طرح نگهداشت و افزایش تولید 27 مخزن

THERMAL/MECHANICAL CALCULATION BOOK FOR RICH-LEAN GLYCOL H.E. (E-200)

نگهداشت و افزایش تولید میدان نفتی بینک

V00	DEC. 2024	IFI	MFS	M.Fakharian	S.Faramarzpour	
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Status:

IFA: Issued For Approval
IFI: Issued For Information
AFC: Approved For Construction

REVISION RECORD SHEET

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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2019

Analysis Performed by :

Job File : C:\USERS\TECHNICAL2\DESKTOP\E-200 FRONT.Pvdb

Date of Analysis : Dec 31,2024 10:13am

PV Elite 2020, January 2020

ASME Code, Section VIII Division 1, 2019

Diameter Spec : 96.266 mm. OD		
Vessel Design Length, Tangent to Tangent	3772.40	mm.
Specified Datum Line Distance	0.00	mm.
Shell Side Design Temperature	220	°C
Channel Side Design Temperature	165	°C
Shell Side Design Pressure	5.800	bars
Channel Side Design Pressure	7.500	bars
Shell Side Hydrostatic Test Pressure	8.151	bars
Channel Side Hydrostatic Test Pressure	9.922	bars
Wind Design Code	ASCE-2010	
Earthquake Design Code	ASCE 7-2010	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-312 TP316L	...	...	S31603	No	No
Cone	SA-403 316L	...	...	S31603	No	No
Flange	SA-182 F316L	...	<= 5	S31603	No	No
Nozzle	SA-182 F316L	...	<= 5	S31603	No	No
Nozzle Flg	SA-182 F316L	...	<= 5	S31603	No	No
Tubes	SA-213 TP316L	...	...	S31603	No	No
Tubesheet	SA-182 F316L	...	<= 5	S31603	No	No
Flg Bolting	SA-193 B8M	1	...	S31600	No	No

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.
Impact Tested is based on material selection and material data properties.

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Shell	5.809	1.03	42.000	0.0000	N/A	?
Shell FLG.	5.809	1.03	48.000	0.0000	N/A	?
Front Channel FLG.	7.506	1.03	69.000	0.0000	N/A	?
Front Channel Barrel	7.508	1.03	140.000	0.0000	N/A	?
TS Inlet	7.500	1.03	12.000	0.0000	N/A	?

Liquid Level: 91.55 mm. Dens.: 999.542 kg/m³ Sp. Gr.: 1.000

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Cylinder	3400.0	3400.0	3.0	2.7	1.5	0.9	1.00	1.00
Body Flg	3480.0	80.0	...	40.0	29.2	29.2	1.00	1.00
Body Flg	3628.0	80.0	...	40.0	34.8	34.8	1.00	1.00
Conical	3717.0	89.0	...	5.5	1.5	0.3	1.00	1.00
Body Flg	3772.4	55.4	...	14.2	...	...	1.00	1.00

Weights:

Fabricated	- Bare W/O Removable Internals	402.7	kg.
Shop Test	- Fabricated + Water (Full)	475.2	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	417.1	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	967.1	kg.
Empty	- Fab. + Intls. + Details + Wghts.	967.1	kg.
Operating	- Empty + Operating Liquid (No CA)	989.3	kg.
Field Test	- Empty Weight + Water (Full)	489.7	kg.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
S1 (1in)	11	OK	...	OK	1.50	OK	Passed
S2 (1in)	11	OK	...	OK	1.50	OK	Passed

Nozzle MAWP Summary:

Minimum MAWP Nozzles : 11 Nozzle : S1 (1in) [Shellside]

Note: MAWPs (Internal Case) shown above are at the High Point.

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
10	S1 (1in)	3250.000	90.000	56.334
10	S2 (1in)	3250.000	270.000	56.334

The nozzle spacing is computed by the following:

= Sqrt($ll^2 + lc^2$) where

ll - Arc length along the inside vessel surface in the long. direction.

lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.

No interference violations have been detected !

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	CYLINDER: 3.0mm. THK X 96.3mm. ID X 3400.0mm.	SA-312 TP316L
1	BODY FLANGE: 40.0mm. THK X 96.3mm. OD	SA-182 F316L
1	BODY FLANGE: 40.0mm. THK X 72.0mm. OD	SA-182 F316L
1	CONE: 5.5mm. THK X 77.4mm. ID X 89.0mm.	SA-403 316L
1	BODY FLANGE: 14.2mm. THK X 27.9mm. OD	SA-182 F316L
1	INSULATION: 3400mm X 60mm THK	
1	INSULATION: 80mm X 60mm THK	
1	TUBESHEET: 89mm X 45mm THK	SA-182 F316L
4	TUBES: 3490mm X 19mm DIA X 1mm THK	SA-213 TP316L
1	INSULATION: 84mm X 60mm THK	
1	INSULATION: 89mm X 60mm THK	
1	INSULATION: 55mm X 60mm THK	
1	GASKET: 102mm. OD X 96mm. ID	...
10	BODY FLANGE BOLTS: 15mm. DIA	SA-193 B8M
20	NUTS FOR BODY FLANGE BOLTS: 15mm. DIA	...
1	NAMEPLATE	...

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm	Reinforcing Pad Diameter	Reinforcing Pad Thk mm	Cut Length in	Flg Class
S1 (1in)	1.000 in	Actual	LW	2.008	12.800	...	...	59.9	150
S2 (1in)	1.000 in	Actual	LW	2.008	12.800	...	...	59.9	150

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must

be increased. The Re-Pad WIDTH around the nozzle is calculated as follows:
Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (mm.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
S1 (1in)	SA-182 F316L	2.667	8.000	...	...	...
S2 (1in)	SA-182 F316L	2.667	8.000	...	...	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
S1 (1in)	3250.000	90.0	50.00	0.00	Shell
S2 (1in)	3250.000	270.0	50.00	0.00	Shell

Minimum Design Metal Temperature Results Summary :

Description	Curve Notes	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
Shell FLG.	[11]	-196						
Shell	[16]	-196						
S1 (1in)	[15]	-196						
Nozzle Flg	[5]	-196						
S2 (1in)	[15]	-196						
Nozzle Flg	[5]	-196						
Tubesheet: SS	[13]	-196						
Warmest MDMT:		-196						
Front Channel	[11]	-196						
Nozzle Flg	[5]	-196						
Front Channel	[16]	-196						
Warmest MDMT:		-196						

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-196.0	5.0	Pass
Channel/Tube	-196.0	5.0	Pass

Notes:

[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
[21] - Bolting Material

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

```
Class From To : Basic Element Checks.
==============================================================================

Class From To: Check of Additional Element Data
==============================================================================
```

Warning: Shell FLG. and Front Channel FL
There are mating flanges in this model that have different design pressures. This will generate different bolt loads. If a tubesheet is in between these flanges, PV Elite will compute the mating flange loads for you. If there is not a tubesheet physically separating these flanges, you must enter in the mating flange loads into the flange dialog.

Warning:
There is a flange in this model connected to an element whose temperature is different. The bolt allowable stress is based on it's parent design temperature. You may need to manually adjust the operating bolt allowable stress to a value based upon a representative maximum temperature the bolts will be subject to.

PV Elite Vessel Analysis Program: Input Data

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	5.8	bars
Channel Side Design Pressure	7.5	bars
Shell Side Design Temperature	220.0	°C
Channel Side Design Temperature	165.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	Lethal	
Service Type, Channel Side	Lethal	
MDMT (CET), Shell Side	5.0	°C
MDMT (CET), Tube Side	5.0	°C
User defined MAWP, Shell Side	10.9	bars
User defined MAWP, Channel Side	0	bars
User defined MAPnc, Shell Side	0	bars
User defined MAPnc, Channel Side	0	bars
User defined Test Pres., Shell Side	0	bars
User defined Test Pres., Channel Side	0	bars

Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Type of Construction	Welded	
Use Higher Longitudinal Stresses (Flag)	N	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	Y	

Load Case 1	NP+EW+WI+FW+BW
Load Case 2	NP+EW+EE+FS+BS
Load Case 3	NP+OW+WI+FW+BW
Load Case 4	NP+OW+EQ+FS+BS
Load Case 5	NP+HW+HI
Load Case 6	NP+HW+HE
Load Case 7	IP+OW+WI+FW+BW
Load Case 8	IP+OW+EQ+FS+BS
Load Case 9	EP+OW+WI+FW+BW
Load Case 10	EP+OW+EQ+FS+BS
Load Case 11	HP+HW+HI
Load Case 12	HP+HW+HE
Load Case 13	IP+WE+EW
Load Case 14	IP+WF+CW
Load Case 15	IP+VO+OW
Load Case 16	IP+VE+EW
Load Case 17	NP+VO+OW

Load Case 18		FS+BS+IP+OW	
Load Case 19		FS+BS+EP+OW	
Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	120	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		100	mm.
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm.
Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	
Seismic Design Code		ASCE 7-2010	
Seismic Load Reduction Scale Factor		0.700	
Importance Factor		1.250	
Table Value Fa		1.111	
Table Value Fv		1.575	
Short Period Acceleration value Ss		1.377	
Long Period Acceleration Value Sl		0.367	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		3.000	
Site Class		C	
Component Elevation Ratio	z/h	0.000	
Amplification Factor	Ap	0.000	
Force Factor		0.000	
Consider Vertical Acceleration		No	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0)		1.020	
User Value of Sd1 (used if > 0)		0.385	
Design Pressure + Static Head		Y	
Consider MAP New and Cold in Noz. Design		N	
Consider External Loads for Nozzle Des.		Y	
Use ASME VIII-1 Appendix 1-9		N	
Material Database Year		Current w/Addenda or Code Year	

Configuration Directives:

Do not use Nozzle MDMT Interpretation VIII-1 01-37	No
Use Table G instead of exact equation for "A"	Yes
Shell Head Joints are Tapered	Yes
Compute "K" in corroded condition	Yes
Use Code Case 2286	No
Use the MAWP to compute the MDMT	Yes
For thickness ratios <= 0.35, MDMT will be -155F (-104C)	Yes
For PWHT & P1 Materials the MDMT can be < -55F (-48C)	No

Using Metric Material Databases, ASME II D	No
Calculate B31.3 type stress for Nozzles with Loads	Yes
Reduce the MDMT due to lower membrane stress	Yes
Consider Longitudinal Stress in MDMT calcs. (Div. 1)	Yes

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Cylinder	
Description	Shell	
Distance "FROM" to "TO"	3400	mm.
Inside Diameter	96.266	mm.
Element Thickness	2.667	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	3.048	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	5.8	bars
Design Temperature Internal Pressure	220	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-312 TP316L	
Allowable Stress, Ambient	115.15	N./mm²
Allowable Stress, Operating	79.129	N./mm²
Allowable Stress, Hydrotest	155.14	N./mm²
Material Density	8027.2	kg/m³
P Number Thickness	0	mm.
Yield Stress, Operating	118.54	N./mm²
External Pressure Chart Name	HA-4	
UNS Number	S31603	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	10	
Detail Type	Liquid	
Detail ID	Liquid: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	91.554	mm.
Liquid Density	999.54	kg/m³
Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	3400	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³
Element From Node	10	
Detail Type	Nozzle	
Detail ID	S1 (1in)	

Dist. from "FROM" Node / Offset dist	3250	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.02105	kN
Grade of Attached Flange	GR 2.3	
Nozzle Matl	SA-182 F316L	

Element From Node	10	
Detail Type	Nozzle	
Detail ID	S2 (1in)	
Dist. from "FROM" Node / Offset dist	3250	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.02105	kN
Grade of Attached Flange	GR 2.3	
Nozzle Matl	SA-182 F316L	

Element From Node	10	
Detail Type	Weight	
Detail ID	REAR	
Dist. from "FROM" Node / Offset dist	0	mm.
Miscellaneous Weight	2.2554	kN
Offset from Element Centerline	0	mm.

Element From Node	10	
Detail Type	Weight	
Detail ID	BAFFLE	
Dist. from "FROM" Node / Offset dist	1750	mm.
Miscellaneous Weight	0.4903	kN
Offset from Element Centerline	0	mm.

Element From Node	10	
Detail Type	Weight	
Detail ID	LEG 1	
Dist. from "FROM" Node / Offset dist	440	mm.
Miscellaneous Weight	0.4903	kN
Offset from Element Centerline	45	mm.

Element From Node	10	
Detail Type	Weight	
Detail ID	LEG 2	
Dist. from "FROM" Node / Offset dist	3030	mm.
Miscellaneous Weight	0.4903	kN
Offset from Element Centerline	45	mm.

Element From Node	10	
Detail Type	Weight	
Detail ID	UPPER HEX	
Dist. from "FROM" Node / Offset dist	3030	mm.

Miscellaneous Weight	2.4515	kN
Offset from Element Centerline	45	mm.
Element From Node	10	
Detail Type	Weight	
Detail ID	UPPER HEX	
Dist. from "FROM" Node / Offset dist	440	mm.
Miscellaneous Weight	2.4515	kN
Offset from Element Centerline	45	mm.

Element From Node	20	
Element To Node	30	
Element Type	Flange	
Description	Shell FLG.	
Distance "FROM" to "TO"	80	mm.
Flange Inside Diameter	96.266	mm.
Element Thickness	40	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	5.8	bars
Design Temperature Internal Pressure	220	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-182 F316L	
Allowable Stress, Ambient	115.1	N./mm²
Allowable Stress, Operating	79.1	N./mm²
Allowable Stress, Hydrotest	155.1	N./mm²
Material Density	8027.2	kg/m³
P Number Thickness	0	mm.
Yield Stress, Operating	118.5	N./mm²
External Pressure Chart Name	HA-4	
UNS Number	S31603	
Class / Thickness / Grade :: <= 5		
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	kN
Class of Standard Flange		
Grade of Standard Flange		
Weld is pre-Heated	No	
Element From Node	20	
Detail Type	Liquid	
Detail ID	Liquid: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	91.554	mm.
Liquid Density	999.54	kg/m³
Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	0	mm.

Height/Length of Insulation	80	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³

Element From Node	30	
Element To Node	50	
Element Type	Flange	
Description	Front Channel FLG.	
Distance "FROM" to "TO"	80	mm.
Flange Inside Diameter	72	mm.
Element Thickness	40	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	7.5	bars
Design Temperature Internal Pressure	165	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-182 F316L	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	kN
Class of Standard Flange		
Grade of Standard Flange		
Weld is pre-Heated	No	

Element From Node	30	
Detail Type	Liquid	
Detail ID	Liquid: 30	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	65.3	mm.
Liquid Density	999.54	kg/m³

Element From Node	30	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	85	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³

Element From Node	50	
Element To Node	60	
Element Type	Conical	
Description	Front Channel Barrel	
Distance "FROM" to "TO"	89	mm.
Element Outside Diameter	88.9	mm.
Element Thickness	5.49	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.

Design Internal Pressure	7.5	bars
Design Temperature Internal Pressure	165	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-403 316L	
Allowable Stress, Ambient	115.15	N./mm²
Allowable Stress, Operating	113.15	N./mm²
Allowable Stress, Hydrotest	155.14	N./mm²
Material Density	8027.2	kg/m³
P Number Thickness	0	mm.
Yield Stress, Operating	128.01	N./mm²
External Pressure Chart Name	HA-4	
UNS Number	S31603	
Product Form	Smls. & wld. fittings	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Cone Diameter at "To" End	33.4	mm.
Design Length of Cone	89	mm.
Half Apex Angle of Cone	17.31736	degrees
Toriconical (Y/N)	N	
Weld is pre-Heated	No	
Element From Node	50	
Detail Type	Liquid	
Detail ID	Liquid: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	77.927	mm.
Liquid Density	999.54	kg/m³
Element From Node	50	
Detail Type	Insulation	
Detail ID	Ins: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	89	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³

Element From Node	60	
Element To Node	70	
Element Type	Flange	
Description	TS Inlet	
Distance "FROM" to "TO"	55.372	mm.
Flange Inside Diameter	27.86	mm.
Element Thickness	14.224	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	7.5	bars
Design Temperature Internal Pressure	165	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	

Material Name	SA-182 F316L	
Allowable Stress, Ambient	115.15	N./mm²
Allowable Stress, Operating	85.569	N./mm²
Allowable Stress, Hydrotest	155.14	N./mm²
Material Density	8027.2	kg/m³
P Number Thickness	0	mm.
Yield Stress, Operating	128.01	N./mm²
External Pressure Chart Name	HA-4	
UNS Number	S31603	
Class / Thickness / Grade :: <= 5		
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	kN
Class of Standard Flange		
Grade of Standard Flange		
Weld is pre-Heated	No	
Element From Node	60	
Detail Type	Insulation	
Detail ID	Ins: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	55.372	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³

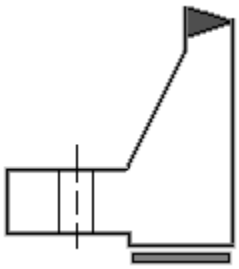
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
Shell		3400	...	3400	...
Shell FLG.		3480	...	80	...
Front Channel F		3628.02	...	80	...
Front Channel B		3717.02	...	89	...
TS Inlet		3772.4	...	55.372	...

Flange Input Data Values **Description: FLANGE :**

Shell FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	5.81	bars
Design Temperature		220	°C
Internal Corrosion Allowance	ci	0.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	96.266	mm.
Flange Outside Diameter	A	215.900	mm.
Flange Thickness	t	40.0000	mm.
Thickness of Hub at Small End	go	3.0480	mm.
Thickness of Hub at Large End	g1	15.0000	mm.
Length of Hub	h	40.0000	mm.
Flange Material		SA-182 F316L	
Flange Material UNS number		S31603	
Flange Allowable Stress At Temperature	Sfo	79.10	N./mm²
Flange Allowable Stress At Ambient	Sfa	115.10	N./mm²
Bolt Material		SA-193 B8M	
Bolt Allowable Stress At Temperature	Sb	96.67	N./mm²
Bolt Allowable Stress At Ambient	Sa	129.63	N./mm²
Diameter of Bolt Circle	C	177.800	mm.
Nominal Bolt Diameter	a	15.8750	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		10	
Flange Face Outside Diameter	Fod	102.300	mm.
Flange Face Inside Diameter	Fid	96.266	mm.
Flange Facing Sketch		9, Code Sketch 6	
Gasket Outside Diameter	Go	102.000	mm.
Gasket Inside Diameter	Gi	96.266	mm.
Gasket Factor	m	5.5000	
Gasket Design Seating Stress	y	124.11	N./mm²
Column for Gasket Seating		1, Code Column I	
Gasket Thickness	tg	10.0000	mm.
Flange Face Nubbin Width	w	10.0000	mm.



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Hub Small End Required Thickness due to Internal Pressure:
```
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (5.81*(96.266/2+0.0))/(79.1*1.0-0.6*5.81)+Ca
= 0.3551 mm.
```

Hub Small End Hub MAWP:
```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (79.1 * 1.0 * 3.048)/(48.133 + 0.6 * 3.048 )
= 48.253 bars
```

```
Corroded Flange ID,      Bcor = B+2*Fcor              96.266  mm.
Corroded Large Hub,     g1Cor = g1-ci                 15.000  mm.
Corroded Small Hub,     g0Cor = go-ci                  3.048  mm.
Code R Dimension,           R = (C-B)/2 - g1         25.767  mm.

Gasket Contact Width,       N = (Go - Gi) / 2          2.867  mm.
Basic Gasket Width,        bo =      w / 8            1.250  mm.
Effective Gasket Width,     b = bo                    1.250  mm.
Gasket Reaction Diameter,   G = (Go + Gi) / 2        99.133  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
= 0.785 * G² * Peq
= 0.785 * 99.133² * 5.809
= 4.483 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
= 2 * b * Pi * G * m * P
= 2 * 1.25 * 3.1416 * 99.133 * 5.5 * 5.81
= 2.487 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
= Pi * Bcor² * P  / 4
= 3.1416 * 96.266² *5.809/4
= 4.228 kN
```
Pressure Force on Flange Face [Ht]:
```
= H - Hd
= 4 - 4
= 0.256 kN
```
Operating Bolt Load [Wm1]:
```
= max( H + Hp + H'p, 0 )
= max( 4 + 2 + 0, 0 )
= 6.971 kN
= 8.301 kN, Mating Flange Load Governs
```
Gasket Seating Bolt Load [Wm2]:
```
= y * b * Pi * G  + yPart * bPart * lp
= 124.11*1.25*3.141*99.133+0.0*0.0*0.0
= 48.311 kN
= 69.310 kN, Mating Flange Load Governs
```
Required Bolt Area [Am]:
```
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 8/97, 69/130
```

= 5.347 cm²

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 15.875 + 6 * 40.0/(5.5 + 0.5)
= 71.750 mm.

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 177.8 * sin(3.142/10)
= 54.943 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(54.943/(2 * 15.875 + 40.0)), 1)
= 1.0000

Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm²	5.347	13.032	
Radial Distance between Hub and Bolts:	23.812	25.767	
Radial Distance between Bolts and Edge:	19.050	19.050	
Circ. Spacing between the Bolts:	38.100	54.943	71.750

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 13.032 * 129.63/(124.11 * 3.14 * (102.0 + 96.27))
= 2.185 mm.

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * Ab
= 129.63 * 13.0322
= 168.92 kN

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 8 - 4
= 3.82 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (177.8 - 99.133)/2
= 39.3335 mm.

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (25.767 + 15.0 + 39.3335)/2
= 40.0503 mm.

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 25.767 + (15.0/2.0)
= 33.2670 mm.

Summary of Moments for Internal Pressure: (N-m)

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	4.	33.2670	1.0000	141.
Face Pressure,	Mt	0.	40.0503	1.0000	10.
Gasket Load,	Mg	4.	39.3335	1.0000	150.
Gasket Seating,	Matm	169.	39.3335	1.0000	6647.

Total Moment for Operation, Mop = 301. N-m
Total Moment for Gasket seating, Matm = 6647. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor) = 17.129 mm.
Hub Ratio, h/h0 = HL / H0 = 2.335
Thickness Ratio, g1/g0 = (g1Cor/goCor) = 4.921

Flange Factors for Integral Flange:

Factor F			0.486	
Factor V			0.017	
Factor f			1.000	
Factors from Figure 2-7.1		K =	2.243	
	T = 1.421	U =	2.804	
	Y = 2.552	Z =	1.496	
	d = 25773.855 mm.³	e =	0.0284	mm.^-1
Stress Factors		ALPHA =	2.135	
	BETA = 2.514	GAMMA =	1.503	
	DELTA = 2.483	Lamda =	3.986	

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.0*301/96.266)/(3.9861*15.0²)
= 3.49 N./mm²

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.0*6647/96.266)/(3.9861*15.0²)
= 76.96 N./mm²

Radial Flange Stress, Operating [SRo]:
= (Beta * Mop / Bcor) / (L * t²)
= (2.5137*301/96.266)/(3.9861*40.0²)
= 1.23 N./mm²

Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (2.5137*6647/96.266)/(3.9861*40.0²)
= 27.20 N./mm²

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (2.552*301/(40.0²*96.266))-1.4963*1
= 3.14 N./mm²

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (2.552*6647/(40.0²*96.266))-1.4963*27

= 69.39 N./mm²

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (3+max(1,3))/2
= 3.32 N./mm²

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (77+max(27,69))/2
= 73.17 N./mm²

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 8/13.0322
= 6.37 N./mm²

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (69/13.0322)
= 53.19 N./mm²

Flange Stress Analysis Results: N./mm²

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	3.49	118.65	76.96	172.65
Radial Flange	1.23	79.10	27.20	115.10
Tangential Flange	3.14	79.10	69.39	115.10
Maximum Average	3.32	79.10	73.17	115.10
Bolting	6.37	96.67	53.19	129.63

Minimum Required Flange Thickness	29.159 mm.
Estimated M.A.W.P. (Operating)	105 bars
Estimated Finished Weight of Flange at given Thk.	10.4 kg.
Estimated Unfinished Weight of Forging at given Thk	18.8 kg.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go² * ho * Ki)
= 52.14*6646.8/1.0*999.68*0.017/(2.246*195129*3.048²*17.129*0.3)
= 0.287 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc² * ho * Ki)
= 52.14*301.2/1.0*999.68*0.017/(2.246*181064*3.048²*17.129*0.3)
= 0.014 (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go² * ho * Ki)
= 52.14*6646.8/1.0*999.68*0.017/(3.986*195129*3.048²*17.129*0.3)
= 0.162 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

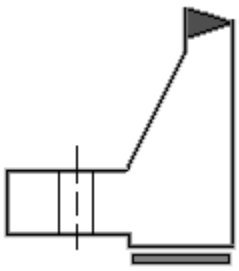
```
= 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )
= 52.14*301.2/1.0*999.68*0.017/(3.986*181064*3.048^2*17.129*0.3)
= 0.008    (should be <= 1)
```

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Flange Input Data Values **Description: FLANGE :**

Front Channel FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	7.51	bars
Design Temperature		165	°C
Internal Corrosion Allowance	ci	0.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	72.000	mm.
Flange Outside Diameter	A	215.900	mm.
Flange Thickness	t	40.0000	mm.
Thickness of Hub at Small End	go	3.0500	mm.
Thickness of Hub at Large End	g1	15.0000	mm.
Length of Hub	h	40.0000	mm.
Flange Material		SA-182 F316L	
Flange Material UNS number		S31603	
Flange Allowable Stress At Temperature	Sfo	85.57	N./mm²
Flange Allowable Stress At Ambient	Sfa	115.15	N./mm²
Bolt Material		SA-193 B8M	
Bolt Allowable Stress At Temperature	Sb	104.96	N./mm²
Bolt Allowable Stress At Ambient	Sa	129.63	N./mm²
Diameter of Bolt Circle	C	177.800	mm.
Nominal Bolt Diameter	a	15.8750	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		10	
Flange Face Outside Diameter	Fod	92.700	mm.
Flange Face Inside Diameter	Fid	72.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	88.000	mm.
Gasket Inside Diameter	Gi	72.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.5000	mm.



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Hub Small End Required Thickness due to Internal Pressure:
```
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (7.51*(72.0/2+0.0))/(85.57*1.0-0.6*7.51)+Ca
= 0.3175 mm.
```

Hub Small End Hub MAWP:
```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (85.57 * 1.0 * 3.05)/(36.0 + 0.6 * 3.05 )
= 68.985 bars
```

Corroded Flange ID,	Bcor = B+2*Fcor	72.000	mm.
Corroded Large Hub,	g1Cor = g1-ci	15.000	mm.
Corroded Small Hub,	g0Cor = go-ci	3.050	mm.
Code R Dimension,	R = (C-B)/2 - g1	37.900	mm.
Gasket Contact Width,	N = (Go - Gi) / 2	8.000	mm.
Basic Gasket Width,	bo = N / 2	4.000	mm.
Effective Gasket Width,	b = bo	4.000	mm.
Gasket Reaction Diameter,	G = (Go + Gi) / 2	80.000	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
= 0.785 * G² * Peq
= 0.785 * 80.0² * 7.506
= 3.773 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
= 2 * b * Pi * G * m * P
= 2 * 4.0 * 3.1416 * 80.0 * 3.0 * 7.51
= 4.528 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
= Pi * Bcor² * P  / 4
= 3.1416 * 72.0² *7.5064/4
= 3.056 kN
```
Pressure Force on Flange Face [Ht]:
```
= H - Hd
= 4 - 3
= 0.717 kN
```
Operating Bolt Load [Wm1]:
```
= max( H + Hp + H'p, 0 )
= max( 4 + 5 + 0, 0 )
= 8.301 kN
```
Gasket Seating Bolt Load [Wm2]:
```
= y * b * Pi * G  + yPart * bPart * lp
= 68.95*4.0*3.141*80.0+0.0*0.0*0.0
= 69.310 kN
```
Required Bolt Area [Am]:
```
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 8/105, 69/130
= 5.347 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

```
  = 2a + 6t/(m + 0.5)
  = 2 * 15.875 + 6 * 40.0/(3.0 + 0.5)
  = 100.321 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 177.8 * sin( 3.142/10 )
  = 54.943 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 54.943/( 2 * 15.875 + 40.0 )), 1 )
  = 1.0000
```

Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm²	5.347	13.032	
Radial Distance between Hub and Bolts:	23.812	37.900	
Radial Distance between Bolts and Edge:	19.050	19.050	
Circ. Spacing between the Bolts:	38.100	54.943	100.321

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 13.032 * 129.63/(68.95 * 3.14 * (88.0 + 72.0) )
  = 4.874 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * Ab
  = 129.63 * 13.0322
  = 168.92 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 8 - 4
  = 4.53 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 177.8 - 80.0 )/2
  = 48.9000 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 37.9 + 15.0 + 48.9 )/2
  = 50.9000 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 37.9 + ( 15.0/2.0 )
  = 45.4000 mm.
```

Summary of Moments for Internal Pressure: (N-m)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	3.	45.4000	1.0000	139.
Face Pressure, Mt	1.	50.9000	1.0000	37.
Gasket Load, Mg	5.	48.9000	1.0000	221.
Gasket Seating, Matm	169.	48.9000	1.0000	8263.

Total Moment for Operation, Mop = 397. N-m
Total Moment for Gasket seating, Matm = 8263. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor) = 14.819 mm.
Hub Ratio, h/h0 = HL / H0 = 2.699
Thickness Ratio, g1/g0 = (g1Cor/goCor) = 4.918

Flange Factors for Integral Flange:

Factor F = 0.470
Factor V = 0.016
Factor f = 1.000
Factors from Figure 2-7.1: K = 2.999
T = 1.206, U = 2.054
Y = 1.869, Z = 1.250
d = 17828.049 mm.³, e = 0.0317 mm.^-1
Stress Factors: ALPHA = 2.269
BETA = 2.691, GAMMA = 1.881
DELTA = 3.590, Lamda = 5.471

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.0*397/72.0)/(5.4712*15.0²)
= 4.48 N./mm²

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.0*8263/72.0)/(5.4712*15.0²)
= 93.20 N./mm²

Radial Flange Stress, Operating [SRo]:
= (Beta * Mop / Bcor) / (L * t²)
= (2.6915*397/72.0)/(5.4712*40.0²)
= 1.69 N./mm²

Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (2.6915*8263/72.0)/(5.4712*40.0²)
= 35.28 N./mm²

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (1.8694*397/(40.0²*72.0))-1.2503*2
= 4.32 N./mm²

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (1.8694*8263/(40.0²*72.0))-1.2503*35
= 89.94 N./mm²

Average Flange Stress, Operating [SAo]:
```
= ( SHo + max( SRo, STo ) ) / 2
= (4+max(2,4))/2
= 4.40 N./mm²
```
Average Flange Stress, Seating [SAa]:
```
= ( SHa + max( SRa, STa ) ) / 2
= (93+max(35,90))/2
= 91.57 N./mm²
```

Bolt Stress, Operating [BSo]:
```
= Wm1 / Ab
= 8/13.0322
= 6.37 N./mm²
```
Bolt Stress, Seating [BSa]:
```
= ( Wm2 / Ab )
= (69/13.0322)
= 53.19 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	4.48	128.35	93.20	172.72
Radial Flange	1.69	85.57	35.28	115.15
Tangential Flange	4.32	85.57	89.94	115.15
Maximum Average	4.40	85.57	91.57	115.15
Bolting	6.37	104.96	53.19	129.63

Minimum Required Flange Thickness	34.773 mm.
Estimated M.A.W.P. (Operating)	124 bars
Estimated Finished Weight of Flange at given Thk.	11.2 kg.
Estimated Unfinished Weight of Forging at given Thk	20.9 kg.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
= 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
= 52.14*8263.4/1.0*999.68*0.016/(4.102*195129*3.05²*14.819*0.3)
= 0.207   (should be <= 1)
```

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
```
= 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
= 52.14*396.8/1.0*999.68*0.016/(4.102*184966*3.05²*14.819*0.3)
= 0.010   (should be <= 1)
```

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
= 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
= 52.14*8263.4/1.0*999.68*0.016/(5.471*195129*3.05²*14.819*0.3)
= 0.155   (should be <= 1)
```

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

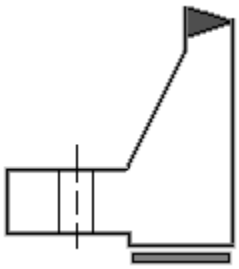
```
= 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )
= 52.14*396.8/1.0*999.68*0.016/(5.471*184966*3.05^2*14.819*0.3)
= 0.008    (should be <= 1)
```

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Flange Input Data Values **Description: FLANGE :**

TS Inlet

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	7.50	bars
Design Temperature		165	°C
Internal Corrosion Allowance	ci	0.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		No	
Flange Inside Diameter	B	27.860	mm.
Flange Outside Diameter	A	107.950	mm.
Flange Thickness	t	14.2240	mm.
Thickness of Hub at Small End	go	3.3800	mm.
Thickness of Hub at Large End	g1	17.3990	mm.
Length of Hub	h	41.1480	mm.
Flange Material		SA-182 F316L	
Flange Material UNS number		S31603	
Flange Allowable Stress At Temperature	Sfo	85.57	N./mm²
Flange Allowable Stress At Ambient	Sfa	115.15	N./mm²
Bolt Material		SA-193 B8M	
Bolt Allowable Stress At Temperature	Sb	104.96	N./mm²
Bolt Allowable Stress At Ambient	Sa	129.63	N./mm²
Diameter of Bolt Circle	C	79.248	mm.
Nominal Bolt Diameter	a	12.7000	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		4	
Flange Face Outside Diameter	Fod	50.800	mm.
Flange Face Inside Diameter	Fid	27.860	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	47.752	mm.
Gasket Inside Diameter	Gi	31.750	mm.
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.
Flange Class		150	
Flange Grade		GR 2.3	
Flange Series	Series	A	



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Hub Small End Required Thickness due to Internal Pressure:
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (7.5*(27.86/2+0.0))/(85.57*1.0-0.6*7.5)+Ca
= 0.1227 mm.

Hub Small End Hub MAWP:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (85.57 * 1.0 * 3.38)/(13.93 + 0.6 * 3.38)
= 181.229 bars

Corroded Flange ID,	Bcor = B+2*Fcor	27.860	mm.
Corroded Large Hub,	g1Cor = g1-ci	17.399	mm.
Corroded Small Hub,	g0Cor = go-ci	3.380	mm.
Code R Dimension,	R = (C-B)/2 - g1	8.295	mm.
Gasket Contact Width,	N = (Go - Gi) / 2	8.001	mm.
Basic Gasket Width,	bo = N / 2	4.000	mm.
Effective Gasket Width,	b = bo	4.000	mm.
Gasket Reaction Diameter,	G = Go (Self-Energizing)	47.752	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.785 * 47.752² * 7.5
= 1.343 kN
Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P
= 2 * 4.0005 * 3.1416 * 47.752 * 0.0 * 7.5
= 0.000 kN
Hydrostatic End Load at Flange ID [Hd]:
= Pi * Bcor² * P / 4
= 3.1416 * 27.86² *7.5/4
= 0.457 kN
Pressure Force on Flange Face [Ht]:
= H - Hd
= 1 - 0.5
= 0.886 kN
Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)

= max(1 + 0 + 0, 0)
= 1.343 kN

Gasket Seating Bolt Load [Wm2]:
= y * b * Pi * G + yPart * bPart * lp
= 0.0*4.0005*3.141*47.752+0.0*0.0*0.0
= 0.000 kN

Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 1/105, 0/130
= 0.128 cm²

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 129.63 * (0.128 + 3.2516)/2
= 21.90 kN

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 1 - 1
= 0.00 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (79.248 - 47.752)/2
= 15.7480 mm.

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (8.295 + 17.399 + 15.748)/2
= 20.7210 mm.

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 8.295 + (17.399/2.0)
= 16.9945 mm.

Summary of Moments for Internal Pressure: (N-m)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	0.	16.9945	1.1892	9.
Face Pressure, Mt	1.	20.7210	1.1892	22.
Gasket Load, Mg	0.	15.7480	1.1892	0.
Gasket Seating, Matm	22.	15.7480	1.1892	410.

Total Moment for Operation, Mop 31. N-m
Total Moment for Gasket seating, Matm 410. N-m

You chose not to perform Stress Calculations on this Standard Flange.
The pressure rating of the flange will be used to check code compliance.

Estimated Finished Weight of Flange at given Thk. 1.4 kg.
Estimated Unfinished Weight of Forging at given Thk 3.8 kg.

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm²
Shell		5.809	3.048	...	96.266	79.129
Shell FLG.		5.809	...	...	96.266	79.1
Front Channel FL		7.5064	...	...	72	85.569
Front Channel Ba		7.5076	...	...	88.9	113.15
TS Inlet		7.5	...	...	27.86	85.569

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
Shell		5.8	42.4223	61.745	2.667	1.5
Shell FLG.		5.8	48.2444	140.761	40	29.1592
Front Channel FL		7.5	68.9784	152.754	40	34.7726
Front Channel Ba		7.5	140.003	142.483	5.49	1.5
TS Inlet		7.5	11.7601	15.9001	14.224	No Calc

Summary of Heat Exchanger Maximum Allowable Working Pressures :

Note:
For Exchanger designs, the following values include MAWPs that consider the tubesheet, tubes, tube/tubesheet joint etc. These values were determined by iteration. Review the tubesheet analysis report for more information.

```
Shell Side MAWP      =              11 bars
Shell Side MAPnc     =              16 bars
Channel Side  MAWP   =              12 bars
Channel Side  MAPnc  =              16 bars
```

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

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Cylindrical Shell From 10 To 20 SA-312 TP316L at 220 °C

Shell
Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (5.809*48.133)/(79.13*1.0-0.6*5.809)

= 0.3549 + 0.0000 = 0.3549 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.009 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (79.13*1.0*2.667)/(48.133+0.6*2.667)
= 42 - 0.01 = 42 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (115.15*1.0*2.667)/(48.133+0.6*2.667)
= 62 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (5.809*(48.133+0.6*2.667))/(1.0*2.667)
= 10.833 N./mm²

SA-312 TP316L, Min Metal Temp without impact per UHA-51: -196 °C

Conical Section From 50 To 60 SA-403 316L at 165 °C

Front Channel Barrel
Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:
= (P*Do)/(2*cos(a)*(S*E+0.4*P)) per Appendix 1-4 (e)
= (7.508*88.9)/(2*0.9547*(113.15*1.0+0.4*7.51))
= 0.3081 + 0.0000 = 0.3081 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.008 bars
= (2*S*E*t*cos(a))/(D-0.8*t*cos(a)) per Appendix 1-4 (e)(5)
= (2*113.15*1.0*(5.49)*0.9547)/(88.9-0.8*(5.49)*0.9547)
= 140 - 0.01 = 140 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t*cos(a))/(D-0.8*t*cos(a)) per Appendix 1-4(e)
= (2*115.15*1.0*5.49*0.9547)/(88.9-0.8*5.49*0.9547)
= 142 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(D-0.8*t*cos(a)))/(2*E*t*cos(a))
= (7.508*(88.9-0.8*(5.49)*0.9547))/(2*1.0*(5.49)*0.9547)
= 6.067 N./mm²

SA-403 316L, Min Metal Temp without impact per UHA-51: -196 °C

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          15.318  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S         8.151  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       20.670  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          12.961  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)      8.294  bars
Pressure per App 27-4  = M.A.W.P.                        10.900  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          15.558  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S         9.922  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       20.661  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          13.164  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     10.725  bars
Pressure per App 27-4  = M.A.W.P.                        11.760  bars
```

UG-99(b) Note 36, Test Pressure Calculation [Shell Side]:

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 5.8 * 1.081
  = 8.151 bars
```

UG-99(b) Note 36, Test Pressure Calculation [Channel Side]:

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 7.5 * 1.018
  = 9.922 bars
```

Horizontal Test performed per: UG-99b (Note 36)

Please note that Nozzle, Shell, Head, Flange, etc MAWPs are all considered when determining the hydrotest pressure for those test types that are based on the MAWP of the vessel.

Stresses on Elements due to Test Pressure (N./mm² & bars):

From To	Stress	Allowable	Ratio	Pressure
Shell	15.2	155.1	0.098	8.16
Front Channel Barrel	8.0	155.1	0.052	9.93

Stress ratios for Nozzle and Pad Materials (N./mm²):

Description	Pad/Nozzle	Ambient	Operating	Ratio
S1 (1in)	Nozzle	115.15	79.13	1.455
S2 (1in)	Nozzle	115.15	79.13	1.455
Minimum				1.455

Stress ratios for Pressurized Vessel Elements (N./mm²):

Description	Ambient	Operating	Ratio
Shell	115.15	79.13	1.455
Shell FLG.	115.10	79.10	1.455
Front Channel FLG.	115.15	85.57	1.346
Front Channel Barrel	115.15	113.15	1.018
TS Inlet	115.15	85.57	1.346
Minimum			1.018

Stress ratios for Exchanger Materials (N./mm²):

Description	Ambient	Operating	Ratio
Tube Material	115.15	106.52	1.081
Tubesheet Material	115.15	79.13	1.455
Minimum			1.081

Hoop Stress in Nozzle Wall during Pressure Test (N./mm²):

Description	Ambient	Operating	Ratio
S1 (1in)	1.30	155.14	0.008
S2 (1in)	1.30	155.14	0.008

Elements Suitable for Test Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm²
10	20	3400	101.6	2.667	0.00077443	53.6347
20	30	No Calc	...	40	No Calc	No Calc
30	50	No Calc	...	40	No Calc	No Calc
50	60	89	88.3787	5.49	0.021984	91.8292
60	70	No Calc	...	14.224	No Calc	No Calc

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	2.667	0.91902	1.034	18.771
20	30	40	29.1592	1.034	No Calc
30	50	40	34.7726	1.034	No Calc
50	60	5.49	0.29297	1.034	76.0535
60	70	14.224	No Calc	1.034	No Calc
Minimum					19

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	3400	262929	No Calc	No Calc
20	30	No Calc	No Calc	No Calc	No Calc
30	50	No Calc	No Calc	No Calc	No Calc
50	60	89	5917.79	No Calc	No Calc
60	70	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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Cylindrical Shell From 10 to 20 Ext. Chart: HA-4 at 100 °C

Shell

Elastic Modulus from Chart: HA-4 at 100 °C: 186872176.000 KPa.

Results for Maximum Allowable Ext. Pressure						MAEP
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
2.667	101.60	3400.00	38.10	33.4646	0.0007744	53.63

MAEP = (4*B)/(3*(Do/t)) = (4*53.6347)/(3*38.0952) = 18.771 bars

Results for Required Thickness						Tca
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.919	101.60	3400.00	110.55	33.4646	0.0000918	8.57

MAEP = (4*B)/(3*(Do/t)) = (4*8.5741)/(3*110.5523) = 1.034 bars

Results for Maximum Stiffened Length						Slen
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
2.667	101.60	262929.16	38.10	50.0000	0.0007738	53.62

MAEP = (4*B)/(3*(Do/t)) = (4*53.6233)/(3*38.0952) = 18.7671 bars

---

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm.	Corroded Metal Wgt. kg.	Corroded ID Volume Cm.	Extra due Misc % kg.
10	20	25.9552	18681	25.9552	18681	2.59552
20	30	10.3765	582.376	10.3765	582.376	1.03765
30	50	11.1854	325.779	11.1854	325.779	1.11854
50	60	0.71504	190.28	0.71504	190.28	0.071504
60	70	1.38779	33.7614	1.38779	33.7614	0.13878
Total		49	19813.23	49	19813.23	4

For elements specified as shell side elements, the volume(s) shown above for those elements, reflects the displacement of the tubes.

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	18.3315	1700	2.35585	Liquid: 10
10	Insl	12.9462	1700	...	Ins: 10
10	Nozl	2.36125	3250	60.833	S1 (1in)
10	Nozl	2.36125	3250	60.833	S2 (1in)
10	Wght	230	...	...	REAR
10	Wght	50	1750	...	BAFFLE
10	Wght	50	440	45	LEG 1
10	Wght	50	3030	45	LEG 2
10	Wght	250	3030	45	UPPER HEX
10	Wght	250	440	45	UPPER HEX
20	Liqd	0.57148	40	2.35585	Liquid: 20
20	Insl	0.46227	40	...	Ins: 10
30	Liqd	0.31034	40	3.35	Liquid: 30
30	Insl	0.54401	42.5	...	Ins: 10
50	Liqd	0.19016	44.5	-14.1393	Liquid: 50
50	Insl	0.21784	44.5	...	Ins: 50
60	Insl	0.27713	27.686	...	Ins: 60
20	FTsh	2.04682	122.5	...	TS
20	Tube	11.321	-1645	...	Tubes

Total Weight of Each Detail Type:

Liquid	19.4
Insulation	14.4
Nozzles	4.7
Weights	880.0
Exchanger Components	13.4
Liquid in Tubes	2.7

Sum of the Detail Weights 934.7 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	54.6	54.6	54.6	54.6	54.6	54.6
Nozzles	4.7	4.7	4.7	4.7	4.7	4.7
Wld Weights	330.0	330.0	330.0	330.0	330.0	330.0
Exchanger	13.4	13.4	13.4	13.4	13.4	13.4
Insulation	...	...	14.4	14.4	14.4	14.4
Empty Weights	...	...	...	550.0	550.0	...
Test Weights	...	50.0	...	...	...	...
Ope Weights	...	...	...	...	...	550.0
Ope. Liquid	...	...	...	...	...	19.4
Tube Ope Lqd	...	...	...	...	...	2.7
Test Liquid	...	19.8	...	...	...	...
Tube Tst Lqd	...	2.7	...	...	...	...
Totals	402.7	475.2	417.1	967.1	967.1	989.3

Field Installation Options:

Miscellaneous Weight Percent: 10.0 %

Note that the above value for the miscellaneous weight percent has been applied to the shells/heads/flange/tubesheets/tubes etc. in the weight calculations for metallic components.

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	402.7 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	475.2 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	417.1 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	967.1 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	967.1 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	989.3 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	989.3 kg.
Field Test Wt.	- Empty Weight + Water (Full)	489.7 kg.

Exchanger Tube Data

Volume of Exchanger tubes	:	2749.4 Cm.
Weight of Ope Liq in tubes	:	2.7 kg.
Weight of Water in tubes	:	2.7 kg.

Note:
The Corroded Weight and thickness are used in the Horizontal Vessel Analysis (Ope Case) and Earthquake Load Calculations.

Note: The Field Test weight as computed in the corroded condition.

Outside Surface Areas of Elements:

From	To	Surface Area cm²
10	20	10933.7
20	30	723.291
30	50	724.866
50	60	179.095
60	70	214.665
Total		12775.627 cm²

Nozzle Flange MAWP Results: (bars & °C)

Nozzle Description	Flange Rating Ope.	Flange Rating Ambient	Design Temp	Class	Grade/ Group	Equiv. Press	Max Pressure UG-44(b)	Max Pressure 50%	Max Pressure DNV
S1 (1in)	10.92	15.90	220	150	GR 2.3	...	...	...	...
S2 (1in)	10.92	15.90	220	150	GR 2.3	...	...	...	...

Shellside Flange Rating

```
Lowest Flange Pressure Rating was (Ope)[ShellSide]:     10.920  bars
Lowest Flange Pressure Rating was (Amb)[ShellSide]:     15.900  bars
```

Channelside Flange Rating

ANSI Ratings are per ANSI/ASME B16.5 2013 Metric Edition

Warning:
There are nozzles in this model, but no flange MAWPs were de-rated. Be sure this is what you intended. There is a check box in the nozzle dialog that instructs PV Elite to perform the de-rating for each nozzle flange. See ASME VIII-1, UG-44(b) for more information.

Conical Reinforcement Calculations, ASME VIII Div. 1, App. 1

Input Values:

Front Channel Barrel

Design Internal Pressure, Small End		7.508	bars
Design Internal Pressure, Large End		7.508	bars
Temperature for Internal Pressure		165.0	°C
Design External Pressure		1.034	bars
Temperature for External Pressure		100.0	°C
Cone Material		SA-403 316L	
Cone Allowable Stress at Temperature	Ss	113.15	N./mm²
Cone Allowable Stress At Ambient		115.15	N./mm²
Longitudinal Joint Efficiency of Cone		1.00	
Circumferential Joint Efficiency of Cone		1.00	
Actual Thickness of Cone	Tc	5.4900	mm.
Corrosion Allowance for Cone	Cac	0.0000	mm.
Diameter Basis for Cone and Cylinders		ID	
Diameter of Small End of Cone	Ds	21.899	mm.
Diameter of Large End of Cone	Dl	77.399	mm.
Half Apex Angle for Cone		17.32	degrees
Axial Length of Cone	Lc	89.000	mm.
Small End Cylinder Material		SA-182 F316L	
Small Cylinder Allowable Stress at Operating	Ss	113.15	N./mm²
Small Cylinder Allowable Stress At Ambient		115.15	N./mm²
Joint Efficiency of Small Cylinder	Es	1.0000	
Actual Thickness of Small Cylinder	Ts	5.4900	mm.
Corrosion Allowance for Small Cylinder	Cas	0.0000	mm.
Axial Length of Small Cylinder	Ls	55.372	mm.
Large End Cylinder Material		SA-182 F316L	
Large Cylinder Allowable Stress at Operating	Sl	113.15	N./mm²
Large Cylinder Allowable Stress At Ambient		115.15	N./mm²
Joint Efficiency of Large Cylinder	El	1.0000	
Actual Thickness of Large Cylinder	Tl	5.4900	mm.
Corrosion Allowance for Large Cylinder	Cal	0.0000	mm.
Axial Length of Large Cylinder	Ll	80.000	mm.
Type of Reinforcement at Large End of Cone:		None	
Large End Reinforcing/Knuckle Material			
Large Reinforcing/Knuckle Allowable, Operating		115.15	N./mm²
Large Reinforcing/Knuckle Allowable, Ambient		115.15	N./mm²
Type of Reinforcement at Small End of Cone:		None	
Small End Reinforcing/Knuckle Material			
Small Reinforcing/Knuckle Allowable, Operating		115.15	N./mm²
Small Reinforcing/Knuckle Allowable, Ambient		115.15	N./mm²

Calculated Values:

```
Elastic Modulus Data from ASME Section II Part D at 100 °C

Elastic Modulus of Cone Material                0.189E+09 KPa. at 100 °C
Elastic Modulus of Small Cylinder Material      0.189E+09 KPa. at 100 °C
Elastic Modulus of Large Cylinder Material      0.189E+09 KPa. at 100 °C
Elastic Modulus of Large End Reinforcement      0.189E+09 KPa. at 100 °C
Elastic Modulus of Small End Reinforcement      0.189E+09 KPa. at 100 °C

Elastic Modulus Data from ASME Section II Part D at 165 °C

Elastic Modulus of Cone Material                0.185E+09 KPa. at 164 °C
Elastic Modulus of Small Cylinder Material      0.185E+09 KPa. at 164 °C
Elastic Modulus of Large Cylinder Material      0.185E+09 KPa. at 164 °C
Elastic Modulus of Large End Reinforcement      0.185E+09 KPa. at 164 °C
Elastic Modulus of Small End Reinforcement      0.185E+09 KPa. at 164 °C
```

Axial forces and moments are not computed for Horizontal geometries.
Compute them manually and enter the loads using the Force/Moment dialog.
Place the loads at the ends of the cone as needed.

Note: Neither end of Cone is a Line of Support

```
Maximum Centroid Reinforcement Distance Large End     3.8939  mm.
Maximum Centroid Reinforcement Distance Small End     2.3750  mm.
```

Note: No ring was found close enough to the large end to be considered.

Note: No ring was found close enough to the small end to be considered.

Reinforcement Calculations for Cone / Large Cylinder:

Required Area of Reinforcement for Large End Under Internal Pressure

```
Large end ratio of pressure to allowable stress    P/Ss E1    0.00664
Large end max. half apex angle w/o reinforcement     delta     26.271  degrees
Large end actual half apex angle                     alpha     17.317  degrees
```

Because delta is greater than alpha, reinforcement calculations are not required for the large end under internal pressure.

Required Area of Reinforcement for Large End Under External Pressure

```
Large end ratio of pressure to allowable stress    P/Ss E1    0.00107
Large end max. half apex angle w/o reinforcement     delta      2.674  degrees
Large end actual half apex angle                     alpha     17.317  degrees
```

Intermediate Value [k]:

```
  = max( Y / ( Srl * Erl ), 1 )
  = max( 0.18289E+11/( 115.1 * 0.18919E+09 ), 1 )
  = 1.0000
```

where [Y] is:

```
  = Large End All. Stress * Large End Elastic Modulus (Ext. temp.)
```

```
  = 96.7 * 0.18919E+09
  = 18288777216.0 N./mm²^2

 Allowable Stress of Large End Material (Ext. Temp)    96.7  N./mm²
 Allowable Stress of Cone Material (Ext. Temp)         115.1  N./mm²
```

Required Area of Reinforcement, Large End, External [Arl]:

```
  = (k*QL*DL*tan(angle)/(2*Sc*E2))
  = (1.0*0.0023*88.3787*0.312/(2*113*1.0))
  = 0.00278 cm²
```

Force per Length, Cone Large End External Pressure [QL]:

```
  = Pext( Rl/2 ) + f1
  = 1.034( 44.189/2 ) + 0.0
  = 0.002 kN/mm.
```

Axial Load per Unit Circumference excluding Pressure [f1]:

```
  = Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
  = +.0/(pi(88.379-5.49))+.0/(pi(44.189-5.49/2)(44.189-5.49/2))
  = 0.0 kN/mm.
```

Available Area of Reinforcement, Large End, External [Ael]:

```
  = 0.55( Dl*tc )½ * ( tc/cos(alpha) )
  = 0.55( 88.379 * 5.49 )½ * ( 5.49/0.955 )
  = 0.6967 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

```
 Area of reinforcement required per App. 1-8(1)        0.0028  cm²
 Area of reinforcement in shell per App. 1-8(2)        0.6967  cm²
 Area of reinforcement in stiffening ring              0.0000  cm²
```

Reinforcement Calculations for Cone / Small Cylinder:

Required Area of Reinforcement for Small End under Internal Pressure

```
 Small end ratio of pressure to allowable stress    P/Ss E1    0.00664
 Small end max. half apex angle w/o reinforcement     delta      6.981  degrees
 Small end actual half apex angle                     alpha     17.317  degrees
```

Intermediate Value [k]:

```
  = max( Y / ( Sr * Ers ), 1 )
  = max( 0.20928E+11/( 115.1 * 0.18496E+09 ), 1 )
  = 1.0000
```

where [Y] is:

```
  = Small End All. Stress * Small End Elastic Modulus (Int. temp.)
  = 113.1 * 0.18496E+09
  = 20927504384.0 N./mm²^2
```

Decay Length, Cone Small End:

```
  = 1.4 * sqrt( Rs( ts - ca ) )
  = 1.4 * sqrt( 10.949( 5.49 - 0.0 ) )
  = 10.854 mm.
```

Required Area of Reinforcement, Small End, Internal [Ars]:

= k*QS*Rs/(Sc*E2)*tan(alpha)
= 1.0 * 0.0041 * 10.9493/(113 * 1.0) * 0.312
= 0.00124 cm²

Force per Length, Cone Small End [QS]:

= P(Rs/2) + f2
= 7.508(10.949/2) + 0.0
= 0.004 kN/mm.

Axial Load per Unit Circumference excluding Pressure [f2]:

= Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
= -0.0/(pi(21.899+5.49))+.0/(pi(10.949+5.49/2)(10.949+5.49/2))
= 0.0 kN/mm.

Area of Reinforcement Available in Small End Shell [Aes]:

= (tc - tr) * sqrt(Rs*tc/cos(alpha))
= (5.49 - 0.076) * sqrt(10.949* 5.49/0.955)
= 0.4296 cm²

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	0.0012	cm²
Area of reinforcement in shell per App. 1-5(4)	0.4296	cm²
Area of reinforcement in stiffening ring	0.0000	cm²

Required Area of Reinforcement for Small End Under External Pressure

Allowable Stress of Small End Material (Ext. Temp)	96.7	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	115.1	N./mm²

Intermediate Value [k]:

= max(Y / (Srs * Ers), 1)
= max(0.18289E+11/(115.1 * 0.18919E+09), 1)
= 1.0000

where [Y] is:

= Small End All. Stress * Small End Elastic Modulus (Ext. temp.)
= 96.7 * 0.18919E+09
= 18288777216.0 N./mm²^2

Area of Reinforcement Required in Small End Shell [Ars]:

= k * QS * Ds * tan(alpha) / (2 * Sc * E2)
= 1.0*0.0008*32.8787*0.3118/(2*113*1.0)
= 0.000385 cm²

Force per Length, Cone Small End [QS]:

= Pext(Rs/2) + f2
= 1.034(16.439/2) + 0.0
= 0.001 kN/mm.

Axial Load per Unit Circumference excluding Pressure [f2]:

= Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
= +.0/(pi(32.879-5.49))+.0/(pi(16.439-5.49/2)(16.439-5.49/2))
= 0.0 kN/mm.

Area of Reinforcement Available in Small End Shell [Aes]:

= 0.55(Ds*tc)½*[(tc-tr)/cos(alpha)]
= 0.55(32.879*5.49)½*[(5.49-0.148)/0.955]
= 0.4135 cm²

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.0004	cm²
Area of reinforcement in shell per App. 1-8(4)	0.4135	cm²
Area of reinforcement in stiffening ring	0.0000	cm²

Note: The following calculations are only required per 1-5(g)(1) and do include external loads due to wind or seismic. These discontinuity stresses are computed at the shell/cone junction and do not include effects of local stiffening from a junction ring.

Results for Discontinuity Stresses per Bednar p. 236 2nd Edition

Stress Type	Stress	Allowable	Location	
Tensile Stress	1.47	339.45	Small Cyl. Long.	
Compres. Stress	0.00	-339.45	Small Cyl. Long.	*
Membrane Stress	2.17	-169.72	Small End Tang.	
Tensile Stress	1.51	339.45	Cone Longitudinal	
Compres. Stress	0.00	-339.45	Cone Longitudinal	*
Compres Stress	2.25	-169.72	Cone Tangential	
Tensile Stress	5.63	339.45	Large Cyl. Long.	
Compres. Stress	0.00	-339.45	Large Cyl. Long.	*
Membrane Stress	4.13	-169.72	Large End Tang.	
Tensile Stress	5.77	339.45	Cone Longitudinal	
Compres. Stress	0.00	-339.45	Cone Longitudinal	*
Compres Stress	4.40	-169.72	Cone Tangential	

Note: An asterisk (*) denotes that this stress was not applicable for this combination of loads.

Maximum Allowable Pressure Calculations for Cone to Shell Junction:

Pressure Case	Pressure bars	Reason for Failure at this Pressure
MAWP	141.717	Thickness due to internal pressure, Cone Large End
MAPnc	144.220	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

Shop/Field Installation Options :

Insulation is installed in the Shop.

Note : The CG is computed from the first Element From Node

Center of Gravity of the Liquid	1800.775 mm.
Center of Gravity of the Insulation	1895.825 mm.
Center of Gravity of the Nozzles	3250.000 mm.
Center of Gravity of the Added Weights (Operating)	1282.386 mm.
Center of Gravity of the Added Weights (Empty)	1282.386 mm.
Center of Gravity of the Tubesheet(s)	3522.500 mm.
Center of Gravity of the Tubes	1755.000 mm.
Center of Gravity of Bare Shell New and Cold	2574.962 mm.
Center of Gravity of Bare Shell Corroded	2574.962 mm.
Vessel CG in the Operating Condition	1393.578 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1384.382 mm.

Input, Nozzle Desc: S1 (1in) **From: 10**

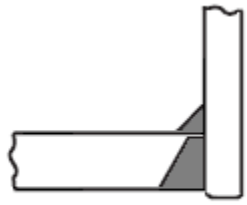
Pressure for Reinforcement Calculations	P	5.800	bars
Temperature for Internal Pressure	Temp	220	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-312 TP316L	
Shell Allowable Stress at Temperature	Sv	79.13	N./mm²
Shell Allowable Stress At Ambient	Sva	115.15	N./mm²
Inside Diameter of Cylindrical Shell	D	96.27	mm.
Design Length of Section	L	3400.0002	mm.
Shell Finished (Minimum) Thickness	t	2.6670	mm.
Shell Internal Corrosion Allowance	c	0.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3250.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-182 F316L	
Material UNS Number		S31603	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	79.13	N./mm²
Allowable Stress At Ambient	Sna	115.15	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.8000	mm.
Flange Material		SA-182 F316L	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	50.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	2.6670	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 2.3	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: S1 (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.504  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (5.8*48.133)/(79*1.0-0.6*5.8)
  = 0.3544 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 12.7(exp([5.8/(79.13*1.0]-1)
  = 0.0934 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.1670 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl     56.3340  mm.
Parallel to Vessel Wall                          Rn+tn+t    28.1670  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      6.6675  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 79.1/79.1 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 79.1/79.1 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
```

```
= min( 1.0, 1.0 )
= 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.090	0.117	NA
Area in Shell	A1	0.715	0.541	NA
Area in Nozzle Wall	A2	1.694	1.685	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.338	0.338	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.748	2.563	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(25.4*0.919*1+2*12.8*0.919*1(1-1.0))
= 0.117 cm²
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

```
= d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
= 30.934( 1.0 * 2.667 - 1.0 * 0.919 ) - 2 * 12.8
  ( 1.0 * 2.667 - 1.0 * 0.919 ) * ( 1 - 1.0 )
= 0.541 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 6.67 )( 12.8 - 0.17 )1.0
= 1.685 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
= ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
= ( 8.0² - 0.3022 ) * 1.0 + ( 0.0² -0.0 ) * 1.0
= 0.338 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures      ta = 0.1670 mm.
Wall Thickness per UG16(b),                      tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 0.3544 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 1.5000 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                   tb3 = 3.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
```

```
  = min[ 3.42, max( 1.5, 1.5 ) ]
  = 1.5000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 0.167, 1.5 )
  = 1.5000 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

SA-312 TP316L, Min Metal Temp without impact per UHA-51: -196 °C

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: S1 (1in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.0480  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld         2.1336 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, ( 0.1167 - 0.5407 + 2 * 12.8 * 1.0 *
    (1.0 * 2.667 - 0.919 ) )79)
  = 0.19 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.6846 + 0.0 + 0.3378 - 0.0 * 1.0 ) * 79
  = 16.00 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.6846 + 0.0 + 0.3378 + ( 0.6828 ) ) * 79
  = 21.40 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.6846 + 0.0 + 0.3378 + 0.0 + ( 0.6828 ) ) * 79
  = 21.40 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 51.0 * 8.0 * 0.49 * 79
  = 25. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 19.1) * ( 12.8 - 0.0 ) * 0.7 * 79
= 43. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 51.0 * ( 2.667 - 0.0 ) * 0.74 * 79
= 13. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 25 + 43 ) = 67 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 25 + 0 + 13 + 0 ) = 37 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 25 + 13 + 0 ) = 37 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 67 kN , must exceed W = 0 kN  or W1 = 16 kN
Path 2-2 = 37 kN , must exceed W = 0 kN  or W2 = 21 kN
Path 3-3 = 37 kN , must exceed W = 0 kN  or W3 = 21 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   11  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 7.3098 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 59.9768 mm.

Input, Nozzle Desc: S2 (1in) **From: 10**

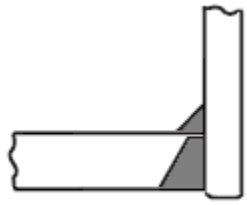
Pressure for Reinforcement Calculations	P	5.809	bars
Temperature for Internal Pressure	Temp	220	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-312 TP316L	
Shell Allowable Stress at Temperature	Sv	79.13	N./mm²
Shell Allowable Stress At Ambient	Sva	115.15	N./mm²
Inside Diameter of Cylindrical Shell	D	96.27	mm.
Design Length of Section	L	3400.0002	mm.
Shell Finished (Minimum) Thickness	t	2.6670	mm.
Shell Internal Corrosion Allowance	c	0.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3250.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-182 F316L	
Material UNS Number		S31603	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	79.13	N./mm²
Allowable Stress At Ambient	Sna	115.15	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.8000	mm.
Flange Material		SA-182 F316L	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	50.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	2.6670	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 2.3	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: S2 (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.504  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]

```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (5.81*48.133)/(79*1.0-0.6*5.81)
= 0.3549 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
= R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
= 12.7(exp([5.81/(79.13*1.0]-1)
= 0.0936 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.1670 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)          Dl     56.3340  mm.
Parallel to Vessel Wall                       Rn+tn+t    28.1670  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp     6.6675  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 79.1/79.1 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 79.1/79.1 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:

```
= min( fr2, fr4 )
```

```
= min( 1.0, 1.0 )
= 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.090	0.117	NA
Area in Shell	A1	0.715	0.541	NA
Area in Nozzle Wall	A2	1.694	1.685	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.338	0.338	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.747	2.563	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(25.4*0.919*1+2*12.8*0.919*1(1-1.0))
= 0.117 cm²
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

```
= d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
= 30.934( 1.0 * 2.667 - 1.0 * 0.919 ) - 2 * 12.8
  ( 1.0 * 2.667 - 1.0 * 0.919 ) * ( 1 - 1.0 )
= 0.541 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 6.67 )( 12.8 - 0.17 )1.0
= 1.685 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
= ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
= ( 8.0² - 0.3022 ) * 1.0 + ( 0.0² -0.0 ) * 1.0
= 0.338 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures      ta = 0.1670 mm.
Wall Thickness per UG16(b),                      tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 0.3549 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 1.5000 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                   tb3 = 3.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
```

```
  = min[ 3.42, max( 1.5, 1.5 ) ]
  = 1.5000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 0.167, 1.5 )
  = 1.5000 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

SA-312 TP316L, Min Metal Temp without impact per UHA-51: -196 °C

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: S2 (1in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.0480  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld         2.1336 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, ( 0.1167 - 0.5407 + 2 * 12.8 * 1.0 *
    (1.0 * 2.667 - 0.919 ) )79)
  = 0.19 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.6846 + 0.0 + 0.3378 - 0.0 * 1.0 ) * 79
  = 16.00 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.6846 + 0.0 + 0.3378 + ( 0.6828 ) ) * 79
  = 21.40 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.6846 + 0.0 + 0.3378 + 0.0 + ( 0.6828 ) ) * 79
  = 21.40 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 51.0 * 8.0 * 0.49 * 79
  = 25. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 19.1) * ( 12.8 - 0.0 ) * 0.7 * 79
= 43. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 51.0 * ( 2.667 - 0.0 ) * 0.74 * 79
= 13. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 25 + 43 ) = 67 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 25 + 0 + 13 + 0 ) = 37 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 25 + 13 + 0 ) = 37 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 67 kN , must exceed W = 0 kN  or W1 = 16 kN
Path 2-2 = 37 kN , must exceed W = 0 kN  or W2 = 21 kN
Path 3-3 = 37 kN , must exceed W = 0 kN  or W3 = 21 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   11  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 7.3098 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 59.9768 mm.

Input Echo, Tubesheet Number 1, Description: TS

Shell Data:

Main Shell Description: Shell

Shell Maximum Design Pressure	Psd,max	5.80	bars
Shell Maximum Operating Pressure	Psox,max	5.80	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	3.0480	mm.
Shell Internal Corrosion Allowance	cas	0.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	96.266	mm.
Shell Temperature for Internal Pressure	Ts	220.00	°C
Shell Material		SA-312 TP316L	
Shell Material UNS Number		S31603	
Shell Allowable Stress at Temperature	Ss	79.13	N./mm²
Shell Allowable Stress at Ambient		115.15	N./mm²

Channel Description: Front Channel Barrel

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	7.50	bars
Channel Maximum Operating Pressure	Ptox,max	7.50	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	5.4900	mm.
Channel Corrosion Allowance	cac	0.0000	mm.
Inside Diameter of Channel	Dc	22.420	mm.
Channel Design Temperature	TEMPC	220.00	°C
Channel Material		SA-403 316L	
Channel Material UNS Number		S31603	
Channel Allowable Stress at Temperature	Sc	106.52	N./mm²
Channel Allowable Stress at Ambient		115.15	N./mm²

Tube Data:

Number of Tube Holes	Nt	4	
Tube Wall Thickness	et	1.6500	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	3490.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	3445.00	mm.
Design Temperature of the Tubes		220.00	°C
Tube Material		SA-213 TP316L	
Tube Material UNS Number		S31603	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. tube	
Tube Allowable Stress at Temperature		106.52	N./mm²
Tube Allowable Stress At Ambient		115.15	N./mm²
Tube Yield Stress At design Temperature	Syt	118.54	N./mm²
Tube Pitch (Center to Center Spacing)	P	28.5750	mm.
Tube Layout Pattern		Triangular	
Fillet Weld Leg	af	2.0000	mm.
Groove Weld Leg	ag	2.0000	mm.
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	

Radius to Outermost Tube Hole Center	ro	23.812	mm.
Largest Center-to-Center Tube Distance	Ul	0.0000	mm.
Length of Expanded Portion of Tube	ltx	30.0000	mm.
Distance from Channel Side where Exp. Starts		12.0000	mm.
Min. Distance from Shell Side where Exp. Stops		3.0000	mm.
Tube-side pass partition groove depth	hg	0.0000	mm.
Area of Tube Layout	Ap	5.4	cm^2
Perimeter of Tube Layout	Cp	152.4	mm.

Tubesheet Data:

Tubesheet TYPE: U-tube, Gasketed both Sides, Conf. d

Tubesheet Design Metal Temperature	T	220.00	°C
Tubesheet Material		SA-182 F316L	
Tubesheet Material UNS Number		S31603	
Tubesheet Allowable Stress at Temperature	S	79.13	$N./mm^2$
Tubesheet Allowable Stress at Ambient	Tt	115.15	$N./mm^2$
Thickness of Tubesheet	h	45.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	0.0000	mm.
Tubesheet Outside Diameter	A	89.500	mm.
Dimension G for the Channel Side	Gc	80.000	mm.
Area of the Untubed Lanes	AL	0.0	cm^2
Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	1.0340	bars
Channel Side Min. Design Pressure	Ptd,min	1.0340	bars

Additional Data for Gasketed Tubesheets:

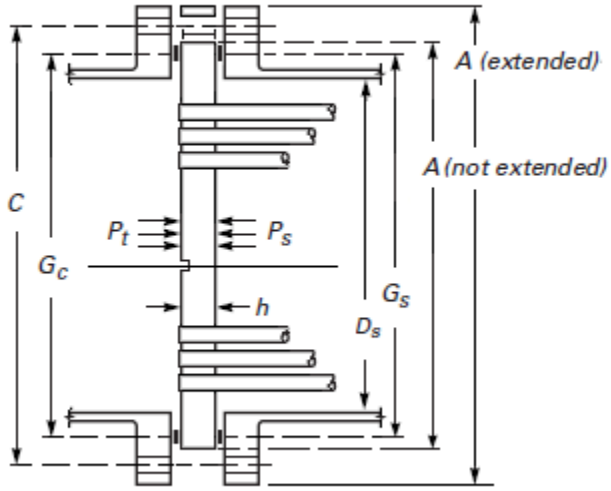
Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	215.900	mm.
Flange Inside Diameter	B	96.266	mm.
Flange Face Outside Diameter	Fod	102.300	mm.
Flange Face Inside Diameter	Fid	96.266	mm.
Gasket Outside Diameter	Go	102.000	mm.
Gasket Inside Diameter	Gi	96.266	mm.
Small end Hub thk.	g0	3.0480	mm.
Large end Hub thk.	g1	15.0000	mm.
Gasket Factor,	m	5.50	
Gasket Design Seating Stress	y	124.11	$N./mm^2$
Flange Facing Sketch		Code Sketch 6	
Column for Gasket Seating		Code Column I	
Gasket Thickness	tg	10.0000	mm.
Contact Width of the Metallic Ring		10.0000	mm.
Full face Gasket Flange Option		Program Selects	

Bolting Information:

Diameter of Bolt Circle	C	177.800	mm.
Nominal Bolt Diameter	dB	15.8750	mm.

Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	10	
Bolt Material		SA-193 B8M	
Bolt Allowable Stress At Temperature	Sb	120.31	N./mm²
Bolt Allowable Stress At Ambient	Sa	129.63	N./mm²
Weld between Flange and Shell/Channel		0.0000	mm.
Alternate Flange Operating Bolt Load, Wm1		8.30	kN
Alternate Flange Seating Bolt Load, Wm2		69.31	kN
Alternate Flange Design Bolt Load, W		168.92	kN
Tubesheet Integral with		None	
Tubesheet Extended as Flange		No	

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2019

Elasticity/Expansion Material Properties :

Shell - TM-1 Material Group G

Elastic Mod. at Design Temperature	220.0 °C	0.18105E+09	KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.19512E+09	KPa.

Channel - TM-1 Material Group G

Elastic Mod. at Design Temperature	220.0 °C	0.18105E+09	KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.19512E+09	KPa.

Tubes - TM-1 Material Group G

```
 Elastic Mod. at Tubsht. Design Temp.    220.0 °C      0.18105E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.19512E+09 KPa.
```

TubeSheet - TM-1 Material Group G

```
 ---------------------------------------------------------------
 Elastic Mod. at Design Temperature      220.0 °C      0.18105E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.19512E+09 KPa.
```

Tube Required Thickness under Internal Pressure (Tubeside pressure):

Thickness Due to Internal Pressure:

```
  = (P*(D/2-CAE)) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
  = (8.53*(19.05/2-0.0)/(106.52*1.0+0.4*8.53)
  = 0.0761 + 0.0000 = 0.0761 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
 External Pressure Chart     HA-4              at       220.00  °C
 Elastic Modulus for Material                     180185728.00  KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A         B
   1.6500      19.05    3468.81      11.55    50.0000  0.0082522          60.73
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *60.728 )/( 3 *11.5455 ) = 70.1279 bars
```

Results for Reqd Thickness for Ext. Pressure (Tca):

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A         B
   0.3294      19.05    3468.81      57.82    50.0000  0.0003290          29.64
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *29.6402 )/( 3 *57.8247 ) = 6.8341 bars
```

Summary of Tube Required Thickness Results:

```
 Total Required Thickness including Corrosion all.          0.3294  mm.
 Allowable Internal Pressure at Corroded thickness         198.24  bars
 Required Internal Design Pressure                           8.53  bars
 Allowable External Pressure at Corroded thickness          70.13  bars
 Required External Design Pressure                           6.83  bars
 Required Thickness due to Shell Side pressure               0.3294  mm.

 ---------------------------------------------------------------
```

Detailed Results for load Case D1 un-corr. (Psd,min + Ptd,max)

```
 ---------------------------------------------------------------
```

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII Division 1, 2019

```
 Gasket Contact Width,       N = (Goc-Gic) / 2             8.000  mm.
 Basic Gasket Width,        b0 = N / 2.0                   4.000  mm.
 Effective Gasket Width,     b = b0                        4.000  mm.
 Gasket Reaction Diameter,   G = (Go+Gi) / 2.0            80.000  mm.

 Flange Design Bolt Load, Seating Condition    W  :      168.92  kN
 Flange Design Bolt Load, Operating Condition  Wm1:        8.29  kN
```

Gasket Reaction Diameter (Gc or Gs as applicable): 99.133 mm.

Results for ASME U-tube Tubesheet Calculations for Configuration d,
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.333) * (66.67/(0.8 * 79.13)) * [-1.03 - 7.5] + 0.0
= 0.6755 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 23.8125 + 19.05 = 66.675 mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
= (p - dt) / p
= (28.575 - 19.05)/28.575 = 0.333

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
= Gs / Do (Configurations d, e, f)
= 80.0/66.675 = 1.1998

Compute the Ratio [Rhoc]:
= Gc / Do (Configurations d)
= 80.0/66.675 = 1.1998

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
= $Do^2/16$ * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt]
= $66.675^2/16$ * [(1.2 - 1) * (1.2^2 + 1) * -1.034 -
(1.2 - 1) * (1.2^2 + 1) * 7.5]
= -1156.0817 bars*$mm.^2$

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:
= ltx/h = 30.0/45.0 = 0.6667 (must be 0 <= rho <= 1)

Compute the Effective Tube Hole Diameter [d*]:
= max(dt - 2tt*(Et/E)(St/S)(rho), dt - 2tt)
= max(19.05 -2*1.65 *(.18105E+09/.18105E+09)*
(106/79)*(0.667), 19.05 -2*1.65)
= 16.0886 mm.

Compute the Effective Tube Pitch [p*]:
= p / sqrt(1 - 4 * min(AL * CNV_factor, 4*Do*p)/(Pi * Do²))
= 28.575/sqrt(1 - 4 * min(0.0 *100.0, 4*66.675 *28.575)
(3.141* 66.675^2))
= 28.5750 mm.

Compute the Effective Ligament Efficiency for Bending [mu*]:
= (p* - d*)/p* = (28.575 - 16.0886)/28.575 = 0.43697

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
h/p = 1.574803 ; mu* = 0.436971
E*/E = 0.479666 ; nu* = 0.296791 ; E* = 86845184. KPa.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:
= A/Do = 89.5/66.675 = 1.3423

Determine Coefficient [F]:
= (1 - nu*)/E* * (E * ln(K))
= (1 - 0.3)/86845184 * (0.18105E+09 * ln(1.34))
= 0.4316

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= -1156.1 + 8.3 * (80.0 - 99.133)/(2 * pi * 66.675)
= -4943.9424 bars*mm.²

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:
= ((M*) - Do²/32 * F * (Ps - Pt)) / (1 + F)
= ((-4943.94) - 66.675²/32 * 0.432 * (-1.03 - 7.5))/(1 + 0.43)
= -3095.9688 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= -3095.97 + 66.675²/64 * (3 + 0.297)(-1.03 - 7.5)
= -5050.2637 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(-3095.969), abs(-5050.264))
= 5050.2637 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 5050.264/((0.437) * (45.0 - 0.0)²)
= 3.4246 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 79.13 = 158.26 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 5048.046/((0.4488) * (6.5314 - 0.0)²
= 158.2013 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 6.5314 + 0.0 + 0.0 = 6.5314 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(6.5314, 0.6755) = 6.5314 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(-1.03 - 7.5) = 8.534 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 79.13 * 0.333 * 45.0/66.67 = 569.62 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.333)*(66.67/45.0)*[-1.03-7.5]N./mm²
= 0.95 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 1.65)1.65
= 0.902 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 1.65 * (19.05 - 1.65) * 106.52 = 9.606 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 5.5752 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 8.6162 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 9.6064 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.3461

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.7609 mm.

Minimum Required Fillet Weld Leg afr 1.3805 mm.
Minimum Required Groove Weld Leg agr 1.3805 mm.

Tube-Tubesheet Jt allowable, 9.61 is >= tube strength 9.61 kN
Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D1 un-corr. (Psd,min + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	3.4	<=	158.3 N./mm²	Ok
Tubesheet shear stress	0.9	<=	63.2 N./mm²	Ok

Thickness results for loadcase D1 un-corr. (Psd,min + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	6.531	45.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.380	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.380	2.000	Ok

Detailed Results for load Case D2 un-corr. (Psd,max + Ptd,min)

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width, N = (Go-Gi) / 2 2.867 mm.
Basic Gasket Width, b0 = w / 8 1.250 mm.
Effective Gasket Width, b = b0 1.250 mm.
Gasket Reaction Diameter, G = (Go+Gi) / 2.0 99.133 mm.

Flange Design Bolt Load, Seating Condition W : 168.92 kN
Flange Design Bolt Load, Operating Condition Wm1: 6.96 kN

Results for ASME U-tube Tubesheet Calculations for Configuration d,
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.333) * (66.67/(0.8 * 79.13)) * [5.8 - -1.03] + 0.0

```
= 0.5409 mm.
```

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:

```
= 2 * ro + dt
= 2 * 23.8125 + 19.05 = 66.675 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:

```
= (p - dt) / p
= (28.575 - 19.05 )/28.575 = 0.333
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:

```
= Gs / Do (Configurations d, e, f)
= 99.133/66.675 = 1.4868
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 80.0/66.675 = 1.1998
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 66.675²/16 * [ (1.487 - 1) * (1.487² + 1) * 5.8 -
  (1.2 - 1) * (1.2² + 1) * -1.034 ]
= 2658.7896 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:

```
= ltx/h = 30.0/45.0 = 0.6667 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:

```
= max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
= max( 19.05 -2*1.65 *(.18105E+09/.18105E+09)*
     ( 106/79 )*( 0.667 ), 19.05 -2*1.65 )
= 16.0886 mm.
```

Compute the Effective Tube Pitch [p*]:

```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 28.575/sqrt( 1 - 4 * min( 0.0 *100.0, 4*66.675 *28.575 )
  (3.141* 66.675²) )
= 28.5750 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:

```
= (p* - d*)/p* = (28.575 - 16.0886 )/28.575 = 0.43697
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.

```
 h/p =   1.574803 ;  mu* =   0.436971
E*/E =   0.479666 ;  nu* =   0.296791 ;  E* = 86845184. KPa.
```

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:
= A/Do = 89.5/66.675 = 1.3423

Determine Coefficient [F]:
= (1 - nu*)/E* * (E * ln(K))
= (1 - 0.3)/86845184 * (0.18105E+09 * ln(1.34))
= 0.4316

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 2658.8 + 7.0 * (80.0 - 99.133)/(2 * pi * 66.675)
= -520.0747 bars*mm.²

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:
= ((M*) - Do²/32 * F * (Ps - Pt)) / (1 + F)
= ((-520.07) - 66.675²/32 * 0.432 * (5.8 - -1.03))/(1 + 0.43)
= -649.5122 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= -649.51 + 66.675²/64 * (3 + 0.297)(5.8 - -1.03)
= 915.4814 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(-649.512), abs(915.481))
= 915.4814 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 915.481/((0.437) * (45.0 - 0.0)²)
= 0.6208 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 79.13 = 158.26 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 836.689/((0.4488) * (2.6586 - 0.0)²
= 158.2578 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 2.6586 + 0.0 + 0.0 = 2.6586 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(2.6586, 0.5409) = 2.6586 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(5.8 - -1.03) = 6.834 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 79.13 * 0.333 * 45.0/66.67 = 569.62 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.333)*(66.67/45.0)*[5.8--1.03]N./mm²
= 0.76 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 1.65)1.65
= 0.902 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 1.65 * (19.05 - 1.65) * 106.52 = 9.606 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 5.5752 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 8.6162 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 9.6064 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.3461

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.7609 mm.

Minimum Required Fillet Weld Leg afr 1.3805 mm.

```
 Minimum Required Groove Weld Leg             agr      1.3805  mm.

 Tube-Tubesheet Jt allowable, 9.61 is >= tube strength 9.61 kN
```
Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D2 un-corr. (Psd,max + Ptd,min):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	0.6	<=	158.3 N./mm²	Ok
Tubesheet shear stress	0.8	<=	63.2 N./mm²	Ok

Thickness results for loadcase D2 un-corr. (Psd,max + Ptd,min):

Thickness (mm.)	Required	Actual	P/F	
Tubesheet Thickness :	2.659	45.000	Ok	|
Tube-Tubesheet Fillet Weld Leg :	1.380	2.000	Ok	|
Tube-Tubesheet Groove Weld Leg :	1.380	2.000	Ok	|

Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII Division 1, 2019

```
 Gasket Contact Width,       N = (Go-Gi) / 2              2.867  mm.
 Basic Gasket Width,        b0 =      w / 8              1.250  mm.
 Effective Gasket Width,     b = b0                      1.250  mm.
 Gasket Reaction Diameter,   G = (Go+Gi) / 2.0          99.133  mm.

 Flange Design Bolt Load, Seating Condition    W  :     168.92  kN
 Flange Design Bolt Load, Operating Condition  Wm1:       6.96  kN
```

Results for ASME U-tube Tubesheet Calculations for Configuration d,
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:
```
  = 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
  = 1/(4 * 0.333 ) * (66.67/(0.8 * 79.13 )) * [5.8 - 7.5 ] + 0.0
  = 0.1346 mm.
```

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
  = 2 * ro + dt
  = 2 * 23.8125 + 19.05 = 66.675 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:

```
  = (p - dt) / p
  = (28.575 - 19.05 )/28.575 = 0.333
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
```
  = Gs / Do (Configurations d, e, f)
  = 99.133/66.675 = 1.4868
```

Compute the Ratio [Rhoc]:
```
  = Gc / Do (Configurations d)
  = 80.0/66.675 = 1.1998
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
```
  = Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
  = 66.675²/16 * [ (1.487 - 1) * (1.487² + 1) * 5.8 -
    (1.2 - 1) * (1.2² + 1) * 7.5 ]
  = 1502.7078 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:
```
  = ltx/h = 30.0/45.0 = 0.6667 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:
```
  = max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
  = max( 19.05 -2*1.65 *(.18105E+09/.18105E+09)*
       ( 106/79 )*( 0.667 ), 19.05 -2*1.65 )
  = 16.0886 mm.
```

Compute the Effective Tube Pitch [p*]:
```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 28.575/sqrt( 1 - 4 * min( 0.0 *100.0, 4*66.675 *28.575 )
    (3.141* 66.675²) )
  = 28.5750 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
  = (p* - d*)/p* = (28.575 - 16.0886 )/28.575 = 0.43697
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
   h/p =   1.574803 ;  mu* =   0.436971
  E*/E =   0.479666 ;  nu* =   0.296791 ;  E* = 86845184. KPa.
```

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:
```
  = A/Do = 89.5/66.675 = 1.3423
```

Determine Coefficient [F]:
```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.3 )/86845184 * ( 0.18105E+09 * ln(1.34 ) )
```

= 0.4316

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 1502.7 + 8.3 * (80.0 - 99.133)/(2 * pi * 66.675)
= -2288.3850 bars*mm.²

Note: W is the maximum of the bolt loads between the shell and channel sides.*

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:
= ((M*) - Do²/32 * F * (Ps - Pt)) / (1 + F)
= ((-2288.39) - 66.675²/32 * 0.432 * (5.8 - 7.5))/(1 + 0.43)
= -1527.2629 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= -1527.26 + 66.675²/64 * (3 + 0.297)(5.8 - 7.5)
= -1916.5647 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(-1527.263), abs(-1916.565))
= 1916.5647 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 1916.565/((0.437) * (45.0 - 0.0)²)
= 1.2996 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 79.13 = 158.26 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 1910.901/((0.4488) * (4.0185 - 0.0)²
= 158.2023 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 4.0185 + 0.0 + 0.0 = 4.0185 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(4.0185, 0.1346) = 4.0185 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(5.8 - 7.5) = 1.7 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 79.13 * 0.333 * 45.0/66.67 = 569.62 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.333)*(66.67/45.0)*[5.8-7.5]N./mm²
= 0.19 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 1.65)1.65
= 0.902 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 1.65 * (19.05 - 1.65) * 106.52 = 9.606 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 5.5752 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 8.6162 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 9.6064 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.3461

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.7609 mm.

Minimum Required Fillet Weld Leg afr 1.3805 mm.
Minimum Required Groove Weld Leg agr 1.3805 mm.

Tube-Tubesheet Jt allowable, 9.61 is >= tube strength 9.61 kN
Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	1.3	<=	158.3 N./mm²	Ok
Tubesheet shear stress	0.2	<=	63.2 N./mm²	Ok

Thickness results for loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	4.019	45.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.380	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.380	2.000	Ok

Detailed Results for load Case D1 corr. (Psd,min + Ptd,max)

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	8.000	mm.
Basic Gasket Width,	b0 = N / 2.0	4.000	mm.
Effective Gasket Width,	b = b0	4.000	mm.
Gasket Reaction Diameter,	G = (Go+Gi) / 2.0	80.000	mm.

Flange Design Bolt Load, Seating Condition	W :	168.92	kN
Flange Design Bolt Load, Operating Condition	Wm1:	8.29	kN

Gasket Reaction Diameter (Gc or Gs as applicable): 99.133 mm.

Results for ASME U-tube Tubesheet Calculations for Configuration d,
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.333) * (66.67/(0.8 * 79.13)) * [-1.03 - 7.5] + 3.0
= 3.6755 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 23.8125 + 19.05 = 66.675 mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
= (p - dt) / p
= (28.575 - 19.05)/28.575 = 0.333

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
```
= Gs / Do (Configurations d, e, f)
= 80.0/66.675 = 1.1998
```

Compute the Ratio [Rhoc]:
```
= Gc / Do (Configurations d)
= 80.0/66.675 = 1.1998
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 66.675²/16 * [ (1.2 - 1) * (1.2² + 1) * -1.034 -
  (1.2 - 1) * (1.2² + 1) * 7.5 ]
= -1156.0817 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:
```
= ltx/h = 30.0/42.0 = 0.7143 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:
```
= max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
= max( 19.05 -2*1.65 *(.18105E+09/.18105E+09)*
     ( 106/79 )*( 0.714 ), 19.05 -2*1.65 )
= 15.8770 mm.
```

Compute the Effective Tube Pitch [p*]:
```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 28.575/sqrt( 1 - 4 * min( 0.0 *100.0, 4*66.675 *28.575 )
  (3.141* 66.675²) )
= 28.5750 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
= (p* - d*)/p* = (28.575 - 15.877 )/28.575 = 0.44437
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
 h/p =   1.469816 ;  mu* =   0.444373
E*/E =   0.493778 ;  nu* =   0.294478 ;  E* = 89400128. KPa.
```

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:
```
= A/Do = 89.5/66.675 = 1.3423
```

Determine Coefficient [F]:
```
= (1 - nu*)/E* * ( E * ln(K) )
= (1 - 0.29 )/89400128 * ( 0.18105E+09 * ln(1.34 ) )
= 0.4207
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= -1156.1 + 8.3 * (80.0 - 99.133)/(2 * pi * 66.675)
= -4943.9424 bars*mm.²

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:
= ((M*) - Do²/32 * F * (Ps - Pt)) / (1 + F)
= ((-4943.94) - 66.675²/32 * 0.421 * (-1.03 - 7.5))/(1 + 0.42)
= -3128.9863 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= -3128.99 + 66.675²/64 * (3 + 0.294)(-1.03 - 7.5)
= -5081.9102 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(-3128.986), abs(-5081.91))
= 5081.9102 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 5081.91/((0.4444) * (42.0 - 0.0)²)
= 3.8901 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 79.13 = 158.26 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 5048.037/((0.4488) * (6.531 - 0.0)²
= 158.2233 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 6.531 + 3.0 + 0.0 = 9.531 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(9.531, 3.6755) = 9.531 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(-1.03 - 7.5) = 8.534 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 79.13 * 0.333 * 42.0/66.67 = 531.65 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.333)*(66.67/42.0)*[-1.03-7.5]N./mm²
= 1.02 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 1.65)1.65
= 0.902 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 1.65 * (19.05 - 1.65) * 106.52 = 9.606 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 5.5752 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 8.6162 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 9.6064 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.3461

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.7609 mm.

Minimum Required Fillet Weld Leg afr 1.3805 mm.
Minimum Required Groove Weld Leg agr 1.3805 mm.

Tube-Tubesheet Jt allowable, 9.61 is >= tube strength 9.61 kN
Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D1 corr. (Psd,min + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	3.9	<=	158.3 N./mm²	Ok
Tubesheet shear stress	1.0	<=	63.2 N./mm²	Ok

Thickness results for loadcase D1 corr. (Psd,min + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	9.531	45.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.380	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.380	2.000	Ok

Detailed Results for load Case D2 corr. (Psd,max + Ptd,min)

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Go-Gi) / 2	2.867	mm.
Basic Gasket Width,	b0 = w / 8	1.250	mm.
Effective Gasket Width,	b = b0	1.250	mm.
Gasket Reaction Diameter,	G = (Go+Gi) / 2.0	99.133	mm.

Flange Design Bolt Load, Seating Condition	W :	168.92	kN
Flange Design Bolt Load, Operating Condition	Wm1:	6.96	kN

Results for ASME U-tube Tubesheet Calculations for Configuration d,
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.333) * (66.67/(0.8 * 79.13)) * [5.8 - -1.03] + 3.0
= 3.5409 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 23.8125 + 19.05 = 66.675 mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
= (p - dt) / p
= (28.575 - 19.05)/28.575 = 0.333

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
```
= Gs / Do (Configurations d, e, f)
= 99.133/66.675 = 1.4868
```

Compute the Ratio [Rhoc]:
```
= Gc / Do (Configurations d)
= 80.0/66.675 = 1.1998
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 66.675²/16 * [ (1.487 - 1) * (1.487² + 1) * 5.8 -
  (1.2 - 1) * (1.2² + 1) * -1.034 ]
= 2658.7896 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:
```
= ltx/h = 30.0/42.0 = 0.7143 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:
```
= max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
= max( 19.05 -2*1.65 *(.18105E+09/.18105E+09)*
     ( 106/79 )*( 0.714 ), 19.05 -2*1.65 )
= 15.8770 mm.
```

Compute the Effective Tube Pitch [p*]:
```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 28.575/sqrt( 1 - 4 * min( 0.0 *100.0, 4*66.675 *28.575 )
  (3.141* 66.675²) )
= 28.5750 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
= (p* - d*)/p* = (28.575 - 15.877 )/28.575 = 0.44437
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
 h/p =   1.469816 ;  mu* =   0.444373
E*/E =   0.493778 ;  nu* =   0.294478 ;  E* = 89400128. KPa.
```

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:
```
= A/Do = 89.5/66.675 = 1.3423
```

Determine Coefficient [F]:
```
= (1 - nu*)/E* * ( E * ln(K) )
= (1 - 0.29 )/89400128 * ( 0.18105E+09 * ln(1.34 ) )
= 0.4207
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 2658.8 + 7.0 * (80.0 - 99.133)/(2 * pi * 66.675)
= -520.0747 bars*mm.²

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:
= ((M*) - Do²/32 * F * (Ps - Pt)) / (1 + F)
= ((-520.07) - 66.675²/32 * 0.421 * (5.8 - -1.03))/(1 + 0.42)
= -647.1996 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= -647.2 + 66.675²/64 * (3 + 0.294)(5.8 - -1.03)
= 916.6957 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(-647.2), abs(916.696))
= 916.6957 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 916.696/((0.4444) * (42.0 - 0.0)²)
= 0.7017 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 79.13 = 158.26 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 836.689/((0.4488) * (2.6586 - 0.0)²
= 158.2578 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 2.6586 + 3.0 + 0.0 = 5.6586 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(5.6586, 3.5409) = 5.6586 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(5.8 - -1.03) = 6.834 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 79.13 * 0.333 * 42.0/66.67 = 531.65 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.333)*(66.67/42.0)*[5.8--1.03]N./mm²
= 0.81 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 1.65)1.65
= 0.902 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 1.65 * (19.05 - 1.65) * 106.52 = 9.606 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 5.5752 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 8.6162 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 9.6064 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.3461

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.7609 mm.

Minimum Required Fillet Weld Leg afr 1.3805 mm.
Minimum Required Groove Weld Leg agr 1.3805 mm.

Tube-Tubesheet Jt allowable, 9.61 is >= tube strength 9.61 kN
Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D2 corr. (Psd,max + Ptd,min):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	0.7	<=	158.3 N./mm²	Ok
Tubesheet shear stress	0.8	<=	63.2 N./mm²	Ok

Thickness results for loadcase D2 corr. (Psd,max + Ptd,min):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	5.659	45.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.380	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.380	2.000	Ok

Detailed Results for load Case D3 corr. (Psd,max + Ptd,max)

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Go-Gi) / 2	2.867	mm.
Basic Gasket Width,	b0 = w / 8	1.250	mm.
Effective Gasket Width,	b = b0	1.250	mm.
Gasket Reaction Diameter,	G = (Go+Gi) / 2.0	99.133	mm.

Flange Design Bolt Load, Seating Condition	W :	168.92	kN
Flange Design Bolt Load, Operating Condition	Wm1:	6.96	kN

Results for ASME U-tube Tubesheet Calculations for Configuration d,
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.333) * (66.67/(0.8 * 79.13)) * [5.8 - 7.5] + 3.0
= 3.1346 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 23.8125 + 19.05 = 66.675 mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
= (p - dt) / p
= (28.575 - 19.05)/28.575 = 0.333

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
= Gs / Do (Configurations d, e, f)
= 99.133/66.675 = 1.4868

Compute the Ratio [Rhoc]:
= Gc / Do (Configurations d)

```
  = 80.0/66.675 = 1.1998
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:

```
  = Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
  = 66.675²/16 * [ (1.487 - 1) * (1.487² + 1) * 5.8 -
    (1.2 - 1) * (1.2² + 1) * 7.5 ]
  = 1502.7078 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:

```
  = ltx/h = 30.0/42.0 = 0.7143 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:

```
  = max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
  = max( 19.05 -2*1.65 *(.18105E+09/.18105E+09)*
       ( 106/79 )*( 0.714 ), 19.05 -2*1.65 )
  = 15.8770 mm.
```

Compute the Effective Tube Pitch [p*]:

```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 28.575/sqrt( 1 - 4 * min( 0.0 *100.0, 4*66.675 *28.575 )
    (3.141* 66.675²) )
  = 28.5750 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:

```
  = (p* - d*)/p* = (28.575 - 15.877 )/28.575 = 0.44437
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.

```
   h/p =   1.469816 ;  mu* =   0.444373
  E*/E =   0.493778 ;  nu* =   0.294478 ;  E* = 89400128. KPa.
```

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
  = A/Do = 89.5/66.675 = 1.3423
```

Determine Coefficient [F]:

```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.29 )/89400128 * ( 0.18105E+09 * ln(1.34 ) )
  = 0.4207
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
  = Mts + W* * (Gc - Gs)/(2 * pi * Do)
  = 1502.7 + 8.3 * (80.0 - 99.133 )/(2 * pi * 66.675 )
  = -2288.3850 bars*mm.²
```

Note: W is the maximum of the bolt loads between the shell and channel sides.*

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:

$= ((M^*) - Do^2/32 * F * (Ps - Pt)) / (1 + F)$

$= ((-2288.39) - 66.675^2/32 * 0.421 * (5.8 - 7.5)) / (1 + 0.42)$

$= -1540.8617$ bars*mm.^{2}

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

$= Mp + Do^2/64 * (3 + rnu^*)(Ps - Pt)$

$= -1540.86 + 66.675^2/64 * (3 + 0.294)(5.8 - 7.5)$

$= -1929.8903$ bars*mm.^{2}

Maximum Bending Moment acting on Tubesheet [M]:

$= Max(abs(Mp), abs(Mo))$

$= Max(abs(-1540.862), abs(-1929.89))$

$= 1929.8903$ bars*mm.^{2}

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:

$= 6 * M / ((mu^*) * (h - hg')^2)$

$= 6 * 1929.89/((0.4444) * (42.0 - 0.0)^2)$

$= 1.4773$ N./mm^2

The Allowable Tubesheet Bending Stress [SigmaAll]:

$= 2 * S = 2 * 79.13 = 158.26$ N./mm^2

Tubesheet Bending Stress at Final Thickness [Sigma]:

$= 6 * M / ((mu^*) * (h - hg')^2$

$= 6 * 1910.899/((0.4488) * (4.0183 - 0.0)^2$

$= 158.2208$ N./mm^2

Required Tubesheet Thickness, for Bending Stress [HreqB]:

$= H + CATS + CATC = 4.0183 + 3.0 + 0.0 = 7.0183$ mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:

$= Max(HreqB, HreqS) = Max(7.0183, 3.1346) = 7.0183$ mm.

UHX-12.5.9 Step 9:

$abs(Ps - Pt) = abs(5.8 - 7.5) = 1.7$ bars

Shear Stress check [Tau_limit]:

$= 3.2 * S * mu * h/Do$

$= 3.2 * 79.13 * 0.333 * 42.0/66.67 = 531.65$ bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:

$= 1/(4* Mu) * (Do/h) * [Ps - Pt]$

$= 1/(4*0.333)*(66.67/42.0)*[5.8-7.5]$N./mm^2

$= 0.20$ N./mm^2

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 1.65)1.65
= 0.902 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 1.65 * (19.05 - 1.65) * 106.52 = 9.606 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 5.5752 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2.0 * (19.05 + 0.67*2.0) * 79.13
= 8.6162 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 9.6064 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.3461

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.7609 mm.

Minimum Required Fillet Weld Leg afr 1.3805 mm.
Minimum Required Groove Weld Leg agr 1.3805 mm.

Tube-Tubesheet Jt allowable, 9.61 is >= tube strength 9.61 kN
Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D3 corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	1.5	<=	158.3 N./mm²	Ok
Tubesheet shear stress	0.2	<=	63.2 N./mm²	Ok

Thickness results for loadcase D3 corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	7.018	45.000	Ok

Tube-Tubesheet Fillet Weld Leg :	1.380	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.380	2.000	Ok

U-Tube Tubesheet results per ASME UHX-12 2019

Results for 6 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht	Extnsn	Bend	---- Tubesheet Stresses Allwd	Shear	Allwd	Case Type	Pass/ Fail
D1uc	6.531	0.324	3	158	1	63	Ps+Pt D1	Ok
D2uc	2.659	0.260	1	158	1	63	Ps+Pt D2	Ok
D3uc	4.019	0.065	1	158	...	63	Ps+Pt D3	Ok
D1c	9.531	0.324	4	158	1	63	Ps+Pt-c D1	Ok
D2c	5.659	0.260	1	158	1	63	Ps+Pt-c D2	Ok
D3c	7.018	0.065	1	158	...	63	Ps+Pt-c D3	Ok
Max:	9.5310	0.324	mm.	0.025		0.016	(Str. Ratio)	

Load Case Definitions:

[Ps & Pt]:
Shell-side and Tube-side Design or Operating Pressures
derived from Psd,min Ptd,max, Psox,min, Ptox,max etc. per the
Load Case Tables

[c]:
With or Without Corrosion Allowance

[D1, D2, D3]:
Design Load Cases using the Maximum and Minimum Design Pressures

[D4]:
Design Load Case using the Minimum (Vacuum) Pressures (if specified)

Note:
Because there was no net pressure differential across the tubesheet due to
the specified pressures psd,min and ptd,min; load case D4 was not processed as
the resulting tubesheet bending stress would be zero.

Summary of Thickness Comparisons for 6 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	9.531	45.000	Ok
Tube Thickness :	0.329	1.650	Ok
Tube-Tubesheet Fillet Weld Leg :	1.380	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.380	2.000	Ok

Note: This is a full strength Tube to Tubesheet Joint.

Tubesheet MAWP used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAWP	0 shellside Stress Rat.	Shellside MAWP	0 tubeside Stress Rat.
Tubesheet Bending Stress	323.765	1.000	1705.08	1.000
Tubesheet Shear Stress	2464.60	0.995	2476.30	1.000
Tube Pressure Stress	198.241	1.000	70.127	1.000
Minimum MAWP	198.241		70.127	

Tubesheet MAPnc used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAPnc	0 shellside Stress Rat.	Shellside MAPnc	0 tubeside Stress Rat.
Tubesheet Bending Stress	512.132	1.000	2618.77	1.000
Tubesheet Shear Stress	826.731	1.000	3857.72	1.000
Tube Pressure Stress	214.303	1.000	107.747	1.000
Minimum MAPnc	214.303		107.747	

(*) Only the design load cases were analyzed to compute the MAWP for determining the test pressure.

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Rear Closure

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2019

Analysis Performed by :

Job File : C:\USERS\TECHNICAL2\DESKTOP\E-200 REAR.Pvdb

Date of Analysis : Dec 31,2024 10:16am

PV Elite 2020, January 2020

ASME Code, Section VIII Division 1, 2019

Diameter Spec : 387.350 mm. ID

Vessel Design Length, Tangent to Tangent	384.95	mm.
Specified Datum Line Distance	50.00	mm.
Internal Design Temperature	165	°C
Internal Design Pressure	7.500	bars
External Design Temperature	100	°C
External Design Pressure	1.034	bars
Maximum Allowable Working Pressure	13.000	bars
External Max. Allowable Working Pressure	18.840	bars
Hydrostatic Test Pressure	9.750	bars
Required Minimum Design Metal Temperature	5.0	°C
Warmest Computed Minimum Design Metal Temperature	-48.0	°C
Wind Design Code	ASCE-2010	
Earthquake Design Code	ASCE 7-2010	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-106 B	...	...	K03006	No	No
Head	SA-234 WPB	...	...	K03006	No	No
Flange	SA-105	...	...	K03504	No	No
Flange	SA-182 F316L	...	<= 5	S31603	No	No
Nozzle	SA-105	...	...	K03504	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.
Impact Tested is based on material selection and material data properties.

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Rear Cover	5.838	1.03	38.300	3.0000	Yes	No
Rear Barrel	5.838	1.03	31.400	3.0000	N/A	No
Rear FLG.	5.838	1.03	33.800	3.0000	N/A	No
Rear FLG.	5.859	1.03	15.000	0.0000	N/A	?

Liquid Level: 596.90 mm. Dens.: 999.542 kg/m³ Sp. Gr.: 1.000

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	0.0	50.0	9.5	9.5	4.5	4.5	1.00	1.00
Cylinder	150.0	150.0	9.5	8.3	4.5	4.2	1.00	1.00
Body Flg	280.4	130.4	...	40.0	39.8	39.8	1.00	1.00
Body Flg	334.9	45.0	...	45.0	39.7	40.2	1.00	1.00

Weights:

Fabricated	- Bare W/O Removable Internals	229.6	kg.
Shop Test	- Fabricated + Water (Full)	276.5	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	238.4	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	238.4	kg.
Empty	- Fab. + Intls. + Details + Wghts.	238.4	kg.
Operating	- Empty + Operating Liquid (No CA)	285.3	kg.
Field Test	- Empty Weight + Water (Full)	271.4	kg.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
V (1in)	13	OK	...	OK	4.50	OK	Passed
D (1in)	13	OK	...	OK	7.50	OK	Passed

Nozzle MAWP Summary:

```
Minimum MAWP Nozzles         :              13 Nozzle  : D (1in)
Minimum MAWP Shells/Flanges  :              13 Element : Rear FLG.
Minimum MAPnc Shells/Flanges :            19.6 Element : Rear FLG.
-------------------------------------------------------------
Computed Vessel M.A.W.P.     :              13 bars
```

Note: MAWPs (Internal Case) shown above are at the High Point.

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	V (1in)	125.000	90.000	62.800
20	D (1in)	125.000	270.000	74.800

The nozzle spacing is computed by the following:

$= Sqrt(ll^2 + lc^2)$ where

ll - Arc length along the inside vessel surface in the long. direction.

lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.

No interference violations have been detected !

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	ELLIPTICAL HEAD: 2.0 X 1, 9.5mm. THK X 387.4mm. ID X 50.0mm.	SA-234 WPB
1	CYLINDER: 9.5mm. THK X 387.4mm. ID X 150.0mm.	SA-106 B
1	BODY FLANGE: 40.0mm. THK X 389.7mm. OD	SA-105
1	BODY FLANGE: 45.0mm. THK X 596.9mm. OD	SA-182 F316L
1	INSULATION: 146mm X 60mm THK	
1	INSULATION: 150mm X 60mm THK	
1	INSULATION: 127mm X 60mm THK	
1	INSULATION: 36mm X 60mm THK	
1	GASKET: 463mm. OD X 422mm. ID	...
16	BODY FLANGE BOLTS: 25mm. DIA	SA-193 B7
32	NUTS FOR BODY FLANGE BOLTS: 25mm. DIA	...
1	NAMEPLATE	...

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm	Reinforcing Pad Diameter	Pad Thk mm	Cut Length in	Flg Class
V (1in)	1.000 in	Actual	LW	2.008	12.800	...	...	160.0	150
D (1in)	1.000 in	Actual	LW	2.008	12.800	...	...	160.0	150

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows: Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (mm.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
V (1in)	SA-105	8.334	10.000	...	...	...
D (1in)	SA-105	8.334	10.000	...	...	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
V (1in)	75.000	90.0	150.00	0.00	Rear Barrel
D (1in)	75.000	270.0	150.00	0.00	Rear Barrel

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
Rear FLG.	[11]	A	-8	-104	-29	0.341	8.334	1.00	Yes
Rear FLG.	[11]		-196						
Rear Cover	[10]	B	-29	-104	-29	0.326	9.525	1.00	Yes
Rear Cover	[7]	B	-29	-104	-29	0.335	9.525	1.00	Yes
Rear Barrel	[8]	B	-29	-104	-29	0.203	8.334	1.00	Yes
V (1in)	[1]	A	-8	-104	-29	0.182	8.334	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
D (1in)	[1]	A	-8	-104	-29	0.183	8.334	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
Bolting	[21]		-48						
Warmest MDMT:			-8	-104					

Required Minimum Design Metal Temperature	5.0	°C
Warmest Computed Minimum Design Metal Temperature	-48.0	°C

Notes:

[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
[21] - Bolting Material

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

```
Class From To : Basic Element Checks.
==============================================================================

Class From To: Check of Additional Element Data
==============================================================================
```

There were no geometry errors or warnings.

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	7.5	bars
Design Internal Temperature	165.0	°C
Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Minimum Design Metal Temperature	5.0	°C
Type of Construction	Welded	
Special Service	Lethal	
Degree of Radiography	RT-1	
Use Higher Longitudinal Stresses (Flag)	N	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	Y	

Load Case 1	NP+EW+WI+FW+BW
Load Case 2	NP+EW+EE+FS+BS
Load Case 3	NP+OW+WI+FW+BW
Load Case 4	NP+OW+EQ+FS+BS
Load Case 5	NP+HW+HI
Load Case 6	NP+HW+HE
Load Case 7	IP+OW+WI+FW+BW
Load Case 8	IP+OW+EQ+FS+BS
Load Case 9	EP+OW+WI+FW+BW
Load Case 10	EP+OW+EQ+FS+BS
Load Case 11	HP+HW+HI
Load Case 12	HP+HW+HE
Load Case 13	IP+WE+EW
Load Case 14	IP+WF+CW
Load Case 15	IP+VO+OW
Load Case 16	IP+VE+EW
Load Case 17	NP+VO+OW
Load Case 18	FS+BS+IP+OW
Load Case 19	FS+BS+EP+OW

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	120	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		100	mm.
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm.
Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.

Type of Terrain (Hill, Escarpment)		Flat
Damping Factor (Beta) for Wind (Ope)		0.0100
Damping Factor (Beta) for Wind (Empty)		0.0000
Damping Factor (Beta) for Wind (Filled)		0.0000
Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.250
Table Value Fa		1.111
Table Value Fv		1.575
Short Period Acceleration value Ss		1.377
Long Period Acceleration Value Sl		0.367
Moment Reduction Factor Tau		1.000
Force Modification Factor R		3.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		1.020
User Value of Sd1 (used if > 0)		0.385
Design Pressure + Static Head		Y
Consider MAP New and Cold in Noz. Design		N
Consider External Loads for Nozzle Des.		Y
Use ASME VIII-1 Appendix 1-9		N
Material Database Year	Current w/Addenda or Code Year	

Configuration Directives:

Do not use Nozzle MDMT Interpretation VIII-1 01-37	No
Use Table G instead of exact equation for "A"	Yes
Shell Head Joints are Tapered	Yes
Compute "K" in corroded condition	Yes
Use Code Case 2286	No
Use the MAWP to compute the MDMT	Yes
For thickness ratios <= 0.35, MDMT will be -155F (-104C)	Yes
For PWHT & P1 Materials the MDMT can be < -55F (-48C)	No
Using Metric Material Databases, ASME II D	No
Calculate B31.3 type stress for Nozzles with Loads	Yes
Reduce the MDMT due to lower membrane stress	Yes
Consider Longitudinal Stress in MDMT calcs. (Div. 1)	Yes

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	Rear Cover	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	387.35	mm.

Element Thickness	9.525	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	9.525	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	5.8	bars
Design Temperature Internal Pressure	220	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-234 WPB	
Allowable Stress, Ambient	117.9	N./mm²
Allowable Stress, Operating	117.9	N./mm²
Allowable Stress, Hydrotest	217.19	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	30.988	mm.
Yield Stress, Operating	203.46	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. & wld. fittings	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	10	
Detail Type	Liquid	
Detail ID	Liquid: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	387.35	mm.
Liquid Density	999.54	kg/m³
Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	-96.838	mm.
Height/Length of Insulation	146.84	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	Rear Barrel	
Distance "FROM" to "TO"	150	mm.
Inside Diameter	387.35	mm.
Element Thickness	8.3344	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	9.525	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	5.8	bars
Design Temperature Internal Pressure	220	°C

Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-106 B	
Allowable Stress, Ambient	117.9	N./mm²
Allowable Stress, Operating	117.9	N./mm²
Allowable Stress, Hydrotest	217.19	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	30.988	mm.
Yield Stress, Operating	203.46	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	20	
Detail Type	Liquid	
Detail ID	Liquid: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	387.35	mm.
Liquid Density	999.54	kg/m³
Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	150	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³
Element From Node	20	
Detail Type	Nozzle	
Detail ID	V (1in)	
Dist. from "FROM" Node / Offset dist	75	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.032	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	D (1in)	
Dist. from "FROM" Node / Offset dist	75	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	270.0	

Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.032	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	Rear FLG.	
Distance "FROM" to "TO"	130.42	mm.
Flange Inside Diameter	389.73	mm.
Element Thickness	40	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	5.8	bars
Design Temperature Internal Pressure	220	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-105	
Allowable Stress, Ambient	137.9	N./mm²
Allowable Stress, Operating	137.13	N./mm²
Allowable Stress, Hydrotest	223.4	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	30.988	mm.
Yield Stress, Operating	209.47	N./mm²
UCS-66 Chart Curve Designation	A	
External Pressure Chart Name	CS-2	
UNS Number	K03504	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	kN
Class of Standard Flange		
Grade of Standard Flange		
Weld is pre-Heated	No	

Element From Node	30	
Detail Type	Liquid	
Detail ID	Liquid: 30	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	389.73	mm.
Liquid Density	999.54	kg/m³

Element From Node	30	
Detail Type	Insulation	
Detail ID	Ins: 30	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	127	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³

Element From Node	40	
Element To Node	50	
Element Type	Flange	
Description	Rear FLG.	
Distance "FROM" to "TO"	45	mm.
Flange Outside Diameter	596.9	mm.
Element Thickness	45	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	5.8	bars
Design Temperature Internal Pressure	220	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-182 F316L	
Allowable Stress, Ambient	115.15	N./mm²
Allowable Stress, Operating	79.129	N./mm²
Allowable Stress, Hydrotest	155.14	N./mm²
Material Density	8027.2	kg/m³
P Number Thickness	0	mm.
Yield Stress, Operating	118.54	N./mm²
External Pressure Chart Name	HA-4	
UNS Number	S31603	
Class / Thickness / Grade :: <= 5		
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	kN
Class of Standard Flange		
Grade of Standard Flange		
Weld is pre-Heated	No	
Element From Node	40	
Detail Type	Liquid	
Detail ID	Liquid: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	596.9	mm.
Liquid Density	999.54	kg/m³
Element From Node	40	
Detail Type	Insulation	
Detail ID	Ins: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	36.576	mm.
Thickness of Insulation	60	mm.
Density	125	kg/m³

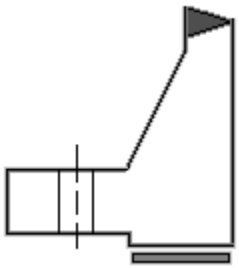
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
Rear Cover		50	...	50	...
Rear Barrel		200	...	150	...
Rear FLG.		330.424	...	130.424	...
Rear FLG.		384.949	...	45	...

Flange Input Data Values **Description: FLANGE :**

Rear FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	5.84	bars
Design Temperature		220	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	389.731	mm.
Flange Outside Diameter	A	596.900	mm.
Flange Thickness	t	40.0000	mm.
Thickness of Hub at Small End	go	8.3344	mm.
Thickness of Hub at Large End	g1	33.7344	mm.
Length of Hub	h	90.4240	mm.
Flange Material		SA-105	
Flange Material UNS number		K03504	
Flange Allowable Stress At Temperature	Sfo	137.13	N./mm²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm²
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm²
Diameter of Bolt Circle	C	539.750	mm.
Nominal Bolt Diameter	a	25.4000	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		16	
Flange Face Outside Diameter	Fod	469.900	mm.
Flange Face Inside Diameter	Fid	389.731	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	463.550	mm.
Gasket Inside Diameter	Gi	422.402	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.



ASME Code, Section VIII Division 1, 2019

Hub Small End Required Thickness due to Internal Pressure:
```
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (5.84*(390/2+3))/(137*1-0.6*5.84)+Ca
= 3.8446 mm.
```

Hub Small End Hub MAWP:
```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137 * 1 * 5.33 )/(198 + 0.6 * 5.33 )
= 36.379 bars
```

Corroded Flange Thickness,	tc = T-ci	37.000	mm.
Corroded Flange ID,	Bcor = B+2*Fcor	395.731	mm.
Corroded Large Hub,	g1Cor = g1-ci	30.734	mm.
Corroded Small Hub,	g0Cor = go-ci	5.334	mm.
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	41.275	mm.
Gasket Contact Width,	N = (Go - Gi) / 2	20.574	mm.
Basic Gasket Width,	bo = N / 2	10.287	mm.
Effective Gasket Width,	b = Cb sqrt(bo)	8.082	mm.
Gasket Reaction Diameter,	G = Go - 2 * b	447.386	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
= 0.785 * G² * Peq
= 0.79 * 447² * 5.84
= 91.774 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
= 2 * b * Pi * G * m * P
= 2 * 8.08 * 3.14 * 447 * 3 * 5.84
= 39.791 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
= Pi * Bcor² * P  / 4
= 3.14 * 396² *5.84/4
= 71.805 kN
```
Pressure Force on Flange Face [Ht]:
```
= H - Hd
= 91.8 - 71.8
= 19.969 kN
```

Operating Bolt Load [Wm1]:
```
= max( H + Hp + H'p, 0 )
= max( 91.8 + 39.8 + 0, 0 )
= 131.565 kN
```
Gasket Seating Bolt Load [Wm2]:
```
= y * b * Pi * G  + yPart * bPart * lp
= 68.9*8.08*3.141*447+0*0*0
= 783.177 kN
```
Required Bolt Area [Am]:
```
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 132/172, 783/172
= 45.438 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
= 2a + 6t/(m + 0.5)
= 2 * 25.4 + 6 * 37/(3 + 0.5)
= 114.229 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
= C * sin( pi / n )
= 540 * sin( 3.14/16 )
= 105.300 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
= max( sqrt( Bs/( 2a + t )), 1 )
= max( sqrt( 105/( 2 * 25.4 + 37 )), 1 )
= 1.0951
```

Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm²	45.438	56.877	
Radial Distance between Hub and Bolts:	34.925	41.275	
Radial Distance between Bolts and Edge:	26.987	28.575	
Circ. Spacing between the Bolts:	57.150	105.300	114.229

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
= Ab * Sa/( y * Pi * (Go + Gi) )
= 56.9  * 172/(68.9 * 3.14 * (464 + 422 ) )
= 5.109 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
= Sa * ( Am + Ab ) / 2
= 172 * ( 45.4 + 56.9 )/2
= 881.76 kN
```
Gasket Load for the Operating Condition [HG]:
```
= Wm1 - H
= 132 - 91.8
= 39.79 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
= (C - G ) / 2
= ( 540 - 447 )/2
= 46.1822 mm.
```

Distance to Face Pressure Reaction [ht]:

```
= ( R + g1 + hg ) / 2
= ( 41.3 + 30.7 + 46.2 )/2
= 59.0959 mm.
```

Distance to End Pressure Reaction [hd]:

```
= R + ( g1 / 2 )
= 41.3 + ( 30.7/2.0 )
= 56.6423 mm.
```

Summary of Moments for Internal Pressure: (N-m)

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	72.	56.6423	1.0951	4456.
Face Pressure,	Mt	20.	59.0959	1.0951	1293.
Gasket Load,	Mg	40.	46.1822	1.0951	2013.
Gasket Seating,	Matm	882.	46.1822	1.0951	44614.

Total Moment for Operation,	Mop		7762. N-m
Total Moment for Gasket seating,	Matm		44614. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor)		45.945 mm.
Hub Ratio,	h/h0 = HL / H0	1.968
Thickness Ratio,	g1/g0 = (g1Cor/goCor)	5.762

Flange Factors for Integral Flange:

Factor F				0.493
Factor V				0.015
Factor f				1.000
Factors from Figure 2-7.1			K =	1.508
	T =	1.707	U =	5.381
	Y =	4.897	Z =	2.568
	d =	0.47509E+06 mm.³	e =	0.0107 mm.^-1
Stress Factors			ALPHA =	1.397
	BETA =	1.529	GAMMA =	0.818
	DELTA =	0.107	Lamda =	0.925

Longitudinal Hub Stress, Operating [SHo]:

```
= ( f * Mop / Bcor ) / ( L * g1² )
= (1*7762/396)/(0.92*30.7²)
= 22.44 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:

```
= ( f * Matm / Bcor ) / ( L * g1² )
= (1*44614/396)/(0.92*30.7²)
= 129.01 N./mm²
```

Radial Flange Stress, Operating [SRo]:

```
= ( Beta * Mop / Bcor ) / ( L * t² )
```

= (1.53*7762/396)/(0.92*37²)
= 23.68 N./mm²

Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (1.53*44614/396)/(0.92*37²)
= 136.10 N./mm²

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (4.9*7762/(37²*396))-2.57*23.7
= 9.31 N./mm²

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (4.9*44614/(37²*396))-2.57*136
= 53.53 N./mm²

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (22.4+max(23.7,9.31))/2
= 23.06 N./mm²

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (129+max(136,53.5))/2
= 132.55 N./mm²

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 132/56.9
= 23.13 N./mm²

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (783/56.9)
= 137.71 N./mm²

Flange Stress Analysis Results: N./mm²

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	22.44	205.69	129.01	206.85
Radial Flange	23.68	137.13	136.10	137.90
Tangential Flange	9.31	137.13	53.53	137.90
Maximum Average	23.06	137.13	132.55	137.90
Bolting	23.13	172.38	137.71	172.38

Minimum Required Flange Thickness	39.827 mm.
Estimated M.A.W.P. (Operating)	33.8 bars
Estimated Finished Weight of Flange at given Thk.	68.8 kg.
Estimated Unfinished Weight of Forging at given Thk	162.3 kg.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*44658/1.1*1000*0.015/(0.92*202713*5.33²*45.9*0.3)
  = 0.429    (should be <= 1)
```

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14*7770/1.1*1000*0.015/(0.92*191214*5.33²*45.9*0.3)
  = 0.079    (should be <= 1)
```

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*44614/1.1*1000*0.015/(0.92*202713*5.33²*45.9*0.3)
  = 0.428    (should be <= 1)
```

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14*7762/1.1*1000*0.015/(0.92*191214*5.33²*45.9*0.3)
  = 0.079    (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.34, Temperature Reduction per Fig. UCS 66.1 = 78 °C

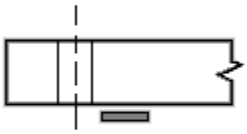
```
 Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

Flange Input Data Values **Description: FLANGE :**

Rear FLG.

Description of Flange Geometry (Type)		Blind	
Design Pressure	P	5.86	bars
Design Temperature		220	°C
Internal Corrosion Allowance	ci	0.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Outside Diameter	A	596.900	mm.
Flange Thickness	t	45.0000	mm.
Flange Material		SA-182 F316L	
Flange Material UNS number		S31603	
Flange Allowable Stress At Temperature	Sfo	79.13	N./mm²
Flange Allowable Stress At Ambient	Sfa	115.15	N./mm²
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm²
Diameter of the Load Reaction, Long Span	D	0.000	mm.
Diameter of the Load Reaction, Short Span	d	0.000	mm.
Perimeter along the Center of the Bolts	L	1695.675	mm.
Diameter of Bolt Circle	C	539.750	mm.
Nominal Bolt Diameter	a	25.4000	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		16	
Flange Face Outside Diameter	Fod	469.900	mm.
Flange Face Inside Diameter	Fid	387.350	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	463.550	mm.
Gasket Inside Diameter	Gi	422.402	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.



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```
Gasket Contact Width,        N = (Go - Gi) / 2          20.574  mm.
Basic Gasket Width,         bo = N / 2                  10.287  mm.
Effective Gasket Width,      b = Cb sqrt(bo)             8.082  mm.
Gasket Reaction Diameter,    G = Go - 2 * b            447.386  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
= 0.785 * G² * Peq
= 0.79 * 447² * 5.86
= 92.094 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
= 2 * b * Pi * G * m * P
= 2 * 8.08 * 3.14 * 447 * 3 * 5.86
= 39.929 kN
```
Operating Bolt Load [Wm1]:
```
= max( H + Hp + H'p, 0 )
= max( 92.1 + 39.9 + 0, 0 )
= 132.023 kN
```
Gasket Seating Bolt Load [Wm2]:
```
= y * b * Pi * G  + yPart * bPart * lp
= 68.9*8.08*3.141*447+0*0*0
= 783.177 kN
```
Required Bolt Area [Am]:
```
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 132/172, 783/172
= 45.438 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
= 2a + 6t/(m + 0.5)
= 2 * 25.4 + 6 * 45/(3 + 0.5)
= 127.943 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
= C * sin( pi / n )
= 540 * sin( 3.14/16 )
= 105.300 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(105/(2 * 25.4 + 45)), 1)
= 1.0484

Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm²	45.438	56.877	
Radial Distance between Bolts and Edge:	26.987	28.575	
Circ. Spacing between the Bolts:	57.150	105.300	127.943

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 56.9 * 172/(68.9 * 3.14 * (464 + 422))
= 5.109 mm.

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 172 * (45.4 + 56.9)/2
= 881.76 kN

Gasket Load for the Operating Condition [HG]:
= Wm1
= 132.02 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (540 - 447)/2
= 46.1822 mm.

Tangential Flange Stress, Flat Head (UG-34), Operating [STo]:
= 1.9 * Wm1 * hG * Bsc/(t² * G) + C * Z * Peq * G²/t²
= 1.9*132*46.2*1.05/(45²*447)+
0.3*1*5.86*447²/45²
= 30.78 N./mm²

Tangential Flange Stress, Flat Head (UG-34), Seating [STa]:
= 1.9 * W * hG * Bsc/ (t² * G)
= 1.9*882*46.2*1.05/(45²*447)
= 89.54 N./mm²

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 132/56.9
= 23.21 N./mm²

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (783/56.9)
= 137.71 N./mm²

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Tangential Flange	30.78	79.13	89.54	115.15
Bolting	23.21	172.38	137.71	172.38

Reqd. Blind Flange Thickness at Center	39.683 mm.
Reqd. Blind Flange Thickness at Gasket	39.683 mm.
Estimated M.A.W.P. (Operating)	15.1 bars
Estimated Finished Weight of Flange at given Thk.	101.1 kg.
Estimated Unfinished Weight of Forging at given Thk	101.1 kg.

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm²
Rear Cover		5.8383	9.525	3	387.35	117.9
Rear Barrel		5.8383	9.525	3	387.35	117.9
Rear FLG.		5.8382	...	3	389.73	137.13
Rear FLG.		5.8585	...	...	596.9	79.129

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
Rear Cover		5.8	38.3	57.7	9.525	4.5
Rear Barrel		5.8	31.4	49.5	8.33437	4.5
Rear FLG.		5.8	33.8	39.1	40	39.8272
Rear FLG.		5.8	15	21.9	45	39.6832
Minimum			13	19.6		

Note : The M.A.P.(NC) is Governed by a Flange !

MAWP: 13 bars, limited by: DESIGN (user specified)

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

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Elliptical Head From 10 To 20 SA-234 WPB , UCS-66 Crv. B at 220 °C

Rear Cover
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (5.84*393*0.98)/(2*118*1-0.2*5.84)
= 0.9550 + 3.0000 = 3.9550 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.038 bars

```
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*118*1*6.52)/(0.98*393+0.2*6.52)
```

= 39.8 - 0.038 = 39.7 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*118*1*9.52)/(1*387+0.2*9.52)
= 57.7 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (5.84*(0.98*393+0.2*6.52))/(2*1*6.52)
= 17.307 N./mm²

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (5.84*197)/(118*1-0.6*5.84)+3
= 3.977 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.038 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118 * 1 * 6.52)/(197 + 0.6 * 6.52)
= 38.4 - 0.038 = 38.3 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))²)/6
= (2 + (393/(2 * 99.8))²)/6
= 0.980118

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 9.52, tr = 2.13, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.33, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 9.52, tr = 2.18, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.33, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Cylindrical Shell From 20 To 30 SA-106 B , UCS-66 Crv. B at 220 °C

Rear Barrel
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (5.84*197)/(118*1-0.6*5.84)
= 0.9768 + 3.0000 = 3.9768 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.038 bars

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118*1*5.33)/(197+0.6*5.33)
= 31.5 - 0.038 = 31.4  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118*1*8.33)/(194+0.6*8.33)
= 49.5 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
= (P*(R+0.6*t))/(E*t)
= (5.84*(197+0.6*5.33))/(1*5.33)
= 21.877 N./mm²
```

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 8.33, tr = 1.08, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.2, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Note: Heads and Shells Exempted to -20F (-29C) by paragraph UG-20F

Hydrostatic Test Pressure Results:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          16.900  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S         9.750  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       25.480  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          14.300  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     10.725  bars
Pressure per App 27-4  = M.A.W.P.                        13.000  bars
```

UG-99(b) Note 36, Test Pressure Calculation:

```
= Test Factor * Design Pressure * Stress Ratio
= 1.3 * 7.5 * 1
= 9.750 bars
```

Horizontal Test performed per: UG-99b (Note 36)

Please note that Nozzle, Shell, Head, Flange, etc MAWPs are all considered when determining the hydrotest pressure for those test types that are based on the MAWP of the vessel.

Stresses on Elements due to Test Pressure (N./mm² & bars):

From To	Stress	Allowable	Ratio	Pressure
Rear Cover	29.0	217.2	0.134	9.79
Rear Barrel	36.7	217.2	0.169	9.79

Stress ratios for Nozzle and Pad Materials (N./mm²):

Description	Pad/Nozzle	Ambient	Operating	Ratio
V (1in)	Nozzle	137.90	137.13	1.006
D (1in)	Nozzle	137.90	137.13	1.006
Minimum				1.006

Stress ratios for Pressurized Vessel Elements (N./mm²):

Description	Ambient	Operating	Ratio
Rear Cover	117.90	117.90	1.000
Rear Barrel	117.90	117.90	1.000
Rear FLG.	137.90	137.13	1.006
Rear FLG.	115.15	79.13	1.455
Minimum			1.000

Hoop Stress in Nozzle Wall during Pressure Test (N./mm²):

Description	Ambient	Operating	Ratio
V (1in)	2.16	223.40	0.010
D (1in)	3.28	223.40	0.015

Elements Suitable for Test Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm²
10	20	No Calc	406.4	6.525	0.0022299	106.135
20	30	362.703	404.019	5.33437	0.0023268	107.027
30	40	No Calc	...	37	No Calc	No Calc
40	50	No Calc	...	45	No Calc	No Calc

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	9.525	4.5	1.034	18.9
20	30	8.33437	4.23586	1.034	18.8
30	40	40	39.8272	1.034	No Calc
40	50	45	40.2082	1.034	No Calc
Minimum					18.8

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	362.703	8381.7	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 100 °C

Rear Cover

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

Results for Maximum Allowable Ext. Pressure	MAEP

Tca	Outer Dia	Do/t	Factor A	Factor B
6.525	406.40	62.28	0.0022299	106.14

MAEP = B/(K0*Do/t) = 106/(0.9 *62.3) = 18.9 bars

Results for Required Thickness | Tca

Tca	Outer Dia	Do/t	Factor A	Factor B
1.052	406.40	386.26	0.0003596	35.95

MAEP = B/(K0*Do/t) = 35.9/(0.9 *386) = 1.03 bars

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (1.73*393*0.98)/(2*118*1-0.2*1.73)
= 0.2824 + 3.0000 = 3.2824 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*118*1*6.52)/(0.98*393+0.2*6.52))/1.67
= 23.8 bars

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(18.9, 23.8)
= 18.933 bars

Thickness requirements per UG-33(a)(1) govern the required thickness of this head.

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 100 °C

Rear Barrel

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

Results for Maximum Allowable Ext. Pressure | MAEP

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
5.334	404.02	362.70	75.74	0.8977	0.0023268	107.03

MAEP = (4*B)/(3*(Do/t)) = (4*107)/(3*75.7) = 18.8 bars

```
Results for Required Thickness                 |                                  Tca  |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  1.236 |     404.02 |      362.70 |    326.91 |    0.8977 |  0.0002536 |    25.36 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*25.4 )/(3*327 ) = 1.03 bars

                                               |                                    |
Results for Maximum Stiffened Length           |                             Slen   |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  5.334 |     404.02 |     8381.70 |     75.74 |   20.7458 |  0.0001983 |    19.82 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*19.8 )/(3*75.7 ) = 3.49 bars

-----------------------------------------------------------------------------------------------------
```

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm.	Corroded Metal Wgt. kg.	Corroded ID Volume Cm.	Extra due Misc % kg.
10	20	18.5192	13502.1	12.6863	14045.2	1.85192
20	30	13.8067	17679.3	9.52963	18231.3	1.38067
30	40	68.7924	15709.7	65.0508	16044.5	6.87924
40	50	101.082	...	101.082	...	10.1082
Total		202	46891.16	188	48320.93	20

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	13.4939	-32.2792	...	Liquid: 10
10	Insl	2.21108	-23.4188	...	Ins: 10
20	Liqd	17.6686	75	...	Liquid: 20
20	Insl	1.64002	75	...	Ins: 20
20	Nozl	3.58945	75	206.375	V (1in)
20	Nozl	3.58945	75	206.375	D (1in)
30	Liqd	15.7001	65.212	...	Liquid: 30
30	Insl	2.25671	63.5	...	Ins: 30
40	Liqd	...	22.5	...	Liquid: 40
40	Insl	2.6863	18.288	...	Ins: 40

Total Weight of Each Detail Type:

Liquid	46.9
Insulation	8.8
Nozzles	7.2
Sum of the Detail Weights	62.8 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	222.4	222.4	222.4	222.4	222.4	222.4
Nozzles	7.2	7.2	7.2	7.2	7.2	7.2
Insulation	...	...	8.8	8.8	8.8	8.8
Ope. Liquid	...	...	...	...	...	46.9
Test Liquid	...	46.9	...	...	...	...
Totals	229.6	276.5	238.4	238.4	238.4	285.3

Field Installation Options:

Miscellaneous Weight Percent: 10.0 %

Note that the above value for the miscellaneous weight percent has been applied to the shells/heads/flange/tubesheets/tubes etc. in the weight calculations for metallic components.

Weight Summary:

```
Fabricated Wt.   - Bare Weight without Removable Internals              229.6 kg.
Shop Test Wt.    - Fabricated Weight + Water ( Full )                  276.5 kg.
Shipping Wt.     - Fab. Weight + removable Intls.+ Shipping App.       238.4 kg.
Erected  Wt.     - Fab. Wt + or - loose items (trays,platforms etc.)   238.4 kg.
Ope. Wt. no Liq - Fab. Weight + Internals. + Details + Weights         238.4 kg.
Operating Wt.    - Empty Weight + Operating Liq. Uncorroded            285.3 kg.
Oper. Wt. + CA   - Corr Wt. + Operating Liquid                         270.0 kg.
Field Test Wt.   - Empty Weight + Water (Full)                         271.4 kg.
```

Note:
The Corroded Weight and thickness are used in the Horizontal Vessel Analysis (Ope Case) and Earthquake Load Calculations.

Note: The Field Test weight as computed in the corroded condition.

Outside Surface Areas of Elements:

From	To	Surface Area cm²
10	20	2428.69
20	30	1915.12
30	40	3654.23
40	50	3642.14
Total		11640.176 cm²

Nozzle Flange MAWP Results: (bars & °C)

Nozzle Description	Flange Rating Ope.	Flange Rating Ambient	Design Temp	Class	Grade/ Group	Equiv. Press	Max Pressure UG-44(b)	Max Pressure 50%	Max Pressure DNV
V (1in)	13.12	19.60	220	150	GR 1.1	...	...	...	...
D (1in)	13.12	19.60	220	150	GR 1.1	...	...	...	...
Min Rating	13.120	19.600 bars [for Core Elements]					0.000	0.000	0.000

ANSI Ratings are per ANSI/ASME B16.5 2013 Metric Edition

Warning:
There are nozzles in this model, but no flange MAWPs were de-rated. Be sure this is what you intended. There is a check box in the nozzle dialog that instructs PV Elite to perform the de-rating for each nozzle flange. See ASME VIII-1, UG-44(b) for more information.

Shop/Field Installation Options :

Insulation is installed in the Shop.

Note : The CG is computed from the first Element From Node

```
Center of Gravity of the Liquid                          126.687 mm.
Center of Gravity of the Insulation                      194.471 mm.
Center of Gravity of the Nozzles                         125.000 mm.

Center of Gravity of Bare Shell New and Cold             278.052 mm.
Center of Gravity of Bare Shell Corroded                 291.038 mm.

Vessel CG in the Operating Condition                     254.955 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition       270.360 mm.
```

Input, Nozzle Desc: V (1in) **From: 20**

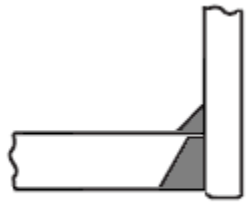
Pressure for Reinforcement Calculations	P	5.800	bars
Temperature for Internal Pressure	Temp	220	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	387.35	mm.
Design Length of Section	L	362.7032	mm.
Shell Finished (Minimum) Thickness	t	8.3344	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		125.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.13	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.8000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: V (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.504  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (5.8*197)/(118*1-0.6*5.8)
  = 0.9704 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 15.7(exp([5.8/(137*1]-1)
  = 0.0665 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2571 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)          Dl     62.8000  mm.
Parallel to Vessel Wall, opening length            d     31.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    13.3359  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137/118 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 137/118)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.305	0.194	NA
Area in Shell	A1	1.370	1.287	NA
Area in Nozzle Wall	A2	2.596	2.545	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.832	0.832	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	4.798	4.664	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(31.4*1.24*1+2*9.8*1.24*1(1-1))
= 0.194 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 31.4 (1 * 5.33 - 1 * 1.24) - 2 * 9.8
(1 * 5.33 - 1 * 1.24) * (1 - 1)
= 1.287 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 13.3)(9.8 - 0.26)1
= 2.545 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10² - 0.17) * 1 + (0² -0) * 1
= 0.832 cm²

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
Wall Thickness for Internal/External pressures ta = 3.2571 mm.

```
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 3.9704 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 4.5000 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                    tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 4.5, 4.5 ) ]
  = 4.5000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 3.26, 4.5 )
  = 4.5000 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:A, Curve:B)

Govrn. thk, tg = 8.33, tr = 0.97, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.18, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)      -104 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
Design Pressure/Ambient Rating = 5.80/19.60 = 0.296
```

Weld Size Calculations, Description: V (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.5250  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.5675 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.19 - 1.29 + 2 * 9.8 * 1 *
    (1 * 5.33 - 1.24 ) )118 )
```

```
  = max( 0, -3.41) kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.55 + 0 + 0.83 - 0 * 1 ) * 118
  = 39.82 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.55 + 0 + 0.83 + ( 1.05 ) ) * 118
  = 52.14 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.55 + 0 + 0.83 + 0 + ( 1.05 ) ) * 118
  = 52.14 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 51 * 10 * 0.49 * 118
  = 46. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 20.6 ) * ( 12.8 - 3 ) * 0.7 * 137
  = 61. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 51 * ( 8.33 - 3 ) * 0.74 * 137
  = 43. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46.3 + 60.9 ) = 107 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46.3 + 0 + 43.4 + 0 ) = 89.6 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46.3 + 43.4 + 0 ) = 89.6 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 107 kN , must exceed W = 0 kN  or W1 = 39 kN
 Path 2-2 = 89 kN , must exceed W = 0 kN  or W2 = 52 kN
 Path 3-3 = 89 kN , must exceed W = 0 kN  or W3 = 52 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   13  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.03 bars

The Drop for this Nozzle is : 1.6861 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.0204 mm.

Input, Nozzle Desc: D (1in) **From: 20**

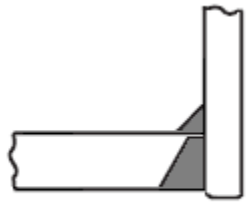
Pressure for Reinforcement Calculations	P	5.838	bars
Temperature for Internal Pressure	Temp	220	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	387.35	mm.
Design Length of Section	L	362.7032	mm.
Shell Finished (Minimum) Thickness	t	8.3344	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		125.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.13	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.8000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: D (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.504  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (5.84*197)/(118*1-0.6*5.84)
  = 0.9768 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (5.84*18.7)/(137*1-0.6*5.84)
  = 0.0798 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2571 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl     74.8000  mm.
Parallel to Vessel Wall, opening length              d     37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     13.3359  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137/118 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 137/118)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.365	0.231	NA
Area in Shell	A1	1.630	1.533	NA
Area in Nozzle Wall	A2	1.792	1.745	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	4.422	4.278	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*1.24*1+2*6.8*1.24*1(1-1))
= 0.231 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 37.4 (1 * 5.33 - 1 * 1.24) - 2 * 6.8
(1 * 5.33 - 1 * 1.24) * (1 - 1)
= 1.533 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 13.3)(6.8 - 0.26)1
= 1.745 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm²

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
Wall Thickness for Internal/External pressures ta = 6.2571 mm.

```
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 3.9768 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 7.5000 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                    tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 7.5, 7.5 ) ]
  = 7.5000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 6.26, 7.5 )
  = 7.5000 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:A, Curve:B)

Govrn. thk, tg = 8.33, tr = 0.98, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.18, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)      -104 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
Design Pressure/Ambient Rating = 5.84/19.60 = 0.298
```

Weld Size Calculations, Description: D (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.5250  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.5675 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
```

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.23 - 1.53 + 2 * 6.8 * 1 *
    (1 * 5.33 - 1.24 ) )118 )
```

```
  = max( 0, -8.78) kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.75 + 0 + 1 - 0 * 1 ) * 118
  = 32.36 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.75 + 0 + 1 + ( 0.73 ) ) * 118
  = 40.92 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.75 + 0 + 1 + 0 + ( 0.73 ) ) * 118
  = 40.92 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 51 * 10 * 0.49 * 118
  = 46. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 22.1 ) * ( 12.8 - 6 ) * 0.7 * 137
  = 45. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 51 * ( 8.33 - 3 ) * 0.74 * 137
  = 43. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46.3 + 45.3 ) = 91.6 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46.3 + 0 + 43.4 + 0 ) = 89.6 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46.3 + 43.4 + 0 ) = 89.6 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 91 kN , must exceed W = 0 kN  or W1 = 32 kN
 Path 2-2 = 89 kN , must exceed W = 0 kN  or W2 = 40 kN
 Path 3-3 = 89 kN , must exceed W = 0 kN  or W3 = 40 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   13  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.03 bars

The Drop for this Nozzle is : 1.6861 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.0204 mm.

FEA for Saddle

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Wed Dec 25 16:42:25 2024.

- Model Notes
- Zick Calculations for Saddles
- Load Case Report
- Solution Data
- ASME Code Stress Output Plots
- Stress Results - Notes
- ASME Overstressed Areas
- Highest Primary Stress Ratios
- Highest Secondary Stress Ratios
- Highest Fatigue Stress Ratios
- Highest Stress Ratios Per Region
- Compressive Stress Summary
- Graphical Results

```
Model Notes
Model Notes

  Input Echo:

  Model Type                    : Cylindrical Shell

  Parent Geometry
        Parent Outside Diam.    :     101.600 mm.
        Thickness               :       3.050 mm.
        Fillet Along Shell      :       2.135 mm.

  Parent Properties:
        Cold Allowable          :       115.1 MPa
        Hot  Allowable          :       113.1 MPa
        Material DB # 1071622.
        Ultimate Tensile (Amb)  :       482.6 MPa
        Yield Strength (Amb)    :       172.4 MPa
        Yield Strength (Hot)    :       128.2 MPa
        Elastic Modulus (Amb)   :    195135.0 MPa
        Poissons Ratio          :       0.300
        Expansion Coefficient   :  0.1677E-04 mm./mm./deg.
        Weight Density          :  0.7872E-04  N /cu.mm.

  Structural Saddle

        Height from Centerline  :     520.000 mm.
        Saddle Plate Width      :      95.500 mm.
```

```
        Axial Web Plate Length :     120.000 mm.
        Web Plate Thickness    :       3.000 mm.
        Flange Plate Thickness :       3.000 mm.
        Saddle Distance from
        front of Cylinder      :     470.000 mm.

        Number of Ribs         :           2

        Repad Thickness        :       3.000 mm.
        Repad Axial Length     :     200.000 mm.
        Repad Angle            :     145.000 deg.

        Integral Repad Model

        Entire vessel is modeled. One saddle is fixed and the
        other is sliding. Weight, temperature and pressure are
        applied but no external forces. External acceleration
        is included.

        Boundary Condition Head is Flat.


   Have fluid head pressure load acting in the -Y direction.
   The fluid height from the bottom of the vessel/pipe is
   95.500 mm..

   The fluid specific gravity is        1.000.

        Nozzle Tilt Angle      :       0.000 deg.
        Distance from Top      :       0.000 mm.
        Distance from Bottom   :    3400.000 mm.

Nozzle Properties
        Cold Allowable         :       108.3 MPa
        Hot  Allowable         :       108.3 MPa
        Material DB # 1004522.
        Ultimate Tensile (Amb) :       379.2 MPa
        Yield Strength (Amb)   :       206.8 MPa
        Yield Strength (Hot)   :       180.6 MPa
        Elastic Modulus (Amb)  :    202720.0 MPa
        Poissons Ratio         :       0.300
        Expansion Coefficient  :  0.1252E-04 mm./mm./deg.
        Weight Density         :  0.7872E-04  N /cu.mm.

Design Operating Cycles        :       7000.
Ambient Temperature (Deg.)     :       21.00

Thermal Stresses will be introduced into this analysis due to the
differences in temperature and/or thermal expansion coefficients.
The following temperatures have been specified for the analysis:

Nozzle Inside  Temperature     :       85.00 deg.
Nozzle Outside Temperature     :       85.00 deg.
Vessel Inside  Temperature     :      165.00 deg.
Vessel Outside Temperature     :      165.00 deg.
Nozzle Pressure                :       0.675 MPa
Vessel Pressure                :       0.675 MPa

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces(  N )  Moments (N-m)
```

Load Case	FX	FY	FZ	MX	MY	MZ
OPER:	2720.0	60880.0	1360.0	0.0	0.0	0.0

FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
OPER:	2720.0	60880.0	1360.0	0.0	0.0	0.0

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

Saddle/Shoe	Vector	:	0.000	1.000	0.000
Vessel Centerline	Vector	:	1.000	0.000	0.000

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Zick Calculations for Saddles
Zick Calculations for Saddles

L.P. Zick Calculation for "Stresses in Large Horizontal
Cylindrical Pressure Vessels on Two Saddle Supports"
THE WELDING JOURNAL RESEARCH SUPPLEMENT, September 1951.

INPUT DATA:

Inside Diameter (Non-corroded)	=	95.500	mm.
Vessel Thickness(Non-corroded)	=	3.050	mm.
Head Thickness (Non-corroded)	=	45.000	mm.
Wear Plate Thickness	=	3.000	mm.
Wear Plate Width	=	200.000	mm.
Wear Plate Angle	=	145.000	deg.
Corrosion Allowance	=	0.000	mm.
Girth Weld Joint Efficiency	=	1.000	
Tangent-to-Tangent Length	=	6800.000	mm.
Saddle Centerline-to-Tangent	=	470.000	mm.
Head Depth	=	24.638	mm.
Saddle Width(along vessel axis)	=	120.000	mm.
Saddle Thickness	=	3.000	mm.
Saddle Contact Angle	=	151.417	deg.
Number of Stiffeners @ea saddle	=	0.000	
Area of Each Stiffener	=	0.000	sq.mm.
Section modulus of ea Stiffener	=	0.0	cu.mm.
Internal Pressure	=	0.675	MPa
Total Weight of Entire Vessel	=	1021.	N

```
Allowable Stress                =    113.100 MPa
Yield Stress                    =    128.200 MPa
Youngs Modulus                  =    195135. MPa

CALCULATED PROPERTIES AND STRESSES:
-----------------------------------

Allowable stresses given below are taken from the
recommendations made in the 1950's paper by Zick.

Effective Shell Angle at Saddle =     93.090 deg.
Mean Radius used in Calculation =     49.275 mm.
Hoop Pressure Stress            =     11.243 MPa
Longitudinal Pressure Stress    =      5.621 MPa

The heads are too far from the saddles.  They will NOT
significantly stiffen the shell. 470.000 > 24.637.

LONGITUDINAL STRESSES
---------------------

K1(at saddle)                   =      0.124
K1(at midspan)                  =      0.719

Longitudinal Membrane Stress    =      4.623 MPa
(At saddle)

Longitudinal Membrane Stress    =     26.817 MPa
(At midspan)

The maximum bending at the vessel section, (resulting in a membrane
stress in the shell wall), may be either tensile or compressive. The
tension stress plus the axial stress due to internal pressure should
not exceed the allowable tensile stress times the girth butt weld
efficiency.

S(long) + PD/4t < (Sallow)(eff)
At Saddle:
(4.62+5.62) < (113.10)(1.000)
10.24 < 113.10

At Midspan:
(26.82+5.62) < (113.10)(1.000)
32.44 < 113.10

The net longitudinal compressive stress in the shell should be the
lesser of 1/2 of the yield strength, or the value given by:
(E/29)(t/r)[ 2 - (2/3)(100)(t/r) ]

1/2 Yield                       =      64.10 MPa

At Midspan:
-21.20 > -885.68 ..................... EXCEEDED

TANGENTIAL SHEAR STRESS
-----------------------

K2  =      0.786
K2w =      0.637 (K2 used for evaluation at equator for wear plate.)
Max Shear Stress   =       2.29 MPa
(Stress in shell and wear plate combined.)

Max Shear @equator =       1.85 MPa
```

(Required for wear plate. This stress in shell only.)

The tangential shear stress should not exceed 0.8 times the
allowable stress in tension.

2.29 < 90.48

CIRCUMFERENTIAL BENDING STRESS AT HORN OF SADDLE

K3 = 0.031
Compressive Stress at Horn = 2.84 MPa
Allowable Bending Stress = 169.65 MPa

K3(for edge of wear plate) = 0.036
Compressive Stress at Saddle Edge = 3.14 MPa

EXTERNAL LOADS

Zick provides a simplified analysis for external loads which assumes
that if a horizontal vessel is designed for an external pressure of
1 psi that it will successfully resist wind and other external
loads encountered in normal service. The approximate length between
stiffeners required by ASME Section VIII is approximated by the
equation: ((12)E/(52.2))(sqt(rt)(t/r)**2)

Required unstiffened length = 305588.250 mm.
Available length = 6816.425 mm.

RING COMPRESSION IN SHELL OVER SADDLE MIDDLE

The vertical compressive stress at the bottom point of shell
contact with the saddle is 0.81 MPa This value
is less than Zick's recommended allowed value of 64.10 MPa.

WEAR PLATE DIMENSION CHECK

The wear plate provided does not sweep out a large enough
angle under the saddle. ..... EXCEED

The distance from the edge of the saddle to the edge of the
wear plate was only -2.759 mm., and needed to be
at least 4.927 mm..

HORIZONTAL SEPARATION FORCE ON SADDLE

Force separating Saddle = 133.81 N
Equivalent Stress = 2.72 MPa
Zick Allowable Stress = 75.40 MPa

PRESSURE STIFFENING ADJUSTMENT

Pressure in this problem will likely have some effect on
stresses and displacements. A first order approximation of
the effect is given below:

Pressure may reduce elastic calc'd displacements by: 1.017.
Pressure may reduce elastic calc'd stresses by: 1.026.

-------- IN LINE ANCHOR LOAD CALCULATION -------------
THIS CALCULATION IS ONLY FOR THE CASE WHERE THE SADDLE
IS USED ON A PIPELINE. LENGTHS AND APPROACHES ARE
ADJUSTED FOR THIS PURPOSE.

Assumed Span Length = 2672.989 mm.
(length between saddles on pipe)

Equivalent Overhang Length = 1543.296 mm.

If this analysis is overstressed then stiffening rings are
probably needed at the anchor support locations.

PROBABLY NEED RINGS IF THIS IS AN INLINE ANCHOR DESIGN

LONGITUDINAL STRESSES

K1(at saddle) = 8.222
K1(at midspan) = -1.321

Longitudinal Membrane Stress = 92.987 MPa
(At saddle)

Longitudinal Membrane Stress = 14.942 MPa
(At midspan)

S(long) + PD/4t < (Sallow)(eff)
At Saddle:
(92.99+5.62) < (113.10)(1.000)
98.61 < 113.10

At Midspan:
(14.94+5.62) < (113.10)(1.000)
20.56 < 113.10

TANGENTIAL SHEAR STRESS

K2 = 0.786
K2w = 0.637 (K2 used for evaluation at equator for wear plate.)

Max Shear Stress = -0.31 MPa
(Stress in shell and wear plate combined.)

Max Shear @equator = -0.25 MPa
(Required for wear plate. This stress in shell only.)

-0.31 < 90.48

CIRCUMFERENTIAL BENDING STRESS AT HORN OF SADDLE

K3 = 0.031
Compressive Stress at Horn = 2.19 MPa
Allowable Bending Stress = 169.65 MPa

K3(for edge of wear plate) = 0.036

```
Compressive Stress at Saddle Edge =       2.42 MPa

EXTERNAL LOADS
--------------

Zick provides a simplified analysis for external loads which assumes
that if a horizontal vessel is designed for an external pressure of
1 psi  that it will successfully resist wind and other external
loads encountered in normal service.  The approximate length between
stiffeners required by ASME Section VIII is approximated by the
equation: ((12)E/(52.2))(sqt(rt)(t/r)**2 )

Required unstiffened length = 305588.250 mm.
Available length            =   2689.414 mm.

RING COMPRESSION IN SHELL OVER SADDLE MIDDLE
--------------------------------------------

The vertical compressive stress at the bottom point of shell
contact with the saddle is 0.62 MPa  This value
is less than Zick's recommended allowed value of 64.10 MPa.

HORIZONTAL SEPARATION FORCE ON SADDLE
-------------------------------------

Force separating Saddle   =     103.20  N
Equivalent Stress         =       2.09 MPa
Zick Allowable Stress     =      75.40 MPa
```

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```
Load Case Report
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            4:40pm   DEC 25,2024



Load Case Report                                          $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   5  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY    (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.

      /-------- Loads in Case   1
        Loads due to Weight

  2   SUSTAINED      (Wgt+Pr)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.

      /-------- Loads in Case   2
```

```
      Loads due to Weight
      Pressure Case    1

3   Thermal ONLY

    Thermal ONLY case run in the event expansion
    stresses exceed the secondary stress allowable.

    /-------- Loads in Case   3
      Temperature Case    1
      Loads from (Thermal Only)

4   OPERATING

    Case run to compute the operating stresses used in
    secondary, peak and range calculations as needed.

    /-------- Loads in Case   4
      Pressure Case    1
      Temperature Case    1
      Loads from (Operating)

5   RANGE          (Fatigue Calc Performed)

    Case run to get the RANGE of stresses.
    as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

    /-------- Combinations in Range Case   5
      Plus  Stress Results from CASE   4
      Minus Stress Results from CASE   1
```

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```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            4:41pm   DEC 25,2024



Solution Data


Maximum Solution Row Size =    1746
Number of Nodes           =   17164
Number of Elements        =    5724
Number of Solution Cases  =       4

Summation of Loads per Case

Case #               FX                FY                FZ

   1                 0.              -726.               0.
   2                 0.             -1230.               0.
   3                 0.                 0.               0.
   4                 0.             -1230.               0.
```

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ASME Code Stress Output Plots
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 4:42pm DEC 25,2024

ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 4

7) Pl+Pb+Q < SPS (OPE,Outside) Case 4

8) Membrane < User (OPE,Membrane) Case 4

9) Bending < User (OPE,Bending) Case 4

10) Pl+Pb+Q < SPS (EXP,Inside) Case 5

11) Pl+Pb+Q < SPS (EXP,Outside) Case 5

12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5

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Stress Results - Notes
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 4:42pm DEC 25,2024

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 1.000000
  Range cases use operating pressure. Primary cases

use design pressure.

- Assume free end displacements of attached pipe
  (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities
  are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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ASME Overstressed Areas
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 4:42pm DEC 25,2024

ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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Highest Primary Stress Ratios
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 4:42pm DEC 25,2024

Highest Primary Stress Ratios $X

Circ Plate for Plate # 1

Pl	SPL	Primary Membrane Load Case 2
5	181	Min Prin. Stress = -2. (77% Neg, 60% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
2%		

Long Plate for Plate # 1

Pl	SPL	Primary Membrane Load Case 2

```
        5            181     Min Prin. Stress = -1. (95% Neg, 94% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             2%

Cylindrical Shell

       Pl            SPL     Primary Membrane Load Case 2
       28            170     Min Prin. Stress = -21. (33% Neg, 24% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            16%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            4:42pm   DEC 25,2024



Highest Secondary Stress Ratios                          $X

In combination case  5 the max range stress divided
by the max component stress is 1.08. The case tensor components
are in some directions additive and so the combination
case will have HIGHER stresses than the largest of any
of the individual cases by between 1 and 50%.

Load      Combined/Max       Combined/Max
Case        (Inside)           (Outside)
------    -------------      -------------
   5         1.075              1.068


Circ Plate for Plate # 1

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 5
      281            387     Min Prin. Stress = -169. (96% Neg, 84% NegHi)
      MPa            MPa     Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            72%


Long Plate for Plate # 1

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 5
      225            387     Min Prin. Stress = -65. (95% Neg, 92% NegHi)
      MPa            MPa     Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            58%


Cylindrical Shell

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 5
      203            342     Min Prin. Stress = -83. (52% Neg, 37% NegHi)
      MPa            MPa     Plot Reference:
```

11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
59%

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Highest Fatigue Stress Ratios
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 4:42pm DEC 25,2024

Highest Fatigue Stress Ratios $X

Circ Plate for Plate # 1

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 5
281	0.085 Life	Stress Concentration Factor = 1.000
MPa	0.485 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 82,600.
Allowable		"B31" Fatigue Stress Allowable = 541.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 549,606.
		WRC 474 99% Probability Cycles = 127,679.
48%		WRC 474 95% Probability Cycles = 177,266.
		BS5500 Allowed Cycles(Curve F) = 31,034.
		Membrane-to-Bending Ratio = 2.112
		Bending-to-PL+PB+Q Ratio = 0.321
		Plot Reference:
		13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5

Long Plate for Plate # 1

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 5
225	0.036 Life	Stress Concentration Factor = 1.000
MPa	0.388 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 195,152.
Allowable		"B31" Fatigue Stress Allowable = 541.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 1,082,326.
		WRC 474 99% Probability Cycles = 251,434.
38%		WRC 474 95% Probability Cycles = 349,085.
		BS5500 Allowed Cycles(Curve F) = 60,788.
		Membrane-to-Bending Ratio = 5.461
		Bending-to-PL+PB+Q Ratio = 0.155
		Plot Reference:
		12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Cylindrical Shell

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 5
203	0.001 Life	Stress Concentration Factor = 1.000
MPa	0.249 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 5,322,214.
Allowable		"B31" Fatigue Stress Allowable = 570.5
816.1		Markl Fatigue Stress Allowable = 659.5
MPa		WRC 474 Mean Cycles to Failure = 1,412,371.

```
      24%                 WRC 474 99% Probability Cycles = 328,107.
                          WRC 474 95% Probability Cycles = 455,535.
                          BS5500 Allowed Cycles(Curve F) = 92,541.
                          Membrane-to-Bending Ratio = 0.650
                          Bending-to-PL+PB+Q Ratio = 0.606
                          Plot Reference:
                          13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5
```

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```
Highest Stress Ratios Per Region
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            4:42pm   DEC 25,2024



Highest Stress Ratios Per Region                          $X


Circ Plate for Plate # 1

       Pl            SPL     Primary Membrane Load Case 2
        5            181     Min Prin. Stress = -2. (77% Neg, 60% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             2%

       Qb            SPS     Primary Bending Load Case 2
        2            387     Min Prin. Stress = -2. (77% Neg, 60% NegHi)
      MPa            MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             0%

   Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
        6            387     Min Prin. Stress = -2. (77% Neg, 60% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             1%

   Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
        5            387     Min Prin. Stress = -2. (77% Neg, 60% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             1%

  S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
        9            433     Min Prin. Stress = -2. (77% Neg, 60% NegHi)
      MPa            MPa     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             2%

   Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
      258            387     Min Prin. Stress = -169. (96% Neg, 85% NegHi)
      MPa            MPa     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            66%

   Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
      281            387     Min Prin. Stress = -169. (96% Neg, 85% NegHi)
```

```
      MPa              MPa      Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
             72%

 Membrane              User     Component Evaluation Load Case 4
      229              387      Min Prin. Stress = -169. (96% Neg, 85% NegHi)
      MPa              MPa      Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 4
             59%

  Bending              User     Component Evaluation Load Case 4
      226              387      Min Prin. Stress = -169. (96% Neg, 85% NegHi)
      MPa              MPa      Plot Reference:
                                9) Bending < User (OPE,Bending) Case 4
             58%

   Pl+Pb+Q              SPS     Primary+Secondary (Inner) Load Case 5
      258              387      Min Prin. Stress = -169. (96% Neg, 84% NegHi)
      MPa              MPa      Plot Reference:
                                10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
             66%

   Pl+Pb+Q              SPS     Primary+Secondary (Outer) Load Case 5
      281              387      Min Prin. Stress = -169. (96% Neg, 84% NegHi)
      MPa              MPa      Plot Reference:
                                11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
             72%

 Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 5
      258     0.059 Life        Stress Concentration Factor = 1.000
      MPa     0.445 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 118,587.
Allowable                       "B31" Fatigue Stress Allowable = 541.5
    579.9                       Markl Fatigue Stress Allowable = 575.0
      MPa                       WRC 474 Mean Cycles to Failure = 730,838.
                                WRC 474 99% Probability Cycles = 169,780.
      44%                       WRC 474 95% Probability Cycles = 235,719.
                                BS5500 Allowed Cycles(Curve F) = 40,151.
                                Membrane-to-Bending Ratio = 1.524
                                Bending-to-PL+PB+Q Ratio = 0.396
                                Plot Reference:
                                12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

 Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 5
      281     0.085 Life        Stress Concentration Factor = 1.000
      MPa     0.485 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 82,600.
Allowable                       "B31" Fatigue Stress Allowable = 541.5
    579.9                       Markl Fatigue Stress Allowable = 575.0
      MPa                       WRC 474 Mean Cycles to Failure = 549,606.
                                WRC 474 99% Probability Cycles = 127,679.
      48%                       WRC 474 95% Probability Cycles = 177,266.
                                BS5500 Allowed Cycles(Curve F) = 31,034.
                                Membrane-to-Bending Ratio = 2.112
                                Bending-to-PL+PB+Q Ratio = 0.321
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate for Plate # 1

       Pl              SPL      Primary Membrane Load Case 2
        5              181      Min Prin. Stress = -1. (95% Neg, 94% NegHi)
      MPa              MPa      Plot Reference:
```

```
                                1) Pl < SPL (SUS,Membrane) Case 2
          2%

        Qb              SPS     Primary Bending Load Case 2
         1              387     Min Prin. Stress = -1. (95% Neg, 94% NegHi)
       MPa              MPa     Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 2
          0%

    Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 2
         5              387     Min Prin. Stress = -1. (95% Neg, 94% NegHi)
       MPa              MPa     Plot Reference:
                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
          1%

    Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 2
         4              387     Min Prin. Stress = -1. (95% Neg, 94% NegHi)
       MPa              MPa     Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
          1%

   S1+S2+S3             4S     Part 5 (5.3.2) Load Case 2
         9              433     Min Prin. Stress = -1. (95% Neg, 94% NegHi)
       MPa              MPa     Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
          2%

    Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 4
       225              387     Min Prin. Stress = -65. (95% Neg, 92% NegHi)
       MPa              MPa     Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
         58%

    Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 4
       225              387     Min Prin. Stress = -65. (95% Neg, 92% NegHi)
       MPa              MPa     Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
         58%

  Membrane             User     Component Evaluation Load Case 4
       219              387     Min Prin. Stress = -65. (95% Neg, 92% NegHi)
       MPa              MPa     Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 4
         56%

   Bending             User     Component Evaluation Load Case 4
        73              387     Min Prin. Stress = -65. (95% Neg, 92% NegHi)
       MPa              MPa     Plot Reference:
                                9) Bending < User (OPE,Bending) Case 4
         18%

    Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 5
       225              387     Min Prin. Stress = -65. (95% Neg, 92% NegHi)
       MPa              MPa     Plot Reference:
                                10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
         58%

    Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 5
       225              387     Min Prin. Stress = -65. (95% Neg, 92% NegHi)
       MPa              MPa     Plot Reference:
                                11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
         58%

  Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
```

```
      225      0.036 Life      Stress Concentration Factor = 1.000
      MPa      0.388 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 195,152.
Allowable                      "B31" Fatigue Stress Allowable = 541.5
    579.9                      Markl Fatigue Stress Allowable = 575.0
      MPa                      WRC 474 Mean Cycles to Failure = 1,082,326.
                               WRC 474 99% Probability Cycles = 251,434.
      38%                      WRC 474 95% Probability Cycles = 349,085.
                               BS5500 Allowed Cycles(Curve F) = 60,788.
                               Membrane-to-Bending Ratio = 5.461
                               Bending-to-PL+PB+Q Ratio = 0.155
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 5
      225      0.036 Life      Stress Concentration Factor = 1.000
      MPa      0.388 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 195,156.
Allowable                      "B31" Fatigue Stress Allowable = 541.5
    579.9                      Markl Fatigue Stress Allowable = 575.0
      MPa                      WRC 474 Mean Cycles to Failure = 1,082,346.
                               WRC 474 99% Probability Cycles = 251,439.
      38%                      WRC 474 95% Probability Cycles = 349,091.
                               BS5500 Allowed Cycles(Curve F) = 60,789.
                               Membrane-to-Bending Ratio = 5.461
                               Bending-to-PL+PB+Q Ratio = 0.155
                               Plot Reference:
                               13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Cylindrical Shell

       Pl            SPL     Primary Membrane Load Case 2
       28            170     Min Prin. Stress = -21. (33% Neg, 24% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             16%

       Qb            SPS     Primary Bending Load Case 2
        3            342     Min Prin. Stress = -21. (33% Neg, 24% NegHi)
      MPa            MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
              0%

   Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
       27            342     Min Prin. Stress = -21. (33% Neg, 24% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
              7%

   Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
       29            342     Min Prin. Stress = -21. (33% Neg, 24% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
              8%

  S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
       42            452     Min Prin. Stress = -21. (33% Neg, 24% NegHi)
      MPa            MPa     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
              9%

   Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
      116            342     Min Prin. Stress = -83. (52% Neg, 37% NegHi)
```

```
      MPa              MPa     Plot Reference:
                               6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
              33%

   Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 4
      203              342     Min Prin. Stress = -83. (52% Neg, 37% NegHi)
      MPa              MPa     Plot Reference:
                               7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
              59%

  Membrane             User    Component Evaluation Load Case 4
        90             342     Min Prin. Stress = -83. (52% Neg, 37% NegHi)
      MPa              MPa     Plot Reference:
                               8) Membrane < User (OPE,Membrane) Case 4
              26%

   Bending             User    Component Evaluation Load Case 4
       138             342     Min Prin. Stress = -83. (52% Neg, 37% NegHi)
      MPa              MPa     Plot Reference:
                               9) Bending < User (OPE,Bending) Case 4
              40%

   Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 5
      116              342     Min Prin. Stress = -83. (52% Neg, 37% NegHi)
      MPa              MPa     Plot Reference:
                               10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
              33%

   Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 5
      203              342     Min Prin. Stress = -83. (52% Neg, 37% NegHi)
      MPa              MPa     Plot Reference:
                               11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
              59%

 Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
      116      0.000 Life      Stress Concentration Factor = 1.000
      MPa      0.142 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
 Allowable                     "B31" Fatigue Stress Allowable = 570.5
    816.1                      Markl Fatigue Stress Allowable = 659.5
      MPa                      WRC 474 Mean Cycles to Failure = 11,817,073.
                               WRC 474 99% Probability Cycles = 2,745,210.
       14%                     WRC 474 95% Probability Cycles = 3,811,380.
                               BS5500 Allowed Cycles(Curve F) = 498,157.
                               Membrane-to-Bending Ratio = 0.650
                               Bending-to-PL+PB+Q Ratio = 0.606
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

 Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 5
      203      0.001 Life      Stress Concentration Factor = 1.000
      MPa      0.249 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 5,322,214.
 Allowable                     "B31" Fatigue Stress Allowable = 570.5
    816.1                      Markl Fatigue Stress Allowable = 659.5
      MPa                      WRC 474 Mean Cycles to Failure = 1,412,371.
                               WRC 474 99% Probability Cycles = 328,107.
       24%                     WRC 474 95% Probability Cycles = 455,535.
                               BS5500 Allowed Cycles(Curve F) = 92,541.
                               Membrane-to-Bending Ratio = 0.650
                               Bending-to-PL+PB+Q Ratio = 0.606
                               Plot Reference:
                               13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5
```

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```
Compressive Stress Summary
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             4:42pm   DEC 25,2024



Compressive Stress Summary (MPa)                        $X

Nomenclature:
-------------
Min Stress       - Compressive Membrane and Bending Stress
Pts in Region    - No. of nodes in the model region
>5% Compression  - 5% or more of Compressive Stress Limit
>50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section
slenderness ratio (elastic buckling) not considered.
                                              >5%    >50%
                         Min        Pts      Compression
 #  Load Type  Case     Stress    in Region   and Bending    Region
--  ---------  ----     ------   ----------  ------------  ----------------
 1  SUSTAINED    2        -21.      35664       33%    24%  Cylindrical Shell
 2  OPERATING    4        -83.      35664       52%    37%  Cylindrical Shell
 3  EXPANSION    5        -83.      35664       52%    37%  Cylindrical Shell
 4  SUSTAINED    2         -2.       8500       77%    60%  Circ Plate for Plate # 1
 5  OPERATING    4       -169.       8500       96%    85%  Circ Plate for Plate # 1

 6  EXPANSION    5       -169.       8500       96%    84%  Circ Plate for Plate # 1
 7  SUSTAINED    2         -1.       1288       95%    94%  Long Plate for Plate # 1
 8  OPERATING    4        -65.       1288       95%    92%  Long Plate for Plate # 1
 9  EXPANSION    5        -65.       1288       95%    92%  Long Plate for Plate # 1
```

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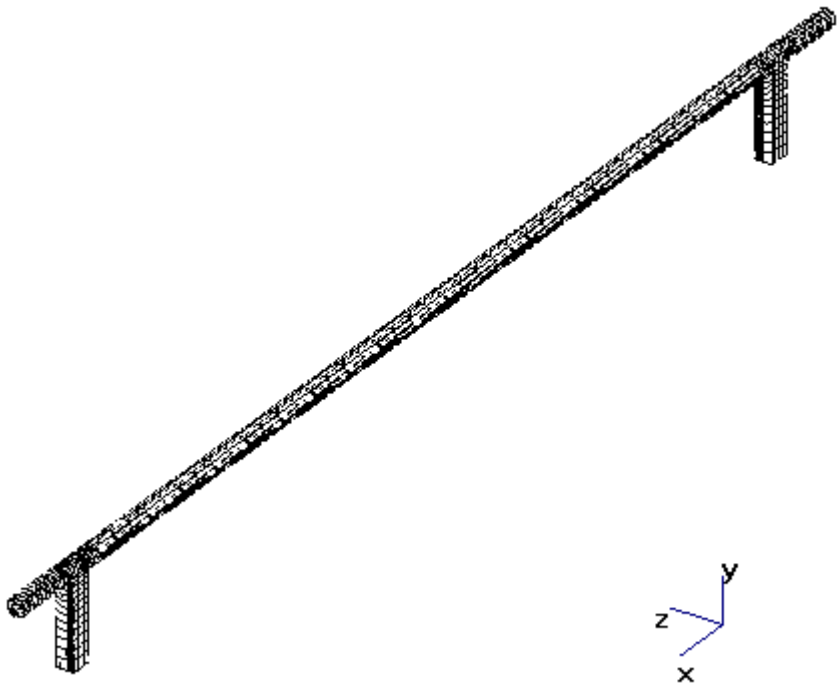
Finite Element Model

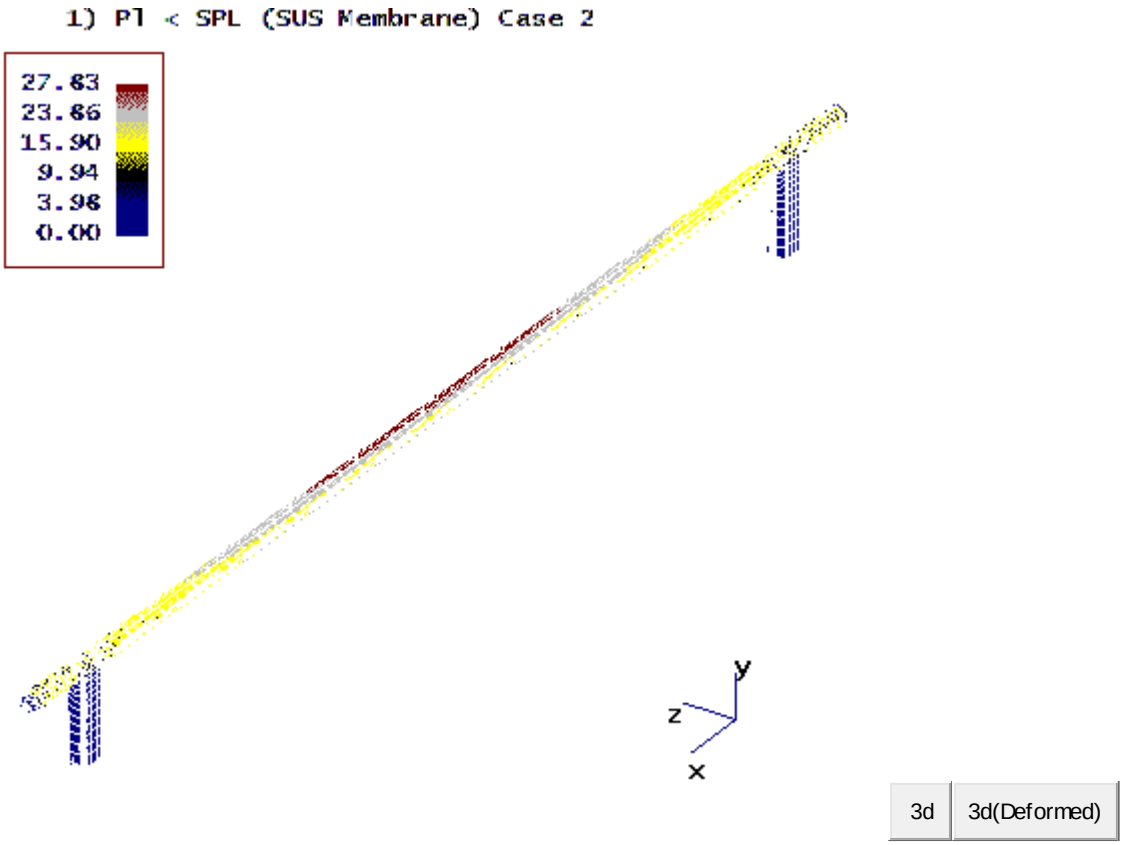
- Finite Element Model
- 1) Pl < SPL (SUS Membrane) Case 2
- 2) Qb < SPS (SUS Bending) Case 2
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 2
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 4
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 4
- 8) Membrane < User (OPE Membrane) Case 4
- 9) Bending < User (OPE Bending) Case 4
- 10) Pl+Pb+Q < SPS (EXP Inside) Case 5
- 11) Pl+Pb+Q < SPS (EXP Outside) Case 5
- 12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 5
- 13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 5

Finite Element Model



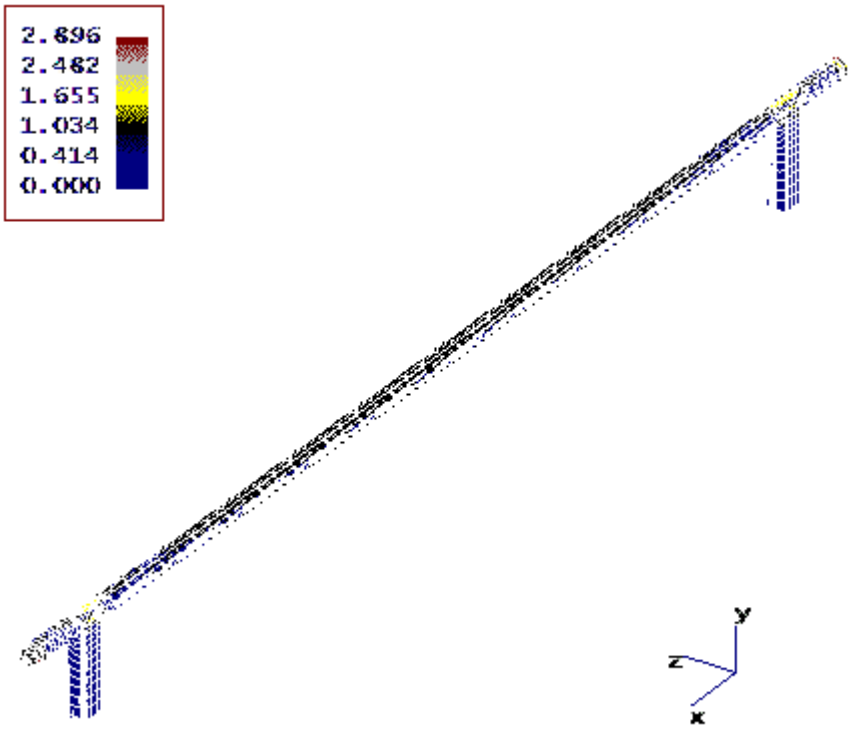
3d

-
-


1) Pl < SPL (SUS Membrane) Case 2
27.83
23.86
15.90
9.94
3.98
0.00
y
z
x
3d
3d(Deformed)

-
-

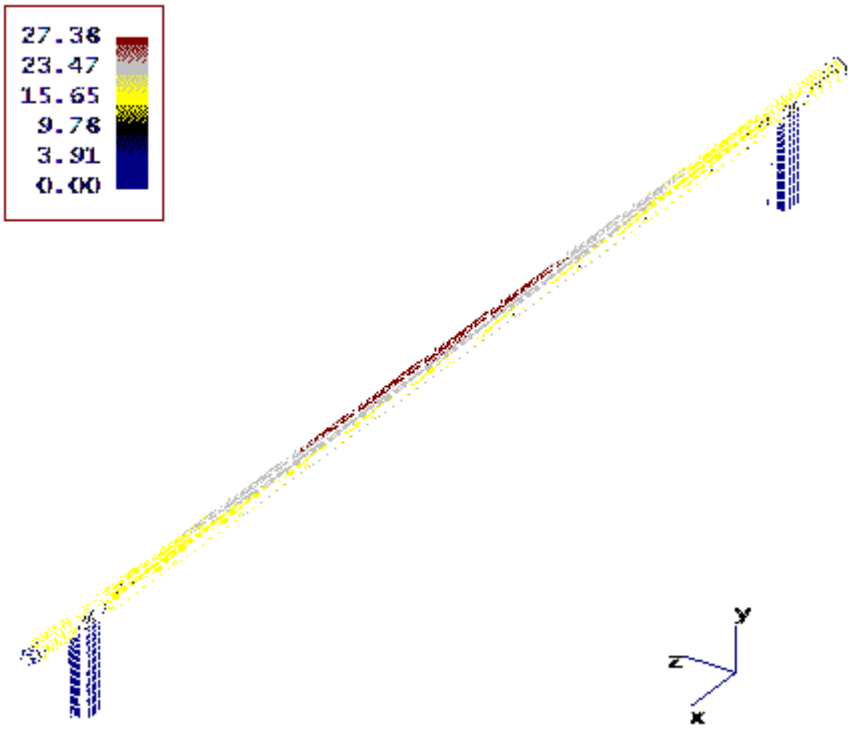
2) Qb < SPS (SUS Bending) Case 2



3d | 3d(Deformed)

-
-

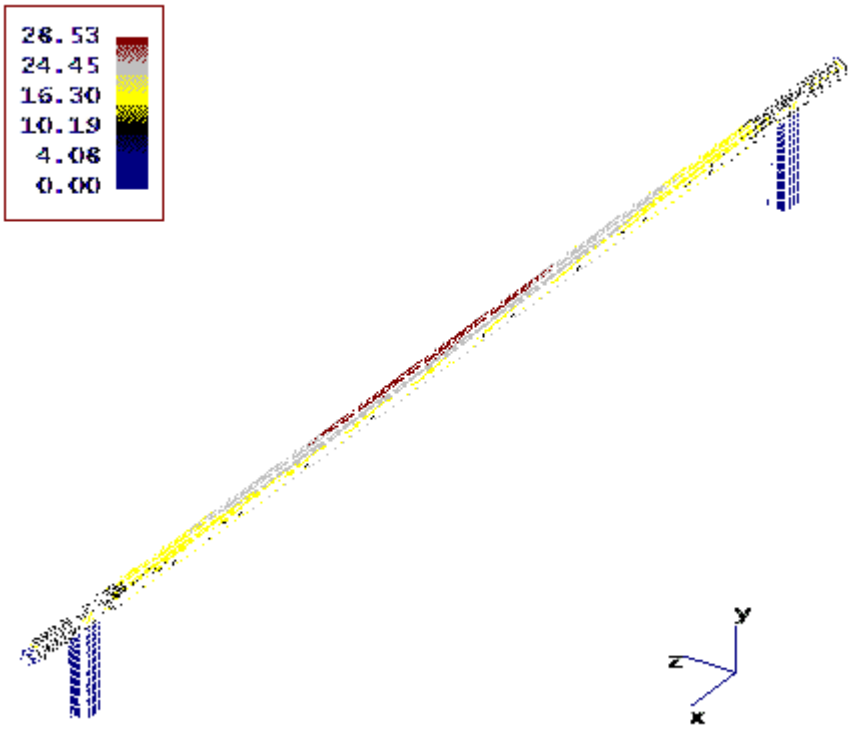
3) Pl+Pb+Q < SPS (SUS Inside) Case 2



3d | 3d(Deformed)

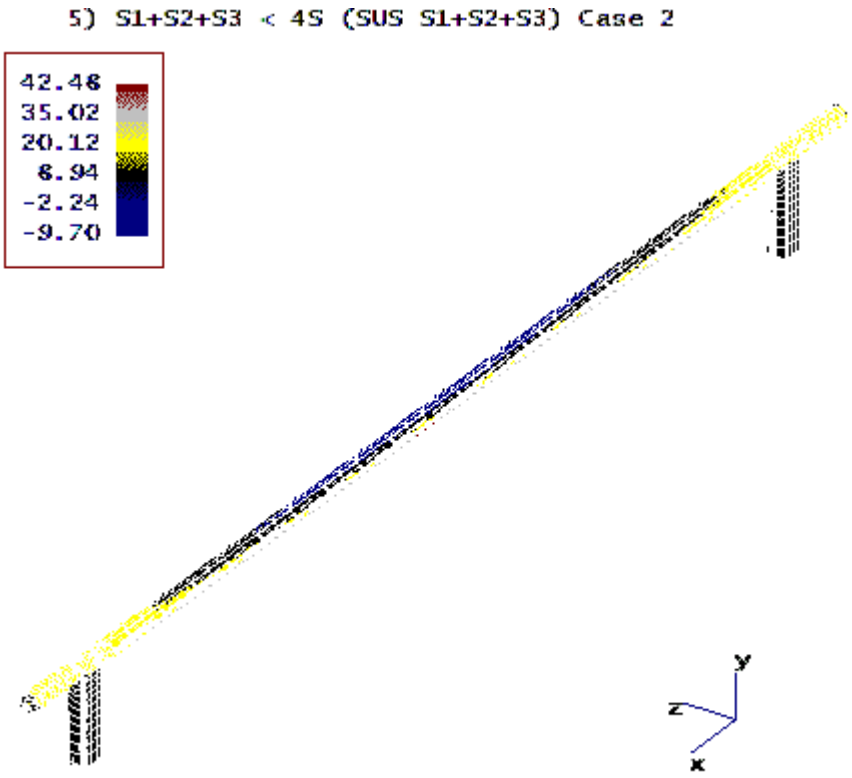
-
-

4) Pl+Pb+Q < SPS (SUS Outside) Case 2



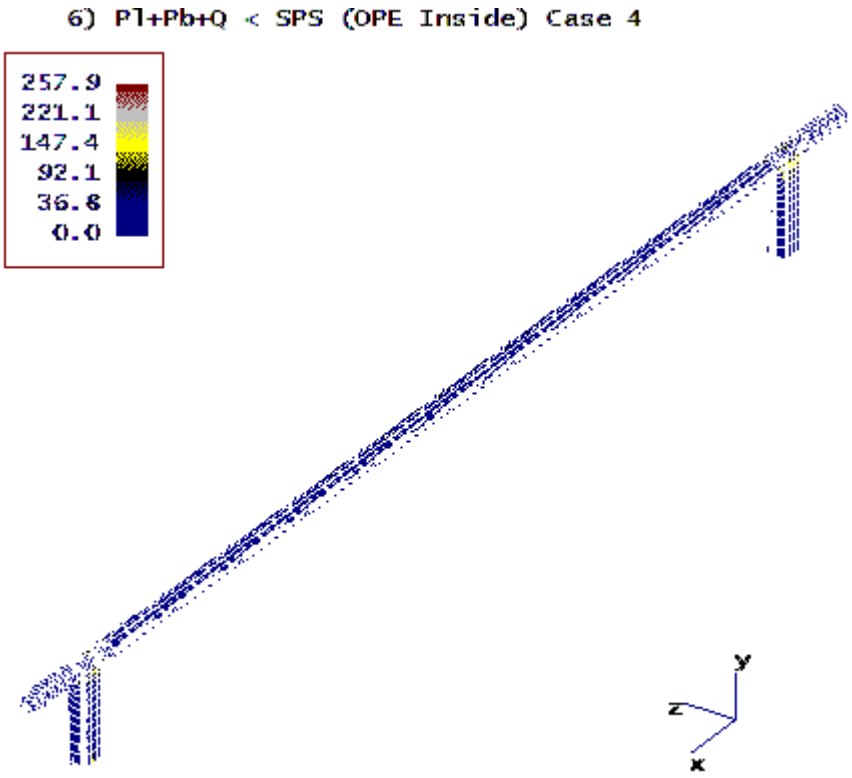
3d | 3d(Deformed)

-
-



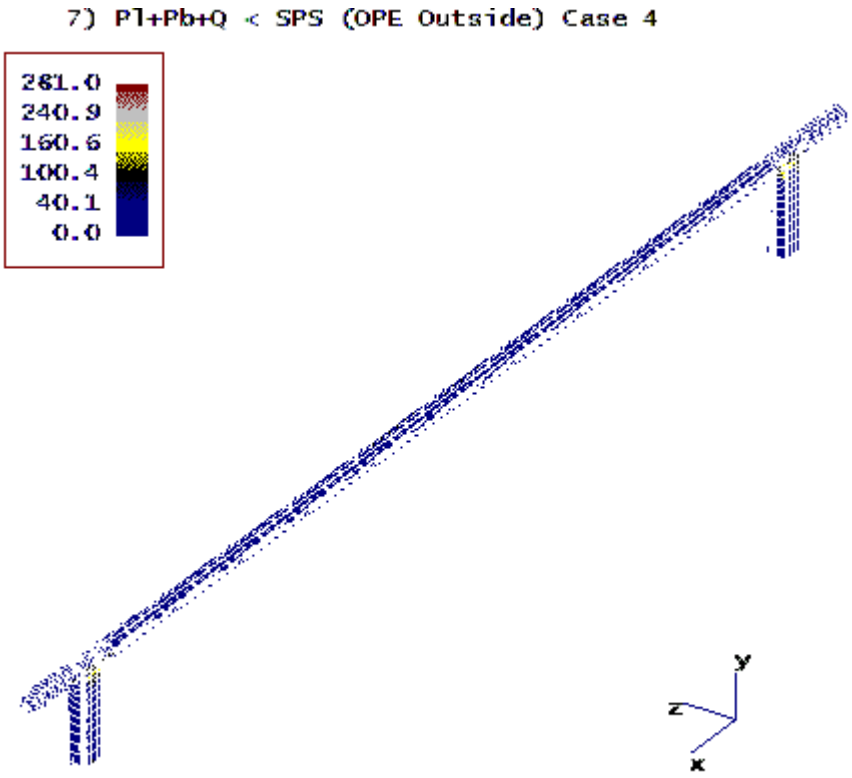
3d | 3d(Deformed)

-
-



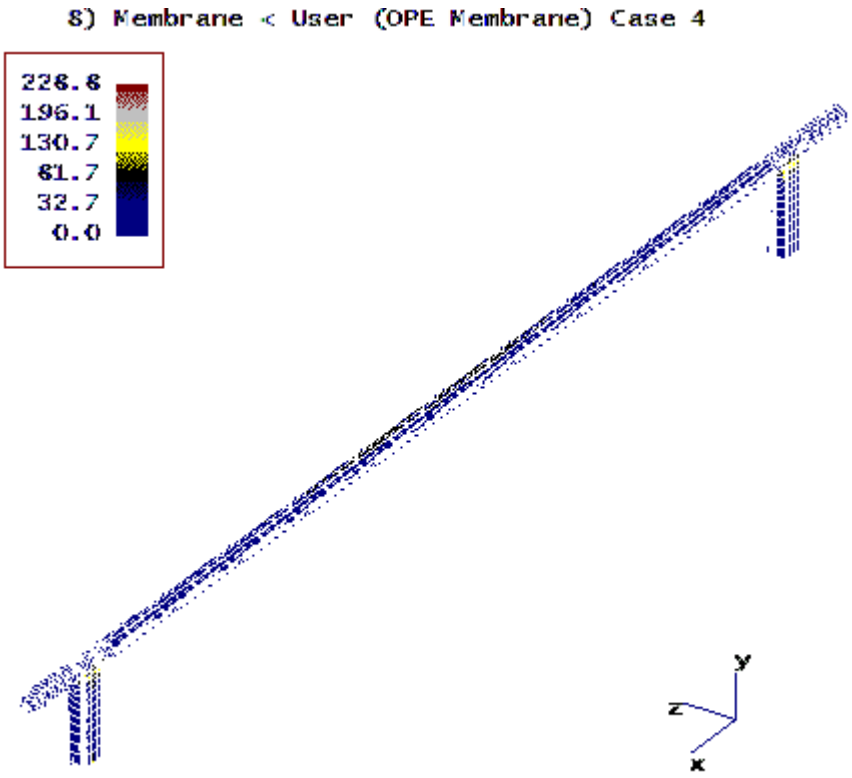
3d | 3d(Deformed)

-
-



3d | 3d(Deformed)

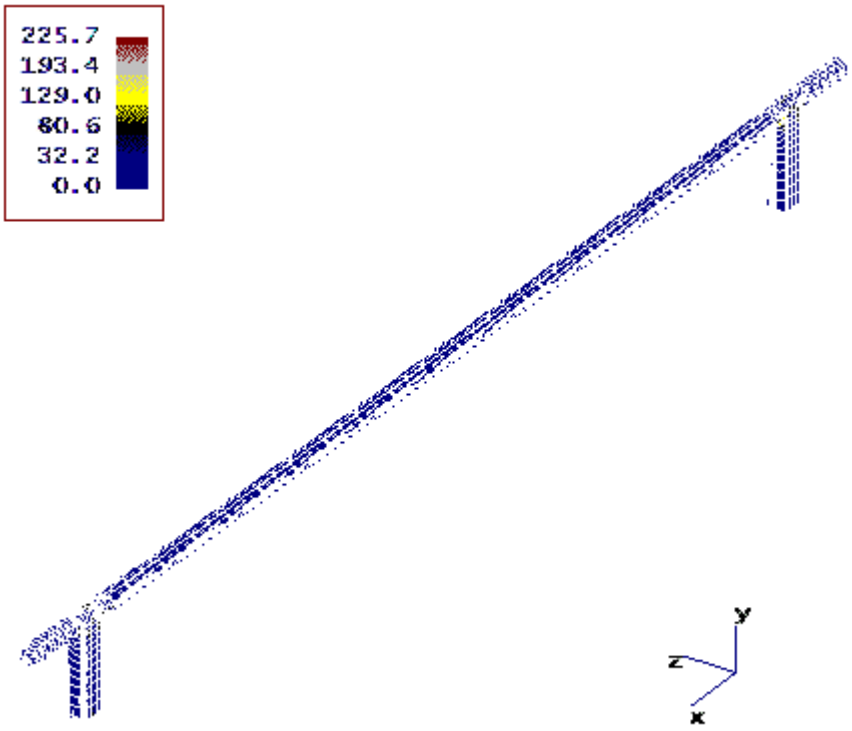
-
-



3d | 3d(Deformed)

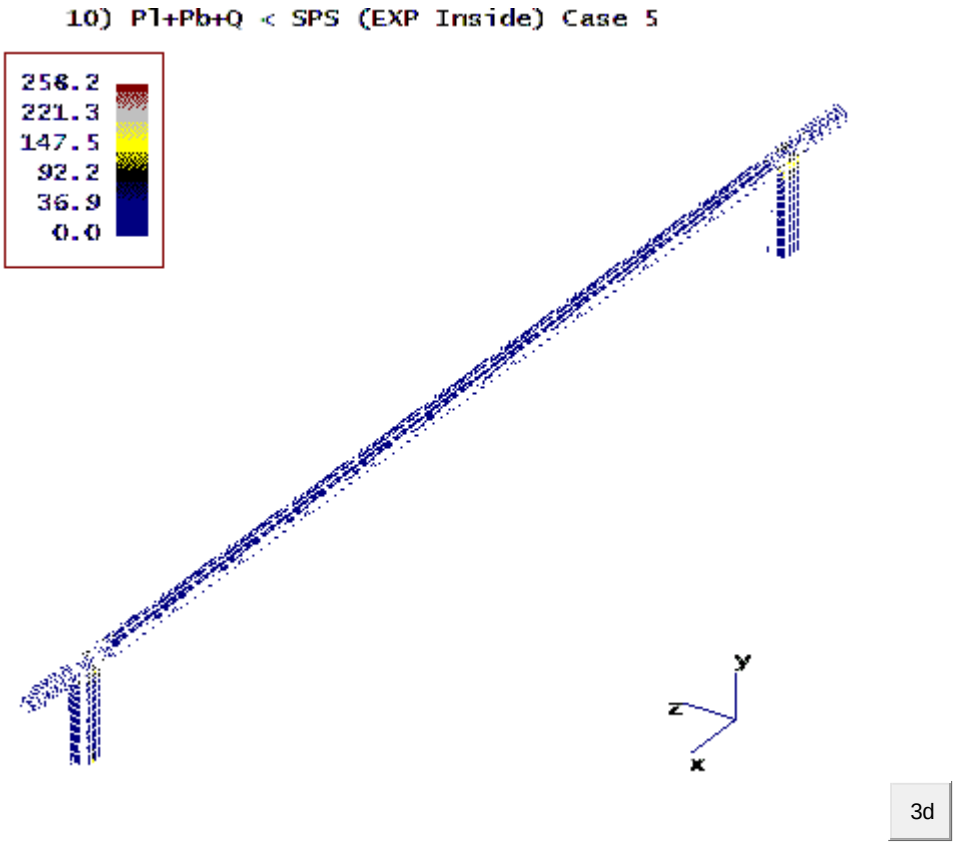
-
-

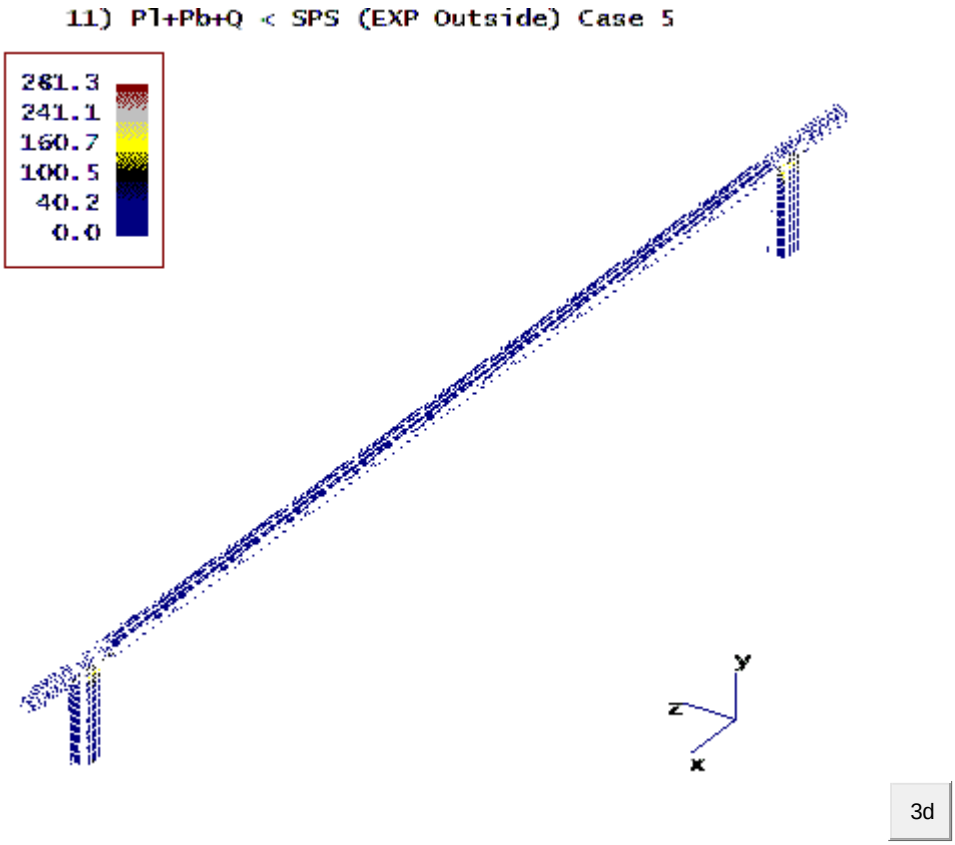
9) Bending < User (OPE Bending) Case 4



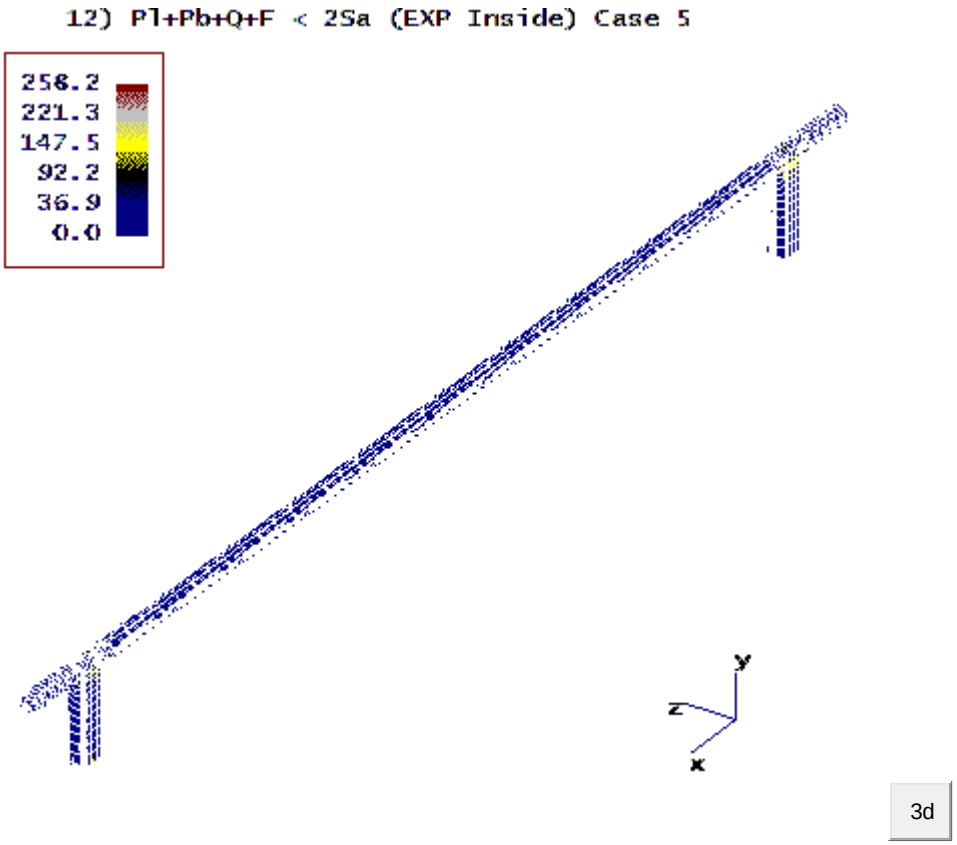
3d | 3d(Deformed)

-
-

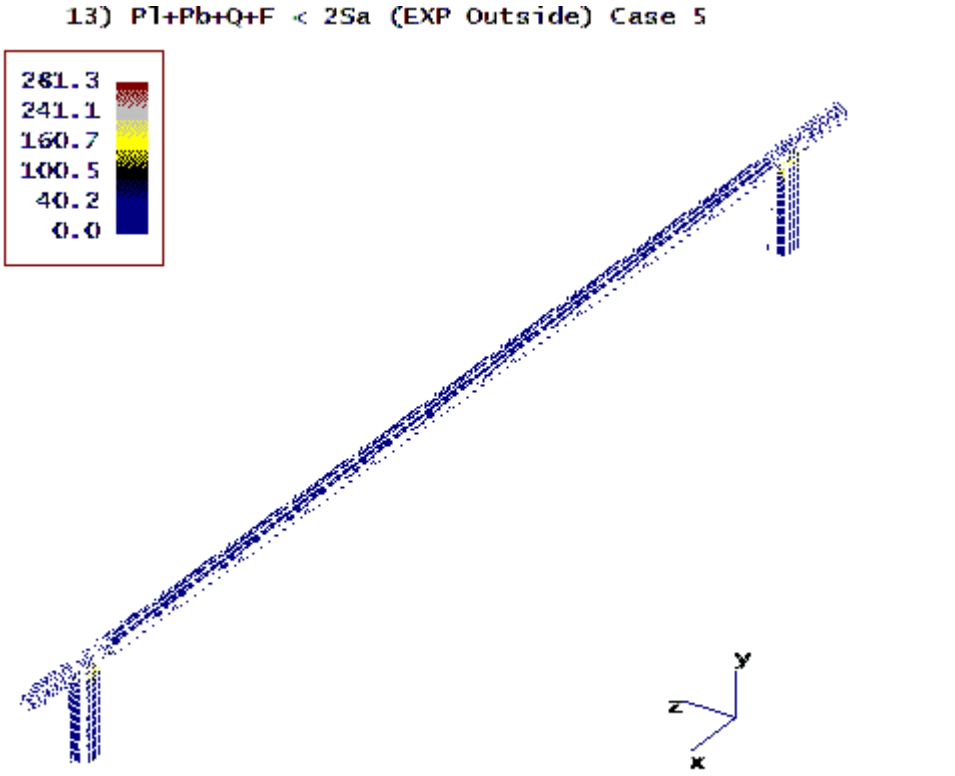

10) Pl+Pb+Q < SPS (EXP Inside) Case 5
258.2
221.3
147.5
92.2
36.9
0.0
Y
Z
X
3d


11) Pl+Pb+Q < SPS (EXP Outside) Case 5
261.3
241.1
160.7
100.5
40.2
0.0
Y
Z
X
3d

-
-


12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 5
258.2
221.3
147.5
92.2
36.9
0.0
Y
Z
X
3d

-
-


13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 5
261.3
241.1
160.7
100.5
40.2
0.0
Y
Z
X
3d

FEA Shell to Rear Junction

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Sun Dec 29 16:27:00 2024.

- Model Notes
- Load Case Report
- Solution Data
- ASME Code Stress Output Plots
- Stress Results - Notes
- ASME Overstressed Areas
- Highest Primary Stress Ratios
- Highest Secondary Stress Ratios
- Highest Fatigue Stress Ratios
- Highest Stress Ratios Per Region
- Stress Intensification Factors
- Allowable Loads
- Compressive Stress Summary
- Flexibilities
- Graphical Results

```
Model Notes
Model Notes

  Input Echo:

  Model Type                    : Flat Head

  Parent Geometry
        Parent Outside Diam.    :     597.000 mm.
        Thickness               :      42.000 mm.
        Attached Shell Length   :     179.100 mm.
        Attached Shell Thick    :       0.000 mm.

  Parent Properties:
        Cold Allowable          :       115.1 MPa
        Hot  Allowable          :        85.5 MPa
        Material DB # 1070822.
        Ultimate Tensile (Amb)  :       482.6 MPa
        Yield Strength (Amb)    :       172.4 MPa
        Yield Strength (Hot)    :       128.2 MPa
        Elastic Modulus (Amb)   :    195135.0 MPa
        Poissons Ratio          :       0.300
        Expansion Coefficient   :  0.1677E-04 mm./mm./deg.
        Weight Density          :  0.0000E+00  N /cu.mm.(NOT USED)
```

```
Nozzle Geometry
       Nozzle Outside Diam.    :     101.600 mm.
       Thickness               :       2.600 mm.
       Length                  :     300.000 mm.
       Location perpendicular
       to the head centerline  :     120.000 mm.

       Nozzle Tilt Angle       :       0.000 deg.

Nozzle Properties
       Cold Allowable          :       115.1 MPa
       Hot  Allowable          :       113.1 MPa
       Material DB # 1071622.
       Ultimate Tensile (Amb)  :       482.6 MPa
       Yield Strength (Amb)    :       172.4 MPa
       Yield Strength (Hot)    :       128.2 MPa
       Elastic Modulus (Amb)   :    195135.0 MPa
       Poissons Ratio          :       0.300
       Expansion Coefficient   :  0.1677E-04 mm./mm./deg.
       Weight Density          :  0.0000E+00  N /cu.mm. (NOT USED)

Design Operating Cycles        :       7000.
Ambient Temperature (Deg.)     :       21.10

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

Nozzle Inside  Temperature     :      165.00 deg.
Nozzle Outside Temperature     :      165.00 deg.
Vessel Inside  Temperature     :      165.00 deg.
Vessel Outside Temperature     :      165.00 deg.

Nozzle Pressure                :       0.750 MPa
Vessel Pressure                :       0.750 MPa

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces(  N )  Moments (N-m)

Load Case        FX          FY          FZ          MX          MY          MZ
-------------------------------------------------------------------------------
 WEIGHT:       667.0       667.0       667.0         0.0         0.0         0.0


FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces(  N )  Moments (N-m)

Load Case        FX          FY          FZ          MX          MY          MZ
-------------------------------------------------------------------------------
 WEIGHT:       667.0       667.0       667.0         0.0         0.0         0.0

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
```

realistic inside surface pressure stresses.

```
Vessel Centerline       Vector:  0.000   1.000   0.000
Nozzle Centerline       Vector:  0.000   1.000   0.000
Zero Degree Orientation Vector:  1.000   0.000   0.000
```

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```
Load Case Report
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            4:26pm   DEC 29,2024
```

```
Load Case Report                                          $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   9  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY    (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.

      /-------- Loads in Case   1
        Loads due to Weight

  2   SUSTAINED      (Wgt+Pr)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.

      /-------- Loads in Case   2
        Loads due to Weight
        Pressure Case    1

  3   OPERATING

      Case run to compute the operating stresses used in
      secondary, peak and range calculations as needed.

      /-------- Loads in Case   3
        Pressure Case    1
        Loads from (Operating)

  4   RANGE          (Fatigue Calc Performed)

      Case run to get the RANGE of stresses.
      as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

      /-------- Combinations in Range Case   4
        Plus  Stress Results from CASE   3
        Minus Stress Results from CASE   1

  5   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
```

```
     /-------- Loads in Case   5
       Loads from (Axial)

 6   Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   6
       Loads from (Inplane)

 7   Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   7
       Loads from (Outplane)

 8   Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   8
       Loads from (Torsion)

 9   Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case   9
       Pressure Case    1
```

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```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            4:26pm   DEC 29,2024



Solution Data


Maximum Solution Row Size =     780
Number of Nodes           =    2431
Number of Elements        =     818
Number of Solution Cases  =       8

Summation of Loads per Case

Case #               FX                  FY                  FZ

   1                667.                667.                667.
   2                667.             182108.                667.
   3                  0.             181441.                  0.
   4                  0.             111509.                  0.
   5                  0.                  0.                  0.
   6                  0.                  0.                  0.
   7                  0.                  0.                  0.
   8                  0.             181441.                  0.
```

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ASME Code Stress Output Plots
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 4:27pm DEC 29,2024

ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2
2) Qb < SPS (SUS,Bending) Case 2
3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
8) Membrane < User (OPE,Membrane) Case 3
9) Bending < User (OPE,Bending) Case 3
10) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5
11) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6
12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7
13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 8
14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 9
15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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Stress Results - Notes
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 4:27pm DEC 29,2024

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 1.000000
  Range cases use operating pressure. Primary cases use design pressure.

- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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ASME Overstressed Areas
FEPipe Version 15.0 Jobname: NOZZLE $P
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ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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Highest Primary Stress Ratios
FEPipe Version 15.0 Jobname: NOZZLE $P
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Highest Primary Stress Ratios $X

Shell Next to Nozzle 1

```
  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
       32            301     Min Prin. Stress = -8. (97% Neg, 78% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             10%
```

Nozzle 1 Next to Shell

```
       Pl            SPL     Primary Membrane Load Case 2
       35            170     Min Prin. Stress = -10. (75% Neg, 65% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             20%
```

Nozzle 1

```
       Pl            SPL     Primary Membrane Load Case 2
       24            170     Min Prin. Stress = -7. (45% Neg, 39% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             14%
```

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```
Highest Secondary Stress Ratios
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Highest Secondary Stress Ratios                          $X

In combination case  4 the max range stress divided
by the max component stress is 1.85. The case tensor components
are in some directions additive and so the combination
case will have HIGHER stresses than the largest of any
of the individual cases by more than 50%.

Load      Combined/Max       Combined/Max
Case        (Inside)           (Outside)
------    -------------      -------------
   4         1.487              1.853


Shell Next to Nozzle 1

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
       32            301     Min Prin. Stress = -8. (97% Neg, 78% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             10%


Nozzle 1 Next to Shell

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
       63            342     Min Prin. Stress = -10. (75% Neg, 65% NegHi)
```

```
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
           18%


Nozzle 1

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
       29            342     Min Prin. Stress = -7. (45% Neg, 39% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            8%
```

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```
Highest Fatigue Stress Ratios
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Highest Fatigue Stress Ratios                               $X


Shell Next to Nozzle 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
       38     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.046 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 501.5
    816.1                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 1.3163E8
                             WRC 474 99% Probability Cycles = 30,579,274.
       4%                    WRC 474 95% Probability Cycles = 42,455,476.
                             BS5500 Allowed Cycles(Curve F) = 38,043,364.
                             Membrane-to-Bending Ratio = 0.093
                             Bending-to-PL+PB+Q Ratio = 0.915
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1 Next to Shell

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       58     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.072 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 570.5
    816.1                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 1.9013E8
                             WRC 474 99% Probability Cycles = 44,169,812.
       7%                    WRC 474 95% Probability Cycles = 61,324,224.
                             BS5500 Allowed Cycles(Curve F) = 9,588,613.
                             Membrane-to-Bending Ratio = 1.261
                             Bending-to-PL+PB+Q Ratio = 0.442
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
```

Nozzle 1

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
25	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.030 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 570.5
816.1		Markl Fatigue Stress Allowable = 659.5
MPa		WRC 474 Mean Cycles to Failure = 1.0349E9
		WRC 474 99% Probability Cycles = 2.4042E8
3%		WRC 474 95% Probability Cycles = 3.3380E8
		BS5500 Allowed Cycles(Curve F) = 1.5501E8
		Membrane-to-Bending Ratio = 9.346
		Bending-to-PL+PB+Q Ratio = 0.097
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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Highest Stress Ratios Per Region
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Highest Stress Ratios Per Region $X

Shell Next to Nozzle 1

Pl	SPL	Primary Membrane Load Case 2
10	128	Min Prin. Stress = -8. (97% Neg, 78% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
7%		
Qb	SPS	Primary Bending Load Case 2
32	301	Min Prin. Stress = -8. (97% Neg, 78% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
10%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
32	301	Min Prin. Stress = -8. (97% Neg, 78% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
10%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
32	301	Min Prin. Stress = -8. (97% Neg, 78% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
10%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
5	342	Min Prin. Stress = -8. (97% Neg, 78% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

```
            1%

Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 3
     29          301     Min Prin. Stress = -6. (92% Neg, 75% NegHi)
    MPa          MPa     Plot Reference:
                         6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            9%

Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 3
     30          301     Min Prin. Stress = -6. (92% Neg, 75% NegHi)
    MPa          MPa     Plot Reference:
                         7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            9%

Membrane         User    Component Evaluation Load Case 3
      8          301     Min Prin. Stress = -6. (92% Neg, 75% NegHi)
    MPa          MPa     Plot Reference:
                         8) Membrane < User (OPE,Membrane) Case 3
            2%

Bending          User    Component Evaluation Load Case 3
     29          301     Min Prin. Stress = -6. (92% Neg, 75% NegHi)
    MPa          MPa     Plot Reference:
                         9) Bending < User (OPE,Bending) Case 3
            9%

Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 4
     27          301     Min Prin. Stress = -7. (97% Neg, 77% NegHi)
    MPa          MPa     Plot Reference:
                         15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            8%

Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 4
     28          301     Min Prin. Stress = -7. (97% Neg, 77% NegHi)
    MPa          MPa     Plot Reference:
                         16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            9%

Pl+Pb+Q+F   Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4
     36      0.000 Life  Stress Concentration Factor = 1.350
    MPa      0.044 Stress Strain Concentration Factor = 1.000
                         Cycles Allowed for this Stress = 1.0000E11
Allowable                "B31" Fatigue Stress Allowable = 501.5
  816.1                  Markl Fatigue Stress Allowable = 659.5
    MPa                  WRC 474 Mean Cycles to Failure = 1.5926E8
                         WRC 474 99% Probability Cycles = 36,997,868.
      4%                 WRC 474 95% Probability Cycles = 51,366,884.
                         BS5500 Allowed Cycles(Curve F) = 48,553,100.
                         Membrane-to-Bending Ratio = 0.093
                         Bending-to-PL+PB+Q Ratio = 0.915
                         Plot Reference:
                         17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F   Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
     38      0.000 Life  Stress Concentration Factor = 1.350
    MPa      0.046 Stress Strain Concentration Factor = 1.000
                         Cycles Allowed for this Stress = 1.0000E11
Allowable                "B31" Fatigue Stress Allowable = 501.5
  816.1                  Markl Fatigue Stress Allowable = 659.5
    MPa                  WRC 474 Mean Cycles to Failure = 1.3163E8
                         WRC 474 99% Probability Cycles = 30,579,274.
      4%                 WRC 474 95% Probability Cycles = 42,455,476.
                         BS5500 Allowed Cycles(Curve F) = 38,043,364.
                         Membrane-to-Bending Ratio = 0.093
```

Bending-to-PL+PB+Q Ratio = 0.915
Plot Reference:
18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Nozzle 1 Next to Shell

Pl	SPL	Primary Membrane Load Case 2
35	170	Min Prin. Stress = -10. (75% Neg, 65% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
20%		
Qb	SPS	Primary Bending Load Case 2
43	342	Min Prin. Stress = -10. (75% Neg, 65% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
12%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
49	342	Min Prin. Stress = -10. (75% Neg, 65% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
14%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
63	342	Min Prin. Stress = -10. (75% Neg, 65% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
18%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
58	452	Min Prin. Stress = -10. (75% Neg, 65% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
12%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
46	342	Min Prin. Stress = -9. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
13%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
42	342	Min Prin. Stress = -9. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
12%		
Membrane	User	Component Evaluation Load Case 3
30	342	Min Prin. Stress = -9. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
8%		
Bending	User	Component Evaluation Load Case 3
32	342	Min Prin. Stress = -9. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		9) Bending < User (OPE,Bending) Case 3
9%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
43	342	Min Prin. Stress = -14. (72% Neg, 68% NegHi)
MPa	MPa	Plot Reference:

15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
12%

Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 4
42		342	Min Prin. Stress = -14. (72% Neg, 68% NegHi)
MPa		MPa	Plot Reference:
			16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
12%			
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 4
58	0.000 Life		Stress Concentration Factor = 1.350
MPa	0.072 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 1.0000E11
Allowable			"B31" Fatigue Stress Allowable = 570.5
816.1			Markl Fatigue Stress Allowable = 659.5
MPa			WRC 474 Mean Cycles to Failure = 1.9013E8
			WRC 474 99% Probability Cycles = 44,169,812.
7%			WRC 474 95% Probability Cycles = 61,324,224.
			BS5500 Allowed Cycles(Curve F) = 9,588,613.
			Membrane-to-Bending Ratio = 1.261
			Bending-to-PL+PB+Q Ratio = 0.442
			Plot Reference:
			17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Outer) Load Case 4
57	0.000 Life		Stress Concentration Factor = 1.350
MPa	0.070 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 1.0000E11
Allowable			"B31" Fatigue Stress Allowable = 570.5
816.1			Markl Fatigue Stress Allowable = 659.5
MPa			WRC 474 Mean Cycles to Failure = 2.0585E8
			WRC 474 99% Probability Cycles = 47,820,560.
7%			WRC 474 95% Probability Cycles = 66,392,832.
			BS5500 Allowed Cycles(Curve F) = 10,497,510.
			Membrane-to-Bending Ratio = 0.987
			Bending-to-PL+PB+Q Ratio = 0.503
			Plot Reference:
			18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Nozzle 1

Pl		SPL	Primary Membrane Load Case 2
24		170	Min Prin. Stress = -7. (45% Neg, 39% NegHi)
MPa		MPa	Plot Reference:
			1) Pl < SPL (SUS,Membrane) Case 2
14%			
Qb		SPS	Primary Bending Load Case 2
11		342	Min Prin. Stress = -7. (45% Neg, 39% NegHi)
MPa		MPa	Plot Reference:
			2) Qb < SPS (SUS,Bending) Case 2
3%			
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 2
29		342	Min Prin. Stress = -7. (45% Neg, 39% NegHi)
MPa		MPa	Plot Reference:
			3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
8%			
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 2
21		342	Min Prin. Stress = -7. (45% Neg, 39% NegHi)
MPa		MPa	Plot Reference:
			4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

```
            6%

S1+S2+S3              4S      Part 5 (5.3.2) Load Case 2
      47             452      Min Prin. Stress = -7. (45% Neg, 39% NegHi)
     MPa             MPa      Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
           10%

  Pl+Pb+Q             SPS      Primary+Secondary (Inner) Load Case 3
      23             342      Min Prin. Stress = -2. (49% Neg, 48% NegHi)
     MPa             MPa      Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            6%

  Pl+Pb+Q             SPS      Primary+Secondary (Outer) Load Case 3
      21             342      Min Prin. Stress = -2. (49% Neg, 48% NegHi)
     MPa             MPa      Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            6%

 Membrane            User     Component Evaluation Load Case 3
      21             342      Min Prin. Stress = -2. (49% Neg, 48% NegHi)
     MPa             MPa      Plot Reference:
                              8) Membrane < User (OPE,Membrane) Case 3
            6%

  Bending             User     Component Evaluation Load Case 3
      10             342      Min Prin. Stress = -2. (49% Neg, 48% NegHi)
     MPa             MPa      Plot Reference:
                              9) Bending < User (OPE,Bending) Case 3
            2%

  Pl+Pb+Q             SPS      Primary+Secondary (Inner) Load Case 4
      24             342      Min Prin. Stress = -9. (57% Neg, 54% NegHi)
     MPa             MPa      Plot Reference:
                              15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            7%

  Pl+Pb+Q             SPS      Primary+Secondary (Outer) Load Case 4
      25             342      Min Prin. Stress = -9. (57% Neg, 54% NegHi)
     MPa             MPa      Plot Reference:
                              16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            7%

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 4
      24     0.000 Life       Stress Concentration Factor = 1.000
     MPa     0.029 Stress     Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 570.5
    816.1                     Markl Fatigue Stress Allowable = 659.5
     MPa                      WRC 474 Mean Cycles to Failure = 1.1354E9
                              WRC 474 99% Probability Cycles = 2.6376E8
       2%                     WRC 474 95% Probability Cycles = 3.6620E8
                              BS5500 Allowed Cycles(Curve F) = 1.7972E8
                              Membrane-to-Bending Ratio = 9.346
                              Bending-to-PL+PB+Q Ratio = 0.097
                              Plot Reference:
                              17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 4
      25     0.000 Life       Stress Concentration Factor = 1.000
     MPa     0.030 Stress     Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 570.5
```

```
   816.1                  Markl Fatigue Stress Allowable = 659.5
     MPa                  WRC 474 Mean Cycles to Failure = 1.0349E9
                          WRC 474 99% Probability Cycles = 2.4042E8
     3%                   WRC 474 95% Probability Cycles = 3.3380E8
                          BS5500 Allowed Cycles(Curve F) = 1.5501E8
                          Membrane-to-Bending Ratio = 9.346
                          Bending-to-PL+PB+Q Ratio = 0.097
                          Plot Reference:
                          18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
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```
Stress Intensification Factors
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Stress Intensification Factors                          $X


Branch/Nozzle Sif Summary

                   Peak      Primary    Secondary      SSI
Axial    :        1.338        1.041        1.981    1.069
Inplane :         1.045        1.008        1.548    1.015
Outplane:         1.031        1.003        1.527    1.007
Torsion :         0.589        0.849        0.873    0.767
Pressure:         5.822        5.660        8.626    1.500

The above stress intensification factors are to be used
in a beam-type analysis of the piping system.  Inplane,
Outplane and Torsional sif's should be used with the
matching branch pipe whose diameter and thickness is given
below.  The axial sif should be used to intensify the
axial stress in the branch pipe calculated by F/A.  The
pressure sif should be used to intensify the nominal
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :       101.600  mm.
Pipe Thk:         2.600  mm.
Z approx:     20013.971  cu.mm.
Z exact :     19515.252  cu.mm.

  (SSI = SIF^x)         Axial    Inpl    Outpl    Tors    Pres
SIF/SSI Exponents:      0.139    0.174    0.091    0.309    0.984

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =         4.347
      Header Pressure i-factor =        12.526

The B31.3 pressure i-factors should be used with with
F/A, where F is the axial force due to pressure, and
A is the area of the pipe wall. This is equivalent to
```

finding the pressure stress from (ip)(PD/4T).

```
B31.3    (Branch)
Peak Stress Sif ....     0.000         Axial
                         1.000         Inplane
                         1.000         Outplane
                         1.000         Torsional
B31.1   (Branch)
Peak Stress Sif ....     0.000         Axial
                         1.000         Inplane
                         1.000         Outplane
                         1.000         Torsional
WRC 330   (Branch)
Peak Stress Sif ....     0.000         Axial
                         1.000         Inplane
                         1.500         Outplane
                         1.000         Torsional
```

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```
Allowable Loads
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```

Allowable Loads $X

SECONDARY Load Type (Range):		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	139692.	40794.	61190.
Inplane Moment	(mm. N)	4313973.	890802.	1889676.
Outplane Moment	(mm. N)	4373326.	903058.	1915675.
Torsional Moment	(mm. N)	7654456.	2236839.	3355258.
Pressure	(MPa)	5.58	0.75	0.75

PRIMARY Load Type:		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	131762.	37948.	56921.
Inplane Moment	(mm. N)	3285432.	676514.	1435104.
Outplane Moment	(mm. N)	3301520.	679827.	1442131.
Torsional Moment	(mm. N)	3898932.	1068516.	1602773.
Pressure	(MPa)	4.22	0.75	0.75

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used

that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

6) High D/T low pressure systems may be subject to instability and should be checked when compressive stresses are present.

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Compressive Stress Summary
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Compressive Stress Summary (MPa) $X

Nomenclature:

Min Stress - Compressive Membrane and Bending Stress
Pts in Region - No. of nodes in the model region
>5% Compression - 5% or more of Compressive Stress Limit
>50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

#	Load Type	Case	Min Stress	Pts in Region	>5% Compression and Bending	>50% Compression and Bending	Region
1	SUSTAINED	2	-7.	1992	45%	39%	Nozzle 1
2	OPERATING	3	-2.	1992	49%	48%	Nozzle 1
3	EXPANSION	4	-9.	1992	57%	54%	Nozzle 1
4	SUSTAINED	2	-10.	120	75%	65%	Nozzle 1 Next to Shell
5	OPERATING	3	-9.	120	66%	62%	Nozzle 1 Next to Shell
6	EXPANSION	4	-14.	120	72%	68%	Nozzle 1 Next to Shell
7	SUSTAINED	2	-8.	960	97%	78%	Shell Next to Nozzle 1
8	OPERATING	3	-6.	960	92%	75%	Shell Next to Nozzle 1
9	EXPANSION	4	-7.	960	97%	77%	Shell Next to Nozzle 1

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Flexibilities
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Flexibilities $X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiff-nesses should be inserted at the surface of the branch/header or nozzle/vessel junction. The general characteristics used for the branch pipe should be:

Outside Diameter = 101.600 mm.
Wall Thickness = 2.600 mm.

Axial Translational Stiffness = 938130. N /mm.
Inplane Rotational Stiffness = 328225408. mm. N /deg
Outplane Rotational Stiffness = 408479328. mm. N /deg

The following stiffness(es) were not generated because of errors in input or because the finite element model is stiffer than the piping model.

Torsional Rotational Stiffness

Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (mm.) = 0.149 In-Plane (mm.) = 0.011 Out-Plane (mm.) = 0.009

PRIMARY
Axial (mm.) = 0.140 In-Plane (mm.) = 0.009 Out-Plane (mm.) = 0.007

Secondary Conservative Displacement = 0.048 mm.
Secondary Realistic Displacement = 0.074 mm.

Primary Conservative Displacement = 0.044 mm.
Primary Realistic Displacement = 0.068 mm.

Intersection Flexibility Factors for Branch/Nozzle
:

Find axial stiffness: K = 3EI/(kd)^3 N /mm.
Find bending and torsional stiffnesses: K = EI/(kd) mm. N per radian.
The EI product is 0.19332E+12 N mm.^2
The value of (d) to use is: 99.000 mm..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor (k) = 0.860
Inplane Flexibility Factor (k) = 0.104
Outplane Flexibility Factor (k) = 0.083

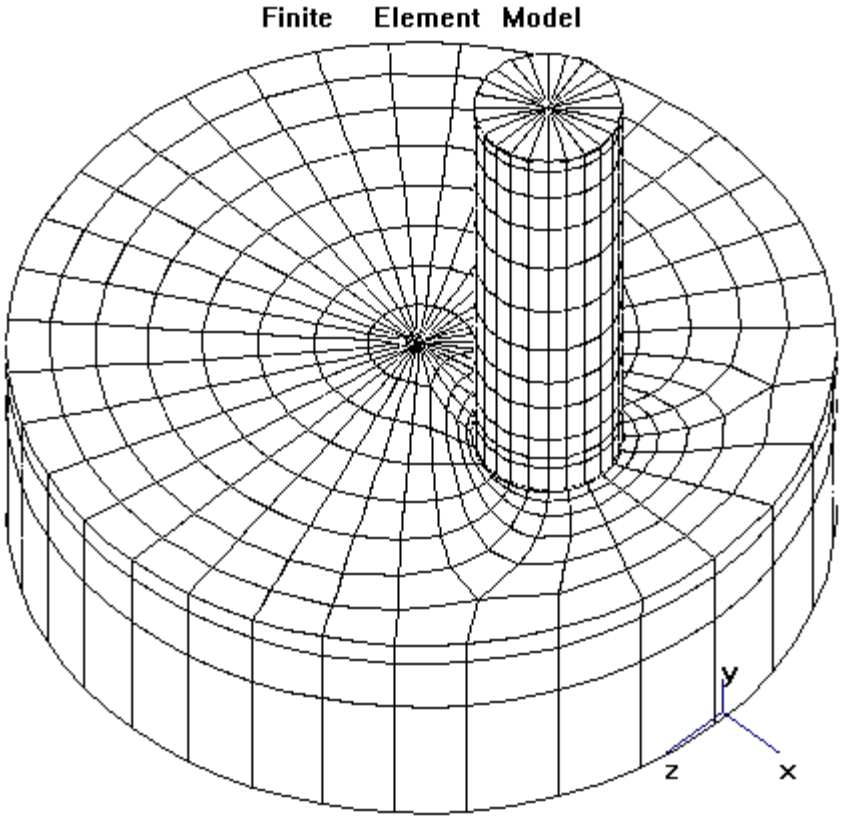
Table of Contents

Finite Element Model

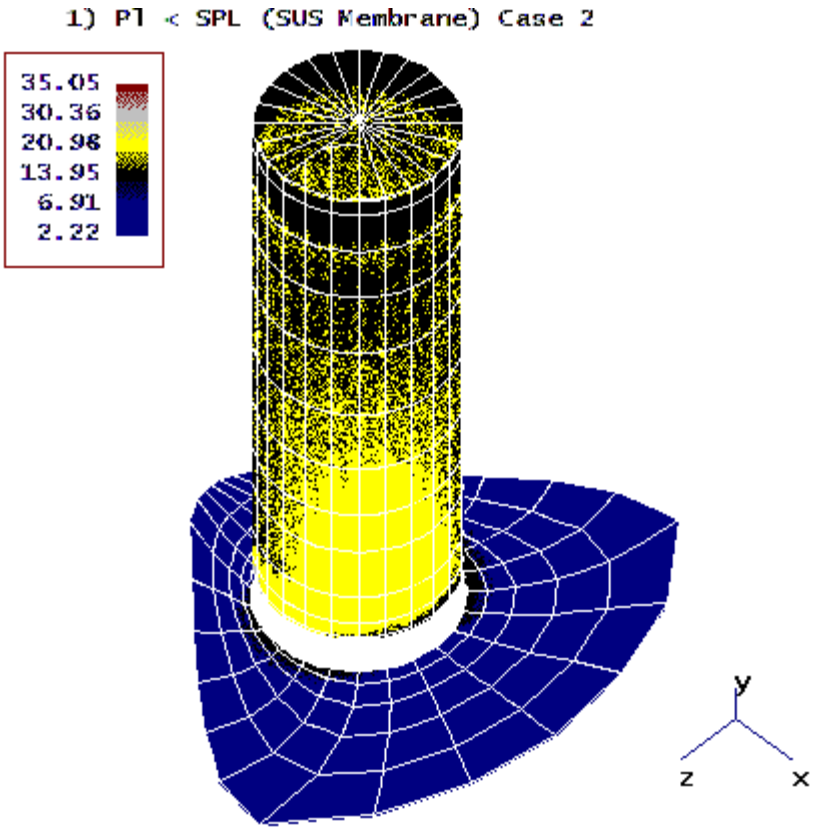
- Finite Element Model

Area of Discontinuity at Nozzle

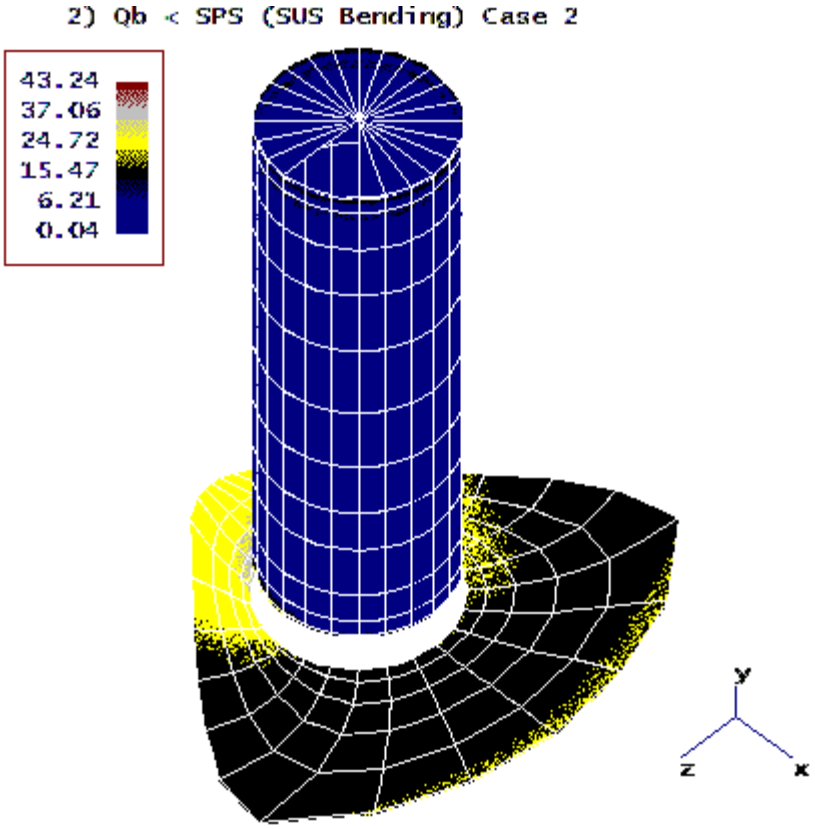
- 1) Pl < SPL (SUS Membrane) Case 2
- 2) Qb < SPS (SUS Bending) Case 2
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 2
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 3
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 3
- 8) Membrane < User (OPE Membrane) Case 3
- 9) Bending < User (OPE Bending) Case 3
- 15) Pl+Pb+Q < SPS (EXP Inside) Case 4
- 16) Pl+Pb+Q < SPS (EXP Outside) Case 4
- 17) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4
- 18) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4
- 10) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5
- 11) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6
- 12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7
- 13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 8
- 14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 9



3d


1) Pl < SPL (SUS Membrane) Case 2
35.05
30.36
20.98
13.95
6.91
2.22
y
z
x
3d(Small)
3d
3d(Deformed)

-
-



3d(Small) 3d 3d(Deformed)

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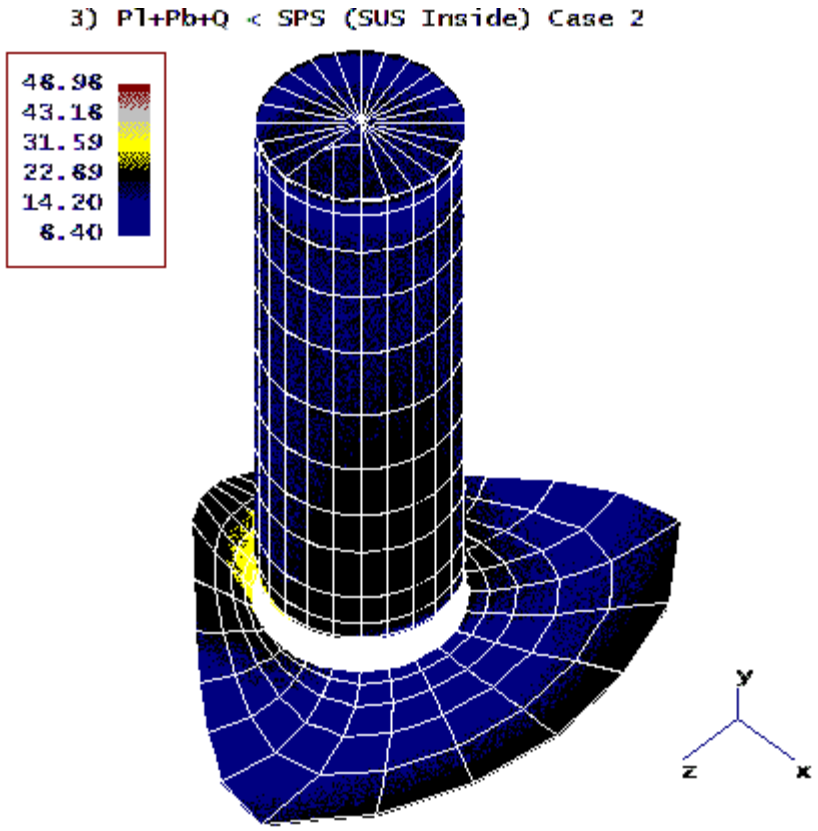
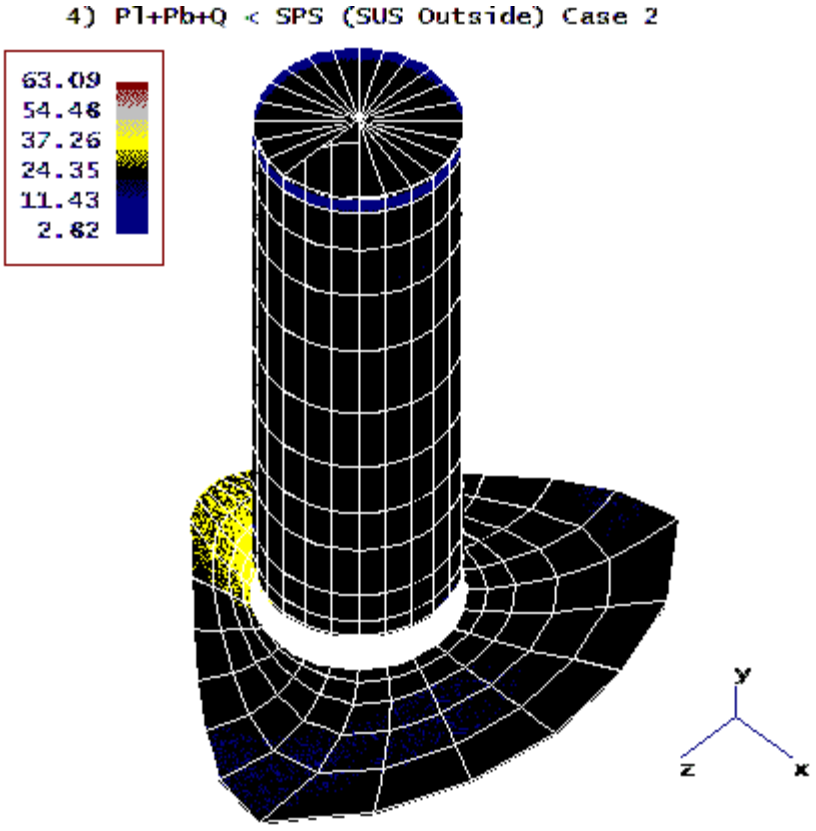


3d(Small) 3d 3d(Deformed)



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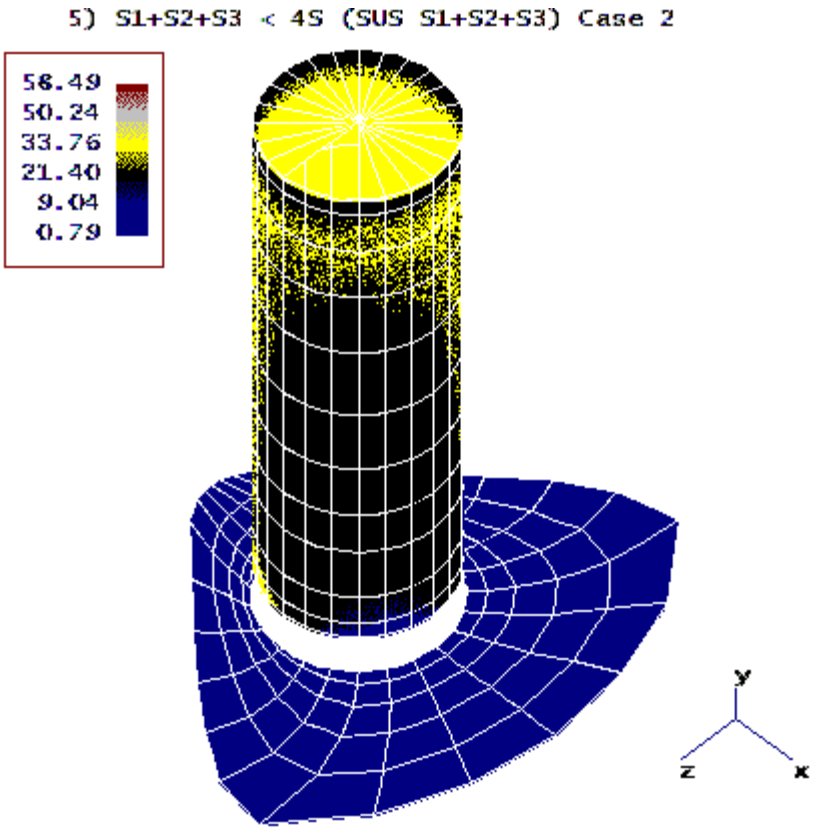
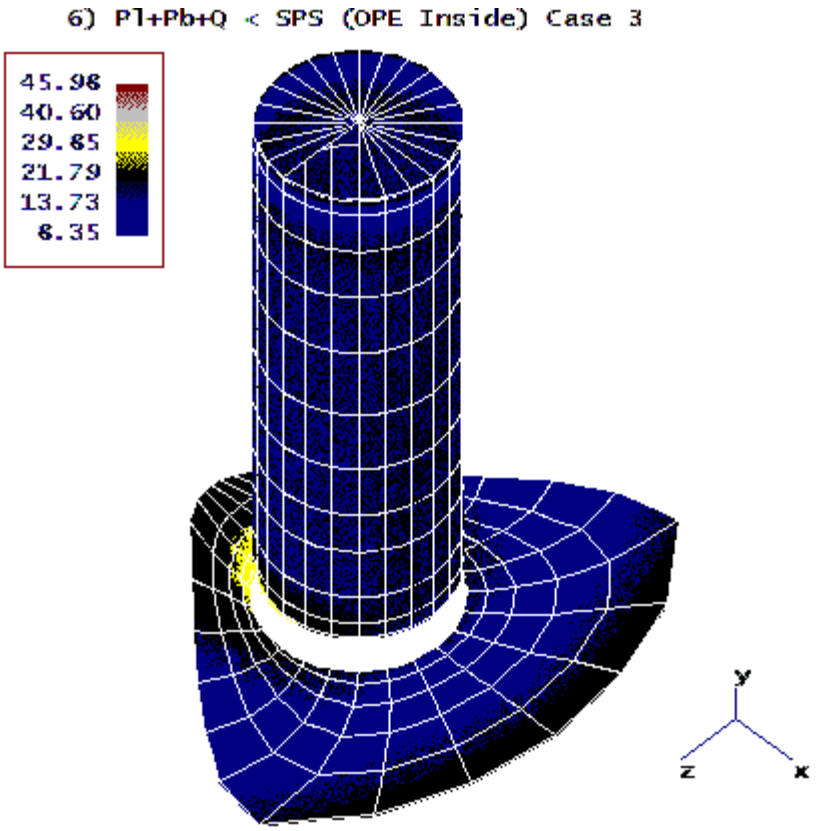
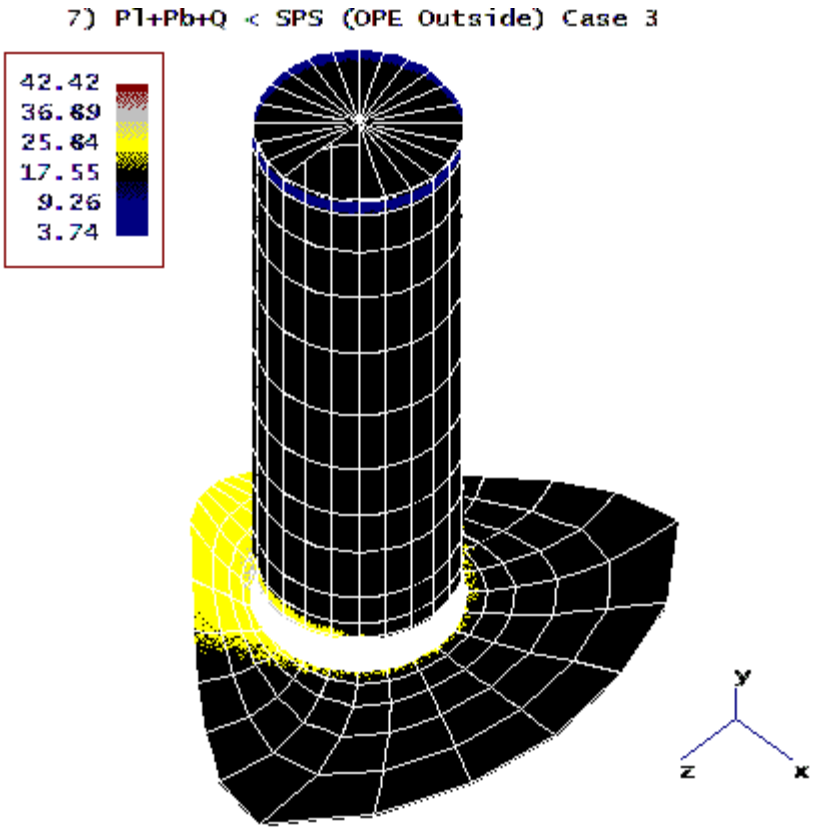
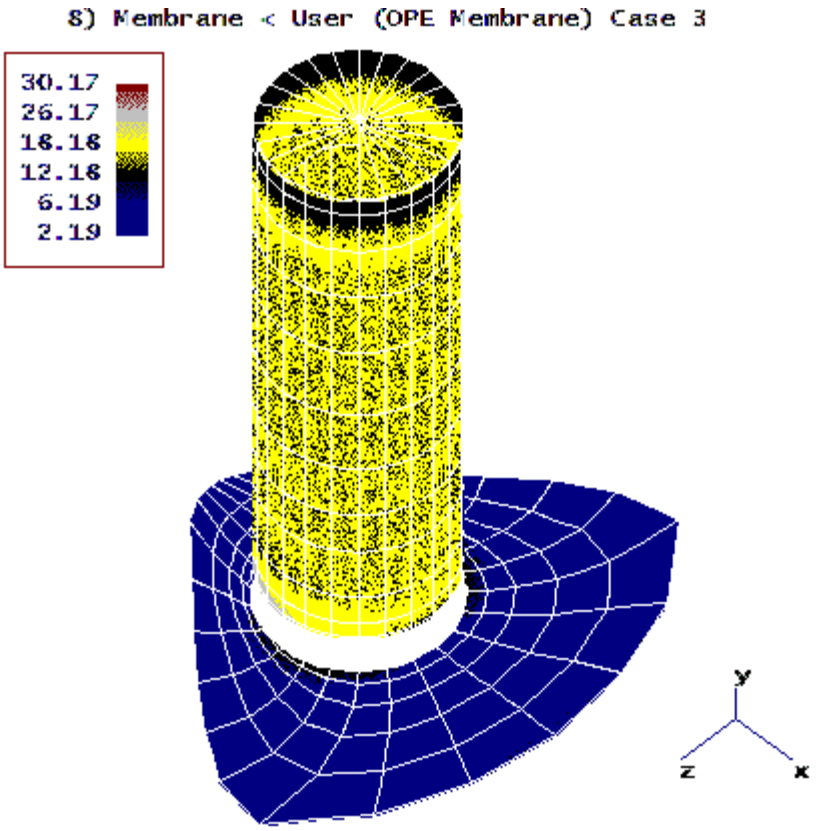


3d(Small) 3d 3d(Deformed)


6) Pl+Pb+Q < SPS (OPE Inside) Case 3
45.98
40.60
29.85
21.79
13.73
6.35
Y
Z
X
3d(Small)
3d
3d(Deformed)



3d(Small) 3d 3d(Deformed)



3d(Small) 3d 3d(Deformed)

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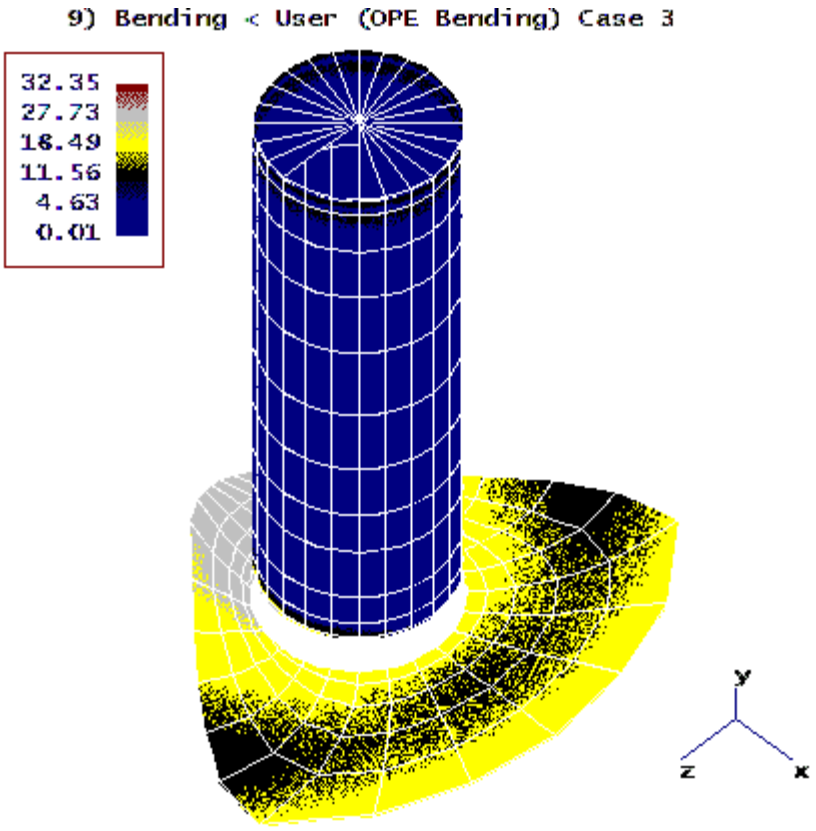
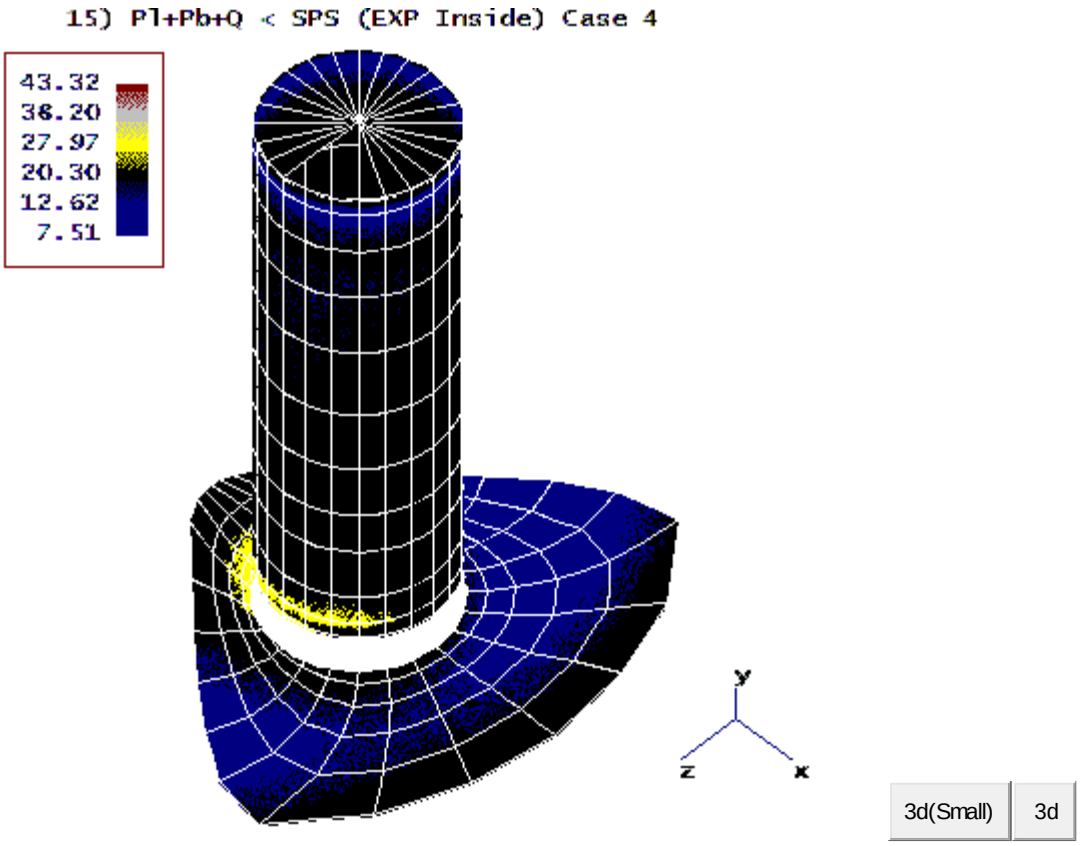
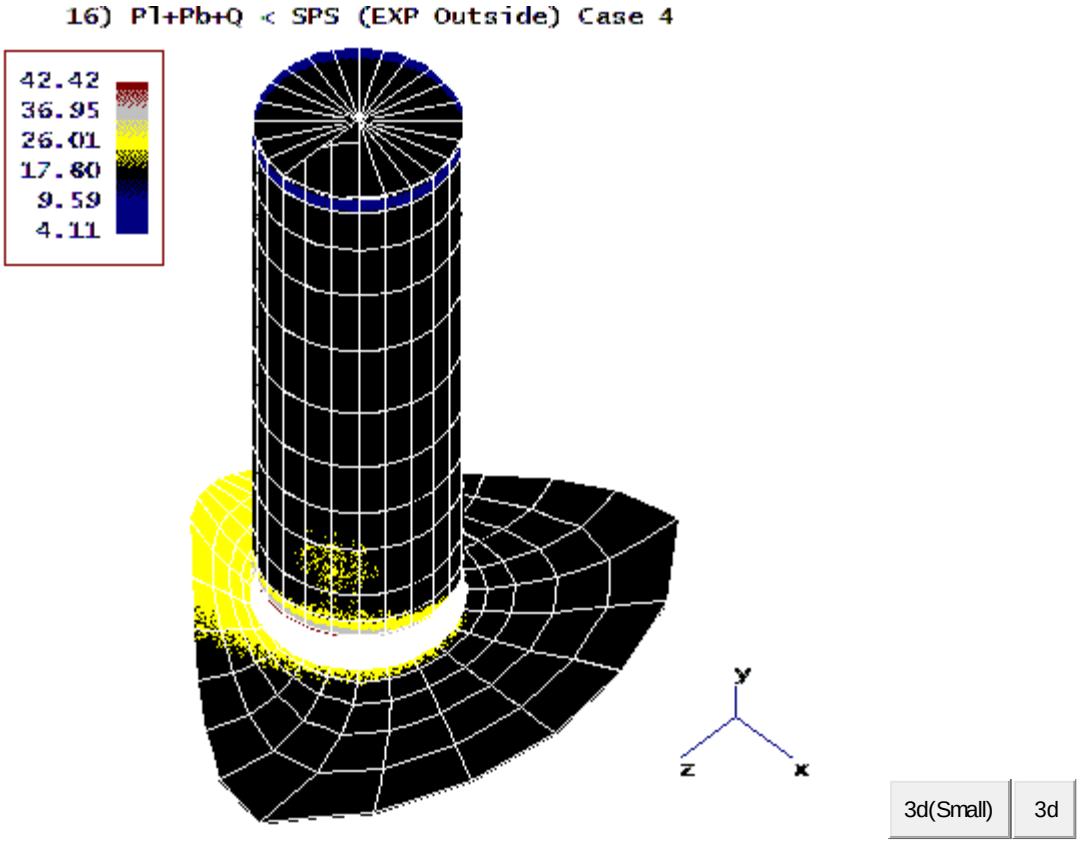
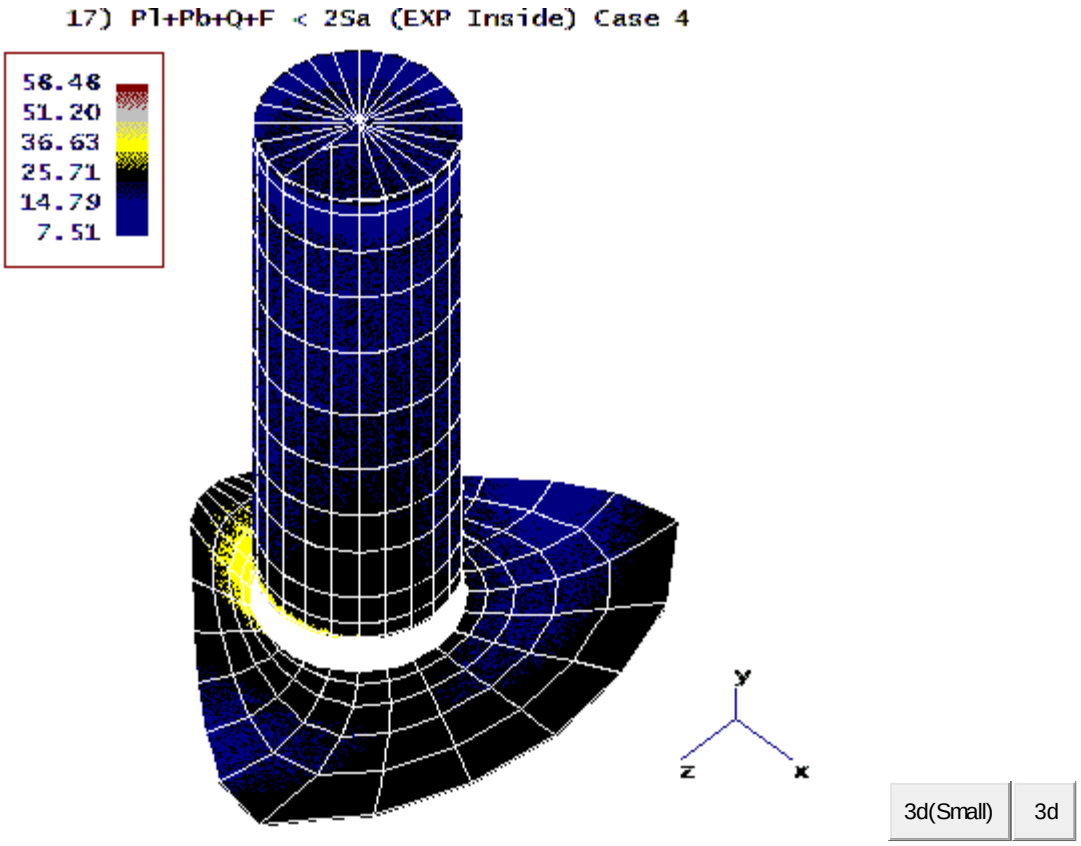
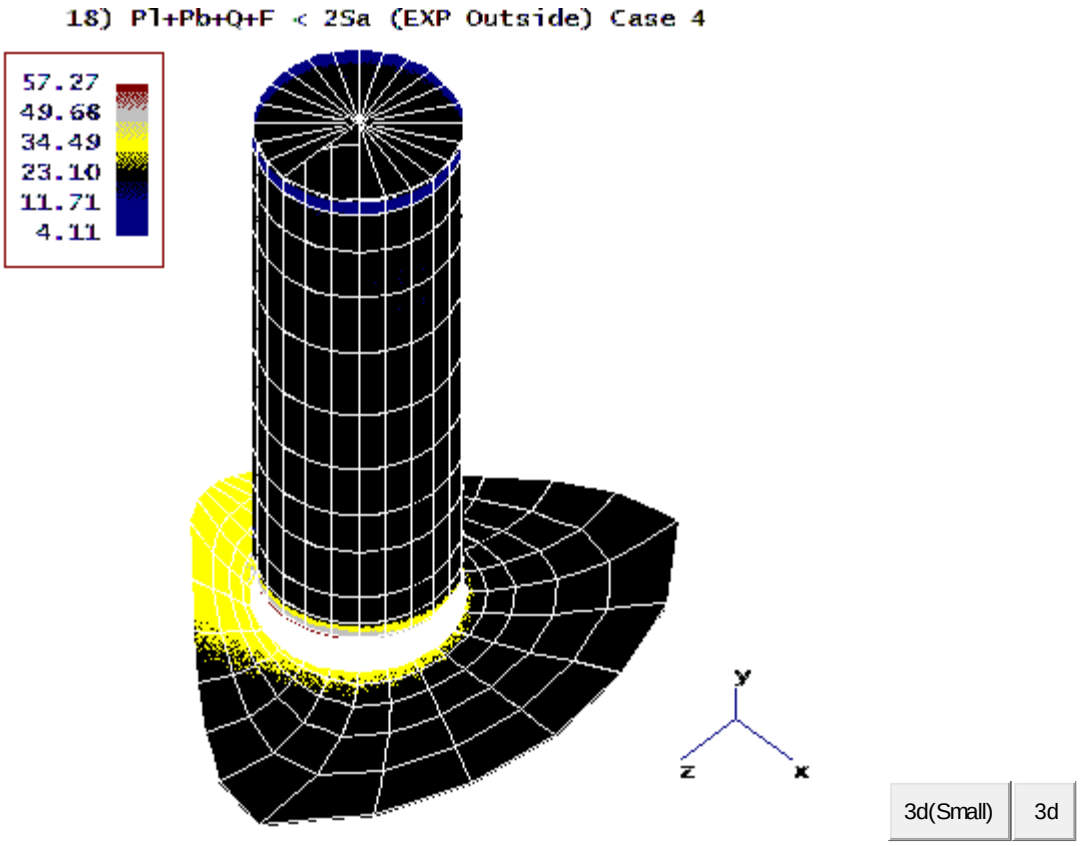

9) Bending < User (OPE Bending) Case 3
32.35
27.73
16.49
11.56
4.63
0.01
y
z
x
3d(Small)
3d
3d(Deformed)


15) Pl+Pb+Q < SPS (EXP Inside) Case 4
43.32
38.20
27.97
20.30
12.62
7.51
Y
Z
X
3d(Small)
3d


16) Pl+Pb+Q < SPS (EXP Outside) Case 4
42.42
36.95
26.01
17.80
9.59
4.11
Y
Z
X
3d(Small)
3d

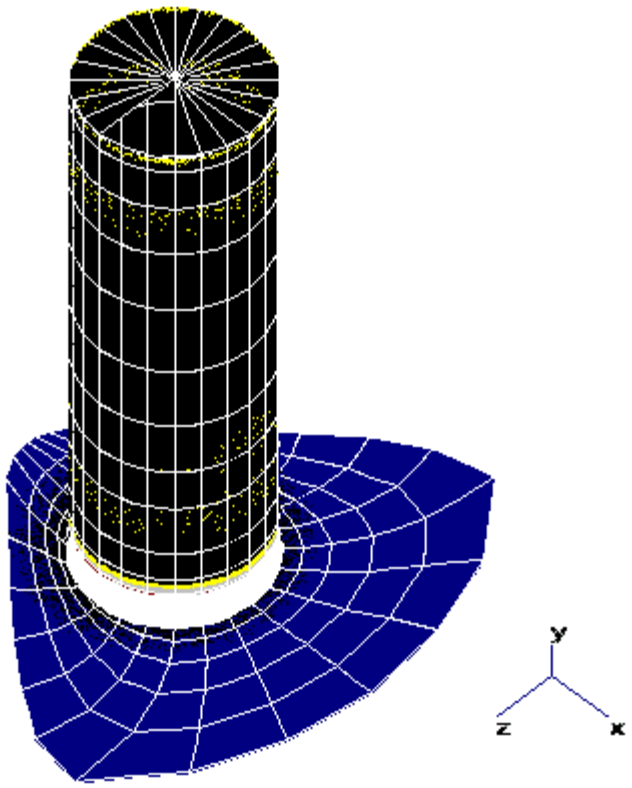

17) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4
58.48
51.20
36.63
25.71
14.79
7.51
Y
Z
X
3d(Small)
3d

-
-


18) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4
57.27
49.68
34.49
23.10
11.71
4.11
Y
Z
X
3d(Small)
3d

-
-

10) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5



3d(Small) 3d 3d(Deformed)

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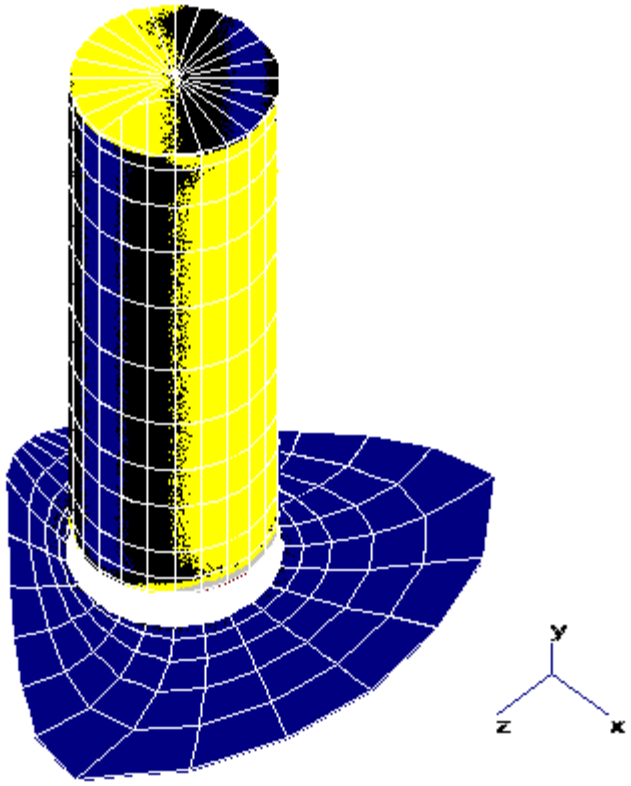
11) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6



3d(Small) 3d 3d(Deformed)

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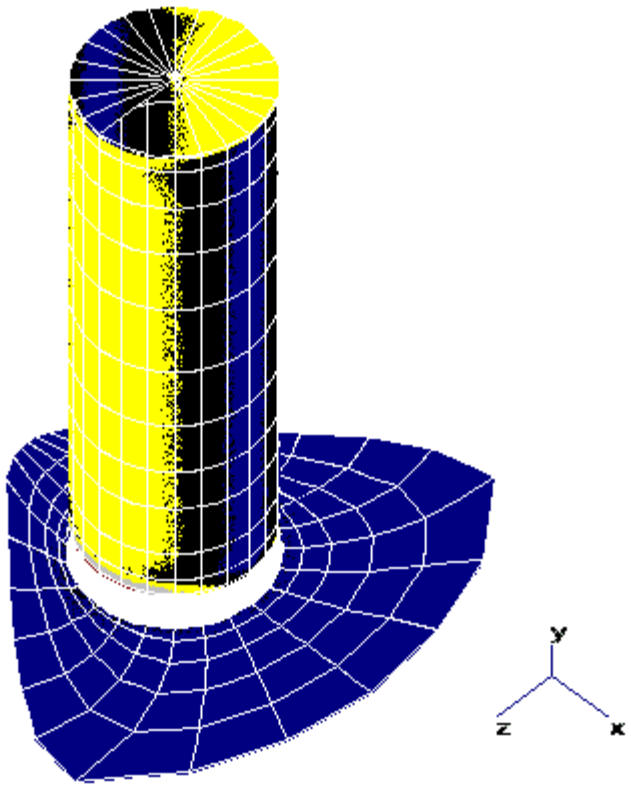
-

12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7



3d(Small) 3d 3d(Deformed)

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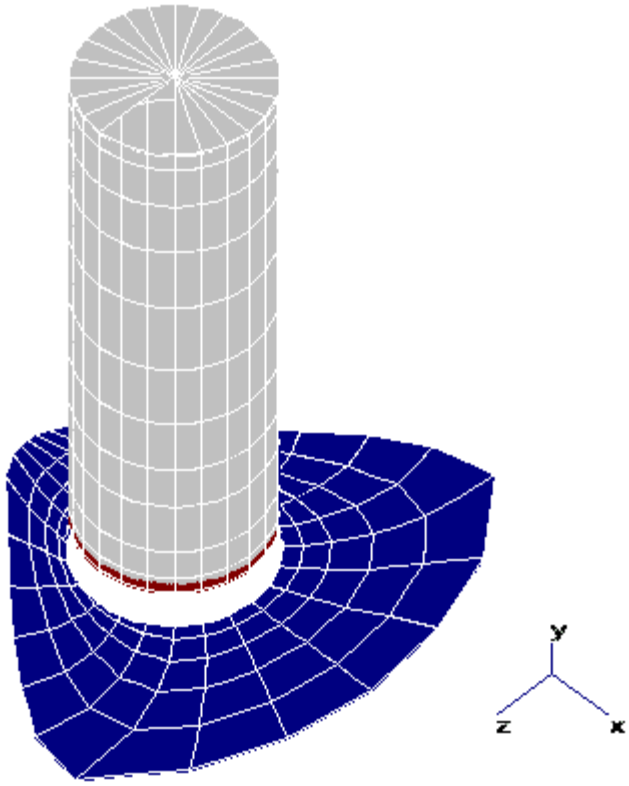
13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 8



3d(Small) 3d 3d(Deformed)

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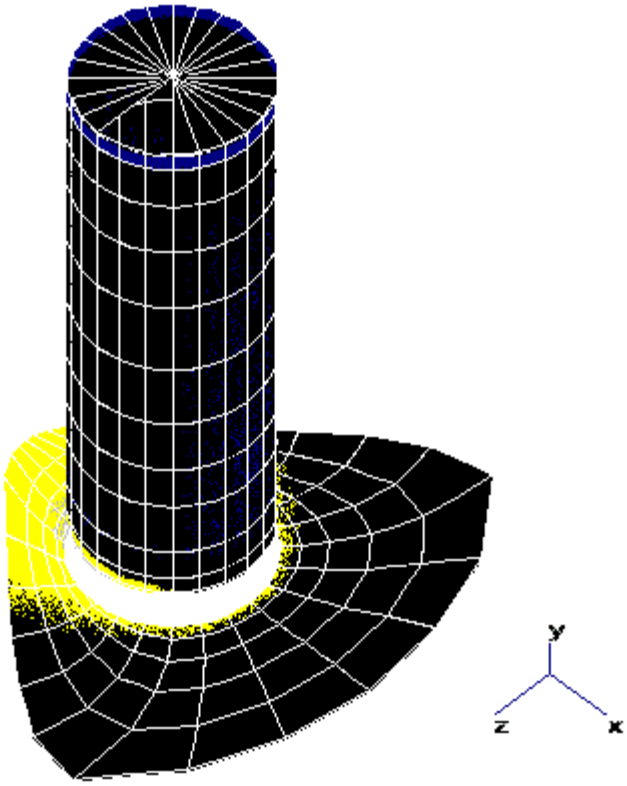
14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 9



3d(Small) | 3d | 3d(Deformed)