hook-nozzle reactions to the existing load. $P_{pre} := P_{nom}$

Load	ΔF (lbf)	LF
$F_x = 2000$ lbf	2,920	1.19
$F_y = 15000$ lbf	160	10.00
$F_z = 2000$ lbf	2,530	1.37
$M_x = 7000$ lbf-ft	12,310	0.28
$M_y = 7000$ lbf-ft	-	10.00
$M_z = 7000$ lbf-ft	24,890	0.14

where: ΔF is the maximum axial hook load from system models (appendix G)

$$LF = \frac{P_{pre}}{\Delta F} \quad \text{is the Load fraction}$$

Figure C13. Typical 3-in. Hook for ISB Jumper
(WHC 1993c, H-2-90175, rev. 6, sh 1)

11.0 HOOK ANALYSIS

11.1 Section (A) of the Hook (nozzle flange location)

Use β as the fraction of hook-guide bending stresses.

$$\beta := \frac{2.46 \text{ in}}{8.65 \text{ in}} \quad \beta = 0.284$$

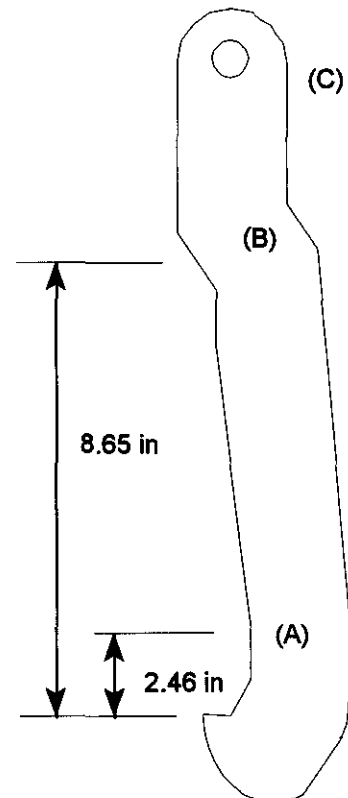
$$P_{limit} = 8750 \cdot \text{lbf} \quad \text{Total axial capacity for one hook (appendix A)}$$

Net load after thermal expansion, pressure, and the pre-load are deducted from the limit load (see appendix B for thermal, pressure, and pre-load axial values)

$$P_{net} := P_{limit} - P_{nom} \quad P_{net} = 5273 \cdot \text{lbf}$$

Also scale S_d values from App. G with α , since they were corrected for 2" area ratios only. See App D Section 2.5.1.

$$\alpha := \frac{0.073}{0.082} \quad \alpha = 0.89$$



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The pipe loads produce both membrane and bending stresses in the hook. To account for the bending and membrane stresses recalculate the P_{limit} and P_{net} in terms of stresses

$$\sigma_{\text{limit}} := \sigma_{\text{bA747}}$$

$$\sigma_{\text{limit}} = 69000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\sigma_{\text{net}} := \frac{P_{\text{net}}}{P_{\text{limit}}} \cdot \sigma_{\text{limit}}$$

$$\sigma_{\text{net}} = 41584 \cdot \frac{\text{lbf}}{\text{in}^2}$$

11.1.1 Interface and pinned system models

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 2000 lbf	2,300	-	4,000	10.00
	Fy = 15000 lbf	100	-	200	10.00
	Fz = 2000 lbf	-	26,300	-	5.57
	Mx = 7000 lbf-ft	-	128,000	-	1.14
	My = 7000 lbf-ft	-	454,000	-	0.32
	Mz = 7000 lbf-ft	19,300	-	34,400	1.54
Hook @ 120-deg.	Fx = 2000 lbf	1,100	22,800	1,900	5.20
	Fy = 15000 lbf	100	-	200	10.00
	Fz = 2000 lbf	1,900	13,100	3,400	6.52
	Mx = 7000 lbf-ft	9,300	64,000	16,500	1.34
	My = 7000 lbf-ft	-	454,000	-	0.32
	Mz = 7000 lbf-ft	9,400	194,000	16,700	0.61

11.1.2 Pin released or allowed to rotate at hook/nut location

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 2000 lbf	2,400	-	4,300	10.00
	Fy = 15000 lbf	100	-	200	10.00
	Fz = 2000 lbf	-	24,600	-	5.95
	Mx = 7000 lbf-ft	-	119,600	-	1.22
	My = 7000 lbf-ft	-	28,000	-	5.23
	Mz = 7000 lbf-ft	20,300	-	36,300	1.47
Hook @ 120-deg.	Fx = 2000 lbf	1,100	21,300	2,000	5.47
	Fy = 15000 lbf	100	-	200	10.00
	Fz = 2000 lbf	1,900	12,300	3,400	6.76
	Mx = 7000 lbf-ft	9,300	59,800	16,600	1.39
	My = 7000 lbf-ft	-	28,300	-	5.17
	Mz = 7000 lbf-ft	9,400	181,300	16,800	0.64

where: $LF = \frac{\sigma_{\text{net}}}{\alpha \cdot Sd + \beta \cdot (Sby + Sbz)}$

Note: The stresses are from appendix G and are the maximum stresses at location (A) on the hook, from the Jumper clamp system model data.

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 3/29/95Checker J. L. JulykDate 3/30/95**11.2 Section (b) of the Hook (Guide location)**

Using the system model bending and direct stresses section (B) is considered. Section (B) is closer to the load axis. Therefore, adjust section (A) limit using the beam membrane plus bending stress formula.

$$\sigma = \frac{P}{A} + \frac{P \cdot L}{S} \quad \text{Axial and bending stress}$$

@ section (A) per drawing H-2-90175 (WHC 1993c)

$$w_{\text{hook}} := 2.28 \cdot \text{in} - 0.78 \cdot \text{in}$$

Width of hook

$$w_{\text{hook}} = 1.5 \cdot \text{in}$$

$$t_{\text{hook}} := 0.97 \cdot \text{in}$$

Thickness of hook

$$A_{\text{hook}} := w_{\text{hook}} \cdot t_{\text{hook}}$$

area of hook

$$A_{\text{hook}} = 1.455 \cdot \text{in}^2$$

$$S_{\text{hook}} := \frac{1}{6} (t_{\text{hook}} \cdot w_{\text{hook}}^2)$$

Section modulus of hook

$$S_{\text{hook}} = 0.364 \cdot \text{in}^3$$

$$L_{\text{effective}} := S_{\text{hook}} \left(\frac{\sigma_{\text{limit}}}{P_{\text{limit}}} - \frac{1}{A_{\text{hook}}} \right)$$

$$L_{\text{effective}} = 2.618 \cdot \text{in}$$

$$L_o := \frac{w_{\text{hook}}}{2} + 0.78 \cdot \text{in} - 0.19 \cdot \text{in} + \frac{0.45 \cdot \text{in}}{2}$$

$$L_o = 1.565 \cdot \text{in}$$

$$\text{Scale by } \Omega := \frac{L_{\text{effective}}}{L_o} \quad \text{on section (B)}$$

$$L_o := \frac{1}{2} (0.375 \cdot \text{in} + 1.82 \cdot \text{in})$$

$$L_o = 1.097 \cdot \text{in}$$

$$L_{\text{effective}} := L_o \cdot \Omega$$

$$L_{\text{effective}} = 1.836 \cdot \text{in}$$

Determine the combined axial and bending stress at the limit load P_{limit}

$$\sigma := P_{\text{limit}} \left(\frac{1}{A_{\text{hook}}} + \frac{L_{\text{effective}}}{S_{\text{hook}}} \right)$$

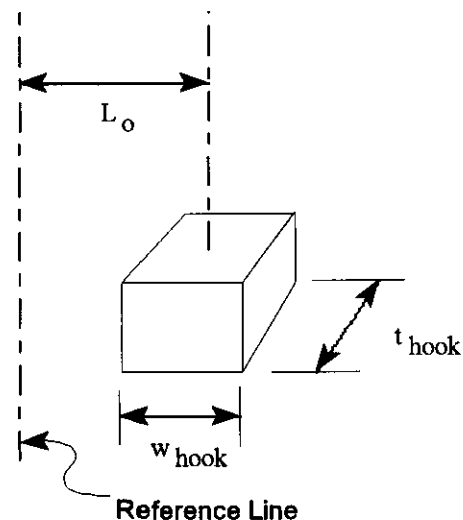
$$\sigma = 50185 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Adjust section (A) σ_{net} for (B)

$$\sigma_{\text{net}} := \sigma_{\text{limit}} - \frac{P_{\text{nom}}}{P_{\text{limit}}} \cdot \sigma$$

$$\sigma_{\text{net}} = 49060 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Figure C14. Sketch of 3-in. Hook section (WHC 1993c)



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11.2.1 Interface and pinned system models

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 2000 lbf	2,300	-	4,000	8.11
	Fy = 15000 lbf	100	-	200	10.00
	Fz = 2000 lbf	-	26,300	-	1.87
	Mx = 7000 lbf-ft	-	128,000	-	0.38
	My = 7000 lbf-ft	-	454,000	-	0.11
	Mz = 7000 lbf-ft	19,300	-	34,400	0.95
Hook @ 120-deg.	Fx = 2000 lbf	1,100	22,800	1,900	1.91
	Fy = 15000 lbf	100	-	200	10.00
	Fz = 2000 lbf	1,900	13,100	3,400	2.70
	Mx = 7000 lbf-ft	9,300	64,000	16,500	0.55
	My = 7000 lbf-ft	-	454,000	-	0.11
	Mz = 7000 lbf-ft	9,400	194,000	16,700	0.22

where: $LF = \frac{\sigma_{net}}{\alpha \cdot Sd + Sby + Sbz}$

Note: The stresses are from appendix G and are the maximum stresses at location (B) on the hook, from the Jumper clamp system model data.

11.2.2 Pin released or allowed to rotate at hook/nut location

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 2000 lbf	2,400	-	4,300	7.62
	Fy = 15000 lbf	100	-	200	10.00
	Fz = 2000 lbf	-	24,600	-	1.99
	Mx = 7000 lbf-ft	-	119,600	-	0.41
	My = 7000 lbf-ft	-	28,000	-	1.75
	Mz = 7000 lbf-ft	20,300	-	36,300	0.90
Hook @ 120-deg.	Fx = 2000 lbf	1,100	21,300	2,000	2.02
	Fy = 15000 lbf	100	-	200	10.00
	Fz = 2000 lbf	1,900	12,300	3,400	2.82
	Mx = 7000 lbf-ft	9,300	59,800	16,600	0.58
	My = 7000 lbf-ft	-	28,300	-	1.73
	Mz = 7000 lbf-ft	9,400	181,300	16,800	0.24

where: $LF = \frac{\sigma_{net}}{\alpha \cdot Sd + Sby + Sbz}$

Note: The stresses are from appendix G and are the maximum stresses at location (B) on the hook, from the Jumper clamp system model data.

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 3/29/95Checker J. L. JulykDate 3/30/95**11.3 Section (C) of the Hook (for the Pin Hole)**Use the system model stresses with a k_c factor for the hook pin hole.**11.3.1 Interface and pinned system models**

	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 2000 lbf	2,300	-	10.00
	Fy = 15000 lbf	100	-	10.00
	Fz = 2000 lbf	-	35,100	0.81
	Mx = 7000 lbf-ft	-	170,800	0.17
	My = 7000 lbf-ft	-	479,000	0.06
	Mz = 7000 lbf-ft	19,300	-	1.65
Hook @ 120-deg.	Fx = 2000 lbf	1,100	30,400	0.91
	Fy = 15000 lbf	100	-	10.00
	Fz = 2000 lbf	1,900	17,500	1.48
	Mx = 7000 lbf-ft	9,300	85,400	0.30
	My = 7000 lbf-ft	-	479,000	0.06
	Mz = 7000 lbf-ft	9,400	259,000	0.11

where:
$$LF = \frac{\sigma_{\text{limit}} - k_c \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}}{k_c \cdot (\alpha \cdot S_d + S_{by})}$$

Note: The stresses are from appendix G and are the maximum stresses at location (C) on the hook, from the Jumper clamp system model data.

$$k_c = \frac{2 \cdot 0.68}{2 \cdot 0.68 - 0.754} \quad k_c = 2.244$$

11.3.2 Pin released or allowed to rotate at hook/nut location

The moments in the hook of section (C) are admitted to the extent of the eccentricity $t_{\text{hook}}/2$ to the edge of the hook at the pin.

$$\sigma_{\text{limit}} = k_c \cdot \frac{(P_{\text{nom}} + LF \cdot S_d \cdot A_{\text{hook}}) \cdot \frac{t_{\text{hook}}}{2}}{S_{\text{hook}}} + k_c \cdot \left(\frac{P_{\text{nom}}}{A_{\text{hook}}} + LF \cdot \alpha \cdot S_d \right) \quad \sigma_{\text{limit}} = 69000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

where:
$$LF = \frac{\sigma_{\text{limit}} - k_c \cdot \frac{P_{\text{nom}} \cdot \frac{t_{\text{hook}}}{2}}{S_{\text{hook}}} - k_c \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}}{k_c \cdot \alpha \cdot S_d + k_c \cdot \left[\alpha \cdot S_d \cdot A_{\text{hook}} \cdot \frac{t_{\text{hook}}}{2} \right]}$$

Note: The stresses are from appendix G and are the maximum stresses at location (C) on the hook, from the Jumper clamp system model data.

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	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 2000 lbf	2,300	-	3.88
	Fy = 15000 lbf	100	-	10.00
	Fz = 2000 lbf	-	-	10.00
	Mx = 7000 lbf-ft	-	-	10.00
	My = 7000 lbf-ft	-	-	10.00
	Mz = 7000 lbf-ft	20,340	-	0.44
Hook @ 120-deg.	Fx = 2000 lbf	1,200	-	7.43
	Fy = 15000 lbf	100	-	10.00
	Fz = 2000 lbf	2,100	-	4.25
	Mx = 7000 lbf-ft	10,100	-	0.88
	My = 7000 lbf-ft	-	-	10.00
	Mz = 7000 lbf-ft	10,200	-	0.87

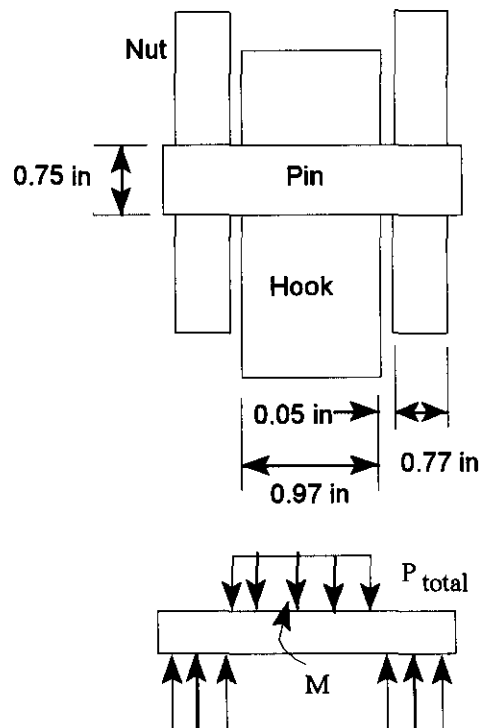
12.0 PIN ANALYSIS

Considerable latitude in pin allowables can be obtained with different assumptions for the bearing load distribution. The most common and conservative is the 4-point assumption is equivalent to a uniform bearing load (Shigley 1989). This is consistent with other assumptions used with the hook and nut.

12.1 Dimensions (WHC 1985a, 1985b, 1993c)

Figure C15. Sketch of 3-in. Hook, Hook pin, and Nut
(four point axial loading condition)

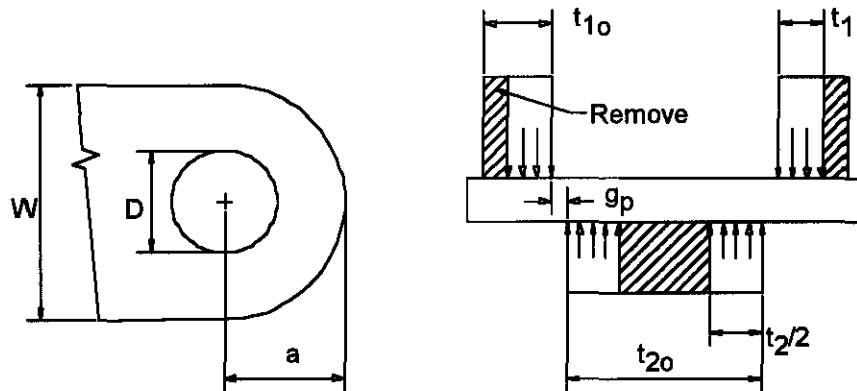
$d_{pin} := 0.75 \text{ in}$	Pin diameter (H-2-32431)
$t_{nut} := 0.77 \text{ in}$	Operating nut thickness (H-2-68210)
$\Delta_{tol} := 0.05 \text{ in}$	tolerance between hook and operating nut (H-2-68210)
$t_{hook} = 0.97 \text{ in}$	hook thickness (H-2-90175)
$A_{pin} := \frac{\pi}{4} \cdot d_{pin}^2$	Area of pin
	$A_{pin} = 0.442 \text{ in}^2$
$S_{pin} := \frac{\pi \cdot d_{pin}^3}{32}$	Section modulus for pin
	$S_{pin} = 0.041 \text{ in}^3$



Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner *LOW*Date 3/29/95Checker J. L. Julyk *JLJ*Date 3/30/95**12.2 Pin analysis with bearing considerations**

Pin-lug capacity estimates should consider the movement of hook and nut bearing forces toward one another thus reducing the lever arm causing bending moments in the pin. The method herein removes lug material away from the bearing areas until margins of the lugs and pin are nearly equal. A weakened lug system that increases the normally calculated pin strength is satisfactory as long as the lugs are as strong as the pin.

Figure C16. Sketch of Pin and Operating Nut for bearing type loading



Ref: Northrup Structural Design manual, ca 1967, Section 204.4 (section 28 of appendix C)

Derived Units:

kip = 1000 · lbf

ksi = 1000 · $\frac{\text{lbf}}{\text{in}^2}$

Connector size: 3 inch

Drawings: Pin: H-2-32431 (WHC 1985a)

Nut: H-2-68210 (WHC 1985b)

Hook: H-2-90175 (WHC 1993c)

Common:

$t_{10} := 0.77 \cdot \text{in}$

$t_{20} := .97 \cdot \text{in}$

$t_1 := t_{10}$

$t_2 := t_{20}$

12.2.1 Nut: (symmetric)

$F_{tu} := S_{uA148}$

$F_{ty} := S_{yA148}$

$a := 3.12 \cdot \text{in} - 2.250 \cdot \text{in}$

$a = 0.87 \cdot \text{in}$

$D := 0.75 \cdot \text{in}$

$W := 1.89 \cdot \text{in}$

$\frac{W}{D} = 2.52$

a. Tension across net section:

$A_t := (W - D) \cdot t_1$

$A_t = 0.878 \cdot \text{in}^2$

$K_t := 0.94$

(curve 1, Fig 204.4-2)

$P'_{tu} := K_t \cdot F_{tu} \cdot A_t$

$P'_{tu} = 74.262 \cdot \text{kip}$

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b. Shear tear-out

$$\frac{a}{D} = 1.16$$

$$\frac{D}{t_1} = 0.974$$

$$K_{br} := 1.09$$

(curve 1, Fig 204.4-3)

$$A_{br} := D \cdot t_1$$

$$A_{br} = 0.577 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br}$$

$$P'_{bru} = 56.653 \cdot \text{kip}$$

c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru}$$

$$\frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 1.09$$

$$C := 1.10$$

(Fig. 204.4-4)

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin}$$

$$P'_y = 41.545 \cdot \text{kip}$$

204.44 Transverse curve. Use curve at 90 deg

$$f := .75$$

(Fig. 204.4-5)

$$P'_{lug} := f \cdot P'_y$$

$$P'_{lug} = 31.159 \cdot \text{kip}$$

12.2.2 Hook

$$F_{tu} := S_{uA747}$$

$$F_{ty} := S_{yA747}$$

$$a := .68 \cdot \text{in}$$

$$D := 0.755 \cdot \text{in}$$

$$W := 1.36 \cdot \text{in}$$

$$\frac{W}{D} = 1.801$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_2$$

$$A_t = 0.587 \cdot \text{in}^2$$

$$K_t := 0.97$$

(curve 1, Fig 204.4-2)

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t$$

$$P'_{tu} = 82.54 \cdot \text{kip}$$

b. Shear tear-out

$$\frac{a}{D} = 0.901$$

$$\frac{D}{t_2} = 0.778$$

$$K_{br} := .70$$

(curve 1, Fig 204.4-3)

$$A_{br} := D \cdot t_2$$

$$A_{br} = 0.732 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br}$$

$$P'_{bru} = 74.334 \cdot \text{kip}$$

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3/30/95c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 0.7 \quad C := 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 64.85 \cdot \text{kip} \quad P'_{hook} := P'_y$$

$$P'_{hook} = 64.85 \cdot \text{kip}$$

12.2.3 Operating Pin

204.45 Account for pin bending

$$F_{ty} := S_y A_{108} \quad F_{tu} := S_u A_{108}$$

$$g_p := .05 \cdot \text{in} \quad R := \frac{.749}{2} \cdot \text{in}$$

a. Pin capacity

$$b := .5 \cdot t_1 + g_p + 0.25 \cdot t_2 \quad b = 0.677 \cdot \text{in}$$

$$Z := \pi \cdot R^2 \cdot 0.4244 \cdot R \quad Z = 0.07 \cdot \text{in}^3$$

$$S := \frac{\pi}{4} \cdot R^3 \quad S = 0.041 \cdot \text{in}^3 \quad f_{\text{shape}} := \frac{Z}{S} \quad f_{\text{shape}} = 1.698$$

$$P'_{\text{pin}} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{\text{pin}} = 22.74 \cdot \text{kip}$$

b. Peaking effect

$$r := \frac{a - \frac{D}{2}}{t_2} \quad r = 0.312 \quad K_{br} = 0.7 \quad (\text{min: } P'_{tu} \text{ or } P'_{bru})$$

$$\gamma := 0.60 \quad (\text{Fig. 204.4-8}) \quad b := 0.5 \cdot t_1 + g_p + \gamma \cdot \frac{t_2}{4} \quad b = 0.581 \cdot \text{in}$$

$$P'_{\text{pin}} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{\text{pin}} = 26.54 \cdot \text{kip}$$

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3/30/95c. Modify t_1 and t_2 to have nearly equal margins

$$P'_{nut} := 2 \cdot P'_{lug} \quad P'_{nut} = 62.318 \cdot \text{kip}$$

$$P'_{hook} = 64.85 \cdot \text{kip}$$

$$P'_{pin} = 26.54 \cdot \text{kip}$$

12.3 Estimate f_1 and f_2 factors to reduce t_{10} and t_{20} for nearly equal limits

Estimate f_1 and f_2 factors to reduce t_{10} and t_{20} for nearly equal limits. For a first cut, estimate the new pin limit by averaging the nut and hook limits and then forming the geometric mean with the old pin limit. Compare this with the old nut and hook limits for f_1 and f_2 .

$$f_1 := 0.68 \quad f_2 := 0.65 \quad (\text{after iteration})$$

$$t_1 := f_1 \cdot t_{10} \quad t_2 := f_2 \cdot t_{20}$$

$$t_1 = 0.524 \cdot \text{in} \quad t_2 = 0.631 \cdot \text{in}$$

12.3.1 Nut: (symmetric)

$$F_{tu} := S_u A_{148} \quad F_{ty} := S_y A_{148}$$

$$a := 3.12 \cdot \text{in} - 2.25 \cdot \text{in} \quad a = 0.87 \cdot \text{in}$$

$$D := 0.75 \cdot \text{in} \quad W := 1.89 \cdot \text{in} \quad \frac{W}{D} = 2.52$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_1 \quad A_t = 0.597 \cdot \text{in}^2 \quad K_t := 0.94 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t \quad P'_{tu} = 50.498 \cdot \text{kip}$$

b. Shear tear-out

$$\frac{a}{D} = 1.16 \quad \frac{D}{t_1} = 1.432 \quad K_{br} := 1.07 \quad (\text{curve 1, Fig 204.4-3})$$

$$A_{br} := D \cdot t_1 \quad A_{br} = 0.393 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br} \quad P'_{bru} = 37.817 \cdot \text{kip}$$

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$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 1.07 \quad C := 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 27.732 \cdot \text{kip}$$

204.44 Transverse curve. Use curve at 90 deg

 $f := .75$

(Fig. 204.4-5)

$$P'_{lug} := f \cdot P'_y \quad P'_{lug} = 20.799 \cdot \text{kip}$$

12.3.2 Hook

$$F_{tu} := S_{uA747} \quad F_{ty} := S_{yA747}$$

$$a := .68 \cdot \text{in}$$

$$D := 0.755 \cdot \text{in}$$

$$W := 1.36 \cdot \text{in}$$

$$\frac{W}{D} = 1.801$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_2 \quad A_t = 0.381 \cdot \text{in}^2 \quad K_t := 0.97 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t \quad P'_{tu} = 53.651 \cdot \text{kip}$$

b. Shear tear-out

$$\frac{a}{D} = 0.901 \quad \frac{D}{t_2} = 1.197 \quad K_{br} := .70 \quad (\text{curve 1, Fig 204.4-3})$$

$$A_{br} := D \cdot t_2 \quad A_{br} = 0.476 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br} \quad P'_{bru} = 48.317 \cdot \text{kip}$$

c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 0.7 \quad C := 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 42.152 \cdot \text{kip} \quad P'_{hook} := P'_y$$

$$P'_{hook} = 42.152 \cdot \text{kip}$$

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$$F_{ty} := S_y A_{108} \quad F_{tu} := S_u A_{108}$$

$$g_p := .05 \cdot \text{in} \quad R := \frac{.749}{2} \cdot \text{in}$$

a. Pin capacity

$$b := .5 \cdot t_1 + g_p + 0.25 \cdot t_2 \quad b = 0.469 \cdot \text{in}$$

$$Z := \pi \cdot R^2 \cdot 0.4244 \cdot R \quad Z = 0.07 \cdot \text{in}^3$$

$$S := \frac{\pi}{4} \cdot R^3 \quad S = 0.041 \cdot \text{in}^3 \quad f_{\text{shape}} := \frac{Z}{S} \quad f_{\text{shape}} = 1.698$$

$$P'_{\text{pin}} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{\text{pin}} = 32.82 \cdot \text{kip}$$

b. Peaking effect

$$r := \frac{a - \frac{D}{2}}{t_2} \quad r = 0.48 \quad K_{br} = 0.7 \quad (\text{min: } P'_{tu} \text{ or } P'_{bru})$$

$$\gamma := 0.37 \quad (\text{Fig. 204.4-8}) \quad b := 0.5 \cdot t_1 + g_p + \gamma \cdot \frac{t_2}{4} \quad b = 0.37 \cdot \text{in}$$

$$P'_{\text{pin}} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{\text{pin}} = 41.625 \cdot \text{kip}$$

c. Check if t1 and t2 give nearly equal margins:

$$P'_{\text{nut}} := 2 \cdot P'_{\text{lug}} \quad P'_{\text{nut}} = 41.599 \cdot \text{kip}$$

$$P'_{\text{hook}} = 42.152 \cdot \text{kip}$$

$$P'_{\text{pin}} = 41.625 \cdot \text{kip}$$

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$$A_{pin} := \frac{\pi \cdot D^2}{4} \quad P'_{shr} := 0.6 \cdot F_{tu} \cdot A_{pin} \cdot 2 \quad P'_{shr} = 66.617 \cdot \text{kip}$$

Pin bending is treated as a yield type limit reflecting a shape factor of 1.70 which is applicable in plastic design. With the usual AISC safety factor of 1.67:

$$P_{b.all} := \frac{P'_{pin}}{1.67} \quad P_{b.all} = 24.925 \cdot \text{kip} \quad (\text{Use})$$

Shear safety factor of 2.5:

$$P_{s.all} := \frac{P'_{shr}}{2.5} \quad P_{s.all} = 26.647 \cdot \text{kip}$$

*Therefore, Bending governs***12.5 Calculated Limit Load**

$$P_{limit} := P_{b.all} \quad P_{limit} = 24925 \cdot \text{lbf} \quad \text{which governs}$$

12.6 Shear limit

$$\tau_{limit} := P_{s.all} \quad \tau_{limit} = 26647 \cdot \text{lbf} \quad \text{Which does not govern}$$

12.7 External Loads

$$P_{net} := P_{limit} - P_{nom} \quad P_{net} = 21449 \cdot \text{lbf}$$

$$\sigma_{net} := \frac{P_{net}}{P_{limit}} \cdot \sigma_{bA108} \quad \sigma_{net} = 70993 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Pin bending stress σ_{pm} caused by hook membrane stress σ_{hm}

$$\sigma_{pm}(\sigma_{hm}) := \frac{\sigma_{hm} \cdot A_{hook}}{P_{limit}} \cdot \sigma_{bA108} \quad \sigma_{pm} \left(1 \cdot \frac{\text{lbf}}{\text{in}^2} \right) = 4.816 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \sigma_{hm} \quad \text{gives a}_{hm}$$

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3/30/95**12.7.1 Determine the pin bending stress σ_{pb} caused by hook bending stress σ_{hb} .**

Use the distribution shown on half the pin (Figure C17).

$$M_{\text{hook}} := 1 \cdot \text{lbf} \cdot \text{in}$$

assumed hook moment equal to 1

$$P_1 := \frac{M_{\text{hook}}}{2 \cdot \frac{2}{3} \cdot \frac{t_{\text{hook}}}{2}}$$

$$P_1 = 1.546 \cdot \text{lbf}$$

$$P_2 := \frac{M_{\text{hook}}}{2 \cdot \left(\frac{t_{\text{hook}}}{2} + \Delta_{\text{tol}} + \frac{t_{\text{nut}}}{2} \right)}$$

$$P_2 = 0.543 \cdot \text{lbf}$$

shear force

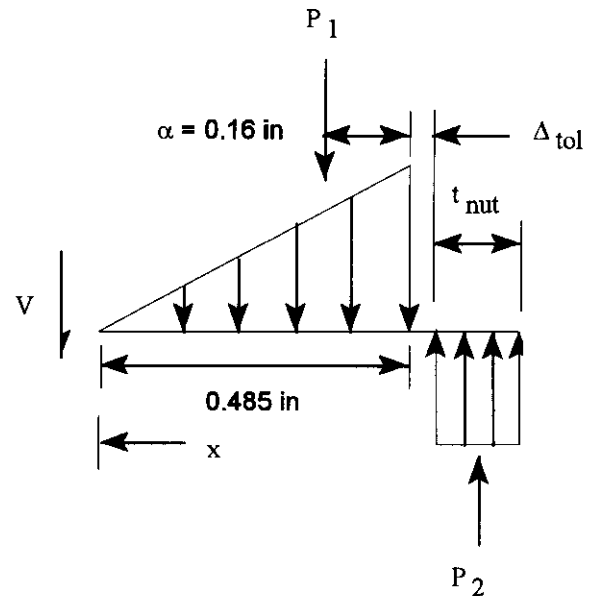
$$V := P_1 - P_2$$

$$V = 1.003 \cdot \text{lbf}$$

The maximum displacement is determined as the following

$$M_h(x) := V \cdot x - P_1 \cdot \frac{t_{\text{hook}}}{6} \cdot \left[\frac{x}{\left(\frac{t_{\text{hook}}}{2} \right)} \right]^3$$

Figure C17. Sketch of pin loading from bending.



Taking the derivative of both sides of the equation, to determine the maximum displacement, the equation simplifies to

$$x_{\text{max}} := \sqrt[4]{\frac{V}{P_1 \cdot \frac{t_{\text{hook}}^2}{4}}}$$

$$x_{\text{max}} = 0.391 \cdot \text{in}$$

Therefore, the maximum moment in the pin is

$$M_{\text{max}} := V \cdot x_{\text{max}} - P_1 \cdot \frac{t_{\text{hook}}}{6} \cdot \left[\frac{x_{\text{max}}}{\left(\frac{t_{\text{hook}}}{2} \right)} \right]^3$$

maximum moment in pin

$$M_{\text{max}} = 0.261 \cdot \text{lbf} \cdot \text{in}$$

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 3/29/95Checker J. L. JulykDate 3/30/95**12.8 Interface and Pinned system model**The pin bending stress σ_{pb} is a function of the hook bending stress σ_{hb} $Z_{pin} := 1.70 \cdot S_{pin}$

$$\sigma_{pb}(\sigma_{hb}) := \frac{M_{max} \cdot \sigma_{hb} \cdot S_{hook}}{M_{hook} \cdot Z_{pin}} \quad \sigma_{pb} \left(1 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2} \right) = 1.349 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2} \sigma_{hb} \quad \text{gives } a_{hbt}$$

Add σ_{pb} and σ_{pm} directly using the hook stresses at the nut and compare with σ_{net} $\sigma_{net} = 70993 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2}$

	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 2000 lbf	2,300	-	7.20
	Fy = 15000 lbf	100	-	10.00
	Fz = 2000 lbf	-	35,100	1.50
	Mx = 7000 lbf-ft	-	170,800	0.31
	My = 7000 lbf-ft	-	479,000	0.11
	Mz = 7000 lbf-ft	19,300	-	0.86
Hook @ 120-deg.	Fx = 2000 lbf	1,100	27,100	1.72
	Fy = 15000 lbf	100	-	10.00
	Fz = 2000 lbf	1,900	17,500	2.24
	Mx = 7000 lbf-ft	9,300	85,400	0.46
	My = 7000 lbf-ft	-	479,000	0.11
	Mz = 7000 lbf-ft	9,400	259,000	0.18

where: $LF = \frac{\sigma_{net}}{a_{hm} \cdot \sigma_{Sd} + a_{hbt} \cdot S_{by}}$

12.9 Pin Released or Pin allowed to rotate @ hook/nut locationThe hook moments are admitted to this extent of the eccentricity to the edge of the hook ($t_{hook}/2$) at the pin.The pin bending stress σ_{pb} is a function of the hook membrane stress σ_{hm}

$$\sigma_{pb} = \frac{M_{max} \cdot (\sigma_{hm} \cdot A_{hook} + P_{nom}) \cdot \frac{t_{hook}}{2}}{M_{hook} \cdot S_{pin}} = \frac{M_{max} \cdot A_{hook} \cdot \frac{t_{hook}}{2}}{M_{hook} \cdot S_{pin}} \left(\sigma_{hm} + \frac{P_{nom}}{A_{hook}} \right)$$

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$$\frac{M_{\max} \cdot A_{\text{hook}} \cdot \frac{t_{\text{hook}}}{2}}{M_{\text{hook}} \cdot Z_{\text{pin}}} = 2.617 \quad \text{gives } a_{\text{hbr}}$$

$$\sigma_{\text{net}} = \text{LF} \cdot \left(a_{\text{hm}} \cdot \sigma_{\text{hm}} + a_{\text{hbr}} \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}} \right) + a_{\text{hbr}} \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}$$

$$\text{where: } \text{LF} = \frac{\sigma_{\text{net}} - a_{\text{hbr}} \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}}{(a_{\text{hm}} + a_{\text{hbr}}) \cdot \sigma_{\text{hm}}} \quad \text{and } \sigma_{\text{hm}} \text{ and } \sigma_{\text{hb}} \text{ are defined as Sd and Sby in the table below.}$$

	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 2000 lbf	2,300	-	4.27
	Fy = 15000 lbf	100	-	10.00
	Fz = 2000 lbf	-	-	10.00
	Mx = 7000 lbf-ft	-	-	10.00
	My = 7000 lbf-ft	-	-	10.00
	Mz = 7000 lbf-ft	20,340	-	0.48
Hook @ 120-deg.	Fx = 2000 lbf	1,200	-	8.18
	Fy = 15000 lbf	100	-	10.00
	Fz = 2000 lbf	2,100	-	4.67
	Mx = 7000 lbf-ft	10,100	-	0.97
	My = 7000 lbf-ft	-	-	10.00
	Mz = 7000 lbf-ft	10,200	-	0.96

13.0 OPERATING NUT

The nut is quite strong compared to the pin. Consider a 50,000 lbf axial loading with three hooks, which is more than the pins can take. We will demonstrate that the nut is stronger than the pins, so that the piping load limitations are derived from the pins analysis that was discussed in section 12.

$d_{\text{hole}} := 0.75\text{-in}$	diameter of nut hole @ pin location (WHC 1985b, H-2-68210)	$L_{\text{nut}} := 1.84\text{-in}$	length of nut (WHC 1985b)
$P_{\text{axial}} := 50000\text{-lbf}$	assumed axial loading on operating nut (applied to three hooks)	$t_{\text{nut}} = 0.77\text{-in}$	thickness of nut (WHC 1985b)

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$$\sigma_{brg} := \frac{\frac{2}{3} \cdot P_{axial}}{d_{hole} \cdot t_{nut}}$$

$$\sigma_{brg} = 57720 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{brA148} = 108000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{O.K.}$$

$$\text{The edge distance/diameter is } \frac{L_{nut}}{2 \cdot (d_{hole})} = 1.227 \quad \text{O.K.}$$

13.2 Bending stress (one ear)

$$\sigma_b(M_{nut}, S_{nut}) := \frac{M_{nut}}{S_{nut}}$$

Moment on one ear of operating nut

$$M_{nut} := \frac{P_{axial}}{6} \cdot (2.25 \cdot \text{in} - 1.38 \cdot \text{in}) \quad M_{nut} = 7250 \cdot \text{lbf} \cdot \text{in}$$

Section modulus on operating nut

$$S_{nut} := \frac{1}{6} \cdot (t_{nut} \cdot L_{nut}^2) \quad S_{nut} = 0.434 \cdot \text{in}^3$$

$$\sigma_b(M_{nut}, S_{nut}) = 16686 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{bA148} = 45000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Therefore, O.K.

13.2.1 Ring Stress

$$\sigma_{ring}(M_{tot}, R, C, S) := \frac{M_{tot} \cdot R}{C(R) \cdot S}$$

where

$$b := 1.38 \cdot \text{in} - \frac{1.75 \cdot \text{in}}{2} \quad b = 0.505 \cdot \text{in}$$

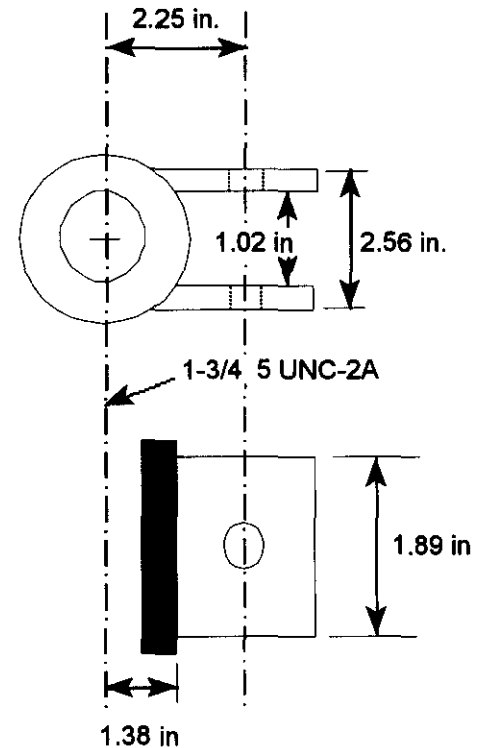
$$C(R) := 2 \cdot \pi \cdot R$$

$$S := b \cdot \frac{L_{nut}^2}{6} \quad S = 0.285 \cdot \text{in}^3$$

$$M_{tot} := P_{axial} \cdot \left(2.25 \cdot \text{in} - 1.38 \cdot \text{in} + \frac{b}{2} \right)$$

$$M_{tot} = 56125 \cdot \text{lbf} \cdot \text{in}$$

moment applied to nut ring

Figure C18. Sketch of Operating Nut
(WHC 1985b, H-2-68210)

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Bending ring stress

$$\sigma_{\text{ring}}(M_{\text{tot}}, R, C, S) = 31347 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{\text{bA148}} = 45000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{Therefore, O.K.}$$

13.3 Shear stress (one ear)

$$\tau := \frac{P_{\text{preload}}}{t_{\text{nut}} L_{\text{nut}}} \quad \tau = 1412 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{\text{vA148}} = 24000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{O.K.}$$

14.0 OPERATING SCREW

$$d_{\text{min}} := 1.49 \cdot \text{in}$$

Minimum thread diameter of screw
(WHC 1985a, H-2-32431)Figure C19. Sketch of Operating Screw
(WHC 1985a, H-2-32431)

$$A_{\text{screw}} := \frac{\pi}{4} d_{\text{min}}^2$$

Area of screw

$$A_{\text{screw}} = 1.744 \cdot \text{in}^2$$

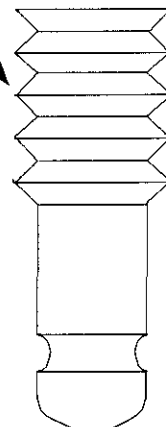
Calculation of membrane stress in screw

$$\sigma_m := \frac{P_{\text{thermal}} + P_{\text{pressure}} + P_{\text{preload}}}{A_{\text{screw}}} \quad \sigma_m = 5982 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Calculation of bending stress in screw

$$\sigma_b := \sigma_{\text{bA193}} - \sigma_m \quad \sigma_b = 57018 \cdot \frac{\text{lbf}}{\text{in}^2}$$

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**14.1 Determination of adjustment factor used for screw bending**

System model output for screw bending stresses at the nut are based on a lever arm from the top of the block of the midheight location in the nut. In the no-slip screw-block model, the lever arm should be taken from the block top to the base of the nut. In the interface element model, the lever arm should be taken from center of the sphere defining the screw bearing surface to the lower edge of the nut.

$$h_{\text{pin}} := (10.43 - 6.22 + 0.24) \cdot \text{in}$$

$$h_{\text{pin}} = 4.45 \cdot \text{in}$$

block-top to mid-nut height

$$d_{\text{scr}} := 1.44 \cdot \text{in}$$

screw diameter (WHC 1985a)

$$W_{\text{lug}} := 1.89 \cdot \text{in}$$

nut length (WHC 1985b)

$$S_{\text{scr}} := \frac{\pi}{32} d_{\text{scr}}^3$$

section modulus of screw

$$R_{\text{cap}} := 1.56 \cdot \text{in}$$

screw bearing radius
(WHC 1985a)

$$S_{\text{scr}} = 0.293 \cdot \text{in}^3$$

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3/30/95In the no-slip model the end load bending contribution from $W_{lug}/2$ is subtract.

$$S_{by} = S_{bANSYS} - \frac{W_{lug}}{2} \cdot \frac{F_{yANSYS}}{S_{pin}}$$

Note: That S_{bANSYS} and F_{yANSYS} @ the nut end, should have the same signIn the interface model the ANSYS output bending stresses are multiplied by a correction factor, β_{iface} .

$$\beta_{iface} = 1 - \frac{W_{lug} + 2 \cdot R_{cap}}{2 \cdot h_{pin}} \quad \beta_{iface} = 0.437 \quad (\text{interface model})$$

These factors should be applied before entering the data in the table below.

14.2 Interface and Pinned system model

Load	Sd (psi)	Sby (psi)	LF
Fx = 2000 lbf	-	22,700	2.38
Fy = 15000 lbf	300	-	10.00
Fz = 2000 lbf	-	22,700	2.38
Mx = 7000 lbf-ft	-	110,500	0.49
My = 7000 lbf-ft	-	-	10.00
Mz = 7000 lbf-ft	-	193,500	0.28

Where: $LF = \frac{\sigma_b}{Sd + Sby}$

Note: that the high bending stresses are from the pin model (screw pinned to block) and they might not be supported by friction forces at the block top. The interface element model shows less than half these moments**14.3 Pin Released or Pin allowed to rotate @ hook/nut location**

Load	Sd (psi)	Sby (psi)	LF
Fx = 2000 lbf	-	33,700	1.60
Fy = 15000 lbf	500	-	10.00
Fz = 2000 lbf	-	33,700	1.60
Mx = 7000 lbf-ft	-	164,300	0.33
My = 7000 lbf-ft	-	-	10.00
Mz = 7000 lbf-ft	-	287,600	0.19

Where: $LF = \frac{\sigma_b}{Sd + Sby}$

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The top of the block was evaluated in appendix B.

The assumed axial load was used in appendix B.

$$F := 21167 \cdot \text{lb} \cdot \text{f}$$

Assumed axial load
obtained from appendix BFigure C20. Sketch of screw/block interaction @ top off block
(WHC 1985a, H-2-32431 and WHC 1994b, H-2-821325)

$$P_m := 6337 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

membrane stresses obtained from
appendix B, @ assumed axial load

Calculation of the limit load

$$F_{\text{limit}} := F \cdot \frac{S_{mA276}}{P_m} \quad F_{\text{limit}} = 66804 \cdot \text{lb} \cdot \text{f}$$

To obtain a lateral load criterion, compare this
with a shear plug using the diameter of the screw

$$P_{\text{limit}} := \pi \cdot d_s \cdot t \cdot \sigma_{vA276}$$

$$P_{\text{limit}} = 68944 \cdot \text{lb} \cdot \text{f}$$

Use the shear plug concept with a factor

$$f_p := \frac{F_{\text{limit}}}{P_{\text{limit}}} \quad f_p = 0.969$$

with lateral loading H

$$V := P_{\text{thermal}} + P_{\text{preload}} \quad V = 10125 \cdot \text{lb} \cdot \text{f}$$

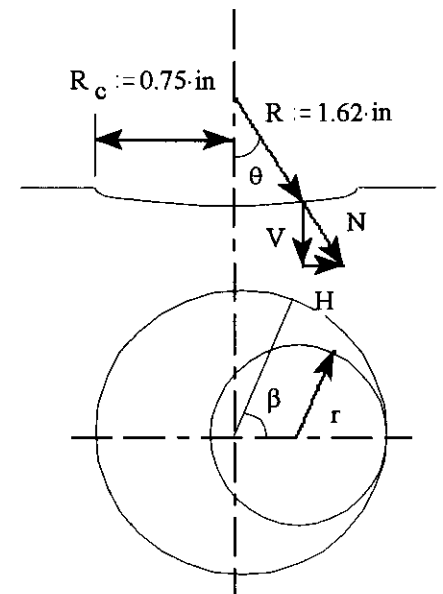
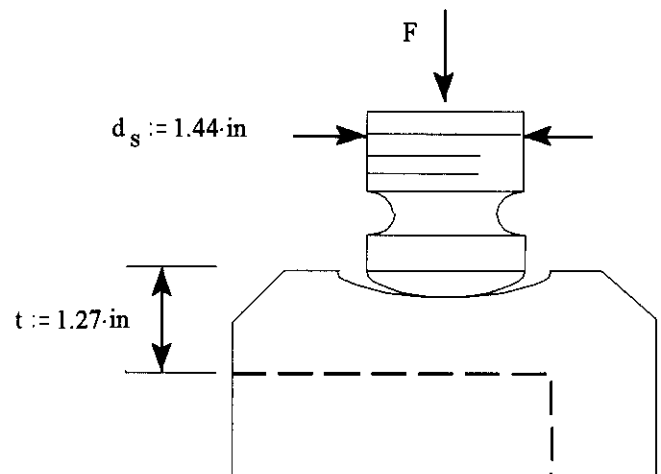
N is carried over circle with radius r.

$$\tan(\theta) = \frac{H}{V} \quad (\text{no friction})$$

$$\cos(\beta) = \frac{R \cdot \tan(\theta)}{R_c} = \frac{R \cdot H}{R_c \cdot V}$$

$$r = R_c \cdot (1 - \cos(\beta)) = R_c \cdot \left(1 - \frac{R \cdot H}{R_c \cdot V}\right)$$

$$P_{\text{limit}}(r) := 2 \cdot \pi \cdot r \cdot t \cdot \sigma_{vA276} \cdot f_p$$



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$$N(r) := P_{\text{limit}}(r)$$

$$H(r) := V \cdot \frac{R_c}{R} \cdot \left(1 - \frac{N(r)}{P_{\text{limit}}(R_c)} \right)$$

Estimate $r := 0.12 \cdot \text{in}$ Therefore, $N(r) = 11134 \cdot \text{lbf}$ and $H(r) = 3937 \cdot \text{lbf}$ Check that the vector sum of $(V + H)$ is less than N

$$\sqrt{V^2 + H(r)^2} = 10864 \cdot \text{lbf} \quad \text{YES (O.K.)}$$

Using a minimum coefficient of friction of $\mu := 0.1$

$$\Delta H := \mu \cdot V \quad \Delta H = 1.013 \cdot 10^3 \cdot \text{lbf}$$

$$H_{\text{limit}}(r) := H(r) + \Delta H \quad H_{\text{limit}}(r) = 4950 \cdot \text{lbf}$$

 V is limited by F_{limit} less the existing V .

$$\text{The load fraction is the minimum of: } LF(r) = \frac{H_{\text{limit}}(r)}{H} \quad \text{or} \quad LF = \frac{F_{\text{limit}} - V}{\Delta V}$$

since H and ΔV do not occur together. As data, they are found at the base of the screw element in the system models

15.1 Interface and Pinned system model

Load	ΔV (lbf)	H (lbf)	LF	where: $LF = \frac{H_{\text{limit}}}{\Delta V + H}$	is conservative
$F_x = 2000 \text{ lbf}$	-	1,800	2.75		
$F_y = 15000 \text{ lbf}$	500	-	10.00		
$F_z = 2000 \text{ lbf}$	-	1,800	2.75		
$M_x = 7000 \text{ lbf-ft}$	-	8,700	0.57		
$M_y = 7000 \text{ lbf-ft}$	-	-	10.00		
$M_z = 7000 \text{ lbf-ft}$	-	15,300	0.32		

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 3/29/95Checker J. L. JulykDate 3/30/95**15.2 Pin Released or Pin allowed to rotate @ hook/nut location**

Load	ΔV (lbf)	H (lbf)	LF
$F_x = 2000$ lbf	-	3,100	1.60
$F_y = 15000$ lbf	500	-	10.00
$F_z = 2000$ lbf	-	3,100	1.60
$M_x = 7000$ lbf-ft	-	15,100	0.33
$M_y = 7000$ lbf-ft	-	-	10.00
$M_z = 7000$ lbf-ft	-	26,400	0.19

where: $LF = \frac{H_{\text{limit}}}{\Delta V + H}$ is conservative

16.0 GUIDE-BLOCK INTERFACE

Figure C21. Sketch of Block and Guide lip interaction

Height of block lip (WHC 1994b, H-2-821325)

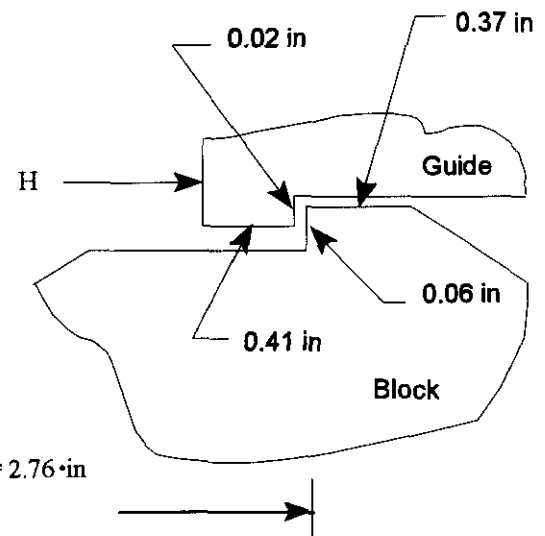
$$h_B := 0.06 \cdot \text{in}$$

outside diameter for block lip
(WHC 1994b, H-2-821325)

$$d_{Bo} := 3.50 \cdot \text{in}$$

inside diameter for block lip
(WHC 1994b, H-2-821325)

$$d_{Bi} := 2.76 \cdot \text{in}$$

**16.1 Block Lip****16.1.1 Allowable Shear Force**

$$A_{vBL} := 0.37 \cdot \text{in} \cdot d_{Bi} \quad A_{vBL} = 1.021 \cdot \text{in}^2 \quad \text{Shear area}$$

$$H_{vBL} := \sigma_{vA276} \cdot A_{vBL} \quad H_{vBL} = 12254 \cdot \text{lbf} \quad \text{Shear limit at top of lip}$$

16.1.2 Allowable Bearing Force

$$A_{bBL} := 0.02 \cdot \text{in} \cdot d_{Bi} \quad A_{bBL} = 0.055 \cdot \text{in}^2 \quad \text{Bearing area}$$

$$H_{bBL} := \sigma_{brA276} \cdot A_{bBL} \quad H_{bBL} = 2484 \cdot \text{lbf} \quad \text{Bearing limit at top lip}$$

16.2 Guide Lip

$$h_G := 0.020 \cdot \text{in} \quad \text{Height of guide lip (WHC 1985d, H-2-68206)}$$

$$d_{Go} := 2.75 \cdot \text{in} \quad \text{outside diameter for hook guide lip (WHC 1985d, H-2-68206)}$$

$$d_{Gi} := 1.93 \cdot \text{in} \quad \text{inside diameter for hook guide lip (WHC 1985d, H-2-68206)}$$

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16.2.1 Allowable Shear Force

$$A_{vGL} := 0.41 \cdot \text{in} \cdot d_{Go}$$

$$A_{vGL} = 1.127 \cdot \text{in}^2$$

Shear area

$$H_{vGL} := \sigma_{vA743} \cdot A_{vGL}$$

$$H_{vGL} = 19731 \cdot \text{lb}f$$

Shear limit at top of lip

16.2.2 Allowable Bearing Force

$$A_{bGL} := 0.02 \cdot \text{in} \cdot d_{Go}$$

$$A_{bGL} = 0.055 \cdot \text{in}^2$$

Bearing area

$$H_{bGL} := \sigma_{brA743} \cdot A_{bGL}$$

$$H_{bGL} = 4620 \cdot \text{lb}f$$

Bearing limit at top lip

16.2.3 Determine the allowable for bearing and shear that the block and guide lip can accomdate

$$H_{allBL} := \text{if}(H_{vBL} < H_{bBL}, H_{vBL}, H_{bBL})$$

$$H_{allBL} = 2484 \cdot \text{lb}f$$

$$H_{allGL} := \text{if}(H_{vGL} < H_{bGL}, H_{vGL}, H_{bGL})$$

$$H_{allGL} = 4620 \cdot \text{lb}f$$

$$H_{allow} := \text{if}(H_{allBL} < H_{allGL}, H_{allBL}, H_{allGL})$$

$$H_{allow} = 2484 \cdot \text{lb}f$$

16.2.4 Interface and Pinned system model results

Load	H (lb)	LF
Fx = 2000 lb	2,500	0.99
Fy = 15000 lb	-	10.00
Fz = 2000 lb	2,500	0.99
Mx = 7000 lb-ft	12,100	0.21
My = 7000 lb-ft	-	10.00
Mz = 7000 lb-ft	21,200	0.12

where: $LF = \frac{H_{allow}}{H}$

16.2.5 Pin Released or Pin allowed to rotate @ hook/nut location

Load	H (lb)	LF
Fx = 2000 lb	4,100	0.61
Fy = 15000 lb	-	10.00
Fz = 2000 lb	4,100	0.61
Mx = 7000 lb-ft	19,900	0.12
My = 7000 lb-ft	-	10.00
Mz = 7000 lb-ft	34,900	0.07

where: $LF = \frac{H_{allow}}{H}$

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3/30/95**16.3 Check for Lift-Out**Consider that $f = 0$, no friction

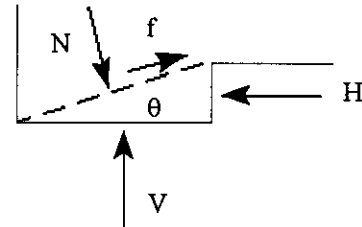
Figure C22. Sketch of guide lift-off from top of block

$$\frac{H}{V} = \tan(\theta) = \frac{0.02 \cdot \text{in}}{0.41 \cdot \text{in}}$$

If the skirt-bolt-guide system has sufficient stiffness to provide V for $\delta = 0.02 \text{ in.}$ deflection, lift-out can not occur

$$\delta := 0.02 \cdot \text{in}$$

$$H_{\text{lift}} = \frac{0.02 \cdot \text{in}}{0.41 \cdot \text{in}} \cdot V \quad V = k_{\text{sbg}} \cdot \delta$$

**16.3.1 Bolt Stiffness (WHC 1991d, H-2-3808)**

$N_{\text{bolts}} := 6$ Number of bolts, at least 2 participate directly

$d_{\text{bolt}} := 0.625 \cdot \text{in}$ diameter of bolts

$l_{\text{bolt}} := 6 \cdot \text{in}$ length of bolts

$E_{\text{bolt}} := 28 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$ modulus of elastic for bolts

$A_{\text{bolt}} := \frac{\pi}{4} \cdot d_{\text{bolt}}^2$ cross-sectional area of bolt $A_{\text{bolt}} = 0.307 \cdot \text{in}^2$

$k_{\text{bolt}} := 2 \cdot E_{\text{bolt}} \cdot \frac{A_{\text{bolt}}}{l_{\text{bolt}}}$ stiffness of bolts $k_{\text{bolt}} = 2.863 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}}$

16.3.2 Guide Stiffness for 2 cantilevers (WHC 1985d, H-2-68206)

$b_{\text{guide}} := 1.31 \cdot \text{in}$ width of guide

$h_{\text{guide}} := 1.25 \cdot \text{in}$ height of guide

$l_{\text{guide}} := 1.55 \cdot \text{in}$ length of guide or span

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$$E_{\text{guide}} := 28 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{modulus of elasticity for guide}$$

$$I_{\text{guide}} := \frac{2 \cdot b_{\text{guide}} \cdot h_{\text{guide}}^3}{12} \quad \text{moment of inertia for guide} \quad I_{\text{guide}} = 0.426 \cdot \text{in}^4$$

$$k_{\text{guide}} := \frac{3 \cdot E_{\text{guide}} \cdot I_{\text{guide}}}{l_{\text{guide}}^3} \quad \text{stiffness of guide} \quad k_{\text{guide}} = 9619096 \cdot \frac{\text{lbf}}{\text{in}}$$

Therefore let, $k_{\text{sbg}} := k_{\text{bolt}}$

$$H_{\text{limit}} := \frac{0.02 \cdot \text{in}}{0.41 \cdot \text{in}} \cdot k_{\text{bolt}} \cdot \delta \quad H_{\text{limit}} = 2794 \cdot \text{lbf}$$

Therefore, the block controls with the H_{bearing} limit.**17.0 Block-Nozzle Moment Transfer ISB jumper**

From Roger Evanson, for 304/304 metal to metal contact, the coefficient of friction can range from 0.2 to 0.7. Assuming a coefficient of friction of 0.40 the frictional force under a normal pre-load torque force (2000 lbf) is determined.

$$\mu := 0.40 \quad \text{coefficient of friction for 304/304 metal to metal contact}$$

$$P := P_{\text{preload}} \quad P = 2000 \cdot \text{lbf} \quad \text{Pre-load for a 50 ft-lbf torque screw load (Squier 1993)}$$

$$N := \sqrt{2} \cdot P \quad N = 2828 \cdot \text{lbf} \quad \text{Normal force acting of surface}$$

$$F := \mu \cdot N \quad F = 1131 \cdot \text{lbf} \quad \text{friction force}$$

The Breakaway friction for a bending moment and torsional load under a pre-load of F are calculated below

$$R_s := 2.65 \cdot \text{in} \quad \text{Radius of Block/Nozzle cone (WHC 1994b, H-2-821324)}$$

$$c := 2 \cdot \pi \quad \text{contact circle}$$

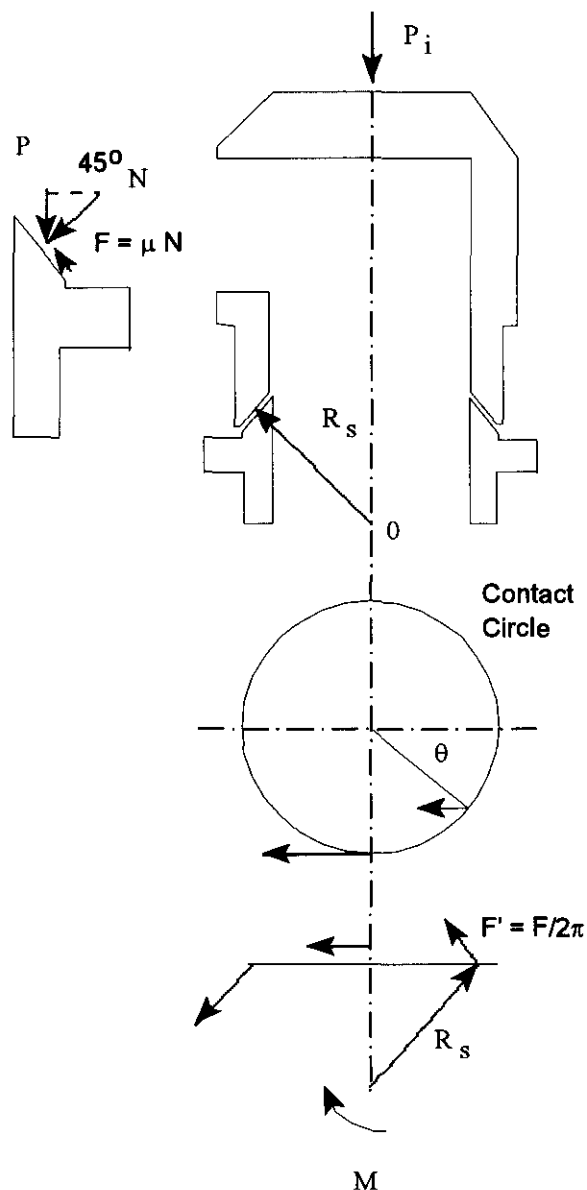
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Figure C23. Block-Nozzle Moment Transfer

$$M := \frac{F \cdot R_s}{2 \cdot \pi} \int_0^c \sqrt{\frac{\cos(\theta) \cdot \cos(\theta)}{2} + \frac{1}{2}} d\theta$$

$M = 215 \cdot \text{ft} \cdot \text{lbf}$ for a 50 ft-lbf torque screw load

Therefore, based on the assumed coefficient of friction of 0.40 the block/nozzle allowable moment that the friction could withstand for pre-load screw torque of 50 is 215 ft-lbf. This is compared to the external moments of 7000 ft-lbf in the x, y, and z-directions, respectively. Since a 50 ft-lbf torque is plausible, and the friction coefficient may be smaller, it is recommended that friction be ignored in the analysis.



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18.0 4-in. Jumper Connector System Model Calculations

18.1 NOZZLE ANALYSIS

$P_{\text{limit}} := 12717 \cdot \text{lbf}$ Total Axial Capacity for one hook (appendix A)

$P_{\text{thermal}} := 11109 \cdot \text{lbf}$ Thermal expansion resistance load (appendix B, section 8.3)

$P_{\text{pressure}} := 429 \cdot \text{lbf}$ Pressure resistance load (appendix B, section 8.4)

$P_{\text{preload}} := 2000 \cdot \text{lbf}$ Preload for 50 ft-lbf torque (Squier 1993)

$P_{\text{nom}} := \frac{1}{3} (P_{\text{thermal}} + P_{\text{pressure}} + P_{\text{preload}})$ $P_{\text{nom}} = 4513 \cdot \text{lbf}$ Nominal load

Net load after thermal expansion, pressure, and the pre-load are deducted from the limit load (see appendix B for thermal, pressure, and pre-load axial values)

$P_{\text{net}} := P_{\text{limit}} - P_{\text{nom}}$ $P_{\text{net}} = 8204 \cdot \text{lbf}$

18.2 Determine the load fractions to use in the nozzle evaluation for the interface, pinned, and pin released system models.

18.2.1 Interface and pinned system model

Load	ΔF (lbf)	LF	where: ΔF is the maximum axial hook load from system models (appendix G)
$F_x = 3000 \text{ lbf}$	4,300	1.91	$LF = \frac{P_{\text{net}}}{\Delta F}$ is the Load fraction
$F_y = 27000 \text{ lbf}$	240	10.00	
$F_z = 3000 \text{ lbf}$	3,730	2.20	
$M_x = 7000 \text{ lbf-ft}$	16,520	0.50	
$M_y = 13000 \text{ lbf-ft}$	-	10.00	
$M_z = 13000 \text{ lbf-ft}$	35,430	0.23	

Full release of the hook from the nozzle is not acceptable as it invalidates the model.

Pro-rate absolute hook-nozzle reactions to the existing load. $P_{\text{pre}} := P_{\text{nom}}$

Load	ΔF (lbf)	LF	where: ΔF is the maximum axial hook load from system models (appendix G)
$F_x = 3000 \text{ lbf}$	4,300	1.05	$LF = \frac{P_{\text{pre}}}{\Delta F}$ is the Load fraction
$F_y = 27000 \text{ lbf}$	240	10.00	
$F_z = 3000 \text{ lbf}$	3,730	1.21	
$M_x = 7000 \text{ lbf-ft}$	16,520	0.27	
$M_y = 13000 \text{ lbf-ft}$	-	10.00	
$M_z = 13000 \text{ lbf-ft}$	35,430	0.13	

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18.2.2 Pin Released or allowed to rotate @ hook/operating nut location

Load	ΔF (lbf)	LF
$F_x = 3000$ lbf	4,700	1.75
$F_y = 27000$ lbf	200	10.00
$F_z = 3000$ lbf	4,100	2.00
$M_x = 7000$ lbf-ft	18,000	0.46
$M_y = 13000$ lbf-ft	-	10.00
$M_z = 13000$ lbf-ft	38,700	0.21

where: ΔF is the maximum axial hook load from system models (appendix G)

$$LF = \frac{P_{net}}{\Delta F} \quad \text{is the Load fraction}$$

Full release of the hook from the nozzle is not acceptable as it invalidateds the model.

Pro-rate absolute hook-nozzle reactions to the existing load. $P_{pre} := P_{nom}$

Load	ΔF (lbf)	LF
$F_x = 3000$ lbf	4,700	0.96
$F_y = 27000$ lbf	200	10.00
$F_z = 3000$ lbf	4,100	1.10
$M_x = 7000$ lbf-ft	18,000	0.25
$M_y = 13000$ lbf-ft	-	10.00
$M_z = 13000$ lbf-ft	38,700	0.12

where: ΔF is the maximum axial hook load from system models (appendix G)

$$LF = \frac{P_{pre}}{\Delta F} \quad \text{is the Load fraction}$$

Figure C24. Typical 4-in. Hook for ISB Jumper
(WHC 1991b, H-2-90176, rev. 4, sh 1)

19.0 HOOK ANALYSIS

19.1 Section (A) of the Hook (nozzle flange location)

Use β as the fraction of hook-guide bending stresses.

$$\beta := \frac{2.4 \cdot \text{in}}{9.09 \cdot \text{in}} \quad \beta = 0.264$$

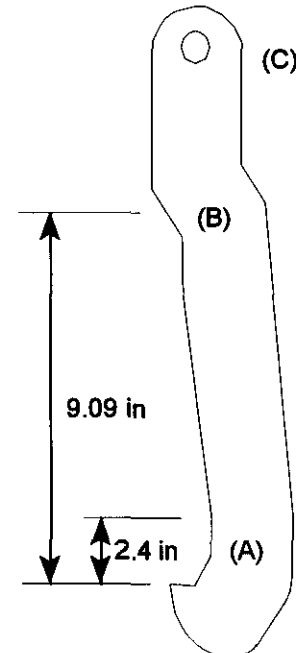
$P_{limit} = 12717 \cdot \text{lbf}$ Total axial capacity for one hook (appendix A)

Net load after thermal expansion, pressure, and the pre-load are deducted from the limit load (see appendix B for thermal, pressure, and pre-load axial values)

$$P_{net} := P_{limit} - P_{nom} \quad P_{net} = 8204 \cdot \text{lbf}$$

Also scale S_d values from App. G with α , since they were corrected for 2" area ratios only. See App D Section 2.5.1.

$$\alpha := \frac{0.059}{0.082} \quad \alpha = 0.72$$



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The pipe loads produce both membrane and bending stresses in the hook. To account for the bending and membrane stresses recalculate the P_{limit} and P_{net} in terms of stresses

$$\sigma_{\text{limit}} := \sigma_{\text{bA747}}$$

$$\sigma_{\text{limit}} = 69000 \cdot \frac{\text{lb}_f}{\text{in}^2}$$

$$\sigma_{\text{net}} := \frac{P_{\text{net}}}{P_{\text{limit}}} \cdot \sigma_{\text{limit}}$$

$$\sigma_{\text{net}} = 44515 \cdot \frac{\text{lb}_f}{\text{in}^2}$$

19.1.1 Interface and pinned system models

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 3000 lbf	3,100	-	6,300	10.00
	Fy = 27000 lbf	200	-	400	10.00
	Fz = 3000 lbf	-	28,500	-	5.92
	Mx = 7000 lbf-ft	-	126,500	-	1.33
	My = 13000 lbf-ft	-	453,000	-	0.37
	Mz = 13000 lbf-ft	25,300	-	51,600	1.40
Hook @ 120-deg.	Fx = 3000 lbf	1,500	24,700	3,000	5.30
	Fy = 27000 lbf	200	-	400	10.00
	Fz = 3000 lbf	2,600	14,300	5,200	6.34
	Mx = 7000 lbf-ft	11,400	63,300	23,300	1.43
	My = 13000 lbf-ft	-	453,000	-	0.37
	Mz = 13000 lbf-ft	12,200	203,500	24,900	0.64

19.1.2 Pin released or allowed to rotate at hook/nut location

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 3000 lbf	3,400	-	6,800	10.00
	Fy = 27000 lbf	200	-	400	10.00
	Fz = 3000 lbf	-	31,200	-	5.40
	Mx = 7000 lbf-ft	-	138,300	-	1.22
	My = 13000 lbf-ft	-	28,100	-	6.00
	Mz = 13000 lbf-ft	27,600	-	56,400	1.28
Hook @ 120-deg.	Fx = 3000 lbf	1,500	27,000	3,000	4.95
	Fy = 27000 lbf	200	-	400	10.00
	Fz = 3000 lbf	2,500	15,600	5,200	6.11
	Mx = 7000 lbf-ft	11,300	69,100	23,000	1.37
	My = 13000 lbf-ft	-	28,100	-	6.00
	Mz = 13000 lbf-ft	12,100	222,400	24,600	0.60

where: $LF = \frac{\sigma_{\text{net}}}{\alpha \cdot Sd + \beta \cdot (Sby + Sbz)}$

Note: The stresses are from appendix G and are the maximum stresses at location (A) on the hook, from the Jumper clamp system model data.

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Using the system model bending and direct stresses section (B) is considered. Section (B) is closer to the load axis. Therefore, adjust section (A) limit using the beam membrane plus bending stress formula.

$$\sigma = \frac{P}{A} + \frac{P \cdot L}{S} \quad \text{Axial and bending stress}$$

@ section (A) per drawing H-2-90176 (WHC 1991b)

$$w_{\text{hook}} := 2.72 \cdot \text{in} - 1.0 \cdot \text{in}$$

Width of hook

$$w_{\text{hook}} = 1.72 \cdot \text{in}$$

$$t_{\text{hook}} := 1.18 \cdot \text{in}$$

Thickness of hook

$$A_{\text{hook}} := w_{\text{hook}} \cdot t_{\text{hook}}$$

area of hook

$$A_{\text{hook}} = 2.03 \cdot \text{in}^2$$

$$S_{\text{hook}} := \frac{1}{6} \cdot (t_{\text{hook}} \cdot w_{\text{hook}}^2)$$

Section modulus of hook

$$S_{\text{hook}} = 0.582 \cdot \text{in}^3$$

$$L_{\text{effective}} := S_{\text{hook}} \cdot \left(\frac{\sigma_{\text{limit}}}{P_{\text{limit}}} - \frac{1}{A_{\text{hook}}} \right)$$

$$L_{\text{effective}} = 2.87 \cdot \text{in}$$

$$L_o := \frac{w_{\text{hook}}}{2} + 1.0 \cdot \text{in} - 0.38 \cdot \text{in} + \frac{0.65 \cdot \text{in}}{2}$$

$$L_o = 1.805 \cdot \text{in}$$

$$\text{Scale by } \Omega := \frac{L_{\text{effective}}}{L_o} \quad \text{on section (B)}$$

Figure C25. Sketch of 4-in. Hook section (WHC 1991b, H-2-90176)

$$L_o := \frac{1}{2} \cdot (0.63 \cdot \text{in} + 2.25 \cdot \text{in})$$

$$L_o = 1.44 \cdot \text{in}$$

$$L_{\text{effective}} := L_o \cdot \Omega$$

$$L_{\text{effective}} = 2.29 \cdot \text{in}$$

Determine the combined axial and bending stress at the limit load P_{limit}

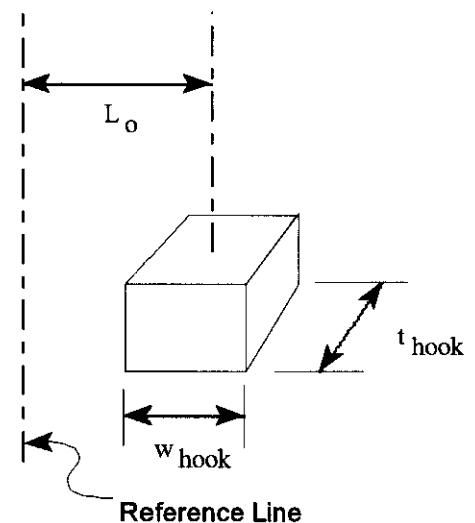
$$\sigma := P_{\text{limit}} \cdot \left(\frac{1}{A_{\text{hook}}} + \frac{L_{\text{effective}}}{S_{\text{hook}}} \right)$$

$$\sigma = 56314 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Adjust section (A) σ_{net} for (B)

$$\sigma_{\text{net}} := \sigma_{\text{limit}} - \frac{P_{\text{nom}}}{P_{\text{limit}}} \cdot \sigma$$

$$\sigma_{\text{net}} = 49017 \cdot \frac{\text{lbf}}{\text{in}^2}$$



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19.2.1 Interface and pinned system models

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 3000 lbf	3,100	-	6,300	5.75
	Fy = 27000 lbf	200	-	400	10.00
	Fz = 3000 lbf	-	28,500	-	1.72
	Mx = 7000 lbf-ft	-	126,500	-	0.39
	My = 13000 lbf-ft	-	453,000	-	0.11
	Mz = 13000 lbf-ft	25,300	-	51,600	0.70
Hook @ 120-deg.	Fx = 3000 lbf	1,500	24,700	3,000	1.70
	Fy = 27000 lbf	200	-	400	10.00
	Fz = 3000 lbf	2,600	14,300	5,200	2.29
	Mx = 7000 lbf-ft	11,400	63,300	23,300	0.52
	My = 13000 lbf-ft	-	453,000	-	0.11
	Mz = 13000 lbf-ft	12,200	203,500	24,900	0.21

where: $LF = \frac{\sigma_{net}}{\alpha \cdot Sd + Sby + Sbz}$

Note: The stresses are from appendix G and are the maximum stresses at location (B) on the hook, from the Jumper clamp system model data.

19.2.2 Pin released or allowed to rotate at hook/nut location

	Load	Sd (psi)	Sby (psi)	Sbz (psi)	LF
Hook @ 0-deg.	Fx = 3000 lbf	3,400	-	6,800	5.30
	Fy = 27000 lbf	200	-	400	10.00
	Fz = 3000 lbf	-	31,200	-	1.57
	Mx = 7000 lbf-ft	-	138,300	-	0.35
	My = 13000 lbf-ft	-	28,100	-	1.74
	Mz = 13000 lbf-ft	24,600	-	56,400	0.66
Hook @ 120-deg.	Fx = 3000 lbf	1,500	27,000	3,000	1.58
	Fy = 27000 lbf	200	-	400	10.00
	Fz = 3000 lbf	2,500	15,600	5,200	2.17
	Mx = 7000 lbf-ft	11,300	69,100	23,000	0.49
	My = 13000 lbf-ft	-	28,100	-	1.74
	Mz = 13000 lbf-ft	12,100	222,400	24,600	0.19

where: $LF = \frac{\sigma_{net}}{\alpha \cdot Sd + Sby + Sbz}$

Note: The stresses are from appendix G and are the maximum stresses at location (B) on the hook, from the Jumper clamp system model data.

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19.3 Section (C) of the Hook (for the Pin Hole)

Use the system model stresses with a k_c factor for the hook pin hole.

19.3.1 Interface and pinned system models

	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 3000 lbf	3,100	-	10.00
	Fy = 27000 lbf	200	-	10.00
	Fz = 3000 lbf	-	37,500	0.78
	Mx = 7000 lbf-ft	-	166,300	0.18
	My = 13000 lbf-ft	-	490,000	0.06
	Mz = 13000 lbf-ft	25,300	-	1.61
Hook @ 120-deg.	Fx = 3000 lbf	1,500	32,500	0.87
	Fy = 27000 lbf	200	-	10.00
	Fz = 3000 lbf	2,600	18,800	1.42
	Mx = 7000 lbf-ft	11,500	83,200	0.32
	My = 13000 lbf-ft	-	490,400	0.06
	Mz = 13000 lbf-ft	12,300	267,500	0.11

where:
$$LF = \frac{\sigma_{\text{limit}} - k_c \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}}{k_c \cdot (\alpha \cdot S_d + S_{by})}$$

Note: The stresses are from appendix G and are the maximum stresses at location (C) on the hook, from the Jumper clamp system model data.

$$k_c = \frac{2 \cdot 0.81}{2 \cdot 0.81 - 0.88} \quad k_c = 2.189$$

19.3.2 Pin released or allowed to rotate at hook/nut location

The moments in the hook of section (C) are admitted to the extent of the eccentricity $t_{\text{hook}}/2$ to the edge of the hook at the pin.

$$\sigma_{\text{limit}} = k_c \cdot \frac{(P_{\text{nom}} + LF \cdot S_d \cdot A_{\text{hook}}) \cdot \frac{t_{\text{hook}}}{2}}{S_{\text{hook}}} + k_c \cdot \left(\frac{P_{\text{nom}}}{A_{\text{hook}}} + LF \cdot S_d \right) \quad \sigma_{\text{limit}} = 69000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

where:
$$LF = \frac{\sigma_{\text{limit}} - k_c \cdot \frac{P_{\text{nom}} \cdot \frac{t_{\text{hook}}}{2}}{S_{\text{hook}}} - k_c \cdot \frac{P_{\text{nom}}}{A_{\text{hook}}}}{k_c \cdot S_d + k_c \cdot \left[\alpha \cdot S_d \cdot A_{\text{hook}} \cdot \frac{\frac{t_{\text{hook}}}{2}}{S_{\text{hook}}} \right]}$$

Note: The stresses are from appendix G and are the maximum stresses at location (C) on the hook, from the Jumper clamp system model data.

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	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 3000 lbf	3,400	-	3.30
	Fy = 27000 lbf	200	-	10.00
	Fz = 3000 lbf	-	-	10.00
	Mx = 7000 lbf-ft	-	-	10.00
	My = 13000 lbf-ft	-	-	10.00
	Mz = 13000 lbf-ft	27,600	-	0.41
Hook @ 120-deg.	Fx = 3000 lbf	1,700	-	6.61
	Fy = 27000 lbf	200	-	10.00
	Fz = 3000 lbf	2,900	-	3.87
	Mx = 7000 lbf-ft	12,900	-	0.87
	My = 13000 lbf-ft	-	-	10.00
	Mz = 13000 lbf-ft	13,800	-	0.81

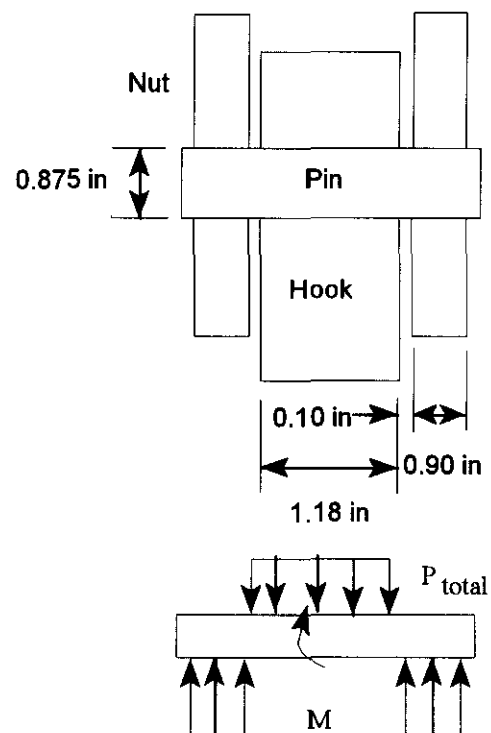
20.0 PIN ANALYSIS

Considerable latitude in pin allowables can be obtained with different assumptions for the bearing load distribution. The most common and conservative is the 4-point assumption is equivalent to a uniform bearing load (Shigley 1989). This is consistent with other assumptions used with the hook and nut.

20.1 Dimensions (WHC 1986b, 1991b, 1988)

$d_{pin} = 0.875 \text{ in}$	Pin diameter (H-2-32441)
$t_{nut} = 0.90 \text{ in}$	Operating nut thickness (H-2-68221)
$\Delta_{tol} = 0.10 \text{ in}$	tolerance between hook and operating nut (H-2-68221)
$t_{hook} = 1.18 \text{ in}$	hook thickness (H-2-90176)
$A_{pin} = \frac{\pi}{4} d_{pin}^2$	Area of pin $A_{pin} = 0.601 \text{ in}^2$
$S_{pin} = \frac{\pi d_{pin}^3}{32}$	Section modulus for pin $S_{pin} = 0.066 \text{ in}^3$

Figure C26. Sketch of Hook, Hook Pin, and Nut (four point axial bending loading)



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Pin-lug capacity estimates should consider the movement of hook and nut bearing forces toward one another thus reducing the lever arm causing bending moments in the pin. The method herein removes lug material away from the bearing areas until margins of the lugs and pin are nearly equal. A weakened lug system that increases the normally calculated pin strength is satisfactory as long as the lugs are as strong as the pin.

Derived Units: kip $\equiv$ 1000 · lbf ksi $\equiv$ 1000 · $\frac{\text{lbf}}{\text{in}^2}$

Drawings: Pin: H-2-32441 (WHC 1988)
Nut: H-2-68221 (WHC 1986b)
Hook: H-2-90176 (WHC1991b)

$$t_{10} := 0.90 \cdot \text{in} \quad t_{20} := 1.15 \cdot \text{in} \quad t_1 := t_{10} \quad t_2 := t_{20}$$
$$\begin{aligned} F_{tu} &:= S_{uA148} & F_{ty} &:= S_{yA148} \\ a &:= 3.75 \cdot \text{in} - 2.688 \cdot \text{in} & a &= 1.062 \cdot \text{in} \\ D &:= 0.876 \cdot \text{in} & W &:= 2.62 \cdot \text{in} \end{aligned}$$

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a. Tension across net section:

$$A_t := (W - D) \cdot t_1 \quad A_t = 1.57 \cdot \text{in}^2 \quad K_t := 0.94 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t \quad P'_{tu} = 132.788 \cdot \text{kip}$$

b. Shear tear-out

$$\frac{a}{D} = 1.212 \quad \frac{D}{t_1} = 0.973 \quad K_{br} := 1.12 \quad (\text{curve 1, Fig 204.4-3})$$

$$A_{br} := D \cdot t_1 \quad A_{br} = 0.788 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br} \quad P'_{bru} = 79.471 \cdot \text{kip}$$

c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 1.12 \quad C := 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 58.279 \cdot \text{kip}$$

204.44 Transverse curve. Use curve at 90 deg

 $f := .75$

(Fig. 204.4-5)

$$P'_{lug} := f \cdot P'_y \quad P'_{lug} = 43.709 \cdot \text{kip}$$

20.2.2 Hook

$$F_{tu} := S_u A_{747} \quad F_{ty} := S_y A_{747}$$

$$a := .81 \cdot \text{in}$$

$$D := 0.881 \cdot \text{in}$$

$$W := 1.92 \cdot \text{in}$$

$$\frac{W}{D} = 2.179$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_2 \quad A_t = 1.195 \cdot \text{in}^2 \quad K_t := 0.95 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t \quad P'_{tu} = 164.591 \cdot \text{kip}$$

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b. Shear tear-out

$$\frac{a}{D} = 0.919 \quad \frac{D}{t_2} = 0.766 \quad K_{br} := .73 \quad (\text{curve 1, Fig 204.4-3})$$

$$A_{br} := D \cdot t_2 \quad A_{br} = 1.013 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br} \quad P'_{bru} = 107.242 \cdot \text{kip}$$

c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 0.73 \quad C := 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 93.559 \cdot \text{kip} \quad P'_{hook} := P'_y$$

$$P'_{hook} = 93.559 \cdot \text{kip}$$

20.2.3 Operating Pin

204.45 Account for pin bending

$$F_{ty} := S_y A_{108} \quad F_{tu} := S_u A_{108}$$

$$g_p := .04 \cdot \text{in} \quad R := \frac{.874}{2} \cdot \text{in}$$

a. Pin capacity

$$b := .5 \cdot t_1 + g_p + 0.25 \cdot t_2 \quad b = 0.777 \cdot \text{in}$$

$$Z := \pi \cdot R^2 \cdot 0.4244 \cdot R \quad Z = 0.111 \cdot \text{in}^3$$

$$S := \frac{\pi}{4} \cdot R^3 \quad S = 0.066 \cdot \text{in}^3 \quad f_{shape} := \frac{Z}{S} \quad f_{shape} = 1.698$$

$$P'_{pin} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{pin} = 31.484 \cdot \text{kip}$$

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b. Peaking effect

$$r := \frac{a - \frac{D}{2}}{t_2} \quad r = 0.321 \quad K_{br} = 0.73 \quad (\text{min: } P'_{tu} \text{ or } P'_{bru})$$

$$\gamma := 0.60 \quad (\text{Fig. 204.4-8}) \quad b := 0.5 \cdot t_1 + g_p + \gamma \frac{t_2}{4} \quad b = 0.662 \cdot \text{in}$$

$$P'_{pin} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{pin} = 36.949 \cdot \text{kip}$$

c. Modify t1 and t2 to have nearly equal margins

$$P'_{nut} := 2 \cdot P'_{lug} \quad P'_{nut} = 87.418 \cdot \text{kip}$$

$$P'_{hook} = 93.559 \cdot \text{kip}$$

$$P'_{pin} = 36.949 \cdot \text{kip}$$

20.3 Estimate f₁ and f₂ factors to reduce t₁₀ and t₂₀ for nearly equal limits

Estimate f₁ and f₂ factors to reduce t₁₀ and t₂₀ for nearly equal limits. For a first cut, estimate the new pin limit by averaging the nut and hook limits and then forming the geometric mean with the old pin limit. Compare this with the old nut and hook limits for f₁ and f₂.

$$f_1 := 0.68 \quad f_2 := 0.64 \quad (\text{after iteration})$$

$$t_1 := f_1 \cdot t_{10} \quad t_2 := f_2 \cdot t_{20}$$

$$t_1 = 0.612 \cdot \text{in} \quad t_2 = 0.736 \cdot \text{in}$$

20.3.1 Nut: (symmetric)

$$F_{tu} := S_{uA148} \quad F_{ty} := S_{yA148}$$

$$a := 3.75 \cdot \text{in} - 2.688 \cdot \text{in} \quad a = 1.062 \cdot \text{in}$$

$$D := 0.876 \cdot \text{in} \quad W := 2.62 \cdot \text{in} \quad \frac{W}{D} = 2.991$$

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a. Tension across net section:

$$A_t := (W - D) \cdot t_1 \quad A_t = 1.067 \cdot \text{in}^2 \quad K_t := 0.94 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t \quad P'_{tu} = 90.296 \cdot \text{kip}$$

b. Shear tear-out

$$\frac{a}{D} = 1.212 \quad \frac{D}{t_1} = 1.431 \quad K_{br} := 1.12 \quad (\text{curve 1, Fig 204.4-3})$$

$$A_{br} := D \cdot t_1 \quad A_{br} = 0.536 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br} \quad P'_{bru} = 54.04 \cdot \text{kip}$$

c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 1.12 \quad C := 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 39.629 \cdot \text{kip}$$

204.44 Transverse curve. Use curve at 90 deg $f := .75$ (Fig. 204.4-5)

$$P'_{lug} := f \cdot P'_y \quad P'_{lug} = 29.722 \cdot \text{kip}$$

20.3.2 Hook

$$F_{tu} := S_{uA747} \quad F_{ty} := S_{yA747}$$

$$a := .81 \cdot \text{in}$$

$$D := 0.881 \cdot \text{in} \quad W := 1.92 \cdot \text{in} \quad \frac{W}{D} = 2.179$$

a. Tension across net section:

$$A_t := (W - D) \cdot t_2 \quad A_t = 0.765 \cdot \text{in}^2 \quad K_t := 0.96 \quad (\text{curve 1, Fig 204.4-2})$$

$$P'_{tu} := K_t \cdot F_{tu} \cdot A_t \quad P'_{tu} = 106.447 \cdot \text{kip}$$

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b. Shear tear-out

$$\frac{a}{D} = 0.919 \quad \frac{D}{t_2} = 1.197 \quad K_{br} = .73 \quad (\text{curve 1, Fig 204.4-3})$$

$$A_{br} := D \cdot t_2 \quad A_{br} = 0.648 \cdot \text{in}^2$$

$$P'_{bru} := K_{br} \cdot F_{tu} \cdot A_{br} \quad P'_{bru} = 68.635 \cdot \text{kip}$$

c. Lug yield. Use min of P'_{tu} , P'_{bru} .

$$P'_{umin} := P'_{bru} \quad \frac{P'_{umin}}{A_{br} \cdot F_{tu}} = 0.73 \quad C = 1.10 \quad (\text{Fig. 204.4-4})$$

$$P'_y := C \cdot \frac{F_{ty}}{F_{tu}} \cdot P'_{umin} \quad P'_y = 59.878 \cdot \text{kip} \quad P'_{hook} := P'_y$$

$$P'_{hook} = 59.878 \cdot \text{kip}$$

20.3.3 Operating Pin

204.45 Account for pin bending

$$F_{ty} := S_y A_{108} \quad F_{tu} := S_u A_{108}$$

$$g_p := .04 \cdot \text{in} \quad R := \frac{.874}{2} \cdot \text{in}$$

a. Pin capacity

$$b := .5 \cdot t_1 + g_p + 0.25 \cdot t_2 \quad b = 0.53 \cdot \text{in}$$

$$Z := \pi \cdot R^2 \cdot 0.4244 \cdot R \quad Z = 0.111 \cdot \text{in}^3$$

$$S := \frac{\pi}{4} \cdot R^3 \quad S = 0.066 \cdot \text{in}^3 \quad f_{\text{shape}} := \frac{Z}{S} \quad f_{\text{shape}} = 1.698$$

$$P'_{\text{pin}} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{\text{pin}} = 46.187 \cdot \text{kip}$$

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b. Peaking effect

$$r := \frac{a - \frac{D}{2}}{t_2} \quad r = 0.502 \quad K_{br} = 0.73 \quad (\text{min: } P'_{tu} \text{ or } P'_{bru})$$

$$\gamma := 0.37 \quad (\text{Fig. 204.4-8}) \quad b := 0.5 \cdot t_1 + g_p + \gamma \cdot \frac{t_2}{4} \quad b = 0.414 \cdot \text{in}$$

$$P'_{pin} := 2 \cdot Z \cdot \frac{F_{ty}}{b} \quad P'_{pin} = 59.116 \cdot \text{kip}$$

c. Check if t_1 and t_2 give nearly equal margins:

$$P'_{nut} := 2 \cdot P'_{lug} \quad P'_{nut} = 59.444 \cdot \text{kip}$$

$$P'_{hook} = 59.878 \cdot \text{kip}$$

$$P'_{pin} = 59.116 \cdot \text{kip}$$

20.4 Check shear

$$A_{pin} := \frac{\pi \cdot D^2}{4} \quad P'_{shr} := 0.6 \cdot F_{tu} \cdot A_{pin} \cdot 2 \quad P'_{shr} = 90.708 \cdot \text{kip}$$

Pin bending is treated as a yield type limit reflecting a shape factor of 1.70 which is applicable in plastic design. With the usual AISC safety factor of 1.67:

$$P_{b.all} := \frac{P'_{pin}}{1.67} \quad P_{b.all} = 35.399 \cdot \text{kip} \quad (\text{Use})$$

Shear safety factor of 2.5:

$$P_{s.all} := \frac{P'_{shr}}{2.5} \quad P_{s.all} = 36.283 \cdot \text{kip}$$

Therefore, Bending governs

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3/30/95**20.5 Calculated Limit Load**

$$P_{\text{limit}} := P_{b,\text{all}}$$

$$P_{\text{limit}} = 35399 \cdot \text{lbf}$$

which governs

20.6 Shear limit

$$\tau_{\text{limit}} := P_{s,\text{all}}$$

$$\tau_{\text{limit}} = 36283 \cdot \text{lbf}$$

Which does not govern

20.7 External Loads

$$P_{\text{net}} := P_{\text{limit}} - P_{\text{nom}}$$

$$P_{\text{net}} = 30886 \cdot \text{lbf}$$

$$\sigma_{\text{net}} := \frac{P_{\text{net}}}{P_{\text{limit}}} \cdot \sigma_{bA108}$$

$$\sigma_{\text{net}} = 71983 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Pin bending stress σ_{pm} caused by hook membrane stress σ_{hm}

$$\sigma_{\text{pm}}(\sigma_{\text{hm}}) := \frac{\sigma_{\text{hm}} \cdot A_{\text{hook}}}{P_{\text{limit}}} \cdot \sigma_{bA108}$$

$$\sigma_{\text{pm}} \left(1 \cdot \frac{\text{lbf}}{\text{in}^2} \right) = 4.73 \cdot \frac{\text{lbf}}{\text{in}^2}$$

 σ_{hm} gives a_{hm} **20.7.1 Determine the pin bending stress σ_{pb} caused by hook bending stress σ_{hb} .**

Use the distribution shown on half the pin (Fig. C28).

Figure C28. Sketch of pin loading from bending

$$M_{\text{hook}} := 1 \cdot \text{lbf} \cdot \text{in}$$

assumed hook moment equal to 1

$$P_1 := \frac{M_{\text{hook}}}{2 \cdot \frac{2}{3} \cdot \frac{t_{\text{hook}}}{2}}$$

$$P_1 = 1.271 \cdot \text{lbf}$$

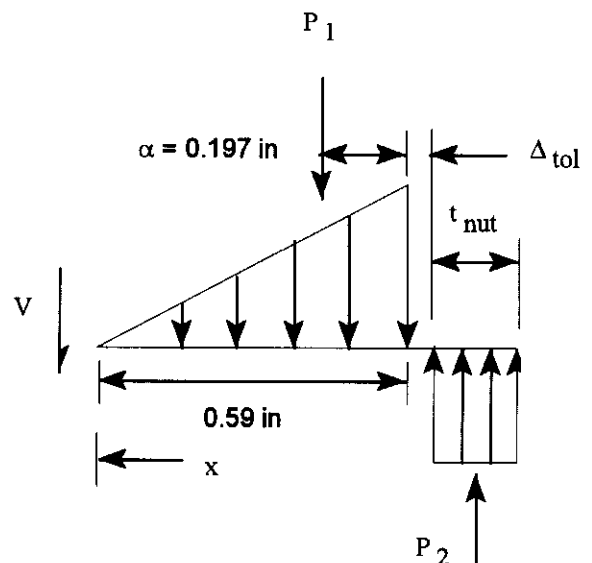
$$P_2 := \frac{M_{\text{hook}}}{2 \cdot \left(\frac{t_{\text{hook}}}{2} + \Delta_{\text{tol}} + \frac{t_{\text{nut}}}{2} \right)}$$

$$P_2 = 0.439 \cdot \text{lbf}$$

shear force

$$V := P_1 - P_2$$

$$V = 0.833 \cdot \text{lbf}$$



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The maximum displacement is determined as the following

$$M_h(x) := V \cdot x - P_1 \cdot \frac{t_{\text{hook}}}{6} \cdot \left[\frac{x}{\left(\frac{t_{\text{hook}}}{2} \right)} \right]^3$$

Taking the derivate of both sides of the equation, to determine the maximum displacement, the equation simplifies to

$$x_{\text{max}} := \sqrt{\frac{V}{P_1 \cdot 4 \cdot \frac{t_{\text{hook}}^2}{2}}} \quad x_{\text{max}} = 0.477 \cdot \text{in}$$

Therefore, the maximum moment in the pin is

$$M_{\text{max}} := V \cdot x_{\text{max}} - P_1 \cdot \frac{t_{\text{hook}}}{6} \cdot \left[\frac{x_{\text{max}}}{\left(\frac{t_{\text{hook}}}{2} \right)} \right]^3 \quad \text{maximum moment in pin} \quad M_{\text{max}} = 0.265 \cdot \text{lb} \cdot \text{in}$$

20.8 Interface and Pinned system model

The pin bending stress σ_{pb} is a function of the hook bending stress σ_{hb} $Z_{\text{pin}} := 1.7 \cdot S_{\text{pin}}$

$$\sigma_{pb}(\sigma_{hb}) := \frac{M_{\text{max}} \cdot \sigma_{hb} \cdot S_{\text{hook}}}{M_{\text{hook}} \cdot Z_{\text{pin}}} \quad \sigma_{pb} \left(1 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2} \right) = 1.379 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2} \cdot \sigma_{hb} \quad \text{gives a hbt}$$

Add σ_{pb} and σ_{pm} directly using the hook stresses at the nut and compare with σ_{net} $\sigma_{\text{net}} = 71983 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2}$

	Load	Sd (psi)	Sby (psi)	LF	
Hook @ 0-deg.	Fx = 3000 lbf	3,100	-	6.82	where: $LF = \frac{\sigma_{\text{net}}}{a_{\text{hm}} \cdot \sigma_{\text{Sd}} + a_{\text{hbt}} \cdot \sigma_{\text{Sby}}}$
	Fy = 27000 lbf	200	-	10.00	
	Fz = 3000 lbf	-	37,500	1.39	
	Mx = 7000 lbf-ft	-	166,300	0.31	
	My = 13000 lbf-ft	-	490,000	0.11	
	Mz = 13000 lbf-ft	25,300	-	0.84	
Hook @ 120-deg.	Fx = 3000 lbf	1,500	32,500	1.44	
	Fy = 27000 lbf	200	-	10.00	
	Fz = 3000 lbf	2,600	18,800	2.07	
	Mx = 7000 lbf-ft	11,500	83,200	0.47	
	My = 13000 lbf-ft	-	490,400	0.11	
	Mz = 13000 lbf-ft	12,300	267,500	0.18	

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20.9 Pin Released or Pin allowed to rotate @ hook/nut location

The hook moments are admitted to this extent of the eccentricity to the edge of the hook ($t_{hook}/2$) at the pin.

The pin bending stress σ_{pb} is a function of the hook membrane stress σ_{hm}

$$\sigma_{pb} = \frac{M_{max} \cdot (\sigma_{hm} \cdot A_{hook} + P_{nom}) \cdot \frac{t_{hook}}{2}}{M_{hook} \cdot S_{pin}} = \frac{M_{max} \cdot A_{hook} \cdot \frac{t_{hook}}{2}}{M_{hook} \cdot S_{pin}} \left(\sigma_{hm} + \frac{P_{nom}}{A_{hook}} \right)$$

$$\frac{M_{max} \cdot A_{hook} \cdot \frac{t_{hook}}{2}}{M_{hook} \cdot Z_{pin}} = 2.839 \quad \text{gives } a_{hbr}$$

$$\sigma_{net} = LF \cdot \left(a_{hm} \cdot \sigma_{hm} + a_{hbr} \cdot \frac{P_{nom}}{A_{hook}} \right) + a_{hbr} \cdot \frac{P_{nom}}{A_{hook}}$$

$$\text{where: } LF = \frac{\sigma_{net} - a_{hbr} \cdot \frac{P_{nom}}{A_{hook}}}{(a_{hm} + a_{hbr}) \cdot \sigma_{hm}}$$

and σ_{hm} and σ_{hb} are defined as S_d and S_{by} in the table below.

	Load	Sd (psi)	Sby (psi)	LF
Hook @ 0-deg.	Fx = 3000 lbf	3,400	-	3.58
	Fy = 27000 lbf	200	-	10.00
	Fz = 3000 lbf	-	-	10.00
	Mx = 7000 lbf-ft	-	-	10.00
	My = 13000 lbf-ft	-	-	10.00
	Mz = 13000 lbf-ft	27,600	-	0.44
Hook @ 120-deg.	Fx = 3000 lbf	1,700	-	7.17
	Fy = 27000 lbf	200	-	10.00
	Fz = 3000 lbf	2,900	-	4.20
	Mx = 7000 lbf-ft	12,900	-	0.94
	My = 13000 lbf-ft	-	-	10.00
	Mz = 13000 lbf-ft	13,800	-	0.88

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner *EW*Date 3/29/95Checker J. L. Julyk *JLJ*Date 3/30/95**21.0 OPERATING NUT**

The nut is quite strong compared to the pin. Consider a 60,000 lbf axial loading with three hooks, which is more than the pins can take. We will demonstrate that the nut is stronger than the pins, so that the piping load limitations are derived from the pins analysis that was discussed in section 20.

$$d_{\text{hole}} := 0.875 \text{ in}$$

diameter of nut hole @ pin location
(WHC 1986b, H-2-68221)

$$L_{\text{nut}} := 2.62 \text{ in}$$

length of nut (WHC 1986b)

$$P_{\text{axial}} := 60000 \text{ lbf}$$

assumed axial loading on operating nut
(applied to three hooks)

$$t_{\text{nut}} = 0.9 \text{ in}$$

thickness of nut
(WHC 1986b)

21.1 Bearing stress @ 60,000 lbf for 3 hooks

$$\sigma_{\text{brg}} := \frac{\frac{2}{3} \cdot P_{\text{axial}}}{d_{\text{hole}} \cdot t_{\text{nut}}}$$

$$\sigma_{\text{brg}} = 50794 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{\text{brA148}} = 108000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{O.K.}$$

$$\text{The edge distance/diameter is } \frac{L_{\text{nut}}}{2 \cdot (d_{\text{hole}})} = 1.497 \quad \text{O.K.}$$

21.2 Bending stress (one ear)

$$\sigma_b(M_{\text{nut}}, S_{\text{nut}}) := \frac{M_{\text{nut}}}{S_{\text{nut}}}$$

Moment on one ear of operating nut

$$M_{\text{nut}} := \frac{P_{\text{axial}}}{6} \cdot (2.69 \text{ in} - 1.75 \text{ in})$$

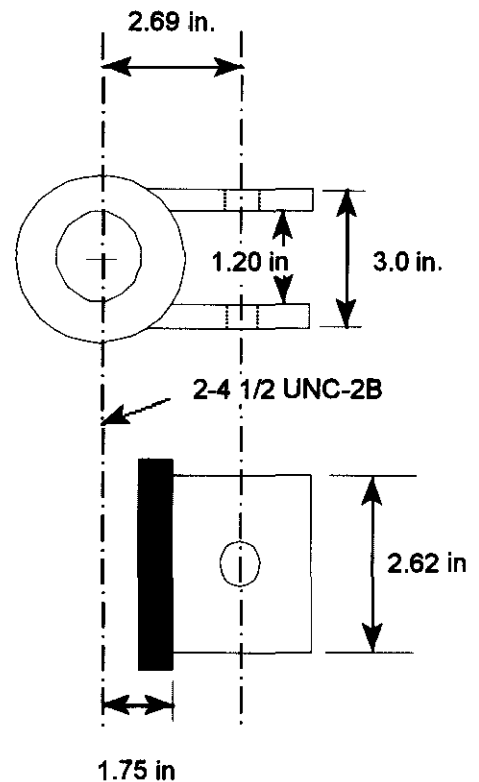
$$M_{\text{nut}} = 9400 \cdot \text{lbf} \cdot \text{in}$$

Section modulus on operating nut

$$S_{\text{nut}} := \frac{1}{6} \cdot (t_{\text{nut}} \cdot L_{\text{nut}}^2) \quad S_{\text{nut}} = 1.03 \cdot \text{in}^3$$

$$\sigma_b(M_{\text{nut}}, S_{\text{nut}}) = 9129 \cdot \frac{\text{lbf}}{\text{in}^2} < \sigma_{\text{bA148}} = 45000 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{Therefore, O.K.}$$

Figure C29. Sketch of 4-in. Operating Nut
(WHC 1986b, H-2-68209)



Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 3/29/95Checker J. L. JulykDate 3/30/95**21.2.1 Ring Stress**

$$\sigma_{\text{ring}}(M_{\text{tot}}, R, C, S) := \frac{M_{\text{tot}} \cdot R}{C(R) \cdot S}$$

where

$$b := 1.75 \cdot \text{in} - \frac{2.0 \cdot \text{in}}{2}$$

$$b = 0.75 \cdot \text{in}$$

$$C(R) := 2 \cdot \pi \cdot R$$

$$S := b \cdot \frac{L_{\text{nut}}^2}{6}$$

$$S = 0.858 \cdot \text{in}^3$$

$$M_{\text{tot}} := P_{\text{axial}} \left(2.69 \cdot \text{in} - 1.75 \cdot \text{in} + \frac{b}{2} \right)$$

$$M_{\text{tot}} = 78900 \cdot \text{lbf} \cdot \text{in}$$

moment applied to nut ring

Bending ring stress

$$\sigma_{\text{ring}}(M_{\text{tot}}, R, C, S) = 14635 \cdot \frac{\text{lbf}}{\text{in}^2}$$

<

$$\sigma_{\text{bA148}} = 45000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Therefore, O.K.

21.3 Shear stress (one ear)

$$\tau := \frac{P_{\text{preload}}}{t_{\text{nut}} \cdot L_{\text{nut}}}$$

$$\tau = 848 \cdot \frac{\text{lbf}}{\text{in}^2}$$

<

$$\sigma_{\text{vA148}} = 24000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

O.K.

22.0 OPERATING SCREW

$$d_{\text{min}} := 1.72 \cdot \text{in}$$

Minimum thread diameter of screw
(WHC 1988, H-2-32441)Figure C30. Sketch of 4-in. Operating Screw
(WHC 1988, H-2-32441)

$$A_{\text{screw}} := \frac{\pi}{4} \cdot d_{\text{min}}^2$$

Area of screw

$$A_{\text{screw}} = 2.324 \cdot \text{in}^2$$

2 - 4 1/2 UNC-2B

Calculation of membrane stress in screw

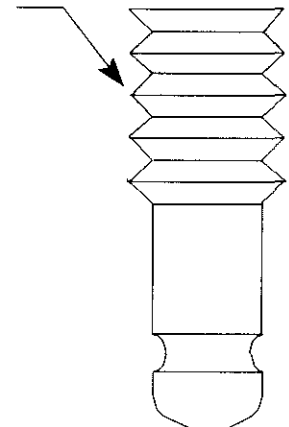
$$\sigma_m := \frac{P_{\text{thermal}} + P_{\text{pressure}} + P_{\text{preload}}}{A_{\text{screw}}}$$

$$\sigma_m = 5826 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Calculation of bending stress in screw

$$\sigma_b := \sigma_{\text{bA193}} - \sigma_m$$

$$\sigma_b = 57174 \cdot \frac{\text{lbf}}{\text{in}^2}$$



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22.1 Determination of adjustment factor used for screw bending

System model output for screw bending stresses at the nut are based on a lever arm from the top of the block of the midheight location in the nut. In the no-slip screw-block model, the lever arm should be taken from the block top to the base of the nut. In the interface element model, the lever arm should be taken from center of the sphere defining the screw bearing surface to the lower edge of the nut.

$$h_{pin} := (11.73 - 7.14 + 0.25) \cdot \text{in}$$

$$d_{scr} := 1.70 \cdot \text{in}$$

screw diameter (WHC 1988)

$$h_{pin} = 4.84 \cdot \text{in} \quad \text{block-top to mid-nut height}$$

$$W_{lug} := 2.62 \cdot \text{in} \quad \text{nut length (WHC 1986b)}$$

$$S_{scr} := \frac{\pi}{32} \cdot d_{scr}^3$$

screw section modulus

$$R_{cap} := 1.94 \cdot \text{in} \quad \text{screw bearing radius (WHC 1988)}$$

$$S_{scr} = 0.482 \cdot \text{in}^3$$

In the no-slip model, the end bending load contribution from $W_{lug}/2$ was subtracted.

$$S_{by} = S_{bANSYS} - \frac{W_{lug}}{2} \cdot \frac{F_{yANSYS}}{S_{pin}}$$

Note: that S_{bANSYS} and F_{yANSYS} , @ the nut end, should have the same sign.

In the interface model, the ANSYS bending stress output is multiplied by an adjustment factor, β_{iface} . These adjustments should be applied before entering the data in the table below.

$$\beta_{iface} := 1 - \frac{W_{lug} + 2 \cdot R_{cap}}{2 \cdot h_{pin}}$$

$$\beta_{iface} = 0.329 \quad (\text{interface model})$$

22.2 Interface and Pinned system model

Load	Sd (psi)	Sby (psi)	LF
Fx = 3000 lbf	-	21,300	2.54
Fy = 27000 lbf	300	-	10.00
Fz = 3000 lbf	-	21,300	2.54
Mx = 7000 lbf-ft	-	94,600	0.57
My = 13000 lbf-ft	-	-	10.00
Mz = 13000 lbf-ft	-	175,600	0.31

Where: $LF = \frac{\sigma_b}{S_d + S_{by}}$

Note: That the high bending stresses are from the pin model (screw pinned to block) and they might not be supported by friction forces at the block top. The interface element model shows less than half these moments

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 5/29/95Checker J. L. JulykDate 3/30/95**22.3 Pin Released or Pin allowed to rotate @ hook/nut location**

Load	Sd (psi)	Sby (psi)	LF
Fx = 3000 lbf	-	39,000	1.39
Fy = 27000 lbf	300	-	10.00
Fz = 3000 lbf	-	39,000	1.39
Mx = 7000 lbf-ft	-	173,000	0.31
My = 13000 lbf-ft	-	-	10.00
Mz = 13000 lbf-ft	-	322,000	0.17

Where: $LF = \frac{\sigma_b}{S_d + S_{by}}$

Figure C31. Sketch of 4-in. Screw/Block interaction @ top of block
(WHC 1994c, H-2-821326, and WHC 1988, H-2-32441)**23.0 TOP OF BLOCK**

The top of the block was evaluated in appendix B.
The assumed axial load is from appendix B.

$F := 34013 \cdot \text{lbf}$ Assumed axial load obtained from appendix B

$P_m := 13270 \cdot \frac{\text{lbf}}{\text{in}^2}$ membrane stresses from appendix B, @ assumed axial load

Calculation of the limit load

$$F_{\text{limit}} := F \cdot \frac{S_{mA276}}{P_m} \quad F_{\text{limit}} = 51263 \cdot \text{lbf}$$

To obtain a lateral load criterion, compare this with a shear plug using the diameter of the screw

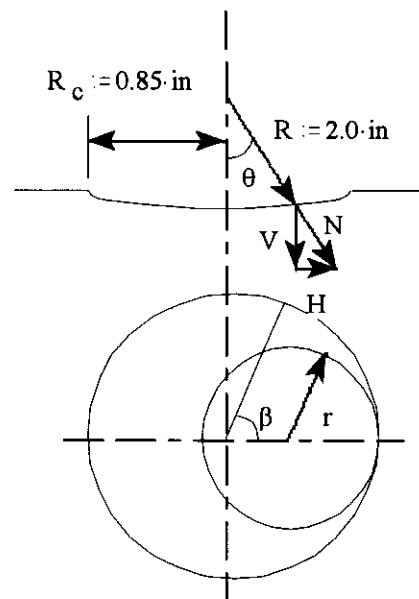
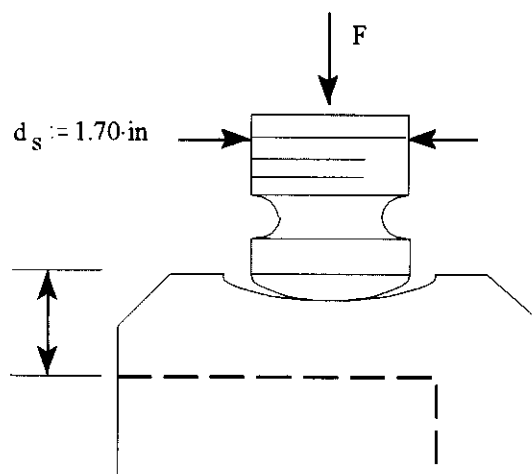
$$P_{\text{limit}} := \pi \cdot d_s \cdot t \cdot \sigma_{vA276} \quad P_{\text{limit}} = 51591 \cdot \text{lbf}$$

Use the shear plug concept with a factor

$$f_p := \frac{F_{\text{limit}}}{P_{\text{limit}}} \quad f_p = 0.994$$

with lateral loading H

$$V := P_{\text{thermal}} + P_{\text{preload}} \quad V = 13109 \cdot \text{lbf}$$



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N is carried over circle with radius r.

$$\tan(\theta) = \frac{H}{V} \quad (\text{no friction})$$

$$\cos(\beta) = \frac{R \cdot \tan(\theta)}{R_c} = \frac{R \cdot H}{R_c \cdot V}$$

$$r = R_c \cdot (1 - \cos(\beta)) = R_c \cdot \left(1 - \frac{R \cdot H}{R_c \cdot V}\right)$$

$$P_{\text{limit}}(r) := 2 \cdot \pi \cdot r \cdot t \cdot \sigma_{\text{vA276}} \cdot f_p$$

$$N(r) := P_{\text{limit}}(r)$$

$$H(r) := V \cdot \frac{R_c}{R} \cdot \left(1 - \frac{N(r)}{P_{\text{limit}}(R_c)}\right)$$

Estimate $r := 0.20 \text{ in}$

Therefore, $N(r) = 12062 \cdot \text{lbf}$ and $H(r) = 4260 \cdot \text{lbf}$

Check that vector sum (V + H) is less than N

$$\sqrt{V^2 + H(r)^2} = 13784 \cdot \text{lbf} \quad \text{YES (O.K.)}$$

Using a minimum coefficient of friction of $\mu := 0.1$

$$\Delta H := \mu \cdot V \quad \Delta H = 1.311 \cdot 10^3 \cdot \text{lbf}$$

$$H_{\text{limit}}(r) := H(r) + \Delta H \quad H_{\text{limit}}(r) = 5571 \cdot \text{lbf}$$

V is limited by F_{limit} less the existing V.

The load fraction is the minimum of: $LF(r) = \frac{H_{\text{limit}}(r)}{H}$ or $LF = \frac{F_{\text{limit}} - V}{\Delta V}$

since H and ΔV do not occur together. As data, they are found at the base of the screw element in the system models

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23.1 Interface and Pinned system model

Load	ΔV (lbf)	H (lbf)	LF
$F_x = 3000$ lbf	-	2,700	2.06
$F_y = 27000$ lbf	700	-	10.00
$F_z = 3000$ lbf	-	2,700	2.06
$M_x = 7000$ lbf-ft	-	12,000	0.46
$M_y = 13000$ lbf-ft	-	-	10.00
$M_z = 13000$ lbf-ft	-	22,200	0.25

where: $LF = \frac{H_{limit}}{\Delta V + H}$ is conservative

23.2 Pin Released or Pin allowed to rotate @ hook/nut location

Load	ΔV (lbf)	H (lbf)	LF
$F_x = 3000$ lbf	-	5,600	0.99
$F_y = 27000$ lbf	700	-	10.00
$F_z = 3000$ lbf	-	5,600	0.99
$M_x = 7000$ lbf-ft	-	24,900	0.22
$M_y = 13000$ lbf-ft	-	-	10.00
$M_z = 13000$ lbf-ft	-	46,200	0.12

where: $LF = \frac{H_{limit}}{\Delta V + H}$ is conservative

24.0 GUIDE-BLOCK INTERFACE

Height of block lip
(WHC 1994c, H-2-821326)

$$h_B := 0.06 \cdot \text{in}$$

outside diameter for block lip
(WHC 1994c, H-2-821326)

$$d_{Bo} := 4.62 \cdot \text{in}$$

inside diameter for block lip
(WHC 1994c, H-2-821326)

$$d_{Bi} := 3.38 \cdot \text{in}$$

24.1 Block Lip

24.1.1 Allowable Shear Force

$$A_{vBL} := 0.62 \cdot \text{in} \cdot d_{Bi}$$

$$A_{vBL} = 2.096 \cdot \text{in}^2$$

Shear area

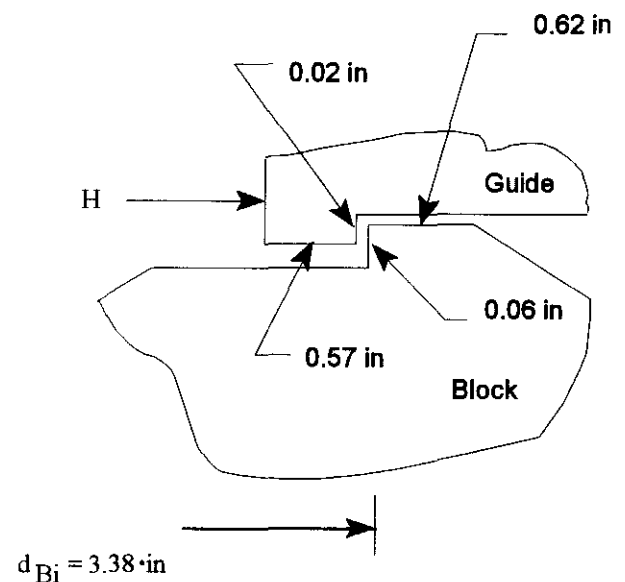
$$H_{vBL} := \sigma_{vA276} \cdot A_{vBL}$$

$$H_{vBL} = 25147 \cdot \text{lbf}$$

Shear limit at top of lip

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Figure C32. Sketch of Guide and Top of Block Lip



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$$A_{bBL} := 0.02 \cdot \text{in} \cdot d_{Bi}$$

$$A_{bBL} = 0.068 \cdot \text{in}^2$$

Bearing area

$$H_{bBL} := \sigma_{brA276} \cdot A_{bBL}$$

$$H_{bBL} = 3042 \cdot \text{lbf}$$

Bearing limit at top lip

24.2 Guide Lip

$$h_G := 0.02 \cdot \text{in}$$

Height of guide lip (WHC 1986d, H-2-68207)

$$d_{Go} := 3.38 \cdot \text{in}$$

outside diameter for hook guide lip (WHC 1986d, H-2-68207)

$$d_{Gi} := 2.24 \cdot \text{in}$$

inside diameter for hook guide lip (WHC 1986d, H-2-68207)

24.2.1 Allowable Shear Force

$$A_{vGL} := 0.57 \cdot \text{in} \cdot d_{Go}$$

$$A_{vGL} = 1.927 \cdot \text{in}^2$$

Shear area

$$H_{vGL} := \sigma_{vA743} \cdot A_{vGL}$$

$$H_{vGL} = 33715 \cdot \text{lbf}$$

Shear limit at top of lip

24.2.2 Allowable Bearing Force

$$A_{bGL} := 0.02 \cdot \text{in} \cdot d_{Go}$$

$$A_{bGL} = 0.068 \cdot \text{in}^2$$

Bearing area

$$H_{bGL} := \sigma_{brA743} \cdot A_{bGL}$$

$$H_{bGL} = 5678 \cdot \text{lbf}$$

Bearing limit at top lip

24.2.3 Determine the allowable for bearing and shear that the block and guide lip can accomdate

$$H_{allBL} := \text{if}(H_{vBL} < H_{bBL}, H_{vBL}, H_{bBL})$$

$$H_{allBL} = 3042 \cdot \text{lbf}$$

$$H_{allGL} := \text{if}(H_{vGL} < H_{bGL}, H_{vGL}, H_{bGL})$$

$$H_{allGL} = 5678 \cdot \text{lbf}$$

$$H_{allow} := \text{if}(H_{allBL} < H_{allGL}, H_{allBL}, H_{allGL})$$

$$H_{allow} = 3042 \cdot \text{lbf}$$

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 3/29/95Checker J. L. JulykDate 3/30/95**24.2.4 Interface and Pinned system model results**

Load	H (lbf)	LF
F _x = 3000 lbf	4,000	0.76
F _y = 27000 lbf	-	10.00
F _z = 3000 lbf	4,000	0.76
M _x = 7000 lbf-ft	17,800	0.17
M _y = 13000 lbf-ft	-	10.00
M _z = 13000 lbf-ft	33,100	0.09

where: $LF = \frac{H_{allow}}{H}$

24.2.5 Pin Released or Pin allowed to rotate @ hook/nut location

Load	H (lbf)	LF
F _x = 3000 lbf	7,600	0.40
F _y = 27000 lbf	-	10.00
F _z = 3000 lbf	7,600	0.40
M _x = 7000 lbf-ft	33,700	0.09
M _y = 13000 lbf-ft	-	10.00
M _z = 13000 lbf-ft	62,500	0.05

where: $LF = \frac{H_{allow}}{H}$

24.3 Check for Lift-OutConsider that $f = 0$, no friction

$$\frac{H}{V} = \tan(\theta) = \frac{0.02 \cdot \text{in}}{0.57 \cdot \text{in}}$$

If the skirt-bolt-guide system has sufficient stiffness to provide V for $\delta = 0.02$ in. deflection, lift-out can not occur

$$\delta := 0.02 \cdot \text{in}$$

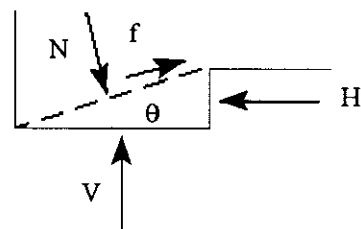
$$H_{lift} = \frac{0.02 \cdot \text{in}}{0.57 \cdot \text{in}} \cdot V \quad V = k_{sbg} \cdot \delta$$

24.3.1 Bolt Stiffness (WHC 1991d, H-2-3808)

$N_{bolts} := 6$ Number of bolts, at least 2 participate directly

$d_{bolt} := 0.625 \cdot \text{in}$ diameter of bolts

Figure C33. Sketch of guide lift-off from top of block



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Originator E. O. Weiner *EOW*

Date 3/29/95

Checker J. L. Julyk *JLJ*

Date 3/30/95

$l_{\text{bolt}} := 6.7 \cdot \text{in}$ length of bolts

$E_{\text{bolt}} := 28 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$ modulus of elastic for bolts

$A_{\text{bolt}} := \frac{\pi}{4} \cdot d_{\text{bolt}}^2$ cross-sectional area of bolt $A_{\text{bolt}} = 0.307 \cdot \text{in}^2$

$k_{\text{bolt}} := 2 \cdot E_{\text{bolt}} \cdot \frac{A_{\text{bolt}}}{l_{\text{bolt}}}$ stiffness of bolts $k_{\text{bolt}} = 2564266 \cdot \frac{\text{lbf}}{\text{in}}$

24.3.2 Guide Stiffness for 2 cantilevers (WHC 1986d, H-2-68207)

$b_{\text{guide}} := 1.23 \cdot \text{in}$ width of guide

$h_{\text{guide}} := 1.25 \cdot \text{in}$ height of guide

$l_{\text{guide}} := 1.56 \cdot \text{in}$ length of guide or span

$E_{\text{guide}} := 28 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$ modulus of elasticity for guide

$I_{\text{guide}} := \frac{2 \cdot b_{\text{guide}} \cdot h_{\text{guide}}^3}{12}$ moment of inertia for guide $I_{\text{guide}} = 0.4 \cdot \text{in}^4$

$k_{\text{guide}} := \frac{3 \cdot E_{\text{guide}} \cdot I_{\text{guide}}}{l_{\text{guide}}^3}$ stiffness of guide $k_{\text{guide}} = 8859096 \cdot \frac{\text{lbf}}{\text{in}}$

Therefore let, $k_{\text{sbg}} := k_{\text{bolt}}$

$H_{\text{limit}} := \frac{0.02 \cdot \text{in}}{0.57 \cdot \text{in}} \cdot k_{\text{bolt}} \cdot \delta$ $H_{\text{limit}} = 1799 \cdot \text{lbf}$

Therefore, the block controls with the H_{bearing} limit.

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. WeinerDate 3/29/95Checker J. L. JulykDate 3/30/95**25.0 Block-Nozzle Moment Transfer ISB jumper**

From Roger Evanson, for 304/304 metal to metal contact, the coefficient of friction can range from 0.2 to 0.7. Assuming a coefficient of friction of 0.40 the frictional force under a normal pre-load torque force (2000 lbf) is determined (Squier 1993).

$\mu := 0.40$ coefficient of friction for 304/304 metal to metal contact

Figure C34. Sketch of Block-Nozzle Moment Transfer

$P := 2000 \cdot \text{lbf}$ Pre-load for a 50 ft-lbf torque screw load

$N := \sqrt{2} \cdot P$ Normal force acting of surface
 $N = 2828 \cdot \text{lbf}$

$F := \mu \cdot N$ friction force
 $F = 1131 \cdot \text{lbf}$

The Breakaway friction for a bending moment and torsional load under a pre-load of F_i are calculated below

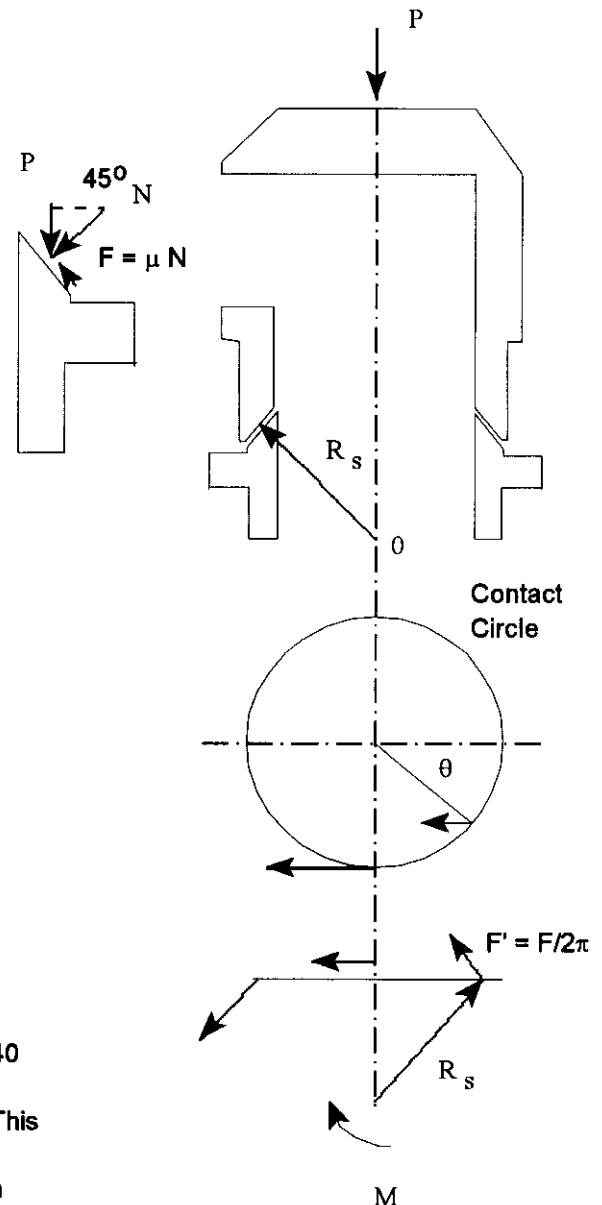
$R_s := 3.34 \cdot \text{in}$ Radius of Block/Nozzle cone (H-2-821326)

$c := 2 \cdot \pi$ contact circle

$$M := \frac{F \cdot R_s}{2 \cdot \pi} \int_0^c \sqrt{\frac{\cos(\theta) \cdot \cos(\theta)}{2} + \frac{1}{2}} d\theta$$

$M = 271 \cdot \text{ft} \cdot \text{lbf}$ for a 50 ft-lbf torque screw load

Therefore, based on the assumed coefficient of friction of 0.40 the block/nozzle allowable moment that the friction could withstand for pre-load screw torque of 50 ft-lbf is 271 ft-lbf. This is compared to the external moments of 7000, 13000, and 13000 ft-lbf in the x, y, and z-directions, respectively. Since a 50 ft-lbf torque is plausible, and the friction coefficient may be smaller, it is recommended that friction be ignored in the analysis.



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Nozzle Stress Interaction

App C uses the worst of the three hook loads to obtain a load fraction for the nozzle. The different hooks need to be considered for load combinations.

At the condition (GI NS PR) that gave M_x and M_z load fractions (2" connector, App G)

Load	$\Delta F_0, \text{lb}_f$	$\Delta F_1, \text{lb}_f$	
Time 4: M_x	0	-8882	$LF = \frac{P_{net}}{\Delta F}$ $P_{net} = 2286 \text{ \#}$
Time 6: M_z	-8205	4103	

App C results (no interaction, see Section 2.2.2)

$$LF_{xG} = \frac{2286}{8882} = 0.257 \quad LF_{zG} = \frac{2286}{8205} = 0.279$$

Let LF_x and LF_z be fractions of M_x & M_z used together. The interaction curve is given by considering both hooks with both M_x and M_y loads:

$$\text{Hook 1: } 1 = LF_1 = \frac{P_{lim}}{8882 LF_x + 4103 LF_z} = \frac{P_{lim}}{\Delta F}$$

$$\text{solve: } \frac{LF_x}{0.262} + \frac{LF_z}{2 \times 0.284} = 1 \quad (\text{straight line})$$

$$\text{Hook 0: } 1 = LF_0 = \frac{P_{lim}}{8205 LF_z}$$

$$\frac{LF_z}{0.284} = 1$$

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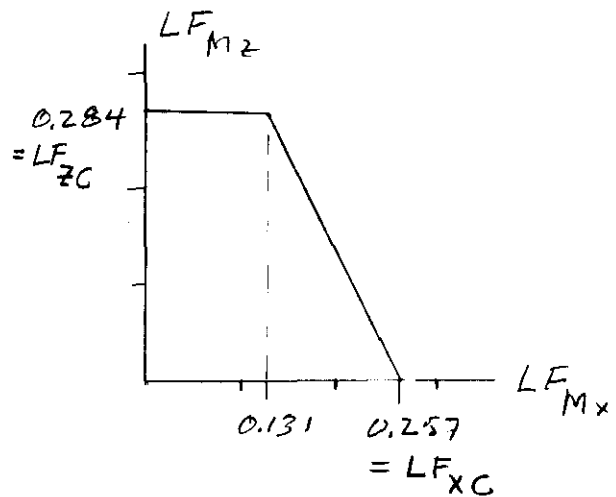
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M_z is the moment that loads all three hooks. M_x loads only the 1 & 2 hooks. Obtain the interaction by extending the LF_{zC} value flat for half the LF_{xC} value, and then connect straight to $(LF_{xC}, 0)$.



The xz pattern is reversed for shear forces, because F_x is like M_z in its ability to produce moments about the nozzle pivot point

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Hook Stress Interaction

Combination of M_x and M_z loadings at Hk C1

Condition: 6E IS PT Size: 2" see App G

Loading	S_d psi	S_{by} psi	S_{b-y} psi	Hk
M_x	9025	-78400	78400	Hk 1
M_z	-4169	-108660	108660	
M_x	-9025	-78400	78400	Hk 2
M_z	-4169	108660	-108660	

S_d = direct stress

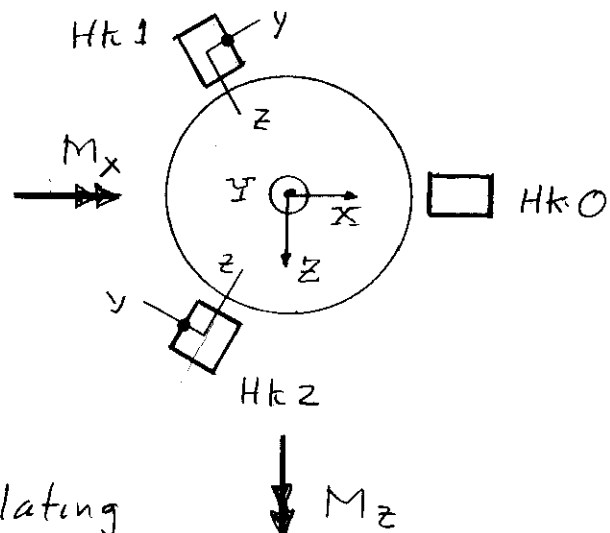
S_{by} = bending stress
at pos. y-axis
point on hook (•)

S_{b-y} = bending stress at
opposite side

Check Hk 2 signs by
envisioning nut (above
 M_x , M_z location) translating
and rotating per M_x and M_z .

Nut does not rotate as much as the block

Use S_d and S_{b-y} for Hk 1 as worst comb.
See MathCAD work below



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Interaction testing

Test components in order of severity. See Table 5.3 for load fractions. Using Appendix G, combine results of individual load components scaled by the maximum acceptable LF load fractions in the table for the structural component in question. The scale factors (s_x , s_y , etc) should be reduced by the factor $I=0.7071$ when two components are being considered for circular interaction. The result of the combined loadings is then evaluated by the appropriate load fraction formulas in Appendix C. Circular interaction is demonstrated if the resulting load fraction is unity or more. Contact conditions for each loading component must be the same. Cross conditions are considered when the two individual loading components produce their worst load fractions in Appendix C with different contact conditions.

Test GdBI, PR (pin moment release) for F_x , F_z circular. See Section 8.0 for notation

Scale App G: GA SL condition:

$$I := 0.7071 \quad s_x := 2.823 \cdot I \quad s_x = 1.996 \quad s_z := 1.119 \cdot I \quad s_z = 0.791$$

$$H_x := 909 \quad H_z := 2271 \quad \text{App G}$$

$$H := \sqrt{(s_x \cdot H_x)^2 + (s_z \cdot H_z)^2} \quad H = 2.554 \cdot 10^3$$

$$\text{App C, Section 8.2: } LF := \frac{2541}{H} \quad LF = 0.995 \quad \text{OK}$$

Test GdBI, PR (pin moment release) for M_x , M_z circular

Scale App G: GA SL condition

$$I := 0.7071 \quad s_x := 0.155 \cdot I \quad s_x = 0.11 \quad s_z := 0.194 \cdot I \quad s_z = 0.137$$

$$H_x := 16360 \quad H_z := 13088 \quad \text{App G}$$

$$H := \sqrt{(s_x \cdot H_x)^2 + (s_z \cdot H_z)^2} \quad H = 2.537 \cdot 10^3$$

$$\text{App C, Section 8.2: } LF := \frac{2541}{H} \quad LF = 1.001 \quad \text{OK}$$

Test HkC1 PT (pin moments transmitted) for F_x , F_z circular. See Section 3.3 for notation.

Scale App G: GI SL condition (note 2/3/95 App C HkC entries need correction)

$$I := 0.7071 \quad s_x := 3.879 \cdot I \quad s_x = 2.743 \quad s_z := 2.503 \cdot I \quad s_z = 1.77$$

$$S_{d,x} := 289 \quad S_{d,z} := 1253 \quad \text{App G}$$

$$S_d := s_x \cdot S_{d,x} + s_z \cdot S_{d,z} \quad S_d = 3.01 \cdot 10^3$$

$$S_{b,x} := 7543 \quad S_{b,z} := 10888 \quad \text{App G}$$

$$S_b := s_x \cdot S_{b,x} + s_z \cdot S_{b,z} \quad S_b = 3.996 \cdot 10^4$$

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App C, Section 3.3.1:

$$LF := \frac{69000 - 2.014 \cdot 4110}{(S_d + S_b) \cdot 2.014}$$

$$LF = 0.702$$

No good: Interaction is linear

Test HkC1 PT (pin moments transmitted) for Mx, Mz circular
Scale App G: GI SL condition

$$I := 0.7071 \quad s_x := 0.348 \cdot I \quad s_x = 0.246 \quad s_z := 0.270 \cdot I \quad s_z = 0.191$$

$$S_{d,x} := 9025 \quad S_{d,z} := -4169 \quad \text{App G}$$

$$S_d := s_x \cdot S_{d,x} + s_z \cdot S_{d,z} \quad S_d = 1.425 \cdot 10^3$$

$$S_{b,x} := 78419 \quad S_{b,z} := 108660 \quad \text{App G}$$

$$S_b := s_x \cdot S_{b,x} + s_z \cdot S_{b,z} \quad S_b = 4.004 \cdot 10^4$$

App C, Section 3.3.1:

$$LF := \frac{69000 - 2.014 \cdot 4110}{(S_d + S_b) \cdot 2.014}$$

$$LF = 0.727$$

No good: Interaction is linear

Test HkC0 PT (pin moments transmitted) for Mx, My circular
Scale App G: GI SL condition

$$I := 0.7071 \quad s_x := 0.194 \cdot I \quad s_x = 0.137 \quad s_z := 0.165 \cdot I \quad s_z = 0.117$$

$$S_{d,x} := 0 \quad S_{d,z} := 0 \quad \text{App G}$$

$$S_d := s_x \cdot S_{d,x} + s_z \cdot S_{d,z} \quad S_d = 0$$

$$S_{b,x} := 156800 \quad S_{b,z} := 125900 \quad \text{App G}$$

$$S_b := s_x \cdot S_{b,x} + s_z \cdot S_{b,z} \quad S_b = 3.62 \cdot 10^4$$

App C, Section 3.3.1:

$$LF := \frac{69000 - 2.014 \cdot 4110}{(S_d + S_b) \cdot 2.014}$$

$$LF = 0.833$$

No good: Interaction is almost linear

Test HkC0 PT (pin moments transmitted) for Mx, My circular
Scale App G: GA SL condition

$$I := 0.7071 \quad s_x := 0.194 \cdot I \quad s_x = 0.137 \quad s_y := 0.165 \cdot I \quad s_y = 0.117$$

$$S_{d,x} := 0 \quad S_{d,y} := 0 \quad \text{App G}$$

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$$S_d := s_x \cdot S_{d,x} + s_y \cdot S_{d,y} \quad S_d = 0$$

$$S_{b,x} := 107000 \quad S_{b,y} := 185060 \quad \text{App G}$$

$$S_b := s_x \cdot S_{b,x} + s_y \cdot S_{b,y} \quad S_b = 3.627 \cdot 10^4$$

App C, Section 3.3.1:

$$LF := \frac{69000 - 2.014 \cdot 4110}{(S_d + S_b) \cdot 2.014} \quad LF = 0.831 \quad \text{No good: Interaction is almost linear}$$

Test GdBI, PR (pin moment release) for Fz and Mx circular

Scale App G: GA SL condition:

$$I := 0.7071 \quad s_x := 0.155 \cdot I \quad s_x = 0.11 \quad s_z := 1.119 \cdot I \quad s_z = 0.791$$

$$H_x := 16360 \quad H_z := 2271 \quad \text{App G}$$

$$H := s_x \cdot H_x + s_z \cdot H_z \quad H = 3.59 \cdot 10^3$$

$$\text{App C, Section 8.0:} \quad LF := \frac{2541}{H} \quad LF = 0.708 \quad \text{No good, is linear}$$

Test HkC0 PT (pin moments transmitted) for Mx, Mz circular

Scale App G: GA SL condition

$$I := 0.7071 \quad s_x := 0.194 \cdot I \quad s_x = 0.137 \quad s_z := 3.65 \cdot I \quad s_z = 2.581$$

$$S_{d,x} := 0 \quad S_{d,z} := 8340 \quad \text{App G}$$

$$S_d := s_x \cdot S_{d,x} + s_z \cdot S_{d,z} \quad S_d = 2.152 \cdot 10^4$$

$$S_{b,x} := 156800 \quad S_{b,z} := 0 \quad \text{App G}$$

$$S_b := s_x \cdot S_{b,x} + s_z \cdot S_{b,z} \quad S_b = 2.151 \cdot 10^4$$

App C, Section 3.3.1:

$$LF := \frac{69000 - 2.014 \cdot 4110}{(S_d + S_b) \cdot 2.014} \quad LF = 0.701 \quad \text{No good: Interaction is linear}$$

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Combining torsional and bending moments

Use linear interaction, because testing could not demonstrate circular interaction is adequate.

Combining shear forces and bending moments

The simple pipe configuration suggests that this should be independent or circular. Testing shows it is linear, perhaps caused by induced bending from the shear forces applied away from the nozzle pivot.

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A minimum composite envelope is constructed with an elliptical shape after curves for all structural items are plotted. ^(Figs C-I.1 thru 6) The axis intercepts with the ellipse gives shear and bending load fractions which are to be tested with circular interaction.

Combining axial force with any other load component

Axial forces are considered independent for the following reasons

- o Axial force limits are controlled by the block. Very little load goes into the hooks - it all goes directly to the nozzle.
- o Non-axial-force limits are controlled by non-block items.
- o A separate unseating criteria keeps almost all axial forces from going into the hooks
- o Axial forces are not involved with the nozzle flange strength. Involvement with the nozzle pipe wall is minimal, being that the influence is by a membrane stress

The axial force limit controlled by the block is to be adjusted so that system model limits applied to the block will not result in an overstress.

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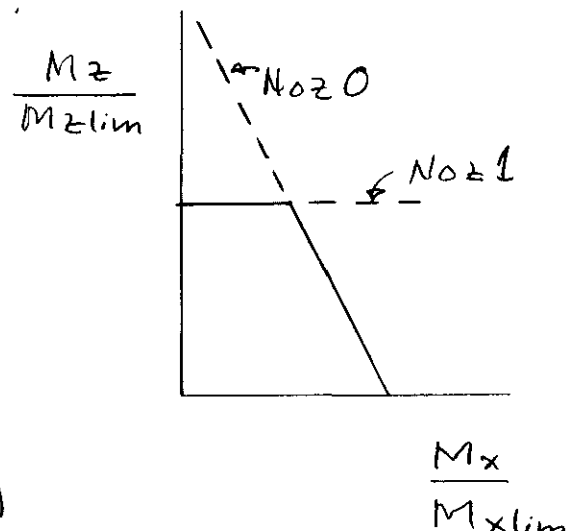
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Combining two shear forces or two bending moments (wrt connector axis):

<u>Item</u>	<u>Combination</u>
Nozzle	Bilinear
Hook Rel.	Bilinear
Hook A/B/C	Linear
Pin	Linear
Screw	Circular
BlockTop	Circular
Guide-Block	Circular

The bilinear combination is really a combination of two linear interactions, one for each of two different hooks.

Interaction curves for the various items (structural components = nozzle, etc) are easily plotted by hand simply by locating the load fractions of Table 5.3 (main report body) on the axes and connecting them with the shapes given above.



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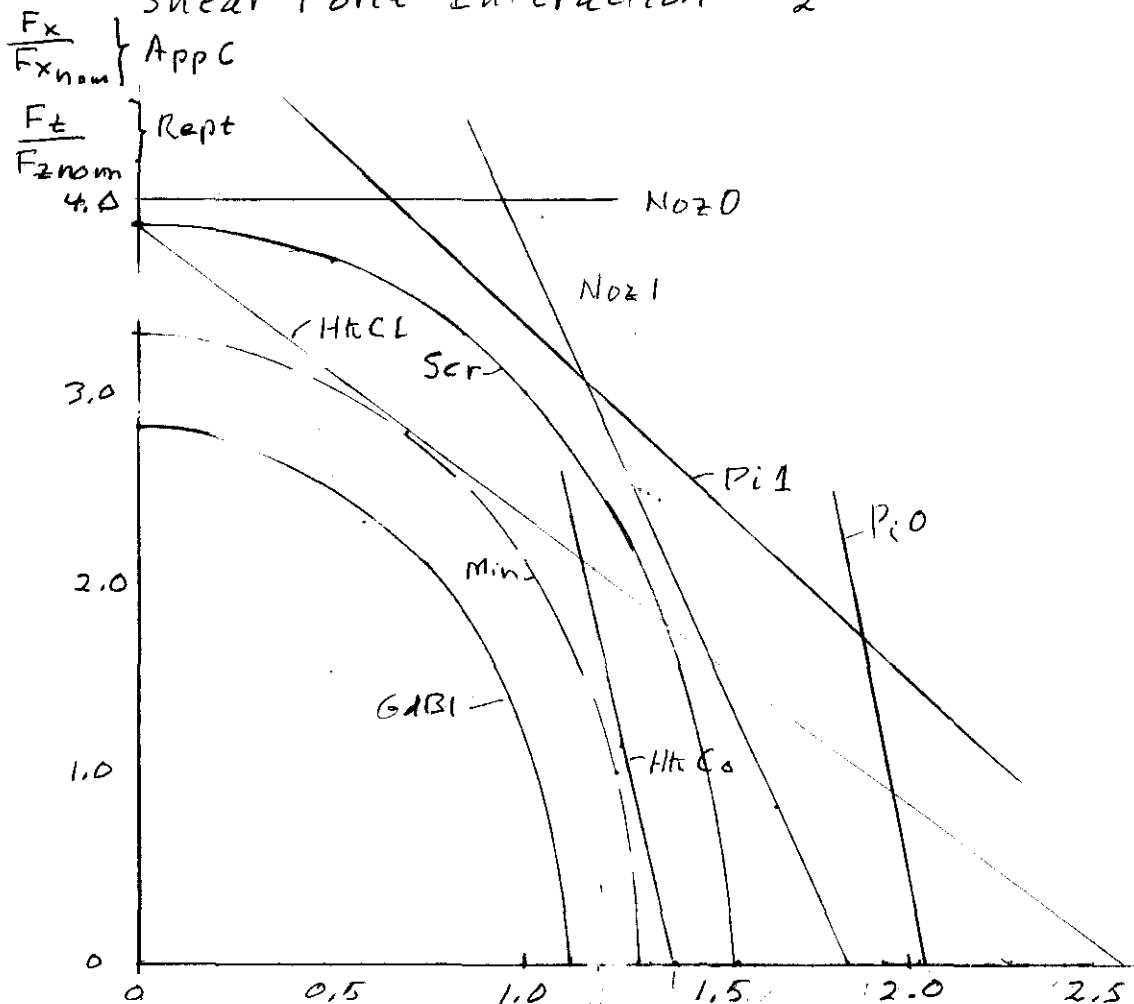
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Fig C-I-1

Shear Force Interaction 2"



Note: Min (dashed) curve
 is the largest ellipse
 inside all interaction
 curves except GdBI.

Axis intercepts provide acceptable values

$\frac{F_z}{F_{znom}}$ $\frac{F_y}{F_{ynom}}$
 App C Rept
 Notation

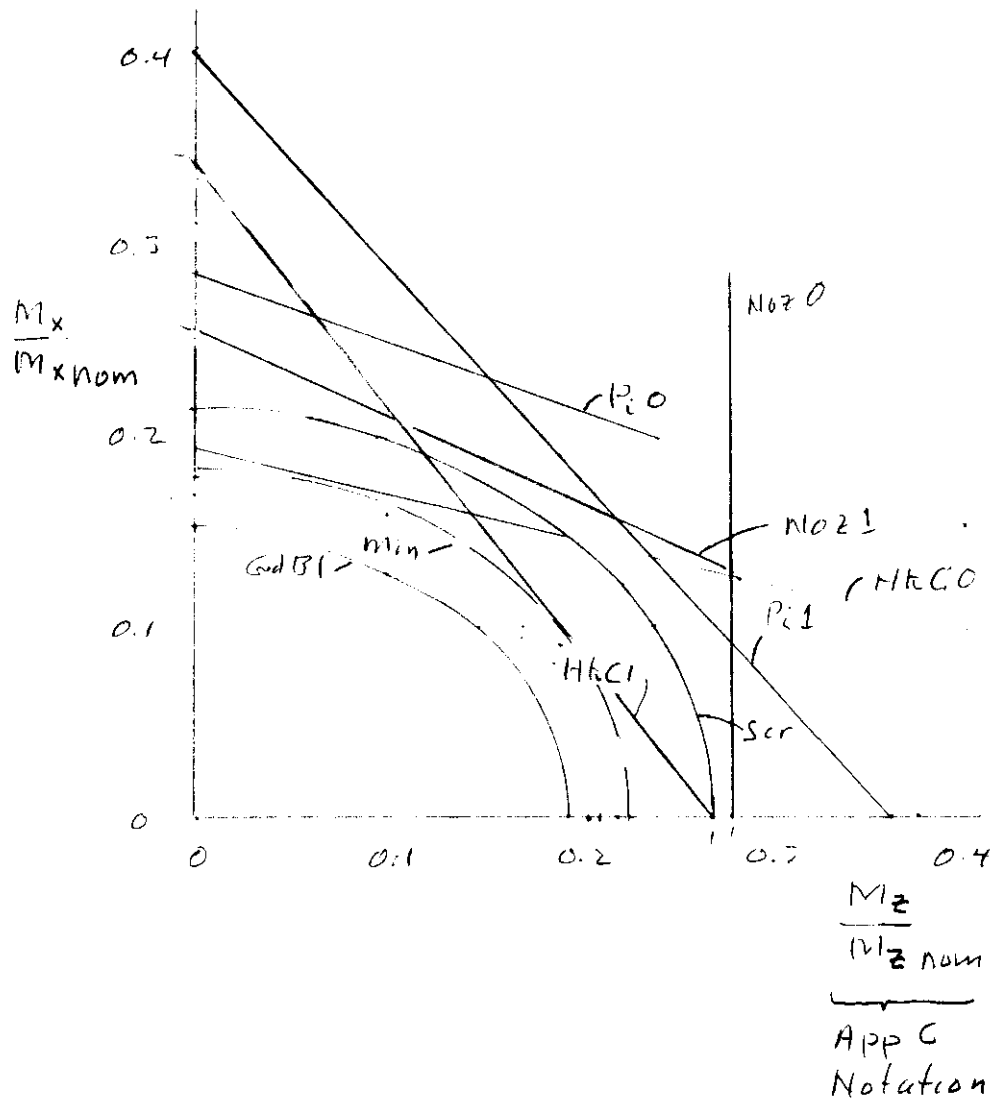
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Fig C-I-2 Bending Interaction 2"



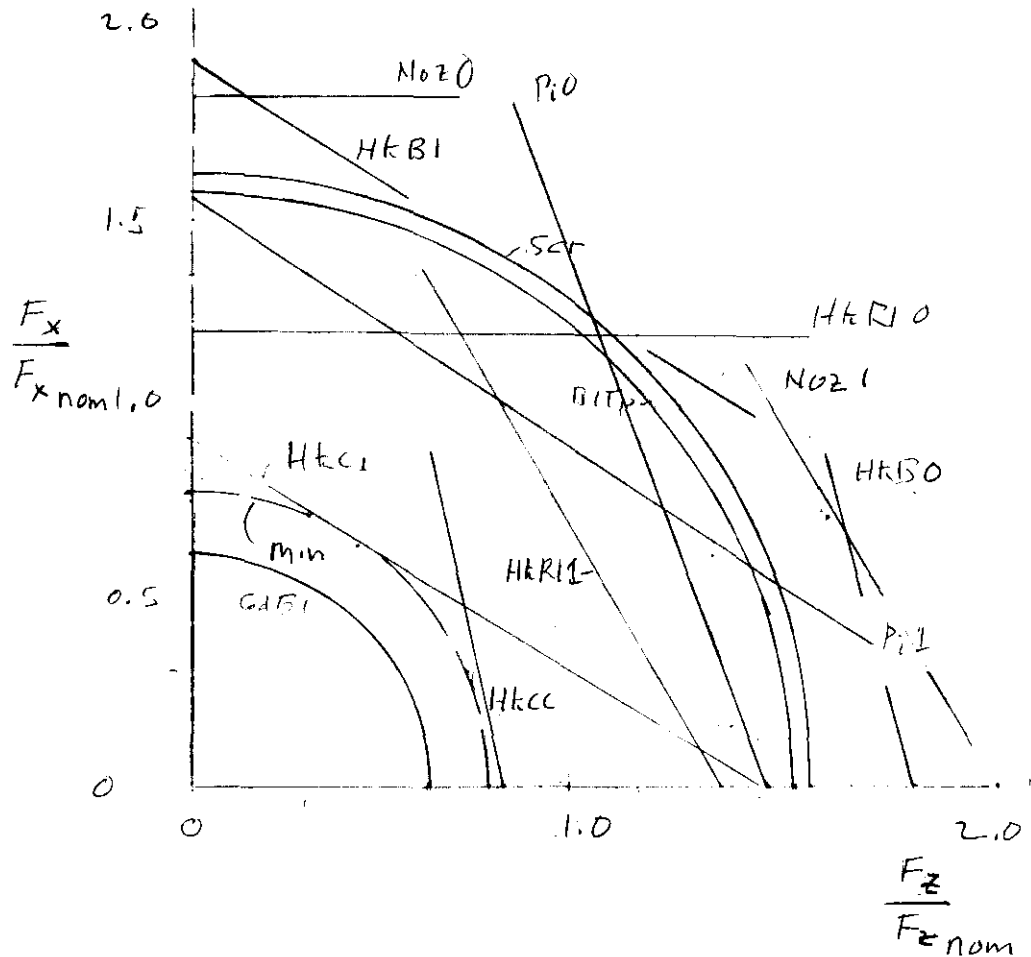
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Fig C-I-3 Shear Interaction 3"



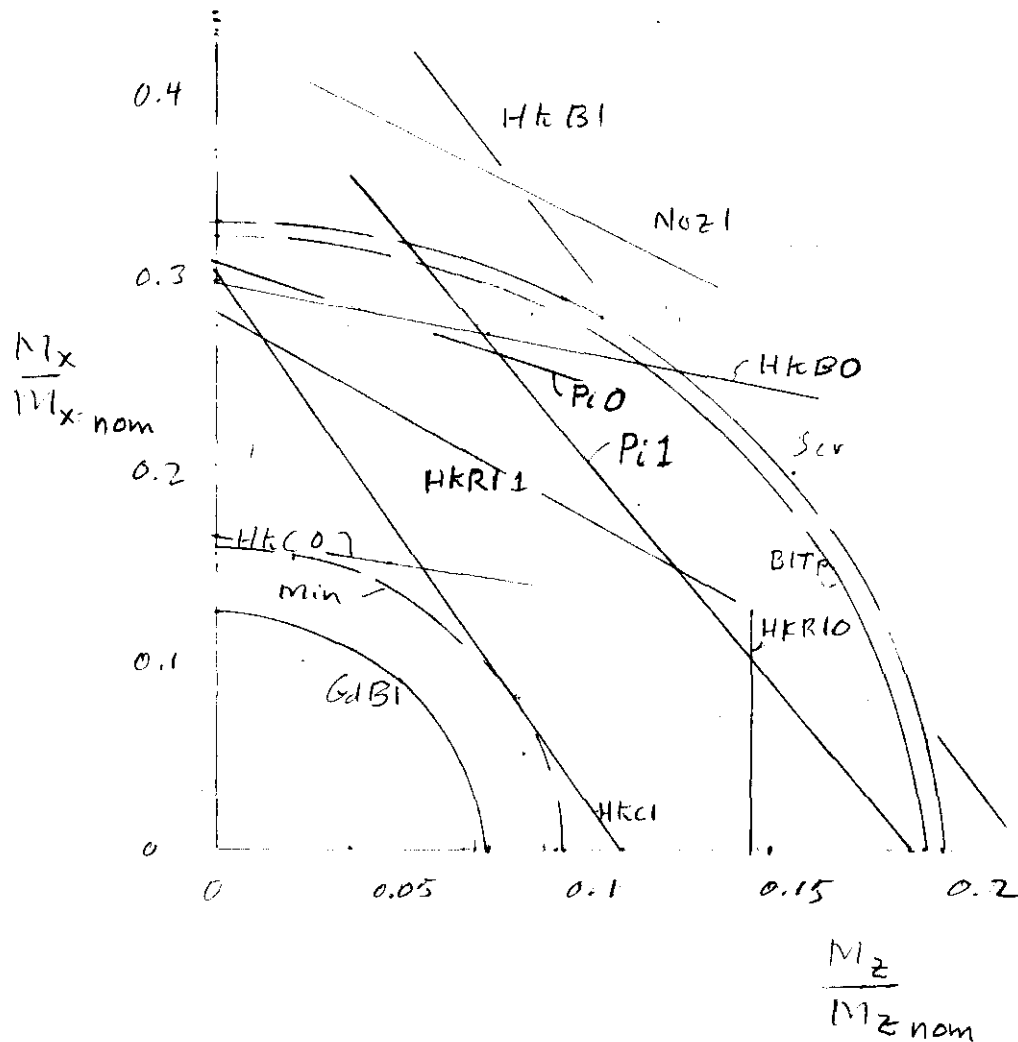
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Fig C-I-4 Bending Interaction 3"

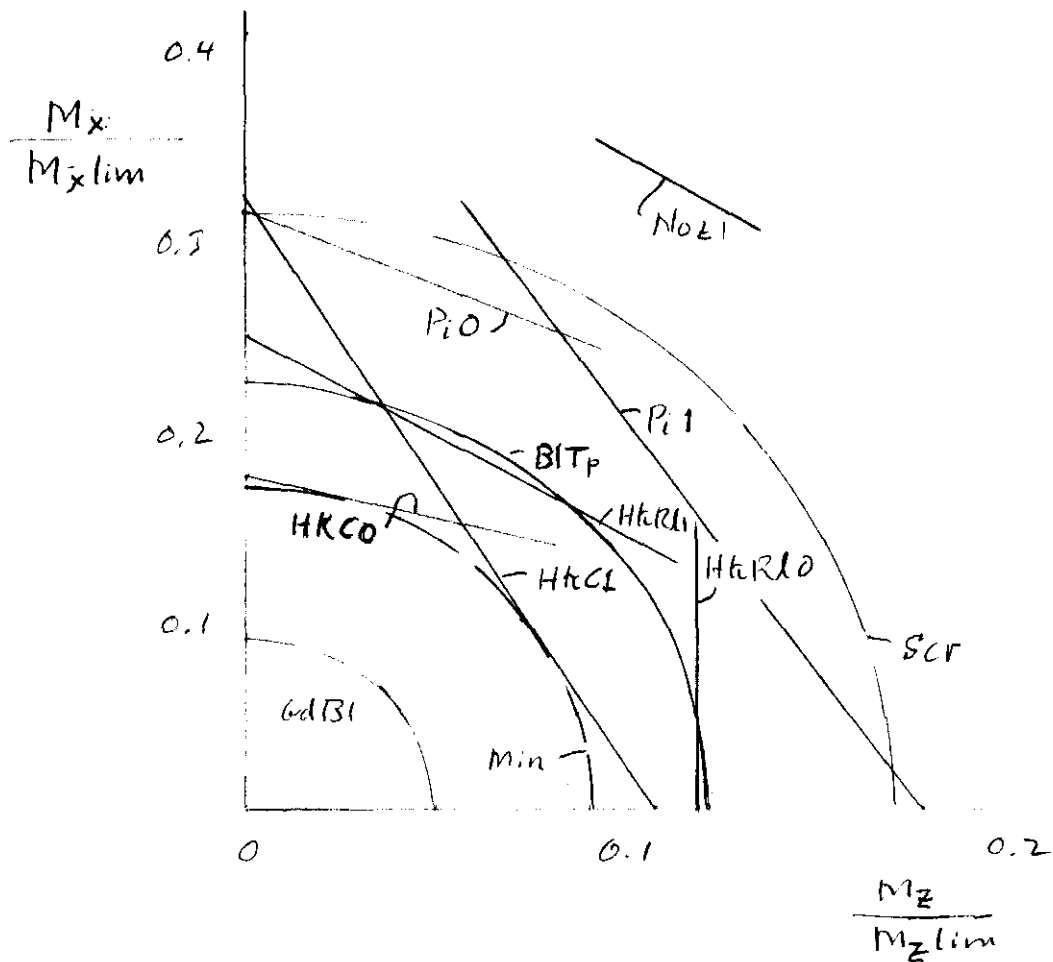


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Fig C-I-6 Bending Interaction, 4"



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Shear and Bending Load Factors

minimum load factors for shear and bending with Guide-Block interface disregarded are as follows (see interaction diagrams, dashed curve, for circular interaction)

Size	LF_{F_z}	LF_{F_x}	LF_{M_z}	LF_{M_x}	LF_{M_y}
2"	1.33	3.32	0.228	0.185	0.164
3"	0.78	0.77	0.091	0.160	0.059
4"	0.74	0.74	0.090	0.170	0.060

Torsional load factors (M_y) are also shown. Multiply by Table 31 nominal loads to obtain limit loads

Size	F_{zlim}	F_{xlim}	M_{zlim}	M_{xlim}	M_{ylim}
"	lbf	lbf	lbf-ft		
2"	1330	1330	365	370	260
3"	1560	1540	630	640	410
4"	2220	2220	1170	1190	780
	use min for shear limit		use min. for bending limit.		torsion

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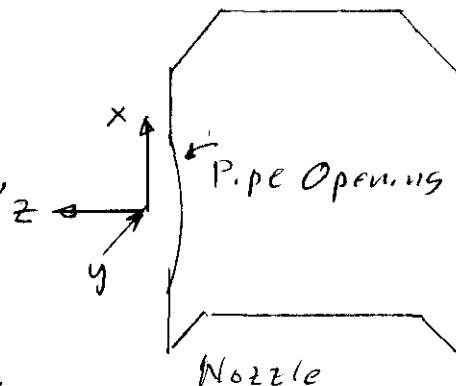
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Interaction - Block

Interaction considerations for the block will maintain the independence of the block-controlled connector-axial acceptable load. Do this by reducing the acceptable axial load ^(App B, Table B-2 etc) through interaction considerations with system model acceptable loads ^(Table 3.4) applied as actual loads. This is best done by treating the pipe section and nozzle regions separately.

Acceptable loads on the block are taken from App B, Tables B2-B7 or, e.g., FBSS0x etc in Section 4.8, broken out as pipe section or nozzle controlled. Note that these loads are individual - each produces allowable stresses. The coordinate system is that of the main body of the report, not App E or App G. The individual loads are shown in Table C-I-1.



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Table C-I-1 Maximum Acceptable Loads on Block

Load Cmpnt (Rept xyz) (Appxyz)	2" , 16F		3" , 16F		4" , 16F	
	Noz	Pipe	Noz	Pipe	Noz	Pipe
F _x	9320	17770	40500	46050	52500	50950
F _y	22000	13900	66300	34900	155800	29140
F _z	24900	22650	97500	57800	139300	70700
M _x	8030	1320	31500	6440	83800	8440
M _y	2450	1630	18070	9360	23600	7940
M _z	3100	2440	17190	11200	32100	13920

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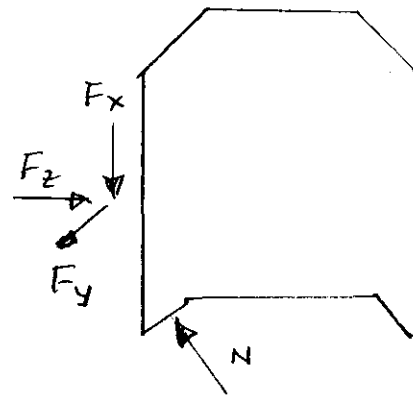
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Nozzle area stresses:

The 45° inclined plane has normal force N . Both F_z and F_x are expected to produce their respective stresses in the same place. Therefore interactions for the nozzle area are



- F_x with F_y or $F_z \sim$ linear (both produce N)
- F_y with $F_z \sim$ circular (typical shear)
- F_x with M_y or $M_z \sim$ linear (both produce N)
- M_y with $M_z \sim$ circular (typical bending)
- F_y with $M_z \sim$ linear (both produce N)

Note: there is no torsional effect at nozzle.

Use interaction criterion:

$$\frac{f_x}{F_x} + \frac{f_s}{F_s} + \frac{m_B}{M_B} \leq 1$$

$$F_s = \min \{ F_y, F_z \} \quad \text{Table C-5-1}$$

$$M_B = \min \{ M_y, M_z \}$$

f_s , m_B from system model, Table 3.4 (repost)

Acceptable axial load:

$$f_x = F_x \left(\frac{f_x}{F_x} \right) \quad \frac{f_x}{F_x} = 1 - \frac{f_s}{F_s} - \frac{m_B}{M_B}$$

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Table C-5-2 - Calculations - Nozzle Area, Acceptable Axial Load

Size	f_s lb _f	F_s →	m_B lb _f -ft	M_B →	f_x/F_x	F_x	f_x
2"	1330	22000	365	2450	.791	9320	7370
3"	1540	66300	630	18070	.942	40500	38100
4"	2220	155800	1170	23600	.936	52500	49100

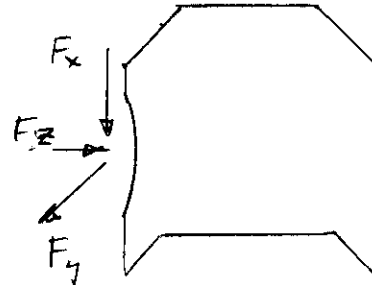
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Pipe section stresses

Interaction is similar to a pipe or nozzle opening. Shear and direct stress resultants are combined with circular interaction.



- F_z with M_x or $M_y \sim$ linear (add stresses)
- F_z with F_x or $F_y \sim$ circular (shear vs dir. stress)
- M_z with M_x, M_y or $F_z \sim$ circular
- M_z with F_x or $F_y \sim$ linear

Use criterion:

$$\sqrt{\frac{f_A^2}{F_A^2} + \frac{f_S^2}{F_S^2}} + \sqrt{\frac{m_T^2}{M_T^2} + \frac{m_B^2}{M_B^2}} \leq 1$$

- $F_A = F_z$ Table C-I-1 $M_T = M_z$ $M_B = \min\{M_y, M_x\}$
- $f_A = F_S$ of system model Table 3.4
- $m_T = m_z = M_B$ of system model
- $m_B = m_x$ or $m_y = M_B$ of system model ($> M_T$ of sys.)
- $f_S^2 = f_x^2 + f_y^2$ solve for f_x
- $f_y = F_S$ of system model
- $F_S = \min\{F_y, F_x\}$ Table C-I-1

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$$\frac{f_x^2}{F_x^2} = \left(1 - \sqrt{\frac{m_F^2}{M_F^2} + \frac{m_B^2}{M_B^2}} \right)^2 - \frac{f_A^2}{F_A^2} - \frac{f_z^2}{F_z^2}$$

Since $f_A = f_z = F_S$ (system model), use only the worst of the last two terms. Calculations are shown in Table C-I-3.

Results:

	Noz	Pipe	Worst
Size	f_x	f_x	f_x
2"	7590	12900	7370
3"	38800	42000	38100
4"	49500	42400	42100

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Table C-I-7 Calculations - Pipe Opening

Size	f_A	F_A	f_T	F_S	m_T	M_T	m_B	M_B
2"	1330	22650	1350	13900	365	2440	365	1320
3"	1540	57800	1540	34900	630	11200	630	6440
4"	2220	70700	2220	29140	1170	13920	1170	7940

	$1 - \sqrt{\frac{m_T}{m_T + m_B}}$	$\frac{F_A}{F_T}$	f_T / F_S	f_x / F_x	F_x	f_x
2"	.686	.059	.096	.679	17770	12070
3"	.887	.027	.044	.886	46050	40800
4"	.830	.031	.076	.827	50950	42100

A
Worst

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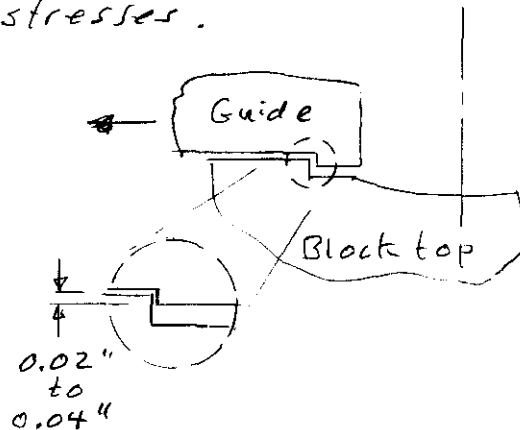
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Guide-Block elimination

Considering bending and shear forces on the connector, some model cases have the hooks contacting the guide which results in loading the block top laterally at the guide-block interface. The small load fractions here are associated with small ledges and large bearing stresses.

These bearing stresses are dismissed, because

1. Typically, bearing stresses do not result in catastrophic failures.
2. The system model variation producing these stresses assumed immediate hook-guide contact. Clearances are such that gap travel could be between 0.02" to 0.08". System models (AppG) without gap contact show 0.03" to 0.05" travel. Thus, the immediate contact could be quite conservative.
3. Considerable compression forces between the guide and block are developed by differential thermal expansion between the block and tie bolts. Friction thus assists in passing the



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hook forces to the block. Estimate: (2" connector)

$$A_{\text{block}} = \frac{\pi}{4} (3.375^2 - 2.062^2) = 5.6 \text{ in}^2$$

$$A_{\text{bolts}} = 6 \times .307 = 1.8 \text{ in}^2 \quad (\text{section 8.3})$$

$$A_{\text{block}} \gg A_{\text{bolts}}$$

$$P \approx E \times T \times A_{\text{bolt}}$$

$$= 30 \times 10^6 \times 10 \times 10^{-6} \times (250 - 70) \times 1.8 = 97000 \text{ }^*$$

P at $\mu = 0.2$ gives lateral force

$$H = 97000 \times 0.2 = 19.4 \text{ K}$$

Force from App G at 0.2 load fraction is
 $13 \text{ K} \times 0.2 = 2.6 \text{ K} \ll 19.4 \text{ K}$ from friction

4. Minimum ledge sizes were used in the guide-block bearing limits, maximum sizes are typically double.

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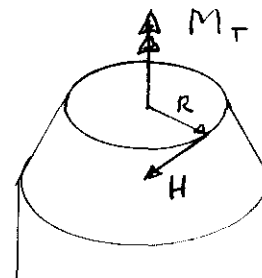
Torsional Moment Release

Consideration was given to dismissing torsional load factors on grounds of unrealistically large rotations developed by the system model. The cases which depended on artificial springs to prevent rigid body modes were dismissed.

The remaining cases involved hook-guide contact which carried torsional moments through the guide into the block. Note that the guide is rigidly connected to the block in the system model. The connection can be provided by frictional forces developed under thermal expansion. From the guide-block load-factor elimination argument, friction can provide

$$H = 19.4 \text{ K at } R = 1" \Rightarrow M_T = 19.4 \text{ "K} \\ \text{vs torsional capacity} = 260 \text{ "K} = 3100 \text{ "K} < 19400 \text{ "K}$$

which is sufficient for the connection. The capacity is controlled by the hook-eye stresses. It is conservative to keep the guide connected to the block as opposed to releasing the torsional moment.



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304L/316L Considerations

These materials have 80% of the S_m for 304/316 used throughout the analysis for the nozzle and block. Straight scaling is not possible because of the preload. Sections of Appendices were rerun with the lower allowable.

Block: From App B, current & 304L rerun; axial load allowables controlled by opening/nozzle areas:

Size	304 F_{250, lb_f}	304L F_{250, lb_f}	Penalty %
2"	9550	6280	34
3"	41100	30850	25
4"	50900	38700	24

The block-top region requires checking H_{lim} (App C sect 7.0) against the excess of the block-top load factor over the controlling load factor (see interaction diagram)

Size	304 H_{lim, lb_f}	304L H_{lim, lb_f}	304 LF_{ctf}/LF_{BITP}	304L $H_{lim} \frac{304L}{304}$	
2"	3790	3240	.225/.421 = .53	.85	OK
3"	-	-	.091/.188 = .48	-	OK
4"	5570	4980	.091/.121 = .75	.89	OK

No penalty is called for.

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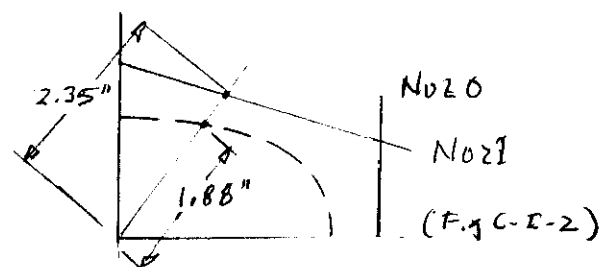
Nozzle Nozzle flange allowables drop below hook allowables. They must be introduced to the nozzle load factor calculation $P_{net}/\Delta F$ of App C Sect. 2.2, where the hook controlled. Units = lbf

Size	304L Noz. All.	Hook Allow.	304 P_{net}	$\Delta P =$ HK-304L Allow.	$1 - \frac{\Delta P}{P_{net}}$
2"	5060	5940	2290	880	.62
3"	7420	8750	5270	1330	.75
4"	10840	12700	8200	1860	.77

This gives the fraction of P_{net} remaining. Compare with the excess of the nozzle load fraction over the controlling load fraction (see interaction diagrams)

Size	$LF_{ct1}/LF_{Noz}^{(1)}$	Penalty
2"	$1.88/2.35 = 0.80$	$1 - .62/.80 = 0.23$
3"	$1.68/3.85 = 0.44$	OK
4"	$1.77/4.00 = 0.44$	OK

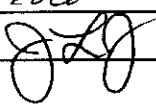
⁽¹⁾ = Scaled along worst radial line in interaction diagram.



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27.0 CONCLUSION

The 2-, 3-, and 4-in., ISB jumper clamp assemblies were structurally evaluated for all components of external piping loads as well as pressurization, pre-load, and thermal effects. Details for the seal block herein include only the top region influenced by bearing of the screw. The remaining block details were covered in Appendix G.

The nozzle and block sections were analyzed to ASME (1989) criteria while the remaining components (hooks, pins, nut and screw) were analyzed to AISC (1989) criteria. Section 1.0 gives the limiting stresses (membrane, bending and bearing) determined by the criteria.

The load stresses needed for the evaluation are provided in Appendix G. Eight sets of stresses for each size of assembly are provided. They represent various combinations of kinematics derived from conditions of guide contact, block-friction, and hook-moment transmission. Pre-load loading to the assemblies includes only the 50 ft-lbf torque load. The piping external loads of Appendix F, Table F2, were considered in their nominal form as input to the system model analysis of Appendix G. The worst kinematic condition was considered at each point in the assembly with the worst signs of the piping external load components.

The evaluation shows that the Appendix F, Table F2, external loads cannot be accommodated by the assemblies. Each of the spatial components (F_x , F_y , ... M_z) was considered independently in the evaluation to determine what fraction of the component is acceptable when acting with the pressurization, torque and thermal loads. These fractions are identified as load fractions. It is recommended that qualification of the jumpers be completed by considering actual piping reactions obtained with jumper stiffnesses included in the piping model. The absolute sum of ratios of piping reaction components (expressed as fractions of the nominal Appendix F, Table F2, components) to minimum load fractions should be less than unity. Minimum load fraction values are presented in the main body of the report.

Subject System Model Evaluation for ISB Jumper ClampOriginator E. O. Weiner EOWDate 3/29/95Checker J. L. JulykDate 3/30/95**28.0 REFERENCES**

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204.4 ANALYSIS OF LUGS AND SHEAR PINS204.41 General

This section presents the basic method of analysis and procedures for the design of lug-pin combinations. The analysis is limited to lugs of uniform thickness loaded axially, obliquely, or transversely in the plane of the lug and parallel to its axis of symmetry. Caution should be used with eye-bolt type lugs or irregular sections. Because lugs are elements with severe stress concentrations, the grain direction of the material with respect to the lug is very important for efficient design. When analyzing any lug-pin combination, all possible modes of failure must be considered. The following modes of failure should be checked by the methods presented:

- a. Tension across the net section - Because of the inherent stress concentration, the load carrying capacity is reduced.
- b. Shear tear-out or bearing - These two are closely related and are covered by a single computation based on empirical curves.
- c. Hoop tension at the tip of the lug - No separate calculation is required since the shear-bearing allowables preclude hoop tension failure.
- d. Yielding of the lug - This is considered excessive beyond a permanent set of (.02 x pin diameter).
- e. Excessive yielding of the bushing (if a bushing is used).
- f. Shearing of the pin.
- g. Bending of the pin - The pin ultimate strength is based on modulus of rupture. (SB-65-2).

204.42 Analysis Procedure

The following outlined procedure gives the allowable load for each possible way in which lug-pin combinations may fail. Adequacy of the part is then determined by comparing each of these allowable loads (yield or ultimate) with the corresponding applied loads by means of the conventional margin of safety calculations.

204.43 Strength of Lugs Under Axial Loading

- a. Tension Across the Net Section - Because of stress concentration, the full P/A stress cannot be carried; therefore, the efficiency factor, K_t , should be used. Select the proper curve for lug material and grain direction from Figure 204.4-1 and enter Figure 204.4-2 with W/D and obtain K_t . Calculate the allowable ultimate load P'_{tu} for axial tension failure:

$$P'_{tu} = K_t F_{tu} A_c$$

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204.43 Strength of Lugs Under Axial Loading. (Cont'd)

where K_t = Tension efficiency factor
from Figure 204.4-2.

F_{tu} = Ultimate tensile strength
of the lug material in the
"F" grain direction. (See
schematic in Figure 204.4-2.)

A_t = Minimum net section area $(W-D)t$

- b. Shear Tear-Out, Bearing, and Hoop Tension - These three types of failures are closely related, and all three can be found by the following procedure: Enter Figure 204.4-3 with a/D and D/t to obtain K_{br} . Calculate the allowable ultimate load, P'_{bru} , for shearing-bearing failure:

$$P'_{bru} = K_{br} F_{tux} A_{br}$$

where K_{br} = Bearing efficiency factor
from Figure 204.4-3

F_{tux} = Ultimate strength of the
lug material in the trans-
verse grain direction.

A_{br} = Projected bearing area, diameter
times the lug thickness

- c. Lug Yield - Yielding of the lug must always be checked, as it frequently occurs at a lower load than would be anticipated from the ratio F_{ty} to F_{tu} . Yielding is considered to be excessive at a permanent set of 0.02 times the pin diameter. Take the smaller of P'_{tu} and P'_{bru} as $P'_{u(min)}$. Enter Figure 204.4-4 with $P'_{u(min)}/A_{br}F_{tux}$ and obtain C . Calculate the allowable yield load for the lug:

$$P'_y = C \frac{F_{tyx}}{F_{tux}} P'_{u(min)}$$

where C = Yield factor from Figure 204.4-4

F_{tyx} = Tensile yield strength of the lug
material in the transverse grain
direction.

- d. Bushing Yield - Take A_{brb} as the smaller of the bearing areas of bushing on pin or bushing on lug. The latter may be smaller as a result of external chamfer of the bushing. Calculate allowable yield bearing load on bushing.

$$P'_{bry} = 1.85 F_{cy} A_{brb}$$

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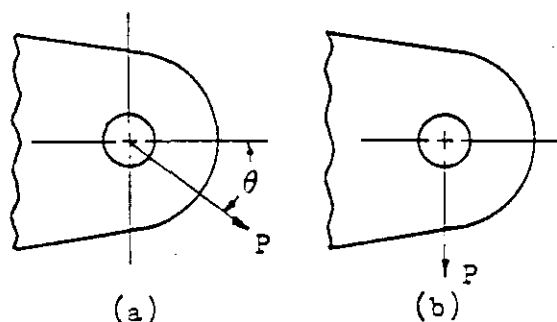
204.43 Strength of Lugs Under Axial Loading. (Cont'd)

where F_{cy} = Compressive yield strength of the bushing material.

A_{brb} = Smallest contact area of pin on bushing or bushing on lug.

e. Pin Shear - Check pin shear in the usual manner.

204.44 Strength of Lugs Under Oblique and Transverse Loads



Lugs may be loaded obliquely (a) or transverse (b) to the axial direction as shown above. Empirical correction factors have been developed by Northrop (reference 3) and others (reference 4 & 5) and are shown in Figure 204.4-5. Multiplication of the allowable axial lug load as determined in Section 204.43 by the correction factor gives the allowable load when the load is applied at an angle to the axis of lug symmetry. The following comments are made regarding the validity of the curves as substantiated by Northrop test configurations shown in Figure 204.4-6 and illustrate the efficiencies that may be derived in lug design:

- Curve ① - This curve is in general use. Northrop test configurations A, G, and I substantiate its use with the exception that configuration I was 5% low at the 45° load position.
- Curve ② - This curve is the minimum correction factor for configuration M of the Northrop Tests for the alloys used. In this configuration the bearing-shear strength is greater in the transverse direction than the axial direction.
- Curve ③ - This curve is the minimum correction factor for configuration K for the alloys tested. It also has a greater bearing - shear strength in the transverse load direction.

204.45 Strength of Lugs with Pin Bending

Pins seldom appear to fail in bending, but excessive bending of the pin concentrates the load at the edges of the lug and causes actual fracture to occur in the lug, therefore, the pin should be stiff enough so that pin deflection will not initiate failure in the lug.

- a. If it is desired to assume conservatively, within an error of 0 to 25 per cent, a uniform distribution of loading on the pin and a gap exists between the inner and outer lugs, as shown in Figure 204.4-7(A), the moment arm b is taken as:

$$b = \frac{t_1}{2} + \frac{t_2}{4} + g$$

The maximum bending moment in the pin is found from:

$$M = \frac{P_u}{2} b$$

The bending stress in the pin that results from the bending moment, M , may be calculated assuming as My/I distribution. The modulus of rupture for the pin can be obtained from SB 65-2.

Often there are other design considerations for a particular application that must be checked, but will not be discussed here, such as limiting the rotation of the end so that there will be free movement under load.

- b. If a more accurate load distribution is necessary, it is possible to make use of the load "peaking up" at the shear planes as shown in Figure 204.4-7(B). The moment arm is obtained as follows: Compute for the inner lug

$$r = \left(a - \frac{D}{2}\right) / t_2 \quad (\text{See schematic in Figure 204.4-8})$$

Take smaller of P'_{bru} and P'_{tu} for inner lug as $P'_{u(min)}$, enter Figure 204.4-8 with $P'_{u(min)} / A_{br} F_{tux}$ and r to obtain the reduction factor, γ , for peaking. Calculate the moment arm b from:

$$b = (t_1/2) + g + \gamma(t_2/4)$$

This reduction for peaking applies only to the inner lug.

- c. If the above analysis should show inadequate pin bending strength but an excess of strength in the lug, it may be possible to take advantage of the excess lug strength to show adequate pin strength as follows:
 1. Consider a portion of the lugs to be inactive, as indicated by the shaded portion in Figure 204.4-7(C). The portion of the thickness to be considered active may have any desired value sufficient to give approximately equal margins of safety for lugs and pin. This active thickness is best chosen by trial and error.

204.45 Strength of Lugs with Pin Bending (Cont'd.)

2. Recalculate all lug margins of safety with allowable loads reduced in the ratio of active thickness to actual thickness. Recalculate pin bending moment, M , equal to $P'_u b/2$, and margin of safety, using a reduced value of b obtained as follows:

Compute for inner lug, Figure 204.4-7(C)

$$r = \left(a - \frac{D}{2}\right) / 2t_{o2}$$

Take smaller of P'_{bru} and P'_{tu} for inner lug, based upon active thickness t_{o2} as $P'_{u(min)}$. Enter Figure 204.4-8

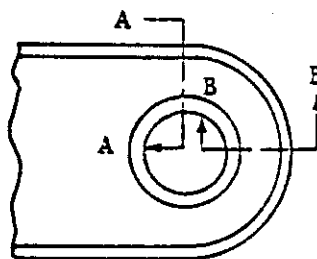
with $P'_{u(min)} / A_{br} F_{tux}$ and r to obtain the reduction factor for peaking γ . Calculate the new b , Figure 204.4-7(C), from the equation:

$$b = \frac{t_{o1}}{2} + g + \frac{\gamma(t_{o2})}{2}$$

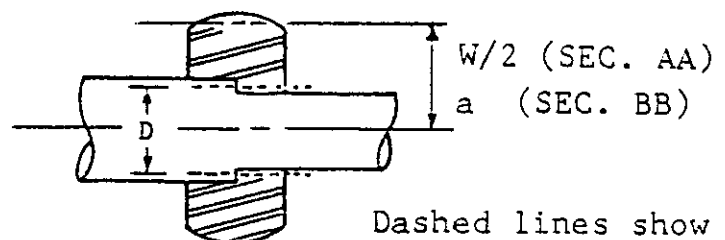
This reduced b should not be used if the resulting eccentricity causes excessive bending stresses in the lugs as shown by Figure 204.4-7(D). If such eccentricity exists, the pin must be strong enough to withstand the loading shown in Figure 204.4-7(B).

204.46 Special Applications

1. Irregular lug section - bearing load distributed over entire thickness - For lugs of irregular section having bearing stress distributed over the entire thickness, analysis is made based on an equivalent lug with a rectangular section having an area equal to the average of the original section. (See schematic Figure 204.4-2.)



(a)



SECTION AA OR BB

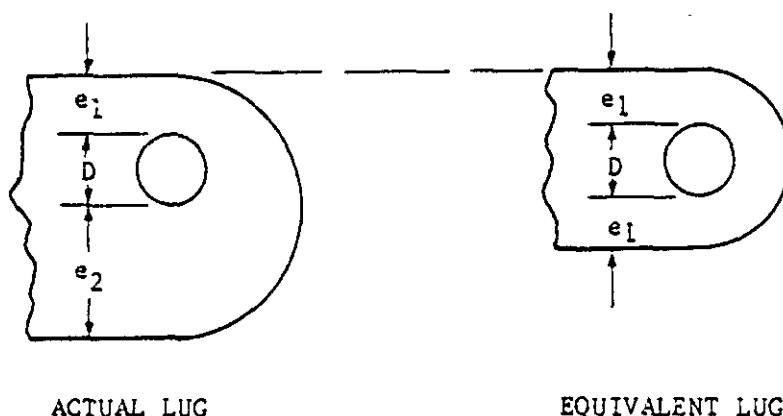
(b)

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204.46 Special Applications (Cont'd)

2. Eccentrically located hole - If the hole is located as shown with e_1 less than e_2 , the ultimate and yield lug loads are determined by obtaining P'_{bru} , P'_{tu} and P'_y for the equivalent lug shown and multiplying by the factor.

$$\text{factor} = \frac{e_1 + e_2 + 2D}{2e_2 + 2D}$$



3. Critical bearing stress - The critical sheet bearing strengths of joints with drilled holes as presented in MIL-HDBK-5 is limited to e/D values between 1.5 and 2.0, and D/t ratios to 5.5. The ultimate and yield bearing stress for geometrical conditions outside this range may be determined in the following manner. This method is applicable to the usual bolt or rivet joint.

- (a) Ultimate bearing stress - For the particular D/t and e/D , obtain K_{bru} from Figure 204.4-3. (Note that "e" is equivalent to "a")

$$F_{bru} = K_{bru} F_{tux}$$

where

F_{tux} = Ultimate strength of lug material in transverse direction.

- (b) Yield bearing stress - With the particular e/D obtain K_{bry} from Figure 204.4-9.

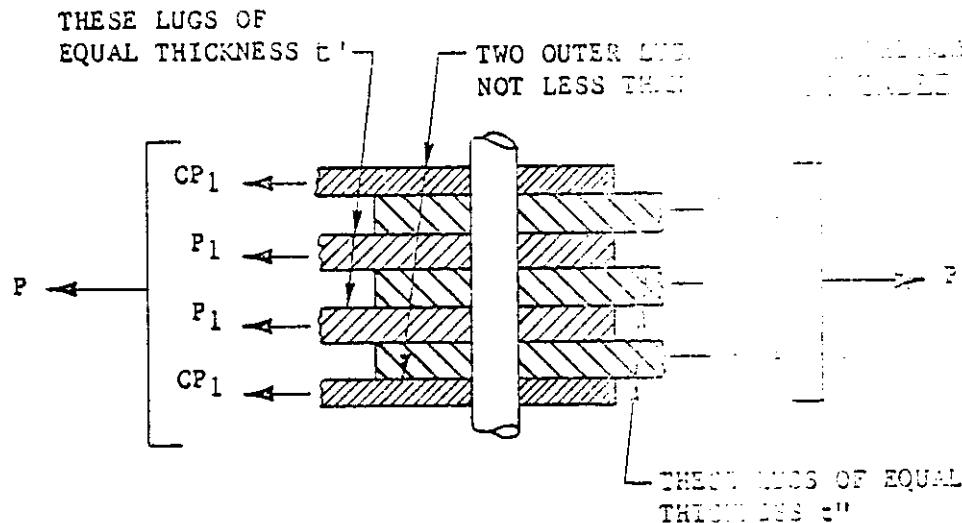
$$F_{bry} = K_{bry} F_{tyx}$$

where

F_{tyx} = Tensile yield stress of lug material in transverse direction.

204.46 Special Applications

4. Multiple shear connections - Lug-pin
the geometry shown below are analyzed
following criteria:



- (a) The load carried by each lug is determined by distributing the total applied load "P" along the lugs as shown and the value of "C" is obtained from Table 204.46-1.
- (b) The maximum shear load on the pin is given in Table 204.46-1.
- (c) The maximum bending moment in the pin is given by the formula, $M = \frac{P_1 b}{2}$ where "b" is given in Table 204.46-1.

TABLE 204.46-1

TOTAL NUMBER OF LUGS INCLUDING BOTH SIDES	C	PIN SHEAR	b
5	.35	.50 P_1	.23 $\frac{t' + t''}{2}$
7	.40	.53 P_1	.33 $\frac{t' + t''}{2}$
9	.43	.54 P_1	.37 $\frac{t' + t''}{2}$
11	.44	.54 P_1	.39 $\frac{t' + t''}{2}$
∞	.50	.50 P_1	.50 $\frac{t' + t''}{2}$

C-125

204.46 Special Applications

References:

1. Cozzone, F.P., Melcon, M.A. and Hoblit, F.M., "Analysis of Lugs and Shear Pins Made of Aluminum or Steel Alloys" Product Engineering, Vol. 21, No. 5, pp. 113-117, May 1950.
2. Melcon, M.A. and Hoblit, F.M., "Development of the Analysis of Lugs and Shear Pins", Product Engineering, June 1953.
3. Norair Tests: TWO #56606.
4. McDonnell Aircraft Structures Manual #339.
5. Republic Aviation Structures Manual, Section 1.6210.
6. Astronautics Structural Manual, Vol. I, NASA, George C. Marshall Space Flight Center, Huntsville, Alabama.

FIGURE 204.4-1

MATERIAL TENSION EFFICIENCY FACTORS FOR LUGS

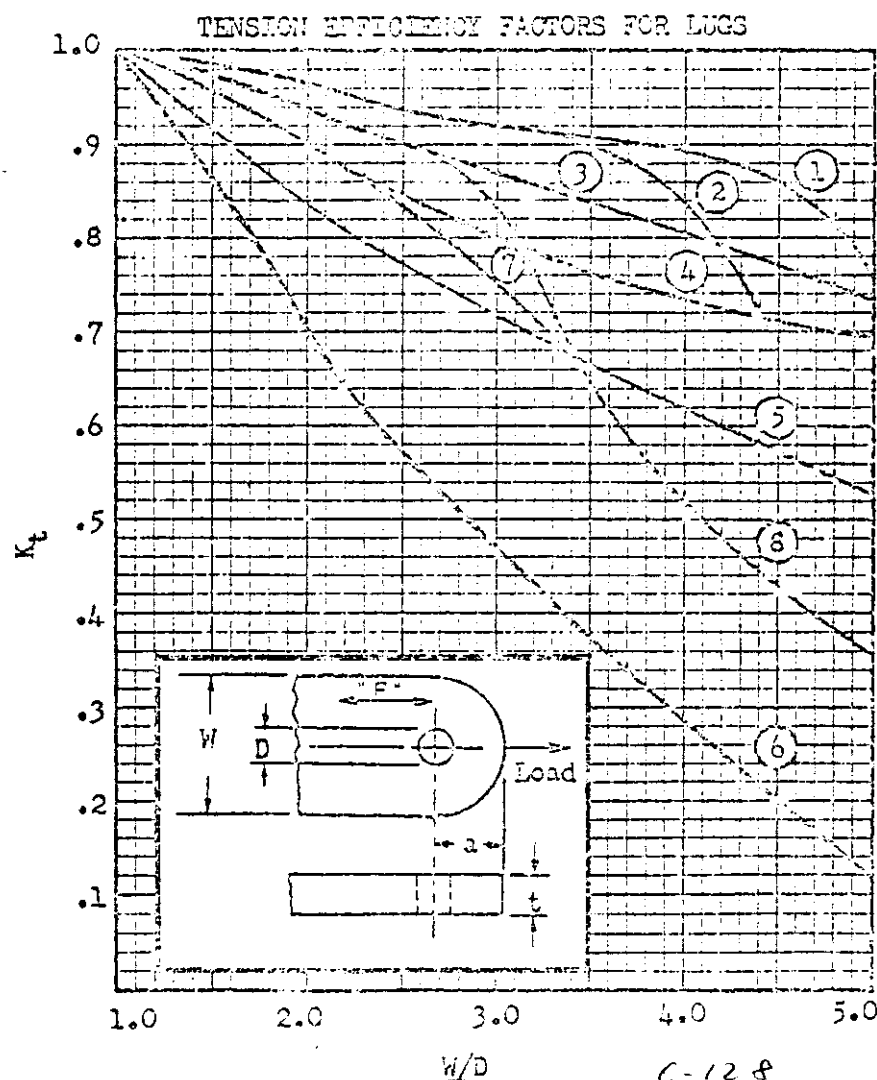
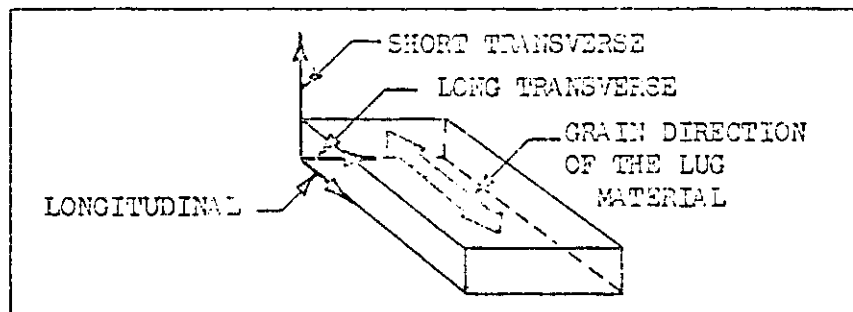
MATERIAL	FORM	GRAIN DIRECTION AT "F"	CURVES	MATERIAL	FORM	GRAIN DIRECTION AT "F"	CURVES
4130	all	L,T,N	1	7075-T6 & 7079-T6	bar & extrusions	L	1
8630	all	L,T,N	1		extrusions	T	2
2014-T6	plate ≤ 0.5 $> 0.5 \leq 1.0$ > 1.0	L,T,N	1		forged billet $< 36 \text{ in}^2$	L	2
		L,T	2		$> 36 \text{ in}^2$	L	4
		L,T	4		$\leq 16 \text{ in}^2$	T	4
	forged billet $\leq 144 \text{ in}^2$ $> 144 \text{ in}^2$ $\leq 36 \text{ in}^2$ $> 36 \text{ in}^2$	L	1		$> 16 \text{ in}^2$	T	5
		L	2		plate ≤ 0.5	L,T	1
		T	2		$> 0.5, \leq 1.0$	L,T	2
	die forging	T	5		> 1.0	L,T	4
		L	1		die forging	L	1
		T	2			T	2
				195-T6	cast		5
2024-T4 T4 or T42	plate & bar	L,T	4	220-T4	cast		5
	extrusions	L,T	3	356-T6	cast		5
				18-8 Annealed	all	L,T,N	7
				18-8, Full Hard	all	L,T,N	8
NOTE: Use Curve 6 for all aluminum alloy plate, bar, forged billet, and die forgings with short transverse grain (N) in the "F" direction.							

204.4 REFERENCED FIGURES

FIGURE 204.4-2

Note: The notations used to indicate the material grain direction as shown are defined as follows:

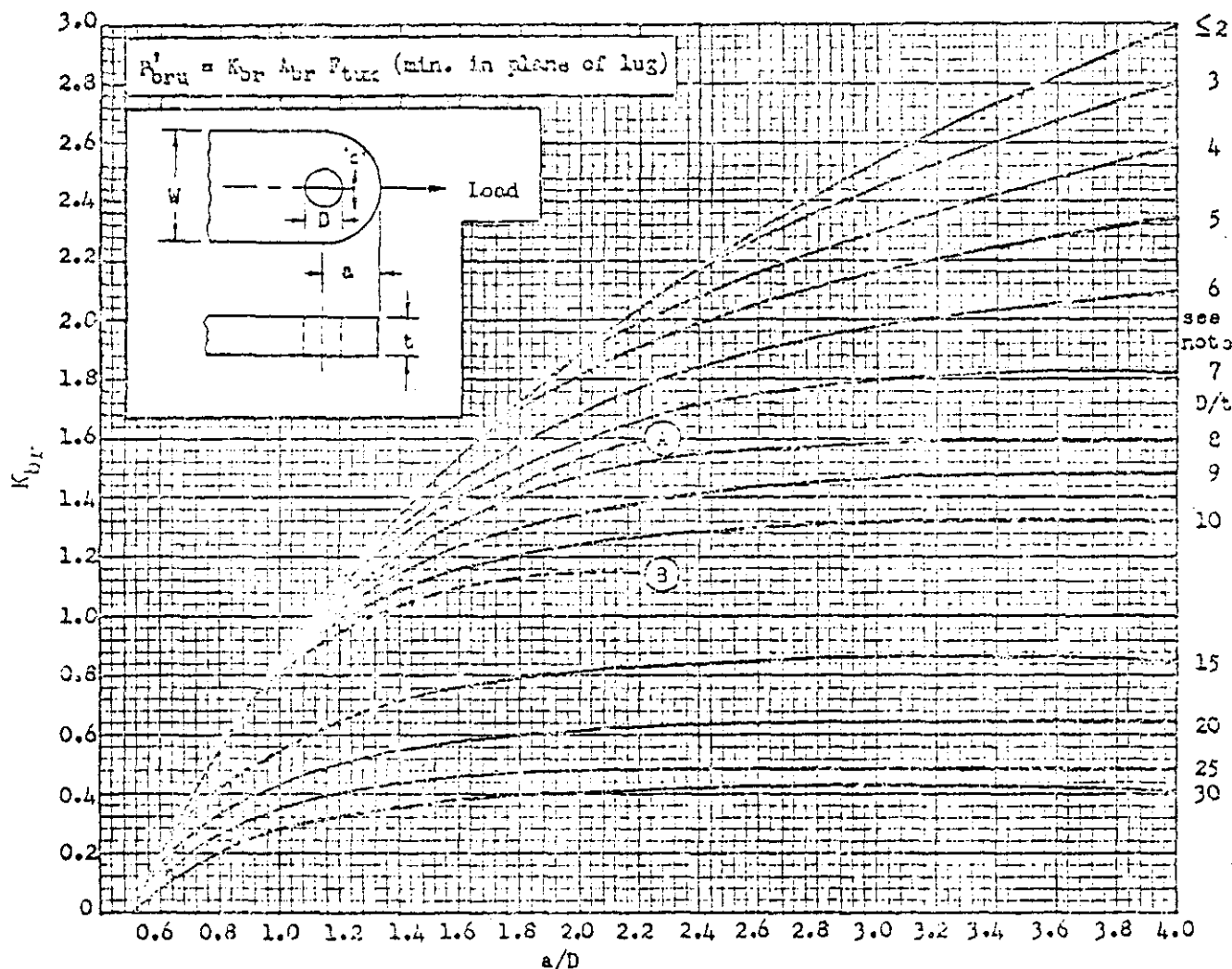
- L = Longitudinal (with grain), parallel to direction of rolling.
- T = Long transverse (cross grain), perpendicular to direction of rolling.
- N = Short transverse (cross grain), normal to direction of rolling (parallel to direction in which thickness reduction takes place).



204.4 REFERENCED FIGURES

FIGURE 204.4-3

SHEAR-BEARING EFFICIENCY FACTORS FOR LUGS



Curve A is a cutoff to be used for all aluminum alloy hand forged billet when the long transverse grain direction has the general direction C in the sketch.

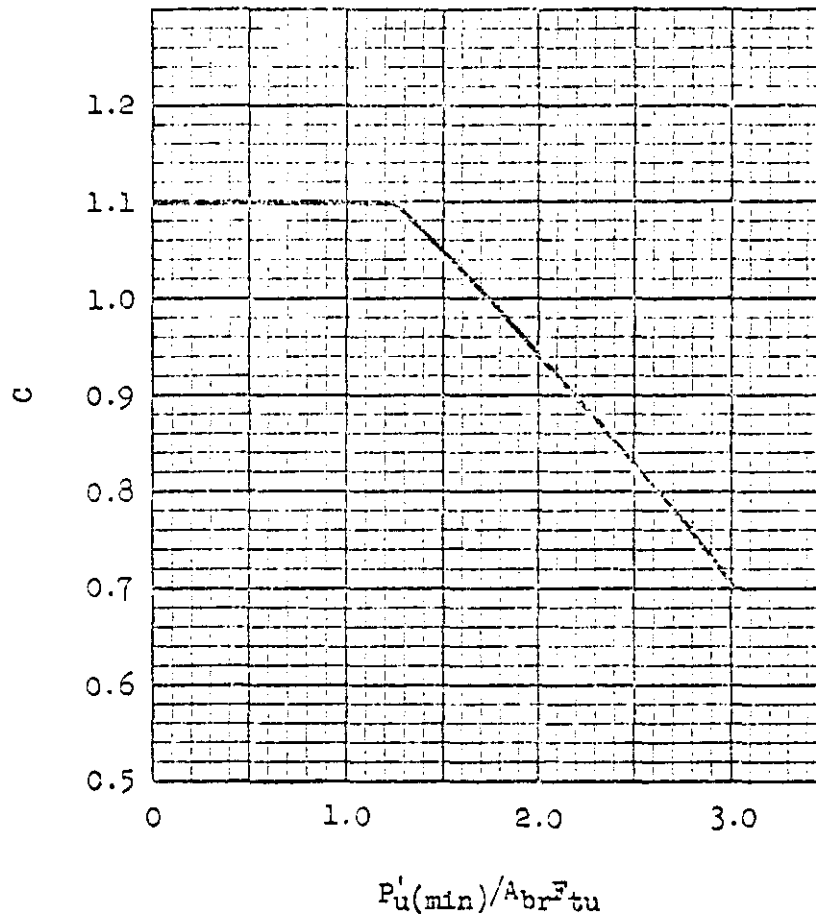
Curve B is a cutoff to be used for all aluminum alloy plate, bar, and hand forged billet when the short transverse grain direction has the general direction C in the sketch, and for die forgings when the lug contains the parting plane in a direction approximately normal to the direction of C.

Note: In addition to the limitations provided by Curves A and B, in no event shall a K_{br} greater than 2.00 be used for lugs made from 0.5 in. thick or thicker aluminum alloy plate, bar, or hand forged billet.

204.4 REFERENCED FIGURES

FIGURE 204.4.4

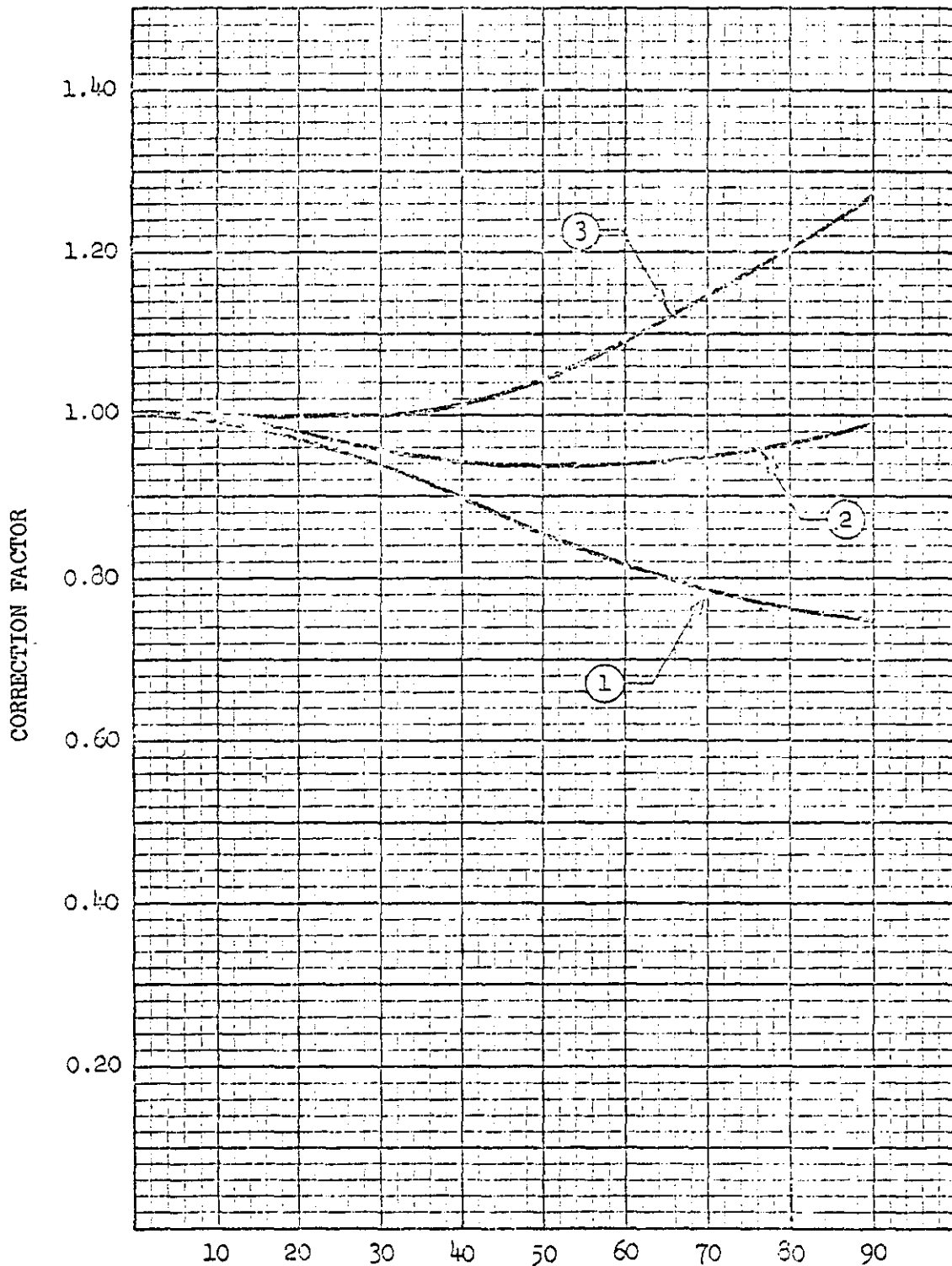
YIELD FACTOR FOR LUGS



204.4 REFERENCED FIGURES

FIGURE 204.4-5

CORRECTION FACTOR FOR OBLIQUE AND
TRANSVERSE LUG LOADS

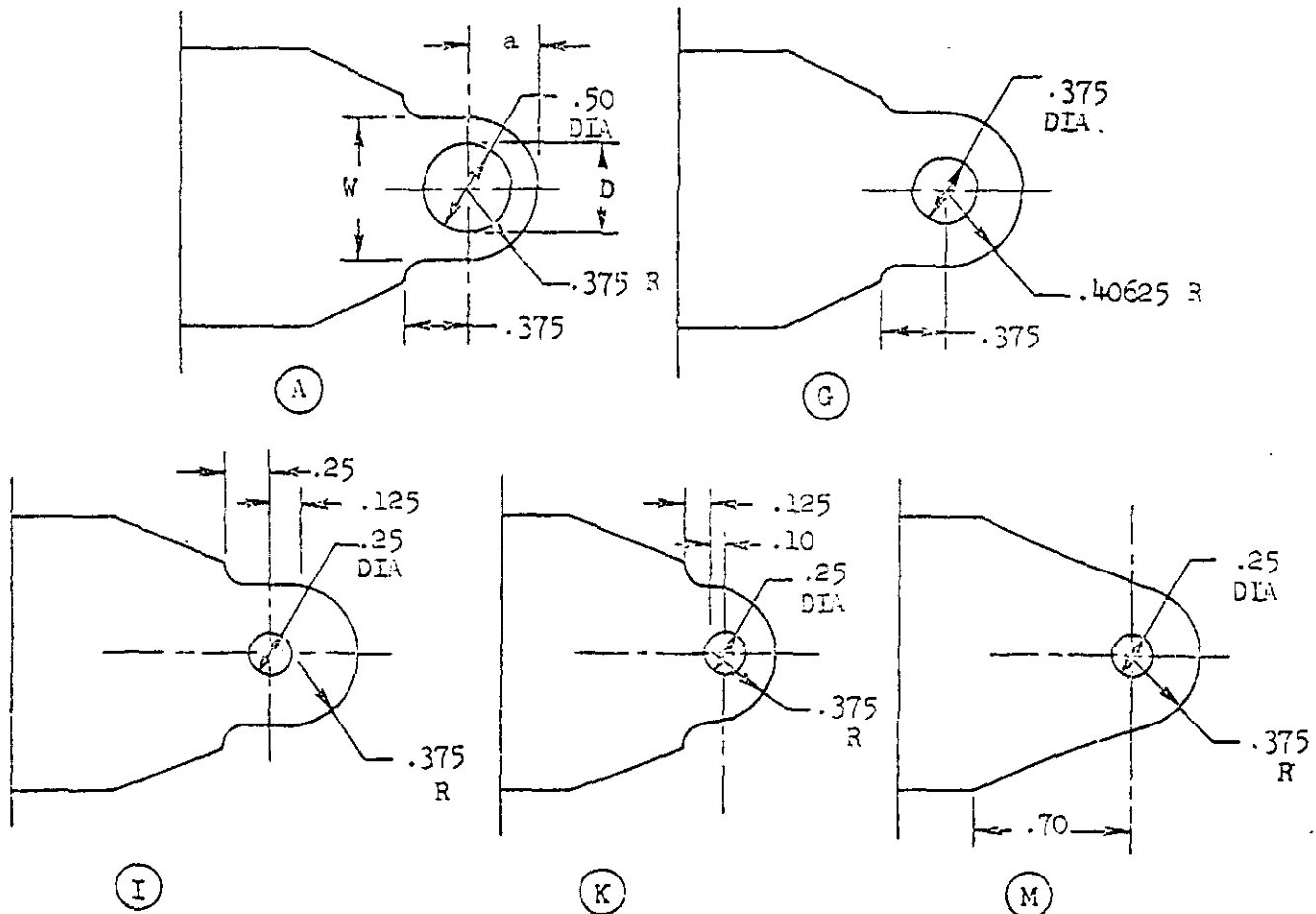


ϕ DEGREES FROM THE AXIAL DIRECTION

204.4 REFERENCED FIGURES

FIGURE 204.4-6

LUG GEOMETRY, AREA PARAMETERS, AND MATERIALS TESTED
BY NONIHROP (REF. 3)



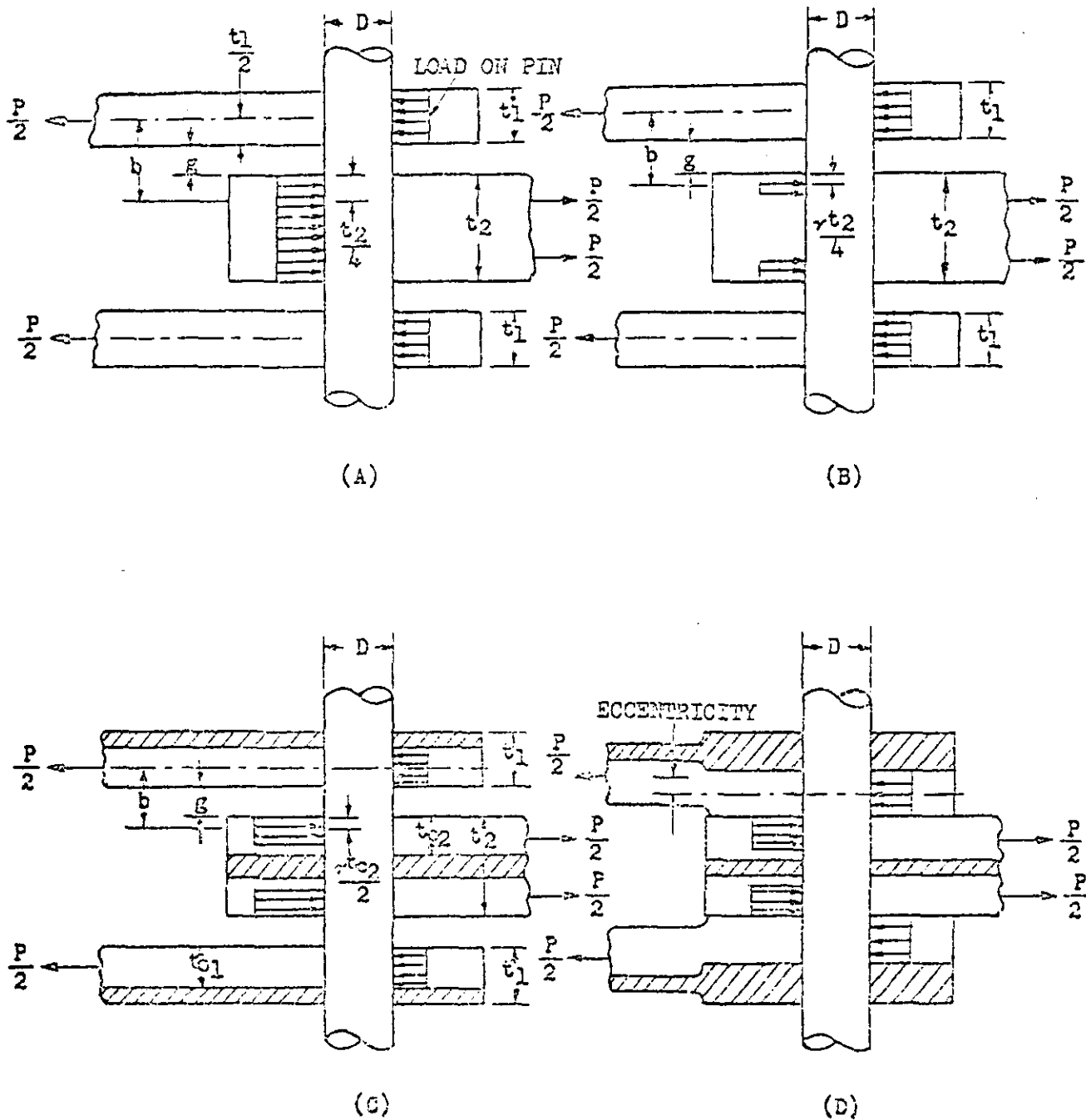
LUG TYPE	A_t	A_{br}	a/D	W/D	D/t
A	0.0625	0.125	0.070	1.500	2.000
G	0.109	0.0938	1.083	2.167	1.500
I	0.125	0.0625	2.000	3.000	1.000
K	0.125	0.0625	1.100	3.000	1.000
M	0.125	0.0625	1.500	3.000	1.000

ALLOYS
7075-T6 PLATE
7075-T6 BILLET
7079-T6 BILLET
2024-T4 PLATE

SPECIMEN THICKNESS = 0.25 INCH

204.4 REFERENCED FIGURES

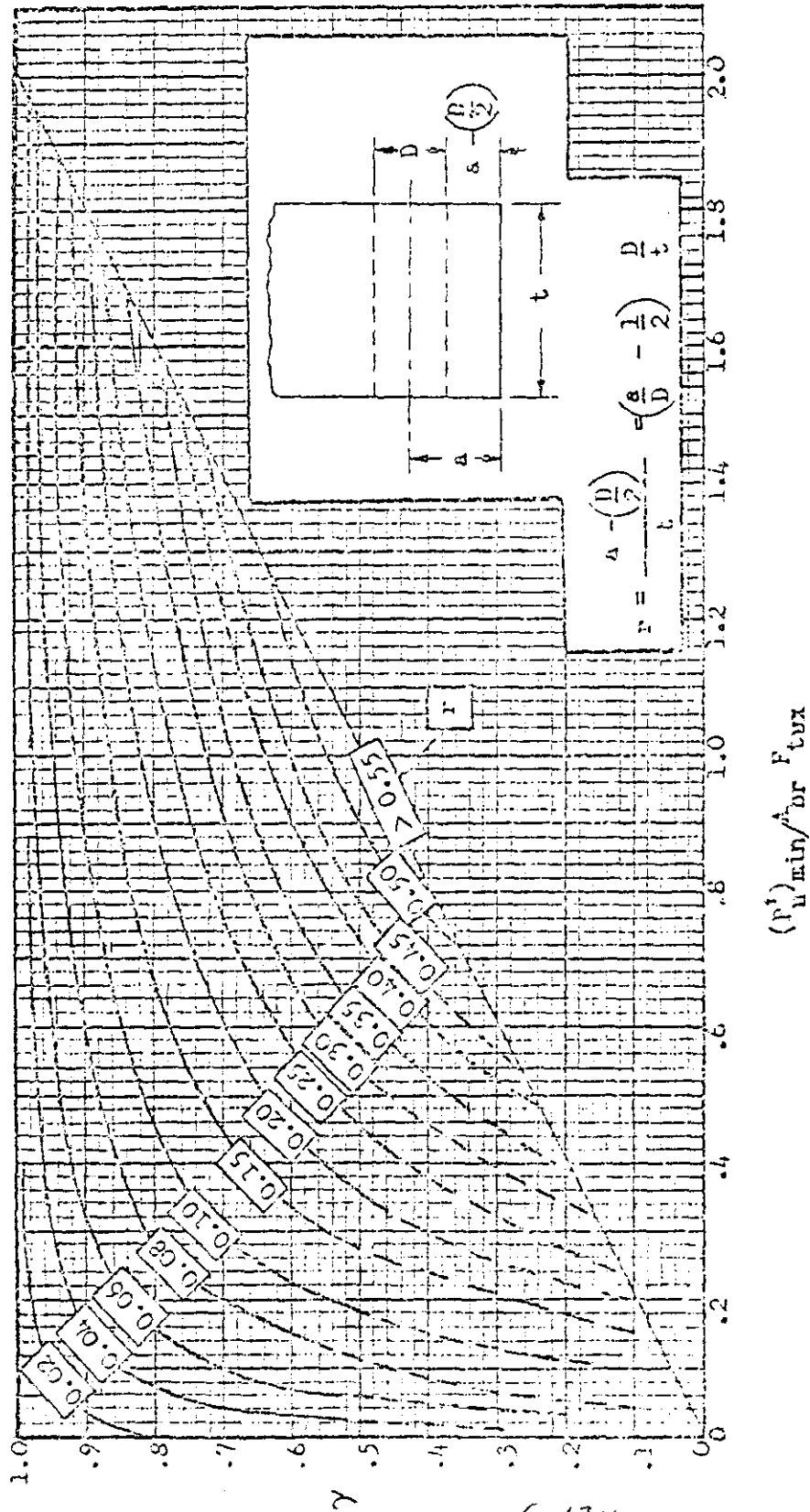
FIGURE 204.4-7



204.4 REFERENCED FIGURES

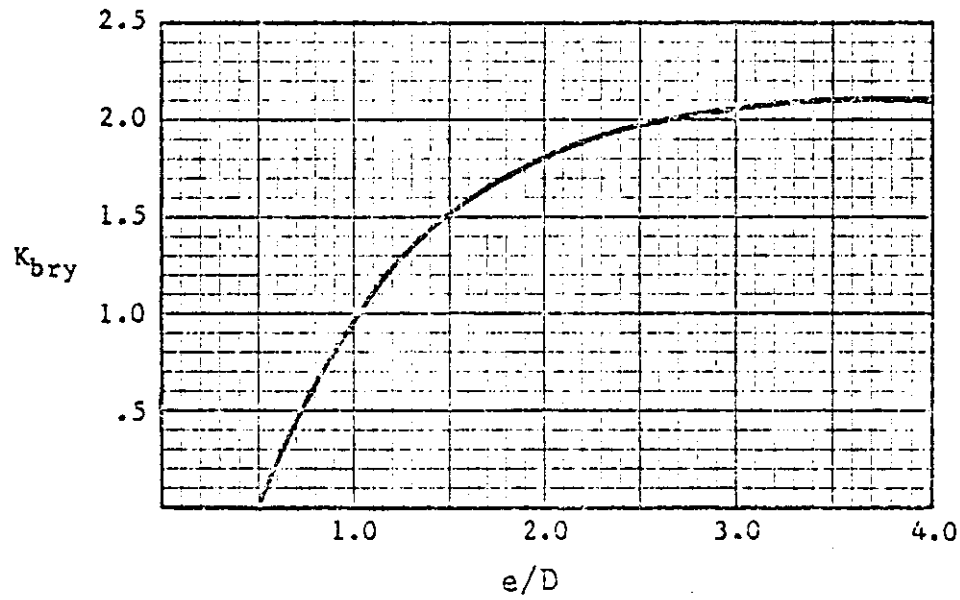
FIGURE 204.4-3

PEAKING FACTORS FOR PIN BENDING



204.4 REFERENCED FIGURES

FIGURE 204.4-9



APPENDIX D

SIZING CALCULATIONS FOR THE SYSTEM MODEL

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed APPENDIX D' OF ISB Jumper DOC.

Author E. O. WEINER

Yes No N/A

[✓] [] []

Problem completely defined.

[✓] [] []

Necessary assumptions explicitly stated and supported.

[] [] [✓]

Computer codes and data files documented..

[✓] [] []

Data used in calculations explicitly stated in document.

[✓] [] []

Data checked for consistency with original source information as applicable.

[✓] [] []

Mathematical derivations checked including dimensional consistency of results.

[] [] [✓]

Models appropriate and used within range of validity or use outside range of established validity justified.

[✓] [] []

Hand calculations checked for errors.

[] [] [✓]

Code run streams correct and consistent with analysis documentation.

[] [] [✓]

Code output consistent with input and with results reported in analysis documentation.

[✓] [] []

Acceptability limits on analytical results applicable and supported. Limits checked against sources.

[✓] [] []

Safety margins consistent with good engineering practices.

[✓] [] []

Conclusions consistent with analytical results and applicable limits.

[✓] [] []

Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number

N/A

Reviewer

John Julyk

Date

1/25/95

Subject System Model Calculations for ISB Jumper ClampOriginator E. O. WeinerDate 1/24/95Checker J. L. JulykDate 1/25/95**1.0 2-in. Jumper Connector Stick Model Sizing Calculations**

The purpose of the stick model development for the jumper connectors was to obtain the internal forces moments distributes from the external pipe loads.

1.1 HOOK: (Uses BEAM4, Reference Drawing: H-2-90174)

$$t_{\text{plate}} := 0.81 \cdot \text{in} = \text{TKY}$$

$$t_{\text{perpendicular}} := 2 \cdot 0.56 \cdot \text{in} \quad t_{\text{perpendicular}} = 1.12 \cdot \text{in} = \text{TKZ}$$

Actual area to be used for K_{Hook} Modification

$$A_{\text{actual}} := t_{\text{plate}} \cdot t_{\text{perpendicular}} \quad A_{\text{actual}} = 0.907 \cdot \text{in}^2$$

K-node is on connector axis

$$I_{\text{Hzz}} := \frac{1}{12} \cdot (A_{\text{actual}} \cdot t_{\text{plate}}^2) \quad I_{\text{Hzz}} = 0.05 \cdot \text{in}^4$$

$$I_{\text{Hyy}} := \frac{1}{12} \cdot (A_{\text{actual}} \cdot t_{\text{perpendicular}}^2) \quad I_{\text{Hyy}} = 0.095 \cdot \text{in}^4$$

For K_{Hook} , Combine hook, nozzle, and stiffnesses
see Appendix B of hook, nozzle, and pin analysis.

$$K_{\text{N1}} := 2.72 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}} \quad K_{\text{N2}} := 3.354 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{Nozzle Stiffness}$$

$$K_{\text{pin}} := 2.565 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{Pin Stiffness}$$

$$K_{\text{H}} := 3 \cdot \left(4.23 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}} \right) \quad \text{Hook Stiffness for three hooks}$$

Combined Stiffness for one hook

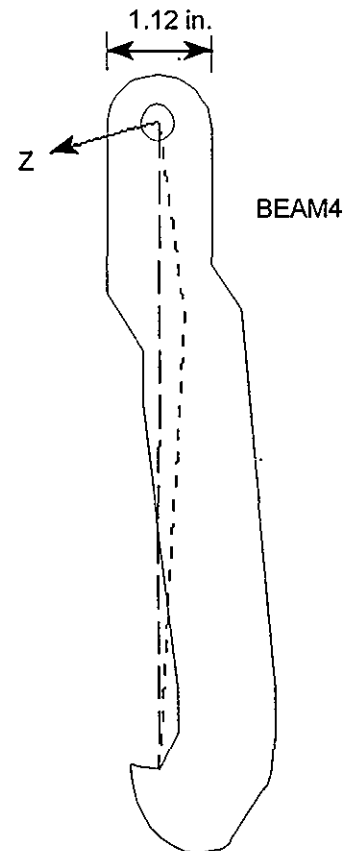
$$K_{\text{Hook}} := \frac{1}{3} \cdot \left(\frac{1}{K_{\text{N1}}} + \frac{1}{K_{\text{N2}}} + \frac{1}{K_{\text{pin}}} + \frac{1}{K_{\text{H}}} \right)^{-1} \quad K_{\text{Hook}} = 2.814 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

$$E_{\text{H}} := 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Modulus of elasticity for hooks, nut and pins
@ room temp (70 deg F, see appendix B)

$$L_{\text{H}} := 7.68 \cdot \text{in}$$

Length of hook



Hook (H-2-90174)

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Subject System Model Calculations for ISB Jumper ClampOriginator E. O. WeinerDate 1/24/95Checker J. L. JulykDate 1/25/95

Calculated Area of hook used in the FEA System Model

$$A_{\text{used}} := \frac{L_H \cdot K_{\text{Hook}}}{E_H} \quad A_{\text{used}} = 0.0745 \cdot \text{in}^2$$

1.2 BLOCK: (Uses BEAM4, Reference Drawing: H-2-821324)

$$R := \frac{3.375 \cdot \text{in} + 2.06 \cdot \text{in}}{2} \quad \text{Approximate radius of Block}$$

$$t_{\text{block}} := \frac{3.375 \cdot \text{in} - 2.06 \cdot \text{in}}{2} \quad \text{Approximate thickness of Block}$$

$$I_{\text{block}} := \pi \cdot R^3 \cdot t_{\text{block}} \quad I_{\text{block}} = 41.453 \cdot \text{in}^4 = I_{zz} = I_{yy} \quad (\text{K-node is in pipe})$$

$$D_{\text{block}} := 3.375 \cdot \text{in} = \text{TKY} = \text{TKZ}$$

$$E_B := 27.4 \cdot 10^6 \cdot \frac{\text{lb}}{\text{in}^2} \quad \text{modulus of elasticity of the block at 250 deg F (see appendix B) for 304 SS}$$

$$K_B := 7.422 \cdot 10^6 \cdot \frac{\text{lb}}{\text{in}} \quad \text{FEA calculated Block Stiffness (Appendix B)}$$

$$L_B := 4.023 \cdot \text{in} - 0.183 \cdot \text{in} + 1.0522 \cdot \text{in} \quad \text{Length of block to point of rotation}$$

$$L_B = 4.892 \cdot \text{in}$$

$$A_B := \frac{L_B \cdot K_B}{E_B} \quad \text{Estimated area of block}$$

$$A_B = 1.325 \cdot \text{in}^2$$

1.3 SCREW: (Uses BEAM4, Reference Drawing: H-2-32421)

$$D_s := 1.03 \cdot \text{in}$$

$$I_s := \frac{\pi}{64} \cdot D_s^4 \quad I_s = 0.055 \cdot \text{in}^4 \quad \text{moment of inertia of screw}$$

$$A_s := \frac{\pi}{4} \cdot D_s^2 \quad A_s = 0.833 \cdot \text{in}^2 \quad \text{area of screw}$$

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Subject System Model Calculations for ISB Jumper Clamp

Originator E. O. Weiner

Date 1/24/95

Checker J. L. Julyk

Date 1/25/95

1.4 NUT: (Uses BEAM4, Reference Drawing: H-2-68209)

K-node on axis

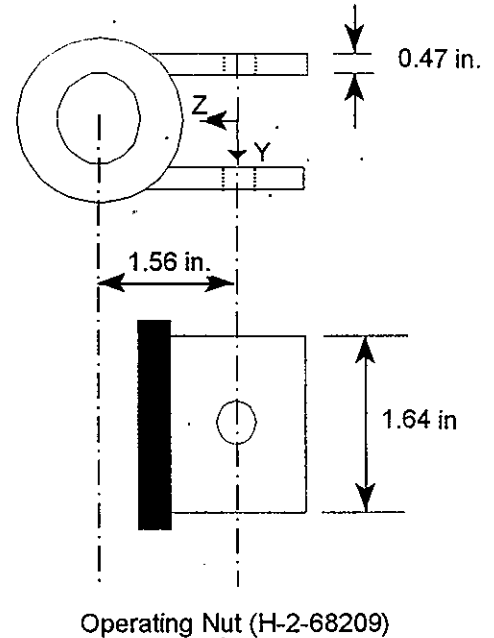
$$I_{Nyy} := \frac{2 \cdot 0.47 \cdot \text{in} \cdot (1.64 \cdot \text{in})^3}{12} \quad I_{Nyy} = 0.346 \cdot \text{in}^4$$

$$I_{Nzz} := \frac{(2 \cdot 0.47 \cdot \text{in})^3 \cdot 1.64 \cdot \text{in}}{12} \quad I_{Nzz} = 0.114 \cdot \text{in}^4$$

$$L_N := 1.56 \cdot \text{in}$$

$$\text{Note: } K_{\text{nut}} := \frac{3 \cdot E_H \cdot I_{Nyy}}{L_N^3} \quad K_{\text{nut}} = 7.918 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}} \gg K_{\text{Hook}}$$

So that the nut flexibility in K_{Hook} is
O.K.



1.4.1 HOOK CHECKS

Bend in hooks should not introduce flexibility to change K_{Hook}

$$\delta_i := \frac{P \cdot \left(\frac{a}{L_i} \right) \cdot L_i^3}{3 \cdot E \cdot I}$$

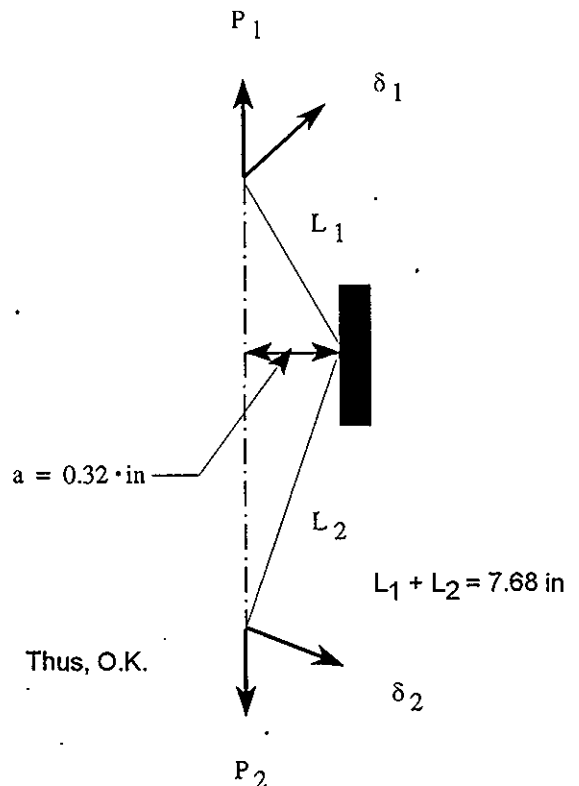
Length at hook and guide location (H-2-90174)

$$a := 0.32 \cdot \text{in}$$

Change in Length

$$\Delta := \sum_i \delta_i \cdot \frac{a}{L_i} = \frac{P \cdot a^2}{3 \cdot E \cdot I} \cdot \sum_i L_i = \frac{P a^2 \cdot L}{3 \cdot E \cdot I}$$

$$k := \frac{P}{\Delta} = \frac{3 \cdot E_H \cdot I_{Hyy}}{a^2 \cdot L_H} = 1.049 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}} \gg K_{\text{Hook}}$$



Thus, O.K.

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Subject System Model Calculations for ISB Jumper ClampOriginator E. O. WeinerDate 1/24/95Checker J. L. JulykDate 1/25/95

Location Guide and hook nodes estimated at $r = 1.56 \text{ in} + 0.32 \text{ in} = 1.88 \text{ in}$. Use cylindrical coordinate system
 $y = 4.64 \text{ in}$, H-2-90174 (center of guide/hook contact)

Location: Block pivot point at $y = -1.0522 \text{ in}$. This is the center of the block/nozzle spherical contact surface
 (H-2-821324).

Location: Hook-Nozzle contact at $r = (3.25 \text{ in} + 2.77 \text{ in})/4 = 1.50 \text{ in}$. and at $y = 0 \text{ in} - 0.12 \text{ in} - 0.50 \text{ in} = -0.62 \text{ in}$.
 (H-2-83572).

Location: Nut/Pin pivot point at $r = 1.56 \text{ in}$ and $y = 7.68 \text{ in} - 0.62 \text{ in} = 7.06 \text{ in}$.

1.5 GUIDE: (Uses BEAM4, Reference Drawing: H-2-68205)

$$b_G := 2 \cdot 1.38 \text{ in} - 0.81 \text{ in} \quad b_G = 1.95 \text{ in} = \text{TKY}$$

$$h_G := 1.0 \text{ in} = \text{TKZ}$$

Calculated moment of Inertia of guide

$$I_{Gyy} := \frac{b_G \cdot h_G^3}{12} \quad I_{Gzz} := \frac{2 \cdot h_G \cdot \left(\frac{b_G}{2}\right)^3}{12}$$

$$I_{Gyy} = 0.162 \cdot \text{in}^4 \quad I_{Gzz} = 0.154 \cdot \text{in}^4$$

Area of guide

$$A_G := b_G \cdot h_G \quad A_G = 1.95 \cdot \text{in}^2$$

1.5.1 HOOK STRESSES

Stress factor for hook membrane stresses to account for area-stiffness modifications

$$f_{\text{mem}} := \frac{A_{\text{used}}}{A_{\text{actual}}} \quad f_{\text{mem}} = 0.082$$

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Subject System Model Calculations for ISB Jumper ClampOriginator E. O. WeinerDate 1/24/95Checker J. L. JulykDate 1/25/95**1.5.2 BLOCK RIGID BODY MODE**

Without guide-hook engagement, the block spins about the y-axis. A rotational spring is used to ground the rotations at are much smaller than what the hooks present to the nut.

$$K_{zz} := \frac{3 \cdot E_H \cdot I_{Hzz}}{L_H^3} \quad K_{zz} = 9.526 \cdot 10^3 \cdot \frac{\text{lbf}}{\text{in}}$$

$$R_{\text{nut}} := 1.56 \cdot \text{in}$$

$$K_{\text{rot}} := 0.01 \cdot 3 \cdot K_{zz} \cdot R_{\text{nut}}^2 \quad K_{\text{rot}} = 696 \cdot \text{lbf} \cdot \text{in}$$

Therefore, K_{rot} used in the FEA Jumper Clamp System Model is 650 lbf-in.

1.6 BOUNDARY CONDITIONS AND COUPLING

1.0) Pin: Couple nut-hook all DOFs except for pin rotation

2.0) Guide/Hook: Couple tangential DOF (engaged)

3.0) Hook/Nozzle: Ball Joint

4.0) Screw/Block: Ball Joint

5.0) Block/Nozzle: Ball Joint

2.0 3-in. Jumper Connector Stick Model Sizing Calculations

The purpose of the stick model development for the jumper connectors was to obtain the internal forces moments distributes from the external pipe loads.

2.1 HOOK: (Uses BEAM4, Reference Drawing: H-2-90175)

$$t_{\text{plate}} := 1.0 \cdot \text{in} = \text{TKY}$$

$$t_{\text{perpendicular}} := 2 \cdot 0.68 \cdot \text{in} \quad t_{\text{perpendicular}} = 1.36 \cdot \text{in} = \text{TKZ}$$

ANALYTICAL CALCULATIONS

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Subject System Model Calculations for ISB Jumper ClampOriginator E. O. WeinerDate 1/24/95Checker J. L. JulykDate 1/25/95Actual area to be used for K_{Hook} Modification

$$A_{\text{actual}} := t_{\text{plate}} \cdot t_{\text{perpendicular}} \quad A_{\text{actual}} = 1.36 \cdot \text{in}^2$$

K-node is on connector axis

$$I_{\text{Hzz}} := \frac{1}{12} \cdot (A_{\text{actual}} \cdot t_{\text{plate}}^2) \quad I_{\text{Hzz}} = 0.113 \cdot \text{in}^4$$

$$I_{\text{Hyy}} := \frac{1}{12} \cdot (A_{\text{actual}} \cdot t_{\text{perpendicular}}^2) \quad I_{\text{Hyy}} = 0.21 \cdot \text{in}^4$$

For K_{Hook} , Combine hook, nozzle, pin, and nut
(see Appendix B of block analysis)

$$K_{\text{N1}} := 4.94 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}} \quad K_{\text{N2}} := 5.45 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{Nozzle Stiffness}$$

$$K_{\text{pin}} := 3.127 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{Pin Stiffness for the three pins}$$

$$K_{\text{H}} := 3 \cdot \left[(3.376 \cdot 10^5) \cdot \frac{\text{lbf}}{\text{in}} \right] \quad \text{Hook Stiffness for three hooks}$$

$$K_{\text{Hook}} := \frac{1}{3} \cdot \left(\frac{1}{K_{\text{N1}}} + \frac{1}{K_{\text{N2}}} + \frac{1}{K_{\text{H}}} + \frac{1}{K_{\text{pin}}} \right)^{-1}$$

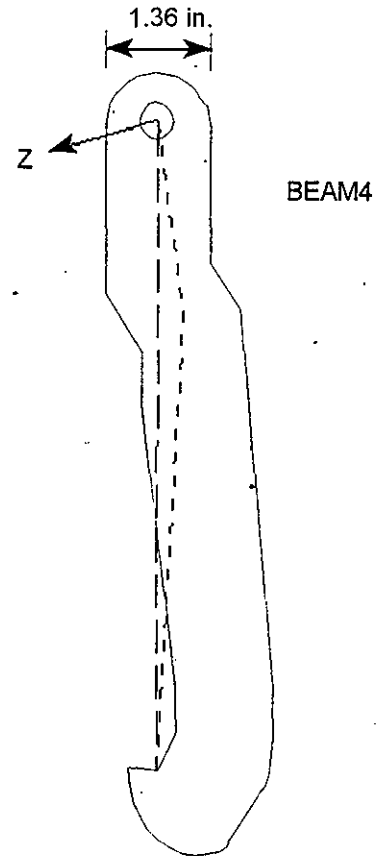
$$K_{\text{Hook}} = 2.543 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{Calculated Hook Stiffness for one hook}$$

$$E_{\text{H}} := 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{Modulus of elasticity for hooks, nut and pins}$$

@ room temp (70 deg F, see appendix B)

$$L_{\text{H}} := 11.259 \cdot \text{in} \quad \text{Length of hook}$$

$$A_{\text{used}} := \frac{L_{\text{H}} \cdot K_{\text{Hook}}}{E_{\text{H}}} \quad A_{\text{used}} = 0.099 \cdot \text{in}^2 \quad \text{Calculated Area of hook used in the FEA System Model}$$



Hook (H-2-90175)

ANALYTICAL CALCULATIONS

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Subject System Model Calculations for ISB Jumper ClampOriginator E. O. WeinerDate 1/24/95Checker J. L. JulykDate 1/25/95**2.2 BLOCK: (Uses BEAM4, Reference Drawing: H-2-821325)**

$$R := \frac{5.0 \cdot \text{in} + 3.06 \cdot \text{in}}{2} \quad \text{Approximate radius of Block}$$

$$t_{\text{block}} := \frac{5.0 \cdot \text{in} - 3.06 \cdot \text{in}}{2} \quad \text{Approximate thickness of Block}$$

$$I_{\text{block}} := \pi \cdot R^3 \cdot t_{\text{block}} \quad I_{\text{block}} = 199.451 \cdot \text{in}^4 = I_{zz} = I_{yy} \quad (\text{K-node is in pipe})$$

$$D_{\text{block}} := 5.0 \cdot \text{in} \quad = \text{TKY} = \text{TKZ}$$

$$E_B := 27.4 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2} \quad \text{modulus of elasticity of the block at 250 deg F} \\ \text{(see appendix B) for 304 SS}$$

$$K_B := 1.049 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{FEA calculated Block Stiffness (Appendix BB)}$$

$$L_B := 6.217 \cdot \text{in} - 0.248 \cdot \text{in} + 1.57 \cdot \text{in} \quad \text{Length of block} \quad L_B = 7.539 \cdot \text{in}$$

$$A_B := \frac{L_B \cdot K_B}{E_B} \quad \text{area of block} \quad A_B = 2.886 \cdot \text{in}^2$$

2.3 SCREW: (Uses BEAM4, Reference Drawing: H-2-32431)

$$D_s := 1.438 \cdot \text{in}$$

$$I_s := \frac{\pi}{64} \cdot D_s^4 \quad I_s = 0.21 \cdot \text{in}^4$$

$$A_s := \frac{\pi}{4} \cdot D_s^2 \quad A_s = 1.624 \cdot \text{in}^2$$

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2.4 NUT: (Uses BEAM4, Reference Drawing: H-2-68210)

K-node on axis

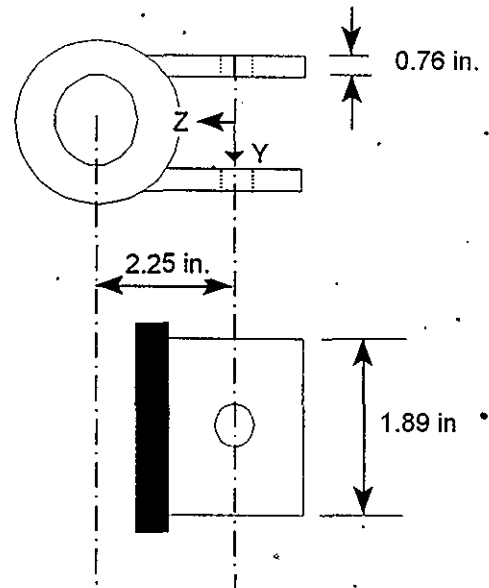
$$I_{Nyy} := \frac{2 \cdot 0.76 \cdot \text{in} \cdot (1.89 \cdot \text{in})^3}{12} \quad I_{Nyy} = 0.855 \cdot \text{in}^4$$

$$I_{Nzz} := \frac{(2 \cdot 0.76 \cdot \text{in})^3 \cdot 1.89 \cdot \text{in}}{12} \quad I_{Nzz} = 0.553 \cdot \text{in}^4$$

$$L_N := 2.25 \cdot \text{in}$$

Note: $K_{nut} := \frac{3 \cdot E_H \cdot I_{Nyy}}{L_N^3} \quad K_{nut} = 6.532 \cdot 10^6 \cdot \frac{\text{lb}}{\text{in}} \gg K_{Hook}$

So that the nut flexibility in K_{Hook} is O.K.



Operating Nut (H-2-68210)

2.4.1 HOOK CHECKS

Bend in hooks should not introduce flexibility to change K_{Hook}

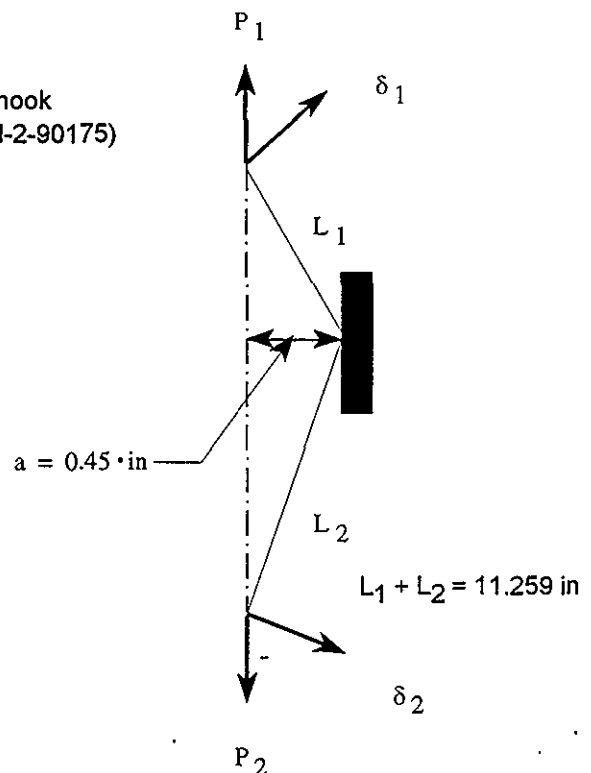
$$\delta_i := \frac{P \cdot \left(\frac{a}{L_i} \right) \cdot L_i^3}{3 \cdot E \cdot I} \quad a := 0.45 \cdot \text{in} \quad \text{Estimated Length at hook and guide location (H-2-90175)}$$

Change in Length

$$\Delta := \sum_i \delta_i \cdot \frac{a}{L_i} = \frac{P \cdot a^2}{3 \cdot E \cdot I} \cdot \sum_i L_i = \frac{P a^2 \cdot L}{3 \cdot E \cdot I}$$

$$k := \frac{P}{\Delta} = \frac{3 \cdot E_H \cdot I_{Hy}}{a^2 \cdot L_H} = 7.999 \cdot 10^6 \cdot \frac{\text{lb}}{\text{in}}$$

$\gg K_{Hook}$ Thus, O.K.



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Location: Guide and hook nodes at an estimated $r = 2.25 \text{ in} + 0.45 \text{ in} = 2.70 \text{ in}$. Use cylindrical coordinate system $y = 7.68 \text{ in}$, estimated from H-2-68210 and H-2-90175 (center of guide/hook contact)

Location: Block pivot point at $y = -1.57 \text{ in}$. This is the center of the block/nozzle spherical contact surface, from drawing H-2-821325.

Location: Hook-Nozzle contact at $r = (4.87 \text{ in} + 4.43 \text{ in})/4 = 2.33 \text{ in}$. and at $y = 0 \text{ in} - 0.20 \text{ in} - 0.625 \text{ in} = -0.83 \text{ in}$ (Estimated from H-2-83573).

Location: Nut/Pin pivot point at $r = 2.25 \text{ in}$ and $y = 11.259 \text{ in} - 0.83 \text{ in} = 10.43 \text{ in}$. (Estimated from H-2-90175).

2.5 GUIDE: (Uses BEAM4, Reference Drawing: H-2-68206)

$$b_G := 2 \cdot 1.81 \cdot \text{in} - 1.0 \cdot \text{in} \quad b_G = 2.62 \cdot \text{in} = \text{TKY}$$

$$h_G := 1.25 \cdot \text{in} = \text{TKZ}$$

$$I_{Gyy} := \frac{b_G \cdot h_G^3}{12} \quad I_{Gyy} = 0.426 \cdot \text{in}^4$$

$$I_{Gzz} := \frac{2 \cdot h_G \cdot \left(\frac{b_G}{2}\right)^3}{12} \quad I_{Gzz} = 0.468 \cdot \text{in}^4$$

$$A_G := b_G \cdot h_G \quad A_G = 3.275 \cdot \text{in}^2$$

2.5.1 HOOK STRESSES

Stress factor for hook membrane stresses to account for area-stiffness modifications

$$f_{\text{mem}} := \frac{A_{\text{used}}}{A_{\text{actual}}} \quad f_{\text{mem}} = 0.073$$

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2.5.2 BLOCK RIGID BODY MODE

Without guide-hook engagement, the block spins about the y-axis. A rotational spring is used to ground the rotations at are much smaller than what the hooks present to the nut.

$$K_{zz} := \frac{3 \cdot E_H \cdot I_{Hzz}}{L_H^3} \quad K_{zz} = 6.908 \cdot 10^3 \cdot \frac{\text{lbf}}{\text{in}}$$

$$R_{\text{nut}} := 2.25 \cdot \text{in}$$

$$K_{\text{rot}} := 0.01 \cdot 3 \cdot K_{zz} \cdot R_{\text{nut}}^2 \quad K_{\text{rot}} = 1049 \cdot \text{lbf} \cdot \text{in}$$

Therefore, K_{rot} used in the FEA Jumper Clamp System Model is 1050 lbf-in.

2.6 BOUNDARY CONDITIONS AND COUPLING

1.0) Pin: Couple nut-hook all DOFs except for pin rotation

2.0) Guide/Hook: Couple tangential DOF (engaged)

3.0) Hook/Nozzle: Ball Joint

4.0) Screw/Block: Ball Joint

5.0) Block/Nozzle: Ball Joint

3.0 4-in. Jumper Connector Stick Model Sizing Calculations

The purpose of the stick model development for the jumper connectors was to obtain the internal forces moments distributes from the external pipe loads.

3.1 HOOK: (Uses BEAM4, Reference Drawing: H-2-90176)

$$t_{\text{plate}} := 1.18 \cdot \text{in} = \text{TKY}$$

$$t_{\text{perpendicular}} := 2 \cdot 0.81 \cdot \text{in} \quad t_{\text{perpendicular}} = 1.62 \cdot \text{in} = \text{TKZ}$$

Estimated area to be used for K_{Hook} Modification

$$A_{\text{actual}} := t_{\text{plate}} \cdot t_{\text{perpendicular}} \quad A_{\text{actual}} = 1.912 \cdot \text{in}^2$$

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K-node is on connector axis

$$I_{Hzz} = \frac{1}{12} \cdot (A_{\text{actual}} \cdot t_{\text{plate}}^2)$$

$$I_{Hzz} = 0.222 \cdot \text{in}^4$$

$$I_{Hyy} = \frac{1}{12} \cdot (A_{\text{actual}} \cdot t_{\text{perpendicular}}^2)$$

$$I_{Hyy} = 0.418 \cdot \text{in}^4$$

For K_{Hook} , Combine hook, nozzle, pin, and nut
(see Appendix B of block analysis)

$$K_{N1} = 5.88 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}}$$

$$K_{N2} = 7.18 \cdot 10^8 \cdot \frac{\text{lbf}}{\text{in}}$$

Nozzle Stiffness

$$K_{\text{pin}} = 3.321 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}}$$

Pin Stiffness for the three pins

$$K_H = 3 \cdot \left[(3.374 \cdot 10^5) \cdot \frac{\text{lbf}}{\text{in}} \right]$$

FEA Hook Stiffness for three hooks

$$K_{\text{Hook}} = \frac{1}{3} \cdot \left(\frac{1}{K_{N1}} + \frac{1}{K_{N2}} + \frac{1}{K_H} + \frac{1}{K_{\text{pin}}} \right)^{-1}$$

$$K_{\text{Hook}} = 2.58 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

Calculated Hook Stiffness for one hook

$$E_H = 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Modulus of elasticity for hooks, nut and pins
@ room temp (70 deg F, see appendix B)

$$L_H = 12.578 \cdot \text{in}$$

Length of hook

$$A_{\text{used}} = \frac{L_H \cdot K_{\text{Hook}}}{E_H}$$

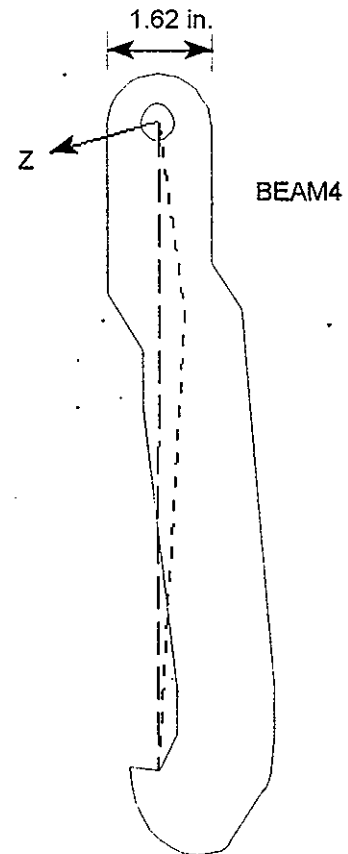
$$A_{\text{used}} = 0.112 \cdot \text{in}^2$$

Calculated Area of hook used in the
FEA System Model

3.2 BLOCK: (Uses BEAM4, Reference Drawing: H-2-821326)

$$R = \frac{6.37 \cdot \text{in} + 4.03 \cdot \text{in}}{2}$$

Approximate radius of Block



Hook (H-2-90176)

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$$t_{\text{block}} := \frac{6.37 \cdot \text{in} - 4.03 \cdot \text{in}}{2}$$

Approximate thickness of Block

$$I_{\text{block}} := \pi \cdot R^3 \cdot t_{\text{block}}$$

$$I_{\text{block}} = 516.828 \cdot \text{in}^4 = I_{zz} = I_{yy} \quad (\text{K-node is in pipe})$$

$$D_{\text{block}} := 6.37 \cdot \text{in}$$

$$= \text{TKY} = \text{TKZ}$$

$$K_B := 1.404 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}}$$

FEA calculated Block Stiffness (Appendix B)

$$L_B := 7.141 \cdot \text{in} + 2.06 \cdot \text{in} - 0.248 \cdot \text{in} \quad \text{Length of block} \quad L_B = 8.953 \cdot \text{in}$$

$$A_B := \frac{L_B \cdot K_B}{E_B}$$

area of block

$$A_B = 4.588 \cdot \text{in}^2$$

3.3 SCREW: (Uses BEAM4, Reference Drawing: H-2-32441)

$$D_s := 1.703 \cdot \text{in}$$

$$I_s := \frac{\pi \cdot D_s^4}{64} \quad I_s = 0.413 \cdot \text{in}^4$$

$$A_s := \frac{\pi \cdot D_s^2}{4} \quad A_s = 2.278 \cdot \text{in}^2$$

3.4 NUT: (Uses BEAM4, Reference Drawing: H-2-68211)

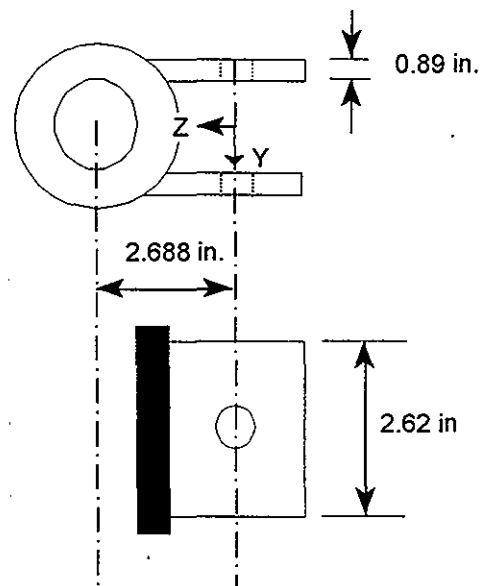
K-node on axis

$$I_{Nyy} := \frac{2 \cdot 0.89 \cdot \text{in} \cdot (2.62 \cdot \text{in})^3}{12} \quad I_{Nyy} = 2.668 \cdot \text{in}^4$$

$$I_{Nzz} := \frac{(2 \cdot 0.89 \cdot \text{in})^3 \cdot 2.62 \cdot \text{in}}{12} \quad I_{Nzz} = 1.231 \cdot \text{in}^4$$

$$L_N := 2.688 \cdot \text{in}$$

$$\text{Note: } K_{\text{nut}} := \frac{3 \cdot E_H \cdot I_{Nyy}}{L_N^3} \quad K_{\text{nut}} = 1.195 \cdot 10^7 \cdot \frac{\text{lbf}}{\text{in}} \gg K_{\text{Hook}}$$

So that the nut flexibility in K_{Hook} is O.K.

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3.4.1 HOOK CHECKS

Bend in hooks should not introduce flexibility to change K_{Hook}

$$\delta_i := \frac{P \cdot \left(\frac{a}{L_i} \right) \cdot L_i^3}{3 \cdot E \cdot I} \quad a := 0.75 \cdot \text{in} \quad \text{Estimated Length at hook and guide location (H-2-90176)}$$

Change in Length

$$\Delta := \sum_i \delta_i \cdot \frac{a}{L_i} = \frac{P \cdot a^2}{3 \cdot E \cdot I} \cdot \sum_i L_i = \frac{P a^2 \cdot L}{3 \cdot E \cdot I}$$

$$k := \frac{P}{\Delta} = \frac{3 \cdot E \cdot I_{Hy}}{a^2 \cdot L_H} = 5.141 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}} \gg K_{Hook} \quad \text{Thus, O.K.}$$

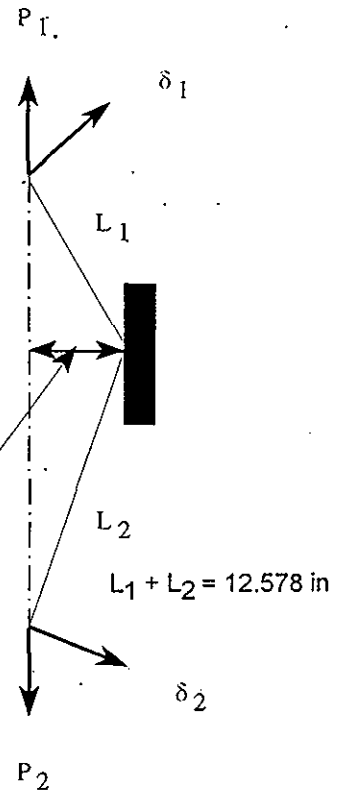
Location: Guide and hook nodes at $r = 2.688 \text{ in} + 0.75 \text{ in} = 3.438 \text{ in}$.Use cylindrical coordinate system $y = 8.45 \text{ in}$, from H-2-68211 and H-2-90176 (center of guide/hook contact)Location: Block pivot point at $y = -2.06 \text{ in}$. This is the center of the block/nozzle spherical contact surface, from drawing H-2-821326.Location: Hook-Nozzle contact at $r = (6.06 \text{ in} + 5.50 \text{ in})/4 = 2.89 \text{ in}$. and at $y = 0 \text{ in} - 0.10 \text{ in} - 0.75 \text{ in} = -0.85 \text{ in}$ (from H-2-83574).Location: Nut/Pin pivot point at $r = 2.688 \text{ in}$ and $y = 12.578 \text{ in} - 0.85 \text{ in} = 11.73 \text{ in}$. (from H-2-90176)

3.5 GUIDE: (Uses BEAM4, Reference Drawing: H-2-68207)

$$b_G := 2 \cdot 1.87 \cdot \text{in} - 1.18 \cdot \text{in} \quad b_G = 2.56 \cdot \text{in} = \text{TKY}$$

$$h_G := 1.25 \cdot \text{in} = \text{TKZ}$$

$$I_{Gyy} := \frac{b_G \cdot h_G^3}{12} \quad I_{Gyy} = 0.417 \cdot \text{in}^4$$



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$$I_{Gzz} := \frac{2 \cdot h_G \cdot \left(\frac{b_G}{2}\right)^3}{12} \quad I_{Gzz} = 0.437 \cdot \text{in}^4$$

$$A_G := b_G \cdot h_G \quad A_G = 3.2 \cdot \text{in}^2$$

3.5.1 HOOK STRESSES

Stress factor for hook membrane stresses to account for area-stiffness modifications

$$f_{\text{mem}} := \frac{A_{\text{used}}}{A_{\text{actual}}} \quad f_{\text{mem}} = 0.059$$

3.5.2 BLOCK RIGID BODY MODE

Without guide-hook engagement, the block spins about the y-axis. A rotational spring is used to ground the rotations at are much smaller than what the hooks present to the nut.

$$K_{zz} := \frac{3 \cdot E_H \cdot I_{Hzz}}{L_H^3} \quad K_{zz} = 9.698 \cdot 10^3 \cdot \frac{\text{lbf}}{\text{in}}$$

$$R_{\text{nut}} := 2.688 \cdot \text{in}$$

$$K_{\text{rot}} := 0.01 \cdot 3 \cdot K_{zz} \cdot R_{\text{nut}}^2 \quad K_{\text{rot}} = 2102 \cdot \text{lbf} \cdot \text{in}$$

Therefore, K_{rot} used in the FEA Jumper Clamp System Model is 2000 lbf-in.

3.6 BOUNDARY CONDITIONS AND COUPLING

- 1.0) Pin: Couple nut-hook all DOFs except for pin rotation
- 2.0) Guide/Hook: Couple tangential DOF (engaged)
- 3.0) Hook/Nozzle: Ball Joint
- 4.0) Screw/Block: Ball Joint
- 5.0) Block/Nozzle: Ball Joint

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4.0 REFERENCES

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WHC, 1985a, *Details, 3" Connector Installation*, Drawing No. H-2-32431, Rev. 15, Westinghouse Hanford Company, Richland, Washington.

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WHC, 1993a, *Hook-2" Connector Purex/Redox Type*, Drawing No. H-2-90174, Rev. 7, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993b, *Hook 3" Connector, Purex/Redox Type*, Drawing No. H-2-90175, Rev. 6, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993c, *2" Male Nozzle Purex Type/HWVP Connector*, Drawing No. H-2-83572, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993d, *Male Nozzle, 3" Purex Type/HWVP Connectors*, Drawing No. H-2-83573, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993e, *Male Nozzle, 4" Purex Type/HWVP Connectors*, Drawing No. H-2-83574, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994a, *Integral Seal Block- 2' Jumper Connector*, Drawing No. H-2-821324, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994b, *Integral Seal Block- 3' Jumper Connector*, Drawing No. H-2-821325, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994c, *Integral Seal Block- 4' Jumper Connector*, Drawing No. H-2-821326, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

APPENDIX E

AXISYMMERTIC SCREW/BLOCK INTERACTION FINITE-ELEMENT MODEL

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Appendix "E" Axisymmetric Screw/Block Interaction Model

Author E. O. Weiner

Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☐	☐	☒	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number

95-002

Reviewer

John Julius

Date

1/25/95

1.0 INTRODUCTION

Inelastic finite element analysis of an axisymmetric model of the top of the 2-in. block was carried out to demonstrate that the region has considerably more strength than elastic analysis might indicate. The screw-block interface was modelled with contact elements. Increased loading from the screw results could produce a spreading of the contact area over the full screw diameter before significant deformation occurs. This appendix serves to justify the modelling consideration of Appendix E that place the axial screw load on the block over the full screw diameter.

2.0 DISCUSSION

Model details are given in Section 4.0, while mesh plots are given in Section 5.2. The ANSYS (1992) system was used with SOLID42 elements for the block and CONTACT48 elements for the interface. The screw material was modelled with 100 ksi yield material, while the block has a yield strength of 26.5 ksi.

Resulting plots in Section 5.2 shows a concentration of plastic strains under the initial bearing point at the center, at the low loading of Step 2 (see the load-displacement table of Section 5.1). This is expected from the classic contact problem with initial contact. From the stress intensities at the same load level, one would expect that a $P_t + P_b$ calculation along the axis would soon exceed $1.5S_m$ (about 30 ksi). At Step 6 with four times the load, a failure mode is yet to be identified. At Step 8 with six times the load, a region with substantially less than a 1% average strain has developed through the block thickness at the outside diameter of the screw. This is considered a conservative measure of collapse in accordance for ASME (1992) Section VIII 4-136.3 which permits loading to 2/3 of a lower bound collapse load. Thus a permissible load of $4.76 \times .667 = 31.8$ kip is indicated, 50% more than that derived in Appendix E. The force-displacement plot of Section 5.2 shows that the collapse criterion of 6-153 is satisfied at Step 8. At this point, full contact has been made as evidenced by the majority of yielding taking place under the outer diameter of the screw.

3.0 CONCLUSIONS

Appendix E evaluates the capacity of the block top region with a uniform pressure over the full screw diameter. Results of this section show that full contact is achieved before collapse of the top, and therefore the modelling consideration of Appendix E is justified.

4.0 MODEL DETAILS

4.1 MODEL DATABASE

The following are CDWRITE model details. Nodes and elements are deleted as they are shown in grid plots.

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CM,_CDWELEM,ELEM ! get list of users selected elements
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CMSEL,S,_CDWELEM ! restore users selected elements
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PRED,OFF,,OFF
ERESX,DEFA
ACEL, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00
OMEGA, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00, 0
DOMEGA, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00
CGLOC, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00
CGOMEG, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00
DCGOME, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00

```

```
IRLF, 0
D, 49,UY , 0.000000000E+00, 0.000000000E+00
D, 55,UY , 0.000000000E+00, 0.000000000E+00
D, 56,UY , 0.000000000E+00, 0.000000000E+00
D, 57,UY , 0.000000000E+00, 0.000000000E+00
D, 58,UY , 0.000000000E+00, 0.000000000E+00
D, 59,UY , 0.000000000E+00, 0.000000000E+00
D, 60,UY , 0.000000000E+00, 0.000000000E+00
D, 658,UY , -6.800000000E-02, 0.000000000E+00
/GOPR
```

4.2 LOAD STEPS

Note: dnode is node 658, the top center node of the screw section.

```
d,dnode,uy,-.0610
solve
nsubst,2
d,dnode,uy,-.0620
solve
d,dnode,uy,-.0630
solve
d,dnode,uy,-.0640
solve
nsubst,3
d,dnode,uy,-.0660
solve
d,dnode,uy,-.0680
solve
d,dnode,uy,-.0700
solve
d,dnode,uy,-.0730
solve
d,dnode,uy,-.0760
solve
d,dnode,uy,-.0800
solve
```

4.3 POST26 DIRECTIVES

```
/post26
*status
NSOL,2,cnode,U,Y
RFORCE,3,dnode,F,Y
ADD,4,2,,,cdisp1,,, -1
ADD,5,3,,,sforce,,, -1
PRVAR,2,3,4,5
/AXLAB,X,cdisp1
/AXLAB,Y,sforce
XVAR,4
PLVAR,5
```

5.0 RESULTS

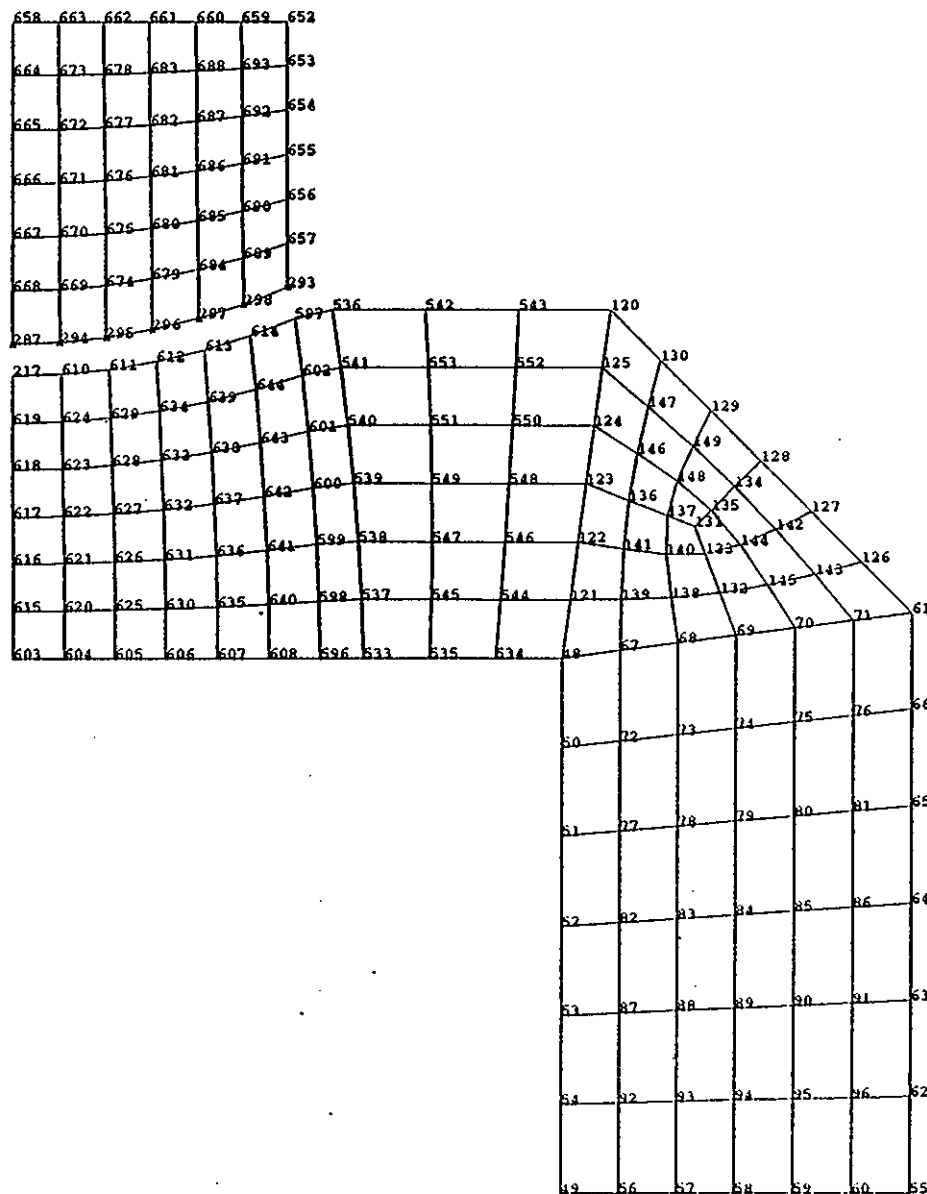
5.1 LOAD-DISPLACEMENT TABLE

***** ANSYS POST26 VARIABLE LISTING *****

TIME	217 UY UY	658 FY FY	4 ADD cdispl	5 ADD sforce
1.0000	-0.647154E-03	-2855.54	0.647154E-03	2855.54
2.0000	-0.137605E-02	-6914.50	0.137605E-02	6914.50
3.0000	-0.217926E-02	-11835.0	0.217926E-02	11835.0
4.0000	-0.306573E-02	-16659.9	0.306573E-02	16659.9
5.0000	-0.496746E-02	-25577.1	0.496746E-02	25577.1
6.0000	-0.695390E-02	-33519.1	0.695390E-02	33519.1
7.0000	-0.897545E-02	-40142.4	0.897545E-02	40142.4
8.0000	-0.119913E-01	-47660.2	0.119913E-01	47660.2

5.2 PLOTS

1

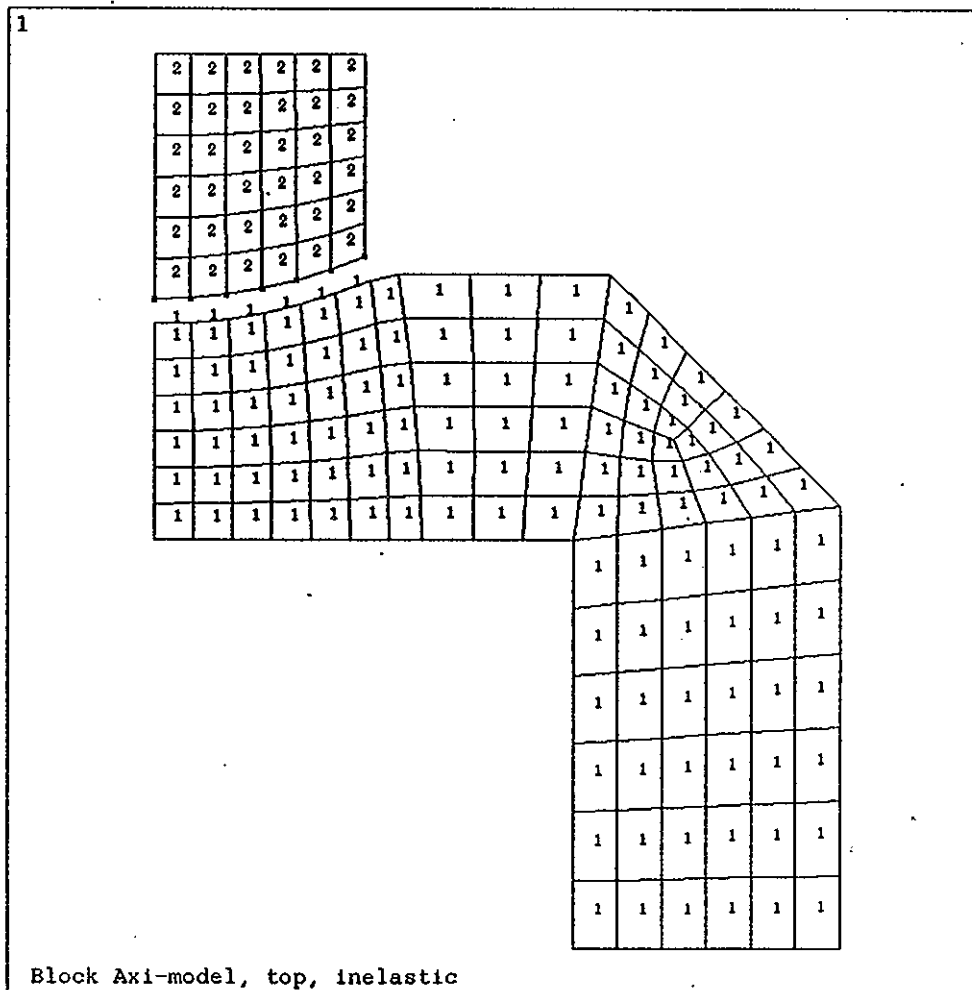


ANSYS 5.0 A
OCT 21 1994
13:55:18
PLOT NO. 1
ELEMENTS
TYPE NUM

ZV =1
DIST=1.205
XF =0.84375
YF. =3.405
PRECISE HIDDEN

Block Axi-model, top, inelastic

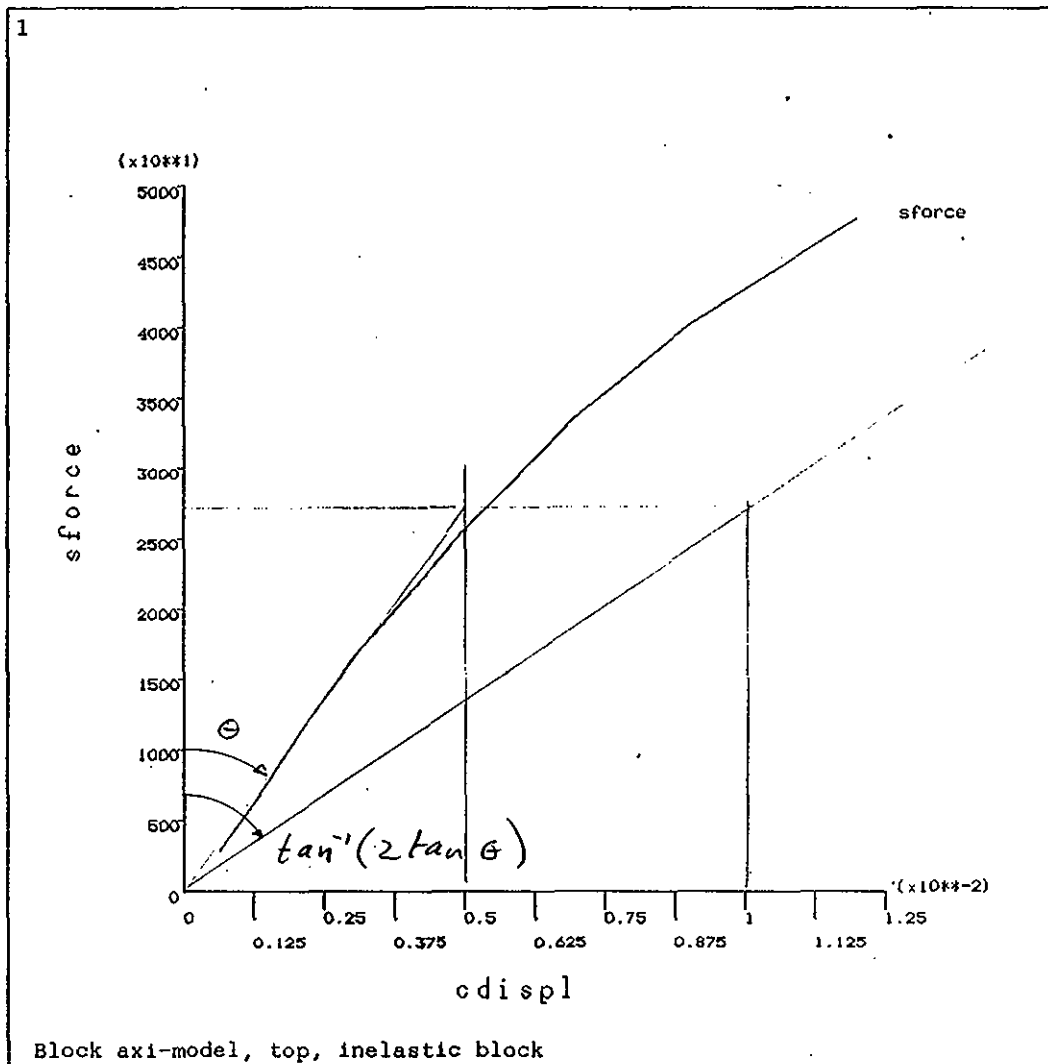
E-7



ANSYS 5.0 A
 JAN 12 1995
 13:33:04
 ELEMENTS
 MAT NOM

ZV =1
 *DIST=1.205
 *XF =0.84375
 *YF =3.405

E-9

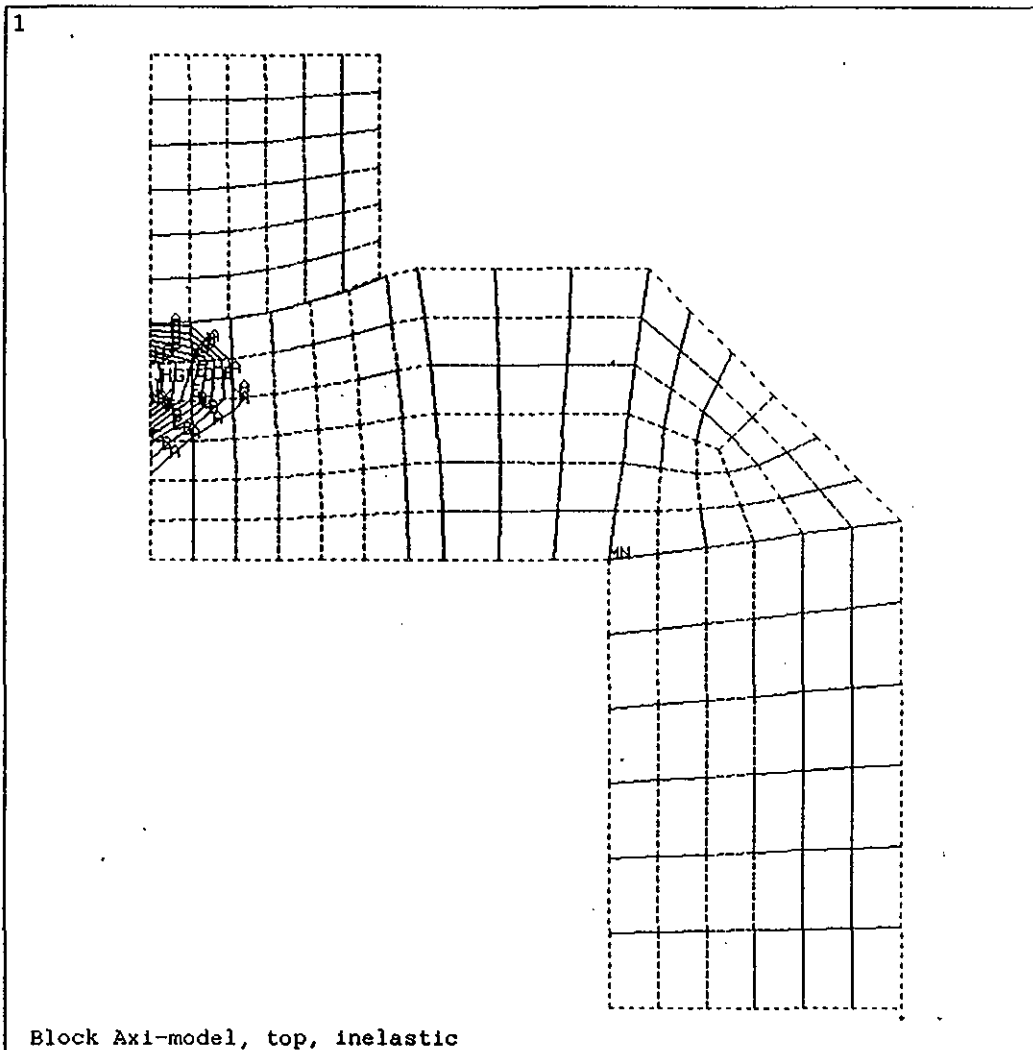


ANSYS 5.0 A
JAN 12 1995
14:23:39
POST26

ZV =1
DIST=0.75
XF. =0.5
YF =0.5
ZF =0.5
XRTO=1

WHC-SD-W236A-DA-002
REVISION 0

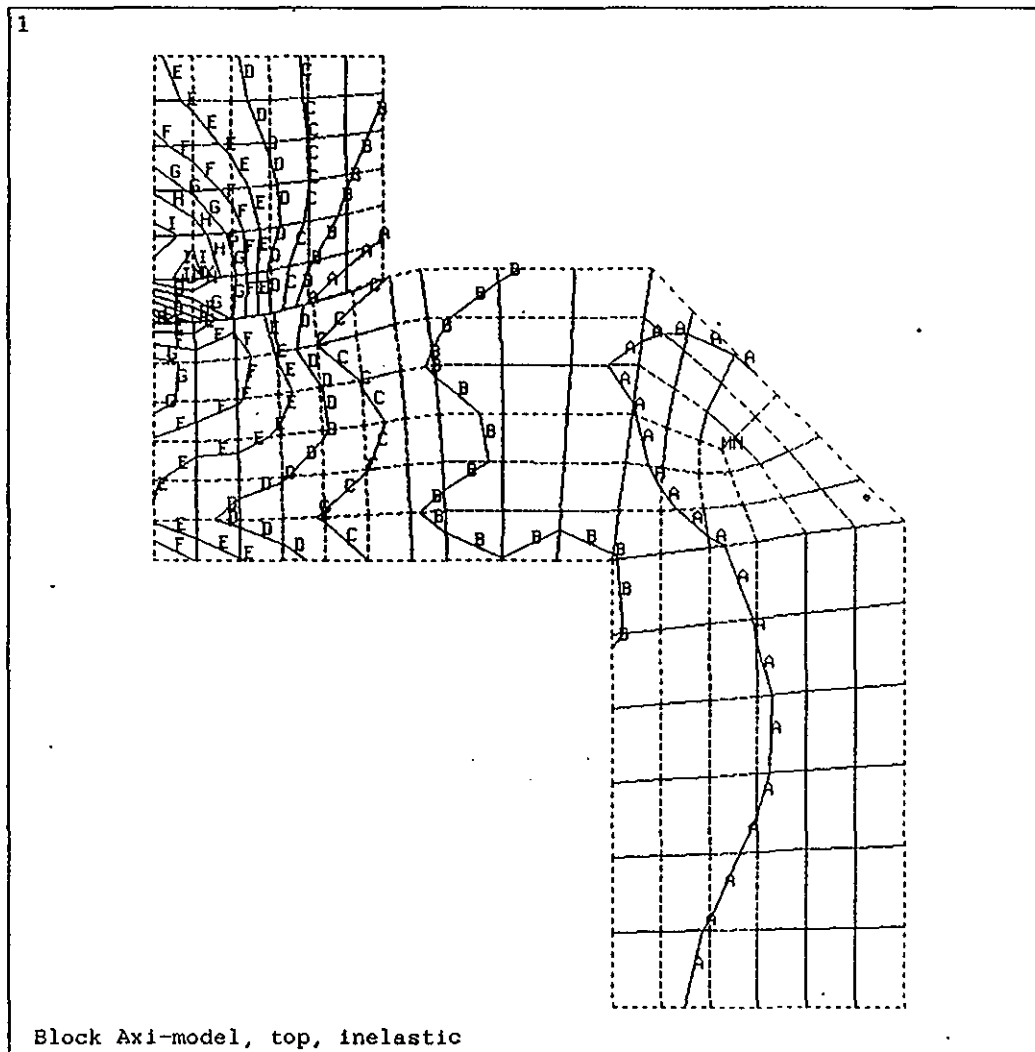
E-10



ANSYS 5.0 A
JAN 12 1995
14:32:51
NODAL SOLUTION
STEP=2
SUB =2
TIME=2
NLEPEQ (AVG)
DMX =0.062
SMX =0.505E-03
A =0.281E-04
B =0.842E-04
C =0.140E-03
D =0.196E-03
E =0.253E-03
F =0.309E-03
G =0.365E-03
H =0.421E-03
I =0.477E-03

WHC-SD-W236A-DA-002
REVISION 0

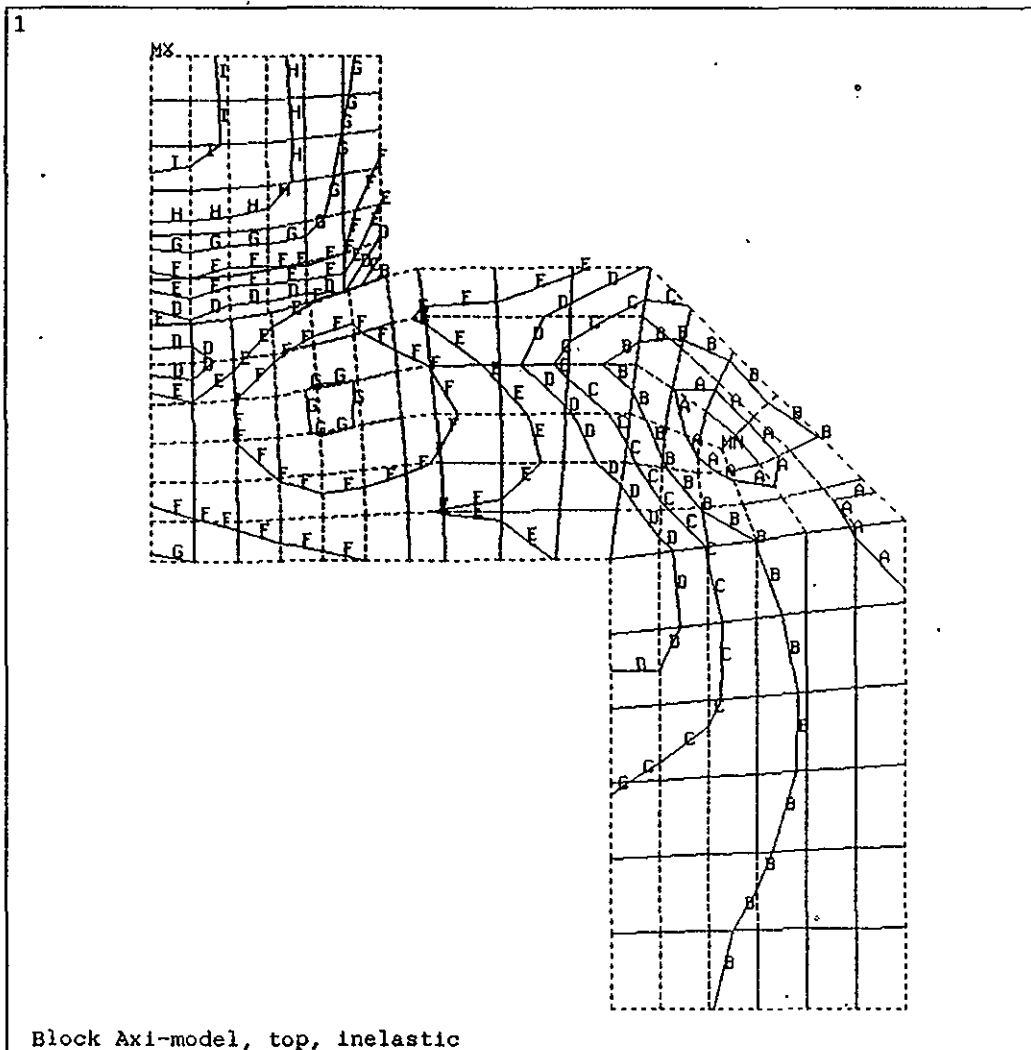
E-11



ANSYS 5.0 A
JAN 12 1995
14:33:22
NODAL SOLUTION
STEP=2
SUB =2
TIME=2
SINT (AVG)
DMX =0.062
SMN =709.944
SMX =37597
A =2759
B =6858
C =10956
D =15055
E =19154
F =23252
G =27351
H =31449
I =35548

WHC-SD-W236A-DA-002
REVISION 0

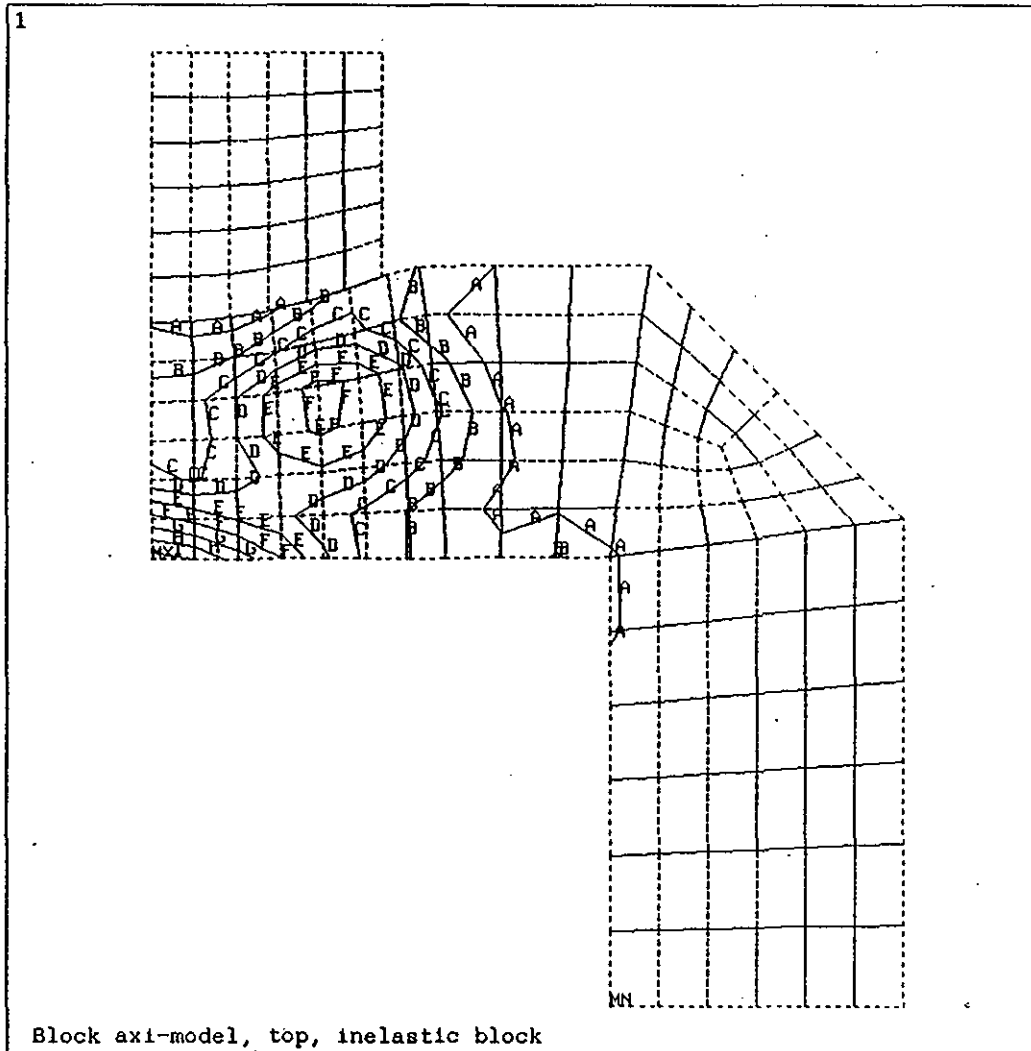
E-12



ANSYS 5.0 A
JAN 12 1995
14:34:24
NODAL SOLUTION
STEP=6
SUB =3
TIME=6
SINT (AVG)
DMX =0.068
SMN =4575
SMX =52639
A =7245
B =12586
C =17926
D =23267
E =28607
F =33947
G =39288
H =44628
I =49969

WHC-SD-W236A-DA-002
REVISION 0

E-13

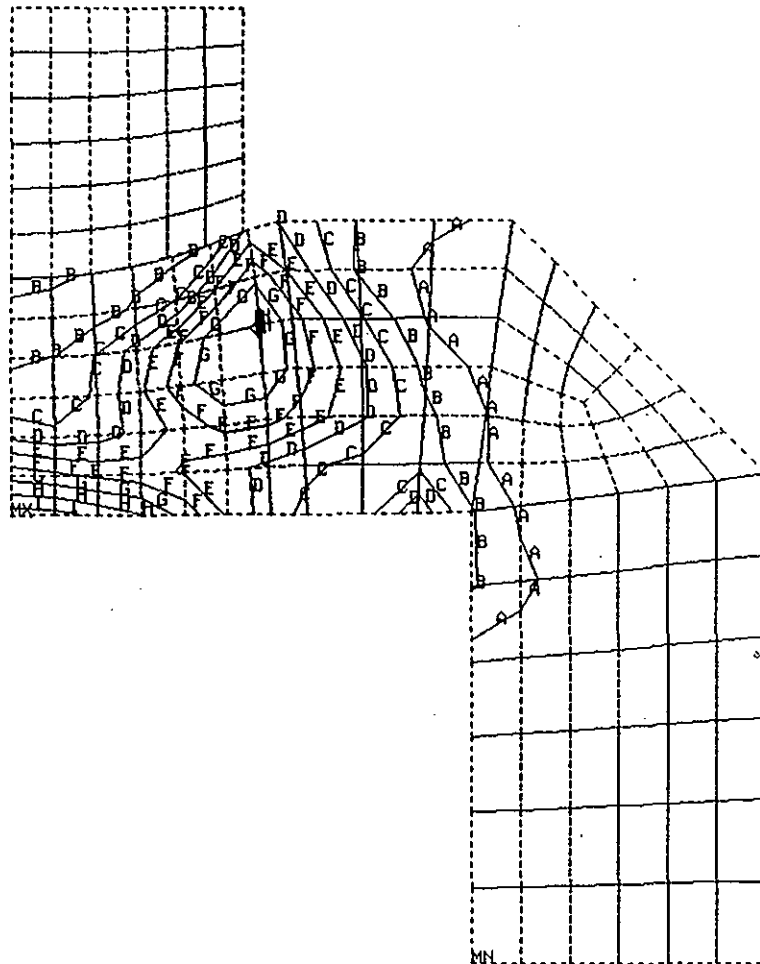


ANSYS 5.0 A
JAN 12 1995
14:30:05
NODAL SOLUTION
STEP=6
SUB =3
TIME=6
NLEPEQ (AVG)
DMX =0.068
SMX =0.005912
A =0.328E-03
B =0.985E-03
C =0.001642
D =0.002299
E =0.002956
F =0.003613
G =0.00427
H =0.004927
I =0.005584

WMC-SD-W236A-DA-002
REVISION 0

E-14

1



Block Axi-model, top, inelastic

ANSYS 5.0 A
JAN 12 1995
14:30:32
NODAL SOLUTION
STEP=8
SUB =3
TIME=8
NLEPEQ (AVG)
DMX =0.073001
SMX =0.008702
A =0.483E-03
B =0.00145
C =0.002417
D =0.003384
E =0.004351
F =0.005318
G =0.006285
H =0.007252
I =0.008219

WMC-SD-W236A-DA-002
REVISION 0

6.0 REFERENCES

ANSYS, 1992, *ANSYS Swanson Analysis Systems*, ANSYS Version, Swanson Analysis Systems, Inc., 5.0a version, Houston, Pennsylvania.

ASME, 1992, *Section VIII, Division 2*, American Society of Mechanical Engineers, New York, New York.

APPENDIX F

PIPING REACTION LOADS BASED ON AUTOPIPE COMPUTER CODE

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Appendix "F" Piping Reaction Loads Based on AUTOPIPE Computer Code
Authors J. L. Julyk, E. C. Ocoma, and E. O. Weiner

<u>Yes</u>	<u>No</u>	<u>N/A</u>	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

MANDATORY Software QA Log Number N/A

W. W. Z. L. S. 4/5/95
Reviewer Date

1.0 PIPING CONFIGURATION

1.1 INTRODUCTION

In order to determine the piping loads that the MWTF jumper could possibly see within the pits an AUTOPIPE scnerio was considered. A piping model of two horizontal jumpers, connected with piping, was modeled in AUTOPIPE. The piping was loaded using the design parameters obtained from the Functional Design Criteria (WHC 1993a).

1.2 SUMMARY

The reactions at the pipe intersection of the jumper are tabulated in Table F1 for the three size jumpers, 2-, 3-, and 4-in. The data in Table F1 is used for the system model evaluation of the 2-, 3-, and 4-in. jumpers found in appendix C. The reactions obtained from the AUTOPIPE models are estimated loads and are used as initial guesses in determining the maximum allowable piping loads that the jumper can withstand. A sketch of the horizontal configuration is shown in Figure F1 below.

Figure F1. W236A Jumper Connector for a Horizontal Position - Global Axis

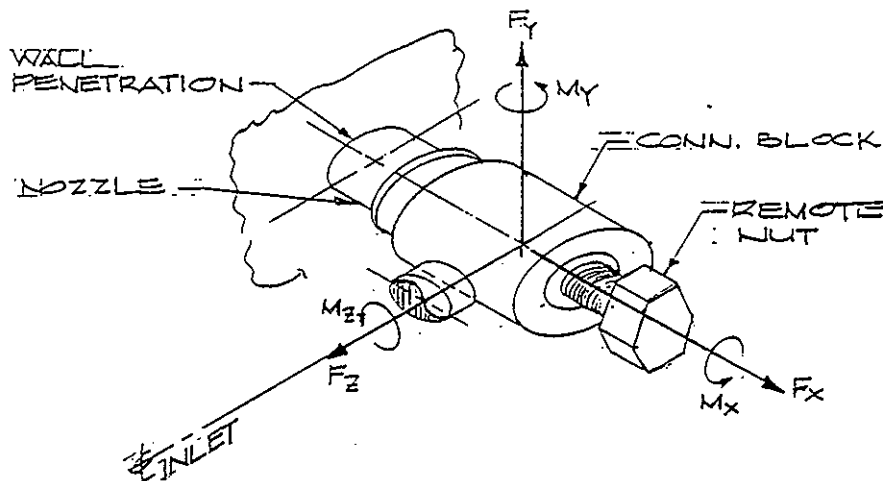


Table F1. W236A Jumper Connector used for system model evaluation in Appendix C.

Jumper Connector Size	Forces, lbf			Moments, ft-lbf		
	Fx	Fy	Fz	Mx	My	Mz
2 Inch	2,300	-1,000	400	1,600	1,600	2,000
3 Inch	15,000	-2,000	2,000	7,000	7,000	4,000
4 Inch	27,000	-3,000	3,000	13,000	13,000	7,000

2.0 ACCEPTABILITY OF CURRENT PIPING LOADS

The piping reactions are provided in a DSI from E. C. Ocoma to S. K. Farnworth. Hand calculations using the established interaction method determine the acceptability of the piping loads.

All of the piping systems considered show acceptable reaction loads to the connectors. The analyses in this appendix do not provide qualification of any piping system, and, as such, they are not to be considered final or used for further qualification efforts. Instead, they show that acceptable piping reactions independently established herein are not overly restrictive based on information available to date on proposed systems.

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject Piping Example

Originator EO Werner

Date 3/27/95

Checker John Gulya

Date 3/27/95

Acceptability of Current Piping Loads

Piping reactions are provided in a DSE from EC Occwa to SK Farnworth titled "Jumper Piping Nozzle Loads", dated March 15, 1995 (attached). They are tested for acceptability here against Table 3.4 of the main report. See the discussion before Table 3.4 (Section 2.0) on acceptable loads, and the example, on how to calculate I (interaction, usage). Components are described with respect to the coordinate system in the main report (Figure 1). Obtain piping analysis reactions $f_x, f_y, f_z, m_x, m_y, m_z$ and

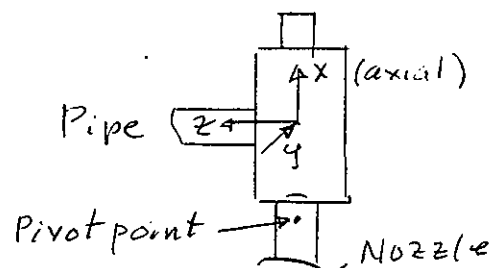
check: f_x vs Tables 3.3 and 3.4 (axial force)

$$\text{calc: } f_s \equiv \sqrt{f_y^2 + f_z^2} \quad m_s \equiv \sqrt{m_y^2 + m_z^2}$$

$$I = f_s / F_{yz} + |m_x| / M_x + m_b / M_{yz}$$

F_{yz}, M_x and M_{yz} from Table 3.4

check: $I \leq 1$



ANALYTICAL CALCULATIONS

Page _____ of _____

Subject Piping Exemplar

Originator CO Werner

Date 3/27/95

Checker W. W. Chas

Date 4/5/95

Size	Point	f_x 16 ft	f_y	f_z 16 ft	m_x 16 ft	m_y	m_z	f_s 16 ft	m_B 46 ft	I
4"	B01	-581 ^{OK}	70	761	6	43	17	764	46	0.39 ^{OK}
	B04	-285 ^{OK}	760	573	2	16	18	952	24	0.45 ^{OK}
	C01	-310 ^{OK}	56	153	65	449	168	163	479	0.56 ^{OK}
	C03	-129 ^{OK}	142	33	36	190	197	146	274	0.34 ^{OK}
	D01	-66 ^{OK}	104	160	51	100	283	191	300	0.41 ^{OK}
	D03	-72 ^{OK}	360	28	23	118	92	361	150	0.32 ^{OK}
2"	E01	-417 ^{OK}	234	39	50	180	43	237	185	0.88 ^{OK}
	E03	-114 ^{OK}	419	237	7	58	173	482	182	0.90 ^{OK}
3"	A01	-371 ^{OK}	300	266	5	56	42	401	70	0.39 ^{OK}
	A09	-260 ^{OK}	268	179	13	52	20	322	56	0.33 ^{OK}
	B08	-89 ^{OK}	43	175	8	62	4	180	62	0.24 ^{OK}

DON'T SAY IT --- Write It!

DATE: March 15, 1995

TO: SK Farnworth

H5-57

FROM: EC Ocoma

E.C. Ocoma

H5-57

Telephone: 6-0332

cc: EO Weiner H5-57
VJ Cruz B4-08
MS Ruben E6-46
~~JE [REDACTED] H5-57~~
MM Ahmed B4-40
MT Husain E6-37
AW Bjorkedal B4-40
TB Salzano E6-37

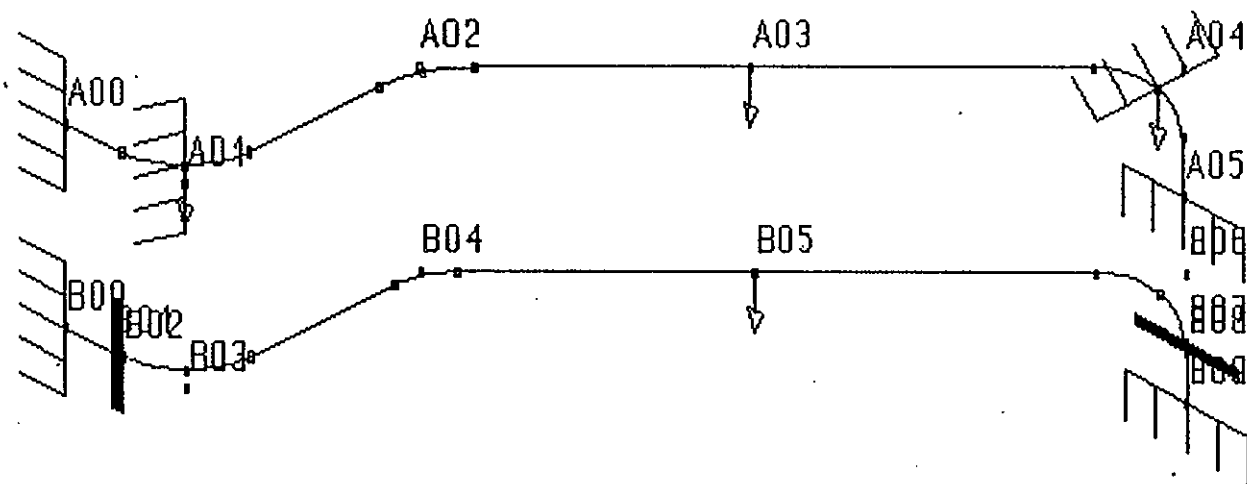
SUBJECT: JUMPER PIPING NOZZLE LOADS

The attached are copies of three piping analyses performed to generate piping nozzle loads. The analyses models are similar to the preliminary jumper piping models provided by Mechanical Engineering (AW Bjorkedal/MM Ahmed/MT Husain). The difference is in the modeling of the connector with the piping. The piping nozzle loads may be used in the analysis of 2", 3", and 4" diameter connectors to determine the acceptability of the calculated allowable load capacities of each connector detail parts.

In parallel with this effort, the connector analyses were also improved by reducing conservatism and revising some assumptions that can be justified. The preliminary results (table attached) of the revised analyses indicate that the connectors latest allowable nozzle loads envelope the new piping nozzle loads in the attachments. It shall be noted that only one (1) preliminary piping model was used each for the 2" and 3" dia. and three (3) for the 4" diameter. Also, the $\Delta T = 140$ deg.F used in the models may be less than the ΔT of other systems for the W236A project.

If you have any question, please call me at 6-0332.

Attachments



PROJECT W320 W/O ER4319
JUMPER 320 ISO J3 REV.0



WHC-SD-W236A-DA-002
REVISION 0

Figure Model 32A14E0 -- 4" Dia.

SEGMENT 'A' - M. AHMED'S MODEL (~~CORRECTED BY E~~)
SEGMENT 'B' - E. OCOMA'S MODEL

REVISION 0

320A14EO PROJECT W320 W/O ER4319
03/08/95 JUMPER 320 ISO J3 REV.0

WESTINGHOUSE/BOEING CO
AutoPIPE+4.50 MODEL PAGE 1

**
** AUTOPIPE SYSTEM DATA LISTING **
**

SYSTEM NAME : 320A14EO

PROJECT ID : PROJECT W320 W/O ER4319
JUMPER 320 ISO J3 REV.0

PREPARED BY : _____
EC OCOMA

CHECKED BY : _____

PIPING CODE : 831.3

AMBIENT TEMP. (deg F) : 40.0

COMPONENT LIBRARY : AUTOPIPE

MATERIAL LIBRARY : AUTOB313

MODEL REVISION NUMBER : 2

320A1480 PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/08/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 2

POINT DATA LISTING

POINT NAME	TYPE	-----OFFSETS (ft)-----			PIPE ID	DESCRIPTION
		X	Y	Z		
*** SEGMENT A						
A00	Run	0	0	0	PIPE-4	
A01	Bend	0.63	0	0		Short Elbow, Radius = 4.00 inch Bend angle change = 90.00 deg Mid point at 50.00 percent SIF - In = 2.56, Out = 2.13
A02	Bend	0	0	-1.22		Long Elbow, Radius = 6.00 inch Bend angle change = 45.00 deg Mid point at 50.00 percent SIF - In = 1.95, Out = 1.63
A03	Run	0.87	0	-0.87		
A04	Bend	1.13	0	-1.13		Short Elbow, Radius = 4.00 inch Bend angle change = 90.00 deg Mid point at 50.00 percent SIF - In = 2.56, Out = 2.13
A05	Run	0	-0.63	0		
*** SEGMENT B						
B00	Run	0	-1.00	0	PIPE-4	
B01	Flex	0.25	0	0		Wt= 159 lb, Ar= 12.7 sq.in Axial = 23300000 Tors= 304.0 Y-Shear= 25200.0 Bend= 2079.0 Z-Shear= 25200.0 Bend= 2079.0
B02	Run	0.05	0	0		
B03	Bend	0.33	0	0		Short Elbow, Radius = 4.00 inch Bend angle change = 90.00 deg Mid point at 50.00 percent SIF - In = 2.56, Out = 2.13
B04	Bend	0	0	-1.22		Short Elbow, Radius = 4.00 inch Bend angle change = 45.00 deg SIF - In = 2.56, Out = 2.13
B05	Run	0.87	0	-0.87		
B06	Bend	1.13	0	-1.13		Short Elbow, Radius = 4.00 inch Bend angle change = 90.00 deg Mid point at 50.00 percent SIF - In = 2.56, Out = 2.13
B07	Flex	0	-0.33	0		Wt= 142 lb, Ar= 12.7 sq.in Axial = 23300000 Tors= 304.0 Y-Shear= 25200.0 Bend= 2079.0 Z-Shear= 25200.0 Bend= 2079.0
B08	Run	0	-0.05	0		

ΔH MED'S MODEL

CONNECTOR
STIFFNESS
MODELED AS FLEX. JT

REVISED
MODEL
WITH
FLEX. JT.

CONNECTOR
STIFFNESS
MODELED AS FLEX. JT.

320A14EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/08/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 3

P O I N T D A T A L I S T I N G

POINT -----OFFSETS (ft)-----
NAME TYPE X Y Z PIPE ID DESCRIPTION

809 , Run 0 -0.25 0

Total weight of empty pipes : 109 lb

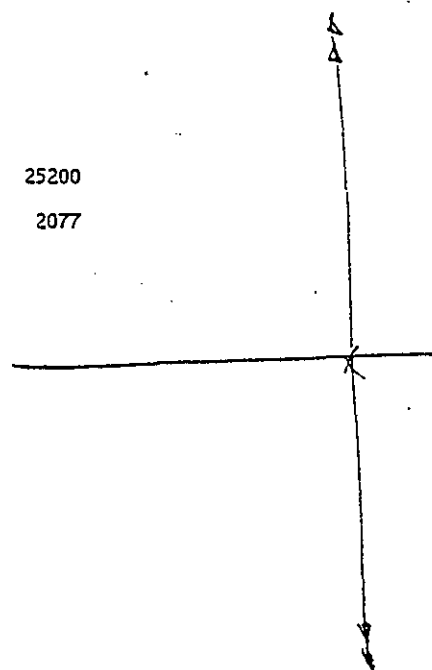
320A14EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/08/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 4

COMPONENT DATA LISTING

POINT NAME	COORDINATE(ft) X Y Z	DATA TYPE	DESCRIPTION
*** SEGMENT A			
A00	0.00 0.00 0.00	ANCHOR	Rigid Thermal movements : None
A01 N	0.29 0.00 0.00		
A01	0.63 0.00 0.00	TI	
A01 M	0.53 0.00 -0.10	ANCHOR	Translational stiffness lb/in X= 23300000 Y= 25200 Z= 25200 Rotational stiffness ft-lb/deg X= 304 Y= 2077 Z= 2077 Thermal movements : None
		WEIGHT	159 lb , No offsets
A01 F	0.63 0.00 -0.33		
A02 N	0.63 0.00 -1.01		
A02	0.63 0.00 -1.22	TI	
A02 M	0.67 0.00 -1.20		
A02 F	0.77 0.00 -1.37		
A03	1.49 0.00 -2.09	WEIGHT	8 lb , No offsets
A04 N	2.39 0.00 -2.98		
A04	2.62 0.00 -3.22	TI	
A04 M	2.55 -0.10 -3.15	ANCHOR	Translational stiffness lb/in X= 25200 Y= 23300000 Z= 25200 Rotational stiffness ft-lb/deg X= 2077 Y= 304 Z= 2077 Thermal movements : None
		WEIGHT	142 lb , No offsets
A04 F	2.62 -0.33 -3.22		
A05	2.62 -0.63 -3.22	ANCHOR	Rigid Thermal movements : None
*** SEGMENT 8			
800	0.00 -1.00 0.00	ANCHOR	Rigid Thermal movements : None
801	0.25 -1.00 0.00		
802	0.30 -1.00 0.00		
803 N	0.30 -1.00 0.00		
803	0.63 -1.00 0.00	TI	
803 M	0.54 -1.00 -0.10		
803 F	0.63 -1.00 -0.33		
804 N	0.63 -1.00 -1.08		
804	0.63 -1.00 -1.22	TI	
804 F	0.73 -1.00 -1.32		
805	1.50 -1.00 -2.09	WEIGHT	8 lb , No offsets
806 N	2.40 -1.00 -2.98		
806	2.63 -1.00 -3.22	TI	
806 M	2.56 -1.10 -3.15		
806 F	2.63 -1.33 -3.22		
807	2.63 -1.33 -3.22		
808	2.63 -1.38 -3.22		
809	2.63 -1.63 -3.22	ANCHOR	Rigid

THESE 2 CLOSELY SPACED
ANCHORS ARE CREATING
THE HIGH ~~ANCHOR~~ FORCES & MOMENTS
THIS IS NO GOOD

AHMED'S
MODEL



REVISED
MODEL

320A14E0 PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/08/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 5

C O M P O N E N T D A T A L I S T I N G

POINT ---COORDINATE(ft)--- DATA
NAME X Y Z TYPE DESCRIPTION

Thermal movements : None

Number of points in the system : 33

320A14EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/08/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 6

PIPE DATA LISTING

Pipe ID/ Material	Nom/ Sch	O.D. inch	-----Thickness(inch)----- W.Th. Corr Mill Insu Ling				Spec Grav	Weight(lb/ft) Pipe Other Total			
PIPE-4 A312-TP304L STD	4	4.500	0.237	0.06	0.03	0	0	1.25	11.04	0	17.94

320A14EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/08/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 RESULT PAGE 1

RESTRAINT REACTIONS

Point name	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
A00	Anchor								
	GR	1	-200	8	200.	-32	-2	-87	93
	T1	-38586	-3	10877	40090	-189	-590	251	669
	P1	-553	0	151	573	-3	-7	3	8
	R1	5	0	5	7	1	3	1	3
	R2	0	27	1	27	4	0	12	12
	R3	45	0	46	64	0	18	1	18
	SUM	-39139	-203	11036	40665	-224	-600	-167	662
	RESP	49	27	51	76	6	21	13	26
	TOTAL	39188	230	11088	40727	230	621	180	686
A01 M	Anchor								
	GR	-6	-5	0	8	0	0	-4	4
	T1	31409	14	-146	31409	-1	488	34	489
	P1	454	0	-2	454	0	7	0	7
	R1	42	0	0	42	0	0	0	0
	R2	1	1	0	1	0	0	0	0
	R3	42	0	1	42	0	0	0	0
	SUM	31856	10	-148	31857	-1	495	31	496
	RESP	85	1	1	85	0	1	1	1
	TOTAL	31941	10	149	31942	1	496	32	497
A04 M	Anchor								
	GR	0	-207	0	207	1	0	1	2
	T1	-78	54354	-57	54354	-8	-24.	153	155
	P1	-1	772	-1	772	0	0	2	2
	R1	1	33	0	33	0	0	1	1
	R2	0	27	0	27	0	0	0	0
	R3	0	19	1	19	0	0	0	1
	SUM	-80	54919	-58	54919	-7	-24	156	158
	RESP	1	79	1	79	1	0	1	1
	TOTAL	81	54998	59	54998	8	24	157	159
A05	Anchor								
	GR	6	13	-8	17	3	-1	3	5
	T1	7256	-54366	-10674	55877	-2723	-1950	-1212	3561
	P1	101	-772	-148	792	-37	-27	-16	49
	R1	41	33	5	53	1	3	18	18
	R2	1	1	1	2	0	0	0	1
	R3	2	19	33	38	14	3	2	14
	SUM	7362	-55124	-10831	56658	-2757	-1978	-1225	3607
	RESP	44	54	39	80	15	6	21	26
	TOTAL	7407	55178	10870	56724	2772	1984	1245	3629

NOZZLE LOADS OF OLD MODEL

320A14EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/08/95 JUMPER 320 ISO J3 REV.0 AUTOPIPE+4.50 RESULT PAGE 6

GLOBAL FORCES & MOMENTS

Point name	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
A05	GR	6	13	-8	17	3	-1	3	5
	T1	7256	-54366	-10674	55877	-2723	-1950	-1212	3561
	P1	101	-772	-148	792	-37	-27	-16	49
	R1	41	33	5	53	1	3	18	18
	R2	1	2	1	2	0	0	0	1
	R3	2	19	32	38	14	3	2	14
	SUM	7362	-55124	-10831	56658	-2757	-1978	-1225	3607
	RESP	44	55	38	80	15	6	21	26
	TOTAL	7406	55179	10869	56725	2772	1984	1245	3629
*** Segment A end ***									
*** Segment B begin ***									
800	GR	5	200	-6	201	1	1	46	46
	T1	525	-67	-694	872	-6	138	-27	141
	P1	8	-1	-11	14	0	2	-1	2
	R1	68	4	8	69	0	1	2	2
	R2	1	41	4	41	0	1	10	10
	R3	1	12	62	63	0	17	3	18
	SUM	538	132	-711	901	-6	140	18	142
	RESP	70	56	74	116	0	20	15	25
	TOTAL	608	188	784	1010	6	161	32	164
801	GR	5	37	-6	38	1	-1	-4	4
	T1	525	-67	-694	872	-6	-36	-11	38
	P1	8	-1	-11	14	0	-1	0	1
	R1	41	4	8	42	0	3	1	4
	R2	1	23	4	23	0	0	0	1
	R3	1	12	36	38	0	2	1	2
	SUM	538	-31	-711	892	-6	-37	-15	40
	RESP	43	38	47	75	0	6	2	6
	TOTAL	581	70	758	958	6	43	17	47
802	GR	5	37	-6	38	1	-1	-10	10
	T1	525	-67	-694	872	-6	-70	-7	71
	P1	8	-1	-11	14	0	-1	0	1
	R1	15	0	8	17	0	4	1	4
	R2	1	5	1	5	0	0	2	2
	R3	1	2	9	9	0	0	1	1
	SUM	538	-31	-711	892	-6	-73	-17	75
	RESP	17	8	17	25	0	5	3	6
	TOTAL	555	39	728	916	6	77	21	80

CONNECTOR LOADS

4" - HORIZ.
X-AXIAL
ANCHORED AT N.P. 800 (-X)
AT FLEX JT.

320A14EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/08/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 RESULT PAGE 9

GLOBAL FORCES & MOMENTS

Point name	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
~~807~~	GR	5	-192	-6	192	7	0	13	15
	T1	525	-67	-694	872	-21	1	-26	33
	P1	8	-1	-11	14	0	0	0	0
	R1	26	0	11	29	1	0	1	1
	R2	2	23	5	24	1	0	2	2
	R3	6	1	33	33	1	0	1	1
	SUM	538	-261	-711	929	-15	1	-13	19
	RESP	35	24	49	65	4	1	3	5
808	TOTAL	573	285	760	993	18	2	16	24
	GR	5	-192	-6	192	7	0	13	15
	T1	525	-67	-694	872	-56	1	-52	76
	P1	8	-1	-11	14	-1	0	-1	1
	R1	50	0	11	52	2	0	2	2
	R2	2	39	5	39	1	0	2	2
	R3	6	1	57	57	3	0	1	3
	SUM	538	-261	-711	929	-50	1	-39	64
809	RESP	59	41	73	102	5	1	4	7
	TOTAL	597	301	784	1030	55	2	44	71
	GR	5	-197	-6	197	5	0	12	13
	T1	525	-67	-694	872	-229	1	-183	294
	P1	8	-1	-11	14	-3	0	-3	4
	R1	50	0	11	52	4	0	15	15
	R2	2	39	5	39	1	0	2	2
	R3	6	1	57	57	16	0	2	16
	SUM	538	-265	-711	930	-228	1	-174	287
	RESP	59	41	73	102	21	1	18	28
	TOTAL	597	306	784	1032	249	2	192	315

*** Segment B end ***

CONNECTOR LOADS

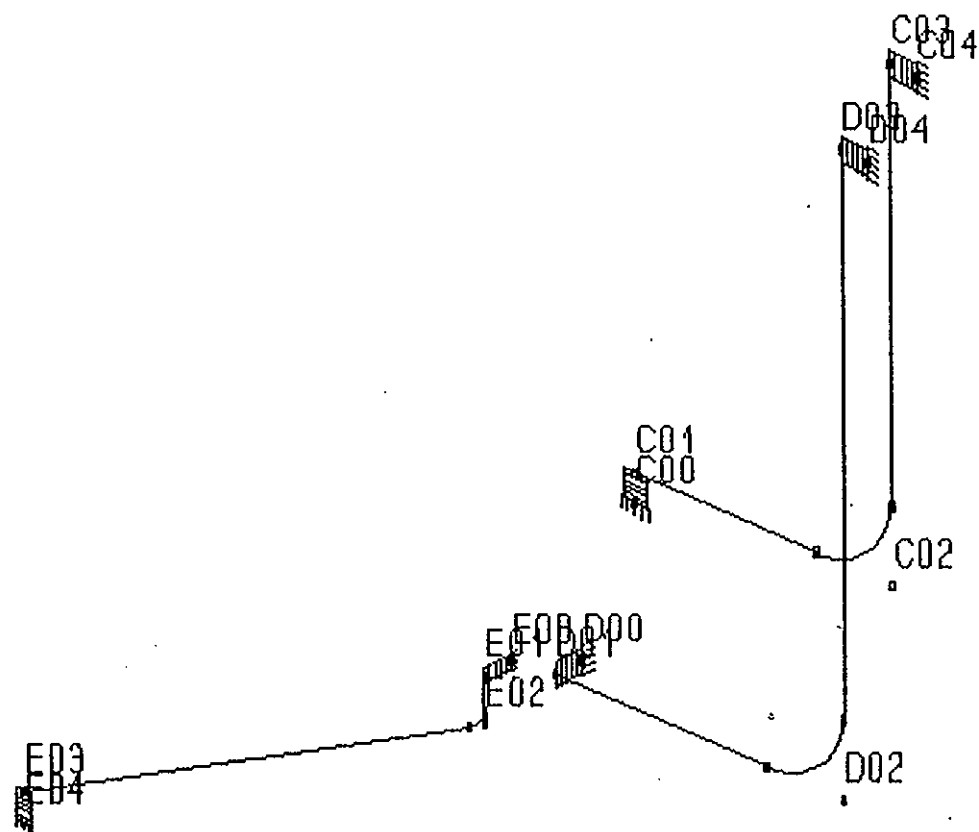
AT FLEX. JT

4" VERT.

Y-AXIAL

ANCHORED @ N.P. 309 (-Y)

~~AT FLEX. JT.~~



CONDENSER JUMPERS DWG. NO. ES236AWMD27
AND H-2-819702

WHC-SD-W236A-DA-002
REVISION 0

Figure Model PVT1WECO Segment C & D = 4", Seg E + 2" di

PVT1WECO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 MODEL PAGE 1

**
** AUTOPIPE SYSTEM DATA LISTING **
**

SYSTEM NAME : PVT1WECO

PROJECT ID : CONDENSER JUMPERS DWG. NO. ES236AWM027
AND H-2-819702

PREPARED BY : _____
EC OCOMA

CHECKED BY : _____

PIPING CODE : 831.3

AMBIENT TEMP. (deg F) : 70.0

COMPONENT LIBRARY : AUTOPIPE

MATERIAL LIBRARY : AUTOB313

MODEL REVISION NUMBER : 2

THIS IS A M. HUSAIN'S REVISED MODEL.

PVT1WECO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 MODEL PAGE 2

POINT DATA LISTING

POINT NAME	TYPE	-----OFFSETS (ft)-----			PIPE ID	DESCRIPTION
X	Y	Z				
*** SEGMENT C						
C00	Flex	-6.50	-3.54	12.00	4SCH40	Wt= 122 lb , Ar= 12.7 sq.in Axial = 23300000 Tors= 304.0 Y-Shear= 25200.0 Bend= 2079.0 Z-Shear= 25200.0 Bend= 2079.0
C01	Run	0	0.63	0		
C02	Bend	5.56	-0.01	-0.51		Elbow, Radius = 20.00 inch Bend angle change = 90.05 deg SIF - In = 1.00, Out = 1.00
C03	Flex	0	10.95	0		Wt= 122 lb , Ar= 12.7 sq.in Axial = 23300000 Tors= 304.0 Y-Shear= 25200.0 Bend= 2079.0 Z-Shear= 25200.0 Bend= 2079.0
C04	Run	0.63	0	0		
*** SEGMENT D						
D00	Flex	-6.50	-6.26	13.25	4SCH40	Wt= 122 lb , Ar= 12.7 sq.in Axial = 23300000 Tors= 304.0 Y-Shear= 25200.0 Bend= 2079.0 Z-Shear= 25200.0 Bend= 2079.0
D01	Run	0	0	0.63		
D02	Bend	6.18	0	-0.59		Elbow, Radius = 20.00 inch Bend angle change = 90.00 deg SIF - In = 1.00, Out = 1.00
D03	Flex	0	13.67	0		Wt= 122 lb , Ar= 12.7 sq.in Axial = 23300000 Tors= 304.0 Y-Shear= 25200.0 Bend= 2079.0 Z-Shear= 25200.0 Bend= 2079.0
D04	Run	0.63	0	0		
*** SEGMENT E						
E00	Flex	-8.19	-7.10	13.25	2SCH40	Wt= 30 lb , Ar= 3.4 sq.in Axial = 13500000 Tors= 107.0 Y-Shear= 27800.0 Bend= 659.0 Z-Shear= 27800.0 Bend= 659.0
E01	Run	0	0	0.63		
E02	Bend	0	-1.03	0.00		Long Elbow, Radius = 3.00 inch Bend angle change = 90.10 deg SIF - In = 1.73, Out = 1.44
E03	Flex	-4.00	0	6.91		Wt= 30 lb , Ar= 3.4 sq.in Axial = 13500000 Tors= 107.0

* THE ONLY CHANGE MADE TO THE M. HUSAIN'S MODEL WAS ADDING THE STIFFNESS VALUES OF THE FLEX JOINT. THE FLEX JOINTS WERE ALREADY MODELED BUT WERE RIGID ELEMENTS.

PVT1WECO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 MODEL PAGE 3

P O I N T D A T A L I S T I N G

POINT NAME	TYPE	-----OFFSETS (ft)-----			PIPE ID	DESCRIPTION
		X	Y	Z		
						Y-Shear= 27800.0 Bend= 659.0
						Z-Shear= 27800.0 Bend= 659.0
E04	Run	0	-0.63	0		

Total weight of empty pipes : 420 lb

PVT1WECO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 MODEL PAGE 4

COMPONENT DATA LISTING

POINT NAME	---COORDINATE(ft) X	Y	Z	DATA TYPE	DESCRIPTION
*** SEGMENT C					
C00	-6.50	-3.54	12.00	ANCHOR	Rigid Thermal movements : T1
C01	-6.50	-2.91	12.00		
C02 N	-2.60	-2.92	11.64		
C02	-0.94	-2.92	11.49	TI	
C02 F	-0.94	-1.25	11.49		
C03	-0.94	8.03	11.49		
C04	-0.31	8.03	11.49	ANCHOR	Rigid Thermal movements : None
*** SEGMENT D					
D00	-6.50	-6.26	13.25	ANCHOR	Rigid Thermal movements : None
D01	-6.50	-6.26	13.88		
D02 N	-1.97	-6.26	13.45		
D02	-0.32	-6.26	13.29	TI	
D02 F	-0.32	-4.60	13.29		
D03	-0.32	7.40	13.29		
D04	0.31	7.40	13.29	ANCHOR	Rigid Thermal movements : None
*** SEGMENT E					
E00	-8.19	-7.10	13.25	ANCHOR	Rigid Thermal movements : None
E01	-8.19	-7.10	13.88		
E02 N	-8.19	-7.87	13.88		
E02	-8.19	-8.12	13.88	TI	
E02 F	-8.31	-8.12	14.09		
E03	-12.19	-8.12	20.79		
E04	-12.19	-8.75	20.79	ANCHOR	Rigid Thermal movements : None

Number of points in the system : 21

PVT1WECO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 MODEL PAGE 5

PIPE DATA LISTING

Pipe ID/ Material	Nom/ Sch	O.D. inch	-----Thickness(inch)----- W.Th. Corr Mill Insu Ling				Spec Grav	Weight(lb/ft) Pipe Other Total			
4SCH40 AU	4 40	4.500	0.237	0.02	0.03	0	0	1.00	11.04	0	16.56
2SCH40 AU	2 40	2.000	2.375	0.154	0.02	0.02	0	0	1.00	3.74	0 5.19

PVTIWE CO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 RESULT PAGE 10

GLOBAL FORCES & MOMENTS

Point	Load	FORCES (lb)				MOMENTS (ft-lb)			
name	combination	X	Y	Z	Result	X	Y	Z	Result

*** Segment C begin ***

C00	GR	-6	51	0	52	3	1	29	29
	T1	111	249	-6	272	54	-6	329	333
	P1	0	1	0	1	0	0	1	1
	R1	37	5	5	37	7	5	12	15
	R2	19	8	2	21	1	0	7	7
	R3	3	1	44	44	70	54	6	89
	SUM	106	301	-6	319	57	-5	359	363
	RESP	59	14	50	79	77	60	25	100
	TOTAL	165	315	56	360	134	65	384	412

C01	GR	-6	51	0	52	3	1	25	26
	T1	111	249	-6	272	58	-6	399	403
	P1	0	1	0	1	0	0	1	1
	R1	29	5	4	29	9	5	11	15
	R2	15	3	1	16	1	0	6	6
	R3	3	1	44	44	97	54	7	112
	SUM	106	301	-6	319	61	-5	425	430
	RESP	47	9	50	69	107	60	24	125
	TOTAL	153	310	56	350	168	65	449	484

4" VERT. CONN. LOADS

Y-AXIAL

ANCHORED AT N.P. C00(-Y)

C02 N	GR	-6	-13	0	15	-4	-1	-49	49
	T1	111	249	-6	272	-31	10	-572	573
	P1	0	1	0	1	0	0	-2	2
	R1	18	5	3	19	9	11	10	18
	R2	11	5	1	12	1	0	8	8
	R3	1	1	25	25	97	118	12	153
	SUM	106	236	-6	259	-35	9	-623	624
	RESP	30	11	28	43	106	129	30	170
	TOTAL	136	247	34	284	142	138	653	682

C02 F	GR	-6	-57	0	57	1	-2	-10	10
	T1	111	249	-6	272	-59	17	-800	802
	P1	0	1	0	1	0	0	-3	3
	R1	2	17	2	17	13	15	14	24
	R2	1	18	0	18	1	0	8	8
	R3	3	2	18	18	138	159	15	211
	SUM	106	193	-6	220	-59	15	-812	815
	RESP	6	36	20	42	151	174	38	234
	TOTAL	112	229	26	256	210	190	850	896

PVTIWE CO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 RESULT PAGE 11

GLOBAL FORCES & MOMENTS

Point name	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
C03	GR	-6	-332	0	332	0	-2	-64	64
	T1	111	249	-6	272	-3	17	231	232
	P1	0	1	0	1	0	0	1	1
	R1	19	27	2	33	3	15	7	17
	R2	1	29	0	29	0	0	7	7
	R3	3	3	26	26	30	159	16	163
	SUM	106	-83	-6	134	-3	15	167	168
	RESP	23	59	27	69	33	174	30	180
	TOTAL	129	142	33	195	36	190	197	276
C04	GR	-6	-332	0	332	0	-2	107	107
	T1	111	249	-6	272	-3	13	74	76
	P1	0	1	0	1	0	0	0	0
	R1	19	27	2	33	3	14	11	18
	R2	1	29	0	29	0	0	11	11
	R3	3	3	26	26	30	148	15	152
	SUM	106	-83	-6	134	-3	12	181	182
	RESP	23	59	27	69	33	162	38	170
	TOTAL	129	142	33	195	36	174	219	282

*** Segment C end ***

*** Segment D begin ***

D00	GR	-8	48	1	49	-52	-7	4	53
	T1	55	104	-2	118	-32	18	46	59
	P1	0	0	0	0	0	0	0	0
	R1	44	5	2	44	2	14	0	14
	R2	24	8	1	25	4	9	0	10
	R3	2	0	62	62	47	241	0	246
	SUM	47	153	-1	160	-84	11	50	99
	RESP	69	13	66	96	53	264	1	269
	TOTAL	116	166	66	213	137	274	51	311
D01	GR	-8	48	1	49	16	-2	4	17
	T1	55	104	-2	118	34	-17	46	59
	P1	0	0	0	0	0	0	0	0
	R1	34	4	2	35	2	15	0	16
	R2	20	3	1	20	1	6	0	7
	R3	3	1	62	62	47	242	0	247
	SUM	47	153	-1	160	50	-19	50	73
	RESP	57	7	66	87	50	264	1	269
	TOTAL	104	160	66	202	100	283	51	305

CONNECTOR LOADS
4" HORIZ.
X - AXIAL
ANCHORED @ N.P. C04 (+X)

CONNECTOR LOADS
4" HORIZ.
Z - AXIAL
ANCHORED @ D00 (-Z)

PVT1WECO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 RESULT PAGE 12

GLOBAL FORCES & MOMENTS

Point name	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
D02 N	GR	-8	-27	1	28	12	1	-43	44
	T1	55	104	-2	118	-12	-3	-426	426
	P1	0	0	0	0	0	0	-2	2
	R1	23	5	1	23	2	2	16	17
	R2	15	6	0	16	0	2	12	12
	R3	2	1	42	42	47	41	3	62
	SUM	47	77	-1	90	0	-2	-470	470
	RESP	39	12	43	60	49	45	31	74
D02 F	TOTAL	86	89	44	132	49	48	502	506
	GR	-8	-71	1	71	17	2	-16	23
	T1	55	104	-2	118	-24	2	-508	508
	P1	0	0	0	0	0	0	-2	2
	R1	2	21	0	21	4	4	17	18
	R2	1	22	0	22	1	0	12	12
	R3	1	1	11	12	116	111	6	161
	SUM	47	34	-1	58	-8	4	-494	494
D03	RESP	4	45	12	46	121	115	35	170
	TOTAL	51	79	13	95	129	118	530	558
	GR	-8	-391	1	391	0	2	-79	79
	T1	55	104	-2	118	2	2	148	148
	P1	0	0	0	0	0	0	1	1
	R1	23	35	0	42	1	4	9	9
	R2	1	37	0	37	0	0	9	9
	R3	1	1	27	27	21	111	6	113
D04	SUM	47	-287	-1	291	1	4	69	69
	RESP	25	73	27	82	22	115	23	119
	TOTAL	72	360	28	368	23	118	92	152
	GR	-8	-391	1	391	0	3	129	129
	T1	55	104	-2	118	2	1	82	82
	P1	0	0	0	0	0	0	0	0
	R1	23	35	0	42	1	3	14	15
	R2	1	37	0	37	0	0	14	14
	R3	1	1	27	27	21	104	5	106
	SUM	47	-287	-1	291	1	3	211	211
	RESP	25	73	27	82	22	108	34	115
	TOTAL	72	360	28	368	23	111	246	271

CONNECTOR LOADS
4" - HORIZ.
X - AXIAL
ANCHORED @ N.P. D04 (+X)

*** Segment D end ***

*** Segment E begin ***

PVTIWE CO CONDENSER JUMPERS DWG. NO. ES236AWM027 WESTINGHOUSE/BOEING CO
03/08/95 AND H-2-819702 AutoPIPE+4.50 RESULT PAGE 13

GLOBAL FORCES & MOMENTS

Point name	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
E00	GR	9	26	-17	32	-22	4	0	23
	T1	-239	-61	425	491	-139	-106	-49	182
	P1	0	0	0	0	0	0	0	0
	R1	3	1	4	5	3	2	1	4
	R2	0	4	1	4	2	0	0	2
	R3	1	0	4	4	2	1	0	2
	SUM	-230	-35	409	470	-162	-102	-49	197
	RESP	5	5	9	11	7	2	2	8
E01	TOTAL	235	39	418	481	169	105	50	205
	GR	9	26	-17	32	3	-2	0	4
	T1	-239	-61	425	491	-177	44	-49	189
	P1	0	0	0	0	0	0	0	0
	R1	3	0	4	5	3	0	1	3
	R2	0	3	1	3	1	0	0	1
	R3	1	0	3	4	2	0	0	2
	SUM	-230	-35	409	470	-174	42	-49	186
E02 N	RESP	4	4	8	10	6	1	2	6
	TOTAL	234	39	417	480	180	43	50	192
	GR	9	22	-17	29	-9	-2	-7	12
	T1	-239	-61	425	491	152	44	136	209
	P1	0	0	0	0	0	0	0	0
	R1	2	0	4	4	0	0	1	1
	R2	0	3	1	3	0	0	0	0
	R3	1	0	3	3	0	0	0	1
E02 F	SUM	-230	-39	409	470	143	42	129	197
	RESP	3	3	7	9	1	1	2	2
	TOTAL	233	42	416	479	144	43	131	199
	GR	9	20	-17	28	-9	-2	-7	11
	T1	-239	-61	425	491	246	42	188	312
	P1	0	0	0	0	0	0	0	0
	R1	2	0	3	4	1	1	2	2
	R2	0	0	1	1	0	0	0	0
E03	R3	1	0	1	2	1	1	1	1
	SUM	-230	-41	409	471	237	40	182	301
	RESP	3	0	6	6	3	2	2	4
	TOTAL	233	41	414	477	239	43	184	305
	GR	9	-50	-17	54	-9	0	-7	12
	T1	-239	-61	425	491	-162	-6	-47	169
	P1	0	0	0	0	0	0	0	0
	R1	7	0	3	7	0	0	2	2
E04	R2	0	3	1	3	0	0	0	0
	R3	1	0	6	6	1	0	1	1
	SUM	-230	-111	409	482	-171	-6	-54	180
	RESP	8	3	10	13	2	0	3	4
	TOTAL	237	114	419	495	173	7	58	182
	GR	9	-50	-17	54	-9	0	-7	12
	T1	-239	-61	425	491	-162	-6	-47	169
	P1	0	0	0	0	0	0	0	0

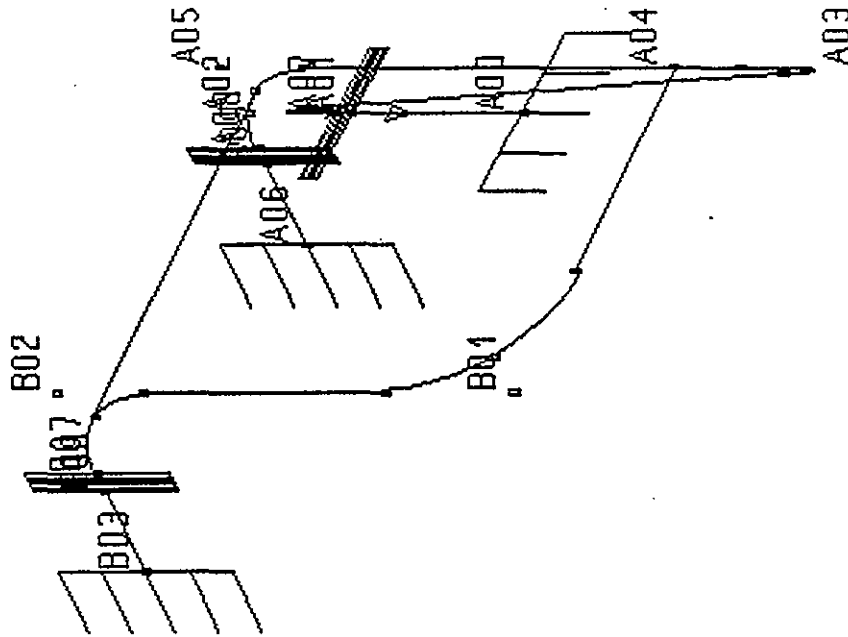
CONNECTOR LOADS

2" - HORIZ.
Z - AXIAL
~~2" - VERT.~~

~~2" - AXIAL~~
ANCHORED @ N.P. E00 (-Z)

CONNECTOR LOADS

2" - VERT.
Y - AXIAL
ANCHORED @ N.P. E04 (-Y)



PROJECT W320 W/O ER4319
JUMPER 320 ISO J3 REV.0

Figure Model 320A3E0 -- 3" Dia.

6- 320A3EO *REVISED MODEL FROM 320A3*
03/09/95 PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 1

** AUTOPIPE SYSTEM DATA LISTING **
**

SYSTEM NAME : 320A3EO

PROJECT ID : PROJECT W320 W/O ER4319
JUMPER 320 ISO J3 REV.0

PREPARED BY : EC OCOMA

CHECKED BY : _____

PIPING CODE : 831.3

AMBIENT TEMP. (deg F) : 40.0

COMPONENT LIBRARY : AUTOPIPE

MATERIAL LIBRARY : AUTO8313

MODEL REVISION NUMBER : 1

320A3EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/09/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 2

POINT DATA LISTING

POINT NAME TYPE -----OFFSETS (ft)-----
X Y Z PIPE ID DESCRIPTION

*** SEGMENT A

A00 Run 0 0 0 PIPE-1
A01 Flex 0 0.50 0

Wt= 77 lb , Ar= 7.4 sq.in
Axial = 19000000 Tors= 148.0
Y-Shear= 24700.0 Bend= 1332.0
Z-Shear= 24700.0 Bend= 1332.0

STIFFNESS OF CONNECTOR
MODELED AS FLEX JT.

A07 Run 0 0.05 0
A02 Bend 0 0.25 0

Short Elbow, Radius = 3.00 inch
Bend angle change = 90.00 deg
Mid point at 50.00 percent
SIF - In = 2.33, Out = 1.94

A03 Bend 2.00 0 1.86

Long Elbow, Radius = 4.50 inch
Bend angle change = 90.00 deg
Mid point at 50.00 percent
SIF - In = 1.78, Out = 1.48

A04 Tee 0 0.57 0
A05 Bend 0 1.34 0

Short Elbow, Radius = 3.00 inch
Bend angle change = 90.00 deg
Mid point at 50.00 percent
SIF - In = 2.33, Out = 1.94

A08 Flex 0 0 0.25

Wt= 92 lb , Ar= 7.4 sq.in
Axial = 19000000 Tors= 148.0
Y-Shear= 24700.0 Bend= 1332.0
Z-Shear= 24700.0 Bend= 1332.0

SAME

A09 Run 0 0 0.05
A06 Run 0 0 0.25

*** SEGMENT B

A04 Tee 2.00 1.37 1.86 PIPE-1
B01 Bend -1.00 0 0

Long Elbow, Radius = 4.50 inch
Bend angle change = 90.00 deg
Mid point at 50.00 percent
SIF - In = 1.78, Out = 1.48

B02 Bend 0 1.34 0

Short Elbow, Radius = 3.00 inch
Bend angle change = 90.00 deg
Mid point at 50.00 percent
SIF - In = 2.33, Out = 1.94

B07 Flex 0 0 0.25

Wt= 92 lb , Ar= 7.4 sq.in
Axial = 19000000 Tors= 148.0
Y-Shear= 24700.0 Bend= 1332.0
Z-Shear= 24700.0 Bend= 1332.0

SAME

320A3EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/09/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 3

P O I N T D A T A L I S T I N G

POINT		-----OFFSETS (ft)-----			PIPE ID	DESCRIPTION
NAME	TYPE	X	Y	Z		
908	Run	0	0	0.05		
803	Run	0	0	0.25		

Total weight of empty pipes : 63 lb

320A3EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/09/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 4

COMPONENT DATA LISTING

POINT NAME	---COORDINATE(ft) X	Y	Z	DATA TYPE	DESCRIPTION
*** SEGMENT A					
A00	0.00	0.00	0.00	ANCHOR	Rigid Thermal movements : None
A01	0.00	0.50	0.00	WEIGHT	12 lb , No offsets
A07	0.00	0.55	0.00		
A02 N	0.00	0.55	0.00		
A02	0.00	0.80	0.00	TI	
A02 M	0.05	0.73	0.05	WEIGHT	77 lb , No offsets
A02 F	0.18	0.80	0.17		
A03 N	1.73	0.80	1.60		
A03	2.00	0.80	1.86	TI	
A03 M	1.92	0.91	1.78		
A03 F	2.00	1.18	1.86		
A04	2.00	1.37	1.86	TEE	816.9 welding tee SIF - In = 1.22, Out = 1.30
A05 N	2.00	2.46	1.86		
A05	2.00	2.71	1.86	TI	
A05 M	2.00	2.64	1.93		
A05 F	2.00	2.71	2.11		
A08	2.00	2.71	2.11		
A09	2.00	2.71	2.16		
A06	2.00	2.71	2.41	ANCHOR	Rigid Thermal movements : None
*** SEGMENT B					
A04	2.00	1.37	1.86	TEE	816.9 welding tee SIF - In = 1.22, Out = 1.30
B01 N	1.38	1.37	1.86		
B01	1.00	1.37	1.86	TI	
B01 M	1.11	1.48	1.86		
B01 F	1.00	1.75	1.86		
B02 N	1.00	2.46	1.86		
B02	1.00	2.71	1.86	TI	
B02 M	1.00	2.64	1.93	TIE	ID : B02 M1, Connected to A05 M Stiffness = RIGID Gap-Minus = 0.12, Plus = 0.12 inch Friction = 0.00 Gaps set Weightless
B02 F	1.00	2.71	2.11		
B07	1.00	2.71	2.11		
B08	1.00	2.71	2.16		
B03	1.00	2.71	2.41	ANCHOR	Rigid Thermal movements : None

Number of points in the system : 31

320A3EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
 03/09/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 MODEL PAGE 5

PIPE DATA LISTING

Pipe ID/ Material	Nom/ Sch	O.D. inch	-----Thickness(inch)----- W.Th. Corr Mill Insu Ling				Spec Grav	Weight(lb/ft) Pipe Other Total			
PIPE-1 A312-TP304L STD	3.000	3.500	0.216	0.06	0.03	0	0	1.25	7.75	0	11.76

320A3E0 PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/09/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 RESULT PAGE 2

GLOBAL FORCES & MOMENTS

Point name	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
*** Segment A begin ***									
A00	GR	6	198	3	198	-3	0	5	
	T1	216	237	254	409	93	-5	-66	114
	P1	3	3	4	6	1	0	-1	
	R1	50	2	8	51	5	1	26	26
	R2	3	33	2	34	1	0	2	
	R3	4	3	46	46	23	0	4	24
	SUM	225	438	261	557	91	-4	-62	110
	RESP	57	39	56	89	30	1	31	43
	TOTAL	282	477	316	638	121	5	93	153
A01	GR	6	192	3	192	-4	0	8	
	T1	216	237	254	409	-34	-5	42	54
	P1	3	3	4	6	-1	0	1	
	R1	50	2	8	51	2	1	3	
	R2	3	33	2	34	1	0	1	
	R3	4	3	46	46	1	0	2	
	SUM	225	432	261	552	-39	-4	50	64
	RESP	57	39	56	89	4	1	6	7
	TOTAL	282	471	316	633	42	5	56	71
A01	GR	6	103	3	103	-4	0	8	
	T1	216	237	254	409	-34	-5	42	54
	P1	3	3	4	6	-1	0	1	
	R1	34	2	8	35	2	1	3	
	R2	3	23	2	23	1	0	1	
	R3	4	3	30	31	1	0	2	
	SUM	225	343	261	486	-39	-4	50	64
	RESP	41	28	40	64	4	1	6	7
	TOTAL	266	371	300	547	42	5	56	71
A07	GR	6	103	3	103	-4	0	8	
	T1	216	237	254	409	-47	-5	53	71
	P1	3	3	4	6	-1	0	1	
	R1	21	2	4	22	2	1	4	
	R2	2	14	1	14	1	0	1	
	R3	2	3	17	18	1	0	2	
	SUM	225	343	261	486	-52	-4	62	81
	RESP	25	20	23	39	4	1	7	8
	TOTAL	250	363	283	524	56	5	68	88

3"-VERT. CONN. LOADS
Y-AXIAL
INCURRED BELOW (-Y)
@ A00 N.P.

320A3EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/09/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 RESULT PAGE 5

GLOBAL FORCES & MOMENTS

Point name	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
A05 M	GR	4	-32	6	33	3	-1	-1	3
	T1	222	262	201	398	-79	36	-4	86
	P1	3	3	3	5	-1	1	0	1
	R1	5	8	8	12	2	3	1	4
	R2	1	4	1	4	0	0	0	1
	R3	1	1	9	9	3	0	0	3
	SUM	229	233	210	388	-77	35	-5	84
	RESP	7	13	18	23	6	4	1	7
	TOTAL	236	246	228	410	83	39	5	92
A05 F	GR	4	-35	6	36	-3	-2	0	4
	T1	222	262	201	398	-47	-3	12	49
	P1	3	3	3	5	-1	0	0	1
	R1	5	8	8	12	4	2	1	5
	R2	1	4	1	5	1	0	0	1
	R3	1	1	9	9	4	0	0	4
	SUM	229	230	210	387	-51	-5	12	53
	RESP	7	13	18	24	9	3	1	9
	TOTAL	236	244	229	409	60	8	13	62
A08	GR	4	-127	6	127	-3	-2	0	4
	T1	222	262	201	398	-47	-4	12	49
	P1	3	3	3	5	-1	0	0	1
	R1	21	14	8	26	4	2	1	5
	R2	1	15	1	15	1	0	0	1
	R3	2	1	25	25	4	0	0	4
	SUM	229	138	210	340	-51	-5	12	53
	RESP	24	30	34	51	9	3	1	9
	TOTAL	252	168	244	389	60	8	13	62
A09	GR	4	-127	6	127	-7	-2	0	8
	T1	222	262	201	398	-34	-15	12	39
	P1	3	3	3	5	0	0	0	0
	R1	36	14	8	40	5	2	1	5
	R2	1	25	1	25	1	0	0	1
	R3	2	1	40	40	4	0	0	4
	SUM	229	138	210	340	-42	-17	12	47
	RESP	39	41	49	75	10	3	1	10
	TOTAL	268	179	260	414	52	20	13	57
A06	GR	4	-130	6	130	-39	-3	0	39
	T1	222	262	201	398	31	-70	12	77
	P1	3	3	3	5	0	-1	0	1
	R1	36	14	8	40	8	10	1	13
	R2	1	25	1	25	7	0	0	7
	R3	2	1	40	40	4	1	0	4
	SUM	229	135	210	339	-8	-73	12	75
	RESP	39	41	49	75	19	11	1	22
	TOTAL	268	176	260	413	27	84	13	90

*** Segment A end ***

3" HORIZ. CONN. LOADS
Z-AXIAL
ANCHORED @ N.P. A06 (+Z)

320A3EO PROJECT W320 W/O ER4319 WESTINGHOUSE/BOEING CO
03/09/95 JUMPER 320 ISO J3 REV.0 AutoPIPE+4.50 RESULT PAGE 8

GLOBAL FORCES & MOMENTS

Point game	Load combination	FORCES (lb)				MOMENTS (ft-lb)			
		X	Y	Z	Result	X	Y	Z	Result
B08	GR	2	-115	-4	115	-5	-1	0	5
	T1	-6	-25	53	59	-50	-1	8	50
	P1	0	0	1	1	-1	0	0	1
	R1	36	10	2	38	2	1	1	2
	R2	1	24	0	24	1	0	0	1
	R3	2	2	36	36	4	0	0	4
	SUM	-4	-140	50	148	-56	-2	7	56
	RESP	39	36	38	65	6	2	1	7
B03	TOTAL	43	175	89	201	62	4	8	63
	GR	2	-118	-4	118	-34	-2	0	34
	T1	-6	-25	53	59	-56	1	8	56
	P1	0	0	1	1	-1	0	0	1
	R1	36	10	2	38	1	10	1	10
	R2	1	24	0	24	7	0	0	7
	R3	2	2	36	36	3	1	0	4
	SUM	-4	-142	50	151	-91	-1	7	91
	RESP	39	36	38	65	11	11	1	16
	TOTAL	43	178	89	203	102	12	8	103

3" - HORIZ. CONN. LOADS
Z-AXIAL
ANCHORED @ N.P. B03 (FZ)

*** Segment 8 end ***

APPENDIX G

FINITE-ELEMENT SYSTEM MODELS AT A PRE-LOAD OF 50 FT-LBF
FOR 2-, 3-, AND 4-IN. SIZES

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed APPENDIX "G" OF ISB JUMPER DOC.
Author E. O. WEINER

Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number 95-002

John Julius
Reviewer

1/25/95
Date

1.0 DESCRIPTION OF THE JUMPER CLAMP SYSTEM MODEL

A system model for the jumper clamp was constructed with ANSYS (1992) to determine how external pipe loads were carried to the nozzle.

Calculations given in Appendix C, Section 9.0, show that only about 350 ft-lbf bending moment can be transferred directly from the block to the nozzle for a 2-in. connector with a preload of 5000 lbf and a nozzle-block friction coefficient of 0.4. Since this is a small part of the currently-specified moment (components of 1600 and 2000 ft-lbf), it is clear that the balance of the moment must be carried through the hooks to the nozzle. Two such load paths from pipe to the nozzle are identified: (1) through the screw, nut, pins and hooks and (2) through the guide into the hooks. Since friction cannot be relied upon, no friction is assumed at the block-nozzle interface.

For expediency, the system model avoids gap and friction elements. Closing of gaps in the screw-nut-pin-hook and guide-hook interfaces is complex process for which simplifying assumptions are necessary. Given a preload, the load path through the screw, nut, pins and hooks is considered continuous except for rotations about the pin axis. The hooks are assumed to slide in the radial guide slots without any restraint to rotation. With the preload, the screw load path is considered active immediately. The preload is not included in the system model. Stresses from the current analysis are to be superimposed on the preload, pressure and thermal stresses.

The guide-hook interface has gaps such that the load path through that interface might activate at some point after external pipe loads are applied. Consequently, two configurations, with and without the guide contacting the hook, were analyzed. Other variations to the model include friction between the block and screw and hook moment transmission to the pins. Details of these kinematics are given below. The worst stresses among all the are to be used for the capacity checks of Appendix C.

Components are identified by element numbers as follows (see Section 7.2).

Elmt	Component
1-2	block
3	screw
4-6	nut
7	pipe extension
8-12	hook
16-19	guide

Kinematics are as follows:

- o ANSYS BEAM4 elements are used everywhere except for a weak COMBIN14 springs at the bottom of the block and between the screw and block. They prevent torsional rigid body modes of the block and screw under some of the kinematical variations.
- o The relatively rigid block includes an extension into the nozzle to the center of rotation of the block relative to the nozzle assuming no

friction. This accounts for free rotation of the block about the nozzle which can only be resisted by friction at the block-nozzle interface as well as load paths through the hooks.

- o All hook nodes and related coincident nodes have degrees of freedom aligned with a cylindrical coordinate system using the NROTATE command. The axis of this system coincides with the axis of the screw.
- o A MATRIX27 element was derived to provide lateral resistance between the screw and block top attributed to preload and the depression in which the screw bears. Both rolling (no-slip element) and free sliding (interface element) conditions were derived. Details are given in Section 7.1. The elements were incorporated into the basic model without the elements using the scripts of Section 5.4.
- o Hook-pin moments were released for another variation in the kinematics to see if the high stresses developed in the pins could be relieved by increasing the pin-hook tolerances.
- o The guide interacts with the hooks by coupling tangential displacement degrees of freedom at the common nodes. Guide removal is achieved by removing these couplings.
- o Hook-nozzle and block-nozzle contacts are 3D pins to ground.

2.0 CONCLUSIONS

System model hook stresses above 100 ksi indicate clearly that the nominal external piping reactions of Appendix F too high. Detailed analysis from the results of this analysis are given in Appendix C.

3.0 LEGEND

fx	force, beam axial, lbf
fy	force, beam lateral y
fz	force, beam lateral z
si	screw, i-node (at block)
gi	guide, i-node (at block)
sj	screw, j-node (at nut)
sd	stress, direct, psi
sbyt	stress, bending, y-direction, top
sbzt	stress, bending, z-direction, top
hg0	hook, at guide, inline with pipe
hg1	hook, at guide, 120 degrees from pipe axis
hn0	hook, at nut
hz2	hook, at nozzle, 240 degrees from pipe axis
ra	reaction, along nozzle axis
rt	reaction, tangential to nozzle axis
bt	block top
ux	global x (inline with pipe) displacement, in.
uy	global y (nozzle axis) displacement
rotx	rotation about global x, rad.

Local beam axes are as follows: the local Z-axis points toward the k-node which is on the connector axis unless the beam is on the connector axis. The

pipe serves for k-nodes of other elements. The beam X-axis is along the beam.

Results are given in Section 6.0. Each connector size has eight cases representing the kinematic variations of guide activation, screw-block slippage and hook-pin moment transmission.

4.0 LOAD CASES

Loads are applied at the intersection of the pipe and block. Axes shown here are those of the ANSYS model, not the model of Appendix F. The load values reflect the sums of GRAV, THER and SEIS cases of Appendix F.

Time	Component	2"	3"	4"
1	fx, lbf	400	2000	3000
2	fy, lbf	2300	15000	27000
3	fz, lbf	1000	2000	3000
4	mx, ft-lbf	2000	4000	7000
5	my, ft-lbf	1600	7000	13000
6	mz, ft-lbf	1600	7000	13000

5.0 MODEL DETAILS

5.1 BASIC JUMPER CLAMP SYSTEM MODELS

The following are CDWRITE results of the basic system models. Details of the 3" and 4" cases in common with the 2" case are omitted.

```

Fri Dec 30 11:44:45 PST 1994
File: guide2in.cdw
/COM,ANSYS REVISION 5.0          A      11:42:44    12/30/1994
/NOPT
/TITLE, LC6 (+1600 ft-lbf about Z-axis) **
ANTYPE, 0
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NUMOFF,MAT,     5
NUMOFF,REAL,    6
NUMOFF,COUP,    53
NUMOFF,TYPE,    5
NUMOFF,CSYS,    11
ET, 1, 4
KEYOP, 1, 6, 1
ET, 2, 14
KEYOP, 2, 2, 5
ET, 3, 4
KEYOP, 3, 6, 1
ET, 4, 4
KEYOP, 4, 6, 1
ET, 5, 4
KEYOP, 5, 6, 1
DOF,UX,UY,UZ,ROTX,ROTY,ROTZ,
TYPE, 2
REAL, 2
R,R5.0,1,LOC,1,1.50000000,41.0000000,41.0000000
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R,R5.0,2,LOC,1,695.000000,
R,R5.0,3,LOC,1,0.83000000,5.50000000E-02,5.50000000E-02
R,R5.0,3,LOC,4,1.03000000,1.0300000,
R,R5.0,4,LOC,1,2.17000000,0.16000000,0.35000000
R,R5.0,4,LOC,4,1.56000000,2.0000000,
R,R5.0,5,LOC,1,7.45000000E-02,4.96000000E-02,9.48300000E-02
R,R5.0,5,LOC,4,1.12000000,0.81000000,

```

```

R,R5.0, 6,LOC, 1, 1.95000000 , 0.150000000 , 0.150000000
R,R5.0, 6,LOC, 4, 1.00000000 , 1.95000000 ,
LOCAL,R5.0,LOC, 11, 1, 0.00000000E+00, 4.64000000 , 0.00000000E+00
LOCAL,R5.0,ANG, 11, 1, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00
LOCAL,R5.0,PRM, 11, 1, 1.00000000 , 1.00000000
CSCIR, 11, 0, 0
CSYS, 0
N,R5.0,LOC, 1, 0.00000000E+00, -1.05220000 ,
N,R5.0,LOC, 2, 0.00000000E+00, 2.28000000 ,
N,R5.0,LOC, 3, 0.00000000E+00, 3.84000000 ,
N,R5.0,LOC, 4, 0.00000000E+00, 3.84000000 ,
N,R5.0,LOC, 5, 0.00000000E+00, 7.02000000 ,
N,R5.0,LOC, 6, 1.56000000 , 7.02000000 , 0.00000000E+00
N,R5.0,ANG, 6, 0.00000000E+00, -90.0000000 ,
N,R5.0,LOC, 7, -0.780000160 , 7.02000000 , -1.35099991
N,R5.0,ANG, 7, 90.0000000 , 30.0000050 , 90.0000000
N,R5.0,LOC, 8, -0.780000160 , 7.02000000 , 1.35099991
N,R5.0,ANG, 8, -90.0000000 , 29.9999950 , -90.0000000
N,R5.0,LOC, 9, 1.56000000 , 7.02000000 , 0.00000000E+00
N,R5.0,ANG, 9, 0.00000000E+00, -90.0000000 ,
N,R5.0,LOC, 10, -0.780000160 , 7.02000000 , -1.35099991
N,R5.0,ANG, 10, 90.0000000 , 30.0000050 , 90.0000000
N,R5.0,LOC, 11, -0.780000160 , 7.02000000 , 1.35099991
N,R5.0,ANG, 11, -90.0000000 , 29.9999950 , -90.0000000
N,R5.0,LOC, 12, 1.88000000 , 4.64000000 , 0.00000000E+00
N,R5.0,ANG, 12, 0.00000000E+00, -90.0000000 ,
N,R5.0,LOC, 13, -0.939944679 , 4.64000000 , -1.62803194
N,R5.0,ANG, 13, 90.0000000 , 30.0000050 , 90.0000000
N,R5.0,LOC, 14, -0.939944679 , 4.64000000 , 1.62803194
N,R5.0,ANG, 14, -90.0000000 , 29.9999950 , -90.0000000
N,R5.0,LOC, 15, 1.56000000 , -0.620000000 , 0.00000000E+00
N,R5.0,ANG, 15, 0.00000000E+00, -90.0000000 ,
N,R5.0,LOC, 16, -0.780000160 , -0.620000000 , -1.35099991
N,R5.0,ANG, 16, 90.0000000 , 30.0000050 , 90.0000000
N,R5.0,LOC, 17, -0.780000160 , -0.620000000 , 1.35099991
N,R5.0,ANG, 17, -90.0000000 , 29.9999950 , -90.0000000
N,R5.0,LOC, 18, -1.69000000 , 2.28000000 ,
N,R5.0,LOC, 21, 0.00000000E+00, 4.64000000 ,
N,R5.0,LOC, 22, 1.88000000 , 4.64000000 , 0.00000000E+00
N,R5.0,ANG, 22, 0.00000000E+00, -90.0000000 ,
N,R5.0,LOC, 23, -0.939944679 , 4.64000000 , -1.62803194
N,R5.0,ANG, 23, 90.0000000 , 30.0000050 , 90.0000000
N,R5.0,LOC, 24, -0.939944679 , 4.64000000 , 1.62803194
N,R5.0,ANG, 24, -90.0000000 , 29.9999950 , -90.0000000
N,R5.0,LOC, 30, 0.00000000E+00, -1.50000000 ,
N,R5.0,LOC, 31, 0.00000000E+00, 5.21000000 ,
EN,R5.0,ATTR, 3, 1, 1, 1, 0
EN,R5.0,NODE, 1, 2, 18,
EN,R5.0,ATTR, 3, 2, 1, 1, 2, 0
EN,R5.0,NODE, 2, 3, 18,
EN,R5.0,ATTR, 3, 4, 1, 4, 4, 0
EN,R5.0,NODE, 5, 6, 3,
EN,R5.0,ATTR, 3, 4, 1, 4, 5, 0
EN,R5.0,NODE, 5, 7, 3,
EN,R5.0,ATTR, 3, 4, 1, 4, 6, 0
EN,R5.0,NODE, 5, 8, 3,
EN,R5.0,ATTR, 3, 4, 1, 4, 7, 0
EN,R5.0,NODE, 2, 18, 3,
EN,R5.0,ATTR, 3, 5, 1, 5, 8, 0
EN,R5.0,NODE, 9, 12, 3,
EN,R5.0,ATTR, 3, 5, 1, 5, 9, 0
EN,R5.0,NODE, 10, 13, 3,
EN,R5.0,ATTR, 3, 5, 1, 5, 10, 0
EN,R5.0,NODE, 11, 14, 3,
EN,R5.0,ATTR, 3, 5, 1, 5, 11, 0
EN,R5.0,NODE, 12, 15, 3,
EN,R5.0,ATTR, 3, 5, 1, 5, 12, 0
EN,R5.0,NODE, 13, 16, 3,
EN,R5.0,ATTR, 3, 5, 1, 5, 13, 0
EN,R5.0,NODE, 14, 17, 3,
EN,R5.0,ATTR, 3, 1, 1, 1, 16, 0
EN,R5.0,NODE, 3, 21, 18,
EN,R5.0,ATTR, 3, 1, 1, 6, 17, 0
EN,R5.0,NODE, 21, 22, 3,
EN,R5.0,ATTR, 3, 1, 1, 6, 18, 0
EN,R5.0,NODE, 21, 23, 3,
EN,R5.0,ATTR, 3, 1, 1, 6, 19, 0

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EN,R5.0,NODE, 21, 24, 3,
EN,R5.0,ATTR, 2, 1, 2, 2, 20, 0
EN,R5.0,NODE, 30, 1,
EN,R5.0,ATTR, 3, 3, 3, 3, 21, 0
EN,R5.0,NODE, 4, 31, 18,
EN,R5.0,ATTR, 3, 3, 3, 3, 22, 0
EN,R5.0,NODE, 31, 5, 18,
EN,R5.0,ATTR, 2, 1, 2, 2, 23, 0
EN,R5.0,NODE, 3, 4,
MPTEMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,EX, 1, 1, 27000000.0,
MPTEMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,EX, 2, 1, 27000000.0,
MPTEMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,EX, 3, 1, 27000000.0,
MPTEMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,EX, 4, 1, 27000000.0,
MPTEMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,EX, 5, 1, 27000000.0,
CP,R5.0, 2, 1,UX, 3, 4,
CP,R5.0, 2, 2,UY, 3, 4,
CP,R5.0, 2, 3,UZ, 3, 4,
CP,R5.0, 2, 31,UX, 6, 9,
CP,R5.0, 2, 32,UY, 6, 9,
CP,R5.0, 2, 33,UZ, 6, 9,
CP,R5.0, 2, 34,ROTX, 6, 9,
CP,R5.0, 2, 35,ROTZ, 6, 9,
CP,R5.0, 2, 36,UX, 7, 10,
CP,R5.0, 2, 37,UX, 8, 11,
CP,R5.0, 2, 38,UY, 7, 10,
CP,R5.0, 2, 39,UY, 8, 11,
CP,R5.0, 2, 40,UZ, 7, 10,
CP,R5.0, 2, 41,UZ, 8, 11,
CP,R5.0, 2, 42,ROTX, 7, 10,
CP,R5.0, 2, 43,ROTX, 8, 11,
CP,R5.0, 2, 44,ROTZ, 7, 10,
CP,R5.0, 2, 45,ROTZ, 8, 11,
CP,R5.0, 2, 51,UY, 12, 22,
CP,R5.0, 2, 52,UY, 13, 23,
CP,R5.0, 2, 53,UY, 14, 24,
AUTOTS,OFF
NSUBST, 1
KBC, 0
KUSE, 0
TIME, 0.000000000E+00
TREF, 0.000000000E+00
ALPHAD, 0.000000000E+00
BETAD, 0.000000000E+00
DMPRAT, 0.000000000E+00
TIMINT,OFF,STRU
CRPLIM, 0.100000000
NCNV, 1, 0.000000000E+00, 0, 0.000000000E+00, 0.000000000E+00
LNSRCH,OFF
NEQIT, 0
PRED,OFF,,OFF
ERESX,DEFA
OUTPR,BASI, ALL,
OUTRES, ALL, ALL,
ACEL, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00,
OMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0
DOMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGLOC, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGOMEG, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
DCGOME, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
IRLF, 0
D, 1,UX, 0.000000000E+00, 0.000000000E+00
D, 1,UY, 0.000000000E+00, 0.000000000E+00
D, 1,UZ, 0.000000000E+00, 0.000000000E+00
D, 15,UX, 0.000000000E+00, 0.000000000E+00
D, 15,UY, 0.000000000E+00, 0.000000000E+00
D, 15,UZ, 0.000000000E+00, 0.000000000E+00
D, 16,UX, 0.000000000E+00, 0.000000000E+00
D, 16,UY, 0.000000000E+00, 0.000000000E+00
D, 16,UZ, 0.000000000E+00, 0.000000000E+00
D, 17,UX, 0.000000000E+00, 0.000000000E+00
D, 17,UY, 0.000000000E+00, 0.000000000E+00
D, 17,UZ, 0.000000000E+00, 0.000000000E+00

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D, 30, ROTY, 0.000000000E+00, 0.000000000E+00
F, 2, MZ, 19200.0000, 0.000000000E+00
/GOPR

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/COM, ANSYS REVISION 5.0 A 11:43:01 12/30/1994

/NOPR

/TITLE, Jumper connector, jsmodel, 3 in

ANTYPE, 0

NUMOFF, NODE, 31

NUMOFF, ELEM, 23

NUMOFF, MAT, 5

NUMOFF, REAL, 6

NUMOFF, COUP, 53

NUMOFF, TYPE, 5

NUMOFF, CSYS, 11

ET, 1, 4

KEYOP, 1, 6, 1

ET, 2, 14

KEYOP, 2, 2, 5

ET, 3, 4

KEYOP, 3, 6, 1

ET, 4, 4

KEYOP, 4, 6, 1

ET, 5, 4

KEYOP, 5, 6, 1

DOF, UX, UY, UZ, ROTX, ROTY, ROTZ,

TYPE, 2

REAL, 2

R, R5.0, 1, LOC, 1, 3.28000000, 199.500000, 199.500000

R, R5.0, 1, LOC, 4, 5.00000000, 5.00000000,

R, R5.0, 2, LOC, 1, 1050.000000,

R, R5.0, 3, LOC, 1, 1.62400000, 0.210000000, 0.210000000

R, R5.0, 3, LOC, 4, 1.43800000, 1.43800000,

R, R5.0, 4, LOC, 1, 3.27500000, 0.855000000, 0.553000000

R, R5.0, 4, LOC, 4, 1.84000000, 2.62000000,

R, R5.0, 5, LOC, 1, 9.900000000E-02, 0.113000000, 0.210000000

R, R5.0, 5, LOC, 4, 1.36000000, 1.00000000,

R, R5.0, 6, LOC, 1, 3.28000000, 0.468000000, 0.426000000

R, R5.0, 6, LOC, 4, 1.25000000, 2.62000000,

LOCAL, R5.0, LOC, 11, 1, 0.000000000E+00, 4.64000000, 0.000000000E+00

LOCAL, R5.0, ANG, 11, 1, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00

LOCAL, R5.0, PRM, 11, 1, 1.00000000, 1.00000000

CSCIR, 11, 0, 0

CSYS, 0

N, R5.0, LOC, 1, 0.000000000E+00, -1.56810000,

N, R5.0, LOC, 2, 0.000000000E+00, 3.36000000,

N, R5.0, LOC, 3, 0.000000000E+00, 5.97000000,

N, R5.0, LOC, 4, 0.000000000E+00, 5.97000000,

N, R5.0, LOC, 5, 0.000000000E+00, 10.43000000,

N, R5.0, LOC, 6, 2.25000000, 10.43000000, 0.000000000E+00

N, R5.0, ANG, 6, 0.000000000E+00, -90.00000000,

N, R5.0, LOC, 7, -1.12500000, 10.43000000, -1.94900000

N, R5.0, ANG, 7, 90.00000000, 30.00000000, 90.00000000

N, R5.0, LOC, 8, -1.12500000, 10.43000000, 1.94900000

N, R5.0, ANG, 8, -90.00000000, 30.00000000, -90.00000000

N, R5.0, LOC, 9, 2.25000000, 10.43000000, 0.000000000E+00

N, R5.0, ANG, 9, 0.000000000E+00, -90.00000000,

N, R5.0, LOC, 10, -1.12500000, 10.43000000, -1.94900000

N, R5.0, ANG, 10, 90.00000000, 30.00000000, 90.00000000

N, R5.0, LOC, 11, -1.12500000, 10.43000000, 1.94900000

N, R5.0, ANG, 11, -90.00000000, 30.00000000, -90.00000000

N, R5.0, LOC, 12, 2.70000000, 7.68000000, 0.000000000E+00

N, R5.0, ANG, 12, 0.000000000E+00, -90.00000000,

N, R5.0, LOC, 13, -1.35000000, 7.68000000, -2.33826859

N, R5.0, ANG, 13, 90.00000000, 30.00000000, 90.00000000

N, R5.0, LOC, 14, -1.35000000, 7.68000000, 2.33826859

N, R5.0, ANG, 14, -90.00000000, 30.00000000, -90.00000000

N, R5.0, LOC, 15, 2.25000000, -0.830000000, 0.000000000E+00

N, R5.0, ANG, 15, 0.000000000E+00, -90.00000000,

N, R5.0, LOC, 16, -1.12500000, -0.830000000, -1.94900000

N, R5.0, ANG, 16, 90.00000000, 30.00000000, 90.00000000

N, R5.0, LOC, 17, -1.12500000, -0.830000000, 1.94900000

N, R5.0, ANG, 17, -90.00000000, 30.00000000, -90.00000000

N, R5.0, LOC, 18, -2.50000000, 3.36000000,

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N,R5.0,LOC, 21, 0.00000000E+00, 7.68000000 , 0.00000000E+00
N,R5.0,LOC, 22, 2.70000000 , 7.68000000 , 0.00000000E+00
N,R5.0,ANG, 22, 0.00000000E+00, -90.00000000 , 0.00000000E+00
N,R5.0,LOC, 23, -1.35000000 , 7.68000000 , -2.33826859
N,R5.0,ANG, 23, 90.00000000 , 30.00000000 , 90.00000000
N,R5.0,LOC, 24, -1.35000000 , 7.68000000 , 2.33826859
N,R5.0,ANG, 24, -90.00000000 , 30.00000000 , -90.00000000
N,R5.0,LOC, 30, 0.00000000E+00, -2.10000000 , 0.00000000E+00
N,R5.0,LOC, 31, 0.00000000E+00, 7.58900000 , 0.00000000E+00
EN,R5.0,ATTR, 3, 1, 1, 1, 0
EN,R5.0,NODE, 1, 2, 18,
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F, 2,MZ , -84000.0000 , 0.00000000E+00
/GOPR

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/COM,ANSYS REVISION 5.0

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11:43:22

12/30/1994

/NOPR

/TITLE,Jumper Clamp System Model - Guide Engaged (4-in Jumper)

ANTYPE, 0

NUMOFF,NODE, 31

NUMOFF,ELEM, 23

NUMOFF,MAT, 5

NUMOFF,REAL, 6

NUMOFF,COUP, 53

NUMOFF,TYPE, 5

NUMOFF,CSYS, 11

ET, 1, 4

KEYOP, 1, 6, 1

ET, 2, 14

KEYOP, 2, 2, 5

ET, 3, 4

KEYOP, 3, 6, 1

ET, 4, 4

KEYOP, 4, 6, 1

ET, 5, 4

KEYOP, 5, 6, 1

DOF,UX,UY,UZ,ROTX,ROTY,ROTZ,

TYPE, 2

REAL, 2

R,R5.0, 1,LOC, 1, 5.22000000 , 517.000000 , 517.000000

R,R5.0, 1,LOC, 4, 6.37000000 , 6.37000000 ,

R,R5.0, 2,LOC, 1, 2000.00000 ,

R,R5.0, 3,LOC, 1, 2.27800000 , 0.413000000 , 0.413000000

R,R5.0, 3,LOC, 4, 1.70300000 , 1.70300000 ,

R,R5.0, 4,LOC, 1, 3.20000000 , 2.67000000 , 1.23000000

R,R5.0, 4,LOC, 4, 2.62000000 , 1.78000000 ,

R,R5.0, 5,LOC, 1, 0.112000000 , 0.222000000 , 0.418000000

R,R5.0, 5,LOC, 4, 1.62000000 , 1.18000000 ,

R,R5.0, 6,LOC, 1, 3.20000000 , 0.440000000 , 0.420000000

R,R5.0, 6,LOC, 4, 1.25000000 , 2.56000000 ,

LOCAL,R5.0,LOC, 11, 1, 0.00000000E+00, 4.64000000 , 0.00000000E+00

LOCAL,R5.0,ANG, 11, 1, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00

LOCAL,R5.0,PRM, 11, 1, 1.00000000 , 1.00000000

CSCIR, 11, 0, 0

CSYS, 0

N,R5.0,LOC, 1, 0.00000000E+00, -2.05690000 ,

N,R5.0,LOC, 2, 0.00000000E+00, 4.26000000 ,

N,R5.0,LOC, 3, 0.00000000E+00, 6.89300000 ,

N,R5.0,LOC, 4, 0.00000000E+00, 6.89300000 ,

N,R5.0,LOC, 5, 0.00000000E+00, 11.73000000 ,

N,R5.0,LOC, 6, 2.68800000 , 11.73000000 , 0.00000000E+00

N,R5.0,ANG, 6, 0.00000000E+00, -90.00000000 ,

N,R5.0,LOC, 7, -1.34400000 , 11.73000000 , -2.32800000

N,R5.0,ANG, 7, 90.00000000 , 30.00000000 , 90.00000000

N,R5.0,LOC, 8, -1.34400000 , 11.73000000 , 2.32800000

N,R5.0,ANG, 8, -90.00000000 , 30.00000000 , -90.00000000

N,R5.0,LOC, 9, 2.68800000 , 11.73000000 , 0.00000000E+00

N,R5.0,ANG, 9, 0.00000000E+00, -90.00000000 ,

N,R5.0,LOC, 10, -1.34400000 , 11.73000000 , -2.32800000

N,R5.0,ANG, 10, 90.00000000 , 30.00000000 , 90.00000000

N,R5.0,LOC, 11, -1.34400000 , 11.73000000 , 2.32800000

N,R5.0,ANG, 11, -90.00000000 , 30.00000000 , -90.00000000

N,R5.0,LOC, 12, 3.44000000 , 8.45000000 , 0.00000000E+00

N,R5.0,ANG, 12, 0.00000000E+00, -90.00000000 ,

```

N,R5.0,LOC, 13, -1.71986550 , 8.45000000 , -2.97920504
N,R5.0,ANG, 13, 90.00000000 , 30.00000000 , 90.00000000
N,R5.0,LOC, 14, -1.71986550 , 8.45000000 , 2.97920504
N,R5.0,ANG, 14, -90.00000000 , 30.00000000 , -90.00000000
N,R5.0,LOC, 15, 2.68800000 , -0.85000000 , 0.00000000E+00
N,R5.0,ANG, 15, -90.00000000 , -90.00000000 , -90.00000000
N,R5.0,LOC, 16, -1.34400000 , -0.85000000 , -2.32800000
N,R5.0,ANG, 16, 90.00000000 , 30.00000000 , 90.00000000
N,R5.0,LOC, 17, -1.34400000 , -0.85000000 , 2.23800000
N,R5.0,ANG, 17, -90.00000000 , 30.00000000 , -90.00000000
N,R5.0,LOC, 18, -3.18500000 , 4.26000000 ,
N,R5.0,LOC, 21, 0.00000000E+00, 8.45000000 ,
N,R5.0,LOC, 22, 3.44000000 , 8.45000000 , 0.00000000E+00
N,R5.0,ANG, 22, 0.00000000E+00, -90.00000000 ,
N,R5.0,LOC, 23, -1.71986550 , 8.45000000 , -2.97920504
N,R5.0,ANG, 23, 90.00000000 , 30.00000000 , 90.00000000
N,R5.0,LOC, 24, -1.71986550 , 8.45000000 , 2.97920504
N,R5.0,ANG, 24, -90.00000000 , 30.00000000 , -90.00000000
N,R5.0,LOC, 30, 0.00000000E+00, -2.51000000 ,
N,R5.0,LOC, 31, 0.00000000E+00, 8.89300000 ,
EN,R5.0,ATTR, 3, 1, 1, 1, 1, 0
EN,R5.0,NODE, 1, 2, 18,
...
F, 2,MZ , -84000.0000 , 0.00000000E+00
/GOPR

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5.2 LOAD STEP INPUTS

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File: guide2in.stp
/solu
c*** 2 inch loads
ANTYP,STAT
OUTRES,ALL,ALL
OUTPR,BASIC,ALL
csys,0
allsel
ddelete,all,all
fdelete,all,all
C*** Boundary Conditions **
D,1,UX,0,0,1,1,UY,UZ
D,15,UX,0,0,17,1,UY,UZ
d,30,roty
C*** External Applied Forces **
FORCEX=400
FORCEY=2300
FORCEZ=1000
MOMENTX=(2000)*12
MOMENTY=(1600)*12
MOMENTZ=(1600)*12
C*** Forces Applied at Pipe Connection **
/title, LC1 (+400 lbf in the X direction) **
F,2,FX,FORCEX,,2,1
SOLVE
fdelete,all,all
/title, LC2 (+2300 lbf in the Y direction) **
F,2,FY,FORCEY,,2,1
SOLVE
fdelete,all,all
/title, LC3 (+1000 lbf in the Z direction) **
F,2,FZ,FORCEZ,,2,1
SOLVE
fdelete,all,all
C*** Moments at pipe connection **
/title, LC4 (+2000 ft-lbf about X-axis) **
F,2,MX,MOMENTX,,2,1
SOLVE
fdelete,all,all
/title, LC5 (+1600 ft-lbf about Y-axis) **
F,2,MY,MOMENTY,,2,1
SOLVE
fdelete,all,all
/title, LC6 (+1600 ft-lbf about Z-axis) **
F,2,MZ,MOMENTZ,,2,1

*go,:end
fdelete,all,all
/title, LC7 (Combined worst case for Fy = -2300) **
F,2,FX,FORCEX,,2,1
F,2,FY,-FORCEY,,2,1
F,2,FZ,FORCEZ,,2,1
F,2,MX,MOMENTX,,2,1
F,2,MY,-MOMENTY,,2,1
F,2,MZ,-MOMENTZ,,2,1
SOLVE
fdelete,all,all
/title, LC8 (Combined worst case for Fy = +2300) **
F,2,FX,FORCEX,,2,1
F,2,FY,FORCEY,,2,1
F,2,FZ,FORCEZ,,2,1
F,2,MX,MOMENTX,,2,1
F,2,MY,-MOMENTY,,2,1
F,2,MZ,-MOMENTZ,,2,1
SOLVE
: end
FINISH

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c*** 3 inch loads

/SOLU

ANTYP,STAT

OUTRES,ALL,ALL

OUTPR,BASIC,ALL

csys,0

allsel

ddele,all,all

fdele,all,all

C*** Boundary Conditions **

D,1,UX,0,0,1,1,UY,UZ

D,15,UX,0,0,17,1,UY,UZ

d,30,roty

C*** External Applied Forces **

FORCEX=2000

FORCEY=15000

FORCEZ=2000

MOMENTX=(4000)*12

MOMENTY=(7000)*12

MOMENTZ=(7000)*12

C*** Forces Applied at Pipe Connection **

/title, LC1 (+2000 lbf in the X direction) **

F,2,FX,FORCEX,,2,1

SOLVE

fdele,all,all

/title, LC2 (+15000 lbf in the Y direction) **

F,2,FY,FORCEY,,2,1

SOLVE

fdele,all,all

/title, LC3 (+2000 lbf in the Z direction) **

F,2,FZ,FORCEZ,,2,1

SOLVE

fdele,all,all

C*** Moments at pipe connection **

/title, LC4 (+4000 ft-lbf about X-axis) **

F,2,MX,MOMENTX,,2,1

SOLVE

fdele,all,all

/title, LC5 (+7000 ft-lbf about Y-axis) **

F,2,MY,MOMENTY,,2,1

SOLVE

fdele,all,all

/title, LC6 (+7000 ft-lbf about Z-axis) **

F,2,MZ,MOMENTZ,,2,1

SOLVE

*go,:end

fdele,all,all

/title, LC7 (Combined worst case for Fy = -15000) **

F,2,FX,FORCEX,,2,1

F,2,FY,-FORCEY,,2,1

F,2,FZ,FORCEZ,,2,1

F,2,MX,MOMENTX,,2,1

F,2,MY,-MOMENTY,,2,1

F,2,MZ,-MOMENTZ,,2,1

SOLVE

fdele,all,all

/title, LC8 (Combined worst case for Fy = +15000) **

F,2,FX,FORCEX,,2,1

F,2,FY,FORCEY,,2,1

F,2,FZ,FORCEZ,,2,1

F,2,MX,MOMENTX,,2,1

F,2,MY,-MOMENTY,,2,1

F,2,MZ,-MOMENTZ,,2,1

SOLVE

:end

FINISH

Fri Dec 30 11:45:34 PST 1994

File: guide4in.stp

c*** 4 inch loads

/SOLU

ANTYP,STAT

OUTRES,ALL,ALL

```

OUTPR,BASIC,ALL
csys,0
allsel
ddelete,all,all
fdelete,all,all
C*** Boundary Conditions **
D,1,UX,0,0,1,1,UY,UZ
D,15,UX,0,0,17,1,UY,UZ
d,30,roty
C*** External Applied Forces **
FORCEX=3000
FORCEY=27000
FORCEZ=3000
MOMENTX=(7000)*12
MOMENTY=(13000)*12
MOMENTZ=(13000)*12
C*** Forces Applied at Pipe Connection **
/title, LC1 (+3000 lbf in the X direction) **
F,2,FX,FORCEX,,2,1
SOLVE
fdelete,all,all
/title, LC2 (+27000 lbf in the Y direction) **
F,2,FY,FORCEY,,2,1
SOLVE
fdelete,all,all
/title, LC3 (+3000 lbf in the Z direction) **
F,2,FZ,FORCEZ,,2,1
SOLVE
fdelete,all,all
C*** Moments at pipe connection **
/title, LC4 (+7000 ft-lbf about X-axis) **
F,2,MX,MOMENTX,,2,1
SOLVE
fdelete,all,all
/title, LC5 (+13000 ft-lbf about Y-axis) **
F,2,MY,MOMENTY,,2,1
SOLVE
fdelete,all,all
/title, LC6 (+13000 ft-lbf about Z-axis) **
F,2,MZ,MOMENTZ,,2,1
SOLVE
*go,:end
fdelete,all,all
/title, LC7 (Combined worst case for Fy = -27000) **
F,2,FX,FORCEX,,2,1
F,2,FY,-FORCEY,,2,1
F,2,FZ,FORCEZ,,2,1
F,2,MX,MOMENTX,,2,1
F,2,MY,-MOMENTY,,2,1
F,2,MZ,-MOMENTZ,,2,1
SOLVE
fdelete,all,all
/title, LC8 (Combined worst case for Fy = +27000) **
F,2,FX,FORCEX,,2,1
F,2,FY,FORCEY,,2,1
F,2,FZ,FORCEZ,,2,1
F,2,MX,MOMENTX,,2,1
F,2,MY,-MOMENTY,,2,1
F,2,MZ,-MOMENTZ,,2,1
SOLVE
:end
FINISH

```

5.3 POST26 DIRECTIVES

The POST26 directives shown here are common to all connector sizes.

```
Fri Dec 30 11:45:34 PST 1994
File: guide.p26
/post26
numvar,20
c*** hook reactions at nozzle, global axial and tangential
rforce, 2,15, f, z,hz0-ra
rforce, 3,16, f, z,hz1-ra
rforce, 4,17, f, z,hz2-ra
rforce, 5,15, f, y,hz0-rt
rforce, 6,16, f, y,hz1-rt
rforce, 7,17, f, y,hz2-rt
store,new
prvar,2,3,4,5,6,7
c*** upper hook section stresses at guide, 0 and 120 degr
esol, 2, 8,, ls, 6, hg0-sd
esol, 3, 8,, ls, 7, hg0-sbyt
esol, 4, 8,, ls, 9, hg0-sbzt
esol, 5, 9,, ls, 6, hg1-sd
esol, 6, 9,, ls, 7, hg1-sbyt
esol, 7, 9,, ls, 9, hg1-sbzt
store,new
add, 2, 2,,,hg0-sd,,, .082      ! area used / actual area
add, 5, 5,,,hg1-sd,,, .082
prvar,2,3,4,5,6,7
c*** upper hook section stresses at nut, 0 and 120 degr
esol, 2, 8,, ls, 1, hn0-sd
esol, 3, 8,, ls, 2, hn0-sbyt
esol, 4, 8,, ls, 4, hn0-sbzt
esol, 5, 9,, ls, 1, hn1-sd
esol, 6, 9,, ls, 2, hn1-sbyt
esol, 7, 9,, ls, 4, hn1-sbzt
store,new
add, 2, 2,,,hg0-sd,,, .082
add, 5, 5,,,hg1-sd,,, .082
prvar,2,3,4,5,6,7
c*** screw forces and stresses at nut
esol, 2, 22,, smisc, 7, sj-fx
esol, 3, 22,, smisc, 8, sj-fy
esol, 4, 22,, smisc, 9, sj-fz
esol, 5, 22,, ls, 6, sj-sd
esol, 6, 22,, ls, 7, sj-sbyt
esol, 7, 22,, ls, 9, sj-sbzt
store,new
prvar,2,3,4,5,6,7
c*** screw and guide forces at block top
esol, 2, 21,, smisc, 1, si-fx
esol, 3, 21,, smisc, 2, si-fy
esol, 4, 21,, smisc, 3, si-fz
esol, 5,16,, smisc, 1, gi-fx
esol, 6,16,, smisc, 2, gi-fy
esol, 7,16,, smisc, 3, gi-fz
store,new
prvar,2,3,4,5,6,7
c*** block forces and moments at top of block
esol, 2, 2,, smisc, 7, bt-fx
esol, 3, 2,, smisc, 8, bt-fy
esol, 4, 2,, smisc, 9, bt-fz
esol, 5, 2,, smisc, 10, bt-mx
esol, 6, 2,, smisc, 11, bt-my
esol, 7, 2,, smisc, 12, bt-mz
store,new
prvar,2,3,4,5,6,7
c*** block top displacements
nsol, 2, 3, u, x, bt-ux
nsol, 3, 3, u, y, bt-uy
nsol, 4, 3, u, z, bt-uz
nsol, 5, 3, rot, x, bt-rotx
nsol, 6, 3, rot, y, bt-roty
nsol, 7, 3, rot, z, bt-rotz
```



```

store,new
prvar,2,3,4,5,6,7
c*** nut displacements
nsol, 2, 5, u, x, nut-ux
nsol, 3, 5, u, y, nut-uy
nsol, 4, 5, u, z, nut-uz
nsol, 5, 5, rot, x, nut-rotx
nsol, 6, 5, rot, y, nut-rotz
nsol, 7, 5, rot, z, nut-rotz
store,new
prvar,2,3,4,5,6,7
c*** Hook-pin and hook-guide relative displacements
nsol, 2, 6, rot, x
nsol, 3, 9, rot, x
nsol, 5, 7, rot, x
nsol, 6, 10, rot, x
nsol, 8, 12, rot, x
nsol, 9, 22, rot, x
nsol, 12, 13, rot, x
nsol, 13, 23, rot, x
nsol, 15, 12, u, y
nsol, 16, 22, u, y
nsol, 18, 13, u, y
nsol, 19, 23, u, y
store,new
add, 4, 2, 3,,drrph0,,, 1., -1.
add, 7, 5, 6,,drrph1,,, 1., -1.
add, 10, 8, 9,,drrhg0,,, 1., -1.
add, 14, 12, 13,,drrhg1,,, 1., -1.
add, 17, 15, 16,,duthg0,,, 1., -1.
add, 20, 18, 19,,duthg1,,, 1., -1.
prvar,4,7,10,14,17,20
c*** Screw-guide and screw-block relative displacements
nsol, 2, 31, u, x
nsol, 3, 21, u, x
nsol, 5, 31, u, z
nsol, 6, 21, u, z
nsol, 8, 31, rot, x
nsol, 9, 21, rot, x
nsol, 12, 31, rot, z
nsol, 13, 21, rot, z
nsol, 15, 4, u, x
nsol, 16, 3, u, x
nsol, 18, 4, u, z
nsol, 19, 3, u, z
store,new
add, 4, 2, 3,,duxsg,,, 1., -1.
add, 7, 5, 6,,duzsg,,, 1., -1.
add, 10, 8, 9,,drxsg,,, 1., -1.
add, 14, 12, 13,,drzsg,,, 1., -1.
add, 17, 15, 16,,duxsb,,, 1., -1.
add, 20, 18, 19,,duzsb,,, 1., -1.
prvar,4,7,10,14,17,20
c***
finish

```

5.4 RUN SCRIPTS

Run scripts for the 3" and 4" connectors are updated from the 2" script with minor changes for the MATRIX27 elements and labelling. Details of the 3" and 4" cases in common with the 2" case are omitted.

Wed Jan 4 07:56:49 PST 1995
 File: f2in.scr

```
# Jumper connector system model script. EO Weiner 1/3/95
# Use guide?in.db as basic data base. This model has:
#   Guide active
#   No-slip screw-block connection
#   Pin moments transmitted
# The variations are temporarily changed in the database herein:
#   Guide inactive
#   Interface element screw-block connection
#   Pin moments released
# one at a time with appropriate headers echoed before the post26
# is collected. p26fmt strips unneeded output from the post26
# output and f-formats the data suitable for subsequent use. sed.o26
# are sed directives that precondition input for p26fmt.
# File guide?in.stp are loads steps; guide.p26 has post26 input.
# Final output file is 2in.tbl.
# Edit this script for each size connector by s;2in;3in;g, changing
# 2 inch echo, and changing h, r1 and r2 in the matrix27 input.
# Usage: csh 2in.scr >&csh.out &
#
rm 2in.tbl          # fresh post26 output file
rm 2in.out          # fresh generic ansys output
#
echo "\014" >>2in.tbl      # page break
echo \ 'date' >>2in.tbl
echo " 2 inch jumper connector system model" >>2in.tbl
echo " Guide active" >>2in.tbl
echo " No-slip screw-block connection" >>2in.tbl
echo " Pin moments transmitted" >>2in.tbl
#
rm g2in.o26 file.*
ansys <<eof >>2in.out
/batch
resume,guide2in.db
/title, Jumper connector system model, GA, NS, PT
/prep7
c*** Screw/block interface matrix27 element, no-slip
c*** 2 inch
et,9,27,,,4
r1=1.31          ! screw radius
r2=1.37          ! block depression radius
h=7.02-3.84      ! block-nut dy
pre=5000         ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2-pre*h
r,9,0
rmodif,9,51,pdr12
,9,78,pdr12
,9,34,pdr12
,9,73,pdr12
,9,57,-pdr12
,9,40,-pdr12
real,9          ! install the interface element
type,9
e,3,4
fini
/input,guide2in.stp
/output,g2in,o26
/input,guide,p26
/output
fini
/exit,nosave
```

```

eof
#
sed -f sed.o26 g2in.o26 | p26fmt >>2in.tbl
#
#
echo "\014" >>2in.tbl
echo \ 'date' >>2in.tbl
echo " 2 inch jumper connector system model" >>2in.tbl
echo " Guide inactive" >>2in.tbl
echo " No-slip screw-block connection" >>2in.tbl
echo " Pin moments transmitted" >>2in.tbl
#
rm g2in.o26 file.*
ansys <<eof >>2in.out
/batch
resume,guide2in.db
/title, Jumper connector system model, G1, NS, PT
/prep7
cpdele,51,53      ! remove hook-guide coupling
c*** Screw/block interface matrix27 element, no-slip
c*** 2 inch
et,9,27,,,4
r1=1.31          ! screw radius
r2=1.37          ! block depression radius
h=7.02-3.84      ! block-nut dy
pre=5000         ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2-pre*h
r,9,0
rmodif,9,51,pdr12
,9,78,pdr12
,9,34,pdr12
,9,73,pdr12
,9,57,-pdr12
,9,40,-pdr12
real,9           ! install the interface element
type,9
e,3,4
fini
/input,guide2in,stp
/output,g2in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g2in.o26 | p26fmt >>2in.tbl
#
#
echo "\014" >>2in.tbl
echo \ 'date' >>2in.tbl
echo " 2 inch jumper connector system model" >>2in.tbl
echo " Guide active" >>2in.tbl
echo " Interface element screw-block connection" >>2in.tbl
echo " Pin moments transmitted" >>2in.tbl
#
rm g2in.o26 file.*
ansys <<eof >>2in.out
/batch
resume,guide2in.db
/title, Jumper connector system model, GA, IE, PT
/prep7
c*** Screw/block interface matrix27 element
c*** 2 inch
et,9,27,,,4
r1=1.31          ! screw radius
r2=1.37          ! block depression radius
pre=5000         ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2
r,9,pdr
rmodif,9,6,-pdr1
,9,51,pdr12
,9,58,pdr

```

```
,9,63,-pdr1
,9,78,pdr12
,9,24,pdr
,9,25,pdr1
,9,34,pdr12
,9,69,pdr
,9,70,pdr1
,9,73,pdr12
,9,7,-pdr
,9,12,pdr1
,9,52,pdr1
,9,57,-pdr12
,9,30,-pdr
,9,31,-pdr1
,9,39,-pdr1
,9,40,-pdr12
cpdele,1      ! remove ux & uz screw-block couplings
cpdele,3
real,9        ! install the interface element
type,9
e,3,4
fini
/input,guide2in,stp
/output,g2in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g2in.o26 | p26fmt >>2in.tbl
#
#
echo "\014" >>2in.tbl
echo \ 'date' >>2in.tbl
echo " 2 inch jumper connector system model" >>2in.tbl
echo " Guide inactive" >>2in.tbl
echo " Interface element screw-block connection" >>2in.tbl
echo " Pin moments transmitted" >>2in.tbl
#
rm g2in.o26 file.*
ansys <<eof >>2in.out
/batch
resume,guide2in,db
/title, Jumper connector system model, GI, NS, PT
/prep7
cpdele,51,53    ! remove hook-guide coupling
c*** Screw/block interface matrix27 element
c*** 2 inch
et,9,27,,,4
r1=1.31         ! screw radius
r2=1.37         ! block depression radius
pre=5000        ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2
r,9,pdr
rmodif,9,6,-pdr1
,9,51,pdr12
,9,58,pdr
,9,63,-pdr1
,9,78,pdr12
,9,24,pdr
,9,25,pdr1
,9,34,pdr12
,9,69,pdr
,9,70,pdr1
,9,73,pdr12
,9,7,-pdr
,9,12,pdr1
,9,52,pdr1
,9,57,-pdr12
,9,30,-pdr
,9,31,-pdr1
,9,39,-pdr1
,9,40,-pdr12
cpdele,1      ! remove ux & uz screw-block couplings
```

```

cpdele,3
real,9          ! install the interface element
type,9
e,3,4
fini
/input,guide2in,stp
/output,g2in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g2in.o26 | p26fmt >>2in.tbl
#
echo "\014" >>2in.tbl
echo \ 'date' >>2in.tbl
echo " 2 inch jumper connector system model" >>2in.tbl
echo " Guide active" >>2in.tbl
echo " No-slip screw-block connection" >>2in.tbl
echo " Pin moments released" >>2in.tbl
#
rm g2in.o26 file.*
ansys <<eof >>2in.out
/batch
resume,guide2in,db
/title, Jumper connector system model, GA, NS, PR
/prep7
cpdele,34      ! release pin moments
cpdele,42,43
c*** Screw/block interface matrix27 element, no-slip
c*** 2 inch
et,9,27,,,4
r1=1.31        ! screw radius
r2=1.37        ! block depression radius
h=7.02-3.84    ! block-nut dy
pre=5000       ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2-pre*h
r,9,0
rmodif,9,51,pdr12
,9,78,pdr12
,9,34,pdr12
,9,73,pdr12
,9,57,-pdr12
,9,40,-pdr12
real,9          ! install the interface element
type,9
e,3,4
fini
/input,guide2in,stp
/output,g2in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g2in.o26 | p26fmt >>2in.tbl
#
echo "\014" >>2in.tbl
echo \ 'date' >>2in.tbl
echo " 2 inch jumper connector system model" >>2in.tbl
echo " Guide inactive" >>2in.tbl
echo " No-slip screw-block connection" >>2in.tbl
echo " Pin moments released" >>2in.tbl
#
rm g2in.o26 file.*
ansys <<eof >>2in.out
/batch
resume,guide2in,db
/title, Jumper connector system model, GI, NS, PR
/prep7
cpdele,34      ! release pin moments
cpdele,42,43

```

```

cpdele,51,53      ! remove hook-guide coupling
c*** Screw/block interface matrix27 element, no-slip
c*** 2 inch
et,9,27,,,4
r1=1.31           ! screw radius
r2=1.37           ! block depression radius
h=7.02-3.84       ! block-nut dy
pre=5000          ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2-pre*h
r,9,0
rmodif,9,51,pdr12
,9,78,pdr12
,9,34,pdr12
,9,73,pdr12
,9,57,-pdr12
,9,40,-pdr12
real,9            ! install the interface element
type,9
e,3,4
fini
/input,guide2in,stp
/output,g2in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g2in.o26 | p26fmt >>2in.tbl
#
echo "\014" >>2in.tbl
echo \ 'date' >>2in.tbl
echo " 2 inch jumper connector system model" >>2in.tbl
echo " Guide active" >>2in.tbl
echo " Interface element screw-block connection" >>2in.tbl
echo " Pin moments released" >>2in.tbl
#
rm g2in.o26 file.*
ansys <<eof >>2in.out
/batch
resume,guide2in,db
/title, Jumper connector system model, GA, IE, PR
/prep7
cpdele,34         ! release pin moments
cpdele,42,43
c*** Screw/block interface matrix27 element
c*** 2 inch
et,9,27,,,4
r1=1.31           ! screw radius
r2=1.37           ! block depression radius
pre=5000          ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2
r,9,pdr
rmodif,9,6,-pdr1
,9,51,pdr12
,9,58,pdr
,9,63,-pdr1
,9,78,pdr12
,9,24,pdr
,9,25,pdr1
,9,34,pdr12
,9,69,pdr
,9,70,pdr1
,9,73,pdr12
,9,7,-pdr
,9,12,pdr1
,9,52,pdr1
,9,57,-pdr12
,9,30,-pdr
,9,31,-pdr1
,9,39,-pdr1
,9,40,-pdr12

```

```

cpdele,1      ! remove ux & uz screw-block couplings
cpdele,3
real,9        ! install the interface element
type,9
e,3,4
fini
/input,guide2in,stp
/output,g2in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g2in.o26 | p26fmt >>2in.tbl
#
#
echo "\014" >>2in.tbl
echo \ 'date' >>2in.tbl
echo " 2 inch jumper connector system model" >>2in.tbl
echo " Guide inactive" >>2in.tbl
echo " Interface element screw-block connection" >>2in.tbl
echo " Pin moments released" >>2in.tbl
#
rm g2in.o26 file.*
ansys <<eof >>2in.out
/batch
resume,guide2in.db
/title, Jumper connector system model, GI, IE, PR
/prep7
cpdele,34      ! release pin moments
cpdele,42,43
cpdele,51,53   ! remove hook-guide coupling
c*** Screw/block interface matrix27 element
c*** 2 inch
et,9,27,,,4
r1=1.31        ! screw radius
r2=1.37        ! block depression radius
pre=5000       ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2
r,9,pdr
rmodif,9,6,-pdr1
,9,51,pdr12
,9,58,pdr
,9,63,-pdr1
,9,78,pdr12
,9,24,pdr
,9,25,pdr1
,9,34,pdr12
,9,69,pdr
,9,70,pdr1
,9,73,pdr12
,9,7,-pdr
,9,12,pdr1
,9,52,pdr1
,9,57,-pdr12
,9,30,-pdr
,9,31,-pdr1
,9,39,-pdr1
,9,40,-pdr12
cpdele,1      ! remove ux & uz screw-block couplings
cpdele,3
real,9        ! install the interface element
type,9
e,3,4
fini
/input,guide2in,stp
/output,g2in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g2in.o26 | p26fmt >>2in.tbl

```

Wed Jan 4 07:56:49 PST 1995
File: f3in.scr

```
# Jumper connector system model script. EO Weiner 1/3/95
# Use guide?in.db as basic data base. This model has:
#   Guide active
#   No-slip screw-block connection
#   Pin moments transmitted
# The variations are temporarily changed in the database herein:
#   Guide inactive
#   Interface element screw-block connection
#   Pin moments released
# one at a time with appropriate headers echoed before the post26
# is collected. p26fmt strips unneeded output from the post26
# output and f-formats the data suitable for subsequent use. sed.o26
# are sed directives that precondition input for p26fmt.
# File guide?in.stp are loads steps; guide.p26 has post26 input.
# Final output file is 2in.tbl.
# Edit this script for each size connector by s;2in;3in;g, changing
# 2 inch echo, and changing h, r1 and r2 in the matrix27 input.
# Usage: csh 3in.scr >&csh.out &
#
rm 3in.tbl          # fresh post26 output file
rm 3in.out          # fresh generic ansys.output
#
echo "\014" >>3in.tbl      # page break
echo \ 'date' >>3in.tbl
echo " 3 inch jumper connector system model" >>3in.tbl
echo " Guide active" >>3in.tbl
echo " No-slip screw-block connection" >>3in.tbl
echo " Pin moments transmitted" >>3in.tbl
#
rm g3in.o26 file.*
ansys <<eof >>3in.out
/batch
resume,guid3in.db
/title, Jumper connector system model, GA, NS, PT
/prep7
c*** Screw/block interface matrix27 element, no-slip
c*** 3 inch
et,9,27,,,4
r1=1.56             ! screw radius
r2=1.62             ! block depression radius
h=10.43-5.97        ! block-nut dy
pre=5000            ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2-pre*h
r,9,0
rmodif,9,51,pdr12
,9,78,pdr12
,9,34,pdr12
,9,73,pdr12
,9,57,-pdr12
,9,40,-pdr12
real,9              ! install the interface element
type,9
e,3,4
fini
/input,guid3in.stp
/output,g3in.o26
/input,guid,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g3in.o26 | p26fmt >>3in.tbl
#
...
#
#
echo "\014" >>3in.tbl
echo \ 'date' >>3in.tbl
```



```

echo " 3 inch jumper connector system model" >>3in.tbl
echo " Guide active" >>3in.tbl
echo " Interface element screw-block connection" >>3in.tbl
echo " Pin moments transmitted" >>3in.tbl
#
rm g3in.o26 file.*
ansys <<eof >>3in.out
/batch
resume,guide3in.db
/title, Jumper connector system model, GA, IE, PT
/prep7
c*** Screw/block interface matrix27 element
c*** 3 inch
et,9,27,,,4
r1=1.56      ! screw radius
r2=1.62      ! block depression radius
pre=5000     ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2
r,9,pdr
rmodif,9,6,-pdr1
,9,51,pdr12
,9,58,pdr
,9,63,-pdr1
,9,78,pdr12
,9,24,pdr
,9,25,pdr1
,9,34,pdr12
,9,69,pdr
,9,70,pdr1
,9,73,pdr12
,9,7,-pdr
,9,12,pdr1
,9,52,pdr1
,9,57,-pdr12
,9,30,-pdr
,9,31,-pdr1
,9,39,-pdr1
,9,40,-pdr12
cpdele,1      ! remove ux & uz screw-block couplings
cpdele,3
real,9        ! install the interface element
type,9
e,3,4
fini
/input,guide3in.stp
/output,g3in.o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g3in.o26 | p26fmt >>3in.tbl
#
#
...

```

Wed Jan 4 07:56:49 PST 1995
File: f4in.scr

```

# Jumper connector system model script. EO Weiner 1/3/95
# Use guide?in.db as basic data base. This model has:
#   Guide active
#   No-slip screw-block connection
#   Pin moments transmitted
# The variations are temporarily changed in the database herein:
#   Guide inactive
#   Interface element screw-block connection
#   Pin moments released
# one at a time with appropriate headers echoed before the post26
# is collected. p26fmt strips unneeded output from the post26
# output and f-formats the data suitable for subsequent use. sed.o26
# are sed directives that precondition input for p26fmt.
# File guide?in.stp are loads steps; guide.p26 has post26 input.

```

```
# Final output file is 2in.tbl.
# Edit this script for each size connector by s;2in;3in;g, changing
# 2 inch echo, and changing h, r1 and r2 in the matrix27 input,
# Usage: csh 4in.scr >&csh.out &
#
rm 4in.tbl          # fresh post26 output file
rm 4in.out          # fresh generic ansys output
#
echo "\014" >>4in.tbl      # page break
echo \ 'date' >>4in.tbl
echo " 4 inch jumper connector system model" >>4in.tbl
echo " Guide active" >>4in.tbl
echo " No-slip screw-block connection" >>4in.tbl
echo " Pin moments transmitted" >>4in.tbl
#
rm g4in.o26 file.*
ansys <<eof >>4in.out
/batch
resume,guide4in,db
/title, Jumper connector system model, GA, NS, PT
/prep7
c*** Screw/block interface matrix27 element, no-slip
c*** 4 inch
et,9,27,,,4
r1=1.94          ! screw radius
r2=2.00          ! block depression radius
h=11.73-6.89     ! block-nut dy
pre=5000         ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
pdr12=pdr1*r2-pre*h
r,9,0
rmodif,9,51,pdr12
,9,78,pdr12
,9,34,pdr12
,9,73,pdr12
,9,57,-pdr12
,9,40,-pdr12
real,9           ! install the interface element
type,9
e,3,4
fini
/input,guide4in,stp
/output,g4in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g4in.o26 | p26fmt >>4in.tbl
#
...
#
echo "\014" >>4in.tbl
echo \ 'date' >>4in.tbl
echo " 4 inch jumper connector system model" >>4in.tbl
echo " Guide active" >>4in.tbl
echo " Interface element screw-block connection" >>4in.tbl
echo " Pin moments transmitted" >>4in.tbl
#
rm g4in.o26 file.*
ansys <<eof >>4in.out
/batch
resume,guide4in,db
/title, Jumper connector system model, GA, IE, PT
/prep7
c*** Screw/block interface matrix27 element
c*** 4 inch
et,9,27,,,4
r1=1.94          ! screw radius
r2=2.00          ! block depression radius
pre=5000         ! preload
pdr=pre/(r2-r1)
pdr1=pdr*r1
```

```

pdr12=pdr1*r2
r,9,pdr
rmodif,9,6,-pdr1
,9,51,pdr12
,9,58,pdr
,9,63,-pdr1
,9,78,pdr12
,9,24,pdr
,9,25,pdr1
,9,34,pdr12
,9,69,pdr
,9,70,pdr1
,9,73,pdr12
,9,7,-pdr
,9,12,pdr1
,9,52,pdr1
,9,57,-pdr12
,9,30,-pdr
,9,31,-pdr1
,9,39,-pdr1
,9,40,-pdr12
cpdele,1      ! remove ux & uz screw-block couplings
cpdele,3
real,9        ! install the interface element
type,9
e,3,4
fini
/input,guide4in,stp
/output,g4in,o26
/input,guide,p26
/output
fini
/exit,nosave
eof
#
sed -f sed.o26 g4in.o26 | p26fmt >>4in.tbl
#
#
...

```

6.0 RESULTS

Results are presented for each size of connector. The data shown here are those written by the scripts to files ?in.tbl.

Tue Jan 3 14:32:05 PST 1995
2 inch jumper connector system model
Guide active
No-slip screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	535.	-268.	-268.	0.	108.	-108.
2.0	-39.	-39.	-39.	0.	0.	0.
3.0	0.	-1159.	1159.	311.	-156.	-156.
4.0	0.	-8345.	8345.	2240.	-1120.	-1120.
5.0	0.	0.	0.	-4064.	-4064.	-4064.
6.0	-7709.	3854.	3854.	0.	-1552.	1552.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-584.	0.	-1011.	292.	4548.	505.
2.0	43.	0.	74.	43.	0.	74.
3.0	0.	13130.	0.	1264.	-6565.	2189.
4.0	0.	94563.	0.	9103.	-47282.	15764.
5.0	0.	-171574.	0.	0.	-171576.	0.
6.0	8409.	0.	14567.	-4205.	-65516.	-7281.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-584.	0.	0.	292.	1802.	0.
2.0	43.	0.	0.	43.	0.	0.
3.0	0.	5202.	0.	1264.	-2601.	0.
4.0	0.	37457.	0.	9103.	-18726.	0.
5.0	0.	-185059.	0.	0.	-185057.	0.
6.0	8409.	0.	0.	-4205.	-25950.	0.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-243.	0.	0.	-7941.
2.0	-118.	0.	0.	-142.	0.	0.
3.0	0.	-607.	0.	0.	-19853.	0.
4.0	0.	-4369.	0.	0.	-143009.	0.
5.0	0.	0.	0.	0.	-5.	0.
6.0	0.	0.	3495.	0.	0.	114408.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-243.	0.	0.	429.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	-607.	0.	0.	1073.	0.
4.0	0.	-4369.	0.	0.	7728.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	3495.	0.	0.	-6183.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	187.	0.	-420.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	467.	0.	0.	0.	1050.
4.0	0.	3360.	0.	0.	0.	7563.
5.0	0.	0.	0.	-19019.	0.	0.
6.0	0.	0.	-2688.	0.	6051.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.01440	0.00000	0.00000	0.00000	0.00000	-0.00294
2.0	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.03600	0.00735	0.00000	0.00000
4.0	0.00000	0.00000	0.25923	0.05298	0.00000	0.00000
5.0	0.00000	0.00000	-0.00001	0.00000	0.25984	0.00000
6.0	-0.20738	0.00000	0.00000	0.00000	0.00000	0.04239

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.02079	0.00000	0.00000	0.00000	0.00000	-0.00138
2.0	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.05199	0.00345	0.00000	0.00000
4.0	0.00000	0.00000	0.37440	0.02482	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.29265	0.00000
6.0	-0.29952	0.00000	0.00000	0.00000	0.00000	0.01986

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	0.00000	0.00000	-0.00057	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00165	0.00082	0.00000	0.00000
4.0	0.00000	0.00000	-0.01188	0.00594	0.00000	0.00000
5.0	0.00000	0.00000	-0.04647	-0.04647	0.00000	0.00000
6.0	0.00000	0.00000	0.00000	0.00823	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	0.00077	0.00000	0.00000	0.00080	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00193	-0.00199	0.00000	0.00000	0.00000
4.0	0.00000	0.01392	-0.01436	0.00000	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	-0.01113	0.00000	0.00000	-0.01149	0.00000	0.00000

c***

Tue Jan 3 14:32:10 PST 1995
2 inch jumper connector system model
Guide inactive
No-slip screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME ldcs	15 FZ hz0-ra	16 FZ hz1-ra	17 FZ hz2-ra	15 FY hz0-rt	16 FY hz1-rt	17 FY hz2-rt
1.0	534.	-267.	-267.	0.	110.	-110.
2.0	-39.	-39.	-39.	0.	0.	0.
3.0	0.	-1157.	1157.	317.	-158.	-158.
4.0	0.	-8335.	8335.	2283.	-1141.	-1141.
5.0	0.	0.	0.	-2037.	-2037.	-2037.
6.0	-7699.	3850.	3850.	0.	-1581.	1581.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME ldcs	2 ADD 6 hg0-sd	8 LS 7 hg0-sbyt	8 LS 9 hg0-sbzt	5 ADD 6 hg1-sd	9 LS 7 hg1-sbyt	9 LS 9 hg1-sbzt
1.0	-583.	0.	-1010.	292.	4635.	505.
2.0	43.	0.	74.	43.	0.	74.
3.0	0.	13381.	0.	1262.	-6691.	2186.
4.0	0.	96369.	0.	9092.	-48185.	15745.
5.0	0.	-85990.	0.	0.	-85991.	0.
6.0	8399.	0.	14549.	-4199.	-66767.	-7272.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME ldcs	2 ADD 1 hg0-sd	8 LS 2 hn0-sbyt	8 LS 4 hn0-sbzt	5 ADD 1 hg1-sd	9 LS 2 hn1-sbyt	9 LS 4 hn1-sbzt
1.0	-583.	0.	0.	292.	6788.	0.
2.0	43.	0.	0.	43.	0.	0.
3.0	0.	19596.	0.	1262.	-9798.	0.
4.0	0.	141127.	0.	9092.	-70564.	0.
5.0	0.	-125928.	0.	0.	-125929.	0.
6.0	8399.	0.	0.	-4199.	-97777.	0.

c*** screw forces and stresses at nut

TIME ldcs	22 SMIS7 sj-fx	22 SMIS8 sj-fy	22 SMIS9 sj-fz	22 LS 6 sj-sd	22 LS 7 sj-sbyt	22 LS 9 sj-sbzt
1.0	0.	0.	190.	0.	0.	1893.
2.0	-118.	0.	0.	-142.	0.	0.
3.0	0.	475.	0.	0.	4733.	0.
4.0	0.	3424.	0.	0.	34072.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	-2739.	0.	0.	-27258.

c*** screw and guide forces at block top

TIME ldcs	21 SMIS1 si-fx	21 SMIS2 si-fy	21 SMIS3 si-fz	16 SMIS1 gi-fx	16 SMIS2 gi-fy	16 SMIS3 gi-fz
1.0	0.	0.	190.	0.	0.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	475.	0.	0.	0.	0.
4.0	0.	3424.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	-2739.	0.	0.	0.

c*** block forces and moments at top of block

TIME ldcs	2 SMIS7 bt-fx	2 SMIS8 bt-fy	2 SMIS9 bt-fz	2 SMIS10 bt-mx	2 SMIS11 bt-my	2 SMIS12 bt-mz

1.0	0.	0.	190.	0.	-403.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	475.	0.	0.	0.	1006.
4.0	0.	3424.	0.	0.	0.	7249.
5.0	0.	0.	0.	-9532.	0.	0.
6.0	0.	0.	-2739.	0.	5800.	0.

c*** block top displacements

TIME ldcs	3 UX 7 bt-ux	3 UY 8 bt-uy	3 UZ 9 bt-uz	3 ROTX10 bt-rotx	3 ROTY11 bt-roty	3 ROTZ12 bt-rotz
1.0	0.02253	0.00000	0.00000	0.00000	0.00000	-0.00460
2.0	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.05631	0.01151	0.00000	0.00000
4.0	0.00000	0.00000	0.40557	0.08290	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	13.91060	0.00000
6.0	-0.32446	0.00000	0.00000	0.00000	0.00000	0.06632

c*** nut displacements

TIME ldcs	5 UX 7 nut-ux	5 UY 8 nut-uy	5 UZ 9 nut-uz	5 ROTX10 nut-rotx	5 ROTY11 nut-roty	5 ROTZ12 nut-rotz
1.0	0.02690	0.00000	0.00000	0.00000	0.00000	-0.00138
2.0	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.06726	0.00344	0.00000	0.00000
4.0	0.00000	0.00000	0.48438	0.02479	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.16871	0.00000
6.0	-0.38751	0.00000	0.00000	0.00000	0.00000	0.01984

c*** Hook-pin and hook-guide relative displacements

TIME ldcs	4 ADD 9 drrph0	7 ADD 12 drrph1	10 ADD drrhg0	14 ADD drrhg1	17 ADD duthg0	20 ADD duthg1
1.0	0.00000	0.00000	0.00000	-0.00128	0.00000	0.00447
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00369	0.00185	0.01290	-0.00645
4.0	0.00000	0.00000	-0.02663	0.01331	0.09289	-0.04645
5.0	0.00000	0.00000	-0.02809	-0.02809	-25.87610	-25.87460
6.0	0.00000	0.00000	0.00000	0.01845	0.00000	-0.06436

c*** Screw-guide and screw-block relative displacements

TIME ldcs	4 ADD 9 duxsg	7 ADD 12 duzsg	10 ADD drxsg	14 ADD drzsg	17 ADD duxsb	20 ADD duzsb
1.0	-0.00170	0.00000	0.00000	0.00326	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.00425	-0.00816	0.00000	0.00000	0.00000
4.0	0.00000	-0.03065	-0.05876	0.00000	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	0.02452	0.00000	0.00000	-0.04701	0.00000	0.00000

c***

Tue Jan 3 14:32:15 PST 1995
2 inch jumper connector system model
Guide active
Interface element screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	526.	-263.	-263.	0.	136.	-136.
2.0	-39.	-39.	-39.	0.	0.	0.
3.0	0.	-1139.	1139.	394.	-197.	-197.
4.0	0.	-8202.	8202.	2836.	-1418.	-1418.
5.0	0.	0.	0.	-4064.	-4064.	-4064.
6.0	-7576.	3788.	3788.	0.	-1965.	1965.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-574.	0.	-994.	287.	5760.	497.
2.0	43.	0.	74.	43.	0.	74.
3.0	0.	16627.	0.	1242.	-8313.	2151.
4.0	0.	119751.	0.	8947.	-59876.	15493.
5.0	0.	-171574.	0.	0.	-171577.	0.
6.0	8265.	0.	14317.	-4132.	-82967.	-7156.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-574.	0.	0.	287.	5146.	0.
2.0	43.	0.	0.	43.	0.	0.
3.0	0.	14856.	0.	1242.	-7428.	0.
4.0	0.	107001.	0.	8947.	-53499.	0.
5.0	0.	-185058.	0.	0.	-185057.	0.
6.0	8265.	0.	0.	-4132.	-74133.	0.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-54.	0.	0.	-1094.
2.0	-118.	0.	0.	-142.	0.	0.
3.0	0.	-135.	0.	0.	-2735.	0.
4.0	0.	-975.	0.	0.	-19691.	0.
5.0	0.	0.	0.	0.	-3.	0.
6.0	0.	0.	780.	0.	0.	15753.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-54.	0.	0.	290.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	-135.	0.	0.	726.	0.
4.0	0.	-975.	0.	0.	5230.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	780.	0.	0.	-4184.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	236.	0.	-177.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	591.	0.	0.	0.	442.
4.0	0.	4255.	0.	0.	0.	3185.
5.0	0.	0.	0.	-19019.	0.	0.
6.0	0.	0.	-3404.	0.	2548.	0.

c*** block top displacements

TIME ldcs	3 UX 7 bt-ux	3 UY 8 bt-uy	3 UZ 9 bt-uz	3 ROTX10 bt-rotx	3 ROTY11 bt-roty	3 ROTZ12 bt-rotz
1.0	0.01852	0.00000	0.00000	0.00000	0.00000	-0.00378
2.0	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.04629	0.00946	0.00000	0.00000
4.0	0.00000	0.00000	0.33339	0.06815	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.25984	0.00000
6.0	-0.26671	0.00000	0.00000	0.00000	0.00000	0.05452

c*** nut displacements

TIME ldcs	5 UX 7 nut-ux	5 UY 8 nut-uy	5 UZ 9 nut-uz	5 ROTX10 nut-rotx	5 ROTY11 nut-roty	5 ROTZ12 nut-rotz
1.0	0.02677	0.00000	0.00000	0.00000	0.00000	-0.00136
2.0	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.06693	0.00339	0.00000	0.00000
4.0	0.00000	0.00000	0.48208	0.02440	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.29265	0.00000
6.0	-0.38567	0.00000	0.00000	0.00000	0.00000	0.01952

c*** Hook-pin and hook-guide relative displacements

TIME ldcs	4 ADD 9 drrph0	7 ADD 12 drrph1	10 ADD drrhg0	14 ADD drrhg1	17 ADD duthg0	20 ADD duthg1
1.0	0.00000	0.00000	0.00000	-0.00070	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00201	0.00101	0.00000	0.00000
4.0	0.00000	0.00000	-0.01452	0.00726	0.00000	0.00000
5.0	0.00000	0.00000	-0.04647	-0.04647	0.00000	0.00000
6.0	0.00000	0.00000	0.00000	0.01006	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME ldcs	4 ADD 9 duxsg	7 ADD 12 duzsg	10 ADD drxsg	14 ADD drzsg	17 ADD duxsb	20 ADD duzsb
1.0	0.00268	0.00000	0.00000	0.00235	0.00375	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00671	-0.00587	0.00000	0.00000	0.00937
4.0	0.00000	0.04835	-0.04226	0.00000	0.00000	0.06747
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	-0.03868	0.00000	0.00000	-0.03381	-0.05398	0.00000

c***

Tue Jan 3 14:32:20 PST 1995
2 inch jumper connector system model
Guide inactive
Interface element screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME ldcs	15 FZ hz0-ra	16 FZ hz1-ra	17 FZ hz2-ra	15 FY hz0-rt	16 FY hz1-rt	17 FY hz2-rt
1.0	531.	-265.	-265.	0.	122.	-122.
2.0	-39.	-39.	-39.	0.	0.	0.
3.0	0.	-1149.	1149.	352.	-176.	-176.
4.0	0.	-8274.	8274.	2537.	-1268.	-1268.
5.0	0.	0.	0.	-2037.	-2037.	-2037.
6.0	-7643.	3821.	3821.	0.	-1757.	1757.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME ldcs	2 ADD 6 hg0-sd	8 LS 7 hg0-sbyt	8 LS 9 hg0-sbzt	5 ADD 6 hg1-sd	9 LS 7 hg1-sbyt	9 LS 9 hg1-sbzt
1.0	-579.	0.	-1003.	289.	5151.	501.
2.0	43.	0.	74.	43.	0.	74.
3.0	0.	14870.	0.	1253.	-7435.	2170.
4.0	0.	107096.	0.	9025.	-53549.	15629.
5.0	0.	-85990.	0.	0.	-85991.	0.
6.0	8337.	0.	14443.	-4169.	-74199.	-7219.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME ldcs	2 ADD 1 hg0-sd	8 LS 2 hn0-sbyt	8 LS 4 hn0-sbzt	5 ADD 1 hg1-sd	9 LS 2 hn1-sbyt	9 LS 4 hn1-sbzt
1.0	-579.	0.	0.	289.	7543.	0.
2.0	43.	0.	0.	43.	0.	0.
3.0	0.	21776.	0.	1253.	-10888.	0.
4.0	0.	156837.	0.	9025.	-78419.	0.
5.0	0.	-125928.	0.	0.	-125929.	0.
6.0	8337.	0.	0.	-4169.	-108660.	0.

c*** screw forces and stresses at nut

TIME ldcs	22 SMIS7 sj-fx	22 SMIS8 sj-fy	22 SMIS9 sj-fz	22 LS 6 sj-sd	22 LS 7 sj-sbyt	22 LS 9 sj-sbzt
1.0	0.	0.	211.	0.	0.	3492.
2.0	-118.	0.	0.	-142.	0.	0.
3.0	0.	528.	0.	0.	8730.	0.
4.0	0.	3805.	0.	0.	62880.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	-3044.	0.	0.	-50304.

c*** screw and guide forces at block top

TIME ldcs	21 SMIS1 si-fx	21 SMIS2 si-fy	21 SMIS3 si-fz	16 SMIS1 gi-fx	16 SMIS2 gi-fy	16 SMIS3 gi-fz
1.0	0.	0.	211.	0.	0.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	528.	0.	0.	0.	0.
4.0	0.	3805.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	-3044.	0.	0.	0.

c*** block forces and moments at top of block

TIME ldcs	2 SMIS7 bt-fx	2 SMIS8 bt-fy	2 SMIS9 bt-fz	2 SMIS10 bt-mx	2 SMIS11 bt-my	2 SMIS12 bt-mz

1.0	0.	0.	211.	0.	-299.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	528.	0.	0.	0.	748.
4.0	0.	3805.	0.	0.	0.	5385.
5.0	0.	0.	0.	-9532.	0.	0.
6.0	0.	0.	-3044.	0.	4308.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.02290	0.00000	0.00000	0.00000	0.00000	-0.00468
2.0	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.05725	0.01170	0.00000	0.00000
4.0	0.00000	0.00000	0.41232	0.08428	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	13.91060	0.00000
6.0	-0.32986	0.00000	0.00000	0.00000	0.00000	0.06742

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.02865	0.00000	0.00000	0.00000	0.00000	-0.00137
2.0	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.07162	0.00342	0.00000	0.00000
4.0	0.00000	0.00000	0.51583	0.02461	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.16871	0.00000
6.0	-0.41267	0.00000	0.00000	0.00000	0.00000	0.01969

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	0.00000	0.00000	-0.00119	0.00000	0.00356
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00343	0.00171	0.01028	-0.00514
4.0	0.00000	0.00000	-0.02469	0.01234	0.07404	-0.03702
5.0	0.00000	0.00000	-0.02809	-0.02809	-25.87610	-25.87460
6.0	0.00000	0.00000	0.00000	0.01710	0.00000	-0.05129

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.00020	0.00000	0.00000	0.00353	0.00191	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.00050	-0.00884	0.00000	0.00000	0.00477
4.0	0.00000	-0.00359	-0.06366	0.00000	0.00000	0.03437
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	0.00287	0.00000	0.00000	-0.05093	-0.02750	0.00000

c***

Tue Jan 3 14:32:25 PST 1995
2 inch jumper connector system model
Guide active
No-slip screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME ldcs	15 FZ hz0-ra	16 FZ hz1-ra	17 FZ hz2-ra	15 FY hz0-rt	16 FY hz1-rt	17 FY hz2-rt
1.0	538.	-269.	-269.	0.	100.	-100.
2.0	-39.	-39.	-39.	0.	0.	0.
3.0	0.	-1164.	1164.	287.	-144.	-144.
4.0	0.	-8386.	8386.	2070.	-1035.	-1035.
5.0	0.	1.	-1.	-441.	-445.	-445.
6.0	-7746.	3873.	3873.	0.	-1434.	1434.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME ldcs	2 ADD 6 hg0-sd	8 LS 7 hg0-sbyt	8 LS 9 hg0-sbzt	5 ADD 6 hg1-sd	9 LS 7 hg1-sbyt	9 LS 9 hg1-sbzt
1.0	-587.	0.	-1016.	293.	4204.	508.
2.0	43.	0.	74.	43.	0.	74.
3.0	0.	12136.	0.	1270.	-6068.	2199.
4.0	0.	87404.	0.	9147.	-43705.	15841.
5.0	0.	-18611.	0.	-1.	-18783.	-1.
6.0	8450.	0.	14638.	-4225.	-60557.	-7317.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME ldcs	2 ADD 1 hg0-sd	8 LS 2 hn0-sbyt	8 LS 4 hn0-sbzt	5 ADD 1 hg1-sd	9 LS 2 hn1-sbyt	9 LS 4 hn1-sbzt
1.0	-587.	0.	0.	293.	-111.	0.
2.0	43.	0.	0.	43.	0.	0.
3.0	0.	-321.	0.	1270.	161.	0.
4.0	0.	-2314.	0.	9147.	1156.	0.
5.0	0.	493.	0.	-1.	497.	0.
6.0	8450.	0.	0.	-4225.	1602.	0.

c*** screw forces and stresses at nut

TIME ldcs	22 SMIS7 sj-fx	22 SMIS8 sj-fy	22 SMIS9 sj-fz	22 LS 6 sj-sd	22 LS 7 sj-sbyt	22 LS 9 sj-sbzt
1.0	0.	0.	-381.	0.	0.	-11783.
2.0	-118.	0.	0.	-142.	0.	0.
3.0	0.	-953.	0.	0.	-29457.	0.
4.0	0.	-6863.	0.	0.	-212160.	0.
5.0	0.	-9.	0.	0.	17.	0.
6.0	0.	0.	5491.	0.	0.	169728.

c*** screw and guide forces at block top

TIME ldcs	21 SMIS1 si-fx	21 SMIS2 si-fy	21 SMIS3 si-fz	16 SMIS1 gi-fx	16 SMIS2 gi-fy	16 SMIS3 gi-fz
1.0	0.	0.	-381.	0.	0.	554.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	-953.	0.	0.	1384.	0.
4.0	0.	-6863.	0.	0.	9969.	0.
5.0	0.	-9.	0.	0.	13.	0.
6.0	0.	0.	5491.	0.	0.	-7975.

c*** block forces and moments at top of block

TIME ldcs	2 SMIS7 bt-fx	2 SMIS8 bt-fy	2 SMIS9 bt-fz	2 SMIS10 bt-mx	2 SMIS11 bt-my	2 SMIS12 bt-mz

1.0	0.	0.	172.	0.	-489.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	431.	0.	0.	0.	1223.
4.0	0.	3105.	0.	0.	0.	8807.
5.0	0.	4.	0.	-2076.	0.	-20.
6.0	0.	0.	-2484.	0.	7046.	0.

c*** block top displacements

TIME ldcs	3 UX 7 bt-ux	3 UY 8 bt-uy	3 UZ 9 bt-uz	3 ROTX10 bt-rotx	3 ROTY11 bt-roty	3 ROTZ12 bt-rotz
1.0	0.01531	0.00000	0.00000	0.00000	0.00000	-0.00313
2.0	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.03827	0.00782	-0.00005	0.00000
4.0	0.00000	0.00000	0.27557	0.05632	-0.00033	0.00000
5.0	0.00000	0.00000	-0.00129	-0.00026	24.63930	0.00000
6.0	-0.22046	0.00000	0.00000	0.00000	0.00000	0.04506

c*** nut displacements

TIME ldcs	5 UX 7 nut-ux	5 UY 8 nut-uy	5 UZ 9 nut-uz	5 ROTX10 nut-rotx	5 ROTY11 nut-roty	5 ROTZ12 nut-rotz
1.0	0.02262	0.00000	0.00000	0.00000	0.00000	-0.00139
2.0	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.05655	0.00346	-0.00006	0.00000
4.0	0.00000	0.00000	0.40727	0.02495	-0.00045	0.00000
5.0	0.00000	0.00000	-0.00134	0.00000	33.22290	0.00000
6.0	-0.32582	0.00000	0.00000	0.00000	0.00000	0.01996

c*** Hook-pin and hook-guide relative displacements

TIME ldcs	4 ADD 9 drrph0	7 ADD 12 drrph1	10 ADD drrhg0	14 ADD drrhg1	17 ADD duthg0	20 ADD duthg1
1.0	0.00000	-0.00053	0.00000	-0.00051	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.00154	0.00075	-0.00146	0.00075	0.00000	0.00000
4.0	-0.01111	0.00542	-0.01055	0.00541	0.00000	0.00000
5.0	6.78022	6.77993	-6.78203	-6.78215	0.00000	0.00000
6.0	0.00000	0.00764	0.00000	0.00737	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME ldcs	4 ADD 9 duxsg	7 ADD 12 duzsg	10 ADD drxsg	14 ADD drzsg	17 ADD duxsb	20 ADD duzsb
1.0	0.00117	0.00000	0.00000	0.00063	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00293	-0.00157	0.00000	0.00000	0.00000
4.0	0.00000	0.02107	-0.01133	0.00000	0.00000	0.00000
5.0	0.00000	0.00018	0.00025	0.00000	0.00000	0.00000
6.0	-0.01685	0.00000	0.00000	-0.00906	0.00000	0.00000

c***

Tue Jan 3 14:32:30 PST 1995
2 inch jumper connector system model
Guide inactive
No-slip screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	570.	-285.	-285.	0.	0.	0.
2.0	-39.	-39.	-39.	0.	0.	0.
3.0	0.	-1233.	1233.	0.	0.	0.
4.0	0.	-8882.	8882.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-8205.	4103.	4103.	0.	0.	0.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-621.	0.	-1076.	311.	0.	538.
2.0	43.	0.	74.	43.	0.	74.
3.0	0.	0.	0.	1345.	0.	2330.
4.0	0.	0.	0.	9689.	0.	16779.
5.0	0.	0.	0.	0.	0.	0.
6.0	8951.	0.	15505.	-4475.	0.	-7750.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-621.	0.	0.	311.	0.	0.
2.0	43.	0.	0.	43.	0.	0.
3.0	0.	0.	0.	1345.	0.	0.
4.0	0.	0.	0.	9689.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	8951.	0.	0.	-4475.	0.	0.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	0.	0.	0.	-12481.
2.0	-118.	0.	0.	-142.	0.	0.
3.0	0.	0.	0.	0.	-31202.	0.
4.0	0.	0.	0.	0.	-224727.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	179782.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	0.	0.	0.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	0.
4.0	0.	0.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	0.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	0.	0.	-1333.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	3332.
4.0	0.	0.	0.	0.	0.	24000.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	19200.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.06994	0.00000	0.00000	0.00000	0.00000	-0.01429
2.0	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.17485	0.03573	0.00000	0.00000
4.0	0.00000	0.00000	1.25929	0.25738	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	27.62600	0.00000
6.0	-1.00743	0.00000	0.00000	0.00000	0.00000	0.20590

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.07915	0.00000	0.00000	0.00000	0.00000	-0.00147
2.0	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.19786	0.00367	0.00000	0.00000
4.0	0.00000	0.00000	1.42503	0.02642	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	27.62600	0.00000
6.0	-1.14093	0.00000	0.00000	0.00000	0.00000	0.02114

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	-0.00770	0.00000	-0.00341	0.00000	0.02328
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.02223	0.01111	-0.00984	0.00492	0.06721	-0.03361
4.0	-0.16010	0.08005	-0.07086	0.03543	0.48408	-0.24204
5.0	5.64091	5.64091	-5.64091	-5.64091	-13.42540	-13.42540
6.0	0.00000	0.11092	0.00000	0.04909	0.00000	-0.33538

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.00636	0.00000	0.00000	0.01120	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.01589	-0.02800	0.00000	0.00000	0.00000
4.0	0.00000	-0.11446	-0.20170	0.00000	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	0.09157	0.00000	0.00000	-0.16136	0.00000	0.00000

c***

Tue Jan 3 14:32:34 PST 1995
2 inch jumper connector system model
Guide active
Interface element screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	517.	-259.	-259.	0.	163.	-163.
2.0	-39.	-39.	-39.	0.	0.	0.
3.0	0.	-1120.	1120.	472.	-236.	-236.
4.0	0.	-8067.	8067.	3397.	-1699.	-1699.
5.0	0.	0.	0.	-443.	-444.	-444.
6.0	-7452.	3726.	3726.	0.	-2354.	2354.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-564.	0.	-978.	282.	6899.	489.
2.0	43.	0.	74.	43.	0.	74.
3.0	0.	19915.	0.	1222.	-9958.	2116.
4.0	0.	143435.	0.	8800.	-71723.	15239.
5.0	0.	-18708.	0.	0.	-18734.	0.
6.0	8129.	0.	14082.	-4065.	-99378.	-7039.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-564.	0.	0.	282.	-183.	0.
2.0	43.	0.	0.	43.	0.	0.
3.0	0.	-527.	0.	1222.	263.	0.
4.0	0.	-3797.	0.	8800.	1897.	0.
5.0	0.	495.	0.	0.	496.	0.
6.0	8129.	0.	0.	-4065.	2629.	0.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-626.	0.	0.	-11335.
2.0	-118.	0.	0.	-142.	0.	0.
3.0	0.	-1564.	0.	0.	-28338.	0.
4.0	0.	-11263.	0.	0.	-204103.	0.
5.0	0.	-1.	0.	0.	2.	0.
6.0	0.	0.	9011.	0.	0.	163282.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-626.	0.	0.	909.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	-1564.	0.	0.	2271.	0.
4.0	0.	-11263.	0.	0.	16360.	0.
5.0	0.	-1.	0.	0.	2.	0.
6.0	0.	0.	9011.	0.	0.	-13088.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	283.	0.	52.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	708.	0.	0.	0.	-129.
4.0	0.	5096.	0.	0.	0.	-932.
5.0	0.	1.	0.	-2076.	0.	-3.
6.0	0.	0.	-4077.	0.	-746.	0.

c*** block top displacements

TIME ldcs	3 UX 7 bt-ux	3 UY 8 bt-uy	3 UZ 9 bt-uz	3 ROTX10 bt-rotx	3 ROTY11 bt-roty	3 ROTZ12 bt-rotz
1.0	0.03927	0.00000	0.00000	0.00000	0.00000	-0.00803
2.0	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.09819	0.02007	-0.00008	0.00000
4.0	0.00000	0.00000	0.70719	0.14456	-0.00054	0.00000
5.0	0.00000	0.00000	-0.00212	-0.00043	24.63930	0.00000
6.0	-0.56575	0.00000	0.00000	0.00000	0.00000	0.11565

c*** nut displacements

TIME ldcs	5 UX 7 nut-ux	5 UY 8 nut-uy	5 UZ 9 nut-uz	5 ROTX10 nut-rotx	5 ROTY11 nut-roty	5 ROTZ12 nut-rotz
1.0	0.06105	0.00000	0.00000	0.00000	0.00000	-0.00133
2.0	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.15262	0.00333	-0.00010	0.00000
4.0	0.00000	0.00000	1.09926	0.02400	-0.00073	0.00000
5.0	0.00000	0.00000	-0.00267	0.00000	33.22290	0.00000
6.0	-0.87941	0.00000	0.00000	0.00000	0.00000	0.01920

c*** Hook-pin and hook-guide relative displacements

TIME ldcs	4 ADD 9 drrph0	7 ADD 12 drrph1	10 ADD drrhg0	14 ADD drrhg1	17 ADD duthg0	20 ADD duthg1
1.0	0.00000	-0.00440	0.00000	-0.00063	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.01271	0.00633	-0.00181	0.00094	0.00000	0.00000
4.0	-0.09158	0.04556	-0.01305	0.00675	0.00000	0.00000
5.0	6.78038	6.77985	-6.78202	-6.78215	0.00000	0.00000
6.0	0.00000	0.06334	0.00000	0.00915	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME ldcs	4 ADD 9 duxsg	7 ADD 12 duzsg	10 ADD drxsg	14 ADD drzsg	17 ADD duxsb	20 ADD duzsb
1.0	0.01202	0.00000	0.00000	0.00591	0.01567	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.03005	-0.01477	0.00000	0.00000	0.03918
4.0	0.00000	0.21644	-0.10642	0.00000	0.00000	0.28219
5.0	0.00000	-0.00020	0.00043	0.00000	0.00000	-0.00054
6.0	-0.17315	0.00000	0.00000	-0.08513	-0.22575	0.00000

c***

Tue Jan 3 14:32:39 PST 1995
2 inch jumper connector system model
Guide inactive
Interface element screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME ldcs	15 FZ hz0-ra	16 FZ hz1-ra	17 FZ hz2-ra	15 FY hz0-rt	16 FY hz1-rt	17 FY hz2-rt
1.0	570.	-285.	-285.	0.	0.	0.
2.0	-39.	-39.	-39.	0.	0.	0.
3.0	0.	-1233.	1233.	0.	0.	0.
4.0	0.	-8882.	8882.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-8205.	4103.	4103.	0.	0.	0.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME ldcs	2 ADD 6 hg0-sd	8 LS 7 hg0-sbyt	8 LS 9 hg0-sbzt	5 ADD 6 hg1-sd	9 LS 7 hg1-sbyt	9 LS 9 hg1-sbzt
1.0	-621.	0.	-1076.	311.	0.	538.
2.0	43.	0.	74.	43.	0.	74.
3.0	0.	0.	0.	1345.	0.	2330.
4.0	0.	0.	0.	9689.	0.	16779.
5.0	0.	0.	0.	0.	0.	0.
6.0	8951.	0.	15505.	-4475.	0.	-7750.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME ldcs	2 ADD 1 hg0-sd	8 LS 2 hn0-sbyt	8 LS 4 hn0-sbzt	5 ADD 1 hg1-sd	9 LS 2 hn1-sbyt	9 LS 4 hn1-sbzt
1.0	-621.	0.	0.	311.	0.	0.
2.0	43.	0.	0.	43.	0.	0.
3.0	0.	0.	0.	1345.	0.	0.
4.0	0.	0.	0.	9689.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	8951.	0.	0.	-4475.	0.	0.

c*** screw forces and stresses at nut

TIME ldcs	22 SMIS7 sj-fx	22 SMIS8 sj-fy	22 SMIS9 sj-fz	22 LS 6 sj-sd	22 LS 7 sj-sbyt	22 LS 9 sj-sbzt
1.0	0.	0.	0.	0.	0.	-12481.
2.0	-118.	0.	0.	-142.	0.	0.
3.0	0.	0.	0.	0.	-31202.	0.
4.0	0.	0.	0.	0.	-224727.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	179782.

c*** screw and guide forces at block top

TIME ldcs	21 SMIS1 si-fx	21 SMIS2 si-fy	21 SMIS3 si-fz	16 SMIS1 gi-fx	16 SMIS2 gi-fy	16 SMIS3 gi-fz
1.0	0.	0.	0.	0.	0.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	0.
4.0	0.	0.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	0.

c*** block forces and moments at top of block

TIME ldcs	2 SMIS7 bt-fx	2 SMIS8 bt-fy	2 SMIS9 bt-fz	2 SMIS10 bt-mx	2 SMIS11 bt-my	2 SMIS12 bt-mz

1.0	0.	0.	0.	0.	-1333.	0.
2.0	-118.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	3332.
4.0	0.	0.	0.	0.	0.	24000.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	19200.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	1.01668	0.00000	0.00000	0.00000	0.00000	-0.20782
2.0	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	2.54171	0.51954	0.00000	0.00000
4.0	0.00000	0.00000	18.30650	3.74194	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	27.62600	0.00000
6.0	-14.64520	0.00000	0.00000	0.00000	0.00000	2.99355

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	1.29246	0.00000	0.00000	0.00000	0.00000	-0.00147
2.0	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	3.23116	0.00367	0.00000	0.00000
4.0	0.00000	0.00000	23.27220	0.02642	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	27.62600	0.00000
6.0	-18.61780	0.00000	0.00000	0.00000	0.00000	0.02114

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	-0.14524	0.00000	-0.03347	0.00000	0.25383
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.41926	0.20963	-0.09661	0.04831	0.73274	-0.36637
4.0	-3.01968	1.50984	-0.69584	0.34792	5.27752	-2.63876
5.0	5.64091	5.64091	-5.64091	-5.64091	-13.42540	-13.42540
6.0	0.00000	2.09209	0.00000	0.48209	0.00000	-3.65638

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	0.10540	0.00000	0.00000	0.20472	0.26658	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.26351	-0.51181	0.00000	0.00000	0.66644
4.0	0.00000	1.89789	-3.68626	0.00000	0.00000	4.80000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	-1.51831	0.00000	0.00000	-2.94901	-3.84000	0.00000

c***

Wed Jan 4 07:48:12 PST 1995
3 inch jumper connector system model
Guide active
No-slip screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	2768.	-1384.	-1384.	0.	404.	-404.
2.0	-162.	-162.	-162.	0.	0.	0.
3.0	0.	-2396.	2396.	466.	-233.	-233.
4.0	0.	-11669.	11669.	2270.	-1135.	-1135.
5.0	0.	0.	0.	-12315.	-12316.	-12316.
6.0	-23586.	11792.	11792.	0.	-3441.	3441.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2262.	0.	-4033.	1131.	14875.	2015.
2.0	133.	0.	236.	133.	0.	236.
3.0	0.	17176.	0.	1959.	-8585.	3488.
4.0	0.	83642.	0.	9539.	-41805.	16988.
5.0	0.	-453672.	0.	0.	-453709.	-17.
6.0	19280.	0.	34369.	-9639.	-126767.	-17173.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2262.	0.	0.	1131.	2112.	0.
2.0	133.	0.	0.	133.	0.	0.
3.0	0.	2440.	0.	1959.	-1219.	0.
4.0	0.	11875.	0.	9539.	-5930.	-1.
5.0	0.	-478848.	0.	0.	-478905.	-18.
6.0	19280.	0.	0.	-9639.	-17982.	-2.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-1793.	0.	0.	-28483.
2.0	-487.	0.	0.	-300.	0.	0.
3.0	0.	-1793.	0.	0.	-28482.	0.
4.0	0.	-8731.	0.	0.	-138718.	0.
5.0	0.	2.	0.	0.	33.	0.
6.0	-2.	0.	15280.	-2.	0.	242774.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-1793.	0.	0.	2492.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	-1793.	0.	0.	2492.	0.
4.0	0.	-8731.	0.	0.	12137.	0.
5.0	0.	2.	0.	0.	-1.	0.
6.0	-2.	0.	15280.	0.	0.	-21240.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	699.	0.	-4585.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	699.	0.	0.	0.	4585.
4.0	0.	3406.	0.	0.	0.	22329.
5.0	0.	1.	0.	-83138.	0.	-4.
6.0	-2.	0.	-5959.	0.	39077.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.08109	0.00000	0.00000	0.00000	0.00000	-0.01075
2.0	0.00000	0.00079	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.08107	0.01075	0.00000	0.00000
4.0	0.00000	0.00000	0.39476	0.05236	-0.00002	0.00000
5.0	0.00000	0.00000	-0.00025	-0.00003	0.82095	0.00000
6.0	-0.69105	0.00000	0.00000	0.00000	0.00000	0.09166

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.11615	0.00000	0.00000	0.00000	0.00000	-0.00564
2.0	0.00000	0.00074	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.11611	0.00563	0.00000	0.00000
4.0	0.00000	0.00000	0.56545	0.02744	-0.00002	0.00000
5.0	0.00000	0.00000	-0.00034	-0.00002	0.88626	0.00000
6.0	-0.98988	0.00000	0.00000	0.00000	0.00000	0.04805

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	0.00000	0.00000	-0.00251	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00290	0.00145	0.00000	0.00000
4.0	0.00000	0.00000	-0.01412	0.00707	0.00000	0.00000
5.0	0.00000	0.00000	-0.11496	-0.11499	0.00000	0.00000
6.0	0.00000	0.00000	0.00000	0.02141	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.00406	0.00000	0.00000	0.00222	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.00406	-0.00222	0.00000	0.00000	0.00000
4.0	0.00000	-0.01976	-0.01083	0.00000	0.00000	0.00000
5.0	0.00000	0.00002	0.00001	0.00000	0.00000	0.00000
6.0	0.03458	0.00000	0.00000	-0.01895	0.00000	0.00000

c***

Wed Jan 4 07:48:23 PST 1995
3 inch jumper connector system model
Guide inactive
No-slip screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	2711.	-1355.	-1355.	0.	552.	-552.
2.0	-162.	-162.	-162.	0.	0.	0.
3.0	0.	-2347.	2347.	638.	-319.	-319.
4.0	0.	-11432.	11432.	3105.	-1552.	-1552.
5.0	0.	0.	0.	-6180.	-6180.	-6180.
6.0	-23108.	11552.	11552.	0.	-4705.	4705.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2216.	0.	-3951.	1108.	20342.	1974.
2.0	133.	0.	236.	133.	0.	236.
3.0	0.	23488.	0.	1919.	-11740.	3417.
4.0	0.	114385.	0.	9345.	-57175.	16642.
5.0	0.	-227675.	0.	0.	-227692.	-9.
6.0	18889.	0.	33672.	-9443.	-173360.	-16825.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2216.	0.	0.	1108.	27148.	1.
2.0	133.	0.	0.	133.	0.	0.
3.0	0.	31350.	0.	1919.	-15673.	-1.
4.0	0.	152669.	0.	9345.	-76323.	-3.
5.0	0.	-303878.	0.	0.	-303896.	-10.
6.0	18889.	0.	0.	-9443.	-231366.	-8.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	1.	0.	956.	0.	0.	5539.
2.0	-487.	0.	0.	-300.	0.	0.
3.0	0.	956.	0.	0.	5540.	0.
4.0	0.	4657.	0.	0.	26972.	0.
5.0	0.	0.	0.	0.	9.	0.
6.0	-5.	0.	-8150.	-3.	0.	-47196.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	1.	0.	956.	0.	0.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	956.	0.	0.	0.	0.
4.0	0.	4657.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-5.	0.	-8150.	0.	0.	0.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	1.	0.	956.	0.	-2647.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	956.	0.	0.	0.	2647.
4.0	0.	4657.	0.	0.	0.	12894.
5.0	0.	0.	0.	-41723.	0.	-2.
6.0	-5.	0.	-8150.	0.	22565.	0.

c*** block top displacements

TIME ldcs	3 UX 7 bt-ux	3 UY 8 bt-uy	3 UZ 9 bt-uz	3 ROTX10 bt-rotx	3 ROTY11 bt-roty	3 ROTZ12 bt-rotz
1.0	0.15069	0.00000	0.00000	0.00000	0.00000	-0.01999
2.0	0.00000	0.00079	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.15066	0.01998	0.00000	0.00000
4.0	0.00000	0.00000	0.73369	0.09733	-0.00001	0.00000
5.0	0.00000	0.00000	-0.00015	-0.00002	40.26430	0.00000
6.0	-1.28423	0.00000	0.00000	0.00000	0.00000	0.17036

c*** nut displacements

TIME ldcs	5 UX 7 nut-ux	5 UY 8 nut-uy	5 UZ 9 nut-uz	5 ROTX10 nut-rotx	5 ROTY11 nut-roty	5 ROTZ12 nut-rotz
1.0	0.17498	0.00000	0.00000	0.00000	0.00000	-0.00552
2.0	0.00000	0.00074	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.17493	0.00552	0.00000	0.00000
4.0	0.00000	0.00000	0.85191	0.02688	-0.00002	0.00000
5.0	0.00000	0.00000	-0.00020	-0.00001	0.48586	0.00000
6.0	-1.49125	0.00000	0.00000	0.00000	0.00000	0.04707

c*** Hook-pin and hook-guide relative displacements

TIME ldcs	4 ADD 9 drrph0	7 ADD 12 drrph1	10 ADD drrhg0	14 ADD drrhg1	17 ADD duthg0	20 ADD duthg1
1.0	0.00000	0.00000	0.00000	-0.00660	0.00000	0.03162
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00762	0.00381	0.03651	-0.01826
4.0	0.00000	0.00000	-0.03711	0.01856	0.17780	-0.08894
5.0	0.00000	0.00000	-0.06635	-0.06636	107.51300	107.51300
6.0	0.00000	0.00000	0.00000	0.05625	0.00000	-0.26952

c*** Screw-guide and screw-block relative displacements

TIME ldcs	4 ADD 9 duxsg	7 ADD 12 duzsg	10 ADD drxsg	14 ADD drzsg	17 ADD duxsb	20 ADD duzsb
1.0	-0.02507	0.00000	0.00000	0.01459	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.02507	-0.01459	0.00000	0.00000	0.00000
4.0	0.00000	-0.12211	-0.07108	0.00000	0.00000	0.00000
5.0	0.00000	0.00002	0.00001	0.00000	0.00000	0.00000
6.0	0.21371	0.00000	0.00000	-0.12439	0.00000	0.00000

c***

Wed Jan 4 07:48:29 PST 1995
3 inch jumper connector system model
Guide active
Interface element screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	2692.	-1345.	-1345.	0.	605.	-605.
2.0	-162.	-162.	-162.	0.	0.	0.
3.0	0.	-2330.	2330.	698.	-349.	-349.
4.0	0.	-11349.	11349.	3400.	-1700.	-1700.
5.0	0.	0.	0.	-12315.	-12315.	-12315.
6.0	-22939.	11467.	11467.	0.	-5152.	5152.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2200.	0.	-3922.	1100.	22272.	1960.
2.0	133.	0.	236.	133.	0.	236.
3.0	0.	25716.	0.	1905.	-12854.	3392.
4.0	0.	125237.	0.	9277.	-62600.	16520.
5.0	0.	-453685.	0.	0.	-453703.	-17.
6.0	18751.	0.	33425.	-9373.	-189809.	-16702.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2200.	0.	0.	1100.	17562.	1.
2.0	133.	0.	0.	133.	0.	0.
3.0	0.	20280.	0.	1905.	-10138.	0.
4.0	0.	98764.	0.	9277.	-49371.	-2.
5.0	0.	-478875.	0.	0.	-478891.	-18.
6.0	18751.	0.	0.	-9373.	-149672.	-6.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	1.	0.	-661.	0.	0.	-6820.
2.0	-487.	0.	0.	-300.	0.	0.
3.0	0.	-661.	0.	0.	-6820.	0.
4.0	0.	-3221.	0.	0.	-33213.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-5.	0.	5637.	-3.	0.	58128.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	1.	0.	-661.	0.	0.	1708.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	-661.	0.	0.	1708.	0.
4.0	0.	-3221.	0.	0.	8320.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-5.	0.	5637.	0.	0.	-14560.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	1.	0.	1047.	0.	-1964.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	1047.	0.	0.	0.	1964.
4.0	0.	5099.	0.	0.	0.	9563.
5.0	0.	0.	0.	-83138.	0.	0.
6.0	-5.	0.	-8923.	0.	16735.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.11585	0.00000	0.00000	0.00000	0.00000	-0.01537
2.0	0.00000	0.00079	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.11582	0.01536	0.00000	0.00000
4.0	0.00000	0.00000	0.56403	0.07482	-0.00002	0.00000
5.0	0.00000	0.00000	-0.00030	-0.00004	0.82095	0.00000
6.0	-0.98730	0.00000	0.00000	0.00000	0.00000	0.13097

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.16479	0.00000	0.00000	0.00000	0.00000	-0.00548
2.0	0.00000	0.00074	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.16475	0.00548	-0.00001	0.00000
4.0	0.00000	0.00000	0.80231	0.02669	-0.00002	0.00000
5.0	0.00000	0.00000	-0.00041	-0.00002	0.88626	0.00000
6.0	-1.40445	0.00000	0.00000	0.00000	0.00000	0.04673

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	0.00000	0.00000	-0.00372	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00430	0.00215	0.00000	0.00000
4.0	0.00000	0.00000	-0.02095	0.01048	0.00000	0.00000
5.0	0.00000	0.00000	-0.11496	-0.11499	0.00000	0.00000
6.0	0.00000	0.00000	0.00000	0.03175	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	0.00612	0.00000	0.00000	0.00936	0.02272	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00612	-0.00935	0.00000	0.00000	0.02272
4.0	0.00000	0.02980	-0.04557	0.00000	0.00000	0.11065
5.0	0.00000	0.00001	0.00002	0.00000	0.00000	-0.00003
6.0	-0.05215	0.00000	0.00000	-0.07974	-0.19366	0.00000

c***

Wed Jan 4 07:48:34 PST 1995
3 inch jumper connector system model
Guide inactive
Interface element screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	2687.	-1343.	-1343.	0.	618.	-618.
2.0	-162.	-162.	-162.	0.	0.	0.
3.0	0.	-2326.	2326.	713.	-357.	-357.
4.0	0.	-11327.	11327.	3474.	-1737.	-1737.
5.0	0.	0.	0.	-6180.	-6180.	-6180.
6.0	-22896.	11445.	11445.	0.	-5265.	5265.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2196.	0.	-3915.	1098.	22761.	1956.
2.0	133.	0.	236.	133.	0.	236.
3.0	0.	26281.	0.	1901.	-13137.	3386.
4.0	0.	127990.	0.	9259.	-63976.	16489.
5.0	0.	-227681.	0.	0.	-227689.	-9.
6.0	18716.	0.	33363.	-9356.	-193980.	-16671.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2196.	0.	0.	1098.	30377.	1.
2.0	133.	0.	0.	133.	0.	0.
3.0	0.	35077.	0.	1901.	-17536.	-1.
4.0	0.	170827.	0.	9259.	-85401.	-3.
5.0	0.	-303885.	0.	0.	-303892.	-10.
6.0	18716.	0.	0.	-9356.	-258888.	-9.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	1.	0.	1070.	0.	0.	10211.
2.0	-487.	0.	0.	-300.	0.	0.
3.0	0.	1070.	0.	0.	10211.	0.
4.0	0.	5211.	0.	0.	49727.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-6.	0.	-9119.	-3.	0.	-87021.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	1.	0.	1070.	0.	0.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	1070.	0.	0.	0.	0.
4.0	0.	5211.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-6.	0.	-9119.	0.	0.	0.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	1.	0.	1070.	0.	-1790.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	1070.	0.	0.	0.	1790.
4.0	0.	5211.	0.	0.	0.	8718.
5.0	0.	0.	0.	-41723.	0.	0.
6.0	-6..	0.	-9119.	0.	15256.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.15453	0.00000	0.00000	0.00000	0.00000	-0.02050
2.0	0.00000	0.00079	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.15449	0.02049	0.00000	0.00000
4.0	0.00000	0.00000	0.75237	0.09981	-0.00001	0.00000
5.0	0.00000	0.00000	-0.00016	-0.00002	40.26430	0.00000
6.0	-1.31693	0.00000	0.00000	0.00000	0.00000	0.17470

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.18782	0.00000	0.00000	0.00000	0.00000	-0.00547
2.0	0.00000	0.00074	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.18777	0.00547	-0.00001	0.00000
4.0	0.00000	0.00000	0.91446	0.02664	-0.00002	0.00000
5.0	0.00000	0.00000	-0.00022	-0.00001	0.48586	0.00000
6.0	-1.60073	0.00000	0.00000	0.00000	0.00000	0.04664

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	0.00000	0.00000	-0.00638	0.00000	0.02563
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00736	0.00368	0.02959	-0.01481
4.0	0.00000	0.00000	-0.03587	0.01794	0.14412	-0.07210
5.0	0.00000	0.00000	-0.06635	-0.06636	-107.51300	-107.51300
6.0	0.00000	0.00000	0.00000	0.05437	0.00000	-0.21847

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.01590	0.00000	0.00000	0.01576	0.01133	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.01590	-0.01576	0.00000	0.00000	0.01133
4.0	0.00000	-0.07743	-0.07674	0.00000	0.00000	0.05518
5.0	0.00000	0.00000	0.00001	0.00000	0.00000	-0.00002
6.0	0.13551	0.00000	0.00000	-0.13430	-0.09657	0.00000

c***

Wed Jan 4 07:48:38 PST 1995
3 inch jumper connector system model
Guide active
No-slip screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	2776.	-1388.	-1388.	0.	381.	-381.
2.0	-162.	-162.	-162.	0.	0.	0.
3.0	0.	-2404.	2404.	440.	-220.	-220.
4.0	0.	-11706.	11706.	2142.	-1071.	-1071.
5.0	0.	4.	-4.	-749.	-768.	-768.
6.0	-23660.	11829.	11829.	0.	-3247.	3247.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2269.	0.	-4045.	1134.	14036.	2021.
2.0	133.	0.	236.	133.	0.	236.
3.0	0.	16205.	0.	1965.	-8101.	3499.
4.0	0.	78920.	0.	9569.	-39452.	17041.
5.0	0.	-27589.	0.	-3.	-28301.	-6.
6.0	19340.	0.	34476.	-9669.	-119622.	-17226.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2269.	0.	0.	1134.	-501.	0.
2.0	133.	0.	0.	133.	0.	0.
3.0	0.	-579.	0.	1965.	289.	0.
4.0	0.	-2820.	0.	9569.	1408.	0.
5.0	0.	986.	0.	-3.	1010.	0.
6.0	19340.	0.	0.	-9669.	4267.	-1.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-2042.	0.	0.	-32078.
2.0	-487.	0.	0.	-300.	0.	0.
3.0	0.	-2042.	0.	0.	-32078.	0.
4.0	0.	-9944.	0.	0.	-156222.	0.
5.0	0.	-60.	0.	0.	49.	0.
6.0	-2.	0.	17402.	-1.	0.	273389.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-2042.	0.	0.	2702.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	-2042.	0.	0.	2702.	0.
4.0	0.	-9944.	0.	0.	13158.	0.
5.0	0.	-60.	0.	0.	79.	0.
6.0	-2.	0.	17402.	0.	0.	-23026.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	660.	0.	-4882.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	660.	0.	0.	0.	4882.
4.0	0.	3213.	0.	-1.	0.	23777.
5.0	0.	19.	0.	-5143.	0.	-145.
6.0	-2.	0.	-5624.	0.	41609.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.08170	0.00000	0.00000	0.00000	0.00000	-0.01084
2.0	0.00000	0.00079	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.08168	0.01083	-0.00019	0.00000
4.0	0.00000	0.00000	0.39775	0.05276	-0.00092	0.00000
5.0	0.00000	0.00000	-0.01217	-0.00161	75.10240	0.00000
6.0	-0.69627	0.00000	0.00000	0.00000	0.00000	0.09235

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.11804	0.00000	0.00000	0.00000	0.00000	-0.00566
2.0	0.00000	0.00074	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.11800	0.00565	-0.00024	0.00000
4.0	0.00000	0.00000	0.57462	0.02753	-0.00116	0.00000
5.0	0.00000	0.00000	-0.01239	-0.00001	94.28710	0.00000
6.0	-1.00591	0.00000	0.00000	0.00000	0.00000	0.04820

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	-0.00068	0.00000	-0.00233	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.00083	0.00035	-0.00265	0.00139	0.00000	0.00000
4.0	-0.00405	0.00168	-0.01290	0.00679	0.00000	0.00000
5.0	18.83490	18.83630	-18.83620	-18.84000	0.00000	0.00000
6.0	0.00000	0.00579	0.00000	0.01990	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.00355	0.00000	0.00000	0.00194	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.00355	-0.00194	0.00000	0.00000	0.00000
4.0	0.00000	-0.01731	-0.00944	0.00000	0.00000	0.00000
5.0	0.00000	0.00262	0.00156	0.00000	0.00000	0.00000
6.0	0.03030	0.00000	0.00000	-0.01653	0.00000	0.00000

c***

Wed Jan 4 07:48:43 PST 1995
3 inch jumper connector system model
Guide inactive
No-slip screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	2920.	-1460.	-1460.	0.	0.	0.
2.0	-162.	-162.	-162.	0.	0.	0.
3.0	0.	-2529.	2529.	0.	0.	0.
4.0	0.	-12314.	12314.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-24889.	12445.	12445.	0.	0.	0.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2387.	0.	-4255.	1194.	1.	2126.
2.0	133.	0.	236.	133.	0.	236.
3.0	0.	0.	0.	2067.	2.	3681.
4.0	0.	0.	0.	10066.	11.	17928.
5.0	0.	0.	0.	0.	0.	0.
6.0	20344.	0.	36267.	-10172.	-11.	-18118.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2387.	0.	0.	1194.	0.	0.
2.0	133.	0.	0.	133.	0.	0.
3.0	0.	0.	0.	2067.	0.	0.
4.0	0.	0.	0.	10066.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	20344.	0.	0.	-10172.	0.	0.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	0.	0.	0.	-33746.
2.0	-487.	0.	0.	-300.	0.	0.
3.0	0.	0.	0.	0.	-33746.	0.
4.0	0.	0.	0.	0.	-164343.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	287600.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	0.	0.	0.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	0.
4.0	0.	0.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	0.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	0.	0.	-9856.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	9856.
4.0	0.	0.	0.	0.	0.	48000.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	84000.	0.

c*** block top displacements

TIME ldcs	3 UX 7 bt-ux	3 UY 8 bt-uy	3 UZ 9 bt-uz	3 ROTX10 bt-rotx	3 ROTY11 bt-roty	3 ROTZ12 bt-rotz
1.0	0.49790	0.00000	0.00000	0.00000	0.00000	-0.06604
2.0	0.00000	0.00079	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.49788	0.06604	0.00000	0.00000
4.0	0.00000	0.00000	2.42460	0.32163	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	80.00010	0.00000
6.0	-4.24324	0.00000	0.00000	0.00000	0.00000	0.56287

c*** nut displacements

TIME ldcs	5 UX 7 nut-ux	5 UY 8 nut-uy	5 UZ 9 nut-uz	5 ROTX10 nut-rotx	5 ROTY11 nut-roty	5 ROTZ12 nut-rotz
1.0	0.54172	0.00000	0.00000	0.00000	0.00000	-0.00595
2.0	0.00000	0.00074	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.54169	0.00595	0.00000	0.00000
4.0	0.00000	0.00000	2.63796	0.02896	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	80.00010	0.00000
6.0	-4.61671	0.00000	0.00000	0.00000	0.00000	0.05070

c*** Hook-pin and hook-guide relative displacements

TIME ldcs	4 ADD 9 drrph0	7 ADD 12 drrph1	10 ADD drrhg0	14 ADD drrhg1	17 ADD duthg0	20 ADD duthg1
1.0	0.00000	-0.03651	0.00000	-0.01553	0.00000	0.17443
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.04216	0.02108	-0.01794	0.00897	0.20142	-0.10071
4.0	-0.20532	0.10266	-0.08735	0.04367	0.98089	-0.49045
5.0	15.98580	15.98850	-15.98580	-15.98850	-43.96100	-43.96850
6.0	0.00000	0.31117	0.00000	0.13238	0.00000	-1.48658

c*** Screw-guide and screw-block relative displacements

TIME ldcs	4 ADD 9 duxsg	7 ADD 12 duzsg	10 ADD drxsg	14 ADD drzsg	17 ADD duxsb	20 ADD duzsb
1.0	-0.09303	0.00000	0.00000	0.05516	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.09303	-0.05516	0.00000	0.00000	0.00000
4.0	0.00000	-0.45307	-0.26862	0.00000	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	0.79287	0.00000	0.00000	-0.47008	0.00000	0.00000

c***

Wed Jan 4 07:48:48 PST 1995
3 inch jumper connector system model
Guide active
Interface element screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	2702.	-1351.	-1351.	0.	577.	-577.
2.0	-162.	-162.	-162.	0.	0.	0.
3.0	0.	-2339.	2339.	667.	-333.	-333.
4.0	0.	-11392.	11392.	3247.	-1623.	-1623.
5.0	0.	0.	0.	-760.	-762.	-762.
6.0	-23026.	11511.	11511.	0.	-4921.	4921.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2208.	0.	-3937.	1104.	21272.	1967.
2.0	133.	0.	236.	133.	0.	236.
3.0	0.	24561.	0.	1912.	-12279.	3405.
4.0	0.	119611.	0.	9312.	-59800.	16583.
5.0	0.	-28015.	0.	0.	-28088.	-2.
6.0	18822.	0.	33552.	-9409.	-181295.	-16766.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2208.	0.	0.	1104.	-759.	0.
2.0	133.	0.	0.	133.	0.	0.
3.0	0.	-878.	0.	1912.	438.	0.
4.0	0.	-4275.	0.	9312.	2134.	-1.
5.0	0.	1001.	0.	0.	1002.	0.
6.0	18822.	0.	0.	-9409.	6468.	-2.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-3095.	0.	0.	-31219.
2.0	-487.	0.	0.	-300.	0.	0.
3.0	0.	-3095.	0.	0.	-31219.	0.
4.0	0.	-15072.	0.	0.	-152035.	0.
5.0	0.	-6.	0.	0.	5.	0.
6.0	-3.	0.	26375.	-2.	0.	266061.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-3095.	0.	0.	4095.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	-3095.	0.	0.	4095.	0.
4.0	0.	-15072.	0.	0.	19942.	0.
5.0	0.	-6.	0.	0.	8.	0.
6.0	-3.	0.	26375.	0.	0.	-34898.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	1000.	0.	-2318.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	1000.	0.	0.	0.	2318.
4.0	0.	4870.	0.	-1.	0.	11287.
5.0	0.	2.	0.	-5143.	0.	-15.
6.0	-3.	0.	-8523.	0.	19752.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.19313	0.00000	0.00000	0.00000	0.00000	-0.02562
2.0	0.00000	0.00079	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.19310	0.02561	-0.00029	0.00000
4.0	0.00000	0.00000	0.94040	0.12475	-0.00140	0.00000
5.0	0.00000	0.00000	-0.01844	-0.00245	75.10240	0.00000
6.0	-1.64592	0.00000	0.00000	0.00000	0.00000	0.21834

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.29139	0.00000	0.00000	0.00000	0.00000	-0.00550
2.0	0.00000	0.00074	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.29135	0.00550	-0.00036	0.00000
4.0	0.00000	0.00000	1.41889	0.02679	-0.00175	0.00000
5.0	0.00000	0.00000	-0.02219	0.00000	94.28710	0.00000
6.0	-2.48341	0.00000	0.00000	0.00000	0.00000	0.04691

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	-0.01234	0.00000	-0.00285	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.01432	0.00705	-0.00322	0.00172	0.00000	0.00000
4.0	-0.06974	0.03435	-0.01567	0.00836	0.00000	0.00000
5.0	18.83570	18.83590	-18.83610	-18.84010	0.00000	0.00000
6.0	0.00000	0.10517	0.00000	0.02429	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	0.03442	0.00000	0.00000	0.01775	0.06579	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.03442	-0.01775	0.00000	0.00000	0.06579
4.0	0.00000	0.16763	-0.08643	0.00000	0.00000	0.32043
5.0	0.00000	0.00044	0.00244	0.00000	0.00000	-0.00372
6.0	-0.29334	0.00000	0.00000	-0.15126	-0.56076	0.00000

c***

Wed Jan 4 07:48:54 PST 1995
3 inch jumper connector system model
Guide inactive
Interface element screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	2920.	-1460.	-1460.	0.	0.	0.
2.0	-162.	-162.	-162.	0.	0.	0.
3.0	0.	-2529.	2529.	0.	0.	0.
4.0	0.	-12314.	12314.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-24889.	12445.	12445.	0.	0.	0.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2387.	0.	-4255.	1194.	1.	2126.
2.0	133.	0.	236.	133.	0.	236.
3.0	0.	0.	0.	2067.	2.	3681.
4.0	0.	0.	0.	10066.	11.	17928.
5.0	0.	0.	0.	0.	0.	0.
6.0	20344.	0.	36267.	-10172.	-11.	-18118.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2387.	0.	0.	1194.	0.	0.
2.0	133.	0.	0.	133.	0.	0.
3.0	0.	0.	0.	2067.	0.	0.
4.0	0.	0.	0.	10066.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	20344.	0.	0.	-10172.	0.	0.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	0.	0.	0.	-33746.
2.0	-487.	0.	0.	-300.	0.	0.
3.0	0.	0.	0.	0.	-33746.	0.
4.0	0.	0.	0.	0.	-164343.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	287600.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	0.	0.	0.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	0.
4.0	0.	0.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	0.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	0.	0.	-9856.	0.
2.0	-487.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	9856.
4.0	0.	0.	0.	0.	0.	48000.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	84000.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-roty	bt-rotz
1.0	9.62859	0.00000	0.00000	0.00000	0.00000	-1.27732
2.0	0.00000	0.00079	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	9.62857	1.27731	0.00000	0.00000
4.0	0.00000	0.00000	46.89140	6.22056	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	80.00010	0.00000
6.0	-82.06010	0.00000	0.00000	0.00000	0.00000	10.88600

c*** nut displacements *

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-roty	nut-rotz
1.0	11.64370	0.00000	0.00000	0.00000	0.00000	-0.00595
2.0	0.00000	0.00074	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	11.64360	0.00595	0.00000	0.00000
4.0	0.00000	0.00000	56.70470	0.02896	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	80.00010	0.00000
6.0	-99.23350	0.00000	0.00000	0.00000	0.00000	0.05070

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	-0.89038	0.00000	-0.21066	0.00000	2.60920
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-1.02812	0.51406	-0.24325	0.12162	3.01285	-1.50643
4.0	-5.00698	2.50349	-1.18462	0.59231	14.67260	-7.33633
5.0	15.98580	15.98850	-15.98580	-15.98850	-43.96100	-43.96850
6.0	0.00000	7.58830	0.00000	1.79534	0.00000	-22.23700

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.19307	0.00000	0.00000	1.26643	1.97124	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.19307	-1.26643	0.00000	0.00000	1.97124
4.0	0.00000	-0.94024	-6.16755	0.00000	0.00000	9.60000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	1.64543	0.00000	0.00000	-10.79320	-16.80000	0.00000

c***

Thu Jan 5 09:27:54 PST 1995
4 inch jumper connector system model
Guide active
No-slip screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	4304.	-2152.	-2152.	0.	764.	-764.
2.0	-244.	-244.	-244.	0.	0.	0.
3.0	0.	-3727.	3727.	882.	-441.	-441.
4.0	0.	-16521.	16521.	3910.	-1955.	-1955.
5.0	0.	0.	0.	-19159.	-19160.	-19160.
6.0	-35430.	17716.	17716.	0.	-6288.	6288.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-3071.	0.	-6272.	1536.	18062.	3135.
2.0	174.	0.	356.	174.	0.	356.
3.0	0.	20856.	0.	2660.	-10428.	5431.
4.0	0.	92441.	0.	11790.	-46222.	24073.
5.0	0.	-453016.	0.	0.	-453026.	19.
6.0	25284.	0.	51630.	-12643.	-148675.	-25806.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-3071.	0.	0.	1536.	4118.	0.
2.0	174.	0.	0.	174.	0.	0.
3.0	0.	4754.	0.	2660.	-2377.	0.
4.0	0.	21063.	0.	11790.	-10530.	1.
5.0	0.	-490369.	0.	0.	-490384.	20.
6.0	25284.	0.	0.	-12643.	-33880.	2.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-2701.	0.	0.	-28673.
2.0	-733.	0.	0.	-322.	0.	0.
3.0	0.	-2701.	0.	0.	-28674.	0.
4.0	0.	-11972.	0.	0.	-127110.	0.
5.0	0.	1.	0.	0.	9.	0.
6.0	1.	0.	22233.	1.	0.	236055.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-2701.	0.	0.	4024.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	-2701.	0.	0.	4024.	0.
4.0	0.	-11972.	0.	0.	17836.	0.
5.0	0.	1.	0.	0.	0.	0.
6.0	1.	0.	22233.	0.	0.	-33124.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	1323.	0.	-7109.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	1323.	0.	0.	0.	7109.
4.0	0.	5864.	0.	0.	0.	31515.
5.0	0.	0.	0.	-154507.	0.	-2.
6.0	1.	0.	-10891.	0.	58526.	0.

c*** block top displacements

TIME ldcs	3 UX 7 bt-ux	3 UY 8 bt-uy	3 UZ 9 bt-uz	3 ROTX10 bt-rotx	3 ROTY11 bt-rotz	3 ROTZ12 bt-rotz
1.0	0.11883	0.00000	0.00000	0.00000	0.00000	-0.01327
2.0	0.00000	0.00116	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.11882	0.01327	0.00000	0.00000
4.0	0.00000	0.00000	0.52666	0.05884	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.74657	0.00000
6.0	-0.97811	0.00000	0.00000	0.00000	0.00000	0.10928

c*** nut displacements

TIME ldcs	5 UX 7 nut-ux	5 UY 8 nut-uy	5 UZ 9 nut-uz	5 ROTX10 nut-rotx	5 ROTY11 nut-rotz	5 ROTZ12 nut-rotz
1.0	0.16393	0.00000	0.00000	0.00000	0.00000	-0.00725
2.0	0.00000	0.00111	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.16392	0.00725	0.00000	0.00000
4.0	0.00000	0.00000	0.72657	0.03215	0.00000	0.00000
5.0	0.00000	0.00000	0.00001	0.00000	0.80299	0.00000
6.0	-1.34940	0.00000	0.00000	0.00000	0.00000	0.05970

c*** Hook-pin and hook-guide relative displacements

TIME ldcs	4 ADD 9 drrph0	7 ADD 12 drrph1	10 ADD drrhg0	14 ADD drrhg1	17 ADD duthg0	20 ADD duthg1
1.0	0.00000	0.00000	0.00000	-0.00256	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00295	0.00148	0.00000	0.00000
4.0	0.00000	0.00000	-0.01309	0.00655	0.00000	0.00000
5.0	0.00000	0.00000	-0.11595	-0.11596	0.00000	0.00000
6.0	0.00000	0.00000	0.00000	0.02105	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME ldcs	4 ADD 9 duxsg	7 ADD 12 duzsg	10 ADD drxsg	14 ADD drzsg	17 ADD duxsb	20 ADD duzsb
1.0	-0.00024	0.00000	0.00000	0.00346	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.00024	-0.00346	0.00000	0.00000	0.00000
4.0	0.00000	-0.00106	-0.01533	0.00000	0.00000	0.00000
5.0	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000
6.0	0.00197	0.00000	0.00000	-0.02847	0.00000	0.00000

c***

Thu Jan 5 09:28:00 PST 1995
4 inch jumper connector system model
Guide inactive
No-slip screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	4208.	-2104.	-2104.	0.	950.	-950.
2.0	-244.	-244.	-244.	0.	0.	0.
3.0	0.	-3644.	3644.	1096.	-548.	-548.
4.0	0.	-16152.	16152.	4860.	-2430.	-2430.
5.0	0.	0.	0.	-9612.	-9612.	-9612.
6.0	-34637.	17320.	17320.	0.	-7817.	7817.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-3003.	0.	-6132.	1501.	22452.	3065.
2.0	174.	0.	356.	174.	0.	356.
3.0	0.	25926.	0.	2600.	-12963.	5310.
4.0	0.	114915.	0.	11526.	-57459.	23535.
5.0	0.	-227278.	0.	0.	-227283.	9.
6.0	24716.	0.	50474.	-12360.	-184820.	-25227.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-3003.	0.	0.	1501.	30945.	-1.
2.0	174.	0.	0.	174.	0.	0.
3.0	0.	35732.	0.	2600.	-17866.	1.
4.0	0.	158381.	0.	11526.	-79188.	3.
5.0	0.	-313244.	0.	0.	-313249.	12.
6.0	24716.	0.	0.	-12360.	-254729.	10.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	1645.	0.	0.	7680.
2.0	-733.	0.	0.	-322.	0.	0.
3.0	0.	1645.	0.	0.	7680.	0.
4.0	0.	7290.	0.	0.	34035.	0.
5.0	0.	0.	0.	0.	2.	0.
6.0	2.	0.	-13539.	1.	0.	-63209.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	1645.	0.	0.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	1645.	0.	0.	0.	0.
4.0	0.	7290.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	2.	0.	-13539.	0.	0.	0.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	1645.	0.	-4231.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	1645.	0.	0.	0.	4231.
4.0	0.	7290.	0.	0.	0.	18755.
5.0	0.	0.	0.	-77516.	0.	-1.
6.0	2.	0.	-13539.	0.	34829.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.19104	0.00000	0.00000	0.00000	0.00000	-0.02134
2.0	0.00000	0.00116	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.19103	0.02134	0.00000	0.00000
4.0	0.00000	0.00000	0.84675	0.09461	0.00000	0.00000
5.0	0.00000	0.00000	-0.00001	0.00000	39.24200	0.00000
6.0	-1.57254	0.00000	0.00000	0.00000	0.00000	0.17571

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.22421	0.00000	0.00000	0.00000	0.00000	-0.00709
2.0	0.00000	0.00111	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.22420	0.00709	0.00000	0.00000
4.0	0.00000	0.00000	0.99377	0.03143	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.44030	0.00000
6.0	-1.84560	0.00000	0.00000	0.00000	0.00000	0.05837

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	0.00000	0.00000	-0.00575	0.00000	0.03291
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00664	0.00332	0.03800	-0.01900
4.0	0.00000	0.00000	-0.02944	0.01472	0.16844	-0.08422
5.0	0.00000	0.00000	-0.06673	-0.06673	133.60699	133.60699
6.0	0.00000	0.00000	0.00000	0.04735	0.00000	-0.27090

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.01939	0.00000	0.00000	0.01461	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.01939	-0.01461	0.00000	0.00000	0.00000
4.0	0.00000	-0.08597	-0.06475	0.00000	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	0.15966	0.00000	0.00000	-0.12025	0.00000	0.00000

c***

Thu Jan 5 09:28:05 PST 1995
4 inch jumper connector system model
Guide active
Interface element screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	4158.	-2079.	-2079.	0.	1045.	-1045.
2.0	-244.	-244.	-244.	0.	0.	0.
3.0	0.	-3601.	3601.	1207.	-604.	-604.
4.0	0.	-15961.	15961.	5350.	-2675.	-2675.
5.0	0.	0.	0.	-19160.	-19160.	-19160.
6.0	-34229.	17115.	17115.	0.	-8605.	8605.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2967.	0.	-6059.	1484.	24717.	3028.
2.0	174.	0.	356.	174.	0.	356.
3.0	0.	28541.	0.	2570.	-14270.	5247.
4.0	0.	126507.	0.	11390.	-63254.	23258.
5.0	0.	-453019.	0.	0.	-453025.	19.
6.0	24426.	0.	49879.	-12214.	-203463.	-24929.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2967.	0.	0.	1484.	22383.	-1.
2.0	174.	0.	0.	174.	0.	0.
3.0	0.	25846.	0.	2570.	-12922.	1.
4.0	0.	114564.	0.	11390.	-57280.	2.
5.0	0.	-490377.	0.	0.	-490380.	20.
6.0	24426.	0.	0.	-12214.	-184257.	8.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-452.	0.	0.	-2906.
2.0	-733.	0.	0.	-322.	0.	0.
3.0	0.	-452.	0.	0.	-2906.	0.
4.0	0.	-2003.	0.	0.	-12881.	0.
5.0	0.	0.	0.	0.	-1.	0.
6.0	2.	0.	3720.	1.	0.	23923.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-452.	0.	0.	2263.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	-452.	0.	0.	2263.	0.
4.0	0.	-2003.	0.	0.	10029.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	2.	0.	3720.	0.	0.	-18625.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	1811.	0.	-2746.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	1811.	0.	0.	0.	2746.
4.0	0.	8025.	0.	0.	0.	12173.
5.0	0.	0.	0.	-154507.	0.	0.
6.0	2.	0.	-14904.	0.	22607.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.15648	0.00000	0.00000	0.00000	0.00000	-0.01748
2.0	0.00000	0.00116	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.15648	0.01748	0.00000	0.00000
4.0	0.00000	0.00000	0.69361	0.07750	0.00000	0.00000
5.0	0.00000	0.00000	-0.00002	0.00000	0.74657	0.00000
6.0	-1.28814	0.00000	0.00000	0.00000	0.00000	0.14393

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.21657	0.00000	0.00000	0.00000	0.00000	-0.00701
2.0	0.00000	0.00111	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.21657	0.00701	0.00000	0.00000
4.0	0.00000	0.00000	0.95995	0.03106	0.00000	0.00000
5.0	0.00000	0.00000	-0.00001	0.00000	0.80299	0.00000
6.0	-1.78279	0.00000	0.00000	0.00000	0.00000	0.05768

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	0.00000	0.00000	-0.00330	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00381	0.00191	0.00000	0.00000
4.0	0.00000	0.00000	-0.01691	0.00846	0.00000	0.00000
5.0	0.00000	0.00000	-0.11595	-0.11596	0.00000	0.00000
6.0	0.00000	0.00000	0.00000	0.02720	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	0.01263	0.00000	0.00000	0.01028	0.02548	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.01263	-0.01028	0.00000	0.00000	0.02548
4.0	0.00000	0.05600	-0.04558	0.00000	0.00000	0.11296
5.0	0.00000	0.00000	0.00001	0.00000	0.00000	-0.00001
6.0	-0.10400	0.00000	0.00000	-0.08464	-0.20978	0.00000

c***

Thu Jan 5 09:28:10 PST 1995
4 inch jumper connector system model
Guide inactive
Interface element screw-block connection
Pin moments transmitted

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	4183.	-2092.	-2092.	0.	997.	-997.
2.0	-244.	-244.	-244.	0.	0.	0.
3.0	0.	-3622.	3622.	1151.	-576.	-576.
4.0	0.	-16057.	16057.	5104.	-2552.	-2552.
5.0	0.	0.	0.	-9612.	-9612.	-9612.
6.0	-34434.	17218.	17218.	0.	-8209.	8209.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2985.	0.	-6096.	1493.	23579.	3047.
2.0	174.	0.	356.	174.	0.	356.
3.0	0.	27227.	0.	2585.	-13613.	5279.
4.0	0.	120683.	0.	11459.	-60342.	23397.
5.0	0.	-227279.	0.	0.	-227282.	9.
6.0	24573.	0.	50178.	-12287.	-194096.	-25079.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2985.	0.	0.	1493.	32497.	-1.
2.0	174.	0.	0.	174.	0.	0.
3.0	0.	37525.	0.	2585.	-18762.	1.
4.0	0.	166330.	0.	11459.	-83162.	3.
5.0	0.	-313245.	0.	0.	-313248.	12.
6.0	24573.	0.	0.	-12287.	-267512.	11.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	1727.	0.	0.	10025.
2.0	-733.	0.	0.	-322.	0.	0.
3.0	0.	1727.	0.	0.	10025.	0.
4.0	0.	7656.	0.	0.	44435.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	2.	0.	-14218.	1.	0.	-82523.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	1727.	0.	0.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	1727.	0.	0.	0.	0.
4.0	0.	7656.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	2.	0.	-14218.	0.	0.	0.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	1727.	0.	-3492.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	1727.	0.	0.	0.	3492.
4.0	0.	7656.	0.	0.	0.	15480.
5.0	0.	0.	0.	-77516.	0.	0.
6.0	2.	0.	-14218.	0.	28748.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-roty	bt-rotz
1.0	0.19097	0.00000	0.00000	0.00000	0.00000	-0.02134
2.0	0.00000	0.00116	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.19097	0.02134	0.00000	0.00000
4.0	0.00000	0.00000	0.84647	0.09458	0.00000	0.00000
5.0	0.00000	0.00000	-0.00001	0.00000	39.24200	0.00000
6.0	-1.57202	0.00000	0.00000	0.00000	0.00000	0.17565

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-roty	nut-rotz
1.0	0.23045	0.00000	0.00000	0.00000	0.00000	-0.00705
2.0	0.00000	0.00111	0.00000	0.00000	0.00000	0.00000
3.0	-0.00000	0.00000	0.23045	0.00705	0.00000	0.00000
4.0	0.00000	0.00000	1.02148	0.03124	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.44030	0.00000
6.0	-1.89707	0.00000	0.00000	0.00000	0.00000	0.05802

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	0.00000	0.00000	-0.00545	0.00000	0.02795
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	-0.00629	0.00315	0.03227	-0.01614
4.0	0.00000	0.00000	-0.02790	0.01395	0.14306	-0.07153
5.0	0.00000	0.00000	-0.06673	-0.06673	-133.60699	-133.60699
6.0	0.00000	0.00000	0.00000	0.04488	0.00000	-0.23008

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.01257	0.00000	0.00000	0.01490	0.00757	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.01257	-0.01490	0.00000	0.00000	0.00757
4.0	0.00000	-0.05571	-0.06606	0.00000	0.00000	0.03356
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00001
6.0	0.10347	0.00000	0.00000	-0.12268	-0.06232	0.00000

c***

Thu Jan 5 09:28:15 PST 1995
4 inch jumper connector system model
Guide active
No-slip screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	4334.	-2167.	-2167.	0.	707.	-707.
2.0	-244.	-244.	-244.	0.	0.	0.
3.0	0.	-3753.	3753.	816.	-408.	-408.
4.0	0.	-16635.	16635.	3617.	-1808.	-1808.
5.0	0.	2.	-2.	-1182.	-1189.	-1189.
6.0	-35674.	17838.	17838.	0.	-5817.	5817.

** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-3093.	0.	-6315.	1546.	16708.	3157.
2.0	174.	0.	356.	174.	0.	356.
3.0	0.	19292.	0.	2678.	-9647.	5468.
4.0	0.	85512.	0.	11871.	-42759.	24239.
5.0	0.	-27939.	0.	-2.	-28125.	-2.
6.0	25458.	0.	51986.	-12730.	-137532.	-25984.

upper hook section stresses at nut, 0 and 120 degr

IME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-3093.	0.	0.	1546.	-1210.	0.
2.0	174.	0.	0.	174.	0.	0.
3.0	0.	-1398.	0.	2678.	699.	0.
4.0	0.	-6195.	0.	11871.	3097.	0.
5.0	0.	2024.	0.	-2.	2037.	0.
6.0	25458.	0.	0.	-12730.	9961.	1.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-3470.	0.	0.	-36026.
2.0	-733.	0.	0.	-322.	0.	0.
3.0	0.	-3470.	0.	0.	-36026.	0.
4.0	0.	-15382.	0.	0.	-159688.	0.
5.0	0.	-22.	0.	0.	20.	0.
6.0	1.	0.	28566.	0.	0.	296563.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-3470.	0.	0.	4694.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	-3470.	0.	0.	4694.	0.
4.0	0.	-15382.	0.	0.	20806.	0.
5.0	0.	-22.	0.	0.	30.	0.
6.0	1.	0.	28566.	0.	0.	-38641.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	1224.	0.	-7997.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	1224.	0.	0.	0.	7997.
4.0	0.	5425.	0.	0.	0.	35448.
5.0	0.	8.	0.	-9571.	0.	-70.
6.0	1.	0.	-10075.	0.	65832.	0.

c*** block top displacements

TIME	3 UX	3 UY	3 UZ	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.12123	0.00000	0.00000	0.00000	0.00000	-0.01354
2.0	0.00000	0.00116	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.12123	0.01354	-0.00005	0.00000
4.0	0.00000	0.00000	0.53731	0.06003	-0.00023	0.00000
5.0	0.00000	0.00000	-0.00379	-0.00042	73.21450	0.00000
6.0	-0.99789	0.00000	0.00000	0.00000	0.00000	0.11149

c*** nut displacements

TIME	5 UX	5 UY	5 UZ	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.16902	0.00000	0.00000	0.00000	0.00000	-0.00730
2.0	0.00000	0.00111	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.16901	0.00730	-0.00006	0.00000
4.0	0.00000	0.00000	0.74910	0.03237	-0.00029	0.00000
5.0	0.00000	0.00000	-0.00386	0.00000	91.93870	0.00000
6.0	-1.39125	0.00000	0.00000	0.00000	0.00000	0.06012

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD	7 ADD	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	-0.00128	0.00000	-0.00230	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.00149	0.00072	-0.00265	0.00134	0.00000	0.00000
4.0	-0.00661	0.00321	-0.01174	0.00596	0.00000	0.00000
5.0	19.63830	19.63860	-19.64100	-19.64190	0.00000	0.00000
6.0	0.00000	0.01053	0.00000	0.01898	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD	7 ADD	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	0.00086	0.00000	0.00000	0.00305	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00086	-0.00305	0.00000	0.00000	0.00000
4.0	0.00000	0.00380	-0.01351	0.00000	0.00000	0.00000
5.0	0.00000	0.00062	0.00041	0.00000	0.00000	0.00000
6.0	-0.00706	0.00000	0.00000	-0.02509	0.00000	0.00000

c***

Thu Jan 5 09:28:20 PST 1995
4 inch jumper connector system model
Guide inactive
No-slip screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	4700.	-2350.	-2350.	0.	0.	0.
2.0	-244.	-244.	-244.	0.	0.	0.
3.0	0.	-4070.	4070.	0.	0.	0.
4.0	0.	-18041.	18041.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-38690.	19345.	19345.	0.	0.	0.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-3354.	0.	-6849.	1677.	0.	3424.
2.0	174.	0.	356.	174.	0.	356.
3.0	0.	0.	0.	2905.	-1.	5930.
4.0	0.	0.	0.	12875.	-3.	26286.
5.0	0.	0.	0.	0.	0.	0.
6.0	27611.	0.	56381.	-13805.	3.	-28186.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-3354.	0.	0.	1677.	0.	0.
2.0	174.	0.	0.	174.	0.	0.
3.0	0.	0.	0.	2905.	0.	0.
4.0	0.	0.	0.	12875.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	27611.	0.	0.	-13805.	0.	0.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	0.	0.	0.	-39072.
2.0	-733.	0.	0.	-322.	0.	0.
3.0	0.	0.	0.	0.	-39072.	0.
4.0	0.	0.	0.	0.	-173186.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	321632.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	0.	0.	0.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	0.
4.0	0.	0.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	0.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	0.	0.	-18951.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	18951.
4.0	0.	0.	0.	0.	0.	84000.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	156000.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.71149	0.00000	0.00000	0.00000	0.00000	-0.07949
2.0	0.00000	0.00116	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.71149	0.07949	0.00000	0.00000
4.0	0.00000	0.00000	3.15363	0.35235	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	78.00010	0.00000
6.0	-5.85680	0.00000	0.00000	0.00000	0.00000	0.65437

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.76969	0.00000	0.00000	0.00000	0.00000	-0.00792
2.0	0.00000	0.00111	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.76967	0.00792	0.00000	0.00000
4.0	0.00000	0.00000	3.41154	0.03510	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	78.00010	0.00000
6.0	-6.33582	0.00000	0.00000	0.00000	0.00000	0.06520

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	-0.04613	0.00000	-0.01586	0.00000	0.23059
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.05326	0.02663	-0.01831	0.00915	0.26626	-0.13313
4.0	-0.23608	0.11804	-0.08116	0.04058	1.18019	-0.59009
5.0	16.66650	16.66710	-16.66650	-16.66710	-54.66600	-54.66820
6.0	0.00000	0.37971	0.00000	0.13054	0.00000	-1.89814

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	-0.09489	0.00000	0.00000	0.06675	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	-0.09489	-0.06675	0.00000	0.00000	0.00000
4.0	0.00000	-0.42060	-0.29588	0.00000	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	0.78110	0.00000	0.00000	-0.54949	0.00000	0.00000

c***

Thu Jan 5 09:28:25 PST 1995
4 inch jumper connector system model
Guide active
Interface element screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME	15 FZ	16 FZ	17 FZ	15 FY	16 FY	17 FY
ldcs	hz0-ra	hz1-ra	hz2-ra	hz0-rt	hz1-rt	hz2-rt
1.0	4107.	-2054.	-2054.	0.	1143.	-1143.
2.0	-244.	-244.	-244.	0.	0.	0.
3.0	0.	-3557.	3557.	1320.	-660.	-660.
4.0	0.	-15767.	15767.	5849.	-2925.	-2925.
5.0	0.	0.	0.	-1186.	-1187.	-1187.
6.0	-33812.	16907.	16907.	0.	-9408.	9408.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME	2 ADD 6	8 LS 7	8 LS 9	5 ADD 6	9 LS 7	9 LS 9
ldcs	hg0-sd	hg0-sbyt	hg0-sbzt	hg1-sd	hg1-sbyt	hg1-sbzt
1.0	-2931.	0.	-5986.	1466.	27022.	2991.
2.0	174.	0.	356.	174.	0.	356.
3.0	0.	31203.	0.	2538.	-15602.	5183.
4.0	0.	138307.	0.	11252.	-69157.	22975.
5.0	0.	-28052.	0.	0.	-28069.	1.
6.0	24129.	0.	49272.	-12066.	-222445.	-24625.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME	2 ADD 1	8 LS 2	8 LS 4	5 ADD 1	9 LS 2	9 LS 4
ldcs	hg0-sd	hn0-sbyt	hn0-sbzt	hg1-sd	hn1-sbyt	hn1-sbzt
1.0	-2931.	0.	0.	1466.	-1957.	0.
2.0	174.	0.	0.	174.	0.	0.
3.0	0.	-2260.	0.	2538.	1130.	0.
4.0	0.	-10020.	0.	11252.	5009.	0.
5.0	0.	2032.	0.	0.	2033.	0.
6.0	24129.	0.	0.	-12066.	16111.	1.

c*** screw forces and stresses at nut

TIME	22 SMIS7	22 SMIS8	22 SMIS9	22 LS 6	22 LS 7	22 LS 9
ldcs	sj-fx	sj-fy	sj-fz	sj-sd	sj-sbyt	sj-sbzt
1.0	0.	0.	-5613.	0.	0.	-34146.
2.0	-733.	0.	0.	-322.	0.	0.
3.0	0.	-5613.	0.	0.	-34146.	0.
4.0	0.	-24878.	0.	0.	-151354.	0.
5.0	0.	-2.	0.	0.	2.	0.
6.0	2.	0.	46202.	1.	0.	281085.

c*** screw and guide forces at block top

TIME	21 SMIS1	21 SMIS2	21 SMIS3	16 SMIS1	16 SMIS2	16 SMIS3
ldcs	si-fx	si-fy	si-fz	gi-fx	gi-fy	gi-fz
1.0	0.	0.	-5613.	0.	0.	7592.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	-5613.	0.	0.	7592.	0.
4.0	0.	-24878.	0.	0.	33652.	0.
5.0	0.	-2.	0.	0.	3.	0.
6.0	2.	0.	46202.	0.	0.	-62497.

c*** block forces and moments at top of block

TIME	2 SMIS7	2 SMIS8	2 SMIS9	2 SMIS10	2 SMIS11	2 SMIS12
ldcs	bt-fx	bt-fy	bt-fz	bt-mx	bt-my	bt-mz

1.0	0.	0.	1979.	0.	-1234.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	1979.	0.	0.	0.	1234.
4.0	0.	8774.	0.	-1.	0.	5472.
5.0	0.	1.	0.	-9571.	0.	-6.
6.0	2.	0.	-16295.	0.	10162.	0.

c*** block top displacements

TIME	3 UX 7	3 UY 8	3 UZ 9	3 ROTX10	3 ROTY11	3 ROTZ12
ldcs	bt-ux	bt-uy	bt-uz	bt-rotx	bt-rotz	bt-rotz
1.0	0.35224	0.00000	0.00000	0.00000	0.00000	-0.03936
2.0	0.00000	0.00116	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.35224	0.03936	-0.00008	0.00000
4.0	0.00000	0.00000	1.56130	0.17445	-0.00037	0.00000
5.0	0.00000	0.00000	-0.00614	-0.00069	73.21450	0.00000
6.0	-2.89957	0.00000	0.00000	0.00000	0.00000	0.32398

c*** nut displacements

TIME	5 UX 7	5 UY 8	5 UZ 9	5 ROTX10	5 ROTY11	5 ROTZ12
ldcs	nut-ux	nut-uy	nut-uz	nut-rotx	nut-rotz	nut-rotz
1.0	0.52136	0.00000	0.00000	0.00000	0.00000	-0.00692
2.0	0.00000	0.00111	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	0.52135	0.00692	-0.00010	0.00000
4.0	0.00000	0.00000	2.31094	0.03068	-0.00046	0.00000
5.0	0.00000	0.00000	-0.00744	0.00000	91.93870	0.00000
6.0	-4.29177	0.00000	0.00000	0.00000	0.00000	0.05698

c*** Hook-pin and hook-guide relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	drph0	drph1	drhg0	drhg1	duthg0	duthg1
1.0	0.00000	-0.02338	0.00000	-0.00177	0.00000	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-0.02701	0.01347	-0.00202	0.00104	0.00000	0.00000
4.0	-0.11975	0.05972	-0.00896	0.00463	0.00000	0.00000
5.0	19.63860	19.63850	-19.64100	-19.64190	0.00000	0.00000
6.0	0.00000	0.19243	0.00000	0.01457	0.00000	0.00000

c*** Screw-guide and screw-block relative displacements

TIME	4 ADD 9	7 ADD 12	10 ADD	14 ADD	17 ADD	20 ADD
ldcs	duxsg	duzsg	drxsg	drzsg	duxsb	duzsb
1.0	0.08415	0.00000	0.00000	0.03025	0.12776	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.08415	-0.03025	0.00000	0.00000	0.12776
4.0	0.00000	0.37298	-0.13407	0.00000	0.00000	0.56631
5.0	0.00000	-0.00024	0.00068	0.00000	0.00000	-0.00130
6.0	-0.69268	0.00000	0.00000	-0.24899	-1.05172	0.00000

c***

Thu Jan 5 09:28:30 PST 1995
4 inch jumper connector system model
Guide inactive
Interface element screw-block connection
Pin moments released

c*** hook reactions at nozzle, global axial and tangential

TIME ldcs	15 FZ hz0-ra	16 FZ hz1-ra	17 FZ hz2-ra	15 FY hz0-rt	16 FY hz1-rt	17 FY hz2-rt
1.0	4700.	-2350.	-2350.	0.	0.	0.
2.0	-244.	-244.	-244.	0.	0.	0.
3.0	0.	-4070.	4070.	0.	0.	0.
4.0	0.	-18041.	18041.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	-38690.	19345.	19345.	0.	0.	0.

c*** upper hook section stresses at guide, 0 and 120 degr

TIME ldcs	2 ADD 6 hg0-sd	8 LS 7 hg0-sbyt	8 LS 9 hg0-sbzt	5 ADD 6 hg1-sd	9 LS 7 hg1-sbyt	9 LS 9 hg1-sbzt
1.0	-3354.	0.	-6849.	1677.	0.	3424.
2.0	174.	0.	356.	174.	0.	356.
3.0	0.	0.	0.	2905.	-1.	5930.
4.0	0.	0.	0.	12875.	-3.	26286.
5.0	0.	0.	0.	0.	0.	0.
6.0	27611.	0.	56381.	-13805.	3.	-28187.

c*** upper hook section stresses at nut, 0 and 120 degr

TIME ldcs	2 ADD 1 hg0-sd	8 LS 2 hn0-sbyt	8 LS 4 hn0-sbzt	5 ADD 1 hg1-sd	9 LS 2 hn1-sbyt	9 LS 4 hn1-sbzt
1.0	-3354.	0.	0.	1677.	0.	0.
2.0	174.	0.	0.	174.	0.	0.
3.0	0.	0.	0.	2905.	0.	0.
4.0	0.	0.	0.	12875.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	27611.	0.	0.	-13805.	0.	0.

c*** screw forces and stresses at nut

TIME ldcs	22 SMIS7 sj-fx	22 SMIS8 sj-fy	22 SMIS9 sj-fz	22 LS 6 sj-sd	22 LS 7 sj-sbyt	22 LS 9 sj-sbzt
1.0	0.	0.	0.	0.	0.	-39072.
2.0	-733.	0.	0.	-322.	0.	0.
3.0	0.	0.	0.	0.	-39072.	0.
4.0	0.	0.	0.	0.	-173186.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	321632.

c*** screw and guide forces at block top

TIME ldcs	21 SMIS1 si-fx	21 SMIS2 si-fy	21 SMIS3 si-fz	16 SMIS1 gi-fx	16 SMIS2 gi-fy	16 SMIS3 gi-fz
1.0	0.	0.	0.	0.	0.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	0.
4.0	0.	0.	0.	0.	0.	0.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	0.	0.

c*** block forces and moments at top of block

TIME ldcs	2 SMIS7 bt-fx	2 SMIS8 bt-fy	2 SMIS9 bt-fz	2 SMIS10 bt-mx	2 SMIS11 bt-my	2 SMIS12 bt-mz

1.0	0.	0.	0.	0.	-18951.	0.
2.0	-733.	0.	0.	0.	0.	0.
3.0	0.	0.	0.	0.	0.	18951.
4.0	0.	0.	0.	0.	0.	84000.
5.0	0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	156000.	0.

c*** block top displacements

TIME ldcs	3 UX 7 bt-ux	3 UY 8 bt-uy	3 UZ 9 bt-uz	3 ROTX10 bt-rotx	3 ROTY11 bt-roty	3 ROTZ12 bt-rotz
1.0	17.62970	0.00000	0.00000	0.00000	0.00000	-1.96982
2.0	0.00000	0.00116	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	17.62970	1.96982	0.00000	0.00000
4.0	0.00000	0.00000	78.14470	8.73133	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	78.00010	0.00000
6.0	-145.12601	0.00000	0.00000	0.00000	0.00000	16.21530

c*** nut displacements

TIME ldcs	5 UX 7 nut-ux	5 UY 8 nut-uy	5 UZ 9 nut-uz	5 ROTX10 nut-rotx	5 ROTY11 nut-roty	5 ROTZ12 nut-rotz
1.0	21.47810	0.00000	0.00000	0.00000	0.00000	-0.00792
2.0	0.00000	0.00111	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.00000	21.47810	0.00792	0.00000	0.00000
4.0	0.00000	0.00000	95.20260	0.03510	0.00000	0.00000
5.0	0.00000	0.00000	0.00000	0.00000	78.00010	0.00000
6.0	-176.80499	0.00000	0.00000	0.00000	0.00000	0.06520

c*** Hook-pin and hook-guide relative displacements

TIME ldcs	4 ADD 9 drrph0	7 ADD 12 drrph1	10 ADD drrhg0	14 ADD drrhg1	17 ADD duthg0	20 ADD duthg1
1.0	0.00000	-1.47172	0.00000	-0.22733	0.00000	4.17311
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	-1.69940	0.84970	-0.26250	0.13125	4.81869	-2.40934
4.0	-7.53267	3.76633	-1.16356	0.58178	21.35910	-10.67950
5.0	16.66650	16.66710	-16.66650	-16.66710	-54.66600	-54.66820
6.0	0.00000	12.11500	0.00000	1.87139	0.00000	-34.35250

c*** Screw-guide and screw-block relative displacements

TIME ldcs	4 ADD 9 duxsg	7 ADD 12 duzsg	10 ADD drxsg	14 ADD drzsg	17 ADD duxsb	20 ADD duzsb
1.0	0.75201	0.00000	0.00000	1.95708	3.79014	0.00000
2.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3.0	0.00000	0.75201	-1.95708	0.00000	0.00000	3.79014
4.0	0.00000	3.33333	-8.67486	0.00000	0.00000	16.80000
5.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6.0	-6.19047	0.00000	0.00000	-16.11050	-31.20000	0.00000

c***

7.0 SUPPLEMENTARY MATERIAL

7.1 DERIVATION OF THE INTERFACE ELEMENT

DESIGN CALCULATION

WHC-SD-W236A-DA-002
REVISION 0

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject Interface Element
(8) Originator E.O. Weiner Date 1/18/95
(9) Checker J. J. J. J. Date 1/20/95

Assume $\mu = 0$

Resistance to lateral sliding and rotation occurs with the inclination of N to the preload V .

Obtain a stiffness matrix controlled by the preload V :

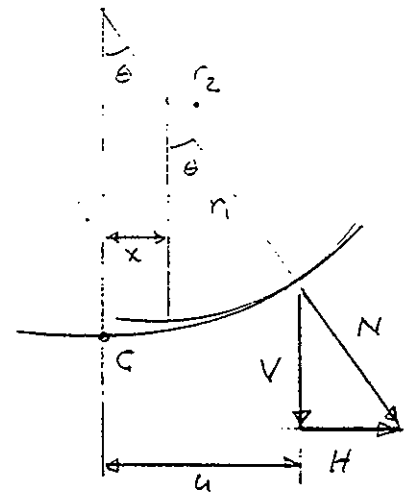
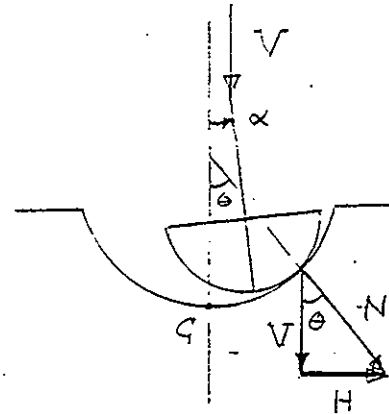
Given $x = 0$ and $\alpha > 0$

$$u = x + r_1 \sin \theta = r_2 \sin \theta$$

$$\sin \theta = \frac{x}{r_2 - r_1} = \frac{x}{\Delta r}$$

$$H = V \theta = V \sin \theta = \frac{V}{\Delta r} x$$

$$\therefore k_{xx} = \frac{V}{\Delta r}$$



Given $\alpha > 0$ and $x = 0$ ($\alpha \sim \text{ccw}$)

$$r_2 \theta_2 = r_1 \theta_1$$

$$\alpha = \theta_1 - \theta_2 = \theta_2 \left(\frac{r_2}{r_1} - 1 \right) = \frac{\Delta r}{r_1} \theta_2$$

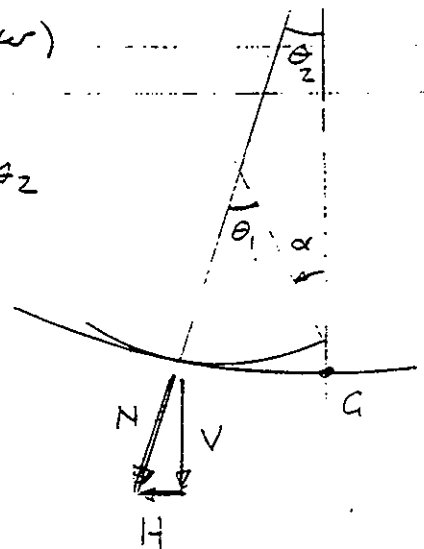
$$-H = V \theta_2 = V \frac{r_1}{\Delta r} \alpha$$

$$\therefore k_{x\alpha} = -V \frac{r_1}{\Delta r}$$

$$M = M_C = V \theta_2 r_2$$

$$= V \frac{r_1 r_2}{\Delta r} \alpha$$

$$\therefore k_{\alpha\alpha} = V \frac{r_1 r_2}{\Delta r} \quad \text{G-76}$$



DESIGN CALCULATION

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 (7) Subject Interface Element
 (8) Originator E.O. Warner Date 1/18/95
 (9) Checker John J. Jelyk Date 1/20/95

Check $k_{xx} = k_{xx}$
 $\alpha = 0 \quad x > 0$:

$$M = -V(u-x) = -Vr_1 \theta = -V_1 \frac{r_1}{\Delta r} \alpha$$

$$\therefore k_{xx} = -V \frac{r_1}{\Delta r}$$

$$\tilde{x} = \begin{bmatrix} x \\ \alpha \end{bmatrix} \quad \tilde{R} = \begin{bmatrix} H \\ M \end{bmatrix} \quad \tilde{k} = \frac{V}{\Delta r} \begin{bmatrix} 1 & -r_1 \\ -r_1 & r_1 r_2 \end{bmatrix}$$

Clearly there are large displacement effects involved with the screw/block kinematics. For example, the center of the screw always rises wrt the block, a second order effect.

Modelling with ANSYS is done with MATRIX27.

Note: simulation with a beam between the screw and block produces positive off diagonal terms vs the negative terms in $\tilde{k}$. MATRIX27 requires I and J-node terms which are obtained with the elastic kernel (Cook, Sect 8.7).

I, J Nodes are coincident:

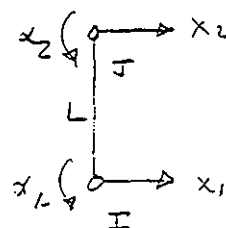
$$d_R = \begin{bmatrix} x_1 \\ x_1 \end{bmatrix} \quad d_E = \begin{bmatrix} x_2 \\ \alpha_2 \end{bmatrix}$$

$$d_E = T d_R \quad (\text{rigid kinematics})$$

$$\begin{bmatrix} x_2 \\ \alpha_2 \end{bmatrix} = \begin{bmatrix} x_1 - \frac{r_1}{r_2} \alpha_1 \\ \alpha_1 \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}}_{T=I} \begin{bmatrix} x_1 \\ \alpha_1 \end{bmatrix}$$

$$k_{EE} = \tilde{k} \text{ above}$$

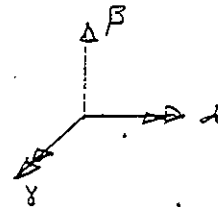
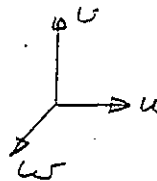
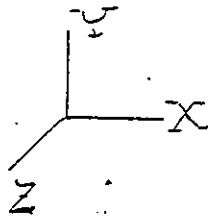
$$IJ \text{ stiffness: } k_{IJ}^{G-27} = \begin{bmatrix} k_{EE} & -k_{EE} \\ -k_{EE} & k_{EE} \end{bmatrix}$$



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 (9) Checker Sch. Julyk Date 1/20/95

Applying k to both the x and z direction



$$X \sim u, x$$

$$y \otimes \rightarrow u$$

$$Z \sim w, -x$$

$$x \otimes \rightarrow w$$

changes off-diagonal signs in k

$$k_{EE} = \begin{bmatrix} 1 & & & & & -r_1 \\ & 0 & & & & \\ & & 1 & & r_1 & \\ & & & r_1 r_2 & & \\ & \text{sym} & & & 0 & \\ & & & & & r_1 r_2 \end{bmatrix}$$

$$d_E = \begin{bmatrix} u \\ v \\ w \\ x \\ y \\ \beta \end{bmatrix}$$

MATRIX 27 Coefficients (normalized to $V/\Delta r$)

$$C_1 = 1 = C_{58}$$

$$6 \quad -r_1 \quad 63$$

$$51 \quad r_1 r_2 \quad 78$$

$$24 \quad 1 \quad 69$$

$$25 \quad r_1 \quad 70$$

$$34 \quad r_1 r_2 \quad 75$$

$$7 \quad -1$$

$$12 \quad r_1 = C_{52}$$

$$57 \quad -r_1 r_2$$

$$30 \quad -1$$

$$71 \quad -r_1 = 39$$

$$40 \quad -r_1 r_2$$

$$KEYOPT(2) = 0$$

$$(3) = 4$$

Connector	r_1	r_2	h
"	"	"	"
2	1.31	1.37	3.18
3	1.56	1.62	4.4
4	1.94	2.06	4.8

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Use ANSYS input script if are in
 & couple UY, nodes 3-4

DESIGN CALCULATION

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 (8) Originator EO Weiner Date 1/18/95
 (9) Checker John Gulyak Date 1/20/95
 (10)

No slippage condition:
moment induced by V is

$$M = V(r_2 \theta_2 - \alpha h)$$

$$\alpha - \theta_1 + \theta_2 = 0$$

$$\alpha = \theta_1 - \theta_2$$

$$r_1 \theta_1 = r_2 \theta_2 \quad (\text{no slip})$$

$$\therefore \theta_1 = \frac{r_2}{r_1} \theta_2 \quad \alpha = \left(\frac{r_2}{r_1} - 1 \right) \theta_2 = \frac{\Delta r}{r_1} \theta_2$$

$$M = V \left(\frac{r_2 r_1}{\Delta r} - h \right) \alpha$$

$$\frac{K_{EE}}{V \left(\frac{r_2 r_1}{\Delta r} - h \right)} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

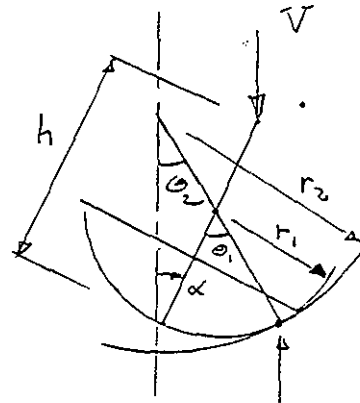
$$K_{IT} = \begin{bmatrix} K_{EE} & -K_{EE} \\ -K_{EE} & K_{EE} \end{bmatrix}$$

h : (in)

$$2'' : 7.02 - 3.84 = 3.18$$

$$3'' : 10.43 - 5.97 = 4.46$$

$$4'' : 11.73 - 6.89 = 4.84$$



$$d_E = \begin{bmatrix} u \\ v \\ w \\ \alpha \\ \beta \\ \alpha \end{bmatrix}$$

matrix 27:

$$C_{34} = C = -C_{40} = C_{73}$$

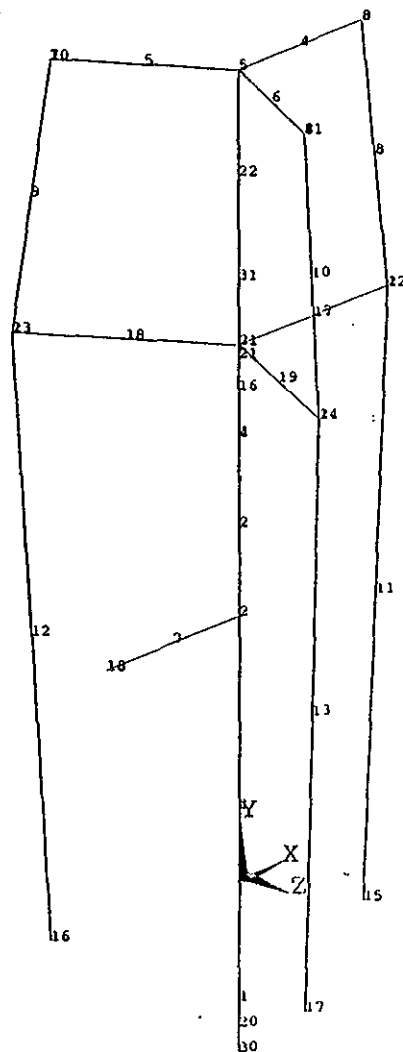
$$C_{51} = C = -C_{52} = C_{78}$$

$$C = V \left(\frac{r_2 r_1}{\Delta r} - h \right)$$

7.2 PLOTS

Grid plots for the 2" system are provided.

1

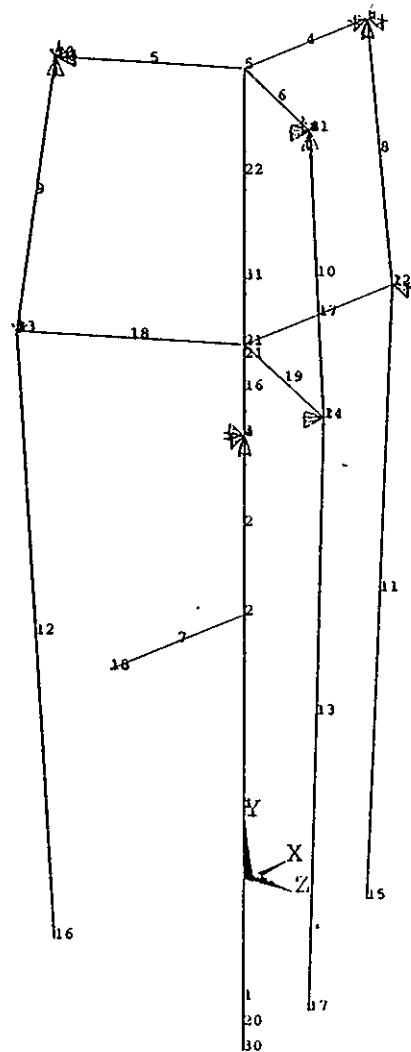


ANSYS 5.0 A
 DEC 1 1994
 13:10:58
 PLOT NO. 1
 ELEMENTS
 ELEM NUM

XV = -0.72
 YV = 0.342
 ZV = 0.604
 DIST = 5.311
 XF = 0.095
 YF = 2.76
 CENTROID HIDDEN

WMC-SD-W236A-DA-002
 REVISION 0

1

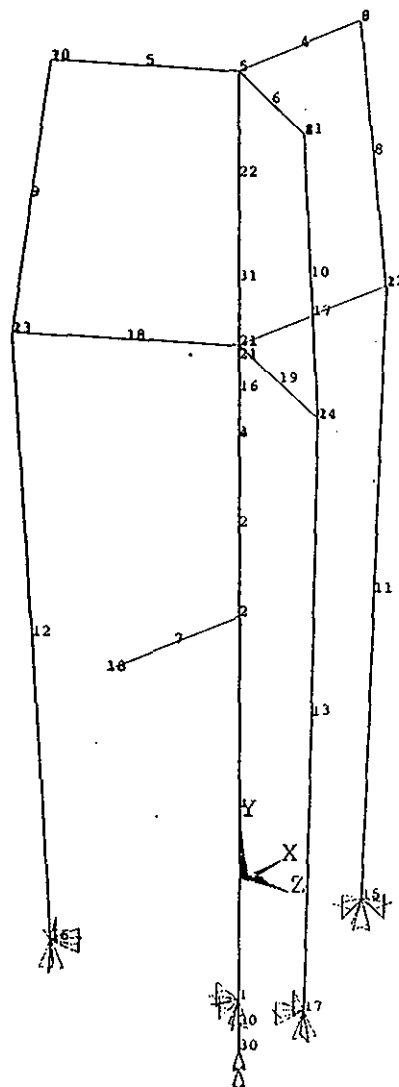


ANSYS 5.0 A
 DEC 1 1994
 13:11:48
 PLOT NO. 1
 ELEMENTS
 ELEM NUM
 CP

XV = -0.72
 YV = 0.342
 ZV = 0.604
 DIST = 5.311
 XF = 0.095
 YF = 2.76
 CENTROID HIDDEN

WHC-SD-M236A-DA-002
 REVISION 0

1

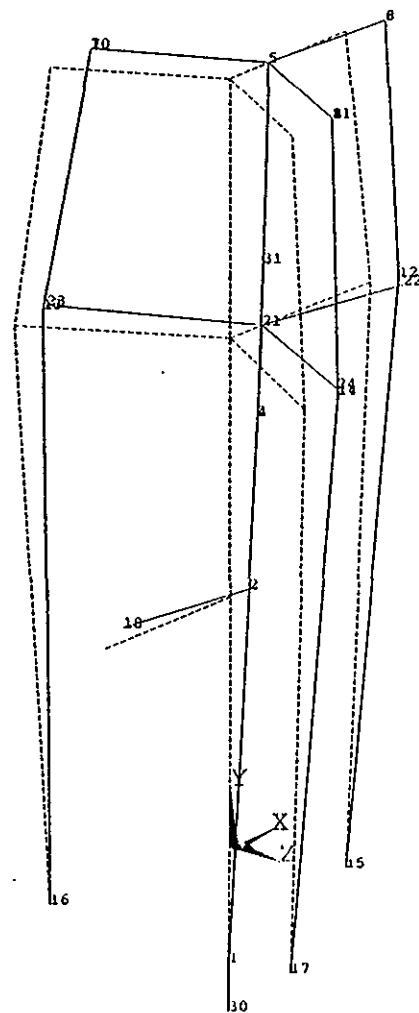


ANSYS 5.0 A
 DEC 1 1994
 13:13:09
 PLOT NO. 1
 ELEMENTS
 ELEM NUM
 U
 ROT

XV = -0.72
 YV = 0.342
 ZV = 0.604
 DIST = 5.311
 XF = 0.095
 YF = 2.76
 CENTROID HIDDEN

jumper clamp system model - guide

1



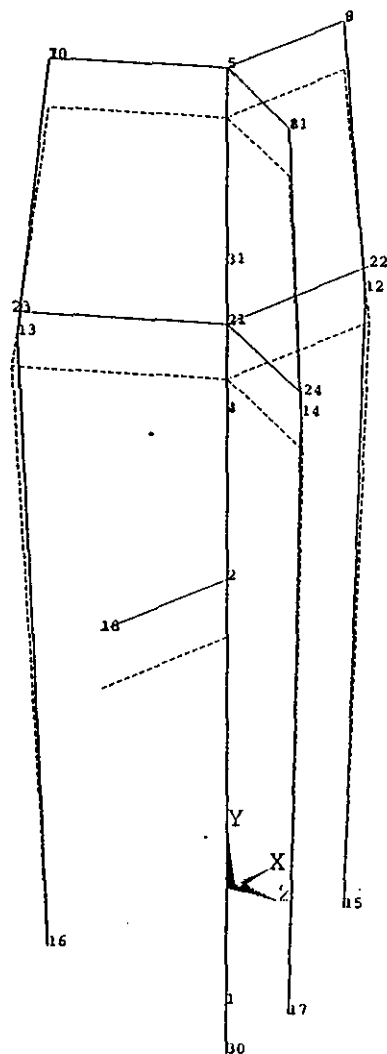
ANSYS 5.0 A
DEC 1 1994
13:22:12
PLOT NO. 1
DISPLACEMENT
STEP=1
SUB =1
TIME=1
RSYS=0
DMX =0.020352

DSCA=26.098
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.58
XF =0.436273
YF =2.99
ZF =0.049637
CENTROID HIDDEN

C1 (+400 lbf in the X direction) **

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1



ANSYS 5.0 A
DEC 1 1994
13:22:46
PLOT NO: 1
DISPLACEMENT
STEP=2
SUB =1
TIME=2
RSYS=0
DMX =0.310E-03

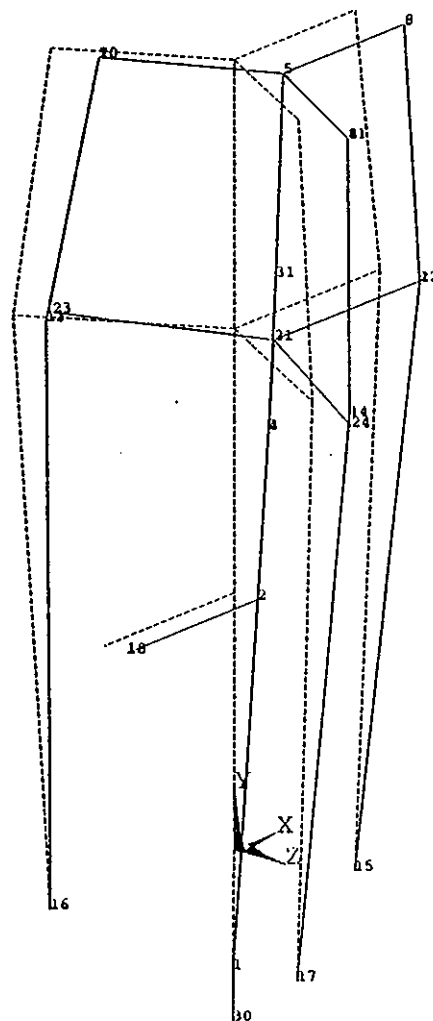
DSCA=1711
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.574
XF =0.094986
YF =2.987
ZF =0.391466
CENTROID HIDDEN

LC2 (+2300 lbf in the Y direction) **

WMC-SD-W236A-DA-002
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1



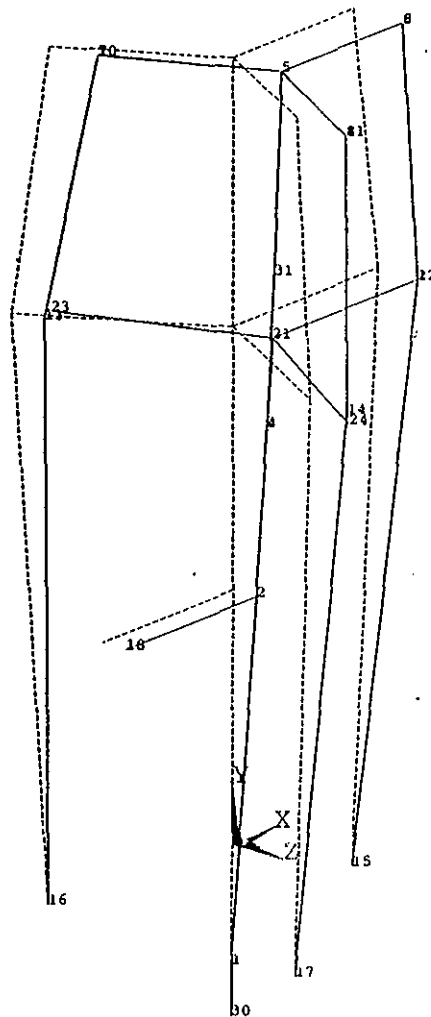
ANSYS 5.0 A
DEC 1 1994
14:18:57
PLOT NO. 1
DISPLACEMENT
STEP=3
SUB =1
TIME=3
RSYS=0
DMX =0.050875

DSCA=10.44
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.437
XF =0.095
YF =2.893
CENTROID HIDDEN

LC3 (+1000 lbf in the Z direction) **

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REVISION 0

1



ANSYS 5.0 A
DEC 1 1994
13:26:00
PLOT NO. 1
DISPLACEMENT
STEP=4
SUB =1
TIME=4
RSYS=0
DMX =0.366405

DSCA=1.45
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.437
XF =0.095
YF =2.893
CENTROID HIDDEN

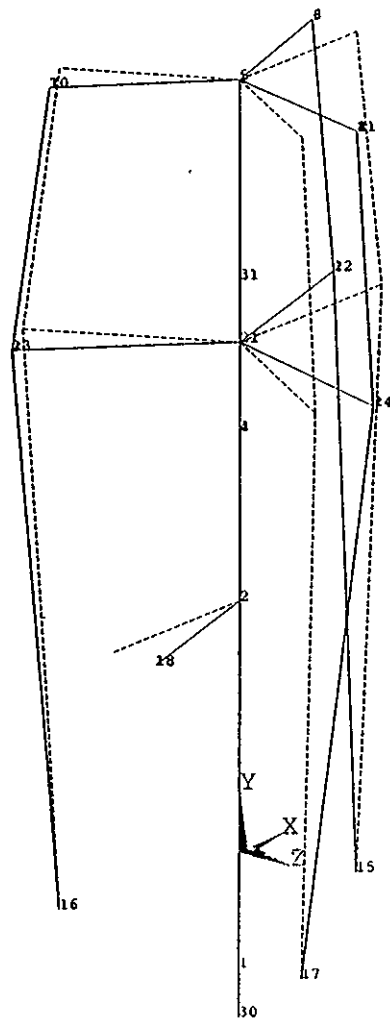
LC4 (+2000 ft-lbf about X-axis) **

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1



ANSYS 5.0 A
DEC 1 1994
13:26:22
PLOT NO. 1
DISPLACEMENT
STEP=5
SUB =1
TIME=5
RSYS=0
DMX =0.486988

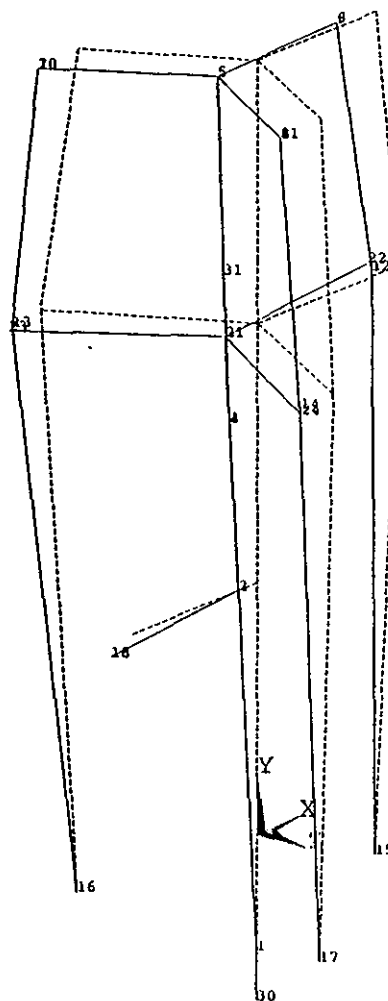
DSCA=1.091
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.569
XF =0.095
YF =3.009
CENTROID HIDDEN

LC5 (+1600 ft-lbf about Y-axis) **

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REVISION 0

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1



ANSYS 5.0 A
DEC 1 1994
13:26:47
PLOT NO. 1
DISPLACEMENT
STEP=6
SUB =1
TIME=6
RSYS=0
DMX =0.29316

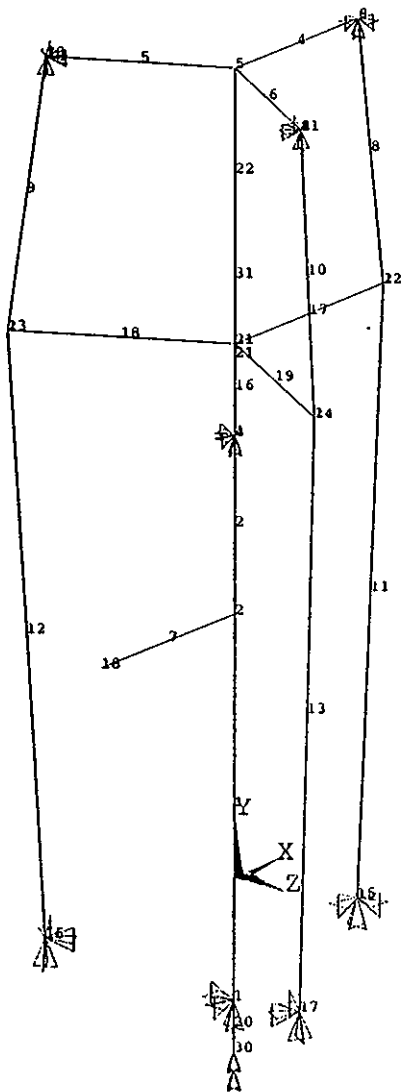
DSCA=1.812
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.545
XF =-0.191003
YF =2.99
ZF =-0.049647
CENTROID HIDDEN

LC6 (+1600 ft-lbf about Z-axis) **

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1



```

ANSYS 5.0 A
DEC 1 1994
14:12:37
PLOT NO.      1
ELEMENTS
ELEM NUM
U
ROT
CP

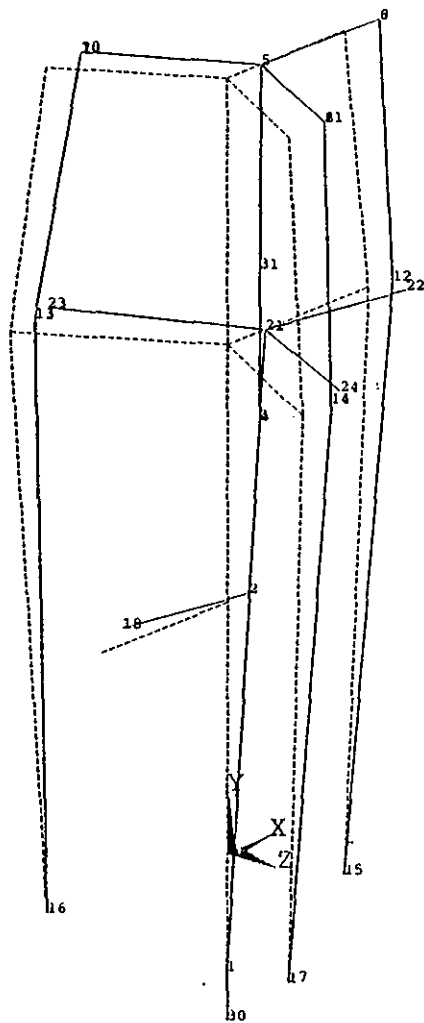
```

```
XV' =-0.72
YV  =0.342
ZV  =0.604
DIST=5.311
XF   =0.095
YF   =2.76
CENTROID HIDDEN
```

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REVISION 0

jumper clamp system model - no guide.

1



ANSYS 5.0 A
 DEC 1 1994
 14:15:27
 PLOT NO. 1
 DISPLACEMENT
 STEP=1
 SUB =1
 TIME=1
 RSYS=0
 DMX =0.038007

DSCA=13.975
 XV =-0.72
 YV =0.342
 ZV =0.604
 DIST=5.556
 XF =0.49481
 YF =2.96
 ZF =0.050939
 CENTROID HIDDEN

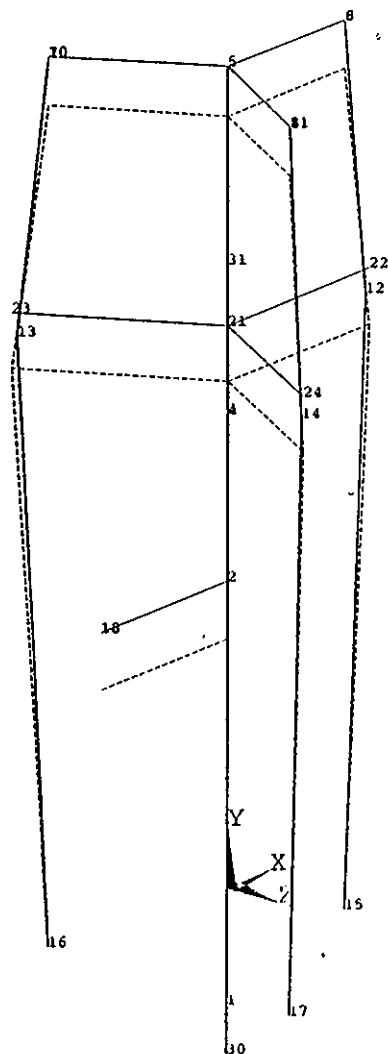
LC1 (+400 lbf in the X direction) **

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1



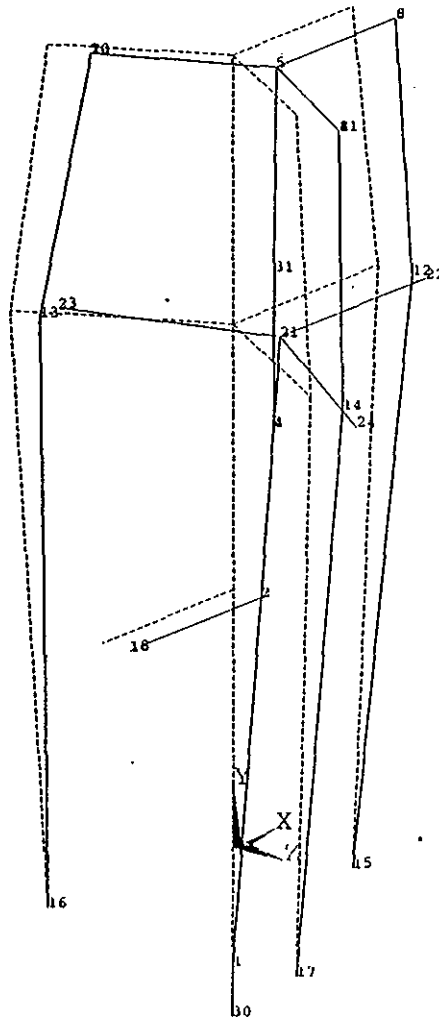
ANSYS 5.0 A
DEC 1 1994
13:34:40
PLOT NO. 1
DISPLACEMENT
STEP=2
SUB =1
TIME=2
RSYS=0
DMX =0.310E-03

DSCA=1711
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.574
XF =0.094987
YF =2.987
ZF =0.391466
CENTROID HIDDEN

LC2 (+2300 lbf in the Y direction) **

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REVISION 0

1



ANSYS 5.0 A
 DEC 1 1994
 13:35:10
 PLOT NO. 1
 DISPLACEMENT
 STEP=3
 SUB =1
 TIME=3
 RSYS=0
 DMX =0.093841

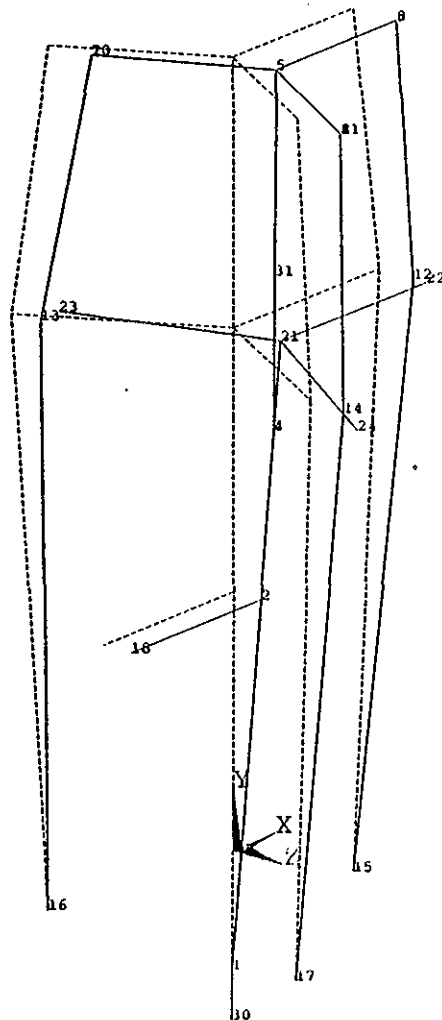
DSCA=5.66
 XV =-0.72
 YV =0.342
 ZV =0.604
 DIST=5.424
 XF =0.095
 YF =2.877
 CENTROID HIDDEN

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LC3 (+1000 lbf in the Z direction) **

WMC-SD-W236A-DA-002
 REVISION 0

1



ANSYS 5.0 A
DEC 1 1994
13:35:42
PLOT NO. 1
DISPLACEMENT
STEP=4
SUB =1
TIME=4
RSYS=0
DMX =0.675903

DSCA=0.785837
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.424
XF =0.095
YF =2.877
CENTROID HIDDEN

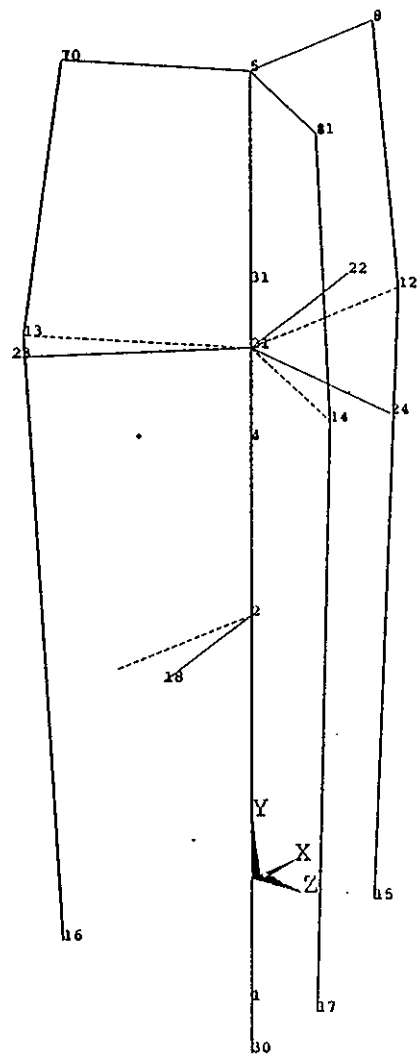
G-94

LC4 (+2000 ft-lbf about X-axis) **

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1



ANSYS 5.0 A
DEC 1 1994
13:36:34
PLOT NO, 1
DISPLACEMENT
STEP=5
SUB =1
TIME=5
RSYS=0
DMX =55.532

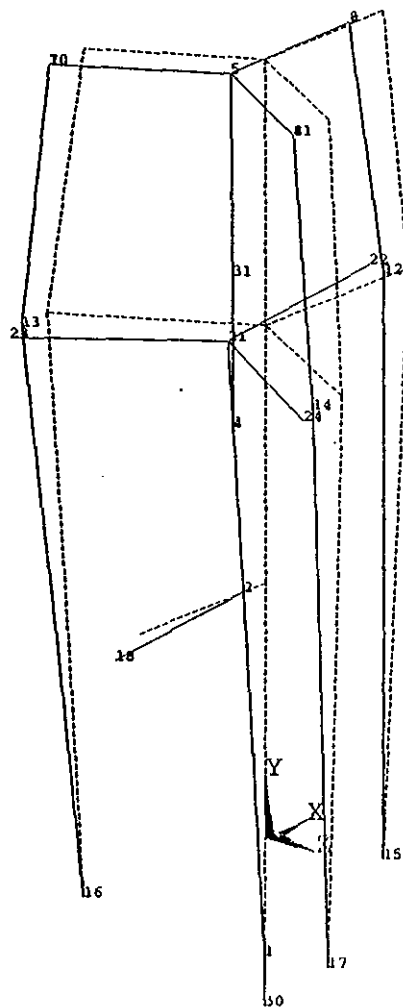
DSCA=0.009565
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.311
XF =0.095
YF =2.76
CENTROID HIDDEN

LC5 (+1600 ft-lbf about Y-axis) **

WHC-SD-W236A-DA-002
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1



ANSYS 5.0 A
DEC 1 1994
13:37:04
PLOT NO. 1
DISPLACEMENT
STEP=6
SUB =1
TIME=6
RSYS=0
DMX =0.547498

DSCA=0.970139
XV =-0.72
YV =0.342
ZV =0.604
DIST=5.522
XF =-0.212616
YF =2.96
ZF =-0.050943
CENTROID HIDDEN

C6 (+1600 ft-lbf about Z-axis) **

-MHC-SD-W236A-DA-002
REVISION 0

8.0 REFERENCES

ANSYS, 1992, *ANSYS User's Manual, Rev 5.0a*, Swanson Analysis Systems, Inc.,
Houston PA.

APPENDIX H

TWO-INCH HOOK FINITE-ELEMENT MODEL USED TO DETERMINE STIFFNESS

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed APPENDIX "H" OF ISB JUMPER DOC.

Author John L. Julyk

Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number 95-002

E.O. Werner
Reviewer

1/25/95
Date

1.0 Description of Hook Finite-Element analysis model

The Finite-Element Analysis (FEA) code used in the 2-in. Hook model is ANSYS (1992) version 5.0a. The 2-in. hook model uses eight node Structural Solid (PLANE82) elements. The material properties used for the 2-in. hook model is cast steel. Reading in the AUTOCAD 2-D Igs file the geometry was created for the finite-element model. General dimensions of the hook are shown in Figure H1 and found in drawing H-2-90174, Rev. 7 (WHC 1993).

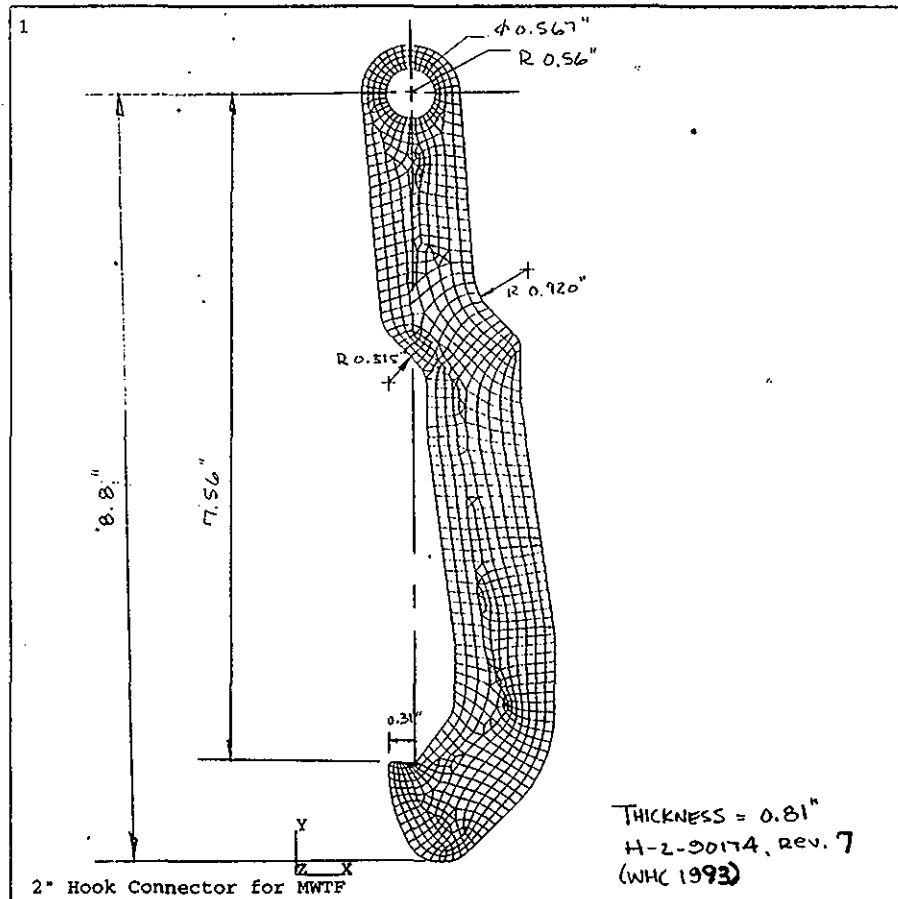
2.0 Calculation of Hook Stiffness

To determine the stiffness of the hooks under axial loading a 17,000 lbf load was applied over the contact length of the hook and the nozzle flange (Figure H2). The hook was restrained conservatively by fixing a circular line of nodes at the pin-hole. This would allow for the maximum hook elastic deflect to occur at the hook/nozzle interface, where the load was applied (Figure H3).

The elastic deflection at node 79 was determined to be the center of the hook loading. The deflection at node 79 is 0.0401919 in. (See Figure H4 for deflected shape). This deflection was then used along with the applied loading of 17,000 lbf to calculate a hook stiffness of 4.2297×10^5 lbf/in. The finite-element stiffness was checked against the calculated hook stiffness, based on curved beam theory, with a 10% difference (appendix B). A ratio of the 2-in. finite-element stiffness to the calculated stiffness was used for the 3-in. and 4-in. hook stiffness calculated in appendix B.

The hook stiffness is used with other components stiffness to determine the total axial stiffness of the jumper assembly under thermal expansion, internal pressure, torque pre-loading, and axial external loading of the jumper connector.

Figure H1. Hook Geometry for 2-in. Jumper Connector



ANSYS 5.0 A
OCT 20 1994
13:26:54
PLOT NO. 1
ELEMENTS
TYPE NUM
ZV =1
DIST=5.148
XF =1.864
YF =4.841
PRECISE HIDDEN

Figure H2. Hook Boundary Conditions for 2-in. Jumper Connector

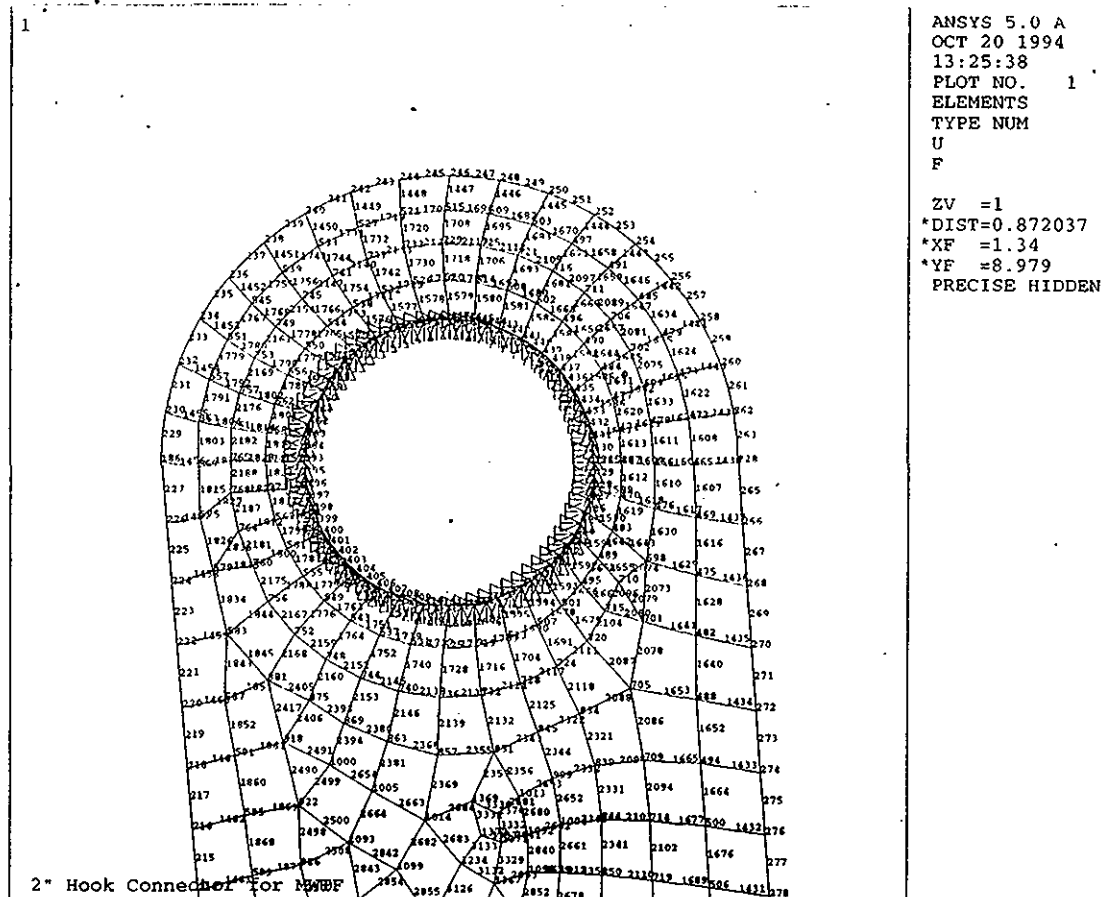


Figure H3. Applied Axial Load to determine 2-in. Hook Stiffness

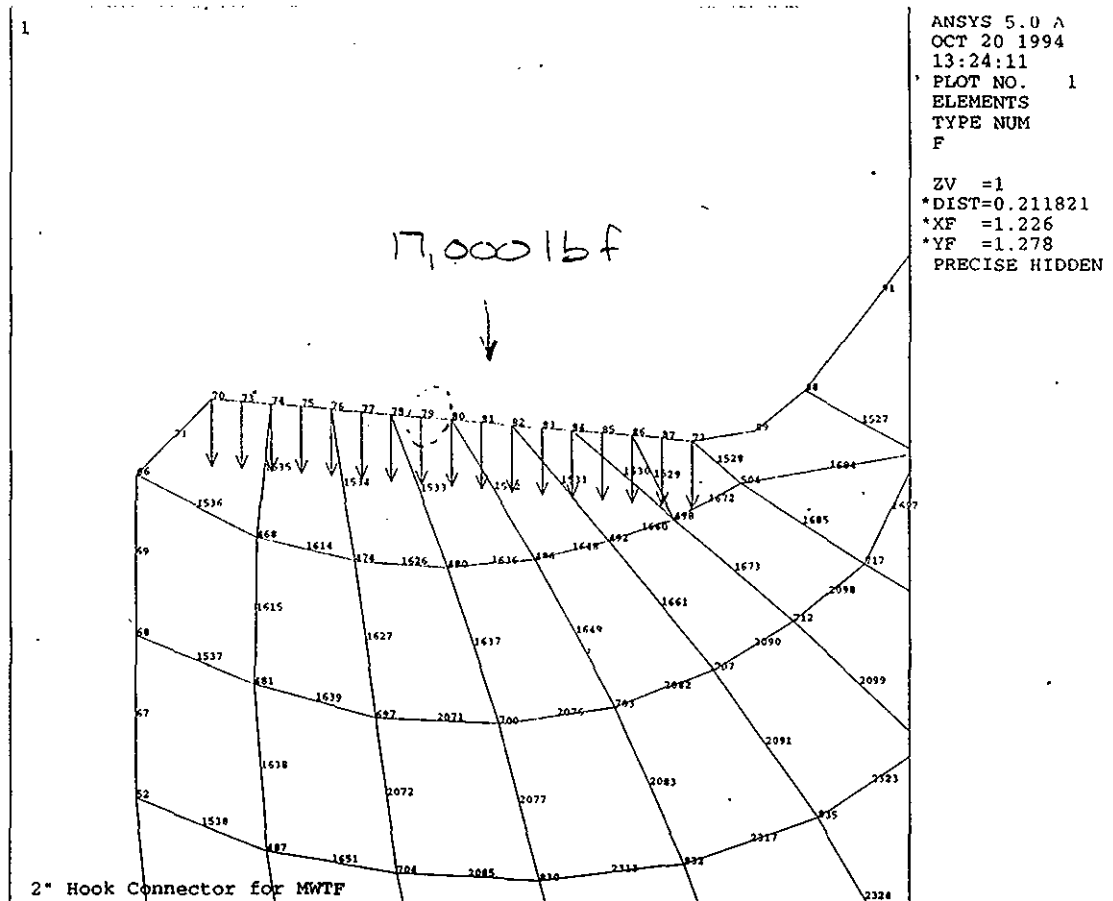
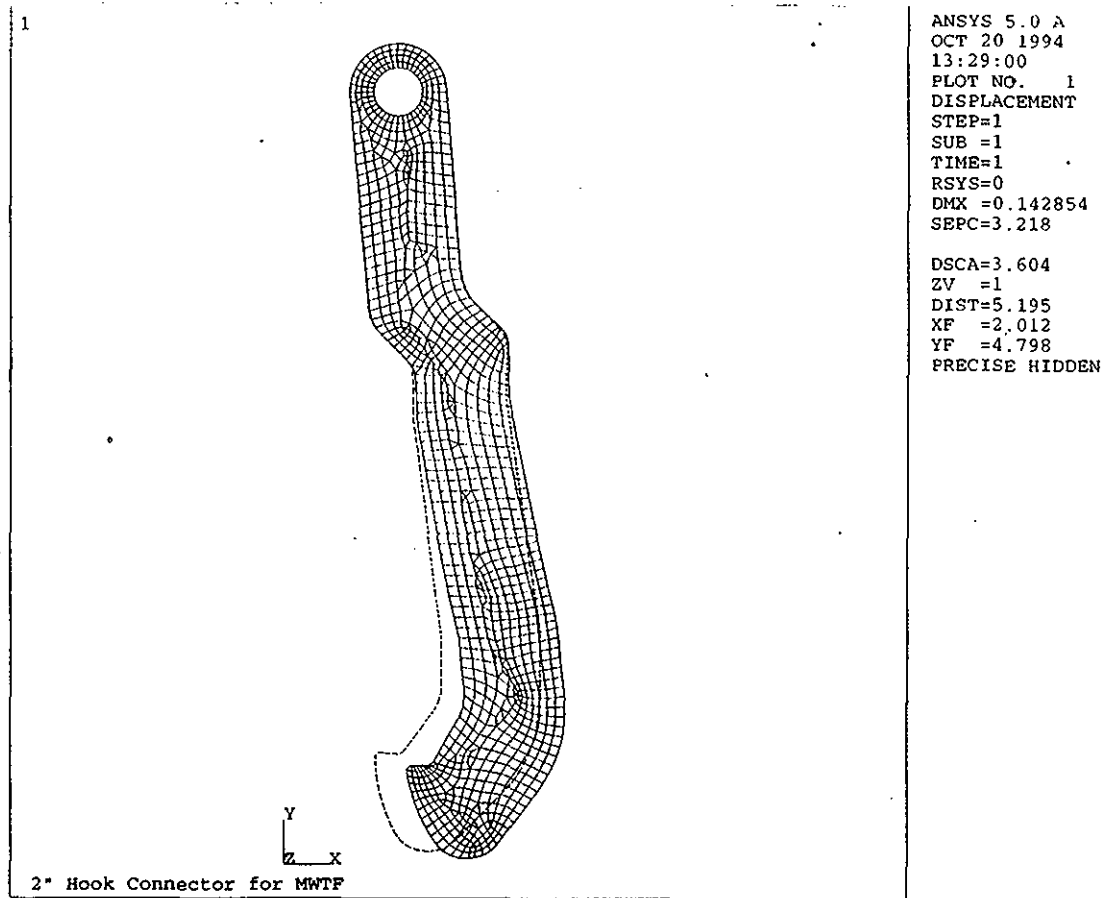


Figure H4. Displacement Plot of 2-in. Hook



2-IN. HOOK MODEL (Input File: hook2.inp)

```

/aux15
C*** Import of AUTOCAD 2-D Hook drawing *
IGES.hook2.igs
FINISH
/FACE,NORMAL
/OUTPUT,hook2.out
/TITLE, 2" Hook Connector for MWTF
/PREP7
C*** HOOK **
ET,1,PLANE82
TYPE,1
REAL,1
KEYO, 1, 3, 3
KEYO, 1, 5, 2
KEYO, 1, 6, 0
R, 1
RMOD, 1, 1, 0.81
MP,EX,1,29e6
MP,DENS,1,0.000734
MP,NUXY,1,0.3
C*** Model Refinement **
LSEL,ALL
LSEL,U,LINE,,1,2,1
AL,ALL
LSEL,S,LINE,,1,2,1
AL,ALL
ASBA,1,2
LSEL,ALL
ASEL,ALL
LESIZE,1,,10
LESIZE,12,4
LESIZE,2,,10
LESIZE,24,,10
LESIZE,40,,10
LESIZE,11,,,8
ESHAPE,3
ESIZE,0.125
AATT,1,1,1
AMESH,3,3,1
C*** Boundary Conditions **
LSEL,ALL
NSEL,ALL
ESEL,ALL
LSEL,S,LINE,,1,2,1,1
D,ALL,ALL
NSEL,ALL
ESEL,ALL
C*** Apply Loads **
HLOAD=-17000/17
LSEL,S,LINE,,11,11,1,1
F,ALL,FY,HLOAD
NSEL,ALL
ESEL,ALL
SAVE
FINISH
/SOLU
ANTYPE,STAT
OUTRES,ALL,ALL
OUTPR,BASIC,ALL
SOLVE
SAVE
FINISH
/EXIT

```

2-IN. HOOK MODEL OUTPUT (file: hook2.out)

```

TTITLE=
2" Hook Connector for MWTF

```

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

```

ENTER /SHOW,DEVICE-NAME TO ENABLE GRAPHIC DISPLAY
ENTER FINISH TO LEAVE PREP7
PRINTOUT KEY SET TO /GOPR (USE /NOPR TO SUPPRESS)

```

C*** HOOK **

Element Type Table 1 - 20

Ref. No.	Element Name	Ref. No.	Element Name
1	-	11	-
2	-	12	-
3	-	13	-
4	-	14	-
5	-	15	-
6	-	16	-
7	-	17	-
8	-	18	-
9	-	19	-
10	-	20	-

Element Type Reference Number (TYPE pointer) 1
Real Constant Reference Number (REAL pointer) 1

Details / Options for Element Type: UNDEFINED

NOT AVAILABLE
CHANGE TYPE POINTER AND TRY AGAIN

Elem Type Ref Number (TYPE pointer) 1
Real Const Ref Number (REAL pointer) 1

ELEMENT TYPE 1 IS PLANE82 2-D 8-NODE STRUCTURAL SOLID
KEYOPT(1-12)= 0 0 0 0 0 0 0 0 0 0 0 0

CURRENT NODAL DOF SET IS UX UY
TWO-DIMENSIONAL MODEL

ELEMENT TYPE SET TO 1

REAL CONSTANT NUMBER= 1

ELEMENT TYPE 1 IS PLANE82 2-D 8-NODE STRUCTURAL SOLID
KEYOPT(1-12)= 0 0 3 0 0 0 0 0 0 0 0 0

CURRENT NODAL DOF SET IS UX UY
TWO-DIMENSIONAL MODEL

ELEMENT TYPE 1 IS PLANE82 2-D 8-NODE STRUCTURAL SOLID
KEYOPT(1-12)= 0 0 3 0 2 0 0 0 0 0 0 0

CURRENT NODAL DOF SET IS UX UY
TWO-DIMENSIONAL MODEL

ELEMENT TYPE 1 IS PLANE82 2-D 8-NODE STRUCTURAL SOLID
KEYOPT(1-12)= 0 0 3 0 2 0 0 0 0 0 0 0

CURRENT NODAL DOF SET IS UX UY
TWO-DIMENSIONAL MODEL

REAL CONSTANT SET 1 ITEMS 1 TO 6
0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
0.00000E+00

MODIFY REAL CONSTANTS FOR SET 1 STARTING WITH 1 NEW
VALUES ARE
0.81000 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
0.00000E+00

MATERIAL 1 EX = 0.2900000E+08

MATERIAL 1 DENS = 0.7340000E-03

MATERIAL 1 NUXY = 0.3000000

C*** Model Refinement **

ALL SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 1 TO 38 STEP 1

38 LINES (OF 38 DEFINED) SELECTED BY LSEL COMMAND.

UNSELECT FOR ITEM=LINE COMPONENT=
IN RANGE 1 TO 2 STEP 1

36 LINES (OF 38 DEFINED) SELECTED BY LSEL COMMAND.

DEFINE AREA BY LIST OF LINES
LINE LIST = ALL SELECTED LINES
(TRAVERSED IN SAME DIRECTION AS LINE 3)

AREA NUMBER = 1

SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 1 TO 2 STEP 1

2 LINES (OF 38 DEFINED) SELECTED BY LSEL COMMAND.

DEFINE AREA BY LIST OF LINES
LINE LIST = ALL SELECTED LINES
(TRAVERSED IN SAME DIRECTION AS LINE 1)

AREA NUMBER = 2

SUBTRACT AREAS
INPUT AREAS = 1 2
INPUT AREAS WILL BE DELETED
OUTPUT AREAS = 3

ALL SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 1 TO 38 STEP 1

38 LINES (OF 38 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT FOR ITEM=AREA COMPONENT=
IN RANGE 1 TO 3 STEP 1

1 AREAS (OF 1 DEFINED) SELECTED BY ASEL COMMAND.

SET DIVISIONS ON LINE 1 (IF SELECTED AND UNMESHED)
FOR ANGLE PER ELEMENT = 10.000 SPACING RATIO = 1.0000

SET DIVISIONS ON LINE 12 (IF SELECTED AND UNMESHED)
FOR ELEMENT SIZE = 4.0000 SPACING RATIO = 1.0000

SET DIVISIONS ON LINE 2 (IF SELECTED AND UNMESHED)
FOR ANGLE PER ELEMENT = 10.000 SPACING RATIO = 1.0000

SET DIVISIONS ON LINE 24 (IF SELECTED AND UNMESHED)
FOR ANGLE PER ELEMENT = 10.000 SPACING RATIO = 1.0000

SET DIVISIONS ON LINE 40 (IF SELECTED AND UNMESHED)
FOR ANGLE PER ELEMENT = 10.000 SPACING RATIO = 1.0000

*** WARNING *** CP= 3.690 TIME= 13:13:45
Undefined line 40.

SET DIVISIONS ON LINE 11 (IF SELECTED AND UNMESHED)
TO NDIV = 8, SPACING RATIO = 1.000

FOR ELEMENT TYPE(S) ALLOWING MULTIPLE SHAPES:
PRODUCE ALL QUADRILATERAL OR BRICK ELEMENTS IF
POSSIBLE.
OTHERWISE PRODUCE MIXED ELEMENT SHAPES.

DEFAULT ELEMENT DIVISIONS PER LINE BASED ON ELEMENT SIZE =
0.125

SET ATTRIBUTES FOR ALL SELECTED AREAS
MAT = 1 REAL = 1 TYPE = 1 ESYS = 0
ATTRIBUTES SET FOR 1 AREAS (OUT OF 1 SELECTED)

GENERATE NODES AND ELEMENTS
IN AREAS 3 TO 3 IN STEPS OF 1

** Meshing of area 3 in progress **
** Meshing of area 3 still in progress ** 666 elements.
** Meshing of area 3 still in progress ** 966 elements.
** AREA 3 MESHED WITH 995 QUADRILATERALS, 58
TRIANGLES **

*** WARNING *** CP= 74.590 TIME= 13:14:56
Element 47 midside node 89 may be improperly located.
(May be ok if singularity is desired.) Ratio= 0.129308792.

*** WARNING *** CP= 76.250 TIME= 13:14:57
Meshing of area 3 produced 1 excessively curved elements. More element
divisions on this area may help.

*** LIST OF ELEMENTS WITH EXCESSIVE CURVATURE ***
47

** Meshing of area 3 completed ** 1053 elements.

NUMBER OF AREAS MESHED = 1
MAXIMUM NODE NUMBER = 3333
MAXIMUM ELEMENT NUMBER = 1053

C*** Boundary Conditions **

ALL SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 1 TO 38 STEP 1

38 LINES (OF 38 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 3333 STEP 1

3333 NODES (OF 3333 DEFINED) SELECTED BY NSEL COMMAND.

ALL SELECT FOR ITEM=ELEM COMPONENT=
IN RANGE 1 TO 1053 STEP 1

1053 ELEMENTS (OF 1053 DEFINED) SELECTED BY ESEL
COMMAND.

SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 1 TO 2 STEP 1

2 LINES (OF 38 DEFINED) SELECTED BY LSEL COMMAND.
SWEEP ALSO SELECTED 2 KEYPOINTS, 72 NODES, 0
ELEMENTS

SPECIFIED CONSTRAINT UX FOR SELECTED NODES 1 TO 3333
BY 1
REAL= 0.000000000E+00 IMAG= 0.000000000E+00
ADDITIONAL DOFS= UY

ALL SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 3333 STEP 1

3333 NODES (OF 3333 DEFINED) SELECTED BY NSEL COMMAND.

ALL SELECT FOR ITEM=ELEM COMPONENT=
IN RANGE 1 TO 1053 STEP 1

1053 ELEMENTS (OF 1053 DEFINED) SELECTED BY ESEL
COMMAND.

C*** Apply Loads **

PARAMETER HLOAD = -1000.000

SELECT FOR ITEM=LINE COMPONENT=
IN RANGE 11 TO 11 STEP 1

1 LINES (OF 38 DEFINED) SELECTED BY LSEL COMMAND.
SWEEP ALSO SELECTED 2 KEYPOINTS, 17 NODES, 0
ELEMENTS

SPECIFIED NODAL LOAD FY FOR SELECTED NODES 1 TO 3333
BY 1
REAL= -1000.00000 IMAG= 0.000000000E+00

ALL SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 3333 STEP 1

3333 NODES (OF 3333 DEFINED) SELECTED BY NSEL COMMAND.

ALL SELECT FOR ITEM=ELEM COMPONENT=
IN RANGE 1 TO 1053 STEP 1

1053 ELEMENTS (OF 1053 DEFINED) SELECTED BY ESEL
COMMAND.

ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= file.db
FOR POSSIBLE RESUME FROM THIS POINT

***** ROUTINE COMPLETED ***** CP= 77.220

*** NOTE *** CP= 77.220 TIME= 13:14:58
A total of 4 warnings and errors written to file.err.

***** ANSYS SOLUTION ROUTINE *****

PERFORM A STATIC ANALYSIS
THIS WILL BE A NEW ANALYSIS

WRITE ALL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES

PRINT BASI ITEMS WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES

***** ANSYS SOLVE COMMAND *****

*** NOTE *** CP= 77.480 TIME= 13:14:59
All shape tests were bypassed for elements associated with the solid
model, because most of them were already done at AMESH or VMESH. Use
CHECK if desired to perform all of the element tests.

SOLUTION OPTIONS

PROBLEM DIMENSIONALITY.....2-D
DEGREES OF FREEDOM.....UX UY
ANALYSIS TYPE.....STATIC (STEADY-STATE)

*** NOTE *** CP= 77.670 TIME= 13:14:59
Present time 0 is less than or equal to the previous time.
Time will default to 1.
** Reordering still in progress **
** Reordering still in progress **

LOAD STEP OPTIONS

LOAD STEP NUMBER.....1
TIME AT END OF THE LOAD STEP.....1.0000
NUMBER OF SUBSTEPS.....1
STEP CHANGE BOUNDARY CONDITIONS.....NO
PRINT OUTPUT CONTROLS
ITEM FREQUENCY COMPONENT
BASI ALL
DATABASE OUTPUT CONTROLS
ITEM FREQUENCY COMPONENT
ALL ALL

***** CENTROID, MASS, AND MASS MOMENTS OF INERTIA

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS = 0.62321E-02

MOM. OF INERTIA MOM. OF INERTIA
CENTROID ABOUT ORIGIN ABOUT CENTROID

XC = 1.9127 IXX = 0.1755 IXX = 0.4238E-01
YC = 4.6212 IYY = 0.2439E-01 IYY = 0.1587E-02
ZC = 0.0000E+00 IZZ = 0.1999 IZZ = 0.4397E-01
IXY = -0.5080E-01 IXY = 0.4285E-02
IYZ = 0.0000E+00 IYZ = 0.0000E+00
IZX = 0.0000E+00 IZX = 0.0000E+00

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE MASS
1 0.623214E-02

Range of element maximum matrix coefficients in global coordinates
Maximum= 155040334 at element 47.
Minimum= 40570255.8 at element 896.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE NUMBER ENAME TOTAL CP AVE CP

1 1053 PLANE82 2.810 0.003

Time at end of element matrix formulation CP= 81.5699997.

Estimated number of active DOF= 6522.
Maximum wavefront= 116.

Time at end of matrix triangularization CP= 86.3300018.

Equation solver maximum pivot= 137953645 at node 3003 UX.

Equation solver minimum pivot= 12315.8652 at node 1759 UX.

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP= 86.710

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1	0.793273E-01	0.220466E-01
2	0.115705	0.904634E-02
3	0.812056E-01	0.221550E-01
4	0.830974E-01	0.221804E-01
5	0.850002E-01	0.221248E-01
6	0.869102E-01	0.219886E-01
7	0.888243E-01	0.217717E-01
8	0.907390E-01	0.214743E-01
9	0.926510E-01	0.210963E-01
10	0.945567E-01	0.206378E-01
11	0.964529E-01	0.200989E-01
12	0.983359E-01	0.194800E-01
13	0.100203	0.187813E-01
14	0.102049	0.180036E-01
15	0.103872	0.171473E-01
16	0.105669	0.162135E-01

17	0.107435	0.152028E-01
18	0.109168	0.141167E-01
19	0.110865	0.129562E-01
20	0.112521	0.117231E-01
21	0.114136	0.104188E-01
22	0.136356	-0.103559E-01
23	0.117153	0.773241E-02
24	0.118612	0.640772E-02
25	0.120079	0.507115E-02
26	0.121552	0.372226E-02
27	0.123030	0.236078E-02
28	0.124512	0.987203E-03
29	0.125997	-0.398270E-03
30	0.127482	-0.179480E-02
31	0.128967	-0.320179E-02
32	0.130451	-0.461812E-02
33	0.131933	-0.604286E-02
34	0.133411	-0.747482E-02
35	0.134886	-0.891291E-02
36	0.140781	-0.208957E-01
37	0.137657	-0.118219E-01
38	0.138753	-0.134441E-01
39	0.139624	-0.151935E-01
40	0.140259	-0.170398E-01

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP= 86.730

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
41	0.140646	-0.189515E-01
42	0.140789	-0.229339E-01
43	0.140785	-0.219147E-01
44	0.132968	-0.360765E-01
45	0.140660	-0.249425E-01
46	0.140261	-0.269137E-01
47	0.139600	-0.288114E-01
48	0.138690	-0.306011E-01
49	0.137548	-0.322505E-01
50	0.136196	-0.337297E-01
51	0.134660	-0.350125E-01
52	0.105314	-0.450250E-01
53	0.131147	-0.370281E-01
54	0.129302	-0.379304E-01
55	0.127433	-0.387837E-01
56	0.125542	-0.395880E-01
57	0.123628	-0.403443E-01
58	0.121692	-0.410524E-01
59	0.119734	-0.417138E-01
60	0.117754	-0.423284E-01
61	0.115751	-0.428976E-01
62	0.113723	-0.434207E-01
63	0.111667	-0.438996E-01
64	0.109582	-0.443310E-01

65 0.107463 -0.447092E-01
 66 0.993996E-01 -0.452465E-01
 67 0.103831 -0.451045E-01
 68 0.102338 -0.451810E-01
 69 0.100849 -0.452276E-01
 70 0.980830E-01 -0.440205E-01
 71 0.987268E-01 -0.446027E-01
 72 0.988507E-01 -0.347400E-01
 73 0.981264E-01 -0.435030E-01
 74 0.981614E-01 -0.429773E-01
 75 0.982008E-01 -0.424261E-01
 76 0.982423E-01 -0.418889E-01
 77 0.982839E-01 -0.413215E-01
 78 0.983288E-01 -0.407683E-01
 79 0.983722E-01 -0.401919E-01
 80 0.984202E-01 -0.396267E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
 86.740

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
81	0.984646E-01	-0.390405E-01
82	0.985147E-01	-0.384621E-01
83	0.985636E-01	-0.378620E-01
84	0.986194E-01	-0.372691E-01
85	0.986683E-01	-0.366577E-01
86	0.987277E-01	-0.360464E-01
87	0.987753E-01	-0.354087E-01
88	0.982309E-01	-0.321976E-01
89	0.987973E-01	-0.332634E-01
90	0.821056E-01	-0.172915E-01
91	0.966034E-01	-0.306338E-01
92	0.949626E-01	-0.291238E-01
93	0.933219E-01	-0.276393E-01
94	0.916859E-01	-0.261648E-01
95	0.900599E-01	-0.246950E-01
96	0.884445E-01	-0.232284E-01
97	0.868390E-01	-0.217625E-01
98	0.852445E-01	-0.202891E-01
99	0.836661E-01	-0.188070E-01
100	0.750828E-01	-0.131447E-01
101	0.804569E-01	-0.158098E-01
102	0.787111E-01	-0.146071E-01
103	0.768979E-01	-0.137085E-01
104	0.568870E-01	-0.999627E-02
105	0.734994E-01	-0.128463E-01
106	0.719153E-01	-0.125780E-01
107	0.703451E-01	-0.123159E-01
108	0.687872E-01	-0.120631E-01
109	0.672432E-01	-0.118118E-01
110	0.657142E-01	-0.115631E-01
111	0.642009E-01	-0.113137E-01
112	0.627044E-01	-0.110633E-01

113 0.612245E-01 -0.108133E-01
 114 0.597576E-01 -0.105586E-01
 115 0.583099E-01 -0.102854E-01
 116 0.187059E-01 -0.649597E-02
 117 0.553203E-01 -0.987111E-02
 118 0.537856E-01 -0.976135E-02
 119 0.522776E-01 -0.966689E-02
 120 0.507899E-01 -0.957729E-02

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
 86.750

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
121	0.493253E-01	-0.948602E-02
122	0.478851E-01	-0.939506E-02
123	0.464684E-01	-0.930388E-02
124	0.450753E-01	-0.921186E-02
125	0.437061E-01	-0.911832E-02
126	0.423606E-01	-0.902331E-02
127	0.410391E-01	-0.892663E-02
128	0.397414E-01	-0.882824E-02
129	0.384675E-01	-0.872803E-02
130	0.372175E-01	-0.862600E-02
131	0.359912E-01	-0.852213E-02
132	0.347887E-01	-0.841644E-02
133	0.336098E-01	-0.830892E-02
134	0.324546E-01	-0.819961E-02
135	0.313228E-01	-0.808852E-02
136	0.302145E-01	-0.797567E-02
137	0.291295E-01	-0.786109E-02
138	0.280678E-01	-0.774481E-02
139	0.270291E-01	-0.762685E-02
140	0.260135E-01	-0.750725E-02
141	0.250209E-01	-0.738603E-02
142	0.240510E-01	-0.726322E-02
143	0.231039E-01	-0.713887E-02
144	0.221794E-01	-0.701303E-02
145	0.212774E-01	-0.688573E-02
146	0.203979E-01	-0.675707E-02
147	0.195408E-01	-0.662709E-02
148	0.172076E-01	-0.624878E-02
149	0.179471E-01	-0.637272E-02
150	0.121954E-01	-0.534702E-02
151	0.165216E-01	-0.613024E-02
152	0.158531E-01	-0.601156E-02
153	0.152018E-01	-0.589329E-02
154	0.145673E-01	-0.577588E-02
155	0.139495E-01	-0.565815E-02
156	0.133508E-01	-0.554315E-02
157	0.127678E-01	-0.543968E-02
158	0.778945E-02	-0.366122E-02
159	0.115977E-01	-0.517402E-02
160	0.110101E-01	-0.498782E-02

2" Hook Connector for MWTF

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.760

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
161	0.104367E-01	-0.478760E-02
162	0.988117E-02	-0.457993E-02
163	0.934041E-02	-0.436816E-02
164	0.881203E-02	-0.414768E-02
165	0.829841E-02	-0.391684E-02
166	0.576473E-02	-0.268207E-02
167	0.735511E-02	-0.340929E-02
168	0.695752E-02	-0.318993E-02
169	0.659695E-02	-0.300635E-02
170	0.627315E-02	-0.285924E-02
171	0.599612E-02	-0.275347E-02
172	0.451423E-02	-0.276937E-02
173	0.557431E-02	-0.265336E-02
174	0.539570E-02	-0.264872E-02
175	0.522567E-02	-0.265097E-02
176	0.506603E-02	-0.266133E-02
177	0.491564E-02	-0.267888E-02
178	0.477392E-02	-0.270311E-02
179	0.463972E-02	-0.273301E-02
180	0.364128E-02	-0.292297E-02
181	0.439839E-02	-0.282254E-02
182	0.427222E-02	-0.287387E-02
183	0.413299E-02	-0.291599E-02
184	0.398014E-02	-0.294223E-02
185	0.381578E-02	-0.294698E-02
186	0.291735E-04	-0.200090E-03
187	0.343857E-02	-0.287678E-02
188	0.324027E-02	-0.282025E-02
189	0.304733E-02	-0.275645E-02
190	0.286118E-02	-0.268661E-02
191	0.268244E-02	-0.261243E-02
192	0.251148E-02	-0.253483E-02
193	0.234840E-02	-0.245502E-02
194	0.219320E-02	-0.237354E-02
195	0.204573E-02	-0.229115E-02
196	0.190581E-02	-0.220818E-02
197	0.177320E-02	-0.212513E-02
198	0.164762E-02	-0.204217E-02
199	0.152883E-02	-0.195959E-02
200	0.141656E-02	-0.187749E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.770

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
201	0.131055E-02	-0.179602E-02
202	0.121058E-02	-0.171522E-02
203	0.111644E-02	-0.163518E-02
204	0.102792E-02	-0.155592E-02
205	0.944855E-03	-0.147749E-02
206	0.867072E-03	-0.139992E-02
207	0.794428E-03	-0.132324E-02
208	0.726782E-03	-0.124752E-02
209	0.664000E-03	-0.117281E-02
210	0.605952E-03	-0.109924E-02
211	0.552496E-03	-0.102687E-02
212	0.503472E-03	-0.955924E-03
213	0.458701E-03	-0.886539E-03
214	0.417965E-03	-0.819015E-03
215	0.380938E-03	-0.753620E-03
216	0.347282E-03	-0.690676E-03
217	0.316494E-03	-0.630611E-03
218	0.287978E-03	-0.573716E-03
219	0.261030E-03	-0.520497E-03
220	0.234785E-03	-0.470995E-03
221	0.208516E-03	-0.425436E-03
222	0.181553E-03	-0.383611E-03
223	0.153734E-03	-0.345095E-03
224	0.125407E-03	-0.309637E-03
225	0.975851E-04	-0.276702E-03
226	0.716740E-04	-0.246773E-03
227	0.488849E-04	-0.220801E-03
228	-0.102701E-04	-0.495193E-04
229	0.143399E-04	-0.185255E-03
230	0.369227E-06	-0.170341E-03
231	-0.118596E-04	-0.155053E-03
232	-0.221666E-04	-0.139761E-03
233	-0.305422E-04	-0.124950E-03
234	-0.371080E-04	-0.110490E-03
235	-0.418794E-04	-0.967620E-04
236	-0.450473E-04	-0.837363E-04
237	-0.467833E-04	-0.717217E-04
238	-0.472719E-04	-0.606088E-04
239	-0.467133E-04	-0.506034E-04
240	-0.452605E-04	-0.415786E-04

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.780

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
241	-0.431150E-04	-0.336590E-04
242	-0.403864E-04	-0.267091E-04
243	-0.372538E-04	-0.207966E-04
244	-0.337903E-04	-0.157950E-04
245	-0.301477E-04	-0.117359E-04
246	-0.263726E-04	-0.850841E-05
247	-0.225910E-04	-0.612340E-05
248	-0.188337E-04	-0.448709E-05
249	-0.152060E-04	-0.360006E-05
250	-0.117317E-04	-0.338299E-05
251	-0.850138E-05	-0.383245E-05
252	-0.553863E-05	-0.487862E-05
253	-0.292567E-05	-0.651653E-05
254	-0.689751E-06	-0.867879E-05
255	0.109062E-05	-0.113587E-04
256	0.238334E-05	-0.144835E-04
257	0.311085E-05	-0.180370E-04
258	0.324555E-05	-0.219319E-04
259	0.271800E-05	-0.261515E-04
260	0.150320E-05	-0.305880E-04
261	-0.441284E-06	-0.351624E-04
262	-0.303010E-05	-0.397860E-04
263	-0.632959E-05	-0.445980E-04
264	0.165216E-02	0.181741E-03
265	-0.162878E-04	-0.563318E-04
266	-0.230989E-04	-0.624690E-04
267	-0.294106E-04	-0.668248E-04
268	-0.336975E-04	-0.694876E-04
269	-0.346377E-04	-0.702161E-04
270	-0.311239E-04	-0.695715E-04
271	-0.225891E-04	-0.679815E-04
272	-0.881982E-05	-0.658310E-04
273	0.101111E-04	-0.635858E-04
274	0.339728E-04	-0.612050E-04
275	0.625378E-04	-0.588857E-04
276	0.955173E-04	-0.564382E-04
277	0.132760E-03	-0.537932E-04
278	0.174121E-03	-0.507720E-04
279	0.219546E-03	-0.472047E-04
280	0.269022E-03	-0.429647E-04

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.790

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
281	0.322578E-03	-0.378889E-04
282	0.380274E-03	-0.318985E-04
283	0.442183E-03	-0.248724E-04
284	0.508395E-03	-0.167675E-04
285	0.578993E-03	-0.751027E-05
286	0.654064E-03	0.292368E-05
287	0.733676E-03	0.145666E-04

288	0.817884E-03	0.274466E-04
289	0.906718E-03	0.415752E-04
290	0.100019E-02	0.570076E-04
291	0.109825E-02	0.737174E-04
292	0.120081E-02	0.918782E-04
293	0.130774E-02	0.111586E-03
294	0.141897E-02	0.133123E-03
295	0.153407E-02	0.156096E-03
296	0.258770E-02	0.903181E-03
297	0.176799E-02	0.205273E-03
298	0.188544E-02	0.242684E-03
299	0.200428E-02	0.295932E-03
300	0.212356E-02	0.367177E-03
301	0.224385E-02	0.457308E-03
302	0.236063E-02	0.570489E-03
303	0.247439E-02	0.718602E-03
304	0.327460E-02	0.231018E-02
305	0.266742E-02	0.112266E-02
306	0.276414E-02	0.135028E-02
307	0.287687E-02	0.158055E-02
308	0.299917E-02	0.181545E-02
309	0.313099E-02	0.205956E-02
310	0.389511E-02	0.324663E-02
311	0.341452E-02	0.254165E-02
312	0.356458E-02	0.277624E-02
313	0.372492E-02	0.301178E-02
314	0.399162E-02	0.337512E-02
315	0.394279E-02	0.331103E-02
316	0.508139E-02	0.400857E-02
317	0.421838E-02	0.362900E-02
318	0.448689E-02	0.381904E-02
319	0.478031E-02	0.394387E-02
320	0.930221E-02	0.517980E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.800

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
321	0.543242E-02	0.406862E-02
322	0.579216E-02	0.414635E-02
323	0.616549E-02	0.423940E-02
324	0.655458E-02	0.434405E-02
325	0.696168E-02	0.445959E-02
326	0.738833E-02	0.458424E-02
327	0.783535E-02	0.471539E-02
328	0.830066E-02	0.485501E-02
329	0.878893E-02	0.500976E-02
330	0.204370E-01	0.932058E-02
331	0.983710E-02	0.543044E-02
332	0.103996E-01	0.567675E-02
333	0.109849E-01	0.591734E-02
334	0.115893E-01	0.615801E-02
335	0.122141E-01	0.640258E-02

336 0.128597E-01 0.664973E-02
337 0.135256E-01 0.689969E-02
338 0.142117E-01 0.715288E-02
339 0.149181E-01 0.740975E-02
340 0.156448E-01 0.767035E-02
341 0.163918E-01 0.793490E-02
342 0.171594E-01 0.820348E-02
343 0.179476E-01 0.847627E-02
344 0.187564E-01 0.875332E-02
345 0.195862E-01 0.903475E-02
346 0.240141E-01 0.104964E-01
347 0.212998E-01 0.960787E-02
348 0.221835E-01 0.989958E-02
349 0.230882E-01 0.101957E-01
350 0.300954E-01 0.124189E-01
351 0.249723E-01 0.108051E-01
352 0.259525E-01 0.111185E-01
353 0.269548E-01 0.114365E-01
354 0.279793E-01 0.117593E-01
355 0.290261E-01 0.120867E-01
356 0.328338E-01 0.132597E-01
357 0.307670E-01 0.126264E-01
358 0.314471E-01 0.128357E-01
359 0.321361E-01 0.130468E-01
360 0.518109E-01 0.187232E-01

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
36.810
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
361	0.338715E-01	0.135749E-01
362	0.349282E-01	0.138940E-01
363	0.360040E-01	0.142171E-01
364	0.370991E-01	0.145441E-01
365	0.382137E-01	0.148750E-01
366	0.393479E-01	0.152098E-01
367	0.405019E-01	0.155484E-01
368	0.416759E-01	0.158907E-01
369	0.428700E-01	0.162366E-01
370	0.440846E-01	0.165860E-01
371	0.453198E-01	0.169385E-01
372	0.465757E-01	0.172936E-01
373	0.478525E-01	0.176518E-01
374	0.491513E-01	0.180115E-01
375	0.504713E-01	0.183689E-01
376	0.560380E-01	0.195608E-01
377	0.528513E-01	0.189317E-01
378	0.539028E-01	0.191427E-01
379	0.549654E-01	0.193527E-01
380	0.575415E-01	0.197240E-01
381	0.590659E-01	0.198965E-01
382	0.606137E-01	0.200777E-01
383	0.621879E-01	0.202623E-01

384	0.637873E-01	0.204478E-01
385	0.654120E-01	0.206343E-01
386	0.670624E-01	0.208211E-01
387	0.687387E-01	0.210071E-01
388	0.704406E-01	0.211913E-01
389	0.721681E-01	0.213728E-01
390	0.739210E-01	0.215508E-01
391	0.756991E-01	0.217236E-01
392	0.775013E-01	0.218898E-01
393	0.000000E+00	0.000000E+00
394	0.000000E+00	0.000000E+00
395	0.000000E+00	0.000000E+00
396	0.000000E+00	0.000000E+00
397	0.000000E+00	0.000000E+00
398	0.000000E+00	0.000000E+00
399	0.000000E+00	0.000000E+00
400	0.000000E+00	0.000000E+00

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
86.830
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
401	0.000000E+00	0.000000E+00
402	0.000000E+00	0.000000E+00
403	0.000000E+00	0.000000E+00
404	0.000000E+00	0.000000E+00
405	0.000000E+00	0.000000E+00
406	0.000000E+00	0.000000E+00
407	0.000000E+00	0.000000E+00
408	0.000000E+00	0.000000E+00
409	0.000000E+00	0.000000E+00
410	0.000000E+00	0.000000E+00
411	0.000000E+00	0.000000E+00
412	0.000000E+00	0.000000E+00
413	0.000000E+00	0.000000E+00
414	0.000000E+00	0.000000E+00
415	0.000000E+00	0.000000E+00
416	0.000000E+00	0.000000E+00
417	0.000000E+00	0.000000E+00
418	0.000000E+00	0.000000E+00
419	0.000000E+00	0.000000E+00
420	0.000000E+00	0.000000E+00
421	0.000000E+00	0.000000E+00
422	0.000000E+00	0.000000E+00
423	0.000000E+00	0.000000E+00
424	0.000000E+00	0.000000E+00
425	0.000000E+00	0.000000E+00
426	0.000000E+00	0.000000E+00
427	0.000000E+00	0.000000E+00
428	0.000000E+00	0.000000E+00
429	0.000000E+00	0.000000E+00
430	0.000000E+00	0.000000E+00
431	0.000000E+00	0.000000E+00

432 0.000000E+00 0.000000E+00
433 0.000000E+00 0.000000E+00
434 0.000000E+00 0.000000E+00
435 0.000000E+00 0.000000E+00
436 0.000000E+00 0.000000E+00
437 0.000000E+00 0.000000E+00
438 0.000000E+00 0.000000E+00
439 0.000000E+00 0.000000E+00
440 0.000000E+00 0.000000E+00

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
86.840
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
441	0.000000E+00	0.000000E+00
442	0.000000E+00	0.000000E+00
443	0.000000E+00	0.000000E+00
444	0.000000E+00	0.000000E+00
445	0.000000E+00	0.000000E+00
446	0.000000E+00	0.000000E+00
447	0.000000E+00	0.000000E+00
448	0.000000E+00	0.000000E+00
449	0.000000E+00	0.000000E+00
450	0.000000E+00	0.000000E+00
451	0.000000E+00	0.000000E+00
452	0.000000E+00	0.000000E+00
453	0.000000E+00	0.000000E+00
454	0.000000E+00	0.000000E+00
455	0.000000E+00	0.000000E+00
456	0.000000E+00	0.000000E+00
457	0.000000E+00	0.000000E+00
458	0.000000E+00	0.000000E+00
459	0.000000E+00	0.000000E+00
460	0.000000E+00	0.000000E+00
461	0.000000E+00	0.000000E+00
462	0.000000E+00	0.000000E+00
463	0.000000E+00	0.000000E+00
464	0.000000E+00	0.000000E+00
465	-0.789662E-05	-0.401586E-04
466	-0.447998E-05	-0.286689E-04
467	-0.134885E-05	-0.150867E-04
468	0.100568	-0.430560E-01
469	-0.187789E-04	-0.515447E-04
470	-0.520854E-05	-0.212237E-04
471	0.728217E-06	-0.115473E-04
472	-0.143049E-05	-0.311009E-04
473	0.196446E-05	-0.234294E-04
474	0.101056	-0.412394E-01
475	-0.302538E-04	-0.642960E-04
476	-0.123269E-04	-0.387459E-04
477	0.178684E-05	-0.865475E-05
478	0.763992E-07	-0.215139E-04
479	0.300104E-05	-0.167185E-04

480 0.101227 -0.394835E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
86.850
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
481	0.103278	-0.429412E-01
482	-0.314529E-04	-0.778653E-04
483	-0.101930E-04	-0.279891E-04
484	0.202174E-05	-0.623853E-05
485	0.199377E-05	-0.109541E-04
486	0.101118	-0.378189E-01
487	0.106331	-0.425509E-01
488	-0.123293E-04	-0.929214E-04
489	-0.143178E-04	-0.335784E-04
490	0.143604E-05	-0.394460E-05
491	-0.786530E-06	-0.642669E-05
492	0.100818	-0.363623E-01
493	0.109640	-0.418947E-01
494	0.288954E-04	-0.107300E-03
495	-0.173704E-04	-0.398397E-04
496	0.868838E-07	-0.203427E-05
497	-0.501411E-05	-0.349618E-05
498	0.100450	-0.350189E-01
499	0.113146	-0.408465E-01
500	0.886339E-04	-0.120265E-03
501	-0.178990E-04	-0.476427E-04
502	-0.189777E-05	-0.751418E-06
503	-0.103368E-04	-0.247044E-05
504	0.998010E-01	-0.336031E-01
505	0.116725	-0.395039E-01
506	0.164882E-03	-0.133001E-03
507	-0.133800E-04	-0.552351E-04
508	-0.436475E-05	-0.274357E-06
509	-0.163898E-04	-0.362610E-05
510	0.993917E-01	-0.300534E-01
511	0.120334	-0.379580E-01
512	0.257490E-03	-0.143730E-03
513	-0.321411E-05	-0.629555E-04
514	-0.716010E-05	-0.738962E-06
515	-0.227720E-04	-0.724430E-05
516	0.970238E-01	-0.270746E-01
517	0.123940	-0.363231E-01
518	0.366310E-03	-0.151307E-03
519	0.117838E-04	-0.722477E-04
520	-0.101188E-04	-0.227544E-05

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
86.860
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
521	-0.290064E-04	-0.136245E-04
522	0.943308E-01	-0.239952E-01
523	0.127485	-0.346125E-01
524	0.491851E-03	-0.155083E-03
525	0.296241E-04	-0.839599E-04
526	-0.130464E-04	-0.502375E-05
527	-0.344938E-04	-0.230743E-04
528	0.913458E-01	-0.208395E-01
529	0.130848	-0.327503E-01
530	0.634831E-03	-0.154689E-03
531	0.472853E-04	-0.977265E-04
532	-0.157025E-04	-0.913661E-05
533	-0.384697E-04	-0.358744E-04
534	0.882211E-01	-0.177628E-01
535	0.133811	-0.306105E-01
536	0.795907E-03	-0.149872E-03
537	0.613716E-04	-0.112060E-03
538	-0.177855E-04	-0.147766E-04
539	-0.399766E-04	-0.522132E-04
540	0.849170E-01	-0.148216E-01
541	0.136137	-0.281050E-01
542	0.975459E-03	-0.140379E-03
543	0.688944E-04	-0.124260E-03
544	-0.189199E-04	-0.221071E-04
545	-0.378807E-04	-0.720867E-04
546	0.813160E-01	-0.122826E-01
547	0.137662	-0.253432E-01
548	0.117437E-02	-0.127838E-03
549	0.679328E-04	-0.130713E-03
550	-0.186510E-04	-0.312715E-04
551	-0.309861E-04	-0.952075E-04
552	0.775358E-01	-0.104317E-01
553	0.138382	-0.225730E-01
554	0.139383E-02	-0.111194E-03
555	0.587135E-04	-0.128938E-03
556	-0.164644E-04	-0.423442E-04
557	-0.182987E-04	-0.120911E-03
558	0.737960E-01	-0.922490E-02
559	0.138342	-0.198983E-01
560	0.163093E-02	-0.833108E-04

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.890
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
561	0.445079E-04	-0.120675E-03
562	-0.118536E-04	-0.552524E-04
563	0.219171E-06	-0.147996E-03
564	0.701450E-01	-0.843989E-02
565	0.137655	-0.170471E-01
566	0.187786E-02	-0.373606E-04
567	0.297978E-04	-0.110461E-03
568	-0.487506E-05	-0.693563E-04
569	0.245549E-04	-0.176581E-03
570	0.666252E-01	-0.792710E-02
571	0.136270	-0.141662E-01
572	0.213511E-02	0.416326E-04
573	0.158703E-04	-0.976034E-04
574	0.442806E-05	-0.836116E-04
575	0.585310E-04	-0.216956E-03
576	0.632803E-01	-0.756317E-02
577	0.134237	-0.115194E-01
578	0.240537E-02	0.177015E-03
579	0.995943E-04	-0.260473E-03
580	0.600851E-01	-0.727120E-02
581	0.131623	-0.908853E-02
582	0.268603E-02	0.398032E-03
583	0.151108E-03	-0.327616E-03
584	0.569807E-01	-0.703632E-02
585	0.128646	-0.672552E-02
586	0.298789E-02	0.733319E-03
587	0.208724E-03	-0.430309E-03
588	0.539160E-01	-0.688150E-02
589	0.125516	-0.432049E-02
590	0.330584E-02	0.117197E-02
591	0.250405E-03	-0.516339E-03
592	0.509125E-01	-0.677122E-02
593	0.122369	-0.182310E-02
594	0.363439E-02	0.167515E-02
595	0.300865E-03	-0.619985E-03
596	0.479860E-01	-0.667380E-02
597	0.119273	0.761890E-03
598	0.396162E-02	0.218864E-02
599	0.362892E-03	-0.732819E-03
600	0.451575E-01	-0.658226E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.900
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
601	0.116239	0.339329E-02
602	0.426738E-02	0.266409E-02
603	0.438757E-03	-0.850582E-03
604	0.424278E-01	-0.648960E-02
605	0.113223	0.601691E-02

606 0.455512E-02 0.306243E-02
607 0.532426E-03 -0.974266E-03
608 0.397965E-01 -0.639172E-02
609 0.110153 0.856067E-02
610 0.489817E-02 0.341701E-02
611 0.646232E-03 -0.110398E-02
612 0.372624E-01 -0.628622E-02
613 0.106996 0.109095E-01
614 0.528133E-02 0.367502E-02
615 0.779883E-03 -0.123717E-02
616 0.348246E-01 -0.617223E-02
617 0.103747 0.129869E-01
618 0.577534E-02 0.379175E-02
619 0.934099E-03 -0.137301E-02
620 0.324823E-01 -0.604962E-02
621 0.100405 0.147577E-01
622 0.635890E-02 0.379304E-02
623 0.110993E-02 -0.151096E-02
624 0.302344E-01 -0.591859E-02
625 0.969763E-01 0.162127E-01
626 0.710471E-02 0.382203E-02
627 0.130876E-02 -0.165057E-02
628 0.280802E-01 -0.577941E-02
629 0.934780E-01 0.173507E-01
630 0.798515E-02 0.391090E-02
631 0.153237E-02 -0.179125E-02
632 0.260187E-01 -0.563235E-02
633 0.899338E-01 0.181746E-01
634 0.898244E-02 0.408896E-02
635 0.178288E-02 -0.193212E-02
636 0.240489E-01 -0.547765E-02
637 0.863701E-01 0.186886E-01
638 0.101078E-01 0.436134E-02
639 0.206267E-02 -0.207179E-02
640 0.221701E-01 -0.531544E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.910

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
641	0.828121E-01	0.189037E-01
642	0.113378E-01	0.470976E-02
643	0.237400E-02	-0.220813E-02
644	0.203859E-01	-0.514660E-02
645	0.792802E-01	0.188528E-01
646	0.126525E-01	0.510898E-02
647	0.271837E-02	-0.233815E-02
648	0.187112E-01	-0.497523E-02
649	0.757881E-01	0.186059E-01
650	0.140394E-01	0.554180E-02
651	0.309208E-02	-0.245614E-02
652	0.171656E-01	-0.480758E-02
653	0.723424E-01	0.182633E-01

654	0.154964E-01	0.599712E-02
655	0.347741E-02	-0.255219E-02
656	0.157432E-01	-0.464793E-02
657	0.689592E-01	0.179072E-01
658	0.170260E-01	0.646748E-02
659	0.383769E-02	-0.260950E-02
660	0.144224E-01	-0.449464E-02
661	0.656575E-01	0.175736E-01
662	0.186311E-01	0.694964E-02
663	0.414705E-02	-0.262345E-02
664	0.131894E-01	-0.433605E-02
665	0.624493E-01	0.172633E-01
666	0.203130E-01	0.744285E-02
667	0.440957E-02	-0.260423E-02
668	0.120215E-01	-0.414720E-02
669	0.593819E-01	0.169669E-01
670	0.220721E-01	0.794839E-02
671	0.465594E-02	-0.257093E-02
672	0.108921E-01	-0.390032E-02
673	0.565492E-01	0.166768E-01
674	0.239130E-01	0.846979E-02
675	0.491143E-02	-0.253585E-02
676	0.980627E-02	-0.359687E-02
677	0.540273E-01	0.163683E-01
678	0.258414E-01	0.900962E-02
679	0.519499E-02	-0.251184E-02
680	0.877078E-02	-0.325766E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.920

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
681	0.516467E-01	0.160077E-01
682	0.278257E-01	0.955940E-02
683	0.549372E-02	-0.250304E-02
684	0.781838E-02	-0.291457E-02
685	0.492388E-01	0.155424E-01
686	0.297664E-01	0.101036E-01
687	0.577382E-02	-0.246211E-02
688	0.702176E-02	-0.258071E-02
689	0.468101E-01	0.149709E-01
690	0.315592E-01	0.106280E-01
691	0.444060E-01	0.143393E-01
692	0.333338E-01	0.111816E-01
693	0.420137E-01	0.136916E-01
694	0.352914E-01	0.117898E-01
695	0.396774E-01	0.130542E-01
696	0.374164E-01	0.124225E-01
697	0.103944	-0.406546E-01
698	-0.229808E-04	-0.530169E-04
699	0.221108E-05	-0.161806E-04
700	0.104128	-0.383284E-01
701	-0.290366E-04	-0.764884E-04

702 0.271918E-05 -0.116133E-04
703 0.103887 -0.360837E-01
704 0.106790 -0.401071E-01
705 -0.113941E-04 -0.110415E-03
706 0.176156E-05 -0.752623E-05
707 0.103255 -0.341493E-01
708 0.109720 -0.394046E-01
709 0.328615E-04 -0.145123E-03
710 -0.236379E-04 -0.548945E-04
711 -0.516957E-06 -0.423974E-05
712 0.102394 -0.325645E-01
713 0.112722 -0.383633E-01
714 0.898338E-04 -0.173916E-03
715 -0.250065E-04 -0.665446E-04
716 -0.388811E-05 -0.210725E-05
717 0.101360 -0.311289E-01
718 0.115825 -0.369075E-01
719 0.162400E-03 -0.204806E-03
720 -0.205739E-04 -0.835149E-04

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.930

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
721	-0.808620E-05	-0.141156E-05
722	0.119047	-0.351799E-01
723	0.251932E-03	-0.235882E-03
724	-0.703089E-05	-0.102812E-03
725	-0.128336E-04	-0.238481E-05
726	0.122385	-0.333505E-01
727	0.357924E-03	-0.264517E-03
728	0.132704E-04	-0.124760E-03
729	-0.178253E-04	-0.525281E-05
730	0.125752	-0.315487E-01
731	0.480727E-03	-0.289250E-03
732	0.393623E-04	-0.151613E-03
733	-0.226975E-04	-0.102532E-04
734	0.128963	-0.297562E-01
735	0.621041E-03	-0.309649E-03
736	0.673583E-04	-0.179523E-03
737	-0.269952E-04	-0.176334E-04
738	0.131777	-0.278665E-01
739	0.779567E-03	-0.325708E-03
740	0.922574E-04	-0.204454E-03
741	-0.301425E-04	-0.276309E-04
742	0.133993	-0.258019E-01
743	0.956798E-03	-0.337536E-03
744	0.110272E-03	-0.224177E-03
745	-0.314236E-04	-0.404370E-04
746	0.135538	-0.236537E-01
747	0.115291E-02	-0.350810E-03
748	0.119193E-03	-0.236744E-03
749	-0.299930E-04	-0.561364E-04

750 0.136463 -0.216826E-01
751 0.138532E-02 -0.380788E-03
752 0.117858E-03 -0.240653E-03
753 -0.249574E-04 -0.746356E-04
754 0.136426 -0.195383E-01
755 0.166155E-02 -0.378301E-03
756 0.103124E-03 -0.229672E-03
757 -0.155705E-04 -0.956045E-04
758 0.135488 -0.172554E-01
759 0.194269E-02 -0.361416E-03
760 0.784704E-04 -0.204133E-03

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.940

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
761	-0.234302E-05	-0.117425E-03
762	0.134074	-0.148230E-01
763	0.223804E-02	-0.322375E-03
764	0.552004E-04	-0.185163E-03
765	0.120069E-04	-0.134934E-03
766	0.132235	-0.125375E-01
767	0.255756E-02	-0.236100E-03
768	0.306608E-04	-0.159699E-03
769	0.129925	-0.105442E-01
770	0.289998E-02	-0.661317E-04
771	0.127091	-0.872228E-02
772	0.326005E-02	0.222321E-03
773	0.123876	-0.685420E-02
774	0.362674E-02	0.638894E-03
775	0.120519	-0.474077E-02
776	0.398813E-02	0.114849E-02
777	0.117209	-0.235148E-02
778	0.433446E-02	0.168676E-02
779	0.114016	0.214290E-03
780	0.466157E-02	0.220495E-02
781	0.110920	0.283509E-02
782	0.497477E-02	0.266685E-02
783	0.107879	0.539421E-02
784	0.529696E-02	0.308286E-02
785	0.104855	0.777595E-02
786	0.559614E-02	0.342386E-02
787	0.101810	0.989519E-02
788	0.609239E-02	0.324105E-02
789	0.987180E-01	0.117021E-01
790	0.676781E-02	0.307736E-02
791	0.955618E-01	0.131817E-01
792	0.760412E-02	0.297014E-02
793	0.923409E-01	0.143336E-01
794	0.860112E-02	0.296896E-02
795	0.890676E-01	0.151659E-01
796	0.974860E-02	0.307233E-02
797	0.857638E-01	0.156900E-01

798 0.110225E-01 0.327378E-02
 799 0.824525E-01 0.159251E-01
 800 0.123907E-01 0.355957E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
 86.950

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
801	0.791353E-01	0.158870E-01
802	0.138286E-01	0.390674E-02
803	0.758098E-01	0.156355E-01
804	0.153275E-01	0.429410E-02
805	0.724779E-01	0.152682E-01
806	0.168873E-01	0.470474E-02
807	0.691480E-01	0.148710E-01
808	0.185120E-01	0.512783E-02
809	0.658627E-01	0.145319E-01
810	0.202064E-01	0.555859E-02
811	0.626656E-01	0.142690E-01
812	0.219748E-01	0.599717E-02
813	0.596118E-01	0.140491E-01
814	0.238211E-01	0.644692E-02
815	0.567619E-01	0.138641E-01
816	0.257481E-01	0.691104E-02
817	0.541561E-01	0.136791E-01
818	0.277295E-01	0.738413E-02
819	0.517292E-01	0.134370E-01
820	0.297166E-01	0.787135E-02
821	0.493855E-01	0.130869E-01
822	0.316688E-01	0.839034E-02
823	0.470504E-01	0.126139E-01
824	0.336100E-01	0.896777E-02
825	0.447013E-01	0.120466E-01
826	0.356228E-01	0.959371E-02
827	0.423324E-01	0.114473E-01
828	0.377395E-01	0.102299E-01
829	0.400118E-01	0.108398E-01
830	0.106976	-0.374355E-01
831	0.576016E-02	0.273396E-02
832	0.106701	-0.346782E-01
833	0.636188E-02	0.239477E-02
834	0.128204E-04	-0.143787E-03
835	0.105882	-0.321304E-01
836	0.109748	-0.366669E-01
837	0.713009E-02	0.210578E-02
838	0.540390E-02	0.224766E-02
839	0.485479E-04	-0.181159E-03
840	0.104600	-0.300471E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=

86.960

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
841	0.112446	-0.357742E-01
842	0.809666E-02	0.191109E-02
843	0.505412E-02	0.175711E-02
844	0.100695E-03	-0.221018E-03
845	0.398965E-04	-0.179321E-03
846	0.102938	-0.284013E-01
847	0.115107	-0.344898E-01
848	0.925645E-02	0.182885E-02
849	0.470509E-02	0.124540E-02
850	0.167826E-03	-0.265889E-03
851	0.784010E-04	-0.233051E-03
852	0.100985	-0.268766E-01
853	0.117880	-0.326762E-01
854	0.105750E-01	0.186007E-02
855	0.435326E-02	0.717612E-03
856	0.252343E-03	-0.315394E-03
857	0.115796E-03	-0.284736E-03
858	0.988984E-01	-0.250276E-01
859	0.120943	-0.306597E-01
860	0.120091E-01	0.199917E-02
861	0.399153E-02	0.215646E-03
862	0.354347E-03	-0.366111E-03
863	0.139707E-03	-0.313038E-03
864	0.969216E-01	-0.215705E-01
865	0.124143	-0.288094E-01
866	0.135211E-01	0.223100E-02
867	0.361781E-02	-0.200265E-03
868	0.473888E-03	-0.414309E-03
869	0.155721E-03	-0.330675E-03
870	-0.938014E-01	-0.185451E-01
871	0.127134	-0.270925E-01
872	0.150899E-01	0.253287E-02
873	0.323311E-02	-0.487330E-03
874	0.611462E-03	-0.458033E-03
875	0.161652E-03	-0.334583E-03
876	0.908523E-01	-0.155421E-01
877	0.129718	-0.253453E-01
878	0.167075E-01	0.288018E-02
879	0.284660E-02	-0.646144E-03
880	0.767724E-03	-0.496991E-03

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
 86.970

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
881	0.170254E-03	-0.352964E-03
882	0.876405E-01	-0.125345E-01
883	0.131848	-0.234931E-01
884	0.183752E-01	0.325200E-02
885	0.247173E-02	-0.710398E-03
886	0.943264E-03	-0.531645E-03
887	0.840378E-01	-0.976104E-02
888	0.133564	-0.216414E-01
889	0.200986E-01	0.363445E-02
890	0.212133E-02	-0.723907E-03
891	0.113295E-02	-0.567528E-03
892	0.801078E-01	-0.750965E-02
893	0.134875	-0.201429E-01
894	0.218849E-01	0.402143E-02
895	0.178604E-02	-0.714555E-03
896	0.133333E-02	-0.614473E-03
897	0.760284E-01	-0.588549E-02
898	0.133364	-0.180401E-01
899	0.237411E-01	0.441296E-02
900	0.719554E-01	-0.480655E-02
901	0.131671	-0.157605E-01
902	0.256723E-01	0.481184E-02
903	0.679638E-01	-0.424800E-02
904	0.129953	-0.135852E-01
905	0.276675E-01	0.521781E-02
906	0.641434E-01	-0.408993E-02
907	0.128328	-0.117870E-01
908	0.297044E-01	0.564216E-02
909	0.605695E-01	-0.409447E-02
910	0.125915	-0.104629E-01
911	0.317548E-01	0.611293E-02
912	0.572199E-01	-0.413392E-02
913	0.122830	-0.942943E-02
914	0.338124E-01	0.666203E-02
915	0.540535E-01	-0.413710E-02
916	0.119228	-0.788361E-02
917	0.359106E-01	0.728125E-02
918	0.210293E-03	-0.441011E-03
919	0.510382E-01	-0.408514E-02
920	0.115579	-0.580370E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.980
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
921	0.380712E-01	0.792033E-02
922	0.256743E-03	-0.541076E-03

923	0.481133E-01	-0.404195E-02
924	0.112095	-0.332670E-02
925	0.403122E-01	0.853562E-02
926	0.318803E-03	-0.653528E-03
927	0.452848E-01	-0.405934E-02
928	0.108799	-0.667661E-03
929	0.426289E-01	0.910791E-02
930	0.379044E-03	-0.742765E-03
931	0.425622E-01	-0.409303E-02
932	0.105670	0.199477E-02
933	0.449741E-01	0.966809E-02
934	0.462062E-03	-0.844794E-03
935	0.398948E-01	-0.406473E-02
936	0.102669	0.451046E-02
937	0.473045E-01	0.101882E-01
938	0.567268E-03	-0.953647E-03
939	0.372836E-01	-0.403382E-02
940	0.997486E-01	0.677086E-02
941	0.495943E-01	0.106209E-01
942	0.694857E-03	-0.106802E-02
943	0.348334E-01	-0.402626E-02
944	0.968596E-01	0.870907E-02
945	0.518796E-01	0.109000E-01
946	0.843465E-03	-0.118481E-02
947	0.325311E-01	-0.399887E-02
948	0.939602E-01	0.102966E-01
949	0.542853E-01	0.110308E-01
950	0.101348E-02	-0.130293E-02
951	0.302994E-01	-0.396418E-02
952	0.910229E-01	0.115284E-01
953	0.569149E-01	0.110989E-01
954	0.120597E-02	-0.142178E-02
955	0.281431E-01	-0.392742E-02
956	0.880375E-01	0.124145E-01
957	0.597863E-01	0.111735E-01
958	0.142256E-02	-0.154097E-02
959	0.260680E-01	-0.387510E-02
960	0.850106E-01	0.129737E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=86.990
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
961	0.628523E-01	0.113175E-01
962	0.166535E-02	-0.166015E-02
963	0.240571E-01	-0.377746E-02
964	0.819579E-01	0.132321E-01
965	0.660449E-01	0.115801E-01
966	0.193725E-02	-0.177977E-02
967	0.221332E-01	-0.363808E-02
968	0.788725E-01	0.131898E-01
969	0.692987E-01	0.119782E-01
970	0.224012E-02	-0.190201E-02

971 0.203272E-01 -0.352391E-02
 972 0.757505E-01 0.129134E-01
 973 0.725385E-01 0.124344E-01
 974 0.257417E-02 -0.202334E-02
 975 0.186272E-01 -0.344864E-02
 976 0.294050E-02 -0.213687E-02
 977 0.170480E-01 -0.338812E-02
 978 0.332488E-02 -0.223916E-02
 979 0.156083E-01 -0.333316E-02
 980 0.369418E-02 -0.232504E-02
 981 0.142751E-01 -0.326027E-02
 982 0.402284E-02 -0.239063E-02
 983 0.130187E-01 -0.316071E-02
 984 0.429506E-02 -0.242394E-02
 985 0.118393E-01 -0.304104E-02
 986 0.452250E-02 -0.241777E-02
 987 0.107475E-01 -0.288656E-02
 988 0.473608E-02 -0.238053E-02
 989 0.972185E-02 -0.268026E-02
 990 0.496297E-02 -0.232514E-02
 991 0.873452E-02 -0.243146E-02
 992 0.520321E-02 -0.225742E-02
 993 0.782335E-02 -0.219717E-02
 994 0.543911E-02 -0.217408E-02
 995 0.704798E-02 -0.199016E-02
 996 0.109548 -0.336001E-01
 997 0.131376 -0.195719E-01
 998 0.592405E-02 0.180192E-02
 999 0.747221E-04 -0.223608E-03
 1000 0.199629E-03 -0.427229E-03

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.000

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1001	0.108754	-0.303972E-01
1002	0.129526	-0.214662E-01
1003	0.659706E-02	0.137691E-02
1004	0.119957E-03	-0.266324E-03
1005	0.194221E-03	-0.423899E-03
1006	0.107124	-0.275549E-01
1007	0.112270	-0.328044E-01
1008	0.127574	-0.232922E-01
1009	0.128642	-0.173494E-01
1010	0.749002E-02	0.994616E-03
1011	0.550091E-02	0.128583E-02
1012	0.179589E-03	-0.317814E-03
1013	0.107620E-03	-0.273401E-03
1014	0.188305E-03	-0.411724E-03
1015	0.104832	-0.254229E-01
1016	0.114604	-0.321891E-01
1017	0.125302	-0.249365E-01
1018	0.126932	-0.146041E-01

1019	0.865212E-02	0.710207E-03
1020	0.510598E-02	0.796592E-03
1021	0.256141E-03	-0.379455E-03
1022	0.102348	-0.238407E-01
1023	0.116866	-0.306247E-01
1024	0.122852	-0.265057E-01
1025	0.125886	-0.124688E-01
1026	0.100643E-01	0.566968E-03
1027	0.473969E-02	0.311144E-03
1028	0.351550E-03	-0.448350E-03
1029	0.100095	-0.224690E-01
1030	0.119292	-0.279463E-01
1031	0.122492	-0.123354E-01
1032	0.116046E-01	0.549869E-03
1033	0.438559E-02	-0.160848E-03
1034	0.467644E-03	-0.519395E-03
1035	0.118436	-0.114010E-01
1036	0.132064E-01	0.643664E-03
1037	0.402651E-02	-0.572363E-03
1038	0.604240E-03	-0.586172E-03
1039	0.114379	-0.959943E-02
1040	0.148785E-01	0.837798E-03

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.010

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1041	0.364944E-02	-0.872784E-03
1042	0.759523E-03	-0.646392E-03
1043	0.110558	-0.721643E-02
1044	0.165902E-01	0.111350E-02
1045	0.325435E-02	-0.105548E-02
1046	0.933934E-03	-0.702169E-03
1047	0.106957	-0.454858E-02
1048	0.183101E-01	0.142266E-02
1049	0.283789E-02	-0.113120E-02
1050	0.111715E-02	-0.754111E-03
1051	0.103599	-0.176232E-02
1052	0.200677E-01	0.171384E-02
1053	0.241714E-02	-0.112378E-02
1054	0.131253E-02	-0.824518E-03
1055	0.100481	0.955027E-03
1056	0.218909E-01	0.201716E-02
1057	0.202321E-02	-0.110409E-02
1058	0.975636E-01	0.345333E-02
1059	0.237692E-01	0.237438E-02
1060	0.947899E-01	0.563179E-02
1061	0.257083E-01	0.273671E-02
1062	0.920992E-01	0.743636E-02
1063	0.277162E-01	0.307793E-02
1064	0.894367E-01	0.884655E-02
1065	0.297865E-01	0.343624E-02
1066	0.867606E-01	0.986628E-02

1067 0.319072E-01 0.384487E-02
 1068 0.840480E-01 0.105160E-01
 1069 0.340631E-01 0.434424E-02
 1070 0.812926E-01 0.108279E-01
 1071 0.362406E-01 0.493929E-02
 1072 0.784888E-01 0.108087E-01
 1073 0.384376E-01 0.557725E-02
 1074 0.756116E-01 0.104964E-01
 1075 0.406636E-01 0.619672E-02
 1076 0.726483E-01 0.997079E-02
 1077 0.429323E-01 0.676351E-02
 1078 0.695525E-01 0.934519E-02
 1079 0.452485E-01 0.728073E-02
 1080 0.663851E-01 0.880843E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.030

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1081	0.475470E-01	0.774125E-02
1082	0.632043E-01	0.843262E-02
1083	0.497930E-01	0.809645E-02
1084	0.600944E-01	0.827051E-02
1085	0.520631E-01	0.827733E-02
1086	0.571553E-01	0.825114E-02
1087	0.544789E-01	0.832416E-02
1088	0.112149	-0.289820E-01
1089	0.127115	-0.198931E-01
1090	0.123004	-0.157743E-01
1091	0.606905E-02	0.791674E-03
1092	0.145059E-03	-0.312353E-03
1093	0.262311E-03	-0.549056E-03
1094	0.110203	-0.250509E-01
1095	0.125343	-0.215837E-01
1096	0.125109	-0.183116E-01
1097	0.682291E-02	0.276045E-03
1098	0.191995E-03	-0.358096E-03
1099	0.262239E-03	-0.532699E-03
1100	0.106782	-0.220583E-01
1101	0.115077	-0.293823E-01
1102	0.123625	-0.231873E-01
1103	0.117950	-0.156520E-01
1104	0.791961E-02	-0.343367E-03
1105	0.559003E-02	0.307950E-03
1106	0.261766E-03	-0.429570E-03
1107	0.326065E-03	-0.642904E-03
1108	0.103301	-0.206211E-01
1109	0.116440	-0.265513E-01
1110	0.120885	-0.244305E-01
1111	0.113361	-0.135856E-01
1112	0.961205E-02	-0.566803E-03
1113	0.517435E-02	-0.128621E-03
1114	0.342480E-03	-0.504542E-03

1115 0.391804E-03 -0.713799E-03
 1116 0.100429 -0.196485E-01
 1117 0.109336 -0.113043E-01
 1118 0.112652E-01 -0.828390E-03
 1119 0.480734E-02 -0.541278E-03
 1120 0.458123E-03 -0.606158E-03

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.040

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1121	0.491647E-03	-0.806211E-03
1122	0.978381E-01	-0.184731E-01
1123	0.105464	-0.869737E-02
1124	0.129687E-01	-0.797074E-03
1125	0.446857E-02	-0.920100E-03
1126	0.606191E-03	-0.699985E-03
1127	0.617595E-03	-0.907733E-03
1128	0.954401E-01	-0.167478E-01
1129	0.101797	-0.585488E-02
1130	0.147581E-01	-0.882156E-03
1131	0.411757E-02	-0.122589E-02
1132	0.763636E-03	-0.780168E-03
1133	0.764408E-03	-0.101082E-02
1134	0.931336E-01	-0.135334E-01
1135	0.984264E-01	-0.295246E-02
1136	0.166166E-01	-0.537323E-03
1137	0.374810E-02	-0.144158E-02
1138	0.937570E-03	-0.853908E-03
1139	0.931728E-03	-0.111414E-02
1140	0.900175E-01	-0.106109E-01
1141	0.953611E-01	-0.174858E-03
1142	0.183402E-01	-0.316618E-03
1143	0.337119E-02	-0.163243E-02
1144	0.112104E-02	-0.920633E-03
1145	0.111948E-02	-0.121572E-02
1146	0.866075E-01	-0.717531E-02
1147	0.925647E-01	0.232718E-02
1148	0.201149E-01	-0.160288E-03
1149	0.279385E-02	-0.156166E-02
1150	0.128912E-02	-0.971491E-03
1151	0.132908E-02	-0.131116E-02
1152	0.824775E-01	-0.486582E-02
1153	0.899782E-01	0.445690E-02
1154	0.221262E-01	-0.136622E-04
1155	0.236426E-02	-0.148916E-02
1156	0.156313E-02	-0.140065E-02
1157	0.784699E-01	-0.299025E-02
1158	0.875322E-01	0.616312E-02
1159	0.239962E-01	0.573332E-03
1160	0.182706E-02	-0.150220E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.050

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1161	0.743271E-01	-0.147433E-02
1162	0.851578E-01	0.742958E-02
1163	0.258467E-01	0.869360E-03
1164	0.212113E-02	-0.161954E-02
1165	0.699230E-01	-0.444296E-03
1166	0.827952E-01	0.826586E-02
1167	0.278555E-01	0.112980E-02
1168	0.242923E-02	-0.174426E-02
1169	0.651336E-01	-0.643092E-03
1170	0.803990E-01	0.870091E-02
1171	0.299535E-01	0.141331E-02
1172	0.276661E-02	-0.182770E-02
1173	0.611470E-01	-0.984766E-03
1174	0.779476E-01	0.875872E-02
1175	0.321559E-01	0.172736E-02
1176	0.316809E-02	-0.194962E-02
1177	0.573075E-01	-0.148987E-02
1178	0.753981E-01	0.845530E-02
1179	0.344463E-01	0.213271E-02
1180	0.354615E-02	-0.203452E-02
1181	0.541056E-01	-0.159985E-02
1182	0.727233E-01	0.785275E-02
1183	0.367007E-01	0.268644E-02
1184	0.393877E-02	-0.216121E-02
1185	0.511262E-01	-0.157726E-02
1186	0.698845E-01	0.708053E-02
1187	0.388833E-01	0.331616E-02
1188	0.421373E-02	-0.225857E-02
1189	0.481984E-01	-0.152543E-02
1190	0.668663E-01	0.629310E-02
1191	0.410615E-01	0.392976E-02
1192	0.440335E-02	-0.227505E-02
1193	0.454380E-01	-0.171799E-02
1194	0.637043E-01	0.570844E-02
1195	0.432645E-01	0.448053E-02
1196	0.455501E-02	-0.222547E-02
1197	0.427713E-01	-0.204751E-02
1198	0.605232E-01	0.545852E-02
1199	0.455059E-01	0.493812E-02
1200	0.473127E-02	-0.214671E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.060

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1201	0.401385E-01	-0.171081E-02
1202	0.575004E-01	0.542608E-02
1203	0.477365E-01	0.528600E-02
1204	0.491797E-02	-0.203499E-02
1205	0.371839E-01	-0.184323E-02
1206	0.547163E-01	0.549467E-02
1207	0.499645E-01	0.550574E-02
1208	0.513051E-02	-0.188678E-02
1209	0.346895E-01	-0.215365E-02
1210	0.522289E-01	0.556521E-02
1211	0.325295E-01	-0.207273E-02
1212	0.302938E-01	-0.212792E-02
1213	0.281468E-01	-0.220418E-02
1214	0.260812E-01	-0.225154E-02
1215	0.241002E-01	-0.213907E-02
1216	0.221259E-01	-0.193348E-02
1217	0.202370E-01	-0.187871E-02
1218	0.184985E-01	-0.189910E-02
1219	0.168650E-01	-0.197569E-02
1220	0.154893E-01	-0.213699E-02
1221	0.141801E-01	-0.213769E-02
1222	0.129249E-01	-0.200155E-02
1223	0.116394E-01	-0.198360E-02
1224	0.105430E-01	-0.198438E-02
1225	0.959992E-02	-0.188840E-02
1226	0.869454E-02	-0.171684E-02
1227	0.784387E-02	-0.154894E-02
1228	0.708032E-02	-0.141349E-02
1229	0.123132	-0.200955E-01
1230	0.617408E-02	-0.241286E-03
1231	0.309925E-03	-0.568348E-03
1232	0.121530	-0.219164E-01
1233	0.683869E-02	-0.851191E-03
1234	0.215375E-03	-0.434220E-03
1235	0.564435E-02	-0.632469E-03
1236	0.423731E-03	-0.673746E-03
1237	0.522718E-02	-0.953978E-03
1238	0.546696E-03	-0.755968E-03
1239	0.488167E-02	-0.121660E-02
1240	0.706702E-03	-0.859888E-03

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.070

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY

1241 0.463475E-02 -0.158560E-02
1242 0.873327E-03 -0.950619E-03
1243 0.422927E-02 -0.176847E-02
1244 0.105838E-02 -0.103720E-02
1245 0.401171E-02 -0.196489E-02
1246 0.125369E-02 -0.110614E-02
1247 0.147304E-02 -0.113465E-02
1248 0.174781E-02 -0.124398E-02
1249 0.202094E-02 -0.136133E-02
1250 0.614672E-02 -0.121411E-02
1251 0.562025E-02 -0.142043E-02
1252 0.523699E-02 -0.158350E-02
1253 0.1117800 -0.234624E-01
1254 0.119070 -0.208149E-01
1255 0.120703 -0.185761E-01
1256 0.115922 -0.191169E-01
1257 0.114720 -0.222532E-01
1258 0.113833 -0.253084E-01
1259 0.112316 -0.171852E-01
1260 0.108323 -0.150767E-01
1261 0.104307 -0.126665E-01
1262 0.100379 -0.992822E-02
1263 0.967079E-01 -0.693874E-02
1264 0.933298E-01 -0.382089E-02
1265 0.903241E-01 -0.849642E-03
1266 0.877330E-01 0.170962E-02
1267 0.854052E-01 0.375389E-02
1268 0.832326E-01 0.527109E-02
1269 0.812259E-01 0.632690E-02
1270 0.793096E-01 0.694814E-02
1271 0.773198E-01 0.711862E-02
1272 0.751515E-01 0.685405E-02
1273 0.727904E-01 0.616966E-02
1274 0.702304E-01 0.521863E-02
1275 0.674982E-01 0.424110E-02
1276 0.643396E-01 0.318442E-02
1277 0.609651E-01 0.296527E-02
1278 0.579683E-01 0.290655E-02
1279 0.550812E-01 0.292827E-02
1280 0.524031E-01 0.300308E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.080

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1281	0.499950E-01	0.305643E-02
1282	0.477822E-01	0.302565E-02
1283	0.456685E-01	0.283061E-02
1284	0.435657E-01	0.245820E-02
1285	0.414873E-01	0.196138E-02
1286	0.394620E-01	0.142980E-02
1287	0.374600E-01	0.798094E-03
1288	0.351104E-01	-0.101753E-03

1289	0.324503E-01	-0.250721E-03
1290	0.301916E-01	-0.433938E-03
1291	0.280666E-01	-0.623607E-03
1292	0.260432E-01	-0.779857E-03
1293	0.243917E-01	-0.833356E-03
1294	0.231747E-01	-0.111930E-02
1295	0.110950	-0.207431E-01
1296	0.107243	-0.182868E-01
1297	0.103220	-0.166699E-01
1298	0.993359E-01	-0.137222E-01
1299	0.953217E-01	-0.110406E-01
1300	0.912584E-01	-0.731010E-02
1301	0.876789E-01	-0.348696E-02
1302	0.853135E-01	-0.418463E-03
1303	0.830729E-01	0.185989E-02
1304	0.808426E-01	0.344048E-02
1305	0.791946E-01	0.486595E-02
1306	0.780848E-01	0.574549E-02
1307	0.768003E-01	0.606829E-02
1308	0.752012E-01	0.567789E-02
1309	0.731649E-01	0.476945E-02
1310	0.704425E-01	0.343409E-02
1311	0.679877E-01	0.291678E-02
1312	0.658301E-01	0.160042E-02
1313	0.100388	-0.171890E-01
1314	0.980975E-01	-0.160501E-01
1315	0.962135E-01	-0.147890E-01
1316	0.840304E-01	-0.286195E-02
1317	0.811559E-01	-0.485272E-03
1318	0.771785E-01	0.176585E-02
1319	0.730529E-01	0.265988E-02
1320	0.770190E-01	0.407011E-02

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=87.090

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1321	0.749854E-01	0.435447E-02
1322	0.765903E-01	0.516334E-02
1323	0.683905E-01	0.151987E-02
1324	0.635935E-02	-0.259873E-02
1325	0.596891E-02	-0.229055E-02
1326	0.647278E-02	-0.229468E-02
1327	0.559819E-02	-0.195162E-02
1328	0.649381E-02	-0.188285E-02
1329	0.610366E-02	-0.206171E-02
1330	0.610755E-02	-0.171495E-02
1331	0.581288E-02	-0.180670E-02
1332	0.634573E-01	0.117437E-02
1333	0.633801E-01	0.191632E-03
1334	0.613076E-01	0.118134E-02
1335	0.585235E-01	0.719615E-03
1336	0.554176E-01	0.571625E-03

1337 0.525202E-01 0.603152E-03
1338 0.497086E-01 0.661067E-03
1339 0.475297E-01 0.108477E-02
1340 0.456742E-01 0.111958E-02
1341 0.437788E-01 0.847624E-03
1342 0.418421E-01 0.393460E-03
1343 0.400699E-01 0.194413E-05
1344 0.383856E-01 -0.536554E-03
1345 0.469363E-01 -0.246041E-03
1346 0.455669E-01 -0.640073E-04
1347 0.439241E-01 -0.487614E-03
1348 0.421322E-01 -0.752996E-03
1349 0.102926E-01 -0.131647E-02
1350 0.952769E-02 -0.131213E-02
1351 0.869347E-02 -0.110088E-02
1352 0.788791E-02 -0.103691E-02
1353 0.742167E-02 -0.112748E-02
1354 0.660270E-02 -0.156880E-02
1355 0.463965E-02 -0.188029E-02
1356 0.448548E-02 -0.199607E-02
1357 0.435789E-02 -0.208082E-02
1358 0.424566E-02 -0.215656E-02
1359 0.169253E-02 -0.100174E-02
1360 0.161704E-02 -0.789983E-03

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:08 OCT 20, 1994 CP=
87.100
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1361	0.149073E-02	-0.942423E-03
1362	0.146276E-02	-0.774370E-03
1363	0.154573E-02	-0.552058E-03
1364	0.149745E-02	-0.642709E-03
1365	0.377208E-03	-0.581700E-03
1366	0.298843E-03	-0.509402E-03
1367	0.223581E-03	-0.418834E-03
1368	0.297707E-03	-0.485463E-03
1369	0.138909E-03	-0.327319E-03
1370	0.137245E-03	-0.317995E-03
1371	0.167328E-03	-0.352542E-03
1372	0.170145E-03	-0.367069E-03
1373	0.793029E-01	0.204421E-01
1374	0.757414E-01	0.201606E-01
1375	0.722526E-01	0.198165E-01
1376	0.688460E-01	0.194576E-01
1377	0.655317E-01	0.191063E-01
1378	0.623156E-01	0.187664E-01
1379	0.592213E-01	0.184393E-01
1380	0.562932E-01	0.181233E-01
1381	0.539642E-01	0.177543E-01
1382	0.517284E-01	0.173621E-01
1383	0.491936E-01	0.167727E-01
1384	0.466907E-01	0.161315E-01

1385 0.442429E-01 0.154629E-01
1386 0.418421E-01 0.147920E-01
1387 0.395099E-01 0.141331E-01
1388 0.372549E-01 0.134846E-01
1389 0.351067E-01 0.128438E-01
1390 0.330802E-01 0.122240E-01
1391 0.315001E-01 0.117315E-01
1392 0.299275E-01 0.112563E-01
1393 0.278992E-01 0.106562E-01
1394 0.258937E-01 0.100614E-01
1395 0.239603E-01 0.948056E-02
1396 0.221245E-01 0.892130E-02
1397 0.203717E-01 0.837882E-02
1398 0.186905E-01 0.784846E-02
1399 0.170894E-01 0.733215E-02
1400 0.155672E-01 0.682985E-02

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.110
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1401	0.141221E-01	0.634262E-02
1402	0.127525E-01	0.587312E-02
1403	0.114600E-01	0.542654E-02
1404	0.102492E-01	0.500530E-02
1405	0.913508E-02	0.462720E-02
1406	0.813911E-02	0.438608E-02
1407	0.724376E-02	0.420366E-02
1408	0.645536E-02	0.407085E-02
1409	0.578354E-02	0.397265E-02
1410	0.518196E-02	0.384614E-02
1411	0.469778E-02	0.361498E-02
1412	0.428227E-02	0.321067E-02
1413	0.408881E-02	0.294905E-02
1414	0.376922E-02	0.247566E-02
1415	0.345887E-02	0.198600E-02
1416	0.315499E-02	0.148722E-02
1417	0.287974E-02	0.102771E-02
1418	0.263237E-02	0.640570E-03
1419	0.237466E-02	0.380558E-03
1420	0.212476E-02	0.209033E-03
1421	0.187869E-02	0.107365E-03
1422	0.164001E-02	0.523347E-04
1423	0.140528E-02	0.118752E-04
1424	0.118662E-02	-0.175932E-04
1425	0.986938E-03	-0.416300E-04
1426	0.806043E-03	-0.612611E-04
1427	0.643621E-03	-0.759936E-04
1428	0.499318E-03	-0.860975E-04
1429	0.372512E-03	-0.918784E-04
1430	0.262503E-03	-0.937957E-04
1431	0.168780E-03	-0.925794E-04
1432	0.913932E-04	-0.893156E-04

1433 0.307670E-04 -0.854824E-04
1434 -0.111873E-04 -0.806994E-04
1435 -0.318126E-04 -0.745138E-04
1436 -0.323892E-04 -0.669107E-04
1437 -0.211538E-04 -0.566905E-04
1438 -0.914752E-05 -0.451446E-04
1439 -0.229855E-05 -0.358155E-04
1440 0.171061E-05 -0.271974E-04

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
.120
OR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

Hook Connector for MWTF

** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

E - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

DE	UX	UY
0.311757E-05	-0.194501E-04	
0.217910E-05	-0.127936E-04	
-0.761662E-06	-0.760006E-05	
-0.532258E-05	-0.422020E-05	
-0.111092E-04	-0.295788E-05	
-0.177192E-04	-0.409952E-05	
0.247129E-04	-0.794593E-05	
0.315689E-04	-0.148222E-04	
-0.376322E-04	-0.250638E-04	
1450 -0.420641E-04	-0.389745E-04	
1451 -0.438067E-04	-0.567468E-04	
1452 -0.416026E-04	-0.783451E-04	
1453 -0.340977E-04	-0.103366E-03	
1454 -0.201867E-04	-0.130999E-03	
1455 0.538599E-06	-0.159803E-03	
1456 0.272630E-04	-0.190213E-03	
1457 0.651835E-04	-0.233397E-03	
1458 0.112591E-03	-0.286791E-03	
1459 0.166532E-03	-0.358271E-03	
1460 0.221916E-03	-0.452581E-03	
1461 0.269249E-03	-0.547214E-03	
1462 0.323962E-03	-0.657290E-03	
1463 0.390125E-03	-0.777427E-03	
1464 0.470608E-03	-0.904318E-03	
1465 0.568531E-03	-0.103750E-02	
1466 0.685744E-03	-0.117630E-02	
1467 0.822638E-03	-0.131895E-02	
1468 0.980107E-03	-0.146477E-02	
1469 0.115929E-02	-0.161329E-02	
1470 0.136164E-02	-0.176406E-02	
1471 0.158894E-02	-0.191646E-02	
1472 0.184327E-02	-0.206943E-02	
1473 0.212687E-02	-0.222120E-02	
1474 0.244177E-02	-0.236891E-02	
1475 0.278906E-02	-0.250816E-02	
1476 0.316591E-02	-0.263191E-02	
1477 0.356049E-02	-0.272776E-02	
1478 0.391291E-02	-0.277134E-02	
1479 0.421503E-02	-0.274874E-02	
1480 0.446856E-02	-0.269242E-02	

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.130
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1481	0.471929E-02	-0.264130E-02
1482	0.499367E-02	-0.260441E-02
1483	0.530128E-02	-0.258729E-02
1484	0.564179E-02	-0.261554E-02
1485	0.601011E-02	-0.266721E-02
1486	0.631896E-02	-0.277497E-02
1487	0.697638E-02	-0.292119E-02
1488	0.663306E-02	-0.287384E-02
1489	0.779198E-02	-0.327097E-02
1490	0.878835E-02	-0.369490E-02
1491	0.984111E-02	-0.408361E-02
1492	0.109498E-01	-0.443524E-02
1493	0.121106E-01	-0.474619E-02
1494	0.132700E-01	-0.494896E-02
1495	0.144931E-01	-0.514046E-02
1496	0.157960E-01	-0.533548E-02
1497	0.171841E-01	-0.553430E-02
1498	0.187059E-01	-0.574213E-02
1499	0.203891E-01	-0.595793E-02
1500	0.221719E-01	-0.617024E-02
1501	0.240471E-01	-0.637645E-02
1502	0.260132E-01	-0.657584E-02
1503	0.280710E-01	-0.676819E-02
1504	0.302215E-01	-0.695325E-02
1505	0.324654E-01	-0.713079E-02
1506	0.348036E-01	-0.730058E-02
1507	0.372368E-01	-0.746245E-02
1508	0.397658E-01	-0.761647E-02
1509	0.423911E-01	-0.776324E-02
1510	0.451133E-01	-0.790427E-02
1511	0.479323E-01	-0.804289E-02
1512	0.508479E-01	-0.818333E-02
1513	0.538464E-01	-0.833992E-02
1514	0.569235E-01	-0.852470E-02
1515	0.599148E-01	-0.890894E-02
1516	0.629866E-01	-0.931799E-02
1517	0.661633E-01	-0.975484E-02
1518	0.694580E-01	-0.102701E-01
1519	0.728438E-01	-0.109344E-01
1520	0.762731E-01	-0.118539E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.140
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1521	0.799788E-01	-0.134614E-01
1522	0.835149E-01	-0.160290E-01
1523	0.867360E-01	-0.190152E-01
1524	0.898940E-01	-0.220301E-01
1525	0.930055E-01	-0.250793E-01
1526	0.959855E-01	-0.281054E-01
1527	0.988025E-01	-0.311200E-01
1528	0.993632E-01	-0.341405E-01
1529	0.995949E-01	-0.355396E-01
1530	0.995209E-01	-0.361683E-01
1531	0.996605E-01	-0.374233E-01
1532	0.997627E-01	-0.387304E-01
1533	0.997716E-01	-0.401304E-01
1534	0.996401E-01	-0.415659E-01
1535	0.993524E-01	-0.430191E-01
1536	0.999699E-01	-0.441715E-01
1537	0.102807	-0.440560E-01
1538	0.105822	-0.437892E-01
1539	0.109611	-0.431141E-01
1540	0.113435	-0.421388E-01
1541	0.117241	-0.409221E-01
1542	0.121015	-0.395114E-01
1543	0.124743	-0.379612E-01
1544	0.128395	-0.362762E-01
1545	0.131910	-0.344174E-01
1546	0.135005	-0.321722E-01
1547	0.137414	-0.293542E-01
1548	0.138962	-0.261290E-01
1549	0.139585	-0.227537E-01
1550	0.139562	-0.203973E-01
1551	0.138957	-0.170439E-01
1552	0.137511	-0.138059E-01
1553	0.135295	-0.109392E-01
1554	0.132515	-0.828343E-02
1555	0.129546	-0.567393E-02
1556	0.126496	-0.305996E-02
1557	0.123437	-0.420043E-03
1558	0.120409	0.224073E-02
1559	0.117423	0.490046E-02
1560	0.114464	0.753286E-02

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.150

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1561	0.111338	0.101414E-01
1562	0.108082	0.125119E-01
1563	0.104708	0.145986E-01
1564	0.101227	0.163788E-01
1565	0.976561E-01	0.178443E-01
1566	0.940174E-01	0.189920E-01
1567	0.903366E-01	0.198218E-01
1568	0.866404E-01	0.203353E-01
1569	0.829550E-01	0.205374E-01
1570	0.793022E-06	-0.454873E-04
1571	-0.423419E-05	-0.369700E-04
1572	-0.765057E-05	-0.288465E-04
1573	-0.968747E-05	-0.217721E-04
1574	-0.104961E-04	-0.158323E-04
1575	-0.103703E-04	-0.110064E-04
1576	-0.957876E-05	-0.719948E-05
1577	-0.834447E-05	-0.430378E-05
1578	-0.684926E-05	-0.221692E-05
1579	-0.523991E-05	-0.846227E-06
1580	-0.363458E-05	-0.108642E-06
1581	-0.212962E-05	0.698751E-07
1582	-0.807743E-06	-0.243287E-06
1583	0.252228E-06	-0.978859E-06
1584	0.969028E-06	-0.204446E-05
1585	0.127281E-05	-0.331049E-05
1586	0.113361E-05	-0.462153E-05
1587	0.589131E-06	-0.615986E-05
1588	-0.430798E-06	-0.801931E-05
1589	-0.227389E-05	-0.113501E-04
1590	-0.486873E-05	-0.151949E-04
1591	-0.751378E-05	-0.185033E-04
1592	-0.100099E-04	-0.221323E-04
1593	-0.116282E-04	-0.263103E-04
1594	-0.104305E-04	-0.295559E-04
1595	-0.554915E-05	-0.322015E-04
1596	0.278461E-05	-0.355522E-04
1597	0.134899E-04	-0.406234E-04
1598	0.246270E-04	-0.476830E-04
1599	0.338399E-04	-0.561263E-04
1600	0.389772E-04	-0.643159E-04

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.160

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1601	0.386438E-04	-0.697396E-04
1602	0.330464E-04	-0.703196E-04
1603	0.244738E-04	-0.666177E-04
1604	0.156642E-04	-0.612451E-04
1605	0.744621E-05	-0.539234E-04
1606	-0.628476E-05	-0.348874E-04
1607	-0.129740E-04	-0.456381E-04

1608 -0.423420E-05 -0.354131E-04
1609 -0.284290E-05 -0.224146E-04
1610 -0.796148E-05 -0.332290E-04
1611 -0.183017E-05 -0.246841E-04
1612 -0.293521E-05 -0.175131E-04
1613 -0.144303E-06 -0.129101E-04
1614 0.100812 -0.421593E-01
1615 0.101922 -0.429946E-01
1616 -0.251377E-04 -0.578772E-04
1617 -0.157774E-04 -0.457969E-04
1618 -0.877920E-05 -0.308948E-04
1619 -0.732108E-05 -0.239489E-04
1620 0.135619E-05 -0.983150E-05
1621 0.499537E-06 -0.168647E-04
1622 0.595158E-06 -0.270060E-04
1623 -0.653220E-06 -0.266231E-04
1624 0.275372E-05 -0.198279E-04
1625 0.212377E-05 -0.199968E-04
1626 0.101141 -0.403714E-01
1627 0.102503 -0.409434E-01
1628 -0.328942E-04 -0.709905E-04
1629 -0.271276E-04 -0.599356E-04
1630 -0.176620E-04 -0.451904E-04
1631 0.198002E-05 -0.726877E-05
1632 0.211080E-05 -0.126378E-04
1633 0.137888E-05 -0.185759E-04
1634 0.272960E-05 -0.135898E-04
1635 0.288928E-05 -0.142719E-04
1636 0.101172 -0.386607E-01
1637 0.102686 -0.388999E-01
1638 0.104811 -0.427447E-01
1639 0.103609 -0.418025E-01
1640 -0.246789E-04 -0.852390E-04

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.170

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1641	-0.305656E-04	-0.786125E-04
1642	-0.120929E-04	-0.302795E-04
1643	-0.170787E-04	-0.421396E-04
1644	0.180470E-05	-0.493912E-05
1645	0.247002E-05	-0.906269E-05
1646	0.806599E-06	-0.843626E-05
1647	0.188844E-05	-0.929775E-05
1648	0.100968	-0.371001E-01
1649	0.102519	-0.369399E-01
1650	0.107994	-0.422182E-01
1651	0.106561	-0.413321E-01
1652	0.560727E-05	-0.100157E-03
1653	-0.124386E-04	-0.103461E-03
1654	-0.158591E-04	-0.361835E-04
1655	-0.195722E-04	-0.452155E-04

1656	0.843060E-06	-0.285115E-05
1657	0.167357E-05	-0.580223E-05
1658	-0.272005E-05	-0.469528E-05
1659	-0.664515E-06	-0.536182E-05
1660	0.100634	-0.357027E-01
1661	0.102063	-0.352310E-01
1662	0.111401	-0.413647E-01
1663	0.109680	-0.406521E-01
1664	0.565004E-04	-0.113938E-03
1665	0.302068E-04	-0.126844E-03
1666	-0.179416E-04	-0.431130E-04
1667	-0.222338E-04	-0.545682E-04
1668	-0.813235E-06	-0.126246E-05
1669	-0.178431E-06	-0.315074E-05
1670	-0.751130E-05	-0.269650E-05
1671	-0.449361E-05	-0.281568E-05
1672	0.100129	-0.343185E-01
1673	0.101444	-0.337503E-01
1674	0.114941	-0.401689E-01
1675	0.112935	-0.396082E-01
1676	0.124727E-03	-0.126803E-03
1677	0.885390E-04	-0.147695E-03
1678	-0.162219E-04	-0.505867E-04
1679	-0.207635E-04	-0.673333E-04
1680	-0.302146E-05	-0.380836E-06

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.180

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1681	-0.290625E-05	-0.140662E-05
1682	-0.132128E-04	-0.272694E-05
1683	-0.928864E-05	-0.195359E-05
1684	0.995946E-01	-0.317741E-01
1685	0.100603	-0.323312E-01
1686	0.118533	-0.387255E-01
1687	0.116277	-0.382095E-01
1688	0.209188E-03	-0.138644E-03
1689	0.162886E-03	-0.169509E-03
1690	-0.905164E-05	-0.579514E-04
1691	-0.120088E-04	-0.805452E-04
1692	-0.563003E-05	-0.358138E-06
1693	-0.629846E-05	-0.802104E-06
1694	-0.194483E-04	-0.506210E-05
1695	-0.147267E-04	-0.303079E-05
1696	0.981974E-01	-0.285586E-01
1697	0.100363	-0.305862E-01
1698	0.100198	-0.284531E-01
1699	0.122138	-0.371363E-01
1700	0.119692	-0.365729E-01
1701	0.309854E-03	-0.147899E-03
1702	0.253915E-03	-0.190351E-03
1703	0.349618E-05	-0.661285E-04

1704 0.341494E-05 -0.949493E-04
1705 -0.848351E-05 -0.132370E-05
1706 -0.101372E-04 -0.152281E-05
1707 -0.257370E-04 -0.999107E-05
1708 -0.204521E-04 -0.630227E-05
1709 0.956743E-01 -0.255302E-01
1710 0.979580E-01 -0.260485E-01
1711 0.125712 -0.354648E-01
1712 0.123164 -0.348405E-01
1713 0.426945E-03 -0.153652E-03
1714 0.361299E-03 -0.208382E-03
1715 0.200530E-04 -0.763620E-04
1716 0.244010E-04 -0.112646E-03
1717 -0.114073E-04 -0.340997E-05
1718 -0.141852E-04 -0.374929E-05
1719 -0.316999E-04 -0.178189E-04
1720 -0.260410E-04 -0.120384E-04

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.190

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1721	0.928346E-01	-0.224152E-01
1722	0.956235E-01	-0.227796E-01
1723	0.129165	-0.336796E-01
1724	0.126620	-0.330837E-01
1725	0.561113E-03	-0.155398E-03
1726	0.485457E-03	-0.222568E-03
1727	0.380699E-04	-0.889870E-04
1728	0.480467E-04	-0.132179E-03
1729	-0.141900E-04	-0.676108E-05
1730	-0.181604E-04	-0.767387E-05
1731	-0.365147E-04	-0.288448E-04
1732	-0.309619E-04	-0.205184E-04
1733	0.897791E-01	-0.193012E-01
1734	0.925718E-01	-0.196884E-01
1735	0.132329	-0.316794E-01
1736	0.129907	-0.312555E-01
1737	0.713071E-03	-0.152837E-03
1738	0.627087E-03	-0.232509E-03
1739	0.542407E-04	-0.103117E-03
1740	0.701205E-04	-0.151597E-03
1741	-0.165672E-04	-0.115328E-04
1742	-0.217119E-04	-0.135016E-04
1743	-0.393775E-04	-0.433132E-04
1744	-0.345390E-04	-0.320029E-04
1745	0.865649E-01	-0.162913E-01
1746	0.895340E-01	-0.166479E-01
1747	0.134973	-0.293573E-01
1748	0.132796	-0.292399E-01
1749	0.883366E-03	-0.145730E-03
1750	0.786854E-03	-0.238063E-03
1751	0.652527E-04	-0.116620E-03

1752 0.867895E-04 -0.169066E-03
1753 -0.182082E-04 -0.178872E-04
1754 -0.243967E-04 -0.214401E-04
1755 -0.392429E-04 -0.613312E-04
1756 -0.359289E-04 -0.466824E-04
1757 0.831041E-01 -0.135444E-01
1758 0.862747E-01 -0.136742E-01
1759 0.136899 -0.267239E-01
1760 0.135066 -0.269544E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.200

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1761	0.107264E-02	-0.134743E-03
1762	0.965182E-03	-0.239141E-03
1763	0.685631E-04	-0.126214E-03
1764	0.953606E-04	-0.182077E-03
1765	-0.187056E-04	-0.259794E-04
1766	-0.256636E-04	-0.316772E-04
1767	-0.349313E-04	-0.827681E-04
1768	-0.341362E-04	-0.645995E-04
1769	0.794004E-01	-0.113506E-01
1770	0.826682E-01	-0.110261E-01
1771	0.138022	-0.239580E-01
1772	0.136600	-0.244989E-01
1773	0.128198E-02	-0.120275E-03
1774	0.116254E-02	-0.239393E-03
1775	0.632929E-04	-0.128736E-03
1776	0.942542E-04	-0.188009E-03
1777	-0.175798E-04	-0.359265E-04
1778	-0.248550E-04	-0.443419E-04
1779	-0.253135E-04	-0.107153E-03
1780	-0.281108E-04	-0.855642E-04
1781	0.756466E-01	-0.982620E-02
1782	0.788039E-01	-0.898681E-02
1783	0.138362	-0.212355E-01
1784	0.137423	-0.221281E-01
1785	0.151061E-02	-0.983683E-04
1786	0.138801E-02	-0.245420E-03
1787	0.512896E-04	-0.123746E-03
1788	0.820455E-04	-0.182332E-03
1789	-0.143176E-04	-0.477469E-04
1790	-0.212564E-04	-0.594447E-04
1791	-0.977015E-05	-0.133526E-03
1792	-0.169877E-04	-0.109108E-03
1793	0.719622E-01	-0.882938E-02
1794	0.748911E-01	-0.757724E-02
1795	0.137999	-0.184726E-01
1796	0.137384	-0.197185E-01
1797	0.175284E-02	-0.615562E-04
1798	0.164396E-02	-0.228763E-03
1799	0.366724E-04	-0.114515E-03

1800 0.621621E-04 -0.165273E-03

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.210
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1801	-0.866249E-05	-0.612130E-04
1802	-0.142282E-04	-0.767940E-04
1803	0.116814E-04	-0.161096E-03
1804	-0.105346E-05	-0.133798E-03
1805	0.683762E-01	-0.818227E-02
1806	0.710351E-01	-0.664490E-02
1807	0.136963	-0.156065E-01
1808	0.136571	-0.171516E-01
1809	0.200452E-02	0.363636E-06
1810	0.190696E-02	-0.196269E-03
1811	0.222715E-04	-0.102943E-03
1812	0.428902E-04	-0.150824E-03
1813	-0.624761E-06	-0.754313E-04
1814	-0.404029E-05	-0.952167E-04
1815	0.403149E-04	-0.195376E-03
1816	0.181979E-04	-0.157155E-03
1817	0.649434E-01	-0.774541E-02
1818	0.672844E-01	-0.610263E-02
1819	0.135255	-0.128423E-01
1820	0.135171	-0.144953E-01
1821	0.226687E-02	0.106545E-03
1822	0.218233E-02	-0.137196E-03
1823	0.965378E-05	-0.895920E-04
1824	0.233927E-04	-0.131396E-03
1825	0.805340E-05	-0.111341E-03
1826	0.782569E-04	-0.237249E-03
1827	0.442470E-04	-0.189431E-03
1828	0.616725E-01	-0.741813E-02
1829	0.637048E-01	-0.583612E-02
1830	0.132932	-0.103026E-01
1831	0.133235	-0.120294E-01
1832	0.253872E-02	0.283843E-03
1833	0.247625E-02	-0.266645E-04
1834	0.125624E-03	-0.292075E-03
1835	0.894271E-04	-0.234624E-03
1836	0.768929E-04	-0.223353E-03
1837	0.585203E-01	-0.715293E-02
1838	0.603216E-01	-0.568817E-02
1839	0.130135	-0.790486E-02
1840	0.130773	-0.981752E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.220
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1841	0.282864E-02	0.556006E-03
1842	0.278973E-02	0.167415E-03
1843	0.180245E-03	-0.377301E-03
1844	0.127413E-03	-0.281021E-03
1845	0.161607E-03	-0.339771E-03
1846	0.554335E-01	-0.696255E-02
1847	0.570965E-01	-0.559039E-02
1848	0.127081	-0.551996E-02
1849	0.127866	-0.772507E-02
1850	0.314002E-02	0.944855E-03
1851	0.312206E-02	0.477199E-03
1852	0.229396E-03	-0.472163E-03
1853	0.189563E-03	-0.393415E-03
1854	0.524020E-01	-0.682699E-02
1855	0.539800E-01	-0.551657E-02
1856	0.123941	-0.306772E-02
1857	0.124694	-0.558842E-02
1858	0.346417E-02	0.141788E-02
1859	0.346569E-02	0.904669E-03
1860	0.274678E-03	-0.567158E-03
1861	0.230532E-03	-0.480219E-03
1862	0.494376E-01	-0.672265E-02
1863	0.509713E-01	-0.543552E-02
1864	0.120818	-0.525530E-03
1865	0.121441	-0.328285E-02
1866	0.379317E-02	0.192790E-02
1867	0.381228E-02	0.141098E-02
1868	0.330349E-03	-0.675659E-03
1869	0.278965E-03	-0.581905E-03
1870	0.465599E-01	-0.662860E-02
1871	0.480461E-01	-0.536521E-02
1872	0.117752	0.208339E-02
1873	0.118239	-0.795515E-03
1874	0.411136E-02	0.242435E-02
1875	0.414986E-02	0.193714E-02
1876	0.398965E-03	-0.791218E-03
1877	0.340807E-03	-0.694045E-03
1878	0.437807E-01	-0.653673E-02
1879	0.452180E-01	-0.532738E-02
1880	0.114726	0.471125E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.230
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1881	0.115126	0.180323E-02
1882	0.440983E-02	0.286320E-02
1883	0.446623E-02	0.243418E-02
1884	0.483439E-03	-0.912059E-03
1885	0.408616E-03	-0.797192E-03
1886	0.411002E-01	-0.644159E-02
1887	0.424921E-01	-0.529754E-02
1888	0.111683	0.729447E-02
1889	0.112070	0.442562E-02
1890	0.472605E-02	0.323992E-02
1891	0.476647E-02	0.286440E-02
1892	0.586971E-03	-0.103879E-02
1893	0.496720E-03	-0.909767E-03
1894	0.385175E-01	-0.633996E-02
1895	0.398428E-01	-0.523405E-02
1896	0.108570	0.974019E-02
1897	0.109016	0.697673E-02
1898	0.508875E-02	0.354576E-02
1899	0.509753E-02	0.325053E-02
1900	0.710564E-03	-0.117027E-02
1901	0.606044E-03	-0.102888E-02
1902	0.360316E-01	-0.623023E-02
1903	0.372702E-01	-0.516515E-02
1904	0.105366	0.119530E-01
1905	0.105925	0.934155E-02
6	0.552566E-02	0.373102E-02
7	0.543798E-02	0.355108E-02
8	0.854362E-03	-0.130482E-02
9	0.736544E-03	-0.115256E-02
0	0.336416E-01	-0.611192E-02
1	0.348263E-01	-0.510413E-02
2	0.102070	0.138768E-01
3	0.102778	0.114395E-01
1914	0.606243E-02	0.379135E-02
1915	0.568528E-02	0.360896E-02
1916	0.101922E-02	-0.144176E-02
1917	0.887877E-03	-0.127880E-02
1918	0.313466E-01	-0.598508E-02
1919	0.325040E-01	-0.502948E-02
1920	0.986844E-01	0.154893E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.240

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1921	0.995612E-01	0.132281E-01
1922	0.672372E-02	0.380722E-02
1923	0.622426E-02	0.351745E-02
1924	0.120635E-02	-0.158059E-02
1925	0.106075E-02	-0.140675E-02

1926	0.291457E-01	-0.584996E-02
1927	0.302643E-01	-0.494674E-02
1928	0.952204E-01	0.167854E-01
1929	0.962688E-01	0.146953E-01
1930	0.753429E-02	0.386636E-02
1931	0.693392E-02	0.344841E-02
1932	0.141732E-02	-0.172083E-02
1933	0.125639E-02	-0.153586E-02
1934	0.270379E-01	-0.570681E-02
1935	0.281091E-01	-0.485869E-02
1936	0.916988E-01	0.177661E-01
1937	0.929092E-01	0.158401E-01
1938	0.847099E-02	0.400089E-02
1939	0.779127E-02	0.343723E-02
1940	0.165410E-02	-0.186174E-02
1941	0.147652E-02	-0.166562E-02
1942	0.250223E-01	-0.555590E-02
1943	0.260408E-01	-0.475883E-02
1944	0.881444E-01	0.184347E-01
1945	0.895005E-01	0.166680E-01
1946	0.953050E-02	0.422283E-02
1947	0.878848E-02	0.352285E-02
1948	0.191895E-02	-0.260223E-02
1949	0.172326E-02	-0.179539E-02
1950	0.230981E-01	-0.539741E-02
1951	0.240505E-01	-0.463239E-02
1952	0.845832E-01	0.187991E-01
1953	0.860666E-01	0.171867E-01
1954	0.107107E-01	0.453403E-02
1955	0.992327E-02	0.370777E-02
1956	0.221426E-02	-0.214056E-02
1957	0.199929E-02	-0.192470E-02
1958	0.212668E-01	-0.523183E-02
1959	0.221490E-01	-0.448145E-02
1960	0.810375E-01	0.188807E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.250

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
1961	0.826317E-01	0.174114E-01
1962	0.119842E-01	0.490788E-02
1963	0.111754E-01	0.398295E-02
1964	0.254201E-02	-0.227417E-02
1965	0.230669E-02	-0.205358E-02
1966	0.195377E-01	-0.506167E-02
1967	0.203539E-01	-0.433988E-02
1968	0.775234E-01	0.187311E-01
1969	0.792069E-01	0.173667E-01
1970	0.133352E-01	0.532343E-02
1971	0.125173E-01	0.432652E-02
1972	0.290138E-02	-0.239867E-02
1973	0.264632E-02	-0.217882E-02

1974 0.179282E-01 -0.489209E-02
 1975 0.186668E-01 -0.421619E-02
 1976 0.740533E-01 0.184358E-01
 1977 0.757978E-01 0.171184E-01
 1978 0.147574E-01 0.576729E-02
 1979 0.139300E-01 0.471806E-02
 1980 0.328223E-02 -0.250571E-02
 1981 0.301697E-02 -0.229449E-02
 1982 0.164448E-01 -0.472840E-02
 1983 0.171046E-01 -0.410151E-02
 1984 0.706382E-01 0.180858E-01
 1985 0.724086E-01 0.167648E-01
 1986 0.162508E-01 0.623005E-02
 1987 0.154082E-01 0.514052E-02
 1988 0.365731E-02 -0.258154E-02
 1989 0.340255E-02 -0.239392E-02
 1990 0.150737E-01 -0.457191E-02
 1991 0.156739E-01 -0.399385E-02
 1992 0.672956E-01 0.177405E-01
 1993 0.690516E-01 0.163894E-01
 1994 0.178181E-01 0.670630E-02
 1995 0.169530E-01 0.558184E-02
 1996 0.399282E-02 -0.261624E-02
 1997 0.376820E-02 -0.246756E-02
 1998 0.137977E-01 -0.441603E-02
 1999 0.143471E-01 -0.388019E-02
 2000 0.640406E-01 0.174182E-01

ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

I. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
 0
 SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2001	0.657579E-01	0.160541E-01
2002	0.194615E-01	0.719400E-02
2003	0.185681E-01	0.603499E-02
2004	0.427772E-02	-0.261278E-02
2005	0.408784E-02	-0.250922E-02
2006	0.125993E-01	-0.424362E-02
2007	0.131027E-01	-0.375040E-02
2008	0.609036E-01	0.171146E-01
2009	0.625552E-01	0.157682E-01
2010	0.211819E-01	0.769339E-02
2011	0.202563E-01	0.649731E-02
2012	0.453022E-02	-0.258576E-02
2013	0.435566E-02	-0.251742E-02
2014	0.114511E-01	-0.402365E-02
2015	0.119281E-01	-0.359365E-02
2016	0.579557E-01	0.168222E-01
2017	0.594948E-01	0.155106E-01
2018	0.229818E-01	0.820685E-02
2019	0.220201E-01	0.696959E-02
2020	0.478065E-02	-0.255123E-02
2021	0.459232E-02	-0.249796E-02

2022	0.103424E-01	-0.375031E-02
2023	0.108180E-01	-0.339074E-02
2024	0.552810E-01	0.165217E-01
2025	0.566533E-01	0.152721E-01
2026	0.248663E-01	0.873743E-02
2027	0.238638E-01	0.745528E-02
2028	0.504992E-02	-0.252084E-02
2029	0.482704E-02	-0.246291E-02
2030	0.928182E-02	-0.342937E-02
2031	0.976134E-02	-0.313560E-02
2032	0.528299E-01	0.161881E-01
2033	0.540901E-01	0.150237E-01
2034	0.268229E-01	0.928228E-02
2035	0.257915E-01	0.795728E-02
2036	0.534206E-02	-0.250650E-02
2037	0.508157E-02	-0.242451E-02
2038	0.828723E-02	-0.308477E-02
2039	0.874858E-02	-0.284267E-02
2040	0.504346E-01	0.157741E-01

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

 WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
 87.270
 FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2041	0.516862E-01	0.147212E-01
2042	0.287866E-01	0.982940E-02
2043	0.277744E-01	0.846870E-02
2044	0.563186E-02	-0.249106E-02
2045	0.535017E-02	-0.238693E-02
2046	0.740749E-02	-0.274181E-02
2047	0.781668E-02	-0.255552E-02
2048	0.480152E-01	0.152557E-01
2049	0.493106E-01	0.143132E-01
2050	0.306552E-01	0.103639E-01
2051	0.297383E-01	0.898491E-02
2052	0.560369E-02	-0.231703E-02
2053	0.586951E-02	-0.238553E-02
2054	0.703291E-02	-0.229338E-02
2055	0.673951E-02	-0.243232E-02
2056	0.455984E-01	0.146536E-01
2057	0.469283E-01	0.137918E-01
2058	0.324395E-01	0.109028E-01
2059	0.316108E-01	0.950826E-02
2060	0.431998E-01	0.140136E-01
2061	0.445514E-01	0.131930E-01
2062	0.343044E-01	0.114834E-01
2063	0.334687E-01	0.100754E-01
2064	0.408355E-01	0.133709E-01
2065	0.421706E-01	0.125700E-01
2066	0.363447E-01	0.121038E-01
2067	0.354540E-01	0.106929E-01
2068	0.385370E-01	0.127362E-01
2069	0.398419E-01	0.119478E-01

WHC-SD-W236A-DA-002
REVISION 0

2070 0.375751E-01 0.113271E-01
2071 0.104035 -0.394982E-01
2072 0.105374 -0.403754E-01
2073 -0.279354E-04 -0.642143E-04
2074 -0.235151E-04 -0.538079E-04
2075 0.265300E-05 -0.136751E-04
2076 0.104008 -0.372138E-01
2077 0.105561 -0.378733E-01
2078 -0.236270E-04 -0.918099E-04
2079 -0.274882E-04 -0.668101E-04
2080 -0.272226E-04 -0.727222E-04

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.280

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2081	0.240747E-05	-0.936151E-05
2082	0.103573	-0.351224E-01
2083	0.105304	-0.353678E-01
2084	0.108262	-0.397505E-01
2085	0.106885	-0.387762E-01
2086	0.750610E-05	-0.128432E-03
2087	-0.174669E-04	-0.999648E-04
2088	-0.731075E-06	-0.125522E-03
2089	0.777378E-06	-0.567431E-05
2090	0.102827	-0.333574E-01
2091	0.104579	-0.331224E-01
2092	0.111226	-0.388784E-01
2093	0.109736	-0.380383E-01
2094	0.593370E-04	-0.159825E-03
2095	0.400629E-04	-0.162905E-03
2096	-0.248220E-04	-0.602524E-04
2097	-0.205531E-05	-0.295902E-05
2098	0.101876	-0.318419E-01
2099	0.103506	-0.312871E-01
2100	0.114278	-0.376297E-01
2101	0.112585	-0.370708E-01
2102	0.124270E-03	-0.189465E-03
2103	0.946395E-04	-0.197542E-03
2104	-0.236977E-04	-0.741909E-04
2105	-0.584219E-05	-0.153003E-05
2106	0.102157	-0.297514E-01
2107	0.117439	-0.360385E-01
2108	0.115467	-0.357008E-01
2109	0.205261E-03	-0.220508E-03
2110	0.164471E-03	-0.235653E-03
2111	-0.149328E-04	-0.919445E-04
2112	-0.103143E-04	-0.163960E-05
2113	0.120717	-0.342611E-01
2114	0.118465	-0.339304E-01
2115	0.302927E-03	-0.250463E-03
2116	0.251429E-03	-0.276105E-03
2117	0.201825E-05	-0.112347E-03

2118 0.155302E-05 -0.124897E-03
2119 -0.151858E-04 -0.351300E-05
2120 0.124068 -0.324469E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.290

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2121	0.121665	-0.320072E-01
2122	0.417206E-03	-0.277237E-03
2123	0.355366E-03	-0.315875E-03
2124	0.253299E-04	-0.136469E-03
2125	0.254537E-04	-0.153460E-03
2126	-0.201296E-04	-0.738015E-05
2127	0.127356	-0.306508E-01
2128	0.124949	-0.301808E-01
2129	0.548651E-03	-0.299865E-03
2130	0.476494E-03	-0.352382E-03
2131	0.526763E-04	-0.163771E-03
2132	0.576529E-04	-0.193905E-03
2133	-0.247444E-04	-0.134836E-04
2134	0.130369	-0.288104E-01
2135	0.128050	-0.284257E-01
2136	0.697983E-03	-0.318133E-03
2137	0.615406E-03	-0.384445E-03
2138	0.795653E-04	-0.190364E-03
2139	0.907287E-04	-0.232940E-03
2140	-0.285233E-04	-0.220681E-04
2141	0.132884	-0.268337E-01
2142	0.130749	-0.266070E-01
2143	0.865816E-03	-0.332099E-03
2144	0.772765E-03	-0.411931E-03
2145	0.101412E-03	-0.213031E-03
2146	0.115664E-03	-0.259241E-03
2147	-0.308277E-04	-0.333540E-04
2148	0.134765	-0.247275E-01
2149	0.132922	-0.246483E-01
2150	0.105250E-02	-0.344509E-03
2151	0.949100E-03	-0.435144E-03
2152	0.115134E-03	-0.229522E-03
2153	0.132996E-03	-0.277972E-03
2154	-0.308799E-04	-0.474887E-04
2155	0.136000	-0.226680E-01
2156	0.134552	-0.226479E-01
2157	0.126640E-02	-0.365590E-03
2158	0.114189E-02	-0.459866E-03
2159	0.119066E-03	-0.237934E-03
2160	0.140582E-03	-0.286196E-03

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=

87.300

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2161	-0.278013E-04	-0.644809E-04
2162	0.136445	-0.206103E-01
2163	0.135669	-0.209129E-01
2164	0.152040E-02	-0.380002E-03
2165	0.135826E-02	-0.499388E-03
2166	0.146351E-02	-0.463604E-03
2167	0.110949E-03	-0.234343E-03
2168	0.144398E-03	-0.297805E-03
2169	-0.207442E-04	-0.841270E-04
2170	0.135957	-0.183967E-01
2171	0.135650	-0.198408E-01
2172	0.179922E-02	-0.370136E-03
2173	0.172068E-02	-0.543640E-03
2174	0.160294E-02	-0.467737E-03
2175	0.908321E-04	-0.216107E-03
2176	-0.948562E-05	-0.105559E-03
2177	0.134782	-0.160389E-01
2178	0.134425	-0.176482E-01
2179	0.208679E-02	-0.342183E-03
2180	0.202757E-02	-0.539140E-03
2181	0.665261E-04	-0.193933E-03
2182	0.442487E-05	-0.125482E-03
2183	0.133156	-0.136797E-01
2184	0.132871	-0.152926E-01
2185	0.239271E-02	-0.280564E-03
2186	0.234968E-02	-0.512816E-03
2187	0.422143E-04	-0.171453E-03
2188	0.207608E-04	-0.146518E-03
2189	0.131081	-0.115401E-01
2190	0.131093	-0.130624E-01
2191	0.272135E-02	-0.155756E-03
2192	0.269709E-02	-0.437630E-03
2193	0.128508	-0.963224E-02
2194	0.129125	-0.111663E-01
2195	0.307129E-02	0.700675E-04
2196	0.306287E-02	-0.273242E-03
2197	0.125482	-0.778677E-02
2198	0.126502	-0.959303E-02
2199	0.343576E-02	0.420597E-03
2200	0.343671E-02	0.145738E-04

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.310

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2201	0.122195	-0.579482E-02
2202	0.123352	-0.814163E-02
2203	0.380116E-02	0.884789E-03
2204	0.380767E-02	0.430113E-03
2205	0.118861	-0.354190E-02
2206	0.119872	-0.631147E-02
2207	0.415669E-02	0.141141E-02
2208	0.416986E-02	0.935223E-03
2209	0.115609	-0.106304E-02
2210	0.116393	-0.407676E-02
2211	0.449509E-02	0.194226E-02
2212	0.451918E-02	0.146804E-02
2213	0.112463	0.153097E-02
2214	0.113054	-0.155568E-02
2215	0.481649E-02	0.243424E-02
2216	0.485694E-02	0.198319E-02
2217	0.109395	0.412090E-02
2218	0.109858	0.108371E-02
2219	0.513466E-02	0.287435E-02
2220	0.518769E-02	0.245973E-02
2221	0.106362	0.659083E-02
2222	0.106774	0.369384E-02
2223	0.544554E-02	0.325309E-02
2224	0.552597E-02	0.291112E-02
2225	0.103327	0.884071E-02
2226	0.103761	0.614189E-02
2227	0.584086E-02	0.333389E-02
2228	0.100259	0.108032E-01
2229	0.100779	0.833121E-02
2230	0.642289E-02	0.316193E-02
2231	0.592471E-02	0.298644E-02
2232	0.971342E-01	0.124460E-01
2233	0.977881E-01	0.102035E-01
2234	0.717538E-02	0.302715E-02
2235	0.656233E-02	0.273295E-02
2236	0.939453E-01	0.137613E-01
2237	0.947604E-01	0.117370E-01
2238	0.808896E-02	0.297207E-02
2239	0.736399E-02	0.253206E-02
2240	0.906978E-01	0.147529E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.320

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2241	0.916813E-01	0.129288E-01
2242	0.915976E-02	0.302190E-02

2243 0.834543E-02 0.243137E-02
2244 0.874089E-01 0.154307E-01
2245 0.885521E-01 0.137880E-01
2246 0.103713E-01 0.317206E-02
2247 0.949845E-02 0.244018E-02
2248 0.841009E-01 0.158097E-01
2249 0.853866E-01 0.143297E-01
2250 0.116939E-01 0.341470E-02
2251 0.107938E-01 0.255585E-02
2252 0.807857E-01 0.159074E-01
2253 0.822045E-01 0.145765E-01
2254 0.130979E-01 0.373070E-02
2255 0.121948E-01 0.276901E-02
2256 0.774628E-01 0.157617E-01
2257 0.790032E-01 0.145367E-01
2258 0.145668E-01 0.409771E-02
2259 0.136701E-01 0.306005E-02
2260 0.741327E-01 0.154516E-01
2261 0.757794E-01 0.142733E-01
2262 0.160964E-01 0.449668E-02
2263 0.152042E-01 0.340623E-02
2264 0.708008E-01 0.150690E-01
2265 0.725071E-01 0.138509E-01
2266 0.176889E-01 0.491364E-02
2267 0.167933E-01 0.378652E-02
2268 0.674927E-01 0.147009E-01
2269 0.692219E-01 0.134250E-01
2270 0.193485E-01 0.534070E-02
2271 0.184398E-01 0.418495E-02
2272 0.642516E-01 0.144002E-01
2273 0.659520E-01 0.130569E-01
2274 0.210798E-01 0.577549E-02
2275 0.201489E-01 0.459221E-02
2276 0.611270E-01 0.141592E-01
2277 0.627570E-01 0.127944E-01
2278 0.228871E-01 0.621972E-02
2279 0.219264E-01 0.500541E-02
2280 0.581769E-01 0.139569E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.340

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2281	0.596969E-01	0.126124E-01
2282	0.247737E-01	0.667667E-02
2283	0.237778E-01	0.542630E-02
2284	0.554507E-01	0.137720E-01
2285	0.568362E-01	0.124821E-01
2286	0.267281E-01	0.714535E-02
2287	0.257069E-01	0.585793E-02
2288	0.529351E-01	0.135579E-01
2289	0.542185E-01	0.123549E-01
2290	0.287130E-01	0.762550E-02

2291	0.276952E-01	0.629767E-02
2292	0.505497E-01	0.132614E-01
2293	0.518024E-01	0.121681E-01
2294	0.306836E-01	0.812845E-02
2295	0.297073E-01	0.675401E-02
2296	0.482095E-01	0.128491E-01
2297	0.494879E-01	0.118535E-01
2298	0.326310E-01	0.867631E-02
2299	0.317086E-01	0.724991E-02
2300	0.458668E-01	0.123284E-01
2301	0.471753E-01	0.114008E-01
2302	0.346078E-01	0.927775E-02
2303	0.337080E-01	0.781432E-01
2304	0.435071E-01	0.117448E-01
2305	0.448354E-01	0.108572E-01
2306	0.366722E-01	0.990890E-02
2307	0.357635E-01	0.843770E-02
2308	0.411623E-01	0.111412E-01
2309	0.424781E-01	0.102778E-01
2310	0.388658E-01	0.105323E-01
2311	0.379024E-01	0.907569E-02
2312	0.401593E-01	0.968793E-02
2313	0.106842	-0.360609E-01
2314	0.108368	-0.370451E-01
2315	0.605499E-02	0.256890E-02
2316	0.558030E-02	0.248888E-02
2317	0.106295	-0.334058E-01
2318	0.108130	-0.341323E-01
2319	0.673589E-02	0.225597E-02
2320	0.614014E-02	0.209437E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.350

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2321	0.293290E-04	-0.163489E-03
2322	0.253278E-04	-0.160175E-03
2323	0.105242	-0.310885E-01
2324	0.107324	-0.312559E-01
2325	0.111101	-0.362161E-01
2326	0.109651	-0.351346E-01
2327	0.759929E-02	0.201410E-02
2328	0.685969E-02	0.173461E-02
2329	0.522693E-02	0.199947E-02
2330	0.565955E-02	0.202947E-02
2331	0.731543E-04	-0.201501E-03
2332	0.609175E-04	-0.201464E-03
2333	0.103767	-0.292229E-01
2334	0.105868	-0.287917E-01
2335	0.113779	-0.351278E-01
2336	0.112360	-0.342894E-01
2337	0.866028E-02	0.187393E-02
2338	0.778925E-02	0.144277E-02

2339 0.487662E-02 0.149666E-02
 2340 0.527459E-02 0.152540E-02
 2341 0.132770E-03 -0.243510E-03
 2342 0.109836E-03 -0.243307E-03
 2343 0.581218E-04 -0.204171E-03
 2344 0.563407E-04 -0.202595E-03
 2345 0.101957 -0.276368E-01
 2346 0.103891 -0.269027E-01
 2347 0.116496 -0.335785E-01
 2348 0.114857 -0.333401E-01
 2349 0.989958E-02 0.184589E-02
 2350 0.895035E-02 0.125711E-02
 2351 0.452478E-02 0.974506E-03
 2352 0.490354E-02 0.102433E-02
 2353 0.208404E-03 -0.290624E-03
 2354 0.173248E-03 -0.291867E-03
 2355 0.962571E-04 -0.257093E-03
 2356 0.920990E-04 -0.254824E-03
 2357 0.107702E-03 -0.278891E-03
 2358 0.999351E-01 -0.259501E-01
 2359 0.101672 -0.253502E-01
 2360 0.119412 -0.316640E-01

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.360

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2361	0.117374	-0.316515E-01
2362	0.112772E-01	0.192862E-02
2363	0.103154E-01	0.120144E-02
2364	0.416628E-02	0.456924E-03
2365	0.454479E-02	0.517622E-03
2366	0.301460E-03	-0.340779E-03
2367	0.253713E-03	-0.347775E-03
2368	0.127397E-03	-0.297954E-03
2369	0.150665E-03	-0.348261E-03
2370	0.979079E-01	-0.232930E-01
2371	0.994994E-01	-0.237430E-01
2372	0.122542	-0.297321E-01
2373	0.120119	-0.293044E-01
2374	0.127516E-01	0.211256E-02
2375	0.118021E-01	0.126394E-02
2376	0.379715E-02	-0.340308E-05
2377	0.418675E-02	0.310088E-04
2378	0.412037E-03	-0.390343E-03
2379	0.352323E-03	-0.407852E-03
2380	0.147789E-03	-0.321216E-03
2381	0.166336E-03	-0.368593E-03
2382	0.953559E-01	-0.200557E-01
2383	0.985002E-01	-0.220212E-01
2384	0.973826E-01	-0.200145E-01
2385	0.125637	-0.279498E-01
2386	0.123498	-0.276582E-01

2387 0.142929E-01 0.237869E-02
 2388 0.133590E-01 0.142821E-02
 2389 0.341762E-02 -0.353143E-03
 2390 0.381982E-02 -0.382324E-03
 2391 0.540428E-03 -0.436404E-03
 2392 0.470076E-03 -0.467611E-03
 2393 0.158956E-03 -0.332212E-03
 2394 0.177296E-03 -0.379077E-03
 2395 0.923233E-01 -0.170401E-01
 2396 0.946201E-01 -0.176441E-01
 2397 0.128425 -0.262183E-01
 2398 0.126219 -0.260154E-01
 2399 0.158867E-01 0.270309E-02
 2400 0.149798E-01 0.167808E-02

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.370

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2401	0.303262E-02	-0.571878E-03
2402	0.343781E-02	-0.676129E-03
2403	0.687216E-03	-0.477807E-03
2404	0.607145E-03	-0.522877E-03
2405	0.166454E-03	-0.343964E-03
2406	0.185780E-03	-0.388217E-03
2407	0.892417E-01	-0.140320E-01
2408	0.919906E-01	-0.145357E-01
2409	0.130782	-0.244188E-01
2410	0.128647	-0.243196E-01
2411	0.175298E-01	0.306277E-02
2412	0.166449E-01	0.199130E-02
2413	0.265298E-02	-0.679802E-03
2414	0.304533E-02	-0.847195E-03
2415	0.853026E-03	-0.514629E-03
2416	0.762914E-03	-0.572452E-03
2417	0.190307E-03	-0.395689E-03
2418	0.858283E-01	-0.111361E-01
2419	0.888257E-01	-0.115731E-01
2420	0.132705	-0.225671E-01
2421	0.130688	-0.224803E-01
2422	0.192256E-01	0.344015E-02
2423	0.183389E-01	0.233276E-02
2424	0.229144E-02	-0.717058E-03
2425	0.264871E-02	-0.917480E-03
2426	0.103572E-02	-0.549697E-03
2427	0.937879E-03	-0.617680E-03
2428	0.820536E-01	-0.862272E-02
2429	0.853177E-01	-0.847113E-02
2430	0.134219	-0.208921E-01
2431	0.132471	-0.206070E-01
2432	0.209807E-01	0.382512E-02
2433	0.200795E-01	0.267008E-02
2434	0.194915E-02	-0.718965E-03

2435 0.226365E-02 -0.920492E-03
 2436 0.123085E-02 -0.590660E-03
 2437 0.112432E-02 -0.661755E-03
 2438 0.780461E-01 -0.669139E-02
 2439 0.812858E-01 -0.619408E-02
 2440 0.134120 -0.190914E-01

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
 87.380
 FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2441	0.228020E-01	0.421457E-02
2442	0.218843E-01	0.301575E-02
2443	0.190017E-02	-0.905830E-03
2444	0.170072E-02	-0.754037E-03
2445	0.166249E-02	-0.629966E-03
2446	0.132222E-02	-0.720776E-03
2447	0.141412E-02	-0.628482E-03
2448	0.739738E-01	-0.534521E-02
2449	0.772370E-01	-0.444889E-02
2450	0.132518	-0.169000E-01
2451	0.132369	-0.188063E-01
2452	0.246957E-01	0.460991E-02
2453	0.237517E-01	0.339059E-02
2454	0.699451E-01	-0.452820E-02
2455	0.731261E-01	-0.315702E-02
2456	0.130813	-0.146724E-01
2457	0.130154	-0.165561E-01
2458	0.266590E-01	0.501246E-02
2459	0.256870E-01	0.377143E-02
2460	0.660401E-01	-0.417150E-02
2461	0.689305E-01	-0.236368E-02
2462	0.129141	-0.126855E-01
2463	0.128441	-0.140962E-01
2464	0.286754E-01	0.542761E-02
2465	0.276886E-01	0.414520E-02
2466	0.623435E-01	-0.409490E-02
2467	0.646315E-01	-0.237620E-02
2468	0.127121	-0.111246E-01
2469	0.127106	-0.121290E-01
2470	0.307197E-01	0.587489E-02
2471	0.297423E-01	0.453688E-02
2472	0.588806E-01	-0.411689E-02
2473	0.608536E-01	-0.254599E-02
2474	0.124372	-0.994624E-02
2475	0.125901	-0.114652E-01
2476	0.327742E-01	0.638431E-02
2477	0.318278E-01	0.497730E-02
2478	0.556221E-01	-0.413729E-02
2479	0.572607E-01	-0.281470E-02
2480	0.121027	-0.865559E-02

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
 87.390
 FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2481	0.122660	-0.108809E-01
2482	0.348522E-01	0.696807E-02
2483	0.339345E-01	0.550249E-02
2484	0.525331E-01	-0.411271E-02
2485	0.540766E-01	-0.287169E-02
2486	0.117401	-0.684073E-02
2487	0.118831	-0.963984E-02
2488	0.369816E-01	0.759725E-02
2489	0.360724E-01	0.611040E-02
2490	0.232491E-03	-0.490449E-03
2491	0.205192E-03	-0.434415E-03
2492	0.495637E-01	-0.406458E-02
2493	0.510788E-01	-0.283575E-02
2494	0.113833	-0.456017E-02
2495	0.114978	-0.769869E-02
2496	0.391822E-01	0.822479E-02
2497	0.382513E-01	0.674926E-02
2498	0.286222E-03	-0.596937E-03
2499	0.227760E-03	-0.484220E-03
2500	0.259016E-03	-0.546064E-03
2501	0.466871E-01	-0.405195E-02
2502	0.481526E-01	-0.278873E-02
2503	0.110442	-0.199076E-02
2504	0.111326	-0.526891E-02
2505	0.414609E-01	0.881906E-02
2506	0.404851E-01	0.736655E-02
2507	0.347477E-03	-0.698191E-03
2508	0.290428E-03	-0.601342E-03
2509	0.439117E-01	-0.407758E-02
2510	0.453586E-01	-0.289397E-02
2511	0.107230	0.670469E-03
2512	0.107877	-0.260626E-02
2513	0.437921E-01	0.938550E-02
2514	0.427781E-01	0.793577E-02
2515	0.418596E-03	-0.793897E-03
2516	0.352371E-03	-0.692820E-03
2517	0.412163E-01	-0.407979E-02
2518	0.426645E-01	-0.307506E-02
2519	0.104165	0.325922E-02
2520	0.104634	0.116788E-03

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 C
 87.400
 FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2521	0.461305E-01	0.992601E-02
2522	0.451089E-01	0.847432E-02
2523	0.512380E-03	-0.899303E-03
2524	0.426449E-03	-0.778905E-03
2525	0.385766E-01	-0.405028E-02
2526	0.400136E-01	-0.289437E-02
2527	0.101204	0.564654E-02
2528	0.101574	0.273189E-02
2529	0.484415E-01	0.104030E-01
2530	0.474235E-01	0.896454E-02
2531	0.628570E-03	-0.101081E-02
2532	0.528812E-03	-0.879460E-03
2533	0.360465E-01	-0.403131E-02
2534	0.372311E-01	-0.294186E-02
2535	0.982989E-01	0.774501E-02
2536	0.986549E-01	0.511016E-02
2537	0.507296E-01	0.107598E-01
2538	0.496914E-01	0.935837E-02
2539	0.766532E-03	-0.112634E-02
2540	0.655506E-03	-0.987445E-03
2541	0.336709E-01	-0.401369E-02
2542	0.347594E-01	-0.309208E-02
2543	0.954046E-01	0.950713E-02
2544	0.958235E-01	0.716790E-02
2545	0.530749E-01	0.109656E-01
2546	0.519690E-01	0.958847E-02
2547	0.925697E-03	-0.124378E-02
2548	0.803173E-03	-0.109742E-02
2549	0.314038E-01	-0.398268E-02
2550	0.325280E-01	-0.303953E-02
2551	0.924861E-01	0.109161E-01
2552	0.930285E-01	0.886380E-02
2553	0.555914E-01	0.110655E-01
2554	0.543797E-01	0.967765E-02
2555	0.110677E-02	-0.136228E-02
2556	0.971823E-03	-0.120814E-02
2557	0.292097E-01	-0.394705E-02
2558	0.302944E-01	-0.304969E-02
2559	0.895245E-01	0.119744E-01
2560	0.902287E-01	0.101849E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.410
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY

2561	0.583403E-01	0.111370E-01
2562	0.570325E-01	0.967579E-02
2563	0.131108E-02	-0.148133E-02
2564	0.116194E-02	-0.131833E-02
2565	0.270939E-01	-0.390244E-02
2566	0.281428E-01	-0.306938E-02
2567	0.865180E-01	0.126964E-01
2568	0.873982E-01	0.111380E-01
2569	0.613077E-01	0.112457E-01
2570	0.599379E-01	0.972347E-02
2571	0.154048E-02	-0.160055E-02
2572	0.137503E-02	-0.142560E-02
2573	0.250507E-01	-0.382703E-02
2574	0.260725E-01	-0.306689E-02
2575	0.834776E-01	0.131045E-01
2576	0.845285E-01	0.117428E-01
2577	0.644364E-01	0.114481E-01
2578	0.630262E-01	0.987694E-02
2579	0.179750E-02	-0.171999E-02
2580	0.161350E-02	-0.152990E-02
2581	0.230833E-01	-0.370807E-02
2582	0.240764E-01	-0.296255E-02
2583	0.804077E-01	0.132115E-01
2584	0.816245E-01	0.120283E-01
2585	0.676596E-01	0.117776E-01
2586	0.662134E-01	0.101960E-01
2587	0.208461E-02	-0.184094E-02
2588	0.188161E-02	-0.164047E-02
2589	0.212188E-01	-0.358164E-02
2590	0.221269E-01	-0.279023E-02
2591	0.773028E-01	0.130511E-01
2592	0.786800E-01	0.119981E-01
2593	0.709072E-01	0.122046E-01
2594	0.694244E-01	0.106629E-01
2595	0.240296E-02	-0.196278E-02
2596	0.218040E-02	-0.176025E-02
2597	0.194660E-01	-0.348748E-02
2598	0.202794E-01	-0.270486E-02
2599	0.741342E-01	0.126723E-01
2600	0.756804E-01	0.117044E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.420
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2601	0.725927E-01	0.112030E-01
2602	0.275330E-02	-0.208030E-02
2603	0.250158E-02	-0.188325E-02
2604	0.178269E-01	-0.341986E-02
2605	0.185603E-01	-0.267684E-02
2606	0.312952E-02	-0.218811E-02
2607	0.285384E-02	-0.198224E-02
2608	0.163184E-01	-0.336225E-02

2609 0.169542E-01 -0.268377E-02
 2610 0.350790E-02 -0.228197E-02
 2611 0.324737E-02 -0.209524E-02
 2612 0.149326E-01 -0.329824E-02
 2613 0.155471E-01 -0.273700E-02
 2614 0.385787E-02 -0.235758E-02
 2615 0.362190E-02 -0.218224E-02
 2616 0.136386E-01 -0.321210E-02
 2617 0.142259E-01 -0.270079E-02
 2618 0.415806E-02 -0.240678E-02
 2619 0.398261E-02 -0.227869E-02
 2620 0.124222E-01 -0.310218E-02
 2621 0.129696E-01 -0.258280E-02
 2622 0.440726E-02 -0.242002E-02
 2623 0.425595E-02 -0.234353E-02
 2624 0.112874E-01 -0.296498E-02
 2625 0.117370E-01 -0.251156E-02
 2626 0.462756E-02 -0.239830E-02
 2627 0.446444E-02 -0.234866E-02
 2628 0.102282E-01 -0.278375E-02
 2629 0.106429E-01 -0.243372E-02
 2630 0.484803E-02 -0.235308E-02
 2631 0.464686E-02 -0.230561E-02
 2632 0.922102E-02 -0.255507E-02
 2633 0.965867E-02 -0.228300E-02
 2634 0.508171E-02 -0.229405E-02
 2635 0.484756E-02 -0.223804E-02
 2636 0.827030E-02 -0.231254E-02
 2637 0.871233E-02 -0.207433E-02
 2638 0.531855E-02 -0.222087E-02
 2639 0.506017E-02 -0.214686E-02
 2640 0.742480E-02 -0.209105E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
 87.430

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2641	0.783203E-02	-0.187536E-02
2642	0.528361E-02	-0.203001E-02
2643	0.551668E-02	-0.207218E-02
2644	0.706352E-02	-0.170601E-02
2645	0.676303E-02	-0.193588E-02
2646	0.109154	-0.319973E-01
2647	0.110912	-0.331991E-01
2648	0.130450	-0.205190E-01
2649	0.130010	-0.184610E-01
2650	0.625224E-02	0.159591E-02
2651	0.570941E-02	0.153949E-02
2652	0.963809E-04	-0.245556E-03
2653	0.906563E-04	-0.247478E-03
2654	0.196745E-03	-0.425625E-03
2655	0.107940	-0.289738E-01
2656	0.110455	-0.296858E-01

2657	0.128549	-0.223789E-01
2658	0.128321	-0.206803E-01
2659	0.702967E-02	0.119383E-02
2660	0.632854E-02	0.107777E-02
2661	0.148692E-03	-0.292129E-03
2662	0.132171E-03	-0.288785E-03
2663	0.190547E-03	-0.418294E-03
2664	0.227358E-03	-0.486103E-03
2665	0.105976	-0.264869E-01
2666	0.108667	-0.262970E-01
2667	0.113438	-0.324954E-01
2668	0.112213	-0.308886E-01
2669	0.126437	-0.241139E-01
2670	0.126460	-0.224387E-01
2671	0.127788	-0.159757E-01
2672	0.127878	-0.186206E-01
2673	0.126874	-0.178320E-01
2674	0.805235E-02	0.860424E-03
2675	0.715054E-02	0.625299E-03
2676	0.529992E-02	0.103587E-02
2677	0.577905E-02	0.104473E-02
2678	0.216532E-03	-0.348446E-03
2679	0.185540E-03	-0.337897E-03
2680	0.125711E-03	-0.293421E-03

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
 87.440

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000

LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2681	0.122211E-03	-0.295103E-03
2682	0.224391E-03	-0.471334E-03
2683	0.200596E-03	-0.424428E-03
2684	0.163279E-03	-0.368168E-03
2685	0.103586	-0.246304E-01
2686	0.105811	-0.237321E-01
2687	0.115736	-0.314039E-01
2688	0.114842	-0.307829E-01
2689	0.124076	-0.257203E-01
2690	0.124464	-0.240623E-01
2691	0.126409	-0.135356E-01
2692	0.124965	-0.151916E-01
2693	0.933836E-02	0.643303E-03
2694	0.828121E-02	0.166763E-03
2695	0.491848E-02	0.546866E-03
2696	0.534412E-02	0.557200E-03
2697	0.302187E-03	-0.413648E-03
2698	0.258606E-03	-0.404735E-03
2699	0.101217	-0.231542E-01
2700	0.102828	-0.222236E-01
2701	0.118080	-0.292808E-01
2702	0.115972	-0.300050E-01
2703	0.121071	-0.272249E-01
2704	0.121869	-0.254690E-01

2705 0.124187 -0.124035E-01
 2706 0.108168E-01 0.559152E-03
 2707 0.983525E-02 -0.108213E-04
 2708 0.455698E-02 0.657505E-04
 2709 0.495434E-02 0.954285E-04
 2710 0.407563E-03 -0.483701E-03
 2711 0.346507E-03 -0.477175E-03
 2712 0.100265 -0.210532E-01
 2713 0.117867 -0.272511E-01
 2714 0.120089 -0.261839E-01
 2715 0.120461 -0.118691E-01
 2716 0.122748 -0.140521E-01
 2717 0.123900E-01 0.594792E-03
 2718 0.114305E-01 -0.148998E-03
 2719 0.419916E-02 -0.377923E-03
 2720 0.459422E-02 -0.347184E-03

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.450

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2721	0.533608E-03	-0.552809E-03
2722	0.462235E-03	-0.563768E-03
2723	0.116404	-0.104988E-01
2724	0.118192	-0.135215E-01
2725	0.140278E-01	0.737187E-03
2726	0.130835E-01	-0.841542E-04
2727	0.383086E-02	-0.733059E-03
2728	0.424505E-02	-0.742215E-03
2729	0.679391E-03	-0.616441E-03
2730	0.604675E-03	-0.643734E-03
2731	0.112464	-0.840382E-02
2732	0.113870	-0.115879E-01
2733	0.157206E-01	0.971452E-03
2734	0.148139E-01	-0.289417E-04
2735	0.344543E-02	-0.971020E-03
2736	0.388025E-02	-0.104540E-02
2737	0.844134E-03	-0.674453E-03
2738	0.761047E-03	-0.713875E-03
2739	0.108752	-0.587634E-02
2740	0.109946	-0.925541E-02
2741	0.174376E-01	0.126414E-02
2742	0.166000E-01	0.284487E-03
2743	0.304010E-02	-0.109592E-02
2744	0.349671E-02	-0.124515E-02
2745	0.102314E-02	-0.728197E-03
2746	0.935221E-03	-0.778651E-03
2747	0.105272	-0.314796E-02
2748	0.106210	-0.661820E-02
2749	0.191771E-01	0.156510E-02
2750	0.183218E-01	0.549404E-03
2751	0.262122E-02	-0.112728E-02
2752	0.309789E-02	-0.138014E-02

2753 0.121246E-02 -0.788800E-03
 2754 0.111860E-02 -0.837996E-03
 2755 0.102034 -0.395878E-03
 2756 0.102697 -0.380516E-02
 2757 0.209677E-01 0.186255E-02
 2758 0.200878E-01 0.773119E-03
 2759 0.221418E-02 -0.111371E-02
 2760 0.260034E-02 -0.134123E-02

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.460

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2761	0.130047E-02	-0.898993E-03
2762	0.139970E-02	-0.882075E-03
2763	0.138642E-02	-0.800852E-03
2764	0.990169E-01	0.221133E-02
2765	0.994527E-01	-0.997573E-03
2766	0.228187E-01	0.219250E-02
2767	0.220047E-01	0.100030E-02
2768	0.218828E-02	-0.129320E-02
2769	0.202224E-02	-0.123470E-02
2770	0.185289E-02	-0.105143E-02
2771	0.961714E-01	0.454865E-02
2772	0.964608E-01	0.163804E-02
2773	0.247277E-01	0.255253E-02
2774	0.238799E-01	0.147307E-02
2775	0.934394E-01	0.653902E-02
2776	0.936755E-01	0.397673E-02
2777	0.267012E-01	0.290478E-02
2778	0.257748E-01	0.180130E-02
2779	0.907629E-01	0.814536E-02
2780	0.910368E-01	0.594324E-02
2781	0.287405E-01	0.325457E-02
2782	0.277831E-01	0.210209E-02
2783	0.880936E-01	0.935940E-02
2784	0.884826E-01	0.750146E-02
2785	0.308363E-01	0.363773E-02
2786	0.298673E-01	0.242322E-02
2787	0.853990E-01	0.101933E-01
2788	0.859576E-01	0.864493E-02
2789	0.329749E-01	0.409108E-02
2790	0.320287E-01	0.278524E-02
2791	0.826645E-01	0.106732E-01
2792	0.834203E-01	0.938851E-02
2793	0.351420E-01	0.463765E-02
2794	0.342515E-01	0.323875E-02
2795	0.798841E-01	0.108185E-01
2796	0.808448E-01	0.976256E-02
2797	0.373296E-01	0.525407E-02
2798	0.364675E-01	0.381381E-02
2799	0.770425E-01	0.106515E-01
2800	0.782175E-01	0.978260E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
\$7.470

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2841	0.156010E-03	-0.332076E-03
2842	0.261706E-03	-0.541812E-03
2843	0.292488E-03	-0.596314E-03
2844	0.108490	-0.235523E-01
2845	0.112019	-0.251822E-01
2846	0.110578	-0.228865E-01
2847	0.124484	-0.223850E-01
2848	0.124238	-0.208401E-01
2849	0.124120	-0.192033E-01
2850	0.734985E-02	-0.194473E-04
2851	0.649098E-02	0.839881E-05
2852	0.225887E-03	-0.393384E-03
2853	0.207500E-03	-0.387881E-03
2854	0.293753E-03	-0.587122E-03
2855	0.284423E-03	-0.552179E-03
2856	0.105037	-0.213392E-01
2857	0.107014	-0.201643E-01
2858	0.115760	-0.279625E-01
2859	0.122255	-0.238088E-01
2860	0.122578	-0.225525E-01
2861	0.115652	-0.146182E-01
2862	0.119326	-0.171121E-01
2863	0.116936	-0.173813E-01
2864	0.873548E-02	-0.447722E-03
2865	0.736362E-02	-0.610207E-03
2866	0.790436E-02	-0.692337E-03
2867	0.537724E-02	0.825704E-04
2868	0.587538E-02	0.399582E-04
2869	0.300974E-03	-0.466662E-03
2870	0.241899E-03	-0.425220E-03
2871	0.279553E-03	-0.457047E-03
2872	0.357360E-03	-0.679013E-03
2873	0.101861	-0.201350E-01
2874	0.103262	-0.186361E-01
2875	0.117121	-0.250025E-01
2876	0.115137	-0.259316E-01
2877	0.121208	-0.231717E-01
2878	0.119343	-0.239482E-01
2879	0.111344	-0.124421E-01
2880	0.112839	-0.153808E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
\$7.490

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2801	-0.395413E-01	0.588317E-02
2802	0.386575E-01	0.444756E-02
2803	0.741210E-01	0.102314E-01
2804	0.755043E-01	0.947553E-02
2805	0.417889E-01	0.647689E-02
2806	0.408598E-01	0.506377E-02
2807	0.710899E-01	0.965488E-02
2808	0.726852E-01	0.891229E-02
2809	0.440814E-01	0.701936E-02
2810	0.430959E-01	0.562216E-02
2811	0.679573E-01	0.907384E-02
2812	0.697176E-01	0.821441E-02
2813	0.463894E-01	0.750873E-02
2814	0.453748E-01	0.610913E-02
2815	0.647827E-01	0.861846E-02
2816	0.666242E-01	0.755321E-02
2817	0.486625E-01	0.791734E-02
2818	0.476394E-01	0.651297E-02
2819	0.616376E-01	0.835105E-02
2820	0.634521E-01	0.707318E-02
2821	0.509208E-01	0.818646E-02
2822	0.498762E-01	0.680045E-02
2823	0.586140E-01	0.826141E-02
2824	0.603062E-01	0.686656E-02
2825	0.532632E-01	0.830112E-02
2826	0.521433E-01	0.692076E-02
2827	0.558079E-01	0.828884E-02
2828	0.573251E-01	0.683985E-02
2829	0.545948E-01	0.690965E-02
2830	0.111177	-0.270130E-01
2831	0.113614	-0.291842E-01
2832	0.112994	-0.271360E-01
2833	0.126229	-0.207381E-01
2834	0.126113	-0.191025E-01
2835	0.124057	-0.170420E-01
2836	0.120474	-0.157165E-01
2837	0.121852	-0.171743E-01
2838	0.643490E-02	0.542341E-03
2839	0.582476E-02	0.543396E-03
2840	0.167875E-03	-0.335367E-03

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
\$7.480

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

NODE	UX	UY
2881	0.104186E-01	-0.692924E-03
2882	0.994670E-02	-0.934981E-03
2883	0.956875E-02	-0.941937E-03
2884	0.914726E-02	-0.844345E-03
2885	0.498536E-02	-0.343559E-03
2886	0.540567E-02	-0.375774E-03
2887	0.398315E-03	-0.554564E-03
2888	0.359596E-03	-0.542750E-03
2889	0.319515E-03	-0.495541E-03
2890	0.439404E-03	-0.760527E-03
2891	0.350159E-03	-0.639711E-03
2892	0.991294E-01	-0.190612E-01
2893	0.100410	-0.184149E-01
2894	0.107394	-0.999577E-02
2895	0.108830	-0.131850E-01
2896	0.121002E-01	-0.815980E-03
2897	0.114487E-01	-0.140276E-02
2898	0.107727E-01	-0.108095E-02
2899	0.463187E-02	-0.741202E-03
2900	0.501485E-02	-0.743930E-03
2901	0.529253E-03	-0.652970E-03
2902	0.501465E-03	-0.679432E-03
2903	0.416118E-03	-0.595347E-03
2904	0.552023E-03	-0.857197E-03
2905	0.457127E-03	-0.739181E-03
2906	0.966354E-01	-0.176100E-01
2907	0.979691E-01	-0.172574E-01
2908	0.103624	-0.726893E-02
2909	0.104886	-0.106754E-01
2910	0.138470E-01	-0.840387E-03
2911	0.129445E-01	-0.140270E-02
2912	0.428664E-02	-0.108423E-02
2913	0.467276E-02	-0.106513E-02
2914	0.682221E-03	-0.740120E-03
2915	0.655356E-03	-0.778238E-03
2916	0.688309E-03	-0.959348E-03
2917	0.581468E-03	-0.831117E-03
2918	0.942849E-01	-0.151330E-01
2919	0.958275E-01	-0.157652E-01
2920	0.100105	-0.439496E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.500
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2921	0.101088	-0.788497E-02
2922	0.156708E-01	-0.717553E-03
2923	0.151198E-01	-0.150391E-02
2924	0.144646E-01	-0.152075E-02
2925	0.392717E-02	-0.134251E-02
2926	0.437284E-02	-0.140156E-02
2927	0.847898E-03	-0.817121E-03

2928	0.817320E-03	-0.863691E-03
2929	0.845270E-03	-0.106247E-02
2930	0.734990E-03	-0.935073E-03
2931	0.915704E-01	-0.120645E-01
2932	0.942262E-01	-0.122844E-01
2933	0.968872E-01	-0.155469E-02
2934	0.975663E-01	-0.494102E-02
2935	0.174657E-01	-0.430976E-03
2936	0.167383E-01	-0.125689E-02
2937	0.355549E-02	-0.154343E-02
2938	0.398575E-02	-0.160289E-02
2939	0.102677E-02	-0.887320E-03
2940	0.996693E-03	-0.943805E-03
2941	0.102269E-02	-0.116491E-02
2942	0.901952E-03	-0.103215E-02
2943	0.883031E-01	-0.887571E-02
2944	0.906369E-01	-0.895373E-02
2945	0.939569E-01	0.108411E-02
2946	0.943437E-01	-0.199728E-02
2947	0.192154E-01	-0.240986E-03
2948	0.184166E-01	-0.110988E-02
2949	0.307410E-02	-0.159482E-02
2950	0.346072E-02	-0.183975E-02
2951	0.368568E-02	-0.179603E-02
2952	0.120325E-02	-0.946111E-03
2953	0.118602E-02	-0.101166E-02
2954	0.122117E-02	-0.126353E-02
2955	0.108835E-02	-0.112624E-02
2956	0.845256E-01	-0.600972E-02
2957	0.871415E-01	-0.532558E-02
2958	0.912660E-01	0.339840E-02
2959	0.914422E-01	0.736239E-03
2960	0.211065E-01	-0.892518E-04

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.510
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
2961	0.201730E-01	-0.102226E-02
2962	0.257289E-02	-0.152420E-02
2963	0.297848E-02	-0.175599E-02
2964	0.137896E-02	-0.105123E-02
2965	0.144275E-02	-0.135605E-02
2966	0.129072E-02	-0.120825E-02
2967	0.804556E-01	-0.391912E-02
2968	0.832521E-01	-0.386620E-02
2969	0.887503E-01	0.531480E-02
2970	0.888530E-01	0.307952E-02
2971	0.230499E-01	0.272792E-03
2972	0.221227E-01	-0.978404E-03
2973	0.226462E-01	-0.560653E-03
2974	0.239712E-02	-0.161746E-02
2975	0.256011E-02	-0.165630E-02

2976 0.218764E-02 -0.142385E-02
2977 0.169141E-02 -0.145122E-02
2978 0.151723E-02 -0.126732E-02
2979 0.763797E-01 -0.222600E-02
2980 0.798045E-01 -0.174566E-02
2981 0.863405E-01 0.679978E-02
2982 0.864660E-01 0.495462E-02
2983 0.249114E-01 0.718387E-03
2984 0.241921E-01 -0.128768E-03
2985 0.197012E-02 -0.156032E-02
2986 0.178700E-02 -0.137317E-02
2987 0.721051E-01 -0.956378E-03
2988 0.757395E-01 0.132046E-03
2989 0.839721E-01 0.785001E-02
2990 0.841926E-01 0.634671E-02
2991 0.268401E-01 0.997135E-03
2992 0.259428E-01 0.437144E-04
2993 0.227143E-02 -0.168129E-02
2994 0.207071E-02 -0.149047E-02
2995 0.675042E-01 -0.551157E-03
2996 0.714715E-01 0.108886E-02
2997 0.691549E-01 0.544510E-03
2998 0.815924E-01 0.848461E-02
2999 0.820085E-01 0.729346E-02
3000 0.288934E-01 0.126904E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.520
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
3001	0.279588E-01	0.252066E-03
3002	0.259408E-02	-0.178555E-02
3003	0.631228E-01	-0.819748E-03
3004	0.654797E-01	0.475362E-03
3005	0.642535E-01	-0.222660E-03
3006	0.791680E-01	0.872992E-02
3007	0.798531E-01	0.782260E-02
3008	0.310433E-01	0.156766E-02
3009	0.300702E-01	0.488776E-03
3010	0.296329E-02	-0.188769E-02
3011	0.592091E-01	-0.124407E-02
3012	0.622571E-01	-0.403856E-03
3013	0.612255E-01	0.967870E-04
3014	0.766666E-01	0.860581E-02
3015	0.776331E-01	0.793764E-02
3016	0.332896E-01	0.192659E-02
3017	0.323006E-01	0.737700E-03
3018	0.335488E-02	-0.199099E-02
3019	0.556925E-01	-0.154728E-02
3020	0.579117E-01	-0.393388E-03
3021	0.740532E-01	0.815137E-02
3022	0.752744E-01	0.765441E-02
3023	0.355630E-01	0.240515E-02

3024	0.347746E-01	0.101781E-02
3025	0.374089E-02	-0.209731E-02
3026	0.526033E-01	-0.158965E-02
3027	0.547568E-01	-0.523822E-03
3028	0.712949E-01	0.746263E-02
3029	0.727565E-01	0.701169E-02
3030	0.377826E-01	0.299659E-02
3031	0.370774E-01	0.174538E-02
3032	0.407566E-02	-0.220975E-02
3033	0.397580E-02	-0.206636E-02
3034	0.496501E-01	-0.155191E-02
3035	0.518177E-01	-0.498341E-03
3036	0.683648E-01	0.668198E-02
3037	0.700568E-01	0.615102E-02
3038	0.399636E-01	0.361871E-02
3039	0.391702E-01	0.237477E-02
3040	0.430774E-02	-0.226641E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.530
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
3041	0.422987E-02	-0.220840E-02
3042	0.468069E-01	-0.162407E-02
3043	0.489474E-01	-0.444893E-03
3044	0.475650E-01	-0.881122E-03
3045	0.652735E-01	0.599671E-02
3046	0.671810E-01	0.526980E-02
3047	0.421545E-01	0.420158E-02
3048	0.412723E-01	0.294630E-02
3049	0.447840E-02	-0.225047E-02
3050	0.432488E-02	-0.221664E-02
3051	0.440933E-01	-0.188650E-02
3052	0.455015E-01	-0.893350E-03
3053	0.621016E-01	0.558165E-02
3054	0.640197E-01	0.444973E-02
3055	0.443769E-01	0.470656E-02
3056	0.434131E-01	0.346933E-02
3057	0.464213E-02	-0.218765E-02
3058	0.445674E-02	-0.215422E-02
3059	0.414431E-01	-0.187668E-02
3060	0.433443E-01	-0.127551E-02
3061	0.424503E-01	-0.139859E-02
3062	0.590004E-01	0.544223E-02
3063	0.607419E-01	0.421385E-02
3064	0.466134E-01	0.511016E-02
3065	0.455852E-01	0.388350E-02
3066	0.482333E-02	-0.209482E-02
3067	0.460790E-02	-0.207140E-02
3068	0.386452E-01	-0.177930E-02
3069	0.401028E-01	-0.856052E-03
3070	0.392559E-01	-0.111733E-02
3071	0.411279E-01	-0.123953E-02

3072 0.560983E-01 0.546113E-02
3073 0.577319E-01 0.416814E-02
3074 0.488432E-01 0.539484E-02
3075 0.477572E-01 0.415420E-02
3076 0.502206E-02 -0.196727E-02
3077 0.477786E-02 -0.195680E-02
3078 0.359243E-01 -0.200237E-02
3079 0.361374E-01 -0.960908E-03
3080 0.377812E-01 -0.119760E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.540

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
3081	0.534643E-01	0.553069E-02
3082	0.548962E-01	0.421246E-02
3083	0.510895E-01	0.553540E-02
3084	0.499773E-01	0.427936E-02
3085	0.487907E-02	-0.173237E-02
3086	0.535758E-02	-0.191953E-02
3087	0.335995E-01	-0.211302E-02
3088	0.348972E-01	-0.113482E-02
3089	0.523135E-01	0.428357E-02
3090	0.314000E-01	-0.210170E-02
3091	0.324879E-01	-0.116404E-02
3092	0.292088E-01	-0.216776E-02
3093	0.302408E-01	-0.128292E-02
3094	0.271025E-01	-0.222939E-02
3095	0.281049E-01	-0.141589E-02
3096	0.250793E-01	-0.219511E-02
3097	0.260606E-01	-0.151795E-02
3098	0.231007E-01	-0.203493E-02
3099	0.242443E-01	-0.149063E-02
3100	0.236341E-01	-0.162490E-02
3101	0.211690E-01	-0.190664E-02
3102	0.226460E-01	-0.153310E-02
3103	0.193561E-01	-0.189055E-02
3104	0.176704E-01	-0.194004E-02
3105	0.161682E-01	-0.205992E-02
3106	0.148262E-01	-0.213924E-02
3107	0.135446E-01	-0.206994E-02
3108	0.122735E-01	-0.199511E-02
3109	0.110844E-01	-0.198629E-02
3110	0.100656E-01	-0.193682E-02
3111	0.104161E-01	-0.164873E-02
3112	0.914007E-02	-0.180137E-02
3113	0.956273E-02	-0.160009E-02
3114	0.826051E-02	-0.163075E-02
3115	0.869292E-02	-0.141002E-02
3116	0.745247E-02	-0.147909E-02
3117	0.786543E-02	-0.129466E-02
3118	0.762870E-02	-0.133457E-02
3119	0.695747E-02	-0.113062E-02

3120 0.724975E-02 -0.127370E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.550

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
3121	0.683702E-02	-0.149451E-02
3122	0.122330	-0.210052E-01
3123	0.121918	-0.193362E-01
3124	0.649654E-02	-0.538006E-03
3125	0.590207E-02	-0.444931E-03
3126	0.261175E-03	-0.499740E-03
3127	0.363908E-03	-0.621611E-03
3128	0.303992E-03	-0.539306E-03
3129	0.120300	-0.213665E-01
3130	0.648211E-02	-0.104244E-02
3131	0.712419E-02	-0.984798E-03
3132	0.218989E-03	-0.427151E-03
3133	0.192427E-03	-0.400051E-03
3134	0.542962E-02	-0.801051E-03
3135	0.589042E-02	-0.917903E-03
3136	0.482543E-03	-0.715615E-03
3137	0.400228E-03	-0.627200E-03
3138	0.504908E-02	-0.109295E-02
3139	0.542141E-02	-0.118416E-02
3140	0.623477E-03	-0.807942E-03
3141	0.475303E-02	-0.141488E-02
3142	0.505795E-02	-0.139810E-02
3143	0.787217E-03	-0.905285E-03
3144	0.442586E-02	-0.168628E-02
3145	0.492539E-02	-0.158831E-02
3146	0.463732E-02	-0.173957E-02
3147	0.962994E-03	-0.993931E-03
3148	0.411886E-02	-0.187226E-02
3149	0.435748E-02	-0.188278E-02
3150	0.115332E-02	-0.107193E-02
3151	0.418298E-02	-0.202180E-02
3152	0.412905E-02	-0.206207E-02
3153	0.136040E-02	-0.112149E-02
3154	0.160639E-02	-0.118840E-02
3155	0.148154E-02	-0.103988E-02
3156	0.188079E-02	-0.130155E-02
3157	0.171971E-02	-0.112328E-02
3158	0.587470E-02	-0.132447E-02
3159	0.612654E-02	-0.146985E-02
3160	0.636971E-02	-0.138754E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=87.560

FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
3161	0.542275E-02	-0.150821E-02
3162	0.571608E-02	-0.161396E-02
3163	0.541568E-02	-0.176544E-02
3164	0.118435	-0.221361E-01
3165	0.116261	-0.228594E-01
3166	0.119886	-0.196943E-01
3167	0.117496	-0.199666E-01
3168	0.115322	-0.206811E-01
3169	0.114118	-0.181509E-01
3170	0.114277	-0.237764E-01
3171	0.112835	-0.214997E-01
3172	0.110316	-0.161295E-01
3173	0.111634	-0.189585E-01
3174	0.106309	-0.138683E-01
3175	0.107784	-0.166771E-01
3176	0.102336	-0.112919E-01
3177	0.103766	-0.146599E-01
3178	0.985360E-01	-0.842511E-02
3179	0.998590E-01	-0.118171E-01
3180	0.950111E-01	-0.536866E-02
3181	0.960147E-01	-0.898044E-02
3182	0.918194E-01	-0.232399E-02
3183	0.922921E-01	-0.556354E-02
3184	0.890222E-01	0.438944E-03
3185	0.889979E-01	-0.217268E-02
3186	0.865640E-01	0.273801E-02
3187	0.865196E-01	0.641388E-03
3188	0.843145E-01	0.451664E-02
3189	0.842351E-01	0.280262E-02
3190	0.822255E-01	0.580157E-02
3191	0.820329E-01	0.435111E-02
3192	0.802645E-01	0.663893E-02
3193	0.802066E-01	0.559296E-02
3194	0.783111E-01	0.703364E-02
3195	0.786958E-01	0.634509E-02
3196	0.762311E-01	0.698524E-02
3197	0.770597E-01	0.659287E-02
3198	0.739650E-01	0.650898E-02
3199	0.751762E-01	0.626625E-02
3200	0.715028E-01	0.568952E-02

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP= 87.570
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEM

NODE	UX	UY
3201	0.729773E-01	0.547068E-02
3202	0.688554E-01	0.472409E-02
3203	0.703358E-01	0.432752E-02
3204	0.659069E-01	0.370474E-02
3205	0.677424E-01	0.358024E-02
3206	0.626392E-01	0.307242E-02
3207	0.650821E-01	0.239731E-02
3208	0.638962E-01	0.217528E-02
3209	0.594557E-01	0.293517E-02
3210	0.611353E-01	0.207441E-02
3211	0.565140E-01	0.291737E-02
3212	0.582438E-01	0.181524E-02
3213	0.537324E-01	0.296610E-02
3214	0.552472E-01	0.175064E-02
3215	0.511909E-01	0.303007E-02
3216	0.524593E-01	0.180203E-02
3217	0.488814E-01	0.304081E-02
3218	0.498490E-01	0.185447E-02
3219	0.467184E-01	0.292696E-02
3220	0.476541E-01	0.205208E-02
3221	0.446099E-01	0.264202E-02
3222	0.456700E-01	0.197367E-02
3223	0.425191E-01	0.220641E-02
3224	0.436710E-01	0.165261E-02
3225	0.404672E-01	0.169184E-02
3226	0.416633E-01	0.117783E-02
3227	0.384535E-01	0.110918E-02
3228	0.397643E-01	0.717694E-03
3229	0.362741E-01	0.339206E-03
3230	0.379206E-01	0.133971E-03
3231	0.337653E-01	-0.178028E-03
3232	0.313091E-01	-0.344390E-03
3233	0.291178E-01	-0.531020E-03
3234	0.270439E-01	-0.703767E-03
3235	0.252096E-01	-0.807379E-03
3236	0.237787E-01	-0.978655E-03
3237	0.109093	-0.195131E-01
3238	0.105225	-0.174779E-01
3239	0.101269	-0.151918E-01
3240	0.101802	-0.169304E-01

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***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP= 87.580
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
3241	0.973201E-01	-0.123775E-01
3242	0.987177E-01	-0.148834E-01
3243	0.932799E-01	-0.916058E-02
3244	0.957685E-01	-0.129035E-01
3245	0.894570E-01	-0.537832E-02

3246 0.864896E-01 -0.194033E-02
3247 0.858439E-01 -0.317442E-02
3248 0.841877E-01 0.728442E-03
3249 0.832199E-01 -0.454455E-03
3250 0.819532E-01 0.265472E-02
3251 0.821115E-01 0.683392E-03
3252 0.800160E-01 0.415671E-02
3253 0.789974E-01 0.259381E-02
3254 0.786386E-01 0.530715E-02
3255 0.781024E-01 0.446557E-02
3256 0.774410E-01 0.590737E-02
3257 0.773353E-01 0.545312E-02
3258 0.759981E-01 0.587199E-02
3259 0.766952E-01 0.561572E-02
3260 0.741783E-01 0.522044E-02
3261 0.758938E-01 0.542157E-02
3262 0.717947E-01 0.409480E-02
3263 0.740719E-01 0.456265E-02
3264 0.692083E-01 0.317214E-02
3265 0.717408E-01 0.304958E-02
3266 0.694104E-01 0.246922E-02
3267 0.669030E-01 0.225208E-02
3268 0.681885E-01 0.221966E-02
3269 0.671038E-01 0.155981E-02
3270 0.646377E-01 0.138465E-02
3271 0.992396E-01 -0.166197E-01
3272 0.971538E-01 -0.154194E-01
3273 0.825843E-01 -0.166299E-02
3274 0.791515E-01 0.651839E-03
3275 0.750983E-01 0.221552E-02
3276 0.770990E-01 0.292010E-02
3277 0.740145E-01 0.350164E-02
3278 0.759986E-01 0.421260E-02
3279 0.768044E-01 0.461765E-02
3280 0.757852E-01 0.475689E-02

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.590
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
3281	0.615761E-02	-0.243748E-02
3282	0.641640E-02	-0.245733E-02
3283	0.578047E-02	-0.211850E-02
3284	0.603501E-02	-0.218278E-02
3285	0.648315E-02	-0.209343E-02
3286	0.628417E-02	-0.217553E-02
3287	0.570300E-02	-0.188340E-02
3288	0.629624E-02	-0.179722E-02
3289	0.654786E-02	-0.172905E-02
3290	0.610497E-02	-0.189240E-02
3291	0.595582E-02	-0.193221E-02
3292	0.595693E-02	-0.176361E-02
3293	0.634184E-01	0.682986E-03

3294	0.623775E-01	0.117752E-02
3295	0.599063E-01	0.946643E-03
3296	0.569580E-01	0.643762E-03
3297	0.539574E-01	0.586975E-03
3298	0.511032E-01	0.631981E-03
3299	0.486124E-01	0.875655E-03
3300	0.465968E-01	0.110231E-02
3301	0.472317E-01	0.416223E-03
3302	0.447207E-01	0.981813E-03
3303	0.456199E-01	0.526563E-03
3304	0.428040E-01	0.617398E-03
3305	0.438505E-01	0.179542E-03
3306	0.409505E-01	0.195191E-03
3307	0.419864E-01	-0.179400E-03
3308	0.392224E-01	-0.270924E-03
3309	0.462490E-01	-0.154185E-03
3310	0.447413E-01	-0.278330E-03
3311	0.430229E-01	-0.622094E-03
3312	0.990592E-02	-0.131501E-02
3313	0.910433E-02	-0.120403E-02
3314	0.828441E-02	-0.106817E-02
3315	0.765244E-02	-0.108281E-02
3316	0.456182E-02	-0.194078E-02
3317	0.442128E-02	-0.203962E-02
3318	0.430142E-02	-0.211943E-02
3319	0.165419E-02	-0.895552E-03
3320	0.158964E-02	-0.971675E-03

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:09 OCT 20, 1994 CP=
87.600
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY
3321	0.153876E-02	-0.782246E-03
3322	0.155613E-02	-0.715061E-03
3323	0.147633E-02	-0.858484E-03
3324	0.147988E-02	-0.709367E-03
3325	0.152150E-02	-0.597995E-03
3326	0.336902E-03	-0.545487E-03
3327	0.260231E-03	-0.463318E-03
3328	0.298225E-03	-0.497542E-03
3329	0.194716E-03	-0.385438E-03
3330	0.137826E-03	-0.322857E-03
3331	0.154055E-03	-0.347674E-03
3332	0.151939E-03	-0.335476E-03
3333	0.168602E-03	-0.359898E-03

MAXIMUMS*
NODE 42 66
VALUE 0.140789 -0.452465E-01
1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

*** NODAL LOAD CALCULATION TIMES
TYPE NUMBER ENAME TOTAL CP AVE CP

1 1053 PLANE82 0.310 0.000

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:20 OCT 20, 1994 CP=
96.650
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** REACTION SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	FX	FY
393	14.2988	199.044
394	0.550198	49.5753
395	19.1024	425.130
396	1.49701	243.899
397	-5.58714	517.413
398	-12.4114	291.411
399	-31.3218	614.071
400	-26.2770	338.574
401	-54.9982	706.111
402	-37.9231	381.486
403	-75.1012	785.043
404	-45.2909	415.033
405	-88.3258	838.776
406	-49.5239	435.064
407	-93.4283	860.504
408	-50.8342	437.552
409	-91.1134	847.673
410	-48.7536	421.554
411	-82.6839	801.799
412	-42.9903	389.199
413	-69.2441	728.348
414	-33.8000	344.789
415	-52.3441	635.681
416	-22.1779	293.790
417	-33.3231	533.584
418	-9.78129	241.508
419	-14.8427	431.602
420	1.75870	192.775
421	0.267593	337.274
422	9.35310	150.256
423	11.0320	257.238
424	11.8916	114.999
425	14.5492	193.080
426	9.95660	87.4867
427	12.1945	145.109
428	5.70232	66.2596
429	5.50471	108.753
430	-1.67250	82.1686
431	-3.20508	36.3478
432	-7.14468	60.2030
433	-5.21159	25.9677
434	-9.53762	42.2909
435	-5.39629	17.4321

1

***** ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 5.0A

WEST. HANFORD VERSION=SGI IRIS4D 13:15:20 OCT 20, 1994 CP=
96.660
FOR SUPPORT CALL BRAD COVERDELL PHONE (509) 376-1921 FAX

2" Hook Connector for MWTF

***** REACTION SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP= 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	FX	FY
436	-8.52637	27.4714
437	-3.92024	10.6224
438	-4.30339	15.8572
439	-0.901594	5.44257
440	2.71632	7.56449
441	3.47439	2.01245
442	12.0490	2.84517
443	8.93170	0.508098
444	23.1474	2.04429
445	15.1647	1.14922
446	35.3802	5.60816
447	21.8253	4.19665
448	47.9987	14.0722
449	28.5018	9.95945
450	60.0921	28.0453
451	34.6944	18.7938
452	70.5562	48.1817
453	39.7981	31.0989
454	78.1169	75.1470
455	43.1136	47.3090
456	81.4538	109.611
457	43.8823	67.8783
458	79.4742	152.298
459	41.4781	93.1936
460	71.6758	204.250
461	35.3527	123.510
462	58.5772	266.397
463	25.9584	159.180
464	40.8247	339.897

TOTAL -0.491696E-07 17000.0

*** NOTE *** CP= 96.680 TIME= 13:15:20
Totals may not be correct if any reaction nodes are in a rotated nodal
coordinate system.

*** LOAD STEP 1 SUBSTEP 1 COMPLETED. CUM ITER = 1
*** TIME = 1.00000 TIME INC = 1.00000 NEW TRIANG MATRIX

*** PROBLEM STATISTICS
ACTUAL NO. OF ACTIVE DEGREES OF FREEDOM = 6522
R.M.S. WAVEFRONT SIZE = 68.5

*** ANSYS BINARY FILE STATISTICS
BUFFER SIZE USED= 4096
2.688 MB WRITTEN ON ELEMENT MATRIX FILE: file.emat
0.828 MB WRITTEN ON ELEMENT SAVED DATA FILE: file.esav
3.656 MB WRITTEN ON TRIANGULARIZED MATRIX FILE: file.tri

1.328 MB WRITTEN ON RESULTS FILE: file.rst

*** NOTE *** CP= 98.010 TIME= 13:15:21
NEW BACKUP FILE NAME= file.dbb.

ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= file.db

FOR POSSIBLE RESUME FROM THIS POINT

FINISH SOLUTION PROCESSING

***** ROUTINE COMPLETED ***** CP = 99.350

*** NOTE *** CP= 99.350 TIME= 13:15:23
A total of 4 warnings and errors written to file.err.

PURGE ALL SOLUTION AND POST DATA
SAVE ALL MODEL DATA

*** NOTE *** CP= 99.480 TIME= 13:15:23
DELETED BACKUP FILE NAME= file.dbb.

*** NOTE *** CP= 99.480 TIME= 13:15:23
NEW BACKUP FILE NAME= file.dbb.

ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= file.db

FOR POSSIBLE RESUME FROM THIS POINT

NUMBER OF WARNING MESSAGES ENCOUNTERED= 4
NUMBER OF ERROR MESSAGES ENCOUNTERED= 0

3.0 REFERENCES

ANSYS, 1992, *ANSYS Swanson Analysis Systems*, ANSYS Version, Swanson Analysis Systems, Inc., 5.0a version, Houston, Pennsylvania.

WHC, 1993, *Hook-2" Connector Purex/Redox Type*, Drawing No. H-2-90174, Rev. 7, Westinghouse Hanford Company, Richland, Washington.

APPENDIX I
THREE-WAY CONNECTOR ANALYSIS

TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed 2-IN. ISB JUMPER 3-WAY CONNECTOR

Authors E. O. Weiner

Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

MANDATORY

Software QA Log Number 95-002

Reviewer

John Dulye

Date

4/25/95

ANALYTICAL CALCULATIONS

Page _____ of _____

Subject 3-Way Connector

Originator E. O. Werner

Date 4/18/95

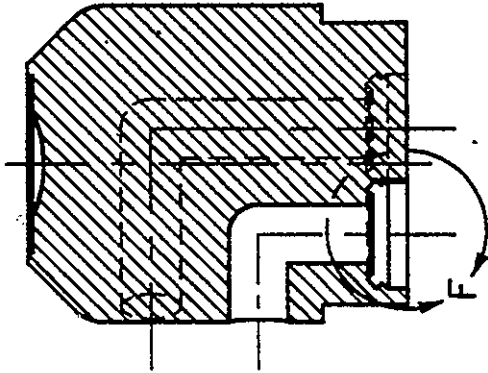
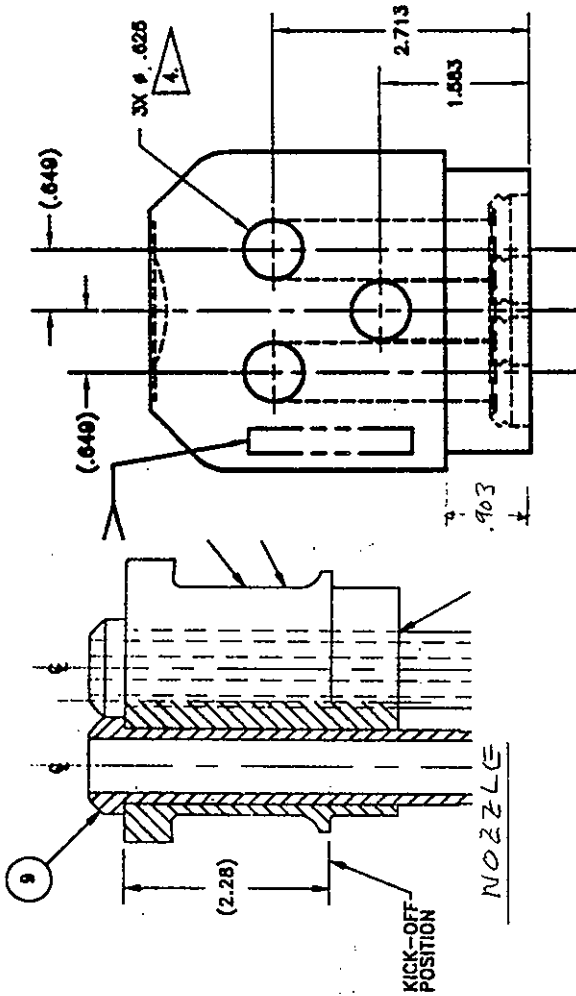
Checker John G. Gyle

Date 4/25/95

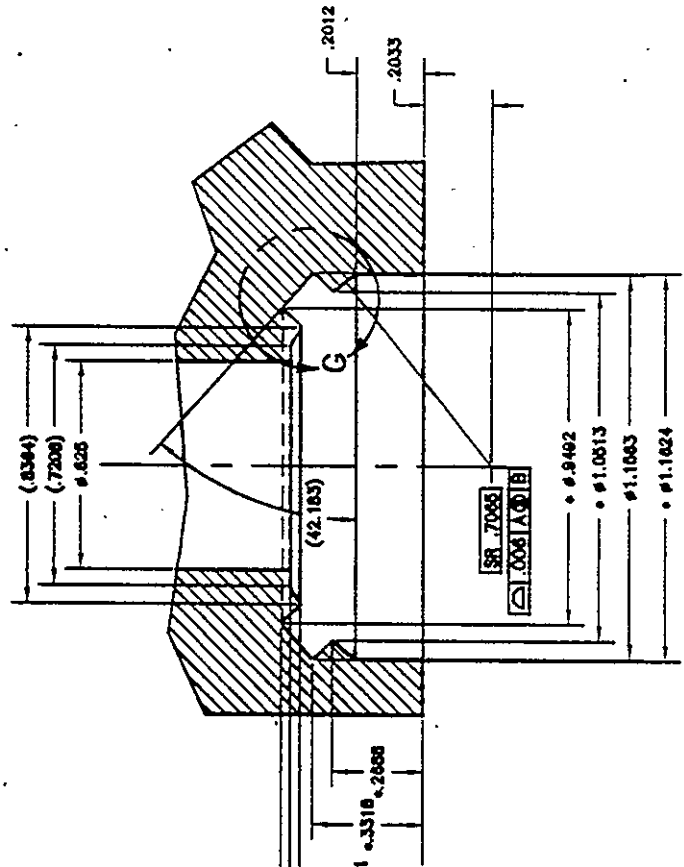
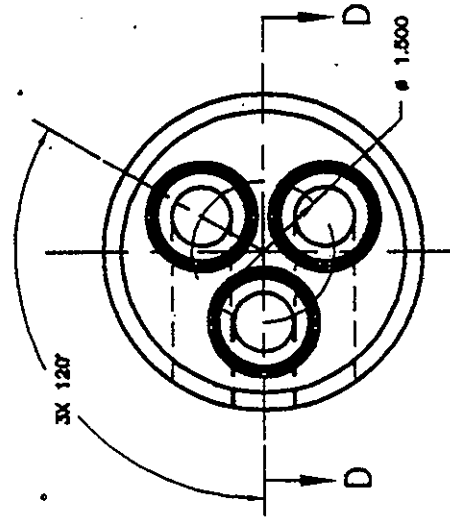
1.0 Introduction

The three way connector is similar to the 2" standard connector, except that the block & nozzle configuration supports three separate piping paths. See the attached drawing excerpts. Analysis consists of three main sections:

- o Lift-off criteria to limit block-nozzle separation to 0.002". Connector stiffnesses are also discussed. The section replaces the non-axial piping reaction limits for the 2" standard connector with new ones related to lift-off.
- o Axial force limits for piping reactions
- o Local block stresses from piping reactions



SECTION D-D



VIEW F 3 PL

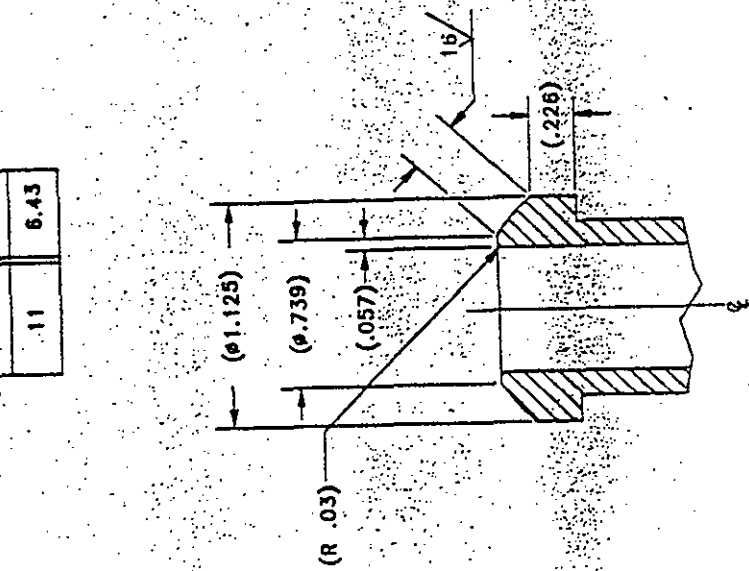
BLOCK, 2" 3-WAY

SCALE 1/1

11-2-82 1577

7

8



VIEW A
SCALE: 2/1

DESIGN CALCULATION

WHC-SD-W236A-DA-002
REVISION 0

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject 3-Way Connector
 (8) Originator Jo Weiner Date 2/28/95
 (9) Checker JZY Date 4/25/95

(10)

20 Lift-off criteria

A criterion to limit lift-off of the block seating surface from the nozzle insert is developed.

Drawings:

Assembly: H-2-821874

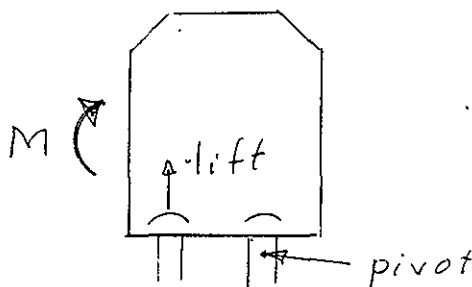
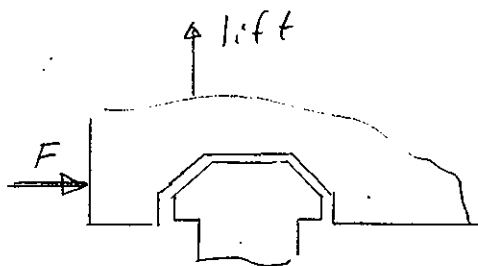
Block: H-2-821399

Nozzle: H-2-83576

Each of the three nozzle inserts and block-gasket seats acts like a standard connector nozzle.

The block can rotate about one seat center as long as there is no interference from the other two seats. Two lift-off mechanisms are possible:

1. Lateral forces can push the block up on an inclined plane on the nozzle insert
2. The block can pivot about two seat centers & lift off at the third.



DESIGN CALCULATION

WHC-SD-4W236A-DA-002
REVISION 0

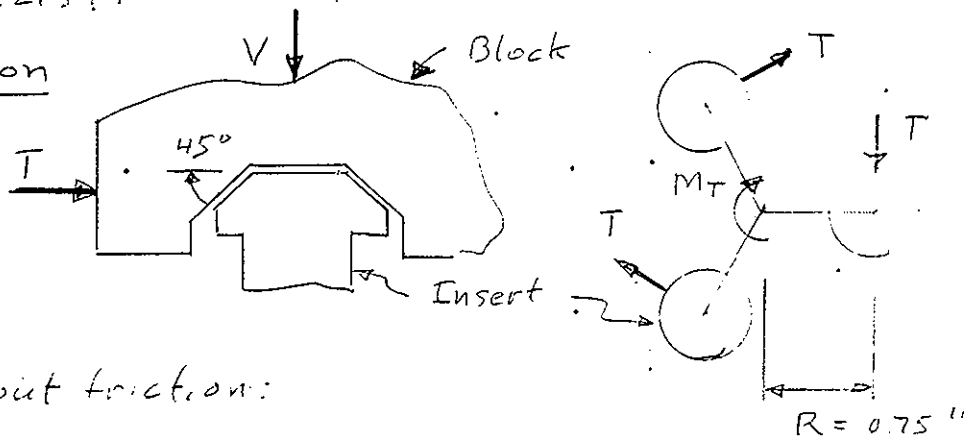
(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject 5 Wing Connection
 (8) Originator EO Weiner Date 2/28/95
 (9) Checker [Signature] Date 4/25/95

(10)

Piping reactions at the pipe-block interface tend to produce the lift-off. Preload and hook/nut stiffness tend to prevent it.

Individual load cases are as follows. See H-2-221399

2.1 Torsion



Without friction:

$$T = V \quad (45^\circ \text{ inclined plane})$$

$$M_T = 3RT = 3RV$$

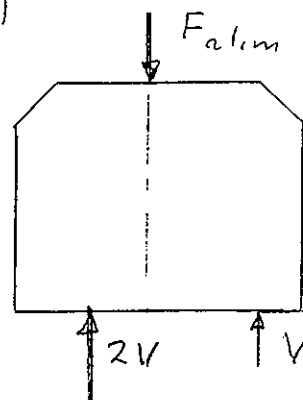
$$3V = F_{\text{alim}}$$

$$\therefore \frac{M_T}{R} = F_{\text{alim}}$$

is the criterion for torsion.

F_{alim} = maximum acceptable

axial force on the block (see below)



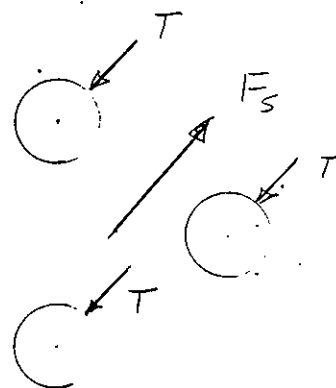
DESIGN CALCULATION

WHC-SD-W236A-DA-002
REVISION 0

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject 2 Way Connector
 (8) Originator EO Weiner Date 2/25/95
 (9) Checker JZG Date 4/25/95

(10)

2.2 Shear $T = V$ $F_s = 3T$
 $3V = F_{lim}$
 $F_s = F_{lim}$



2.3 Limit axial load

$$F_{lim} = F_{torque} - F_{press} + F_{therm} + F_{HK} - F_{pipe}$$

$$F_{torque} = \text{preload from torque, see section 10.3.3} \\ = 5000^{\#} @ 50^{\#}, 10000^{\#} @ 100^{\#}, \\ 15500^{\#} @ 150^{\#}$$

$$F_{press} = \text{pressure load effect on block, see} \\ \text{App B § 4.4, } F_{press} = F_{prel} = 1614^{\#}$$

$$F_{therm} = \text{thermal expansion load. Use } 2 \times 20\% \\ \text{of App B § 4.3 } F_{thermal}; 20\% \sim 531.5^{\#} \\ \text{flange bolting temperature reduction on} \\ \text{allowed (hooks), } F_{therm} = 0.4 \times 5771^{\#} = 2308^{\#}$$

$$F_{pipe} = \text{pipe axial load, neg. for compression}$$

$$F_{HK} = \text{additional load from hook stiffness} \\ \text{times lift-off displacement}$$

Per App B, § 4.2.10, stiffness corresponding to seat opening is $K_{Ea1} = 0.82 \times 10^6 \text{ }^{\#}/\text{in}$. Acceptable lift-off is taken as acceptable gap from catalogs, typically 0.002".

* See ASME B31.3 Section 301.3.2 (b)(4), Note that hooks are exposed while flange bolts are surrounded by the flange.

(10)

$$F_{HK} = K_{EQ1} \times 0.002" = 0.82^{11} \times 0.002"$$

$$= 1640^{#}$$

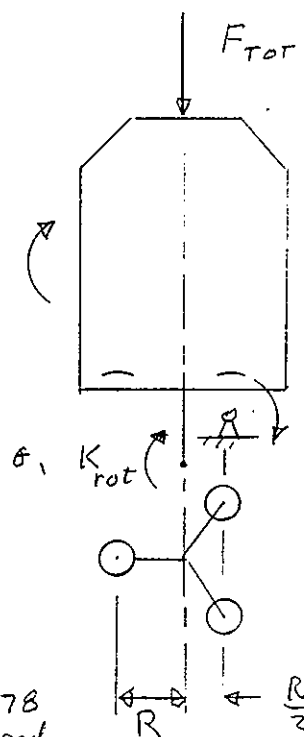
• $F_{\text{elim}} = 5000 - 1610 + 2300 + 1640 = 7330 \text{ \#}$
@ 50 #/ torque, no pipe force

Pivoting along a line of two inserts is resisted by the preload forces, the axial hook stiffness effects and the rotational resistance from the guide, hook, nut, screw system (Krot). Max rotation for 0.002" lift-off is

$$\theta_{\max} = \frac{s}{1.5R} = \frac{0.002}{1.5 \times 0.75} = 0.00178 \text{ rad}$$

Appendix G gives $\theta_x = 0.0843$ rad for $n_x = 2300^{1/4}$ for the 2" connector as the weakest mode.

$$K_{rot} = \frac{2000^{1H}}{0.0843} = 0.0237e6^{1H} = 0.285e6^{11H}$$



DESIGN CALCULATION

WHG-SD-W236A-DA-002
REVISION 0

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject Pin & Connector
(8) Originator FOG/Reiner Date 2/28/95
(9) Checker JZ Date 4/25/95

(10)

This stiffness is for the condition of guide inactive, no-slip interface element and pin moments transmitted. Releasing the pin moments is not appropriate since moment resistance in the pins is expected through eccentric loading. Thus, rotational resistance is

$$M_{rot} = K_{rot} \theta_{max} = .285E6 \frac{\#"}{rad} \times .00178 \text{ rad} \\ = 510 \frac{\#"}{rad}$$

Total resisting moment to overturning:

$$M_{olim} = F_{Tot} \times R/2 + M_{rot}$$

$$F_{Tot} = F_{torque} - F_{press} + F_{therm} + F_{Hic} \\ = 7330 \frac{\#}{ft}$$

$$M_{olim} = 7330 \frac{\#}{ft} \times .75 \frac{ft}{2} + 510 \frac{\#"}{rad} = 3260 \frac{\#"}{rad} \\ = 272 \frac{\#}{ft} @ 50 \frac{\#}{ft} \text{ torque, no pipe load}$$

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject 3-Way Connector

Originator EO Weiner

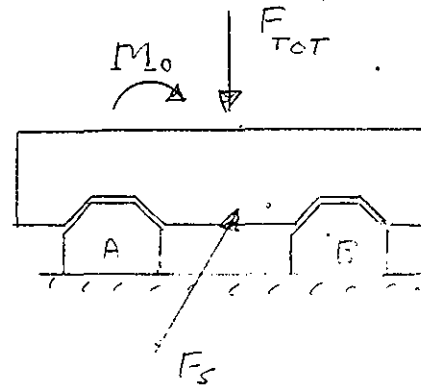
Date 3/28/95

Checker [Signature]

Date 4/25/95

2.5 Interaction for overturning and shear (lift-off)

Considering a two-nozzle configuration, the overturning moment and shear force would both contribute directly to lift-off at insert A.



Consequently, the F_s and M_0 criteria are assumed to interact linearly (conservative). Thus, net piping shear, torsion and overturning moment should satisfy

$$\frac{F_s + M_T/R}{F_{lim} - F_x} + \frac{M_0}{M_{olim} - F_x R/2} < 1$$

Where

$$\begin{aligned} F_{lim} &= 7330 \# @ 50 \# \text{ torque} \\ &= 12330 \# @ 100 \# \text{ torque} \\ &= 17820 \# @ 150 \# \text{ torque} \end{aligned}$$

$$\begin{aligned} M_{olim} &= 272 \# \text{ torque} @ 50 \# \text{ torque} \\ &= 428 \# \text{ torque} @ 100 \# \text{ torque} \\ &= 600 \# \text{ torque} @ 150 \# \text{ torque} \end{aligned}$$

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject 3-Way Connector

Originator EO Weiner

Date 3/28/95

Checker [Signature]

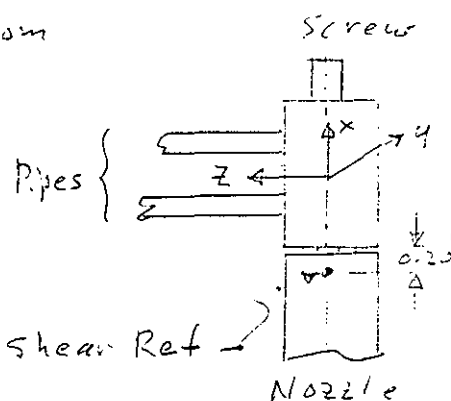
Date 4/25/95

F_s = net piping shear force referenced to nozzle pivot level at connector ϕ

M_T = net torsional moment on connector from piping

M_o = net overturning moment on connector from piping

F_x = net axial load from piping, negative if tending to seat the block-nozzle interface.



Note:

$$M_T = |M_x|$$

$$F_s = \sqrt{F_y^2 + F_z^2} \quad M_o = \sqrt{M_y^2 + M_z^2}$$

$F_x, F_y, F_z, M_x, M_y, M_z$ = net (from three pipes) force and moment components from piping to connector

ANALYTICAL CALCULATIONS

Page _____ of _____

Subject 3-Way Connector

Originator EO Weiner

Date 4/10/95

Checker [Signature]

Date 4/25/95

2.6 Piping loads, upper bound estimates

Obtain upper bound estimates of piping moments considering 1/2" sched 40 304 SS pipe elbows.

$$\left. \begin{aligned} D_i &= 0.622" \quad D_o = 0.844" \quad t = 0.109" \\ A &= 0.250 \text{ in}^2 \quad Z = 0.0407 \text{ in}^3 \end{aligned} \right\} \text{ see (Grinnel, 1963) } \\ \text{p. 244}$$

$$S_y = 30 \text{ ksi} \quad S_h = S_c \text{ (to 250F)} = 20 \text{ ksi} \quad (ASME)$$

Assume $S_L \ll S_h$. Then

$$S_A = 1.25(S_h + S_c) = 50 \text{ ksi} \quad (ASME 302.3.5.1b)$$

Each moment component in the elbow is individually limited to

$$M = \frac{S_A Z}{L} \quad (531.3 \text{ } 319.4, \text{ App D Table D-1})$$

$$i_i = \frac{0.9}{h^{2/3}} \quad i_o = \frac{0.75}{h^{2/3}} \quad h = \frac{\bar{r} R_1}{r_2^2}$$

$$r_2 = \frac{D_o + D_i}{4} = \frac{0.844 + 0.622}{4} = 0.366"$$

$$\bar{r} = 0.109" = t$$

$$R_1 = 1.5" \quad (\text{ANSI B16.9}) \quad (\text{long radius elbow})$$

$$h = \frac{0.109 \times 1.5}{0.366^2} = 1.22$$

$$i_i = \frac{0.9}{1.22^{2/3}} = 0.79 \quad i_o = \frac{0.75}{1.22^{2/3}} = 0.66 \quad \text{Use } i_i = i_o = 1$$

$$M_{+lim} = M_{o lim} = M_{i lim} = 50 \text{ ksi} \times 0.0407 \text{ in}^3 / 1.25 = 2.04 \text{ K-in} \quad \#1$$

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject 3-Way Connector

Originator E O Weiner

Date 4/25/95

Checker [Signature]

Date 4/25/95

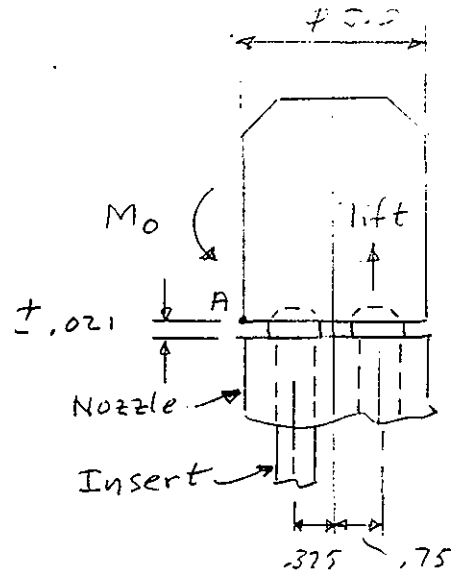
Three 1/2" pipes could produce an overturning moment via nearby elbows of

$$M_o = 3 M_{o,lim} = 3 \times 170 \text{ #'} = 510 \text{ #'}$$

which is more than $M_{o,lim}$ for 50 #' or 100 #' (approx).
Thus checking of piping reactions to the connector will be necessary.

2.7 Bottom-out case

Leak criteria were developed assuming the block will pivot about two of the inserts. This would require some separation between the block & nozzle. Nominally, the block & nozzle are just in contact. Tolerances are (Dwg H-2-821874)



Block spherical seat: $\pm .006$

Nozzle spherical seat: $\pm .005$

Block bottom location $\pm .005$

Nozzle contact surface $\pm .005$

Total (stacked tol.) $\pm .021"$

ANALYTICAL CALCULATIONS

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Subject 3 Way Connector

Originator EO Weiner

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Date 4/25/95

Depending on a bottom-out condition (pivot at A) would raise the allowable Moment by three to four factors - the moment arm to the pressure vector would increase from 0.375" to nearly 1.5" with a max. gap condition, however point it would bottom out only after a lift-off of δ_{lift} :

$$\frac{\delta_{lift}}{.021} = \frac{.75 + .375}{1.5 - .375} = 1 \quad \delta_{lift} = .021$$

which is considered excessive. Therefore, the leakage limits are retained. It is recognized that they may be conservative by, say, a factor of four depending on tolerances and the ability of the O-ring to plug a gap.

ANALYTICAL CALCULATIONS

Page _____ of _____

Subject S Wag Connector

Originator EO Weiner

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Date 4/25/95

2.8 Example

Three sets of piping reactions, referenced to the connector & at the level of the insert spherical seat centers, are given:

Preload torque = 50^{#1}

Line	F _x lb	F _y	F _z	M _x lb-ft	M _y	M _z
1	-100	100	100	-50	20	20
2	-100	200	100	100	10	100
3	-200	-100	-100	-120	-20	40
Net	-400	200	100	-70	150	160

$$F_s = \sqrt{F_y^2 + F_z^2} = \sqrt{200^2 + 100^2} = 224^{\#}$$

$$M_o = \sqrt{M_y^2 + M_z^2} = \sqrt{150^2 + 160^2} = 219^{\#1}$$

$$M_T = |M_x| = 70^{\#1} \quad R = 0.75" = .0625'$$

$$F_{allim} = 7330^{\#} \quad M_{o\ allim} = 272^{\#1} \quad F_x = -400^{\#}$$

$$\frac{F_s + M_T/R}{F_{allim} - F_x} + \frac{M_o}{M_{o\ allim} - F_x R/2}$$

$$= \frac{224 + 70/.0625}{7330 + 400} + \frac{219}{272 + 400 \times .0625/2}$$

$$= \frac{1340}{7730} + \frac{219}{285} = 0.94 \quad \underline{OK}$$

ANALYTICAL CALCULATIONS

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Subject 3 Way Connector
Originator E O Weiner Date 4/12/95
Checker JAG Date 4/25/95

2.9 Connector stiffness

The standard 2" connector has flexibility that can result in significant reductions in piping analysis reactions dominated by thermal loading in the piping. Higher stiffnesses are expected with the 3-way connector, because the bottom or two-point pivot conditions take significant moments before rotation of the block occurs.

Furthermore, 3 1/2" sch. 40 pipes are expected to be more flexible than one 2" line. Thus, significant reductions in reactions caused by flexibility are not expected, and analysis should use hard anchor points for the 3-way connectors.

ANALYTICAL CALCULATIONS

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Subject 3 Way Connector

Originator EO Weiner

Date 4/9/95

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Date 4/25/95

3.0 Allowable seating forces

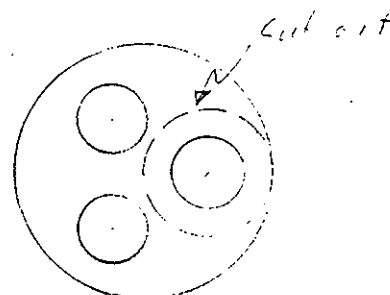
3.1 Block-insert interface

Model block region around one insert as axisym, cylinder shown as dashed cut-out, see Fig 35-1.

Mesh with ANSYS PLANE42 and CONTACT12 elements per

Fig 35-2. Loads are applied

by displacing node 171. Gap elements are used between the insert and block contacting surfaces.



Gap data

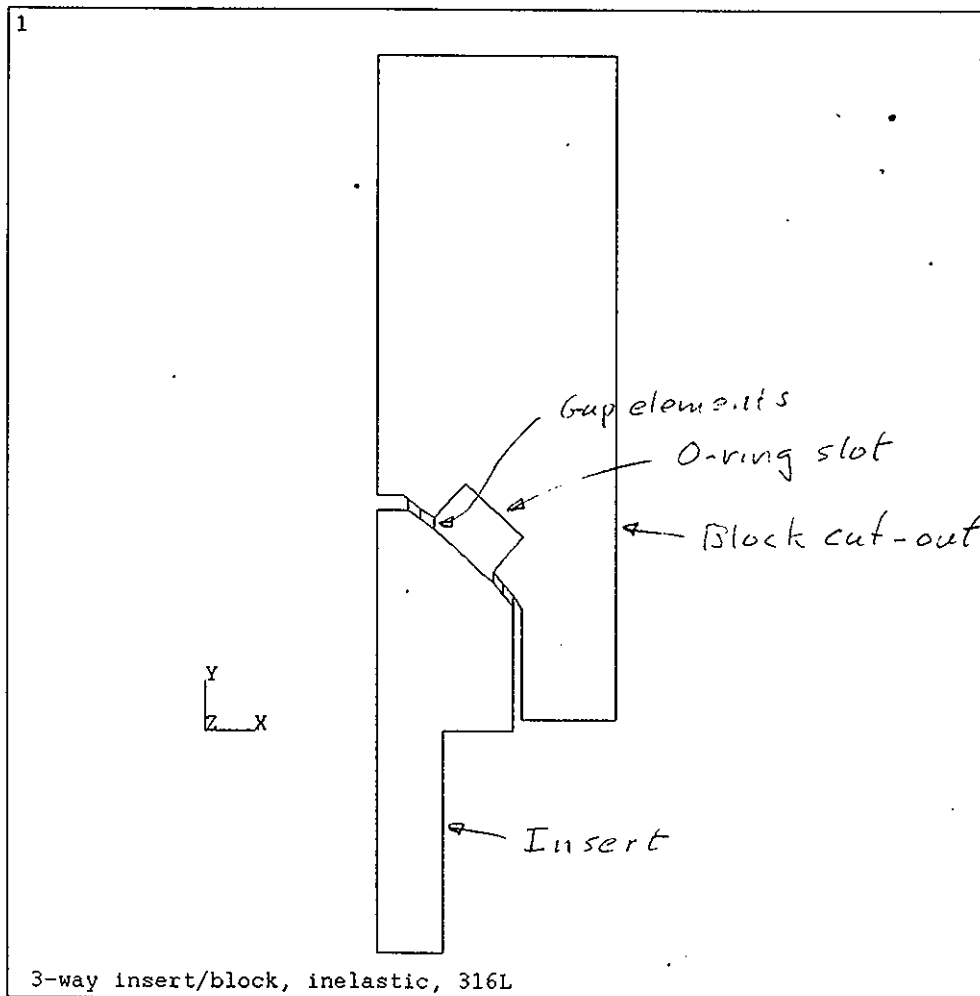
Stiffness $KN \approx f E h$ (ANSYS Procedures, §3.8.3)

$f \approx 1$ (start) varies .01-100

h = radius (axisymmetric) to element

use $KN = 2\pi ER$ which is the stiffness of one square PLANE42 elmt. $\therefore KN \gg$ stiffness of structure. use max $R \approx 0.6"$

I-20

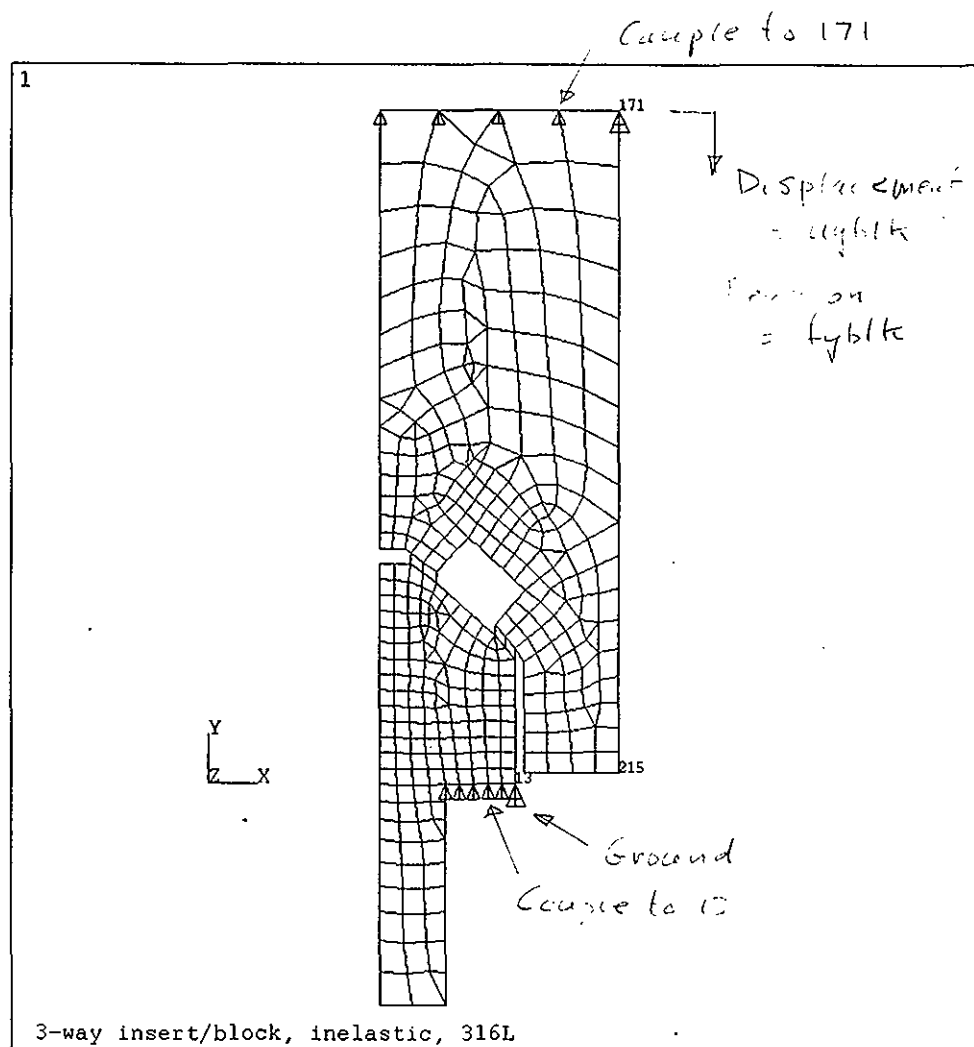


ANSYS 5.0 A
APR 10 1995
10:54:39
ELEMENTS
TYPE NUM

ZV =1
DIST=0.891
XF =0.53125
YF =0.41
PRECISE HIDDEN
EDGE

Fig 3S-1

I-21

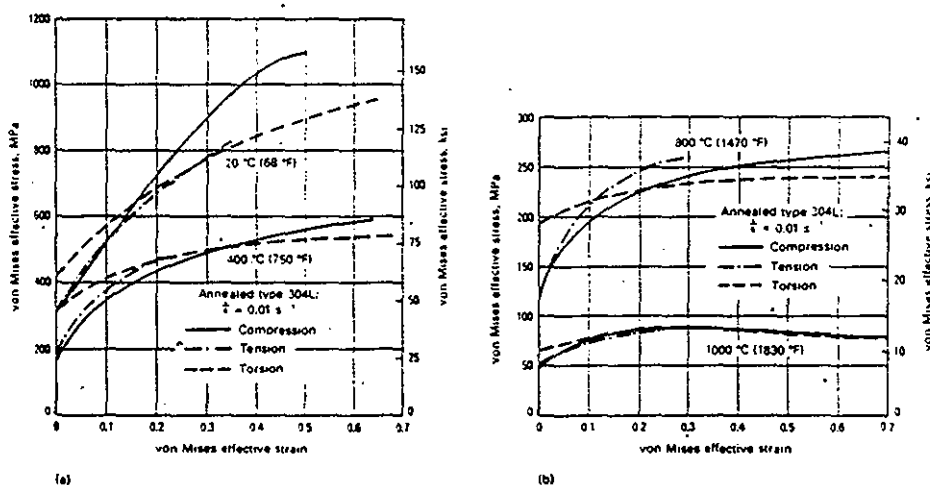


ANSYS 5.0 A
 APR 10 1995
 12:59:39
 ELEMENTS
 TYPE NUM
 U
 CP
 ZV =1
 DIST=0.891
 XF =0.53125
 YF =0.41

Fig. 2.5-2

11-16. Type 304L Stainless Steel: Compression, Tension, and Torsion

30



Comparison of effective stress-strain curves determined for type 304L stainless steel in compression, tension, and torsion. (a) Cold and warm working temperatures. (b) Hot working temperatures.

In the figures above, torsion flow stress data for type 304L are compared to compression and tension data in terms of von Mises effective stress and strain. At cold and warm working temperatures, as well as at low hot working temperatures (800 °C, or 1470 °F), the flow curves from the various tests do not coincide. Generally, there is a lower level of strain hardening in torsion. Thus, although the overall stress levels are similar, the actual shapes of the curves are quite different. Even if other definitions of effective stress and strain are employed, the differences between the curves cannot be eliminated.

However, an estimate of the working loads can still be derived from torsion data plotted in von Mises terms. In contrast to the 20, 400, and 800 °C (68, 750, and 1470 °F) behavior, comparison of type 304L torsion data to tension and compression data is quite good at the hot working temperature of 1000 °C (1830 °F) (see b above). This is most likely a result of the absence of textural and strain-hardening effects.

From: H.E. Boyer, Atlas of Stress-Strain Curves, ASM International, 1980, p. 44073

Source: Metals Handbook, Ninth Edition, Volume 8, Mechanical Testing, American Society for Metals, Metals Park OH, 1985, p 164

ANALYTICAL CALCULATIONS

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Subject 3 Way Connector

Originator EO Weiner

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Checker JZ

Date 4/25/95

$$h - R_{typ} = 0.6" \quad E = 28e6 \text{ psi}$$

$$KN = 2\pi \times 28e6 \times 0.6 = 100e6 \text{ #/in}$$

$$\text{use } 2 \times ; \quad KN = 200e6 \text{ #/in}$$

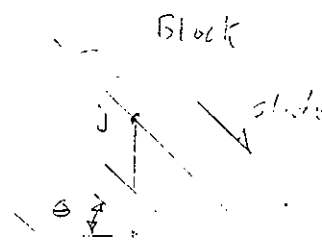
Friction: Use $\mu = 0.2$

Thick: Use -45° (see manual)

Sliding stiffness: use KN

Concept with G instead
of E : $KS \approx 100e6 \text{ #/in}$

Start condition: 2 (closed,
sliding right)



Insert

Material: $E = 28e6 \text{ psi}$

Use 304L/316L $S_y = 20.3 \text{ ksi}$ (304L, ASME Section II
Pt D)

as weakest
mat'l in dwg

$$E_p = \frac{75-50 \text{ ksi}}{0.1} = 250 \text{ ksi}$$

H-2-821874

See Atlas of σ/ϵ , attached, between
0 and 0.10 (10%) strain

Loading: Impose displacements up to .05"

See Table 3S-1, Table 3S-2 is an
abbreviate COWRITE file

Results:

Fig 3S-3: Force displacement curve.

Significant plastic deformation

occurs before bottoming out at

$$u_{yblt} = .021"$$

***** ANSYS POST26 VARIABLE LISTING *****

TIME (Load Step)	171 UY uyblk	215 UY uybot	171 FY fyblk	5 ADD dubot
1.0000	-0.250000E-03	-0.191862E-03	-2590.68	0.581379E-04
2.0000	-0.500000E-03	-0.384756E-03	-5149.49	0.115244E-03
3.0000	-0.750000E-03	-0.591725E-03	-7134.58	0.158275E-03
4.0000	-0.100000E-02	-0.823863E-03	-7974.41	0.176137E-03
5.0000	-0.125000E-02	-0.106403E-02	-8419.84	0.185966E-03
6.0000	-0.150000E-02	-0.130687E-02	-8730.30	0.193130E-03
7.0000	-0.200000E-02	-0.179552E-02	-9188.81	0.204476E-03
8.0000	-0.300000E-02	-0.277676E-02	-9923.90	0.223244E-03
9.0000	-0.500000E-02	-0.474243E-02	-11178.2	0.257567E-03
10.000	-0.800000E-02	-0.769526E-02	-12581.7	0.304738E-03
11.000	-0.120000E-01	-0.116219E-01	-14042.7	0.378145E-03
12.000	-0.200000E-01	-0.191907E-01	-16124.9	0.809348E-03
13.000	-0.300000E-01	-0.281536E-01	-17902.8	0.184638E-02

Table 3S-1

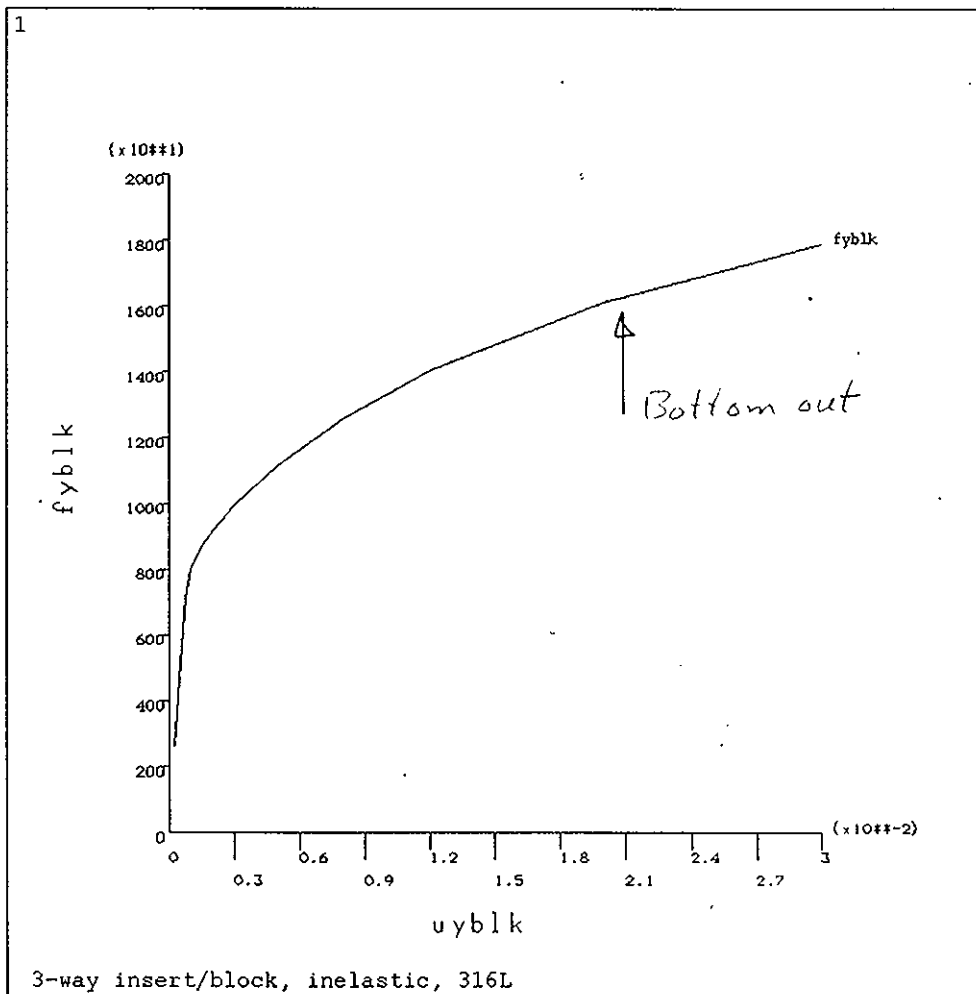
Table 75-2

```

/COM,ANSYS REVISION 5.0      A      09:17:32      04/13/1995
/TITLE, 3-way insert/block, inelastic, 316L
ANTYPE, 0
NUMOFF,NODE, 402
NUMOFF,ELEM, 365
NUMOFF,MAT, 2
NUMOFF,REAL, 2
NUMOFF,COUP, 2
NUMOFF,TYPE, 2
ET, 1, 42
KEYOP, 1, 3, 1
ET, 2, 12
DOF,UX,UY,
MAT, 2
TYPE, 2
REAL, 2
R,R5.0, 1,LOC, 1,
R,R5.0, 2,LOC, 1, -45.0000000, 200000000, 0.000000000E+00
R,R5.0, 2,LOC, 4, 2.00000000, 100000000,
N,R5.0,LOC, 1, 0.312500000, -0.400000000
c***... See mesh plot for nodes
EN,R5.0,ATTR, 4, 1, 1, 1, 0
EN,R5.0,NODE, 1, 3, 59, 58,
c***... See mesh plot for quad elements
EN,R5.0,ATTR, 2, 2, 2, 360, 0
EN,R5.0,NODE, 18, 206,
EN,R5.0,ATTR, 2, 2, 2, 361, 0
EN,R5.0,NODE, 27, 207,
EN,R5.0,ATTR, 2, 2, 2, 362, 0
EN,R5.0,NODE, 26, 203,
EN,R5.0,ATTR, 2, 2, 2, 363, 0
EN,R5.0,NODE, 28, 193,
EN,R5.0,ATTR, 2, 2, 2, 364, 0
EN,R5.0,NODE, 34, 194,
EN,R5.0,ATTR, 2, 2, 2, 365, 0
EN,R5.0,NODE, 33, 192,
MPTMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,EX, 1, 1, 28000000.0,
MPTMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,MU, 2, 1, 0.200000000,
TB,BKIN, 1, 2
TBTEMP, 0.000000000E+00, 1
TBDAT, 1, 20300.0000, 250000.000,
TBTEMP, 250.000000, 2
TBDAT, 1, 20300.0000, 250000.000,
CP,R5.0, 6, 1,UY, 13, 17, 16, 15, 14, 4,
CP,R5.0, 5, 2,UY, 171, 173, 174, 175, 172,
AUTOTS,OFF
NSUBST, 2
KBC, 0
KUSE, 0
MODE, 0, 1
TIME, 0.000000000E+00
TREF, 0.000000000E+00
ALPHAD, 0.000000000E+00
BETAD, 0.000000000E+00
DMPRAT, 0.000000000E+00
TIMINT,OFF,STRU
CRPLIM, 0.100000000
NCNV, 1, 0.000000000E+00, 0, 0.000000000E+00, 0.000000000E+00
LNSRCH,OFF
NEQIT, 0
PRED,OFF,,OFF
ERESX,DEFA
... No accelerations
IRLF, 0
D, 13,UY, 0.000000000E+00, 0.000000000E+00
D, 171,UY, -1.200000000E-02, 0.000000000E+00
/GOPR

```

I-26

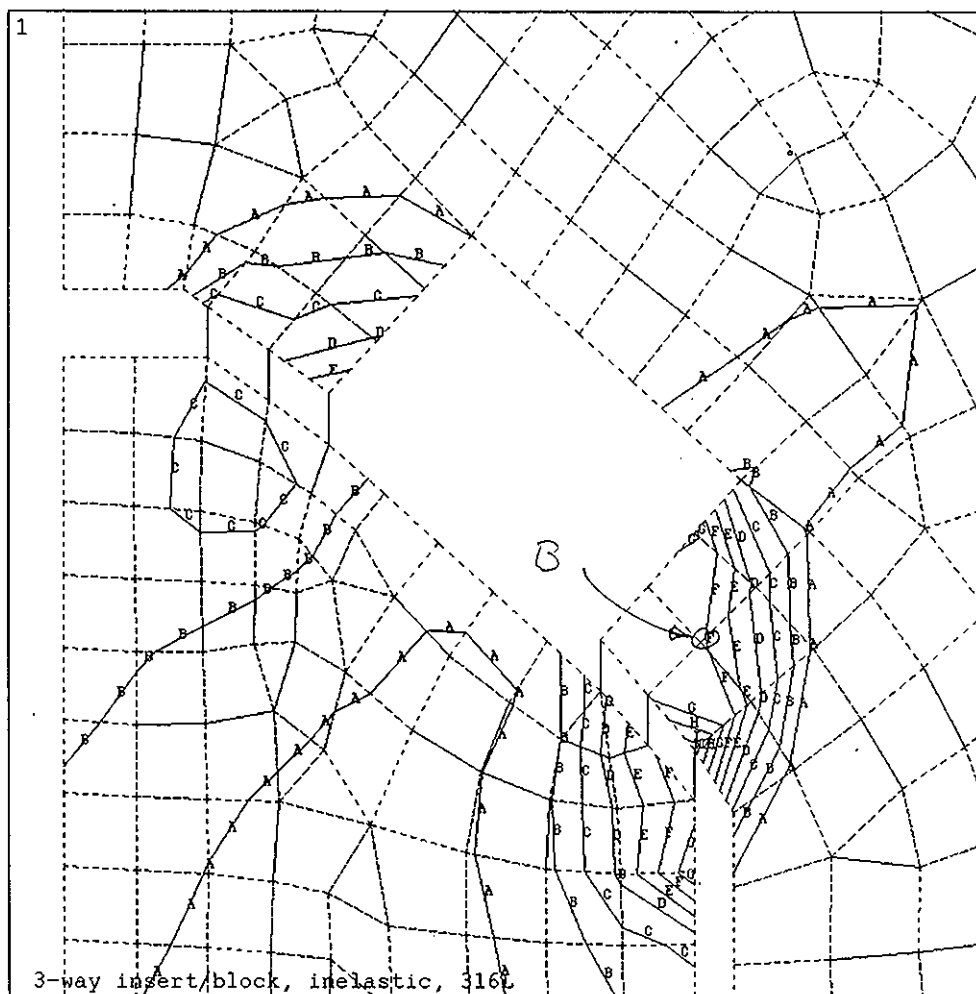


ANSYS 5.0 A
APR 10 1995
12:41:42
POST26

ZV =1
DIST=0.75
XF =0.5
YF =0.5
ZF =0.5
XRTO=1

Figure 2.5.5

I-77



ANSYS 5.0 A
APR 12 1995
14:28:37
NODAL SOLUTION
STEP=12
SUB =2
TIME=12
NLEPEQ (AVG)
DMX =0.020094
SMX =0.157248
A =0.008736
B =0.026208
C =0.04368
D =0.061152
E =0.078624
F =0.096096
G =0.113568
H =0.13104
I =0.148512

Fig 38-4

ANALYTICAL CALCULATIONS

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Subject E-Way Connector

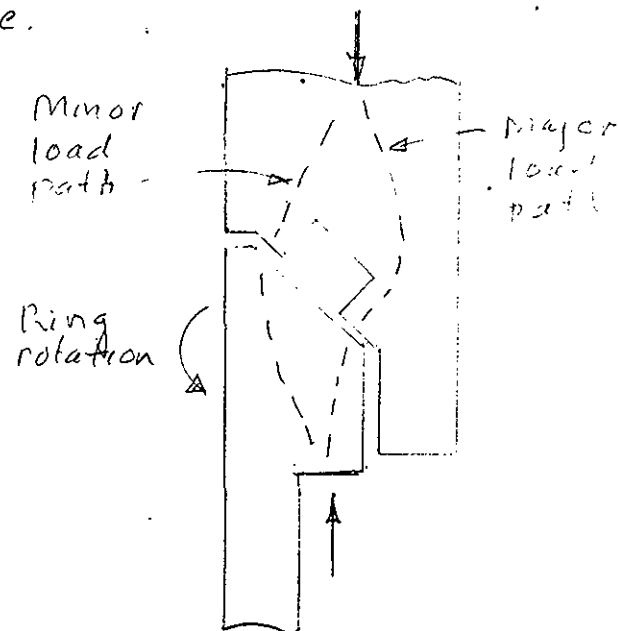
Originator EO Weiner

Date 4/12/95

Checker JL

Date 4/25/95

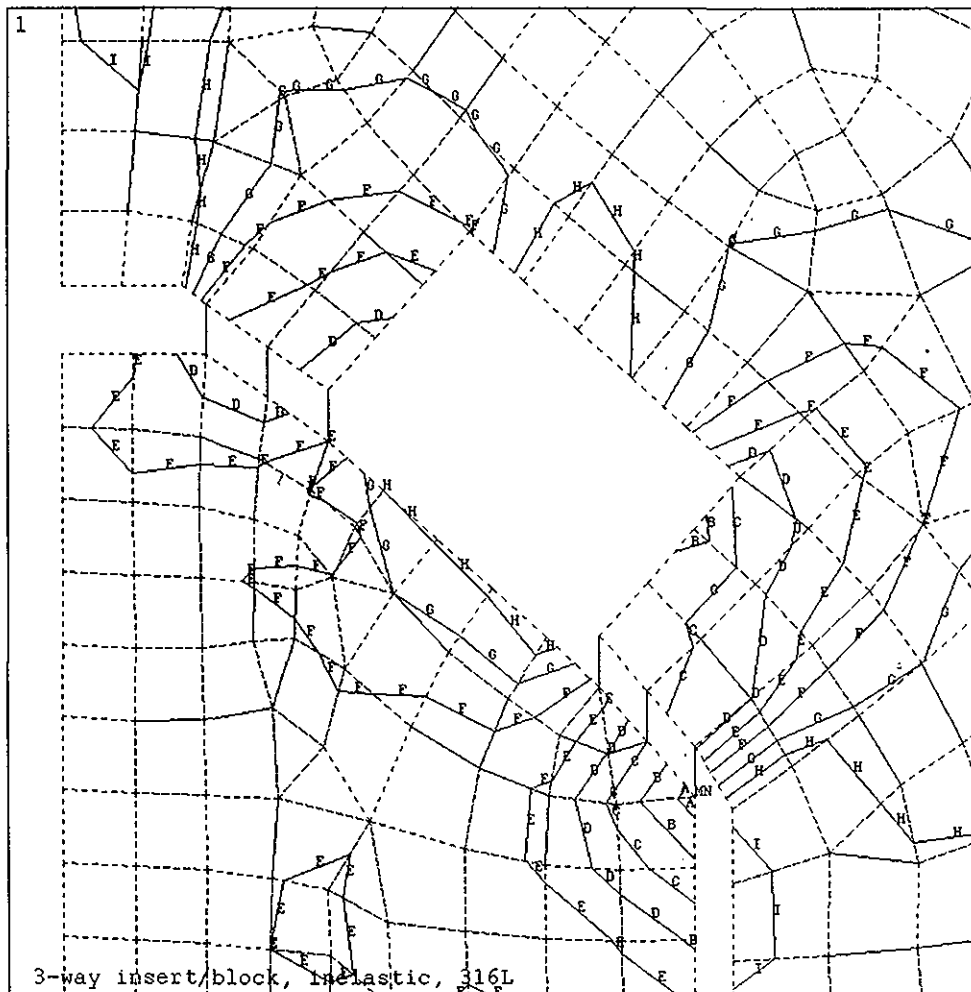
Fig 3S-4: Equivalent plastic strains at step 12. Max. plastic strains are concentrated in region next to O-ring groove. ~10% strain is achieved over depth of groove.



most load passes around the right side of the groove, because the other side is relieved by ring rotation.

Figures 3S-5 thru 7. Principal stresses at step 12: At a representative point (point B in Fig 3S-4)

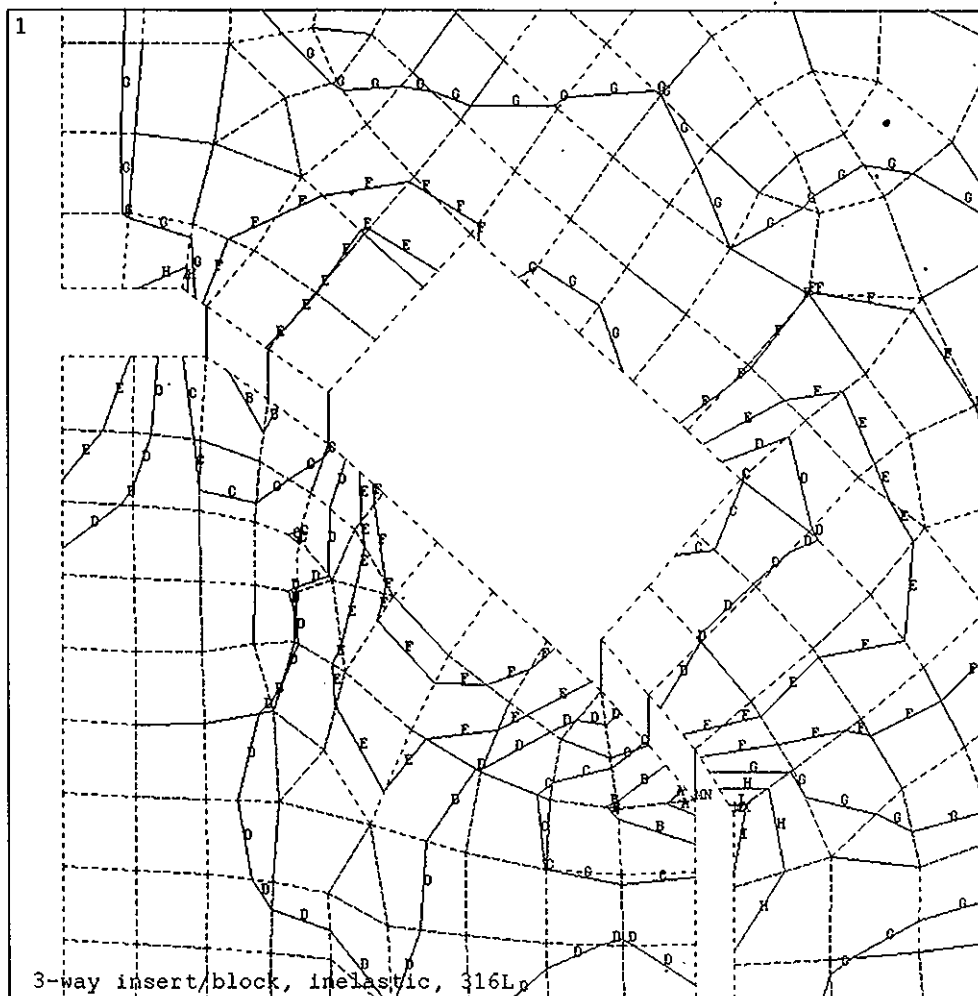
I - 29



ANSYS 5.0 A
 APR 12 1995
 14:30:26
 NODAL SOLUTION
 STEP=12
 SUB =2
 TIME=12
 S3 (AVG)
 DMX =0.020094
 SMN =-69987
 SMX =4836
 A =-65830
 B =-57516
 C =-49203
 D =-40889
 E =-32575
 F =-24262
 G =-15948
 H =-7634
 I =679.63

Fig 3-5

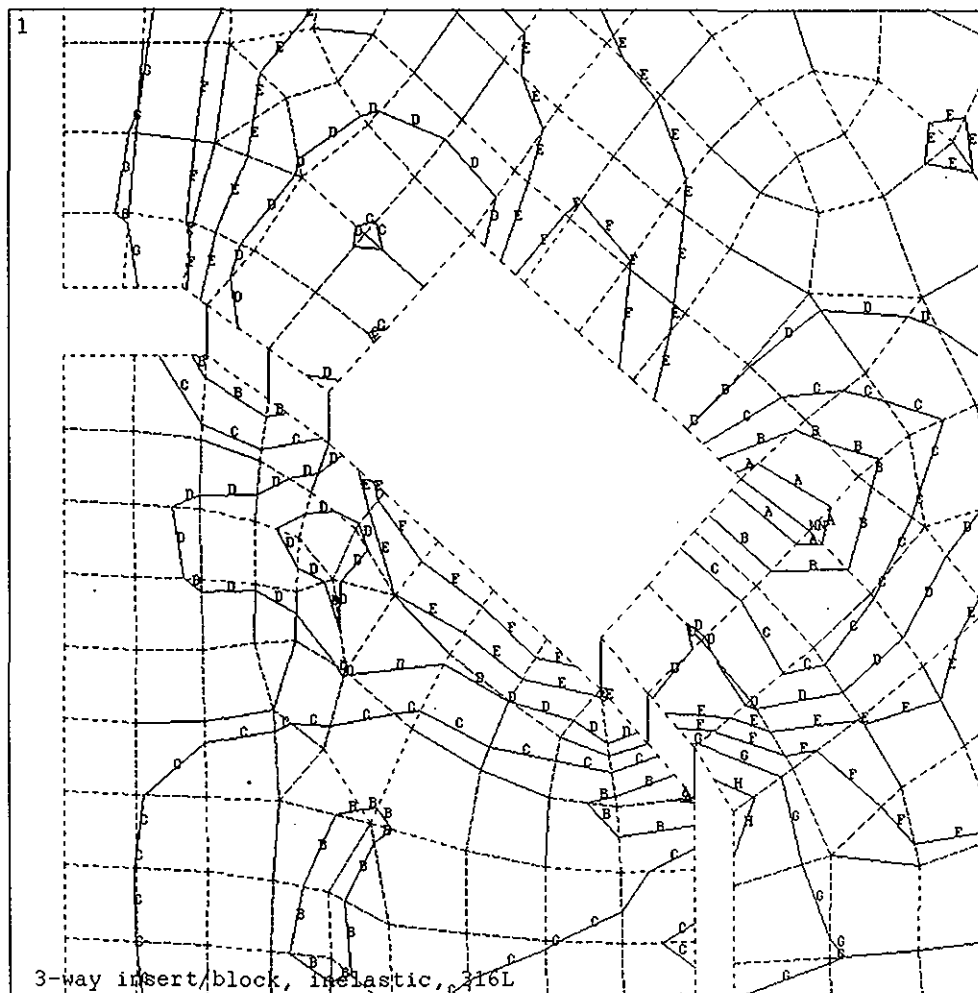
I-30



ANSYS 5.0 A
 APR 12 1995
 14:30:06
 NODAL SOLUTION
 STEP=12
 SUB =2
 TIME=12
 S2 (AVG)
 DMX =0.020094
 SMN =-46097
 SMX =23146
 A =-42250
 B =-34556
 C =-26862
 D =-19169
 E =-11475
 F =-3781
 G =3912
 H =11606
 I =19300

Fig 3S-6

I-31



ANSYS 5.0 A
APR 12 1995
14:29:16
NODAL SOLUTION
STEP=12
SUB =2
TIME=12
S1 (AVG)
DMX =0.020094
SMN =-18015
SMX =36965
A =-14961
B =-8852
C =-2743
D =3366
E =9475
F =15584
G =21692
H =27801
I =33910

Fig 3.8-7

ANALYTICAL CALCULATIONS

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Subject 3-Way Connector

Originator E O Weiner

Date 4/13/95

Checker Jedg

Date 4/25/95

$$\sigma_1 = 3000 \text{ psi}$$

$$\sigma_2 = -19000 \text{ psi}$$

$$\sigma_3 = -48000 \text{ psi}$$

Triaxiality factor: (Fig. 35-5)

$$\begin{aligned} TF &= \frac{\sqrt{2} (\sigma_1 + \sigma_2 + \sigma_3)}{[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]^{1/2}} \\ &= \frac{\sqrt{2} (3 - 19 - 48)}{[(3 + 19)^2 + (-19 + 48)^2 + (-48 - 3)^2]^{1/2}} \end{aligned}$$

$$TF = \frac{\sqrt{2} 64}{62.7} = -1.44$$

$$\text{Total elongation} = 40\% = \epsilon_t$$

Acceptable strain:

$$\epsilon_{all} = \gamma \frac{\epsilon_t}{TF} \quad TF > 1/2$$

$\gamma = 0.3$ (Generous inverse safety factor for high confidence, in addition to stacked tolerances)

$$\epsilon_{all} = \frac{0.3 \times 40}{0.5} = 0.24$$

The average strain of 10% developed over the groove depth is less than ϵ_{all} OK

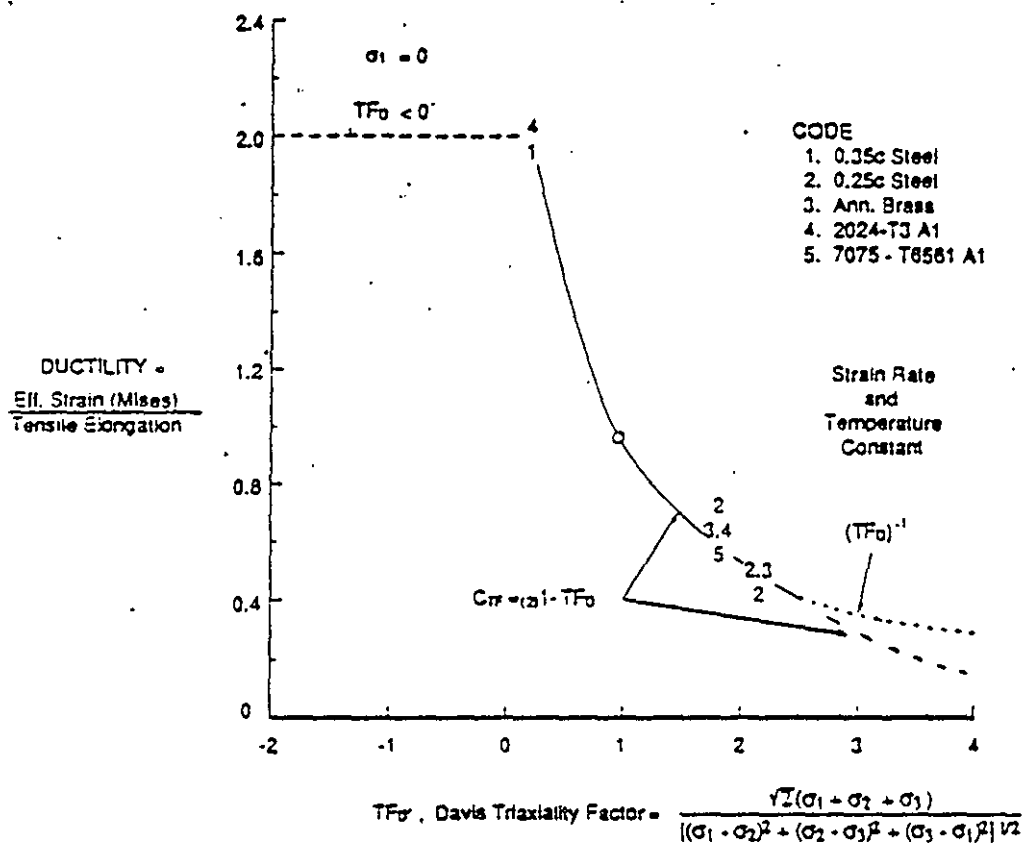


Fig 3.5-B
FIGURE 2. Effect of Stress Triaxiality on Ductility (Ref. 9).

ANALYTICAL CALCULATIONS

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Subject 3-Way Connector

Originator EO Weiner

Date 4/13/95

Checker g z g

Date 4/25/95

Therefore, strains developed at the bot-om-out condition are acceptable. Additionally note

- o The stresses are compressive
- o The one-sided stacking of tolerances assumed is highly unlikely
- o Peak strains are localized and considered non-damaging (as a punch)

After bottom-out, the axial capacity is very large. For axial capacity, use the single-insert capacity at bottom-out (16000#, Fig 70-3) with 2 inserts (assuming overturning moment)

$$F_{2-cap} = 2 \times 16000 = 32000^{\#}$$

and subtract the worst preload & thermal:

$$\begin{aligned} F_{xall} &= F_{2-cap} - F_{preload} - F_{thermal} \\ &= 32000 - 15500 - 5770 \\ &= 10700^{\#} \end{aligned}$$

for the max allowable axial pipe load (net, seating tendency). This is extremely large for 1/2" sched 40 lines. This conclusion would not be possible without the bottom-out condition protecting the insert/block interface

ANALYTICAL CALCULATIONS

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Subject 3-Way Connector
Originator EO Weiner Date 4/13/95
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from excess strain accumulation.

ANALYTICAL CALCULATIONS

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Subject 3-Way Connector

Originator EO Weiner

Date 4/6/95

Checker JLg

Date 4/25/95

3.2 Shear & torque loads

Capacity for shear & torque on connector is checked. Max shear on one insert:

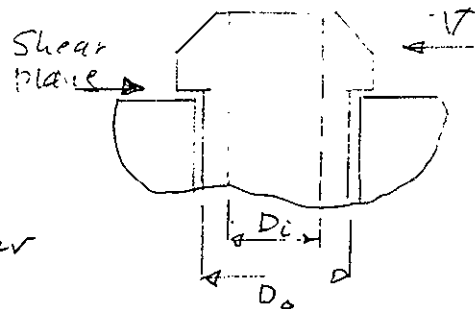
$$V_{max} = (F_s + M_T/R) / 3$$

Allow 0.6 Sm in shear ($\tau = .57 \sigma_{all}$)

$$A_s = \frac{\pi}{4} (D_o^2 - D_i^2) \quad D_o = 0.869" \quad D_i = 0.625"$$

$$A_s = \frac{\pi}{4} (.869^2 - .625^2) \\ = 0.286 \text{ in}^2$$

$$V_{all} = \frac{A}{2} \cdot 0.6 S_m \\ \text{Hollow cylinder} \\ = \frac{0.286}{2} \times 0.6 \times 16.7 \text{ ksi} \\ = 1.43 \text{ k}$$



$$\text{Require} \quad F_s + M_T/R < 3 V_{all} = 4.30 \text{ k}$$

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject 3-Way Connector

Originator E O Weaver

Date 4/6/95

Checker JZG

Date 4/25/95

3.3 Activation of hooks, pins, etc

Leakage criteria allow overturning moments in excess of the righting moment from the preload. The excess moment (from rotation) is

$$M_{rot} = 510 \text{ #"} \quad (\text{Section 2.4})$$

compared to an acceptable overturning moment of $365 \text{ #"} = 4550 \text{ #"} for a standard 2" connector. For axial (unseating) loads, the excess is$

$$F_{HK} = 1640 \text{ #"} \quad (\text{Section 2.5})$$

which is less than the conservative portion (40%) of the thermal load of 5770# used in the analysis of the 2" standard connector. With linear interaction, usage by these excesses is

$$\frac{510}{4550} + \frac{1640}{0.4 \times 5770} = 0.83$$

showing that the lift-off criteria restrain the piping overturning moments and axial forces to within acceptable levels as determined by the analysis of the 2" standard connector. $\therefore$ the 2" 3-way non-block/insert stresses are OK.

ANALYTICAL CALCULATIONS

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Subject 3-Way Connector

Originator LC Weiner

Date 4/13/95

Checker JLJ

Date 4/25/95

4.0 Local Block Stresses

Section at pipe entrance
is equivalent to three
pipes of thickness t_{eff}

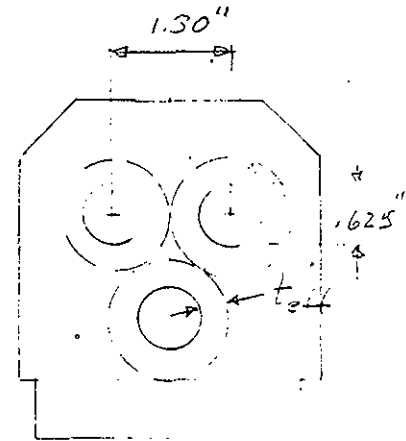
$$t_{eff} = \frac{1}{2} (1.30 - .625) = 0.34"$$

which is three times the
thickness of a 1/2" sched 40 line
coming in. $\therefore$ the block is
much stronger than the pipe
in general.

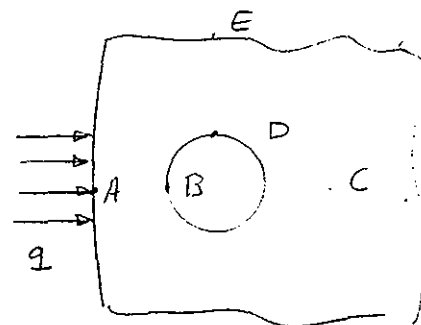
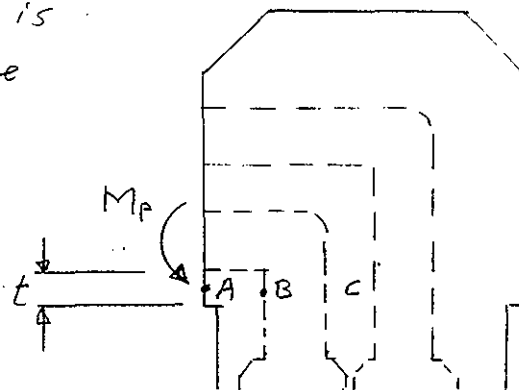
A check is made
for strength at AB -
for tunnel collapse
under bearing from
the incoming pipe moment
 M_p .

$$t = 1.583 - \frac{.625}{2} - .903 = .367$$

Use 304SS $S_y = 30$ ksi
with sched 40 pipe
thickness $t_p = 0.109"$
(Grinnel, p 224)



See DWG H-2-7215-77



ANALYTICAL CALCULATIONS

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Subject 2-Way Connector

Originator EO Weiner

Date 4/13/95

Checker JLJ

Date 4/25/95

$$q = t_p S_y = 0.109" \times 30^{ksi} = 3.27 \text{ K/in}$$

which is applied over one inside diameter and thickness t of the section. Fig's 3L-1 thru 4 show the plane stress model with $q = 1000 \text{ psi}$ applied over a 1" thickness.

Section AB: $P_L = 570 \text{ psi}$ $P_L + P_B = 1155 \text{ psi}$

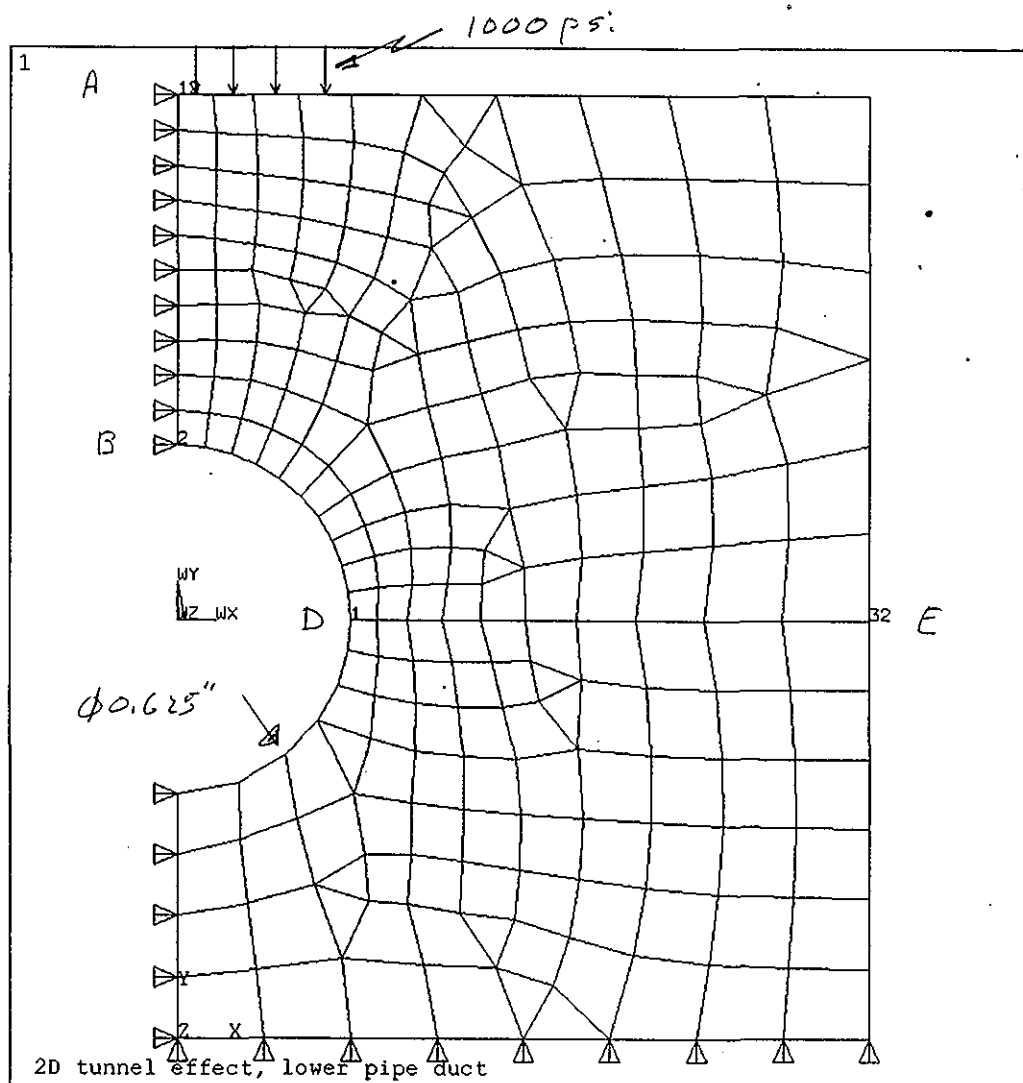
DE: $P_L = 567 \text{ psi}$ $P_L + P_D = 552 \text{ psi}$

Scaling by $t_p S_y$ and t

$$P_L + P_B = \frac{3.27 \text{ K/in}}{1 \text{ ksi} \times .367"} 1155 \text{ psi} = 10.3 \text{ ksi} < 1.5 S_m = 52 \text{ ksi}$$

This shows that the block is definitely stronger than the pipe.

I-440

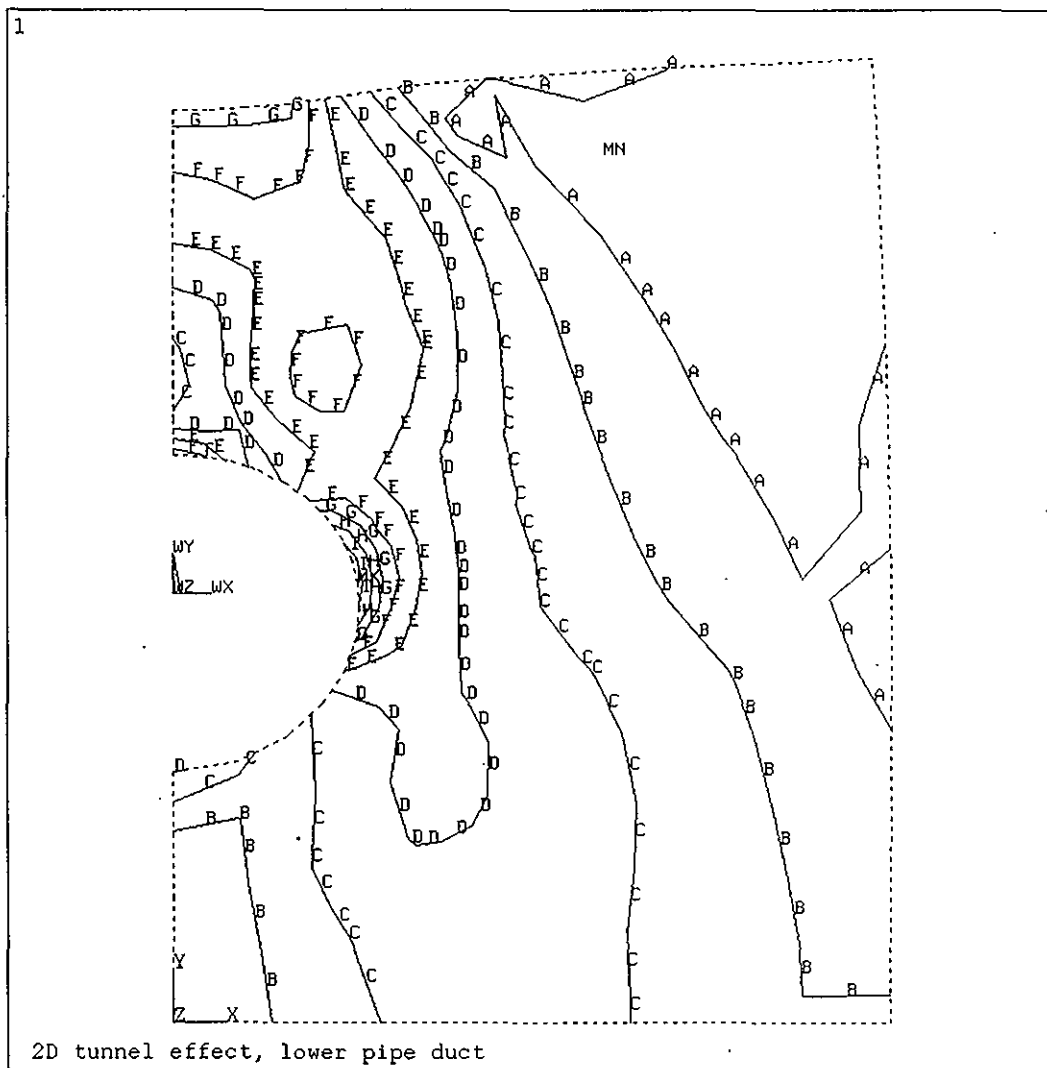


ANSYS 5.0 A
 APR 13 1995
 10:38:35
 ELEMENTS
 TYPE NUM
 U
 PRES
 ZV =1
 DIST=0.928125
 XF =0.625
 YF =0.84375

$T_{ult} = 1"$

Figure 5L-1

I-41



ANSYS 5.0 A
 FEB 22 1995
 11:31:15
 NODAL SOLUTION
 STEP=1
 SUB =1
 TIME=1
 SINT (AVG)
 DMX =44.292
 SMN =24.108
 SMX =1526
 SMXB=1626
 A =107.547
 B =274.425
 C =441.303
 D =608.181
 E =775.059
 F =941.938
 G =1109
 H =1276
 I =1443

Figure 3L-2

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 2 OUTSIDE NODE = 12 [points A to B]

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
-163.1    -562.5    0.0000E+00    54.27    0.0000E+00    0.0000E+00
      S1      S2      S3      SINT      SEQV
0.0000E+00   -155.9   -569.7    569.7    510.0

...

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I  669.1    21.29    0.0000E+00    71.40    0.0000E+00    0.0000E+00
C -163.1    -562.5    0.0000E+00    54.27    0.0000E+00    0.0000E+00
O -995.3   -1146.   0.0000E+00    37.14    0.0000E+00    0.0000E+00
      S1      S2      S3      SINT      SEQV
I  676.8    13.51    0.0000E+00    676.8    670.2
C  0.0000E+00   -155.9   -569.7    569.7    510.0
O  0.0000E+00   -986.7   -1155.   1155.   1081.

...

```

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 1 OUTSIDE NODE = 32 [points D to E]

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

```

** MEMBRANE **
      SX      SY      SZ      SXY      SYZ      SXZ
-77.58    -324.5    0.0000E+00    110.4    0.0000E+00    0.0000E+00
      S1      S2      S3      SINT      SEQV
0.0000E+00   -35.41   -366.7    366.7    350.4

...

** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
      SX      SY      SZ      SXY      SYZ      SXZ
I -164.4    -812.0    0.0000E+00    165.4    0.0000E+00    0.0000E+00
C -77.58    -324.5    0.0000E+00    110.4    0.0000E+00    0.0000E+00
O  9.273    162.9    0.0000E+00    55.44    0.0000E+00    0.0000E+00
      S1      S2      S3      SINT      SEQV
I  0.0000E+00   -124.6   -851.8    851.8    796.8
C  0.0000E+00   -35.41   -366.7    366.7    350.4
O  180.8    0.0000E+00   -8.648    189.4    185.3

...

```

Figure 3L-3

```

/COM,ANSYS REVISION 5.0          A      10:41:07   04/13/1995
/NOPR
/TITLE, 2D tunnel effect, lower pipe duct
ANTYPE, 0
NUMOFF,NODE, 392
NUMOFF,ELEM, 370
NUMOFF,MAT, 1
NUMOFF,REAL, 1
NUMOFF,TYPE, 1
ET, 1, 42
DOF,UX,UY
R,R5.0, 1,LOC, 1,
N,R5.0,LOC, 1, 0.312500000 , 0.750000000
c***... See mesh plot for nodes
EN,R5.0,ATTR, 4, 1, 1, 1, 1, 0
EN,R5.0,NODE, 1, 46, 47, 3,
c***... See mesh plot for elements
MPTMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,EX, 1, 1, 30.6000000
AUTOTS,OFF
NSUBST, 1
KBC, 0
KUSE, 0
TIME, 0.000000000E+00
TREF, 0.000000000E+00
ALPHAD, 0.000000000E+00
BETAD, 0.000000000E+00
DMPRAT, 0.000000000E+00
TIMINT,OFF,STRU
CRPLIM, 0.100000000
NCNV, 1, 0.000000000E+00, 0, 0.000000000E+00, 0.000000000E+00
LNSRCH,OFF
NEQIT, 0
PRED,OFF,,OFF
ERESX,DEFA
c***... No accelerations
IRLF, 0
D, 2,UX, 0.000000000E+00, 0.000000000E+00
c***... See mesh plot for displacement bcs
SFE, 5, 1,PRES,1,R5.0
1000.00000 1000.00000 0.000000000E+00 0.000000000E+00
SFE, 5, 1,PRES,2,R5.0-
0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
c***... See mesh plot for pressures
/GOPR

```

Figure 3L-4

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject _____
Originator _____ Date _____
Checker _____ Date _____

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