طرح نگهداشت و افزایش تولید 27 مخزن

THERMAL/MECHANICAL CALCULATION BOOK FOR LEAN GLYCOL GAS H.E. (E-300)

نگهداشت و افزایش تولید میدان نفتی بینک

Rev.	Date	Purpose of Issue/Status	Prepared by:	Checked by:	Approved by:	CLIENT Approval
V01	MAR.2025	IFI	MFS	M.Fakharian	S.Faramarzpour	
V00	DEC.2024	IFA	MFS	M.Fakharian	S.Faramarzpour	

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-300.Pvdb

Date of Analysis : Mar 10,2025 9:50am

PV Elite 2020, January 2020

ASME Code, Section VIII Division 1, 2019

Diameter Spec : 323.850 x 293.313 mm. OD		
Vessel Design Length, Tangent to Tangent	2642.53	mm.
Specified Datum Line Distance	0.00	mm.
Shell Side Design Temperature	145	°C
Channel Side Design Temperature	95	°C
Shell Side Design Pressure	62.000	bars
Channel Side Design Pressure	59.000	bars
Shell Side Hydrostatic Test Pressure	80.600	bars
Channel Side Hydrostatic Test Pressure	76.700	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-106 B	...	...	K03006	No	No
Head	SA-234 WPB	...	...	K03006	No	No
Flange	SA-105	...	...	K03504	No	No
Nozzle	SA-105	...	...	K03504	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Tubes	SA-179	...	...	K01200	No	No
Tubesheet	SA-266 2	...	...	K03506	No	No
Flg Bolting	SA-193 B7M	...	<= 2 1/2	G41400	No	No
Hrz Bolting	SA-193 B7	...	2 1/2 < t <= 4	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
Channel Cover	59.000	1.03	109.000	3.0000	Yes	No
Channel Barrel	59.000	1.03	92.000	3.0000	N/A	No
Channel FLG.	59.000	1.03	72.000	3.0000	N/A	No
Shell FLG.	62.032	1.03	72.000	3.0000	N/A	No
Shell Barrel	62.029	1.03	92.000	3.0000	N/A	No
Shell Cover	62.029	1.03	109.000	3.0000	Yes	No

Liquid Level: 322.26 mm. Dens.: 0.001 kg./cm³ Sp. Gr.: 1.000

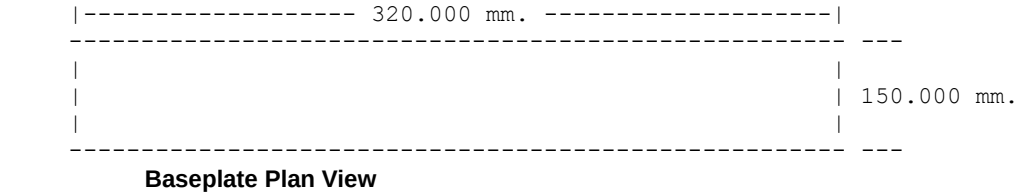
Element Types and Properties:

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	50.0	50.0	17.4	17.4	10.6	4.5	1.00	1.00
Cylinder	400.0	350.0	17.4	15.3	10.9	4.2	1.00	1.00
Body Flg	545.0	145.0	...	60.0	59.5	55.3	1.00	1.00
Body Flg	792.5	145.0	...	60.0	59.5	55.3	1.00	1.00
Cylinder	2592.5	1800.0	17.4	15.3	11.1	5.2	1.00	1.00
Ellipse	2642.5	50.0	17.4	17.4	10.9	4.5	1.00	1.00

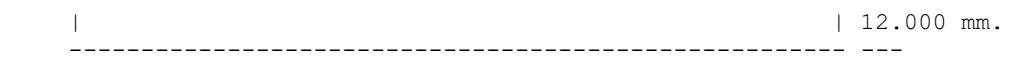
Saddle Parameters:

Saddle Width	80.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	700.000	mm.
Wear Pad Width	100.000	mm.
Wear Pad Thickness	10.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	100.000	mm.
Baseplate Length	320.000	mm.
Baseplate Thickness	12.000	mm.
Baseplate Width	150.000	mm.
Number of Ribs (including outside ribs)	2	
Rib Thickness	10.000	mm.
Web Thickness	10.000	mm.
Height of Center Web	565.000	mm.
Number of Bolts in Baseplate	2	

Baseplate Sketch



Baseplate Plan View



Baseplate Side View

Maximum Tensile Bolt Load	4423.	N

Summary of Maximum Saddle Loads, Operating Case:

Maximum Vertical Saddle Load	26394.33	N
Maximum Transverse Saddle Shear Load	2135.33	N
Maximum Longitudinal Saddle Shear Load	4270.66	N

Summary of Maximum Saddle Loads, Operating Case, Un-Factored:

Maximum Vertical Saddle Load	32848.02	N
Maximum Transverse Saddle Shear Load	15058.59	N
Maximum Longitudinal Saddle Shear Load	6100.94	N

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	12788.15	N
Maximum Transverse Saddle Shear Load	154.51	N
Maximum Longitudinal Saddle Shear Load	62.52	N

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	High Stress Location	Pass Fail
T1 (6in)	WRC-107/537	0.628	n/a	Passed
T2 (6in)	WRC-107/537	0.628	n/a	Passed
S2 (2in)	WRC-107/537	0.669	n/a	Passed
S1 (2in)	WRC-107/537	0.669	n/a	Passed

Weights:

Fabricated - Bare W/O Removable Internals	1164.3	kg.
Shop Test - Fabricated + Water (Full)	1326.3	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	1197.2	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	1197.2	kg.
Empty - Fab. + Intls. + Details + Wghts.	1197.2	kg.
Operating - Empty + Operating Liquid (No CA)	1286.1	kg.
Field Test - Empty Weight + Water (Full)	1300.1	kg.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T1 (6in)	90	OK	...	OK	9.22	OK	Passed
T2 (6in)	90	OK	...	OK	9.22	OK	Passed
S2 (2in)	92	OK	...	OK	7.80	OK	Passed
S1 (2in)	92	OK	...	OK	7.80	OK	Passed

Nozzle MAWP Summary:

Minimum MAWP Nozzles : 92 Nozzle : S2 (2in) [Shellside]
Minimum MAWP Nozzles : 90 Nozzle : T1 (6in) [Tubeside]

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	T1 (6in)	225.000	90.000	310.145
20	T2 (6in)	225.000	270.000	310.145
50	S2 (2in)	1042.525	270.000	113.600
50	S1 (2in)	2246.525	90.000	113.600

The nozzle spacing is computed by the following:

$= \mathrm{Sqrt}(ll^2 + lc^2)$ 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
2	ELLIPTICAL HEAD: 2.0 X 1, 17.4mm. THK X 289.0mm. ID X 50.0mm.	SA-234 WPB
1	CYLINDER: 17.4mm. THK X 293.3mm. ID X 350.0mm.	SA-106 B
2	BODY FLANGE: 60.0mm. THK X 288.8mm. OD	SA-105
1	CYLINDER: 17.4mm. THK X 293.3mm. ID X 1800.0mm.	SA-106 B
1	INSULATION: 121mm X 40mm THK	
1	INSULATION: 350mm X 40mm THK	
1	INSULATION: 165mm X 40mm THK	
1	TUBESHEET: 558mm X 84mm THK	SA-266 2
94	TUBES: 1800mm X 19mm DIA X 2mm THK	SA-179
1	INSULATION: 165mm X 80mm THK	
2	SADDLE: 80mm X 120 DEG	SA-106 B
1	INSULATION: 1800mm X 80mm THK	
1	INSULATION: 121mm X 80mm THK	
1	GASKET: 374mm. OD X 327mm. ID	...
20	BODY FLANGE BOLTS: 31mm. DIA	SA-193 B7M
40	NUTS FOR BODY FLANGE BOLTS: 31mm. 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
S2 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	171.4	600
S1 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	171.4	600
T1 (6in)	6.000 in	80	WN	6.625	10.973	...	...	215.5	600
T2 (6in)	6.000 in	80	WN	6.625	10.973	...	...	215.5	600

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
S2 (2in)	SA-105	15.269	10.000	...	...	...
S1 (2in)	SA-105	15.269	10.000	...	...	...
T1 (6in)	SA-105	15.269	10.000	...	...	...
T2 (6in)	SA-105	15.269	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
S2 (2in)	1042.525	270.0	150.00	0.00	Shell Barrel
S1 (2in)	2246.525	90.0	150.00	0.00	Shell Barrel
T1 (6in)	225.000	90.0	150.00	0.00	Channel Barrel
T2 (6in)	225.000	270.0	150.00	0.00	Channel 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
Shell FLG.	[11]	B	-16	-39	-29	0.587	15.269	1.00	Yes
Shell Barrel	[8]	C	-33	-48	-29	0.685	15.269	1.00	Yes
Shell Cover	[10]	C	-30	-48	-29	0.566	17.450	1.00	Yes
Shell Cover	[7]	C	-30	-48	-29	0.596	17.450	1.00	Yes
S2 (2in)	[1]	B	-16	-34	-29	0.663	15.269	1.00	Yes
Nozzle Flg	[5]	B	-18	-40					
S1 (2in)	[1]	B	-16	-34	-29	0.662	15.269	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
Tubesheet: SS	[13]	C	-42	-48		0.861	21.000	1.00	Yes
Warmest MDMT:			-16	-34					
Channel FLG.	[11]	B	-16	-40	-29	0.579	15.269	1.00	Yes
Channel Cover	[10]	C	-30	-48	-29	0.559	17.450	1.00	Yes
Channel Cover	[7]	C	-30	-48	-29	0.588	17.450	1.00	Yes
Channel Barrel	[8]	C	-33	-104	-29	0.324	15.269	1.00	Yes
T1 (6in)	[1]	B	-16	-37	-29	0.620	15.269	1.00	Yes
Nozzle Flg	[5]	B	-18	-42					
T2 (6in)	[1]	B	-16	-37	-29	0.620	15.269	1.00	Yes
Nozzle Flg	[5]	B	-18	-42					
Tubesheet: CS	[14]	C	-42	-48		0.861	21.000	1.00	Yes
Bolting	[21]		-48						
Warmest MDMT:			-16	-37					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-34.0	5.0	Pass
Channel/Tube	-37.0	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: Channel FLG. and Shell FLG.
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	62	bars
Channel Side Design Pressure	59	bars
Shell Side Design Temperature	145.0	°C
Channel Side Design Temperature	95.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	Lethal	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	5.0	°C
MDMT (CET), Tube Side	5.0	°C
User defined MAWP, Shell Side	0	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]	232	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		1.000	
Table Value Fv		1.330	
Short Period Acceleration value Ss		1.125	
Long Period Acceleration Value Sl		0.460	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		3.000	
Site Class		D	
Component Elevation Ratio	z/h	1.000	
Amplification Factor	Ap	1.000	
Force Factor		0.000	
Consider Vertical Acceleration		Yes	
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	Channel Cover	
Distance "FROM" to "TO"	50	mm.
Element Outside Diameter	323.85	mm.
Element Thickness	17.45	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	17.45	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	59	bars
Design Temperature Internal Pressure	95	°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	217.2	N./mm²
Material Density	0.00775	kg./cm³
P Number Thickness	29.997	mm.
Yield Stress, Operating	221.1	N./mm²
UCS-66 Chart Curve Designation	C	
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	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	-71.438	mm.
Height/Length of Insulation	121.44	mm.
Thickness of Insulation	40	mm.
Density	0.0001249	kg./cm³

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	Channel Barrel	
Distance "FROM" to "TO"	350	mm.
Element Outside Diameter	323.85	mm.

Element Thickness	15.269	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	17.45	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	59	bars
Design Temperature Internal Pressure	95	°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	217.2	N./mm²
Material Density	0.00775	kg./cm³
P Number Thickness	29.007	mm.
Yield Stress, Operating	221.1	N./mm²
UCS-66 Chart Curve Designation	C	
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	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	350	mm.
Thickness of Insulation	40	mm.
Density	0.0001249	kg./cm³
Element From Node	20	
Detail Type	Nozzle	
Detail ID	T1 (6in)	
Dist. from "FROM" Node / Offset dist	175	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	600	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	531.4	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	T2 (6in)	
Dist. from "FROM" Node / Offset dist	175	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	600	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	531.4	N

```
    Grade of Attached Flange                          GR 1.1
    Nozzle Matl                                       SA-105

    Element From Node                                     20
    Detail Type                                       Weight
    Detail ID                                  PASS PARTITION
    Dist. from "FROM" Node / Offset dist                 175  mm.
    Miscellaneous Weight                              196.12  N
    Offset from Element Centerline                         0  mm.

-------------------------------------------------------------------

Element From Node                                         30
Element To Node                                           40
Element Type                                        Flange
Description                                    Channel FLG.
Distance "FROM" to "TO"                                145  mm.
Flange Inside Diameter                              288.84  mm.
Element Thickness                                      60  mm.
Internal Corrosion Allowance                            3  mm.
Nominal Thickness                                       0  mm.
External Corrosion Allowance                            0  mm.
Design Internal Pressure                                59  bars
Design Temperature Internal Pressure                    95  °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                      137.9  N./mm²
    Allowable Stress, Hydrotest                      223.4  N./mm²
    Material Density                               0.00775  kg./cm³
    P Number Thickness                              29.997  mm.
    Yield Stress, Operating                          227.3  N./mm²
    UCS-66 Chart Curve Designation                       B
    External Pressure Chart Name                      CS-2
    UNS Number                                      K03504
    Product Form                                  Forgings
Perform Flange Stress Calculation (Y/N)                  Y
Weight of Standard Flange                                0  N
Class of Standard Flange
Grade of Standard Flange
Weld is pre-Heated                                      No

    Element From Node                                    30
    Detail Type                                  Insulation
    Detail ID                                     Ins: 30
    Dist. from "FROM" Node / Offset dist                 0  mm.
    Height/Length of Insulation                      165.1  mm.
    Thickness of Insulation                             40  mm.
    Density                                     0.0001249  kg./cm³

-------------------------------------------------------------------

Element From Node                                         40
```

Element To Node	50	
Element Type	Flange	
Description	Shell FLG.	
Distance "FROM" to "TO"	145	mm.
Flange Inside Diameter	288.84	mm.
Element Thickness	60	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	62	bars
Design Temperature Internal Pressure	145	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-105	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	N
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	322.26	mm.
Liquid Density	0.0009984	kg./cm³
Element From Node	40	
Detail Type	Insulation	
Detail ID	Ins: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	165.1	mm.
Thickness of Insulation	80	mm.
Density	0.0001249	kg./cm³

Element From Node	50	
Element To Node	60	
Element Type	Cylinder	
Description	Shell Barrel	
Distance "FROM" to "TO"	1800	mm.
Inside Diameter	293.31	mm.
Element Thickness	15.269	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	17.45	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	62	bars
Design Temperature Internal Pressure	145	°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	217.2	N./mm²
Material Density	0.00775	kg./cm³
P Number Thickness	29.007	mm.
Yield Stress, Operating	214.2	N./mm²
UCS-66 Chart Curve Designation	C	
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	50	
Detail Type	Saddle	
Detail ID	Lft Sdl	
Dist. from "FROM" Node / Offset dist	100	mm.
Width of Saddle	80	mm.
Height of Saddle at Bottom	700	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	100	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	
Friction coefficient	0.30000001	
Moment Factor	3.0	
Dimension E at base (optional)	0	mm.
Circumferential Eff. over Saddle	1.0	
Circumferential Eff. at Midspan	1.0	
Tangent to Tangent dist. (optional)	0	mm.
Element From Node	50	
Detail Type	Saddle	
Detail ID	New Sdl	
Dist. from "FROM" Node / Offset dist	1600	mm.
Width of Saddle	80	mm.
Height of Saddle at Bottom	700	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	100	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	
Friction coefficient	0.30000001	
Moment Factor	3.0	
Dimension E at base (optional)	0	mm.
Circumferential Eff. over Saddle	1.0	
Circumferential Eff. at Midspan	1.0	
Tangent to Tangent dist. (optional)	0	mm.
Element From Node	50	
Detail Type	Liquid	
Detail ID	Liquid: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	293.31	mm.
Liquid Density	0.0009984	kg./cm³

Element From Node	50	
Detail Type	Insulation	
Detail ID	Ins: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	1800	mm.
Thickness of Insulation	80	mm.
Density	0.0001249	kg./cm³
Element From Node	50	
Detail Type	Nozzle	
Detail ID	S2 (2in)	
Dist. from "FROM" Node / Offset dist	250	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	600	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	89.138	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	50	
Detail Type	Nozzle	
Detail ID	S1 (2in)	
Dist. from "FROM" Node / Offset dist	1454	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	600	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	89.138	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	50	
Detail Type	Weight	
Detail ID	BAFFLE	
Dist. from "FROM" Node / Offset dist	1000	mm.
Miscellaneous Weight	196.12	N
Offset from Element Centerline	0	mm.

Element From Node	60	
Element To Node	70	
Element Type	Elliptical	
Description	Shell Cover	
Distance "FROM" to "TO"	50	mm.
Element Outside Diameter	323.85	mm.
Element Thickness	17.45	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	17.45	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	62	bars

Design Temperature Internal Pressure	145	°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	217.2	N./mm²
Material Density	0.00775	kg./cm³
P Number Thickness	29.997	mm.
Yield Stress, Operating	214.2	N./mm²
UCS-66 Chart Curve Designation	C	
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	60	
Detail Type	Liquid	
Detail ID	Liquid: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	288.95	mm.
Liquid Density	0.0009984	kg./cm³
Element From Node	60	
Detail Type	Insulation	
Detail ID	Ins: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	121.44	mm.
Thickness of Insulation	80	mm.
Density	0.0001249	kg./cm³

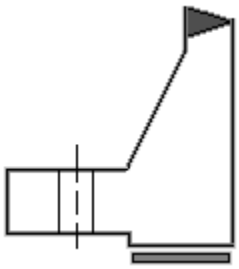
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
Channel Cover		50	...	50	...
Channel Barrel		400	...	350	...
Channel FLG.		545	...	145	...
Shell FLG.		792.525	...	145	...
Shell Barrel		2592.53	...	1800	...
Shell Cover		2642.53	...	50	...

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

Channel FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	59.00	bars
Design Temperature		95	°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	288.840	mm.
Flange Outside Diameter	A	558.800	mm.
Flange Thickness	t	60.0000	mm.
Thickness of Hub at Small End	go	15.2686	mm.
Thickness of Hub at Large End	g1	42.0000	mm.
Length of Hub	h	85.0000	mm.
Flange Material		SA-105	
Flange Material UNS number		K03504	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm²
Bolt Material		SA-193 B7M	
Bolt Allowable Stress At Temperature	Sb	137.90	N./mm²
Bolt Allowable Stress At Ambient	Sa	137.90	N./mm²
Diameter of Bolt Circle	C	488.950	mm.
Nominal Bolt Diameter	a	31.7500	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		20	
Flange Face Outside Diameter	Fod	381.000	mm.
Flange Face Inside Diameter	Fid	288.840	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	374.650	mm.
Gasket Inside Diameter	Gi	327.152	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	4.5000	mm.
Length of Partition Gasket	lp	559.0000	mm.
Width of Partition Gasket	tp	10.0000	mm.
Partition Gasket Factor	mPart	2.5000	
Partition Gasket Design Seating Stress	yPart	25.00	N./mm²



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)
  = (59.0*(288.84/2+3.0))/(137.9*1.0-0.6*59.0)+Ca
  = 9.4739 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.2686)/(147.42 + 0.6 * 12.2686 )
  = 109.299 bars
```

```
 Corroded Flange Thickness, tc = T-ci                    57.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor               294.840  mm.
 Corroded Large Hub,     g1Cor = g1-ci                   39.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                   12.269  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor      58.055  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2           23.749  mm.
 Basic Gasket Width,        bo = N / 2                   11.874  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)              8.683  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b             357.283  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 357.283² * 59.0
  = 591500.250 N
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 8.6835 * 3.1416 * 357.283 * 3.0 * 59.0
    + 2.0 * 559.0 * 5.0 * 2.5 * 59.0
  = 427473.500 N
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 294.84² *59.0/4
  = 402812.531 N
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 591500 - 402813
  = 188687.703 N
```

Operating Bolt Load [Wm1]:
```
= max( H + Hp + H'p, 0 )
= max( 591500 + 427474 + 0, 0 )
= 1018973.750 N
= 1071331.500 N, Mating Flange Load Governs
```
Gasket Seating Bolt Load [Wm2]:
```
= y * b * Pi * G  + yPart * bPart * lp
= 68.95*8.6835*3.141*357.283+25.0*5.0*559.0
= 741845.500 N
```
Required Bolt Area [Am]:
```
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 1071332/138, 741846/138
= 77.696 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
= 2a + 6t/(m + 0.5)
= 2 * 31.75 + 6 * 57.0/(3.0 + 0.5)
= 161.214 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
= C * sin( pi / n )
= 488.95 * sin( 3.142/20 )
= 76.489 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
= max( sqrt( Bs/( 2a + t )), 1 )
= max( sqrt( 76.489/( 2 * 31.75 + 57.0 )), 1 )
= 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	77.696	119.871	
Radial Distance between Hub and Bolts:	44.450	58.055	
Radial Distance between Bolts and Edge:	31.750	34.925	
Circ. Spacing between the Bolts:	71.450	76.489	161.214

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
= Ab * Sa/( y * Pi * (Go + Gi) )
= 119.871 * 137.9/(68.95 * 3.14 * (374.65 + 327.15) )
= 10.874 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
= Sa * ( Am + Ab ) / 2
= 137.9 * ( 77.6956 + 119.8707 )/2
= 1362104.12 N
```
Gasket Load for the Operating Condition [HG]:
```
= Wm1 - H
= 1071332 - 591500
= 479831.25 N
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
= (C - G ) / 2
= ( 488.95 - 357.283 )/2
= 65.8335 mm.
```

Distance to Face Pressure Reaction [ht]:

```
= ( R + g1 + hg ) / 2
= ( 58.055 + 39.0 + 65.8335 )/2
= 81.4442 mm.
```

Distance to End Pressure Reaction [hd]:

```
= R + ( g1 / 2 )
= 58.055 + ( 39.0/2.0 )
= 77.5550 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	402813.	77.5550	1.0000	31253.
Face Pressure,	Mt	188688.	81.4442	1.0000	15374.
Gasket Load,	Mg	479831.	65.8335	1.0000	31602.
Gasket Seating,	Matm	1362104.	65.8335	1.0000	89708.

Total Moment for Operation,	Mop	78228. N-m
Total Moment for Gasket seating,	Matm	89708. N-m

Effective Hub Length,	ho = sqrt(Bcor*goCor)	60.144 mm.
Hub Ratio,	h/h0 = HL / H0	1.413
Thickness Ratio,	g1/g0 = (g1Cor/goCor)	3.179

Flange Factors for Integral Flange:

Factor F				0.621
Factor V				0.056
Factor f				1.000
Factors from Figure 2-7.1			K =	1.895
	T =	1.547	U =	3.521
	Y =	3.204	Z =	1.772
	d = 0.56999E+06 mm.³		e =	0.0103 mm.^-1
Stress Factors			ALPHA =	1.589
	BETA =	1.785	GAMMA =	1.027
	DELTA =	0.325	Lamda =	1.352

Longitudinal Hub Stress, Operating [SHo]:

```
= ( f * Mop / Bcor ) / ( L * g1² )
= (1.0*78228/294.84)/(1.3523*39.0²)
= 128.95 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:

```
= ( f * Matm / Bcor ) / ( L * g1² )
= (1.0*89708/294.84)/(1.3523*39.0²)
= 147.88 N./mm²
```

Radial Flange Stress, Operating [SRo]:

```
= ( Beta * Mop / Bcor ) / ( L * t² )
= (1.7852*78228/294.84)/(1.3523*57.0²)
```

= 107.77 N./mm²

Radial Flange Stress, Seating [SRa]:

= (Beta * Matm/Bcor) / (L * t²)
= (1.7852*89708/294.84)/(1.3523*57.0²)
= 123.59 N./mm²

Tangential Flange Stress, Operating [STo]:

= (Y * Mo / (t² * Bcor)) - Z * SRo
= (3.2038*78228/(57.0²*294.84))-1.7716*108
= 70.62 N./mm²

Tangential Flange Stress, Seating [STa]:

= (y * Matm / (t² * Bcor)) - Z * SRa
= (3.2038*89708/(57.0²*294.84))-1.7716*124
= 80.99 N./mm²

Average Flange Stress, Operating [SAo]:

= (SHo + max(SRo, STo)) / 2
= (129+max(108,71))/2
= 118.36 N./mm²

Average Flange Stress, Seating [SAa]:

= (SHa + max(SRa, STa)) / 2
= (148+max(124,81))/2
= 135.73 N./mm²

Bolt Stress, Operating [BSo]:

= Wm1 / Ab
= 1071332/119.8707
= 89.38 N./mm²

Bolt Stress, Seating [BSa]:

= (Wm2 / Ab)
= (741846/119.8707)
= 61.89 N./mm²

Flange Stress Analysis Results: N./mm²

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	128.95	206.85	147.88	206.85
Radial Flange	107.77	137.90	123.59	137.90
Tangential Flange	70.62	137.90	80.99	137.90
Maximum Average	118.36	137.90	135.73	137.90
Bolting	89.38	137.90	61.89	137.90

Minimum Required Flange Thickness	59.487 mm.
Estimated M.A.W.P. (Operating)	72 bars
Estimated Finished Weight of Flange at given Thk.	102.4 kg.
Estimated Unfinished Weight of Forging at given Thk	202.0 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*89708.4/1.0*999.68*0.056/(1.34*202713*12.269²*60.144*0.3)

```
  = 0.354    (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*78228.3/1.0*999.68*0.056/(1.34*198473*12.269^2*60.144*0.3)
  = 0.316    (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 * go^2 * ho * Ki )
  = 52.14*89708.4/1.0*999.68*0.056/(1.352*202713*12.269^2*60.144*0.3)
  = 0.351    (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*78228.3/1.0*999.68*0.056/(1.352*198473*12.269^2*60.144*0.3)
  = 0.313    (should be <= 1)
```

Minimum Design Metal Temperature Results:

Thickness Ratio = 0.579, Temperature Reduction per Fig. UCS 66.1 = 24 °C

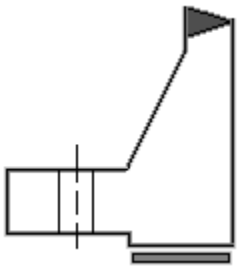
```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -16 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -40 °C
 Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

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

Flange Input Data Values **Description: New Flange :**

Shell FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	62.03	bars
Design Temperature		145	°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	288.840	mm.
Flange Outside Diameter	A	558.800	mm.
Flange Thickness	t	60.0000	mm.
Thickness of Hub at Small End	go	15.2686	mm.
Thickness of Hub at Large End	g1	42.0000	mm.
Length of Hub	h	85.0000	mm.
Flange Material		SA-105	
Flange Material UNS number		K03504	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm²
Bolt Material		SA-193 B7M	
Bolt Allowable Stress At Temperature	Sb	137.90	N./mm²
Bolt Allowable Stress At Ambient	Sa	137.90	N./mm²
Diameter of Bolt Circle	C	488.950	mm.
Nominal Bolt Diameter	a	31.7500	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		20	
Flange Face Outside Diameter	Fod	381.000	mm.
Flange Face Inside Diameter	Fid	288.840	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	374.650	mm.
Gasket Inside Diameter	Gi	327.152	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	4.5000	mm.
Length of Partition Gasket	lp	559.0000	mm.
Width of Partition Gasket	tp	10.0000	mm.
Partition Gasket Factor	mPart	2.5000	
Partition Gasket Design Seating Stress	yPart	25.00	N./mm²



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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)
  = (62.03*(288.84/2+3.0))/(137.9*1.0-0.6*62.03)+Ca
  = 9.8157 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.2686)/(147.42 + 0.6 * 12.2686 )
  = 109.299 bars
```

```
 Corroded Flange Thickness, tc = T-ci                    57.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor               294.840  mm.
 Corroded Large Hub,     g1Cor = g1-ci                   39.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                   12.269  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor      58.055  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2           23.749  mm.
 Basic Gasket Width,        bo = N / 2                   11.874  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)              8.683  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b             357.283  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 357.283² * 62.032
  = 621893.250 N
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 8.6835 * 3.1416 * 357.283 * 3.0 * 62.03
    + 2.0 * 559.0 * 5.0 * 2.5 * 62.0316
  = 449438.250 N
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 294.84² *62.0316/4
  = 423510.156 N
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 621893 - 423510
  = 198383.062 N
```

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(621893 + 449438 + 0, 0)
= 1071331.500 N

Gasket Seating Bolt Load [Wm2]:
= y * b * Pi * G + yPart * bPart * lp
= 68.95*8.6835*3.141*357.283+25.0*5.0*559.0
= 741845.500 N

Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 1071332/138, 741846/138
= 77.696 cm²

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 31.75 + 6 * 57.0/(3.0 + 0.5)
= 161.214 mm.

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 488.95 * sin(3.142/20)
= 76.489 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(76.489/(2 * 31.75 + 57.0)), 1)
= 1.0000

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

	Minimum	Actual	Maximum
Bolt Area, cm²	77.696	119.871	
Radial Distance between Hub and Bolts:	44.450	58.055	
Radial Distance between Bolts and Edge:	31.750	34.925	
Circ. Spacing between the Bolts:	71.450	76.489	161.214

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 119.871 * 137.9/(68.95 * 3.14 * (374.65 + 327.15))
= 10.874 mm.

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 137.9 * (77.6956 + 119.8707)/2
= 1362104.12 N

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 1071332 - 621893
= 449438.28 N

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
= (C - G ) / 2
= ( 488.95 - 357.283 )/2
= 65.8335 mm.
```

Distance to Face Pressure Reaction [ht]:

```
= ( R + g1 + hg ) / 2
= ( 58.055 + 39.0 + 65.8335 )/2
= 81.4442 mm.
```

Distance to End Pressure Reaction [hd]:

```
= R + ( g1 / 2 )
= 58.055 + ( 39.0/2.0 )
= 77.5550 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	423510.	77.5550	1.0000	32859.
Face Pressure,	Mt	198383.	81.4442	1.0000	16164.
Gasket Load,	Mg	449438.	65.8335	1.0000	29600.
Gasket Seating,	Matm	1362104.	65.8335	1.0000	89708.

```
Total Moment for Operation,      Mop                              78622. N-m
Total Moment for Gasket seating, Matm                             89708. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor)           60.144  mm.
Hub Ratio,          h/h0 = HL / H0                     1.413
Thickness Ratio,   g1/g0 = (g1Cor/goCor)               3.179
```

Flange Factors for Integral Flange:

```
Factor F                                               0.621
Factor V                                               0.056
Factor f                                               1.000
Factors from Figure 2-7.1                      K =     1.895
                    T =      1.547             U =     3.521
                    Y =      3.204             Z =     1.772
                    d = 0.56999E+06 mm.³        e =    0.0103 mm.^-1
Stress Factors                           ALPHA =       1.589
                 BETA =      1.785       GAMMA =       1.027
                DELTA =      0.325       Lamda =       1.352
```

Longitudinal Hub Stress, Operating [SHo]:

```
= ( f * Mop / Bcor ) / ( L * g1² )
= (1.0*78622/294.84)/(1.3523*39.0²)
= 129.60 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:

```
= ( f * Matm / Bcor ) / ( L * g1² )
= (1.0*89708/294.84)/(1.3523*39.0²)
= 147.88 N./mm²
```

Radial Flange Stress, Operating [SRo]:

```
= ( Beta * Mop / Bcor ) / ( L * t² )
= (1.7852*78622/294.84)/(1.3523*57.0²)
```

= 108.32 N./mm²

Radial Flange Stress, Seating [SRa]:

= (Beta * Matm/Bcor) / (L * t²)
= (1.7852*89708/294.84)/(1.3523*57.0²)
= 123.59 N./mm²

Tangential Flange Stress, Operating [STo]:

= (Y * Mo / (t² * Bcor)) - Z * SRo
= (3.2038*78622/(57.0²*294.84))-1.7716*108
= 70.98 N./mm²

Tangential Flange Stress, Seating [STa]:

= (y * Matm / (t² * Bcor)) - Z * SRa
= (3.2038*89708/(57.0²*294.84))-1.7716*124
= 80.99 N./mm²

Average Flange Stress, Operating [SAo]:

= (SHo + max(SRo, STo)) / 2
= (130+max(108,71))/2
= 118.96 N./mm²

Average Flange Stress, Seating [SAa]:

= (SHa + max(SRa, STa)) / 2
= (148+max(124,81))/2
= 135.73 N./mm²

Bolt Stress, Operating [BSo]:

= Wm1 / Ab
= 1071332/119.8707
= 89.38 N./mm²

Bolt Stress, Seating [BSa]:

= (Wm2 / Ab)
= (741846/119.8707)
= 61.89 N./mm²

Flange Stress Analysis Results: N./mm²

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	129.60	206.85	147.88	206.85
Radial Flange	108.32	137.90	123.59	137.90
Tangential Flange	70.98	137.90	80.99	137.90
Maximum Average	118.96	137.90	135.73	137.90
Bolting	89.38	137.90	61.89	137.90

Minimum Required Flange Thickness	59.487 mm.
Estimated M.A.W.P. (Operating)	72 bars
Estimated Finished Weight of Flange at given Thk.	102.4 kg.
Estimated Unfinished Weight of Forging at given Thk	202.0 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*89708.4/1.0*999.68*0.056/(1.34*202713*12.269²*60.144*0.3)

```
  = 0.354    (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*78622.4/1.0*999.68*0.056/(1.34*195371*12.269^2*60.144*0.3)
  = 0.322    (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 * go^2 * ho * Ki )
  = 52.14*89708.4/1.0*999.68*0.056/(1.352*202713*12.269^2*60.144*0.3)
  = 0.351    (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*78622.4/1.0*999.68*0.056/(1.352*195371*12.269^2*60.144*0.3)
  = 0.319    (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.587, Temperature Reduction per Fig. UCS 66.1 = 24 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -16 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -39 °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.

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
Channel Cover		59	17.45	3	323.85	117.9
Channel Barrel		59	17.45	3	323.85	117.9
Channel FLG.		59	...	3	288.84	137.9
Shell FLG.		62.032	...	3	288.84	137.9
Shell Barrel		62.029	17.45	3	293.31	117.9
Shell Cover		62.029	17.45	3	323.85	117.9

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.
Channel Cover		59	109.099	140.693	17.4498	10.5598
Channel Barrel		59	92.1158	115.524	15.2686	10.9446
Channel FLG.		59	71.9072	79.0445	60	59.4868
Shell FLG.		62	71.8756	79.0445	60	59.4868
Shell Barrel		62	92.0868	115.524	15.2686	11.1308
Shell Cover		62	109.071	140.693	17.4498	10.9308

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      =              64 bars
Shell Side MAPnc     =              79 bars
Channel Side  MAWP   =              63 bars
Channel Side  MAPnc  =              69 bars
```

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. C at 95 °C

Channel Cover
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
  = (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
  = (59.0*323.85*0.974)/(2*117.9*1.0+2*59.0*(0.974-0.1))
  = 7.5598 + 3.0000 = 10.5598 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

```
  = (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
  = (2*117.9*1.0*14.4498)/(0.974*323.85-2*14.4498*(0.97-0.1))
  = 117 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
  = (2*117.9*1.0*17.4498)/(1.0*323.85-2*17.4498*(1.0-0.1))
  = 141 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
  = (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
  = (59.0*(0.974*323.85-2*14.4498*(0.974-0.1)))/(2*1.0*14.4498)
  = 59.224 N./mm²
```

Straight Flange Required Thickness:

```
  = (P*Ro)/(S*E+0.4*P) + ca   per Appendix 1-1 (a)(1)
  = (59.0*161.925)/(117.9*1.0+0.4*59.0)+3.0
  = 10.945 mm.
```

Straight Flange Maximum Allowable Working Pressure:

```
  = (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
  = (117.9 * 1.0 * 14.4498)/(161.925 - 0.4 * 14.4498 )
  = 109 bars
```

Factor K, corroded condition [Kcor]:

```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 294.95/( 2 * 75.238 ))²)/6
  = 0.973683
```

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 17.45, tr = 8.079, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.559, Temp. Reduction = 26 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve C            -30 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -48 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 17.45, tr = 8.504, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.588, Temp. Reduction = 23 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve C            -30 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -48 °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. C at 95 °C

Channel Barrel
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (59.0*161.925)/(117.9*1.0+0.4*59.0)
= 7.9446 + 3.0000 = 10.9446 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (117.9*1.0*12.2686)/(161.925-0.4*12.2686)
= 92 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (117.9*1.0*15.2686)/(161.925-0.4*15.2686)
= 116 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Ro-0.4*t))/(E*t)
= (59.0*((161.925-0.4*12.2686))/(1.0*12.2686)
= 75.515 N./mm²

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 15.269, tr = 3.971, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.324, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve C	-33 °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 50 To 60 SA-106 B , UCS-66 Crv. C at 145 °C

Shell Barrel
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (62.029*149.6564)/(117.9*1.0-0.6*62.029)
= 8.1308 + 3.0000 = 11.1308 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.029 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (117.9*1.0*12.2686)/(149.6564+0.6*12.2686)
= 92 - 0 = 92 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (117.9*1.0*15.2686)/(146.6564+0.6*15.2686)
= 116 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
= (P*(R+0.6*t))/(E*t)
= (62.029*(149.6564+0.6*12.2686))/(1.0*12.2686)
= 79.392 N./mm²
```

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 15.269, tr = 8.4, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.685, Temp. Reduction = 18 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve C          -33 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Elliptical Head From 60 To 70 SA-234 WPB , UCS-66 Crv. C at 145 °C

Shell Cover
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
= (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
= (62.029*323.85*0.974)/(2*117.9*1.0+2*62.029*(0.974-0.1))
= 7.9308 + 3.0000 = 10.9308 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.029 bars

```
= (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
= (2*117.9*1.0*14.4498)/(0.974*323.85-2*14.4498*(0.97-0.1))
= 117 - 0 = 117  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
= (2*117.9*1.0*17.4498)/(1.0*323.85-2*17.4498*(1.0-0.1))
= 141 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
= (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
= (62.029*(0.974*323.85-2*14.4498*(0.974-0.1)))/(2*1.0*14.4498)
= 62.264 N./mm²
```

Straight Flange Required Thickness:

```
= (P*Ro)/(S*E+0.4*P) + ca   per Appendix 1-1 (a)(1)
= (62.029*161.925)/(117.9*1.0+0.4*62.029)+3.0
= 11.344 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.029 bars

```
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (117.9 * 1.0 * 14.4498)/(161.925 - 0.4 * 14.4498 )
= 109 - 0 = 109  bars
```

Factor K, corroded condition [Kcor]:

```
= ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))^2)/6
= ( 2 + ( 294.95/( 2 * 75.238 ))^2)/6
= 0.973683
```

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 17.45, tr = 8.174, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.566, Temp. Reduction = 25 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve C          -30 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 17.45, tr = 8.606, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.596, Temp. Reduction = 23 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve C          -30 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °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:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          83.223  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S        80.600  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)      102.145  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          70.420  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     88.660  bars
Pressure per App 27-4  = M.A.W.P.                        64.018  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          82.213  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S        76.700  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       89.025  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          69.565  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     84.370  bars
Pressure per App 27-4  = M.A.W.P.                        63.241  bars
```

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

```
= Test Factor * Design Pressure * Stress Ratio
```

```
  = 1.3 * 62.0 * 1.0
  = 80.600 bars
```

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

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 59.0 * 1.0
  = 76.700 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
Channel Cover	77.0	217.2	0.355	76.73
Channel Barrel	98.2	217.2	0.452	76.73
Shell Barrel	103.2	217.2	0.475	80.63
Shell Cover	80.9	217.2	0.373	80.63

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T1 (6in)	Nozzle	137.90	137.90	1.000
T2 (6in)	Nozzle	137.90	137.90	1.000
S2 (2in)	Nozzle	137.90	137.90	1.000
S1 (2in)	Nozzle	137.90	137.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
Channel Cover	117.90	117.90	1.000
Channel Barrel	117.90	117.90	1.000
Channel FLG.	137.90	137.90	1.000
Shell FLG.	137.90	137.90	1.000
Shell Barrel	117.90	117.90	1.000
Shell Cover	117.90	117.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
Tube Material	92.40	92.40	1.000
Tubesheet Material	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
T1 (6in)	94.74	223.40	0.424
T2 (6in)	94.74	223.40	0.424
S2 (2in)	21.68	223.40	0.097
S1 (2in)	21.68	223.40	0.097

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	323.85	14.4498	0.0061971	121.613
20	30	424.079	323.85	12.2686	0.0075771	122.731
30	40	No Calc	...	57	No Calc	No Calc
40	50	No Calc	...	57	No Calc	No Calc
50	60	1874.08	323.85	12.2686	0.0017652	100.852
60	70	No Calc	323.85	14.4498	0.0061971	121.613

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	17.4498	4.5	1.034	60.2877
20	30	15.2686	4.16145	1.034	61.9895
30	40	60	55.3212	1.034	No Calc
40	50	60	55.3212	1.034	No Calc
50	60	15.2686	5.18803	1.034	50.9389
60	70	17.4498	4.5	1.034	60.2877
Minimum					51

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	424.079	22822.9	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	1874.08	91165	No Calc	No Calc
60	70	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

Channel 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
14.450	323.85	22.41	0.0061971	121.61

MAEP = B/(K0*Do/t) = 121.6126/(0.9 *22.4121) = 60.2877 bars

Results for Required Thickness				Tca
Tca	Outer Dia	Do/t	Factor A	Factor B
0.838	323.85	386.26	0.0003596	35.95

MAEP = B/(K0*Do/t) = 35.9494/(0.9 *386.2587) = 1.0341 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)
= (1.727*294.9504*0.974)/(2*117.9*1.0-0.2*1.727)
= 0.2103 + 3.0000 = 3.2103 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*117.9*1.0*14.4498)/(0.974*294.9504+0.2*14.4498))/1.67
= 70 bars

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(60.29, 70.3341)
= 60.288 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

Channel 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
12.269	323.85	424.08	26.40	1.3095	0.0075771	122.73

MAEP = (4*B)/(3*(Do/t)) = (4*122.731)/(3*26.3967) = 61.9895 bars

Results for Required Thickness						Tca
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
1.161	323.85	424.08	278.83	1.3095	0.0002163	21.63

MAEP = (4*B)/(3*(Do/t)) = (4*21.6259)/(3*278.8336) = 1.0341 bars

Results for Maximum Stiffened Length						Slen
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
12.269	323.85	22822.94	26.40	50.0000	0.0015935	98.34

MAEP = (4*B)/(3*(Do/t)) = (4*98.335)/(3*26.3967) = 49.6674 bars

---

Cylindrical Shell From 50 to 60 Ext. Chart: CS-2 at 100 °C

Shell 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
12.269	323.85	1874.08	26.40	5.7869	0.0017652	100.85

MAEP = (4*B)/(3*(Do/t)) = (4*100.8523)/(3*26.3967) = 50.9389 bars

Results for Required Thickness						Tca
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
2.188	323.85	1874.08	148.01	5.7869	0.0001148	11.48

MAEP = (4*B)/(3*(Do/t)) = (4*11.4792)/(3*148.0099) = 1.034 bars

```
                                                  |                                  |
Results for Maximum Stiffened Length              |                             Slen |
--------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
 12.269 |     323.85 |    91164.96 |     26.40 |   50.0000 |  0.0015935 |    98.34 |
--------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*98.335)/(3*26.3967) = 49.6674 bars

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

Elliptical Head From 60 to 70 Ext. Chart: CS-2 at 100 °C

Shell 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 |
 14.450 |     323.85 |       22.41 | 0.0061971 |                               121.61 |
--------------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 121.6126/( 0.9 *22.4121 ) = 60.2877 bars

                                                  |                                  |
Results for Required Thickness                    |                              Tca |
--------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Do/t |  Factor A |                             Factor B |
  0.838 |     323.85 |      386.26 | 0.0003596 |                                35.95 |
--------------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 35.9494/( 0.9 *386.2587 ) = 1.0341 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)
= (1.727*294.9504*0.974)/(2*117.9*1.0-0.2*1.727)
= 0.2104 + 3.0000 = 3.2104 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*117.9*1.0*14.4498)/(0.974*294.9504+0.2*14.4498))/1.67
= 70 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 60.29, 70.3314 )
  = 60.288 bars
```

Thickness requirements per UG-33(a)(1) govern the required thickness of this head.

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	21.7056	6437.86	17.9739	6776.34	2.17056
20	30	46.2133	23653.6	38.6377	24631.2	4.62133
30	40	102.391	9667.83	99.2995	9901.67	10.2391
40	50	102.391	9667.83	99.2995	9901.67	10.2391
50	60	237.668	72883.6	198.708	77911.3	23.7668
60	70	21.7056	6437.86	17.9739	6776.34	2.17056
Total		532	128748.59	471	135898.56	53

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	Insl	0.95294	-10.7187	...	Ins: 10
20	Insl	2.00042	175	...	Ins: 20
20	Nozl	59.6105	175	221.193	T1 (6in)
20	Nozl	59.6105	175	221.193	T2 (6in)
20	Wght	20	175	...	PASS PARTITION
30	Insl	1.55818	82.55	...	Ins: 30
40	Liqd	9.66194	72.5	-16.711	Liquid: 40
40	Insl	3.39409	82.55	...	Ins: 40
50	Sadl	31.3277	100	410.694	Lft Sdl
50	Sadl	31.3277	1600	410.694	New Sdl
50	Liqd	72.8391	900	...	Liquid: 50
50	Insl	22.8378	900	...	Ins: 50
50	Nozl	9.99917	250	172.056	S2 (2in)
50	Nozl	9.99917	1454	172.056	S1 (2in)
50	Wght	20	1000	...	BAFFLE
60	Liqd	6.43394	74.0792	0.00018167	Liquid: 60
60	Insl	2.11541	60.7187	...	Ins: 60
30	FTsh	156.445	196	...	TS
30	Tube	180.734	1054	...	Tubes

Total Weight of Each Detail Type:

Saddles	62.7
Liquid	88.9
Insulation	32.9
Nozzles	139.2
Weights	40.0
Exchanger Components	337.2
Sum of the Detail Weights	700.8 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	585.3	585.3	585.3	585.3	585.3	585.3
Saddles	62.7	62.7	62.7	62.7	62.7	62.7
Nozzles	139.2	139.2	139.2	139.2	139.2	139.2
Wld Weights	40.0	40.0	40.0	40.0	40.0	40.0
Exchanger	337.2	337.2	337.2	337.2	337.2	337.2
Insulation	...	...	32.9	32.9	32.9	32.9
Ope. Liquid	...	...	...	...	...	88.9
Test Liquid	...	128.7	...	...	...	...
Tube Tst Lqd	...	33.3	...	...	...	...
Totals	1164.3	1326.3	1197.2	1197.2	1197.2	1286.1

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	1164.3 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	1326.3 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	1197.2 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	1197.2 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	1197.2 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	1286.1 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	1219.9 kg.
Field Test Wt.	- Empty Weight + Water (Full)	1300.1 kg.

Exchanger Tube Data

Volume of Exchanger tubes :	33271.0 Cm.
Weight of Ope Liq in tubes :	0.0 kg.
Weight of Water in tubes :	33.3 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	1645.57
20	30	3608.88
30	40	3846.15
40	50	3846.15
50	60	18560
60	70	1645.57
Total		33152.305 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
T1 (6in)	93.90	102.10	95	600	GR 1.1	...	...	...	...
T2 (6in)	93.90	102.10	95	600	GR 1.1	...	...	...	...
S2 (2in)	90.50	102.10	145	600	GR 1.1	...	...	...	...
S1 (2in)	90.50	102.10	145	600	GR 1.1	...	...	...	...

Shellside Flange Rating

Lowest Flange Pressure Rating was (Ope)[ShellSide]: 90.500 bars
Lowest Flange Pressure Rating was (Amb)[ShellSide]: 102.100 bars

Channelside Flange Rating

Lowest Flange Pressure Rating was (Ope)[TubeSide]: 93.900 bars
Lowest Flange Pressure Rating was (Amb)[TubeSide]: 102.100 bars

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.

Input Values:

```
Wind Design Code                                  ASCE-7 2010
Wind Load Reduction Scale Factor                        0.600
Basic Wind Speed                        [V]               232  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
```

Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:

```
  = min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q )/( 1 + 1.7 * gV * Izbar)))
  = min(0.85,0.925((1+1.7*3.4*0.228*0.991)/(1+1.7*3.4*0.228)))
  = min(0.85, 0.92 )
  = 0.850
```

```
Natural Frequency of Vessel (Operating)              33.000 Hz
Natural Frequency of Vessel (Empty)                  33.000 Hz
Natural Frequency of Vessel (Test)                   33.000 Hz

Force Coefficient                                [Cf] 0.590
Structure Height to Diameter ratio                    6.379
```

This is classified as a rigid structure. Static analysis performed.

Sample Calculation for the First Element

The ASCE code performs all calculations in Imperial Units only. The wind pressure is therefore computed in these units.

Value of [Alpha] and [Zg]:

```
  Exposure Category: C from Table 26.9.1
  Alpha = 9.5: Zg = 274320. mm.
```

Effective Height [z]:

```
  = Centroid Height + Vessel Base Elevation
  = 700.0 + 100.0 = 800.0 mm.
  = 2.625 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

```
  Because z (2.625 ft.) < 15 ft.
  = 2.01 * ( 15 / Zg ) 2 / Alpha
```

$= 2.01 * (15/900.0)^{2/9.5}$
$= 0.849$

Type of Hill: No Hill

Wind Directionality Factor [Kd]:
$= 0.95$, per Table 26.6-1

As there is No Hill Present: [Kzt]:
$K1 = 0, K2 = 0, K3 = 0$

Topographical Factor [Kzt]:
$= (1 + K1 * K2 * K3)^2$
$= (1 + 0.0* 0.0* 0.0)^2$
$= 1.0$

Velocity Pressure evaluated at height z, Imperial Units [qz]:
$= \max(16, 0.00256 * Kz * Kzt * Kd * V(mph)^2)$
$= \max(16, 0.00256 * 0.849 * 1.0 * 0.95 * 144.162^2)$
$= 42.9$ psf [209.487] Kgs/m^2

Force on the first element [F]:
$= qz * G * Cf * WindArea$
$= 42.906 * 0.85 * 0.59 * 0.704$
$= 15.1$ lbs. [67.3] N

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m²
Channel Cover	800.0	0.000	0.000	0.000	0.849	1.000	209.487
Channel Barrel	800.0	0.000	0.000	0.000	0.849	1.000	209.487
Channel FLG.	800.0	0.000	0.000	0.000	0.849	1.000	209.487
Shell FLG.	800.0	0.000	0.000	0.000	0.849	1.000	209.487
Shell Barrel	800.0	0.000	0.000	0.000	0.849	1.000	209.487
Shell Cover	800.0	0.000	0.000	0.000	0.849	1.000	209.487

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force N
PASS PARTITIO	0.00	800.00	209.49	0.00
BAFFLE	0.00	800.00	209.49	0.00

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm²	Wind Pressure Kgs/m²	Element Wind Load N
10	20	800	484.62	653.656	209.487	40.3801
20	30	800	484.62	1696.17	209.487	104.782
30	40	800	442.608	641.782	209.487	39.6465
40	50	800	538.608	780.982	209.487	48.2457
50	60	800	580.62	10451.2	209.487	645.628
60	70	800	580.62	935.147	209.487	57.7694

Note:
The Wind Loads calculated and printed in the Wind Load calculation report have been factored by the input scalar/load reduction factor of: 0.600.

Be sure the wind speed is in accordance with the specified wind design code.

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.250
Table Value Fa		1.000
Table Value Fv		1.330
Short Period Acceleration value Ss		1.125
Long Period Acceleration Value Sl		0.460
Moment Reduction Factor Tau		1.000
Force Modification Factor R		3.000
Site Class		D
Component Elevation Ratio	z/h	1.000
Amplification Factor	Ap	1.000
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		1.020
User Value of Sd1 (used if > 0)		0.385

Seismic Analysis Results:

Sms = Fa * Ss = 1.0 * 1.125 = 1.125
Sm1 = Fv * S1 = 1.33 * 0.46 = 0.612
Sds = 2/3 * Sms = 2/3 * 1.125 = 0.75

Sds = Max(0.8*Sds, SdsUser)
= Max(0.6, 1.02)
= 1.020

Sd1 = 2/3 * Sm1 = 2/3 * 0.612 = 0.408

Sd1 = Max(0.8*Sd1, Sd1User)
= Max(0.326, 0.385)
= 0.385

Check Approximate Fundamental Period from 12.8-7 [Ta]:
= Ct * hn^x where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)
= 0.020 * ($2.7777^{0.75}$)
= 0.043 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:
= (1/Natural Frequency) = (1/33.0)
= 0.030

Check the Value of T which is the smaller of Cu*Ta and T:
= Minimum Value of (1.4 * 0.043, 0.03) per 12.8.2
= 0.030

Compute the Seismic Force per equation 13.3-1, [Fp]:

```
  = 0.4 * Ap * Sds * W * ( 1 + 2*(z/h) ) / ( R / Ie )
  = 0.4 * 1.0 * 1.02 * 11963 * ( 1 + 2*1.0 )/( 3.0/1.25 )
  = 6100.939 N
```

Check the Maximum value of Fp per equation 13.3-2:

```
  = 1.6 * Sds * I * W
  = 1.6 * 1.02 * 1.25 * 11963 = 24403.76 N
```

Check the Minimum value of Fp per equation 13.3-3:

```
  = 0.3 * 1.02 * 1.25 * 11963
  = 4575.705 N
```

Compute the Total Base Shear V = Fp, [V]:

```
  = 6100.939 N
```

Vertical load per 12.4-4, [YEq]:

```
  = 0.2 * Sds * W
  = 0.2 * 1.02 * 11963
  = 2440.4 N
```

```
 Final Base Shear,      V = 4270.66 N
 Final Vertical Load, YEq = 1708.26 N
```

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight N	Element Ope Load N
10	20	144.475	1495.33	529.883
20	30	146.656	1495.33	537.883
30	40	144.42	1495.33	529.68
40	50	144.42	1495.33	529.68
50	Sadl	146.656	1495.33	537.883
Sadl	60	146.656	1495.33	537.883
50	60	146.656	1495.33	537.883
60	70	144.475	1495.33	529.883

Note:
The Earthquake Loads calculated and printed in the Earthquake Load calculation report have been factored by the input scalar/load reduction factor of: 0.700.

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 Saddles	1642.525 mm.
Center of Gravity of the Liquid	1657.342 mm.
Center of Gravity of the Insulation	1458.844 mm.
Center of Gravity of the Nozzles	428.909 mm.
Center of Gravity of the Added Weights (Operating)	1008.762 mm.
Center of Gravity of the Added Weights (Empty)	1008.762 mm.
Center of Gravity of the Tubesheet(s)	596.000 mm.
Center of Gravity of the Tubes	1454.000 mm.
Center of Gravity of Bare Shell New and Cold	1110.810 mm.
Center of Gravity of Bare Shell Corroded	1080.811 mm.
Vessel CG in the Operating Condition	1078.231 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1050.019 mm.
Vessel CG in the Test Condition	1075.867 mm.

ASME Horizontal Vessel Analysis: Bundle pullout, Left Saddle

This saddle was not processed as the coefficient of friction was specified and the directive was set to only analyze the fixed saddle for this case.

ASME Horizontal Vessel Analysis: Bundle pullout, Right Saddle

This saddle was not processed as the coefficient of friction was specified and the directive was set to only analyze the fixed saddle for this case.

ASME Horizontal Vessel Analysis: Bundle pullout, Left Saddle

This saddle was not processed as the coefficient of friction was specified and the directive was set to only analyze the fixed saddle for this case.

ASME Horizontal Vessel Analysis: Bundle pullout, Right Saddle

This saddle was not processed as the coefficient of friction was specified and the directive was set to only analyze the fixed saddle for this case.

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Width (100.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:

```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 80.0 + 1.56*sqrt( 155.7907 * 12.2686 ), 2 * 100.0 )
= 148.2012 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	155.79	mm.
Stiffened Vessel Length per 4.15.6	L	1995.00	mm.
Distance from Saddle to Vessel tangent	a	100.00	mm.
Saddle Width	b	80.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		117.90	N./mm²
Head Allowable Stress used in Calculation		137.90	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	700.00	mm.
Coefficient of Friction	mu	0.30	
Saddle Force Q, Operating Case		26087.13	N

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	28.09	117.90
Long. Stress at Bottom of Midspan	50.67	117.90
Long. Stress at Top of Saddles	39.10	117.90
Long. Stress at Bottom of Saddles	39.53	117.90
Tangential Shear in Shell	14.38	94.32
Circ. Stress at Horn of Saddle	9.95	147.38
Circ. Compressive Stress in Shell	1.09	117.90

Intermediate Results: Saddle Reaction Q due to Wind or Seismic:

Saddle Reaction Force due to Wind Ft [Fwt]:

```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 936.5/2 + 0 ) * 700.0/297.7828
= 3302.0 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 189.46, 3400.72, 0 ) * 700.0/1500.0
= 1587.0 N
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 4270.66, 3400.72, 0 ) * 700.0/1500.0
= 1993.0 N
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 4271/2 + 0 ) * 700.0/297.7828
= 15058.6 N
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 11029 + max( 1587, 3302, 1993, 15059 )
= 26087.1 N
```

Longitudinal Wind Force [Fl]:
```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 2054.32( 0.0 + ( 0.128 * 1.2 ))
= 189.467 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		26394.33	N
Transverse Shear Load Saddle	Ft	2135.33	N
Longitudinal Shear Load Saddle		4270.66	N

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

Saddle Dimension [E]:
```
= min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
= min( 2( 293.313/2 + 15.269 + 10.0 )sin( 60.0/2 ), 2*155.791 )
= 297.783 mm.
```

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0245	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
```
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -26087*100.0[1-(1-100.0/1995.0+(155.791²-0.0²)/
  (2*100.0*1995.0))/(1+(4*0.0)/(3*1995.0))]
= 27.9 N-m
```

Moment per Equation 4.15.4 [M2]:
```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
```

```
  = 26087*1995/4(1+2(156²-0²)/(1995²))/(1+(4*0)/
    (3*1995))-4*100/1995
  = 10565.2 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 62.014 * 155.791/(2*12.269) - 10565.2/(pi*155.8²*12.269)
  = 28.09 N./mm²
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 62.014 * 155.791/(2 * 12.269) + 10565.2/(pi * 155.8² * 12.269 )
  = 50.67 N./mm²
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 62.014*155.791/(2*12.269)-27.9/(0.1066*pi*155.8²*12.269)
  = 39.10 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 62.014*155.791/(2*12.269)+27.9/(0.1923*pi*155.8²*12.269)
  = 39.53 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
  = Q(L-2a)/(L+(4*h2/3))
  = 26087( 1995.0 - 2 * 100.0)/(1995.0 + ( 4 * 0.0/3))
  = 23471.9 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 23471.88/( 155.7907 * 12.2686 )
  = 14.38 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 155.791 * 12.269 )
  = 34.101 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 26087 * 0.1/( 12.269 * ( 80.0 + 34.1 + 34.1 ) )
  = -1.09 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
  = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -26087/(4*12.269*(80.0+34.101+34.101)) -
     3* 0.0245*26087/(2*12.269²)
  = -9.95 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 80.0 + 1.56 * sqrt( 155.791 * 12.269 ), 2 * 100.0 )
  = 148.20 mm.
```

Distance between Saddle Supports [Ls]:
= 1500.0 mm.

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
= Alpha * Ls(Design Temperature - Ambient Temperature)
= 0.000012 * 1500.0(145.0 - 21.1)
= 2.303 mm.

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	320.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	565.0	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	166.8	12.3	6.1	20.5	12556.6	0.117E+05
Wearplate	100.0	10.0	17.3	10.0	17268.6	0.521E+04
Web	10.0	516.1	280.3	51.6	1446589.5	0.121E+05
BasePlate	150.0	12.0	544.3	18.0	979818.4	0.161E+05
Totals	...	...	...	100.1	2456233.0	0.451E+05

Distance to Centroid [C1]:
= AY / A
= 967.021/100.077
= 245.434 mm.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)²)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 26087.133
= 5309.2974 N

Tension Stress, St = (Fh/As) = 0.6670 N./mm²
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 N./mm²

Saddle Splitting Dimension [d]:
```
= B - R * sin(theta/2)/(theta/2 in radians)
= 700.0 - 149.66 * sin(120.0/2)/1.0472
= 576.235 mm.
```

```
Bending Moment, M  = Fh * d          =       3060.6436  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          1.6652  N./mm²
Allowed Stress, Sa = 2/3 * Yield Str =        159.9640  N./mm²
```

Minimum Thickness of Baseplate per Moss:
```
= ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
= ( 3(26087 + 307)150.0/( 2 * 320.0 * 159.964 ))½
= 10.772 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
```
= 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
= 2 * cos( 90 - 120.0/2 )( 146.656 + 15.269 + 10.0 )
= 297.783 mm.
```

Distance between Ribs [e]:
```
= Web Length / ( Nribs - 1 )
= 297.7828/( 2 - 1 )
= 297.783 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 297.7828 * 150.0/2
= 223.337 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 26087.133/( 320.0 * 150.0 )
= 54.348 N/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 223.3 * 54.35
= 12137.969 N
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 7.0 + 14.889
= 21.889 cm²
```

Compressive Stress [Sc]:
```
= P/Ar
= 12138.0/21.8891
= 5.546 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	70.0	45.0	7.0	31500.0	80.4
Web	148.9	10.0	5.0	14.9	7444.6	25.6
Totals	...	...	...	21.9	38944.6	106.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 80.0 - 10.0
= 70.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 38944.562/21.889
= 17.792 mm.
```

Distance to Centroid [C1]:
```
= max( ytot, Saddle Width - ytot )
= max( 17.792, 80.0 - 17.792 )
= 62.208 mm.
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 106.0/21.889 )
= 22.007 mm.
```

Length of Outer Rib [L]:
```
= Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
= 700.0 - cos( 120.0/2 )( 146.656 + 15.269 + 10.0 ) - 12.0
= 602.038 mm.
```

Intermediate Term [Cc]:
```
= sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
= sqrt( 2 * pi² * 0.19994E+09/239.9 )
= 128.255
```

Slenderness ratio [KL/r]:
```
= KL/r
= 1 * 602.038/22.007
= 27.357
```

Bending Moment [Rm]:
```
= Fl /( 2 * Bplen ) * e * L / 2
= 4270.7/( 2 * 320.0 ) * 297.783 * 602.04/2
= 598.390 N-m
```

Compressive Allowable, KL/r < Cc (27.3571 < 128.2549) per AISC E2-1 [Sca]:
```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 27.36 )²/(2 * 128.25² ))240/
  ( 5/3+3*(27.36)/(8* 128.25)-( 27.36³)/(8*128.25³)
```

= 134.3 N./mm²

AISC Unity Check of Outside Ribs (must be <= 1)

= Sc/Sca + (Rm * C1 / I)/Sba
= 5.55/134.34 + (598.39 * 62.208/1060072)/159.96
= 0.261

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	50.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	11335.7	N
Saddle Load QL (Wind/Seismic contribution)	QL	1993.0	N
Maximum Transverse Force	Ft	2135.3	N
Maximum Longitudinal Force	Fl	4270.7	N
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

= Fl / (Bolt Area * Number of Bolts)
= 4271/(2.17 * 2)
= 9.8 N./mm². Must be less than 180.0 N./mm².

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

= Ft / (Bolt Area * Number of Bolts)
= 2135/(2.17 * 2)
= 4.9 N./mm². Must be less than 180.0 N./mm².

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

= 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:

= Fl / (BoltShearAllowable * Nbolts)
= 4270.66/(180.0 * 2.0)
= 0.1186 cm²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

= B * Ft + Sum of X Moments
= 700.0 * 2135.33 + 0.0
= 1495.34 N-m

Eccentricity (e):

= Rmom / QO

```
 = 1495.34/11335.74
 = 131.86 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis
  = 320.0/2 - 50.01
  = 109.99 mm.

K1 = 3 (e - 0.5 * Bplen)
   = 3 (131.86 - 0.5*320.0)
   = -84.42 mm.

K2 = 6 * n1 * At / Bpwid * (f + e)
   = 6 * 1.0 * 2.17/150.0 * (109.99 + 131.86)
   = 2099.73 mm.²

K3 = -K2 * (0.5 * Bplen + f)
   = -2099.73 * (0.5 * 320.0 + 109.99)
   = -566899.98 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
Y³ + K1 * Y² + K2 * Y + K3 = 0
Y³ + -84.42 * Y² + 2099.73 * Y + -566900. = 0
Y  = 111.31 mm.

Num = (Bplen / 2 - Y / 3 - e)
    = (320.0/2 - 111.31/3 - 131.86)
    = -8.96

Denom = (Bplen / 2 - Y / 3 + f)
      = (320.0/2 - 111.31/3 + 109.99)
      = 232.88
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 11335.74 * -8.96/232.88
  = 436.30 N
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 436.3/( 300.0 * 1.0 )
  = 0.0145 cm²
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.1186, 0.0145]
  = 0.1186 cm²
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(11335.74 + 436.3)/(111.31 * 150.0)
  = 14.10 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
= (Bplen - Weblngth) / 2
= (320.0 - 269.2)/2
= 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
= Tforce * Adist
= 436.3 * 25.4
= 11.09 N-m
```

Equivalent Bearing Pressure (f1):
```
= fc * (Y - Adist) / Y
= 14.1 * (111.31 - 25.4)/111.31
= 10.88 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 150.0/6) * (10.88 + 2 * 14.1)
= 63.07 N-m
```

Baseplate Required Thickness [Treq]:
```
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(11.09,63.07/(150.0 * 142.73))½
= 4.2035 mm.
```

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Note:
Wear Pad Width (100.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 80.0 + 1.56*sqrt( 155.7907 * 12.2686 ), 2 * 200.0 )
= 148.2012 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	155.79	mm.
Stiffened Vessel Length per 4.15.6	L	1995.00	mm.
Distance from Saddle to Vessel tangent	a	200.00	mm.
Saddle Width	b	80.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	75.24	mm.
Shell Allowable Stress used in Calculation		117.90	N./mm²
Head Allowable Stress used in Calculation		117.90	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	

```
Distance from Saddle Base to Centerline        B      700.00  mm.
Coefficient of Friction                       mu        0.30

Saddle Force Q, Operating Case                        17086.54  N

Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                         N./mm² |       N./mm² |
-----------------------------------------------------------------
Long. Stress at Top    of Midspan         34.27 |       117.90 |
Long. Stress at Bottom of Midspan         44.48 |       117.90 |
Long. Stress at Top    of Saddles         43.53 |       117.90 |
Long. Stress at Bottom of Saddles         37.08 |       117.90 |
-----------------------------------------------------------------
Tangential Shear in Shell                  7.97 |        94.32 |
Circ. Stress at Horn of Saddle            11.35 |       147.38 |
Circ. Compressive Stress in Shell          0.71 |       117.90 |
-----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Wind or Seismic:

Saddle Reaction Force due to Wind Ft [Fwt]:

```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 936.5/2 + 0 ) * 700.0/297.7828
= 3302.0 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 189.46, 700.54, 0 ) * 700.0/1500.0
= 326.9 N
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:

```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 4270.66, 700.54, 0 ) * 700.0/1500.0
= 1993.0 N
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 4271/2 + 0 ) * 700.0/297.7828
= 15058.6 N
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 2028 + max( 327, 3302, 1993, 15059 )
= 17086.5 N
```

Longitudinal Wind Force [Fl]:

```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 2054.32( 0.0 + ( 0.128 * 1.2 ))
= 189.467 N
```

Summary of Loads at the base of this Saddle:

```
Vertical Load (including saddle weight)            17393.74  N
Transverse Shear Load Saddle          Ft            2135.33  N
Longitudinal Shear Load Saddle                      4270.66  N
```

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

Saddle Dimension [E]:

```
= min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
= min( 2( 293.313/2 + 15.269 + 10.0 )sin( 60.0/2 ), 2*155.791 )
= 297.783 mm.
```

The Computed K values from Table 4.15.1:

```
K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
K5  = 0.7603     K6  = 0.0529     K7  = 0.0529     K8  = 0.3405
K9  = 0.2711     K10 = 0.0581     K1* = 0.1923
```

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -17087*200.0[1-(1-200.0/1995.0+(155.791²-75.238²)/
  (2*200.0*1995.0))/(1+(4*75.24)/(3*1995.0))]
= -414.1 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 17087*1995/4(1+2(156²-75²)/(1995²))/(1+(4*75)/
  (3*1995))-4*200/1995
= 4774.4 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 62.014 * 155.791/(2*12.269) - 4774.4/(pi*155.8²*12.269)
= 34.27 N./mm²
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 62.014 * 155.791/(2 * 12.269) + 4774.4/(pi * 155.8² * 12.269 )
= 44.48 N./mm²
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 62.014*155.791/(2*12.269)--414.1/(0.1066*pi*155.8²*12.269)
= 43.53 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 62.014*155.791/(2*12.269)+-414.1/(0.1923*pi*155.8²*12.269)
= 37.08 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
= Q(L-2a)/(L+(4*h2/3))
= 17087( 1995.0 - 2 * 200.0)/(1995.0 + ( 4 * 75.24/3))
= 13006.6 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
= K2 * T / ( Rm * t )
= 1.1707 * 13006.64/( 155.7907 * 12.2686 )
= 7.97 N./mm²
```

Decay Length (4.15.22) [x1,x2]:
```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 155.791 * 12.269 )
= 34.101 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= - 0.7603 * 17087 * 0.1/( 12.269 * ( 80.0 + 34.1 + 34.1 ) )
= -0.71 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:
```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -17087/(4*12.269*(80.0+34.101+34.101)) -
   3* 0.0529*17087/(2*12.269²)
= -11.35 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:
```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 80.0 + 1.56 * sqrt( 155.791 * 12.269 ), 2 * 200.0 )
= 148.20 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	320.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	306.0	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	166.8	12.3	6.1	20.5	12556.6	0.117E+05
Wearplate	100.0	10.0	17.3	10.0	17268.6	0.521E+04
Web	10.0	516.1	280.3	51.6	1446589.5	0.121E+05
BasePlate	150.0	12.0	544.3	18.0	979818.4	0.161E+05
Totals	...	...	...	100.1	2456233.0	0.451E+05

Distance to Centroid [C1]:
```
= AY / A
= 967.021/100.077
```

= 245.434 mm.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)²)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 17086.541
= 3477.4817 N

Tension Stress, St = (Fh/As) = 0.4369 N./mm²
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 N./mm²

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 700.0 - 149.66 * sin(120.0/2)/1.0472
= 576.235 mm.

Bending Moment, M = Fh * d = 2004.6593 N-m

Bending Stress, Sb = (M * C1 / I) = 1.0907 N./mm²
Allowed Stress, Sa = 2/3 * Yield Str = 159.9640 N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(17087 + 307)150.0/(2 * 320.0 * 159.964))½
= 8.744 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
= 2 * cos(90 - Saddle Angle/2)(Inside Radius + Shell Thk + Wear Plate Thk)
= 2 * cos(90 - 120.0/2)(146.656 + 15.269 + 10.0)
= 297.783 mm.

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 297.7828/(2 - 1)
= 297.783 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 297.7828 * 150.0/2
= 223.337 cm²

Bearing Pressure [Bp]:
= Q / (BasePlateLength * BasePlateWidth)
= 17086.541/(320.0 * 150.0)

= 35.597 N/cm²

Axial Load [P]:
= Ap * Bp
= 223.3 * 35.6
= 7950.122 N

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 7.0 + 14.889
= 21.889 cm²

Compressive Stress [Sc]:
= P/Ar
= 7950.1/21.8891
= 3.632 N./mm²

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	70.0	45.0	7.0	31500.0	80.4
Web	148.9	10.0	5.0	14.9	7444.6	25.6
Totals	...	...	...	21.9	38944.6	106.

Rib dimension [D]:
= Saddle Width - Web Thickness
= 80.0 - 10.0
= 70.000 mm.

Distance to Centroid from Datum [ytot]:
= AY / A
= 38944.562/21.889
= 17.792 mm.

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(17.792, 80.0 - 17.792)
= 62.208 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(106.0/21.889)
= 22.007 mm.

Length of Outer Rib [L]:
= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 700.0 - cos(120.0/2)(146.656 + 15.269 + 10.0) - 12.0
= 602.038 mm.

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)

= sqrt(2 * pi² * 0.19994E+09/239.9)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 602.038/22.007
= 27.357

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 4270.7/(2 * 320.0) * 297.783 * 602.04/2
= 598.390 N-m

Compressive Allowable, KL/r < Cc (27.3571 < 128.2549) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(27.36)²/(2 * 128.25²))240/
(5/3+3*(27.36)/(8* 128.25)-(27.36³)/(8*128.25³)
= 134.3 N./mm²

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 3.63/134.34 + (598.39 * 62.208/1060072)/159.96
= 0.246

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	50.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	2335.1	N
Saddle Load QL (Wind/Seismic contribution)	QL	1993.0	N
Maximum Transverse Force	Ft	2135.3	N
Maximum Longitudinal Force	Fl	4270.7	N
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
= Fl / (Bolt Area * Number of Bolts)
= 4271/(2.17 * 2)
= 9.8 N./mm². Must be less than 180.0 N./mm².

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
= Ft / (Bolt Area * Number of Bolts)
= 2135/(2.17 * 2)
= 4.9 N./mm². Must be less than 180.0 N./mm².

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

```
  = 0.0 (QO > QL --> No Uplift in Longitudinal direction)
```

Bolt Area due to Shear Load [Bltarears]:

```
  = Fl / ( BoltShearAllowable * Nbolts )
  = 4270.66/(180.0 * 2.0)
  = 0.1186 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 700.0 * 2135.33 + 0.0
  = 1495.34 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 1495.34/2335.15
  = 640.10 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 320.0/2 - 50.01
   = 109.99 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (640.1 - 0.5*320.0)
    = 1440.30 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 2.17/150.0 * (109.99 + 640.1)
    = 6512.29 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -6512.29 * (0.5 * 320.0 + 109.99)
    = -1758236.19 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 1440.3 * Y² + 6512.29 * Y + -0.2E+07 = 0
 Y  = 32.41 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (320.0/2 - 32.41/3 - 640.1)
     = -490.90

 Denom = (Bplen / 2 - Y / 3 + f)
       = (320.0/2 - 32.41/3 + 109.99)
       = 259.18
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 2335.15 * -490.9/259.18
```

= 4422.87 N

Bolt Area Required due to Transverse Load [Bltareart]:
= Tforce / (Stba * Nbt)
= 4422.87/(300.0 * 1.0)
= 0.1474 cm²

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.1186, 0.1474]
= 0.1474 cm²

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
= 2(QO + Tforce) / (Y * Bpwid)
= 2(2335.15 + 4422.87)/(32.41 * 150.0)
= 27.80 bars

Distance from Baseplate Edge to the Web [ADIST]:
= (Bplen - Weblngth) / 2
= (320.0 - 269.2)/2
= 25.4000 mm.

Overturning Moment due To Bolt Tension [Mt]:
= Tforce * Adist
= 4422.87 * 25.4
= 112.39 N-m

Equivalent Bearing Pressure (f1):
= fc * (Y - Adist) / Y
= 27.8 * (32.41 - 25.4)/32.41
= 6.01 bars

Overturning Moment due to Bearing Pressure [Mc]:
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 150.0/6) * (6.01 + 2 * 27.8)
= 99.42 N-m

Baseplate Required Thickness [Treq]:
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(112.39,99.42/(150.0 * 142.73))½
= 5.6113 mm.

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Test Case

Note:
Wear Pad Width (100.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:

```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 80.0 + 1.56*sqrt( 155.7907 * 12.2686 ), 2 * 100.0 )
= 148.2012 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	155.79	mm.
Stiffened Vessel Length per 4.15.6	L	1995.00	mm.
Distance from Saddle to Vessel tangent	a	100.00	mm.
Saddle Width	b	80.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		192.78	N./mm²
Head Allowable Stress used in Calculation		192.78	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	700.00	mm.
Coefficient of Friction	mu	0.30	
Saddle Force Q, Test Case, no Ext. Forces		12480.95	N

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	45.79	192.78
Long. Stress at Bottom of Midspan	56.59	192.78
Long. Stress at Top of Saddles	51.05	192.78
Long. Stress at Bottom of Saddles	51.26	192.78
Tangential Shear in Shell	6.88	128.63
Circ. Stress at Horn of Saddle	4.76	289.17
Circ. Compressive Stress in Shell	0.52	192.78

Intermediate Results: Saddle Reaction Q due to Wind or Seismic:

Saddle Reaction Force due to Wind Ft [Fwt]:

```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 309.0/2 + 0 ) * 700.0/297.7828
= 1089.7 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 62.52, 0.0, 0 ) * 700.0/1500.0
= 29.2 N
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 11391 + max( 29, 1090, 0, 0 )
= 12481.0 N
```

Longitudinal Wind Force [Fl]:
```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 2054.32( 0.0 + ( 0.128 * 1.2 ))
= 189.467 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	12788.15	N
Transverse Shear Load Saddle Ft	154.51	N
Longitudinal Shear Load Saddle	62.52	N

Hydrostatic Test Pressure at center of Vessel 80.615 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

Saddle Dimension [E]:
```
= min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
= min( 2( 293.313/2 + 15.269 + 10.0 )sin( 60.0/2 ), 2*155.791 )
= 297.783 mm.
```

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0245	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
```
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -12481*100.0[1-(1-100.0/1995.0+(155.791²-0.0²)/
  (2*100.0*1995.0))/(1+(4*0.0)/(3*1995.0))]
= 13.4 N-m
```

Moment per Equation 4.15.4 [M2]:
```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 12481*1995/4(1+2(156²-0²)/(1995²))/(1+(4*0)/
  (3*1995))-4*100/1995
= 5054.7 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 80.615 * 155.791/(2*12.269) - 5054.7/(pi*155.8²*12.269)
= 45.79 N./mm²
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 80.615 * 155.791/(2 * 12.269) + 5054.7/(pi * 155.8² * 12.269 )
= 56.59 N./mm²
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 80.615*155.791/(2*12.269)-13.4/(0.1066*pi*155.8²*12.269)
= 51.05 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 80.615*155.791/(2*12.269)+13.4/(0.1923*pi*155.8²*12.269)
= 51.26 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
= Q(L-2a)/(L+(4*h2/3))
= 12481( 1995.0 - 2 * 100.0)/(1995.0 + ( 4 * 0.0/3))
= 11229.7 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

```
= K2 * T / ( Rm * t )
= 1.1707 * 11229.73/( 155.7907 * 12.2686 )
= 6.88 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 155.791 * 12.269 )
= 34.101 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= - 0.7603 * 12481 * 0.1/( 12.269 * ( 80.0 + 34.1 + 34.1 ) )
= -0.52 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -12481/(4*12.269*(80.0+34.101+34.101)) -
   3* 0.0245*12481/(2*12.269²)
= -4.76 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 80.0 + 1.56 * sqrt( 155.791 * 12.269 ), 2 * 100.0 )
= 148.20 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	320.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	565.0	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	166.8	12.3	6.1	20.5	12556.6	0.117E+05
Wearplate	100.0	10.0	17.3	10.0	17268.6	0.521E+04
Web	10.0	516.1	280.3	51.6	1446589.5	0.121E+05
BasePlate	150.0	12.0	544.3	18.0	979818.4	0.161E+05
Totals	...	...	...	100.1	2456233.0	0.451E+05

Distance to Centroid [C1]:
= AY / A
= 967.021/100.077
= 245.434 mm.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)²)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 12480.95
= 2540.1440 N

Tension Stress, St = (Fh/As) = 0.3191 N./mm²
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 N./mm²

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 700.0 - 149.66 * sin(120.0/2)/1.0472
= 576.235 mm.

Bending Moment, M = Fh * d = 1464.3136 N-m

Bending Stress, Sb = (M * C1 / I) = 0.7967 N./mm²
Allowed Stress, Sa = 2/3 * Yield Str = 159.9640 N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(12481 + 307)150.0/(2 * 320.0 * 159.964))½
= 7.498 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
```
= 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
= 2 * cos( 90 - 120.0/2 )( 146.656 + 15.269 + 10.0 )
= 297.783 mm.
```

Distance between Ribs [e]:
```
= Web Length / ( Nribs - 1 )
= 297.7828/( 2 - 1 )
= 297.783 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 297.7828 * 150.0/2
= 223.337 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 12480.95/( 320.0 * 150.0 )
= 26.002 N/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 223.3 * 26.0
= 5807.207 N
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 7.0 + 14.889
= 21.889 cm²
```

Compressive Stress [Sc]:
```
= P/Ar
= 5807.2/21.8891
= 2.653 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	70.0	45.0	7.0	31500.0	80.4
Web	148.9	10.0	5.0	14.9	7444.6	25.6
Totals	...	...	...	21.9	38944.6	106.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 80.0 - 10.0
= 70.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
```

```
  = 38944.562/21.889
  = 17.792 mm.
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 17.792, 80.0 - 17.792 )
  = 62.208 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 106.0/21.889 )
  = 22.007 mm.
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 700.0 - cos( 120.0/2 )( 146.656 + 15.269 + 10.0 ) - 12.0
  = 602.038 mm.
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/239.9 )
  = 128.255
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 602.038/22.007
  = 27.357
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 62.5/( 2 * 320.0 ) * 297.783 * 602.04/2
  = 8.760 N-m
```

Compressive Allowable, KL/r < Cc (27.3571 < 128.2549) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 27.36 )²/(2 * 128.25² ))240/
    ( 5/3+3*(27.36)/(8* 128.25)-( 27.36³)/(8*128.25³)
  = 134.3 N./mm²
```

AISC Unity Check of Outside Ribs (must be <= 1)

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.65/134.34 + ( 8.76 * 62.208/1060072 )/159.96
  = 0.023
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	50.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²

```
Area Available in a Single Bolt                BltArea      2.1705  cm²
Saddle Load QO (Weight)                            QO     11698.5  N
Saddle Load QL (Wind/Seismic contribution)         QL        29.2  N
Maximum Transverse Force                           Ft       154.5  N
Maximum Longitudinal Force                         Fl        62.5  N
Saddle Bolted to Steel Foundation                           Yes
```

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
= Fl / ( Bolt Area * Number of Bolts )
= 63/( 2.17 * 2 )
= 0.1 N./mm².  Must be less than 180.0 N./mm².
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
= Ft / ( Bolt Area * Number of Bolts )
= 155/( 2.17 * 2 )
= 0.4 N./mm².  Must be less than 180.0 N./mm².
```

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

```
= 0.0 (QO > QL --> No Uplift in Longitudinal direction)
```

Bolt Area due to Shear Load [Bltarears]:

```
= Fl / ( BoltShearAllowable * Nbolts )
= 62.52/(180.0 * 2.0)
= 0.0017 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
= B * Ft + Sum of X Moments
= 700.0 * 154.51 + 0.0
= 108.20 N-m
```

Eccentricity (e):

```
= Rmom / QO
= 108.2/11698.49
= 9.25 mm. < Bplen/6 --> No Uplift in Transverse direction
```

Bolt Area due to Transverse Load [Bltareart]:

```
= 0 (No Uplift)
```

Required Area of a Single Bolt [Bltarear]:

```
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.0017, 0.0]
= 0.0017 cm²
```

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle

(per ASME Sec. VIII Div. 2 based on the Zick method.)

Note:
Wear Pad Width (100.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 80.0 + 1.56*sqrt( 155.7907 * 12.2686 ), 2 * 200.0 )
= 148.2012 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	155.79	mm.
Stiffened Vessel Length per 4.15.6	L	1995.00	mm.
Distance from Saddle to Vessel tangent	a	200.00	mm.
Saddle Width	b	80.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	75.24	mm.
Shell Allowable Stress used in Calculation		192.78	N./mm²
Head Allowable Stress used in Calculation		192.78	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	700.00	mm.
Coefficient of Friction	mu	0.30	
Saddle Force Q, Test Case, no Ext. Forces		2411.44	N

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	50.47	192.78
Long. Stress at Bottom of Midspan	51.91	192.78
Long. Stress at Top of Saddles	51.77	192.78
Long. Stress at Bottom of Saddles	50.86	192.78
Tangential Shear in Shell	1.12	128.63
Circ. Stress at Horn of Saddle	1.60	289.17
Circ. Compressive Stress in Shell	0.10	192.78

Intermediate Results: Saddle Reaction Q due to Wind or Seismic:

Saddle Reaction Force due to Wind Ft [Fwt]:
```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 309.0/2 + 0 ) * 700.0/297.7828
= 1089.7 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 62.52, 0.0, 0 ) * 700.0/1500.0
= 29.2 N
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 1322 + max( 29, 1090, 0, 0 )
```

= 2411.4 N

Longitudinal Wind Force [Fl]:
= WindScalar * WindPress(Platform Area + (End Area * WindDiaMult))
= 0.6 * 2054.32(0.0 + (0.128 * 1.2))
= 189.467 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		2718.64	N
Transverse Shear Load Saddle	Ft	154.51	N
Longitudinal Shear Load Saddle		62.52	N

Hydrostatic Test Pressure at center of Vessel 80.615 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

Saddle Dimension [E]:
= min(2(ShellID/2 + t + WearPadThickness)sin(theta/2), 2*Rm)
= min(2(293.313/2 + 15.269 + 10.0)sin(60.0/2), 2*155.791)
= 297.783 mm.

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -2411*200.0[1-(1-200.0/1995.0+(155.791²-75.238²)/
(2*200.0*1995.0))/(1+(4*75.24)/(3*1995.0))]
= -58.4 N-m

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 2411*1995/4(1+2(156²-75²)/(1995²))/(1+(4*75)/
(3*1995))-4*200/1995
= 673.8 N-m

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 80.615 * 155.791/(2*12.269) - 673.8/(pi*155.8²*12.269)
= 50.47 N./mm²

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 80.615 * 155.791/(2 * 12.269) + 673.8/(pi * 155.8² * 12.269)
= 51.91 N./mm²

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)

```
= 80.615*155.791/(2*12.269)--58.4/(0.1066*pi*155.8²*12.269)
= 51.77 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 80.615*155.791/(2*12.269)+-58.4/(0.1923*pi*155.8²*12.269)
= 50.86 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
= Q(L-2a)/(L+(4*h2/3))
= 2411( 1995.0 - 2 * 200.0)/(1995.0 + ( 4 * 75.24/3))
= 1835.6 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

```
= K2 * T / ( Rm * t )
= 1.1707 * 1835.64/( 155.7907 * 12.2686 )
= 1.12 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 155.791 * 12.269 )
= 34.101 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= - 0.7603 * 2411 * 0.1/( 12.269 * ( 80.0 + 34.1 + 34.1 ) )
= -0.10 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -2411/(4*12.269*(80.0+34.101+34.101)) -
   3* 0.0529*2411/(2*12.269²)
= -1.60 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 80.0 + 1.56 * sqrt( 155.791 * 12.269 ), 2 * 200.0 )
= 148.20 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	320.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	306.0	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	166.8	12.3	6.1	20.5	12556.6	0.117E+05
Wearplate	100.0	10.0	17.3	10.0	17268.6	0.521E+04
Web	10.0	516.1	280.3	51.6	1446589.5	0.121E+05
BasePlate	150.0	12.0	544.3	18.0	979818.4	0.161E+05
Totals	...	...	...	100.1	2456233.0	0.451E+05

Distance to Centroid [C1]:
= AY / A
= 967.021/100.077
= 245.434 mm.

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)²)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 2411.445
= 490.7813 N

Tension Stress, St = (Fh/As) = 0.0617 N./mm²
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 N./mm²

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 700.0 - 149.66 * sin(120.0/2)/1.0472
= 576.235 mm.

Bending Moment, M = Fh * d = 282.9201 N-m

Bending Stress, Sb = (M * C1 / I) = 0.1539 N./mm²
Allowed Stress, Sa = 2/3 * Yield Str = 159.9640 N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(2411 + 307)150.0/(2 * 320.0 * 159.964))½
= 3.457 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
= 2 * cos(90 - Saddle Angle/2)(Inside Radius + Shell Thk + Wear Plate Thk)
= 2 * cos(90 - 120.0/2)(146.656 + 15.269 + 10.0)
= 297.783 mm.

Distance between Ribs [e]:
```
= Web Length / ( Nribs - 1 )
= 297.7828/( 2 - 1 )
= 297.783 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 297.7828 * 150.0/2
= 223.337 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 2411.445/( 320.0 * 150.0 )
= 5.024 N/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 223.3 * 5.02
= 1122.011 N
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 7.0 + 14.889
= 21.889 cm²
```

Compressive Stress [Sc]:
```
= P/Ar
= 1122.0/21.8891
= 0.513 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	70.0	45.0	7.0	31500.0	80.4
Web	148.9	10.0	5.0	14.9	7444.6	25.6
Totals	...	...	...	21.9	38944.6	106.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 80.0 - 10.0
= 70.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 38944.562/21.889
= 17.792 mm.
```

Distance to Centroid [C1]:
```
= max( ytot, Saddle Width - ytot )
= max( 17.792, 80.0 - 17.792 )
= 62.208 mm.
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 106.0/21.889 )
= 22.007 mm.
```

Length of Outer Rib [L]:
```
= Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
= 700.0 - cos( 120.0/2 )( 146.656 + 15.269 + 10.0 ) - 12.0
= 602.038 mm.
```

Intermediate Term [Cc]:
```
= sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
= sqrt( 2 * pi² * 0.19994E+09/239.9 )
= 128.255
```

Slenderness ratio [KL/r]:
```
= KL/r
= 1 * 602.038/22.007
= 27.357
```

Bending Moment [Rm]:
```
= Fl /( 2 * Bplen ) * e * L / 2
= 62.5/( 2 * 320.0 ) * 297.783 * 602.04/2
= 8.760 N-m
```

Compressive Allowable, KL/r < Cc (27.3571 < 128.2549) per AISC E2-1 [Sca]:
```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 27.36 )²/(2 * 128.25² ))240/
  ( 5/3+3*(27.36)/(8* 128.25)-( 27.36³)/(8*128.25³)
= 134.3 N./mm²
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
= Sc/Sca + ( Rm * C1 / I )/Sba
= 0.51/134.34 + ( 8.76 * 62.208/1060072 )/159.96
= 0.007
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	50.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	1629.0	N
Saddle Load QL (Wind/Seismic contribution)	QL	29.2	N
Maximum Transverse Force	Ft	154.5	N
Maximum Longitudinal Force	Fl	62.5	N
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 63/( 2.17 * 2 )
  = 0.1 N./mm².  Must be less than 180.0 N./mm².
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 155/( 2.17 * 2 )
  = 0.4 N./mm².  Must be less than 180.0 N./mm².
```

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:
```
  = 0.0 (QO > QL --> No Uplift in Longitudinal direction)
```

Bolt Area due to Shear Load [Bltarears]:
```
  = Fl / ( BoltShearAllowable * Nbolts )
  = 62.52/(180.0 * 2.0)
  = 0.0017 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 700.0 * 154.51 + 0.0
  = 108.20 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 108.2/1628.99
  = 66.40 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 320.0/2 - 50.01
   = 109.99 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (66.4 - 0.5*320.0)
    = -280.81 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 2.17/150.0 * (109.99 + 66.4)
    = 1531.38 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -1531.38 * (0.5 * 320.0 + 109.99)
    = -413452.45 mm.³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -280.81 * Y² + 1531.38 * Y + -413452.47 = 0
 Y  = 280.60 mm.

 Num = (Bplen / 2 - Y / 3 - e)
```

```
     = (320.0/2 - 280.6/3 - 66.4)
     = 0.07

Denom = (Bplen / 2 - Y / 3 + f)
      = (320.0/2 - 280.6/3 + 109.99)
      = 176.45
```

Total Bolt Tension Force [Tforce]:

```
= - QO * Num / Denom
= - 1628.99 * 0.07/176.45
= -0.64 N
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
= Tforce / (Stba * Nbt)
= -0.64/( 300.0 * 1.0 )
= -0.0000 cm²
```

Required Area of a Single Bolt [Bltarear]:

```
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.0017, -0.0]
= 0.0017 cm²
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
= 2(QO + Tforce) / (Y * Bpwid)
= 2(1628.99 + -0.64)/(280.6 * 150.0)
= 0.77 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
= (Bplen - Weblngth) / 2
= (320.0 - 269.2)/2
= 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
= Tforce * Adist
= -0.64 * 25.4
= -0.02 N-m
```

Equivalent Bearing Pressure (f1):

```
= fc * (Y - Adist) / Y
= 0.77 * (280.6 - 25.4)/280.6
= 0.70 bars
```

Overturning Moment due to Bearing Pressure [Mc]:

```
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 150.0/6) * ( 0.7 + 2 * 0.77)
= 3.63 N-m
```

Baseplate Required Thickness [Treq]:

```
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(-0.02,3.63/(150.0 * 142.73))½
= 1.0088 mm.
```

Input, Nozzle Desc: T1 (6in) **From: 20**

Pressure for Reinforcement Calculations	P	59.000	bars
Temperature for Internal Pressure	Temp	95	°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	288.95	mm.
Design Length of Section	L	424.0792	mm.
Shell Finished (Minimum) Thickness	t	15.2686	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		225.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

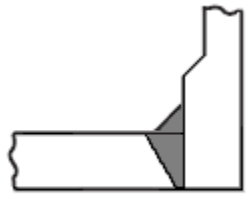
Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	90.0000	mm.
Height of Beveled Transition	L'	18.0000	mm.
Hub Thickness of Integral Nozzle (tn or x+tp)		35.0000	mm.
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	15.2686	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	

Flange Grade GR 1.1

The Pressure Design option was Design Pressure + static head.

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: T1 (6in)

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

Actual Inside Diameter Used in Calculation 5.869 in.
Actual Thickness Used in Calculation 0.378 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)
= (59.0*147.4752)/(118*1.0-0.6*59.0)
= 7.6089 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)
= (59.0*77.54)/(138*1.0-0.6*59.0)
= 3.4050 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.5131 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
= 2.5 * Corroded Hub Thickness
= 2.5 * 32.0 Note: less than the hub height, use (e-2)
= 80.0000 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
Parallel to Vessel Wall (Diameter Limit) Dl 310.1452 mm.

```
Parallel to Vessel Wall, opening length              d    155.0726  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     30.6714  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/117.9 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/117.9 )
= 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	11.799	0.901	NA
Area in Shell	A1	7.226	17.224	NA
Area in Nozzle Wall	A2	17.541	19.315	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
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	25.767	37.539	NA

The Internal 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]:

```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (155.0726*7.6089*1.0+2*32.0*7.6089*1.0*(1-1.0))
= 11.799 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 )
= 155.073( 1.0 * 12.2686 - 1.0 * 7.609 ) - 2 * 32.0
  ( 1.0 * 12.2686 - 1.0 * 7.6089 ) * ( 1 - 1.0 )
= 7.226 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 30.67 )( 32.0 - 3.4 )1.0
= 17.541 cm²
```

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

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm²
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

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

```
 Wall Thickness for Internal/External pressures      ta = 6.4050 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 10.6089 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 10.6089 mm.
 Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                   tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 10.6089, 4.5 ) ]
  = 9.2200 mm.
```

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

```
  = max( ta, tb )
  = max( 6.405, 9.22 )
  = 9.2200 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
 Sustained   :     72.3,  Allowable :    137.9 N./mm²  Passed
 Expansion   :      0.0,  Allowable :    272.5 N./mm²  Passed
 Occasional  :     33.2,  Allowable :    183.4 N./mm²  Passed
 Shear       :      7.5,  Allowable :     96.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 9.601, tr = 3.405, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.516, Temp. Reduction = 30 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -48 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:B, Curve:C)

Govrn. thk, tg = 15.269, tr = 7.609, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.62, Temp. Reduction = 21 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -16 °C
```

```
Min Metal Temp. at Required thickness (UCS 66.1)          -37 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -37 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -42 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
Design Pressure/Ambient Rating = 59.00/102.10 = 0.578
```

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):

```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 32.0 Note: less than the hub height, use (e-2)
  = 80.0000 mm.
```

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

```
Parallel to Vessel Wall (Diameter Limit)              Dl    243.6097  mm.
Parallel to Vessel Wall                          Rn+tn+t    121.8049  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     30.6714  mm.
```

Reinforcement Areas for Large Nozzle (Per App 1-7(a)): (cm²)

AREA AVAILABLE, A1 to A6		No Pad	With Pad
Area Required [Internal Pressure]	AR	7.867	7.867
Area Available in Shell	A1	4.126	4.126
Area Available in Nozzle Wall	A2	17.541	17.541
Area Available in Inward Nozzle	A3	0.000	0.000
Area Available in Welds	A4	1.000	1.000
Area Available in Pad	A5	0.000	0.000
Area Available in Hub	A6	0.000	0.000
TOTAL AREA AVAILABLE	Atot	22.667	22.667

```
The area available without a pad is Sufficient.
```

Note: The Nozzle does not fall within the scope of the diameter requirements of App. 1-7(b). Therefore, the Membrane and Bending stress checks are not required.

Weld Size Calculations, Description: T1 (6in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     14.4498  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	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, (11.7993 - 7.2258 + 2 * 32.0 * 1.0 *
  (1.0 * 12.2686 - 7.6089 ) )118)
= 89073.91 N
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:

```
= (A2+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 17.541 + 1. - 0.0 * 1.0 ) * 118
= 218579.94 N
```

Weld Load [W2]:

```
 = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
= ( 17.541 + 0.0 + 1. + ( 7.8519 ) ) * 118
= 311145.81 N
```

Weld Load [W3]:

```
= (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
= ( 17.541 + 0.0 + 1. + 0.0 ) * 118
= 311145.81 N
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 219.0726 * 10.0 * 0.49 * 118
= 198784. N
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 93.5363) * ( 35.0 - 3.0 ) * 0.7 * 138
= 907623. N
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 219.0726 * ( 15.2686 - 3.0 ) * 0.74 * 138
= 430786. N
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 198784 + 907623 ) = 1106407 N
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 198784 + 0 + 430786 + 0 ) = 629570 N
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 198784 + 430786 + 0 ) = 629570 N
```

Summary of Failure Path Calculations:

```
Path 1-1 = 1106406 N  , must exceed W = 89073 N   or W1 = 218579 N
Path 2-2 = 629570 N   , must exceed W = 89073 N   or W2 = 311145 N
Path 3-3 = 629570 N   , must exceed W = 89073 N   or W3 = 311145 N
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case    90  bars

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

The Drop for this Nozzle is : 50.2686 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.5372 mm.

Warning:
Review Appendix 1-7 (b)(1)(-c) for notes regarding externally applied loads to large nozzles and U-2(g).

Input Echo, WRC107/537 Item 1, Description: T1 (6in) :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	288.950	mm.
Vessel Thickness	Tv	15.269	mm.
Design Temperature	T1	95.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm²
Vessel Hot S.I. Allowable	Smh	117.90	N./mm²

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-106 B

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	149.073	mm.
Nozzle Thickness	Tn	35.000	mm.
Nozzle Material		SA-105	
Nozzle UNS Number		K03504	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm²
Design Internal Pressure	Dp	59.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

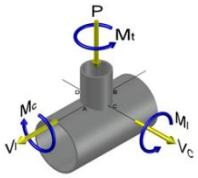
Radial Load	(SUS)	P	9600.0	N
Longitudinal Shear	(SUS)	Vl	9600.0	N

```
Circumferential Shear    (SUS)                Vc      -7200.0   N
Circumferential Moment   (SUS)                Mc      -2880.0   N-m
Longitudinal Moment      (SUS)                Ml      -3740.0   N-m
Torsional Moment         (SUS)                Mt      -4320.0   N-m


Use Interactive Control                                 No
WRC107 Version                           Version   March  1979

Include Pressure Stress Indices per Div. 2                      No
Compute Pressure Stress per WRC-368                             No
Local Loads applied at end of Nozzle/Attachment                 No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Error/Warning Messages for WRC107 Analysis 1
Warning - The ratio Ro/Rm, 0.7131 , must be > 0.0571 and < 0.571.

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 219.073 + 2 * 1.65 * sqrt( 153.609 ( 15.269 - 3.0 ) )
  = 362.331 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                  P        9600.0   N
Circumferential Shear                       VC       -7200.0   N
Longitudinal Shear                          VL        9600.0   N
Circumferential Moment                      MC       -2880.0   N-m
Longitudinal Moment                         ML       -3740.0   N-m
Torsional Moment                            MT       -4320.0   N-m

Dimensionless Parameters used :   Gamma =   12.52
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
-------------------------------------------------------------------
Curves read for 1979              Beta  Figure    Value   Location
-------------------------------------------------------------------
N(PHI) / ( P/Rm )                0.624   4C  !     1.429   (A,B)
N(PHI) / ( P/Rm )                0.624   3C  !     0.819   (C,D)
M(PHI) / ( P )                   0.624   2C1 !     0.018   (A,B)
M(PHI) / ( P )                   0.624   1C  !     0.055   (C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )   0.624   3A  !     0.507   (A,B,C,D)
```

```
M(PHI) / ( MC/(Rm    * Beta) )    0.624   1A  !     0.071    (A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )    0.624   3B  !     1.042    (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )    0.624   1B  !     0.014    (A,B,C,D)

N(x)   / ( P/Rm )                 0.624   3C  !     0.819    (A,B)
N(x)   / ( P/Rm )                 0.624   4C  !     1.429    (C,D)
M(x)   / ( P )                    0.624   1C1 !     0.034    (A,B)
M(x)   / ( P )                    0.624   2C  !     0.032    (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )    0.624   4A  !     1.332    (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )    0.624   2A  !     0.034    (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )    0.624   4B  !     0.518    (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )    0.624   2B  !     0.027    (A,B,C,D)
```

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-7.3	-7.3	-7.3	-7.3	-4.2	-4.2	-4.2	-4.2
Circ. Bend. P	-6.8	6.8	-6.8	6.8	-21.1	21.1	-21.1	21.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	8.1	8.1	-8.1	-8.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	84.8	-84.8	-84.8	84.8
Circ. Memb. ML	21.6	21.6	-21.6	-21.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	21.4	-21.4	-21.4	21.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	28.9	-0.3	-57.1	-0.6	67.6	-59.8	-118.1	93.6
Long. Memb. P	-4.2	-4.2	-4.2	-4.2	-7.3	-7.3	-7.3	-7.3
Long. Bend. P	-13.1	13.1	-13.1	13.1	-12.3	12.3	-12.3	12.3
Long. Memb. MC	0.0	0.0	0.0	0.0	21.2	21.2	-21.2	-21.2
Long. Bend. MC	0.0	0.0	0.0	0.0	40.8	-40.8	-40.8	40.8
Long. Memb. ML	10.7	10.7	-10.7	-10.7	0.0	0.0	0.0	0.0
Long. Bend. ML	41.9	-41.9	-41.9	41.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	35.4	-22.2	-70.0	40.2	42.4	-14.5	-81.6	24.5
Shear VC	-1.7	-1.7	1.7	1.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.3	-2.3	2.3	2.3
Shear MT	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7
Tot. Shear	-6.4	-6.4	-3.0	-3.0	-6.9	-6.9	-2.4	-2.4
Str. Int.	39.3	25.4	70.6	41.2	69.4	60.9	118.3	93.7

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	68.1	74.0	68.1	74.0	68.1	74.0	68.1	74.0
Circ. Pl (SUS)	14.3	14.3	-28.8	-28.8	3.9	3.9	-12.3	-12.3
Circ. Q (SUS)	14.6	-14.6	-28.2	28.2	63.7	-63.7	-105.9	105.9
Long. Pm (SUS)	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Long. Pl (SUS)	6.6	6.6	-14.9	-14.9	14.0	14.0	-28.5	-28.5
Long. Q (SUS)	28.8	-28.8	-55.1	55.1	28.5	-28.5	-53.1	53.1
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-1.7	-1.7	1.7	1.7	-2.3	-2.3	2.3	2.3
Shear Q (SUS)	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7
Pm (SUS)	68.1	74.0	68.1	74.0	68.1	74.0	68.1	74.0
Pm+Pl (SUS)	82.4	88.3	39.4	45.3	72.2	78.1	55.9	61.8
Pm+Pl+Q (Total)	98.4	74.3	47.3	76.8	136.5	24.3	51.5	167.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	73.99	117.90	Passed
Pm+Pl (SUS)	88.34	176.85	Passed
Pm+Pl+Q (TOTAL)	167.68	353.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: T2 (6in) **From: 20**

Pressure for Reinforcement Calculations	P	59.000	bars
Temperature for Internal Pressure	Temp	95	°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	288.95	mm.
Design Length of Section	L	424.0792	mm.
Shell Finished (Minimum) Thickness	t	15.2686	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		225.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

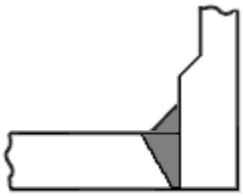
Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	90.0000	mm.
Height of Beveled Transition	L'	18.0000	mm.
Hub Thickness of Integral Nozzle (tn or x+tp)		35.0000	mm.
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	15.2686	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	

Flange Grade GR 1.1

The Pressure Design option was Design Pressure + static head.

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: T2 (6in)

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

Actual Inside Diameter Used in Calculation 5.869 in.
Actual Thickness Used in Calculation 0.378 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)
= (59.0*147.4752)/(118*1.0-0.6*59.0)
= 7.6089 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)
= (59.0*77.54)/(138*1.0-0.6*59.0)
= 3.4050 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.5131 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
= 2.5 * Corroded Hub Thickness
= 2.5 * 32.0 Note: less than the hub height, use (e-2)
= 80.0000 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
Parallel to Vessel Wall (Diameter Limit) Dl 310.1452 mm.

```
Parallel to Vessel Wall, opening length              d    155.0726  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     30.6714  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/117.9 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/117.9 )
= 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	11.799	0.901	NA
Area in Shell	A1	7.226	17.224	NA
Area in Nozzle Wall	A2	17.541	19.315	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
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	25.767	37.539	NA

The Internal 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]:

```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (155.0726*7.6089*1.0+2*32.0*7.6089*1.0*(1-1.0))
= 11.799 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 )
= 155.073( 1.0 * 12.2686 - 1.0 * 7.609 ) - 2 * 32.0
  ( 1.0 * 12.2686 - 1.0 * 7.6089 ) * ( 1 - 1.0 )
= 7.226 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 30.67 )( 32.0 - 3.4 )1.0
= 17.541 cm²
```

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

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm²
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

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

```
 Wall Thickness for Internal/External pressures      ta = 6.4050 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 10.6089 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 10.6089 mm.
 Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                   tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 10.6089, 4.5 ) ]
  = 9.2200 mm.
```

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

```
  = max( ta, tb )
  = max( 6.405, 9.22 )
  = 9.2200 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
 Sustained  :     72.3,  Allowable :    137.9 N./mm²  Passed
 Expansion  :      0.0,  Allowable :    272.5 N./mm²  Passed
 Occasional :     33.2,  Allowable :    183.4 N./mm²  Passed
 Shear      :      7.5,  Allowable :     96.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 9.601, tr = 3.405, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.516, Temp. Reduction = 30 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -48 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:B, Curve:C)

Govrn. thk, tg = 15.269, tr = 7.609, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.62, Temp. Reduction = 21 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -16 °C
```

```
Min Metal Temp. at Required thickness (UCS 66.1)          -37 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :  -37 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -42 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
Design Pressure/Ambient Rating = 59.00/102.10 = 0.578
```

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):

```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 32.0 Note: less than the hub height, use (e-2)
  = 80.0000 mm.
```

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    243.6097  mm.
Parallel to Vessel Wall                          Rn+tn+t  121.8049  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    30.6714  mm.
```

Reinforcement Areas for Large Nozzle (Per App 1-7(a)): (cm²)

AREA AVAILABLE, A1 to A6		No Pad	With Pad
Area Required [Internal Pressure]	AR	7.867	7.867
Area Available in Shell	A1	4.126	4.126
Area Available in Nozzle Wall	A2	17.541	17.541
Area Available in Inward Nozzle	A3	0.000	0.000
Area Available in Welds	A4	1.000	1.000
Area Available in Pad	A5	0.000	0.000
Area Available in Hub	A6	0.000	0.000
TOTAL AREA AVAILABLE	Atot	22.667	22.667

```
The area available without a pad is Sufficient.
```

Note: The Nozzle does not fall within the scope of the diameter requirements of App. 1-7(b). Therefore, the Membrane and Bending stress checks are not required.

Weld Size Calculations, Description: T2 (6in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     14.4498  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld         6.0000 = Min per Code 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, (11.7993 - 7.2258 + 2 * 32.0 * 1.0 *
  (1.0 * 12.2686 - 7.6089 ) )118)
= 89073.91 N
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:

```
= (A2+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 17.541 + 1. - 0.0 * 1.0 ) * 118
= 218579.94 N
```

Weld Load [W2]:

```
 = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
= ( 17.541 + 0.0 + 1. + ( 7.8519 ) ) * 118
= 311145.81 N
```

Weld Load [W3]:

```
= (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
= ( 17.541 + 0.0 + 1. + 0.0 ) * 118
= 311145.81 N
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 219.0726 * 10.0 * 0.49 * 118
= 198784. N
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 93.5363) * ( 35.0 - 3.0 ) * 0.7 * 138
= 907623. N
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 219.0726 * ( 15.2686 - 3.0 ) * 0.74 * 138
= 430786. N
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 198784 + 907623 ) = 1106407 N
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 198784 + 0 + 430786 + 0 ) = 629570 N
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 198784 + 430786 + 0 ) = 629570 N
```

Summary of Failure Path Calculations:

```
Path 1-1 = 1106406 N  , must exceed W = 89073 N   or W1 = 218579 N
Path 2-2 = 629570 N  , must exceed W = 89073 N   or W2 = 311145 N
Path 3-3 = 629570 N  , must exceed W = 89073 N   or W3 = 311145 N
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case    90  bars

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

The Drop for this Nozzle is : 50.2686 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.5372 mm.

Warning:
Review Appendix 1-7 (b)(1)(-c) for notes regarding externally applied loads to large nozzles and U-2(g).

Input Echo, WRC107/537 Item 1, Description: T2 (6in) :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	288.950	mm.
Vessel Thickness	Tv	15.269	mm.
Design Temperature	T1	95.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm²
Vessel Hot S.I. Allowable	Smh	117.90	N./mm²

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-106 B

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	149.073	mm.
Nozzle Thickness	Tn	35.000	mm.
Nozzle Material		SA-105	
Nozzle UNS Number		K03504	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm²
Design Internal Pressure	Dp	59.000	bars
Include Pressure Thrust		No	

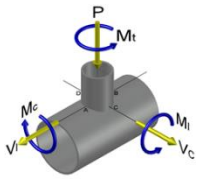
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	9600.0	N
Longitudinal Shear	(SUS)	Vl	9600.0	N
Circumferential Shear	(SUS)	Vc	-7200.0	N
Circumferential Moment	(SUS)	Mc	-2880.0	N-m
Longitudinal Moment	(SUS)	Ml	-3740.0	N-m
Torsional Moment	(SUS)	Mt	-4320.0	N-m

```
 Use Interactive Control                              No
 WRC107 Version                          Version  March  1979

 Include Pressure Stress Indices per Div. 2                 No
 Compute Pressure Stress per WRC-368                        No
 Local Loads applied at end of Nozzle/Attachment            No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Error/Warning Messages for WRC107 Analysis 1
Warning - The ratio Ro/Rm, 0.7131 , must be > 0.0571 and < 0.571.

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 219.073 + 2 * 1.65 * sqrt( 153.609 ( 15.269 - 3.0 ) )
  = 362.331 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
 Radial Load                                  P       9600.0  N
 Circumferential Shear                       VC      -7200.0  N
 Longitudinal Shear                          VL       9600.0  N
 Circumferential Moment                      MC      -2880.0  N-m
 Longitudinal Moment                         ML      -3740.0  N-m
 Torsional Moment                            MT      -4320.0  N-m

 Dimensionless Parameters used :   Gamma =   12.52
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.624	4C	!	1.429	(A,B)
N(PHI) / (P/Rm)	0.624	3C	!	0.819	(C,D)
M(PHI) / (P)	0.624	2C1	!	0.018	(A,B)
M(PHI) / (P)	0.624	1C	!	0.055	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.624	3A	!	0.507	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.624	1A	!	0.071	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.624	3B	!	1.042	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.624	1B	!	0.014	(A,B,C,D)

```
N(x)   / ( P/Rm )                 0.624   3C  !     0.819   (A,B)
N(x)   / ( P/Rm )                 0.624   4C  !     1.429   (C,D)
M(x)   / ( P )                    0.624   1C1 !     0.034   (A,B)
M(x)   / ( P )                    0.624   2C  !     0.032   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )    0.624   4A  !     1.332   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )    0.624   2A  !     0.034   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )    0.624   4B  !     0.518   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )    0.624   2B  !     0.027   (A,B,C,D)
```

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-7.3	-7.3	-7.3	-7.3	-4.2	-4.2	-4.2	-4.2
Circ. Bend. P	-6.8	6.8	-6.8	6.8	-21.1	21.1	-21.1	21.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	8.1	8.1	-8.1	-8.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	84.8	-84.8	-84.8	84.8
Circ. Memb. ML	21.6	21.6	-21.6	-21.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	21.4	-21.4	-21.4	21.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	28.9	-0.3	-57.1	-0.6	67.6	-59.8	-118.1	93.6
Long. Memb. P	-4.2	-4.2	-4.2	-4.2	-7.3	-7.3	-7.3	-7.3
Long. Bend. P	-13.1	13.1	-13.1	13.1	-12.3	12.3	-12.3	12.3
Long. Memb. MC	0.0	0.0	0.0	0.0	21.2	21.2	-21.2	-21.2
Long. Bend. MC	0.0	0.0	0.0	0.0	40.8	-40.8	-40.8	40.8
Long. Memb. ML	10.7	10.7	-10.7	-10.7	0.0	0.0	0.0	0.0
Long. Bend. ML	41.9	-41.9	-41.9	41.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	35.4	-22.2	-70.0	40.2	42.4	-14.5	-81.6	24.5
Shear VC	-1.7	-1.7	1.7	1.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.3	-2.3	2.3	2.3
Shear MT	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7
Tot. Shear	-6.4	-6.4	-3.0	-3.0	-6.9	-6.9	-2.4	-2.4
Str. Int.	39.3	25.4	70.6	41.2	69.4	60.9	118.3	93.7

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	68.1	74.0	68.1	74.0	68.1	74.0	68.1	74.0
Circ. Pl (SUS)	14.3	14.3	-28.8	-28.8	3.9	3.9	-12.3	-12.3
Circ. Q (SUS)	14.6	-14.6	-28.2	28.2	63.7	-63.7	-105.9	105.9
Long. Pm (SUS)	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Long. Pl (SUS)	6.6	6.6	-14.9	-14.9	14.0	14.0	-28.5	-28.5
Long. Q (SUS)	28.8	-28.8	-55.1	55.1	28.5	-28.5	-53.1	53.1
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-1.7	-1.7	1.7	1.7	-2.3	-2.3	2.3	2.3
Shear Q (SUS)	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7
Pm (SUS)	68.1	74.0	68.1	74.0	68.1	74.0	68.1	74.0
Pm+Pl (SUS)	82.4	88.3	39.4	45.3	72.2	78.1	55.9	61.8
Pm+Pl+Q (Total)	98.4	74.3	47.3	76.8	136.5	24.3	51.5	167.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	73.99	117.90	Passed
Pm+Pl (SUS)	88.34	176.85	Passed
Pm+Pl+Q (TOTAL)	167.68	353.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: S2 (2in) **From: 50**

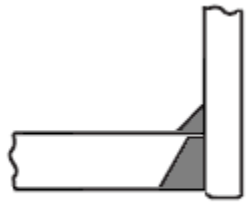
Pressure for Reinforcement Calculations	P	62.029	bars
Temperature for Internal Pressure	Temp	145	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	293.31	mm.
Design Length of Section	L	1874.0792	mm.
Shell Finished (Minimum) Thickness	t	15.2686	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1042.53	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	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	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	15.2686	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	
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: S2 (2in)

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

```
Actual Inside Diameter Used in Calculation          2.000  in.
Actual Thickness Used in Calculation                0.654  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)
  = (62.03*149.6564)/(118*1.0-0.6*62.03)
  = 8.1308 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)
  = (62.03*28.4)/(138*1.0-0.6*62.03)
  = 1.3130 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   113.6000  mm.
Parallel to Vessel Wall, opening length            d    56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   30.6714  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/117.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/117.9 )
```

= 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	4.618	0.621	NA
Area in Shell	A1	2.350	5.726	NA
Area in Nozzle Wall	A2	7.537	8.132	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	10.887	14.858	NA

The Internal 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]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (56.8*8.1308*1.0+2*13.6*8.1308*1.0*(1-1.0))
= 4.618 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)
= 56.8(1.0 * 12.2686 - 1.0 * 8.131) - 2 * 13.6
(1.0 * 12.2686 - 1.0 * 8.1308) * (1 - 1.0)
= 2.350 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 30.67)(13.6 - 1.31)1.0
= 7.537 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10.0² * 1.0 + (0.0)² * 1.0
= 1.000 cm²

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

Wall Thickness for Internal/External pressures ta = 4.3130 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 11.1308 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 11.1308 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.

Wall Thickness per table UG-45 tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.8, max(11.1308, 4.5)]
= 7.8000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(4.313, 7.8)
= 7.8000 mm.

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained :	17.8,	Allowable :	137.9 N./mm²	Passed
Expansion :	0.0,	Allowable :	327.0 N./mm²	Passed
Occasional :	5.2,	Allowable :	183.4 N./mm²	Passed
Shear :	3.3,	Allowable :	96.5 N./mm²	Passed

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:B, Curve:C)

Govrn. thk, tg = 15.269, tr = 8.131, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.663, Temp. Reduction = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-16 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-34 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C
Gov. MDMT of the nozzle to shell joint welded assembly :	-34 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)	-18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)	-40 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 62.03/102.10 = 0.608

Weld Size Calculations, Description: S2 (2in)

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	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, (4.6183 - 2.3503 + 2 * 13.6 * 1.0 *
  (1.0 * 12.2686 - 8.1308 ) )118)
= 40005.70 N
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 7.5372 + 0.0 + 1. - 0.0 * 1.0 ) * 118
= 100645.21 N
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 7.5372 + 0.0 + 1. + ( 3.3371 ) ) * 118
= 139985.69 N
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 7.5372 + 0.0 + 1. + 0.0 + ( 3.3371 ) ) * 118
= 139985.69 N
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 118
= 76221. N
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
= 145163. N
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 84.0 * ( 15.2686 - 3.0 ) * 0.74 * 138
= 165178. N
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 76221 + 145163 ) = 221384 N
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 76221 + 0 + 165178 + 0 ) = 241399 N
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 76221 + 165178 + 0 ) = 241399 N
```

Summary of Failure Path Calculations:

```
Path 1-1 = 221383 N  , must exceed W = 40005 N   or W1 = 100645 N
Path 2-2 = 241398 N  , must exceed W = 40005 N   or W2 = 139985 N
Path 3-3 = 241398 N  , must exceed W = 40005 N   or W3 = 139985 N
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 92 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 : 6.1427 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 171.4113 mm.

Input Echo, WRC107/537 Item 1, Description: S2 (2in) :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	293.313	mm.
Vessel Thickness	Tv	15.269	mm.
Design Temperature	T1	145.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm²
Vessel Hot S.I. Allowable	Smh	117.90	N./mm²

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-105	
Nozzle UNS Number		K03504	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm²
Design Internal Pressure	Dp	62.029	bars
Include Pressure Thrust		No	

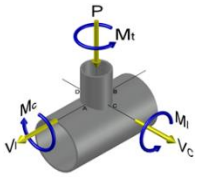
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3200.0	N
Longitudinal Shear	(SUS)	Vl	3200.0	N
Circumferential Shear	(SUS)	Vc	-2400.0	N
Circumferential Moment	(SUS)	Mc	-320.0	N-m
Longitudinal Moment	(SUS)	Ml	-420.0	N-m
Torsional Moment	(SUS)	Mt	-480.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979

```
Include Pressure Stress Indices per Div. 2                No
Compute Pressure Stress per WRC-368                       No
Local Loads applied at end of Nozzle/Attachment           No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 155.791 ( 15.269 - 3.0 ) )
  = 228.272 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                  P        3200.0   N
Circumferential Shear                        VC      -2400.0   N
Longitudinal Shear                           VL       3200.0   N
Circumferential Moment                       MC       -320.0   N-m
Longitudinal Moment                          ML       -420.0   N-m
Torsional Moment                             MT       -480.0   N-m

Dimensionless Parameters used :   Gamma =   12.70
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.236	4C	2.071	(A,B)
N(PHI) / (P/Rm)	0.236	3C	1.654	(C,D)
M(PHI) / (P)	0.236	2C1	0.060	(A,B)
M(PHI) / (P)	0.236	1C	0.088	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.236	3A	0.474	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.236	1A	0.090	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.236	3B	1.459	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.236	1B	0.038	(A,B,C,D)
N(x) / (P/Rm)	0.236	3C	1.654	(A,B)
N(x) / (P/Rm)	0.236	4C	2.071	(C,D)
M(x) / (P)	0.236	1C1	0.091	(A,B)
M(x) / (P)	0.236	2C	0.060	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.236	4A	0.802	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.236	2A	0.050	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.236	4B	0.467	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.236	2B	0.061	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-3.5	-3.5	-3.5	-3.5	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-7.7	7.7	-7.7	7.7	-11.2	11.2	-11.2	11.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	2.2	2.2	-2.2	-2.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	31.3	-31.3	-31.3	31.3
Circ. Memb. ML	8.7	8.7	-8.7	-8.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	17.3	-17.3	-17.3	17.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.	14.8	-4.3	-37.1	12.7	19.5	-20.7	-47.4	37.6
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-3.5	-3.5	-3.5	-3.5
Long. Bend. P	-11.6	11.6	-11.6	11.6	-7.6	7.6	-7.6	7.6
Long. Memb. MC	0.0	0.0	0.0	0.0	3.7	3.7	-3.7	-3.7
Long. Bend. MC	0.0	0.0	0.0	0.0	17.3	-17.3	-17.3	17.3
Long. Memb. ML	2.8	2.8	-2.8	-2.8	0.0	0.0	0.0	0.0
Long. Bend. ML	27.9	-27.9	-27.9	27.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	16.4	-16.3	-45.1	33.9	9.9	-9.5	-32.0	17.8
Shear VC	-1.5	-1.5	1.5	1.5	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.0	-2.0	2.0	2.0
Shear MT	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5
Tot. Shear	-5.0	-5.0	-2.0	-2.0	-5.5	-5.5	-1.6	-1.6
Str. Int.	20.7	18.1	45.6	34.1	22.0	22.9	47.6	37.7

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	72.7	78.9	72.7	78.9	72.7	78.9	72.7	78.9
Circ. Pl (SUS)	5.3	5.3	-12.2	-12.2	-0.6	-0.6	-4.9	-4.9
Circ. Q (SUS)	9.6	-9.6	-24.9	24.9	20.1	-20.1	-42.5	42.5
Long. Pm (SUS)	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3
Long. Pl (SUS)	0.0	0.0	-5.6	-5.6	0.2	0.2	-7.1	-7.1
Long. Q (SUS)	16.4	-16.4	-39.5	39.5	9.7	-9.7	-24.9	24.9
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-1.5	-1.5	1.5	1.5	-2.0	-2.0	2.0	2.0
Shear Q (SUS)	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5
Pm (SUS)	72.7	78.9	72.7	78.9	72.7	78.9	72.7	78.9
Pm+Pl (SUS)	78.0	84.2	60.6	66.8	72.2	78.4	67.9	74.0
Pm+Pl+Q (Total)	88.2	75.0	44.5	91.8	92.8	59.1	25.4	116.5

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	78.89	117.90	Passed
Pm+Pl (SUS)	84.19	176.85	Passed
Pm+Pl+Q (TOTAL)	116.49	353.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: S1 (2in) **From: 50**

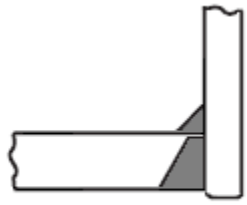
Pressure for Reinforcement Calculations	P	62.000	bars
Temperature for Internal Pressure	Temp	145	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	293.31	mm.
Design Length of Section	L	1874.0792	mm.
Shell Finished (Minimum) Thickness	t	15.2686	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2246.53	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	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	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	15.2686	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	
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: S1 (2in)

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

```
Actual Inside Diameter Used in Calculation          2.000  in.
Actual Thickness Used in Calculation                0.654  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)
  = (62.0*149.6564)/(118*1.0-0.6*62.0)
  = 8.1269 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)
  = (62.0*28.4)/(138*1.0-0.6*62.0)
  = 1.3123 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   113.6000  mm.
Parallel to Vessel Wall, opening length            d    56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   30.6714  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/117.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/117.9 )
```

= 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	4.616	0.621	NA
Area in Shell	A1	2.352	5.726	NA
Area in Nozzle Wall	A2	7.538	8.132	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	10.890	14.858	NA

The Internal 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]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (56.8*8.1269*1.0+2*13.6*8.1269*1.0*(1-1.0))
= 4.616 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)
= 56.8(1.0 * 12.2686 - 1.0 * 8.127) - 2 * 13.6
(1.0 * 12.2686 - 1.0 * 8.1269) * (1 - 1.0)
= 2.352 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 30.67)(13.6 - 1.31)1.0
= 7.538 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10.0² * 1.0 + (0.0)² * 1.0
= 1.000 cm²

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

Wall Thickness for Internal/External pressures ta = 4.3123 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 11.1269 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 11.1269 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.

Wall Thickness per table UG-45 tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.8, max(11.1269, 4.5)]
= 7.8000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(4.3123, 7.8)
= 7.8000 mm.

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained :	17.8,	Allowable :	137.9 N./mm²	Passed
Expansion :	0.0,	Allowable :	327.0 N./mm²	Passed
Occasional :	5.2,	Allowable :	183.4 N./mm²	Passed
Shear :	10.3,	Allowable :	96.5 N./mm²	Passed

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:B, Curve:C)

Govrn. thk, tg = 15.269, tr = 8.127, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.662, Temp. Reduction = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-16 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-34 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C
Gov. MDMT of the nozzle to shell joint welded assembly :	-34 °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)	-48 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607

Weld Size Calculations, Description: S1 (2in)

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	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, (4.6161 - 2.3525 + 2 * 13.6 * 1.0 *
  (1.0 * 12.2686 - 8.1269 ) )118)
= 39966.05 N
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 7.5376 + 0.0 + 1. - 0.0 * 1.0 ) * 118
= 100649.73 N
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 7.5376 + 0.0 + 1. + ( 3.3371 ) ) * 118
= 139990.22 N
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 7.5376 + 0.0 + 1. + 0.0 + ( 3.3371 ) ) * 118
= 139990.22 N
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 118
= 76221. N
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
= 145163. N
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 84.0 * ( 15.2686 - 3.0 ) * 0.74 * 138
= 165178. N
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 76221 + 145163 ) = 221384 N
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 76221 + 0 + 165178 + 0 ) = 241399 N
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 76221 + 165178 + 0 ) = 241399 N
```

Summary of Failure Path Calculations:

```
Path 1-1 = 221383 N  , must exceed W = 39966 N   or W1 = 100649 N
Path 2-2 = 241398 N  , must exceed W = 39966 N   or W2 = 139990 N
Path 3-3 = 241398 N  , must exceed W = 39966 N   or W3 = 139990 N
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 92 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 : 6.1427 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 171.4113 mm.

Input Echo, WRC107/537 Item 1, Description: S1 (2in) :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	293.313	mm.
Vessel Thickness	Tv	15.269	mm.
Design Temperature	T1	145.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm²
Vessel Hot S.I. Allowable	Smh	117.90	N./mm²

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-105	
Nozzle UNS Number		K03504	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm²
Design Internal Pressure	Dp	62.000	bars
Include Pressure Thrust		No	

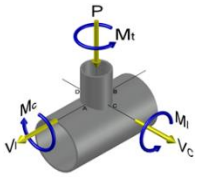
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3200.0	N
Longitudinal Shear	(SUS)	Vl	3200.0	N
Circumferential Shear	(SUS)	Vc	2400.0	N
Circumferential Moment	(SUS)	Mc	320.0	N-m
Longitudinal Moment	(SUS)	Ml	420.0	N-m
Torsional Moment	(SUS)	Mt	480.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979

```
Include Pressure Stress Indices per Div. 2                No
Compute Pressure Stress per WRC-368                       No
Local Loads applied at end of Nozzle/Attachment           No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 155.791 ( 15.269 - 3.0 ) )
  = 228.272 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                  P        3200.0   N
Circumferential Shear                        VC       2400.0   N
Longitudinal Shear                           VL       3200.0   N
Circumferential Moment                       MC        320.0   N-m
Longitudinal Moment                          ML        420.0   N-m
Torsional Moment                             MT        480.0   N-m

Dimensionless Parameters used :   Gamma =   12.70
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.236	4C	2.071	(A,B)
N(PHI) / (P/Rm)	0.236	3C	1.654	(C,D)
M(PHI) / (P)	0.236	2C1	0.060	(A,B)
M(PHI) / (P)	0.236	1C	0.088	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.236	3A	0.474	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.236	1A	0.090	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.236	3B	1.459	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.236	1B	0.038	(A,B,C,D)
N(x) / (P/Rm)	0.236	3C	1.654	(A,B)
N(x) / (P/Rm)	0.236	4C	2.071	(C,D)
M(x) / (P)	0.236	1C1	0.091	(A,B)
M(x) / (P)	0.236	2C	0.060	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.236	4A	0.802	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.236	2A	0.050	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.236	4B	0.467	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.236	2B	0.061	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-3.5	-3.5	-3.5	-3.5	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-7.7	7.7	-7.7	7.7	-11.2	11.2	-11.2	11.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.2	-2.2	2.2	2.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-31.3	31.3	31.3	-31.3
Circ. Memb. ML	-8.7	-8.7	8.7	8.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-17.3	17.3	17.3	-17.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-37.1	12.7	14.8	-4.3	-47.4	37.6	19.5	-20.7
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-3.5	-3.5	-3.5	-3.5
Long. Bend. P	-11.6	11.6	-11.6	11.6	-7.6	7.6	-7.6	7.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-3.7	-3.7	3.7	3.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.3	17.3	17.3	-17.3
Long. Memb. ML	-2.8	-2.8	2.8	2.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.9	27.9	27.9	-27.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	-45.1	33.9	16.4	-16.3	-32.0	17.8	9.9	-9.5
Shear VC	1.5	1.5	-1.5	-1.5	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.0	-2.0	2.0	2.0
Shear MT	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Tot. Shear	5.0	5.0	2.0	2.0	1.6	1.6	5.5	5.5
Str. Int.	47.5	35.1	17.8	16.7	47.6	37.7	22.0	22.9

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	72.7	78.9	72.7	78.9	72.7	78.9	72.7	78.9
Circ. Pl (SUS)	-12.2	-12.2	5.3	5.3	-4.9	-4.9	-0.6	-0.6
Circ. Q (SUS)	-24.9	24.9	9.6	-9.6	-42.5	42.5	20.1	-20.1
Long. Pm (SUS)	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3
Long. Pl (SUS)	-5.6	-5.6	0.0	0.0	-7.1	-7.1	0.2	0.2
Long. Q (SUS)	-39.5	39.5	16.4	-16.4	-24.9	24.9	9.7	-9.7
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.5	1.5	-1.5	-1.5	-2.0	-2.0	2.0	2.0
Shear Q (SUS)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Pm (SUS)	72.7	78.9	72.7	78.9	72.7	78.9	72.7	78.9
Pm+Pl (SUS)	60.5	66.7	78.0	84.2	67.8	74.0	72.2	78.3
Pm+Pl+Q (Total)	45.4	92.7	87.6	74.6	25.3	116.5	92.8	59.1

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	78.86	117.90	Passed
Pm+Pl (SUS)	84.16	176.85	Passed
Pm+Pl+Q (TOTAL)	116.46	353.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input Echo, Tubesheet Number 1, Description: TS

Shell Data:

Main Shell Description: Shell Barrel

Shell Maximum Design Pressure	Psd,max	62.00	bars
Shell Maximum Operating Pressure	Psox,max	62.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	17.4498	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	293.313	mm.
Shell Temperature for Internal Pressure	Ts	145.00	°C
Shell Material		SA-106 B	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Shell Material UNS Number		K03006	
Shell Allowable Stress at Temperature	Ss	117.90	N./mm²
Shell Allowable Stress at Ambient		117.90	N./mm²

Channel Description: Channel Barrel

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	59.00	bars
Channel Maximum Operating Pressure	Ptox,max	59.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	17.4498	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	288.950	mm.
Channel Design Temperature	TEMPC	145.00	°C
Channel Material		SA-106 B	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Channel Material UNS Number		K03006	
Channel Allowable Stress at Temperature	Sc	117.90	N./mm²
Channel Allowable Stress at Ambient		117.90	N./mm²

Tube Data:

Number of Tube Holes	Nt	94	
Tube Wall Thickness	et	2.1100	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	1800.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	1716.00	mm.
Design Temperature of the Tubes		145.00	°C
Tube Material		SA-179	
Tube Material UNS Number		K01200	
Is this a Welded Tube		No	

Tube Material Specification used		Smls. tube	
Tube Allowable Stress at Temperature		92.40	N./mm²
Tube Allowable Stress At Ambient		92.40	N./mm²
Tube Yield Stress At design Temperature	Syt	159.00	N./mm²
Tube Pitch (Center to Center Spacing)	P	23.8000	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	129.783	mm.
Largest Center-to-Center Tube Distance	Ul	57.1500	mm.
Length of Expanded Portion of Tube	ltx	69.0000	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	5.0000	mm.
Area of Tube Layout	Ap	469.0	cm²
Perimeter of Tube Layout	Cp	796.4	mm.

Tubesheet Data:

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

Tubesheet Design Metal Temperature	T	145.00	°C
Tubesheet Material		SA-266 2	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-266 2

Tubesheet Material UNS Number		K03506	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm²
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm²
Thickness of Tubesheet	h	84.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	558.800	mm.

Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	377.80	mm.
Step 1 Depth on the Tubeside	ht1	7.00	mm.
Step 2 Diameter on the Tubeside	dt2	285.70	mm.
Step 2 Depth on the Tubeside	ht2	5.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	377.80	mm.
Step 1 Depth on the Shellside	hs1	7.00	mm.
Step 2 Diameter on the Shellside	ds2	285.70	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		377.80	mm.

Note: Tubesheet diameter is now: 377.800 mm. per UHX-10(b).

Dimension G for the Channel Side	Gc	357.283	mm.
Area of the Untubed Lanes	AL	158.3	cm²
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

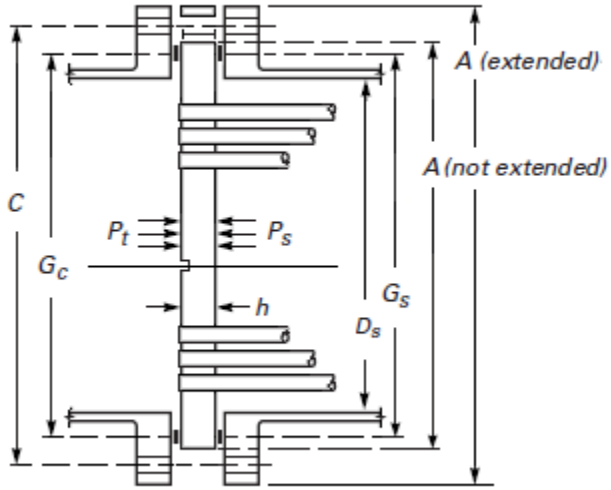
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	558.800	mm.
Flange Inside Diameter	B	288.840	mm.
Flange Face Outside Diameter	Fod	381.000	mm.
Flange Face Inside Diameter	Fid	288.840	mm.
Gasket Outside Diameter	Go	374.650	mm.
Gasket Inside Diameter	Gi	327.152	mm.
Small end Hub thk.	g0	15.2686	mm.
Large end Hub thk.	g1	42.0000	mm.
Gasket Factor,	m	3.00	
Gasket Design Seating Stress	y	68.95	N./mm²
Flange Facing Sketch		Code Sketch 1a	
Column for Gasket Seating		Code Column II	
Gasket Thickness	tg	4.5000	mm.
Full face Gasket Flange Option		Program Selects	
Length of Partition Gasket	lp	559.000	mm.
Width of Partition Gasket	wp	10.0000	mm.
Partition Gasket Factor,	mPart	2.5000	
Partition Gasket Design Seating Stress	yPart	25.00	N./mm²
Partition Gasket Facing Sketch		Code Sketch 1a	
Partition Gasket Column for Gasket Seating		Code Column II	

Bolting Information:

Diameter of Bolt Circle	C	488.950	mm.
Nominal Bolt Diameter	dB	31.7500	mm.
Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	20	
Bolt Material		SA-193 B7M	
Bolt Allowable Stress At Temperature	Sb	137.90	N./mm²
Bolt Allowable Stress At Ambient	Sa	137.90	N./mm²
Weld between Flange and Shell/Channel		0.0000	mm.
Alternate Flange Operating Bolt Load, Wm1		1071331.50	N
Alternate Flange Seating Bolt Load, Wm2		741845.50	N
Alternate Flange Design Bolt Load, W		1362104.12	N
Tubesheet Integral with		None	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	60.0000	mm.
Is Bolt Load Transferred to the Tubesheet		Yes	

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2019

Elasticity/Expansion Material Properties :

Shell - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------------
 Elastic Mod. at Design Temperature      145.0 °C      0.19536E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Channel - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------------
 Elastic Mod. at Design Temperature      145.0 °C      0.19536E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Tubes - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------------
 Elastic Mod. at Tubsht. Design Temp.    145.0 °C      0.19536E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

TubeSheet - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------------
 Elastic Mod. at Design Temperature      145.0 °C      0.19536E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+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)
  = (60.03*(19.05/2-0.0)/(92.4*1.0+0.4*60.03)
  = 0.6032 + 0.0000 = 0.6032 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
External Pressure Chart     CS-1             at       145.00  °C
Elastic Modulus for Material                    199943392.00  KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A         B
   2.1100      19.05    1845.78       9.03    50.0000  0.0134948         95.84
EMAWP = (2.167/(D/T)-0.0833)*B = 150.192 bars
```

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

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A         B
   0.9812      19.05    1845.78      19.41    50.0000  0.0029183         91.80
EMAWP = (4*B)/(3*(D/T)) = ( 4 *91.8008 )/( 3 *19.4146 ) = 63.0423 bars
```

Summary of Tube Required Thickness Results:

```
Total Required Thickness including Corrosion all.          0.9812  mm.
Allowable Internal Pressure at Corroded thickness         224.57  bars
Required Internal Design Pressure                          60.03  bars
Allowable External Pressure at Corroded thickness         150.19  bars
Required External Design Pressure                          63.03  bars
Required Thickness due to Shell Side pressure              0.9812  mm.
```

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

```
Gasket Contact Width,       N = (Goc-Gic) / 2            23.749  mm.
Basic Gasket Width,        b0 = N / 2.0                  11.874  mm.
Effective Gasket Width,     b = SQRT(b0) * 2.5            8.680  mm.
Gasket Reaction Diameter,   G = Go-2.0*b                357.289  mm.


Flange Design Bolt Load, Seating Condition    W  :  1362104.12  N
Flange Design Bolt Load, Operating Condition  Wm1:  1018874.94  N
```

Required Tubesheet Flanged Extension thk. per UHX-9 (operating) [hr_opr]:

```
  = sqrt( 1.9 * WM1 * hg / ( S * G ) )
  = sqrt( 1.9 * 1018874 * 65.83/( 137.9 * 357.283 ) )
  = 50.860 mm.
```

Required Tubesheet Flanged Extension thk. per UHX-9 (seating) [hr_seat]:

```
  = sqrt( 1.9 * W * hg / ( Sa * G ) )
  = sqrt( 1.9 * 1362104 * 65.83/( 137.9 * 357.283 ) )
  = 58.806 mm.
```

```
Gasket Reaction Diameter (Gc or Gs as applicable):     357.289  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 * 0.2) * (278.62/(0.8 * 137.9)) * [-1.03 - 59.0] + 0.0
= 18.9932 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 129.783 + 19.05 = 278.616 mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
= (p - dt) / p
= (23.8 - 19.05)/23.8 = 0.2

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
= Gs / Do (Configurations d, e, f)
= 357.2894/278.616 = 1.2824

Compute the Ratio [Rhoc]:
= Gc / Do (Configurations d)
= 357.283/278.616 = 1.2823

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
= Do^2/16 * [(Rhos-1)*(Rhos^2+1)* Ps - (Rhoc-1) * (Rhoc^2+1) * Pt]
= 278.616^2/16 * [(1.282 - 1) * (1.282^2 + 1) * -1.034 -
(1.282 - 1) * (1.282^2 + 1) * 59.0]
= -217473.9219 bars*mm.^{2}

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

Compute the Ratio [rho]:
= ltx/h = 69.0/84.0 = 0.8214 (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*2.11 *(.19536E+09/.19536E+09)*
(92/137)*(0.821), 19.05 -2*2.11)
= 16.7273 mm.

Compute the Effective Tube Pitch [p*]:
= p / sqrt(1 - 4 * min(AL * CNV_factor, 4*Do*p)/(Pi * Do^2))
= 23.8/sqrt(1 - 4 * min(158.3 *100.0, 4*278.616 *23.8)
(3.141* 278.616^2))
= 27.6603 mm.

Compute the Effective Ligament Efficiency for Bending [mu*]:
= (p* - d*)/p* = (27.6603 - 16.7273)/27.6603 = 0.39526

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

```
   h/p =    3.529412 ;  mu* =    0.395259
  E*/E =    0.407128 ;  nu* =    0.311853 ;  E* = 79536152. KPa.
```

Note: As h/p (3.529) is > 2, data values for h/p = 2 were used.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
  = A/Do = 377.8/278.616 = 1.356
```

Determine Coefficient [F]:

```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.31 )/79536152 * ( 0.19536E+09 * ln(1.36 ) )
  = 0.5147
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
  = Mts + W* * (Gc - Gs)/(2 * pi * Do)
  = -217473.9 + 1018874 * (357.283 - 357.283 )/(2 * pi * 278.616 )
  = -217473.9219 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)
  = ((-217473.92) - 278.616²/32 * 0.515 * (-1.03 - 59.0 ) )/(1 + 0.51 )
  = -94083.9844 bars*mm.²
```

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

```
  = Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
  = -94083.98 + 278.616²/64 * (3 + 0.312 )(-1.03 - 59.0 )
  = -335241.3750 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:

```
  = Max( abs(Mp), abs(Mo) )
  = Max( abs(-94083.984), abs(-335241.37) )
  = 335241.3750 bars*mm.²
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:

```
  = 6 * M / ( (mu*) * ( h - hg')² )
  = 6 * 335241.375/( ( 0.3953 ) * ( 84.0 - 5.0 )² )
  = 81.5452 N./mm²
```

The Allowable Tubesheet Bending Stress [SigmaAll]:

```
  = 2 * S = 2 * 137.9 = 275.8 N./mm²
```

Tubesheet Bending Stress at Final Thickness [Sigma]:

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

= 6 * 339207.656/((0.4135) * (47.2489 - 5.0)²
= 275.7540 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 47.2489 + 0.0 + 0.0 = 47.2489 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(47.2489, 18.9932) = 47.2489 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(-1.03 - 59.0) = 60.034 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 137.9 * 0.2 * 84.0/278.62 = 265.51 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(278.62/84.0)*[-1.03-59.0]N./mm²
= 24.94 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 2.11)2.11
= 1.123 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.11 * (19.05 - 2.11) * 92.4 = 10374.825 N

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) * 92.4
= 6510.2075 N

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) * 92.4
= 10061.2305 N

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10374.8252 N

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5620 mm.

Minimum Required Fillet Weld Leg afr 1.2810 mm.
Minimum Required Groove Weld Leg agr 1.2810 mm.

Tube-Tubesheet Jt allowable, 10374.83 is >= tube strength 10374.83 N
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	81.5	<=	275.8 N./mm²	Ok
Tubesheet shear stress	24.9	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	47.249	84.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	23.749	mm.
Basic Gasket Width,	b0 = N / 2.0	11.874	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.680	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	357.289	mm.

Flange Design Bolt Load, Seating Condition W : 1362104.12 N
Flange Design Bolt Load, Operating Condition Wm1: 1070682.12 N

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 * 0.2) * (278.62/(0.8 * 137.9)) * [62.0 - -1.03] + 0.0
= 19.9423 mm.

UHX-12.5.1 Step 1:

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

```
= 2 * ro + dt
= 2 * 129.783 + 19.05 = 278.616 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:

```
= (p - dt) / p
= (23.8 - 19.05 )/23.8 = 0.2
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:

```
= Gs / Do (Configurations d, e, f)
= 357.2894/278.616 = 1.2824
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 357.283/278.616 = 1.2823
```

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

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 278.616²/16 * [ (1.282 - 1) * (1.282² + 1) * 62.0 -
  (1.282 - 1) * (1.282² + 1) * -1.034 ]
= 228364.0938 bars*mm.²
```

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

Compute the Ratio [rho]:

```
= ltx/h = 69.0/84.0 = 0.8214 ( 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*2.11 *(.19536E+09/.19536E+09)*
     ( 92/137 )*( 0.821 ), 19.05 -2*2.11 )
= 16.7273 mm.
```

Compute the Effective Tube Pitch [p*]:

```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 23.8/sqrt( 1 - 4 * min( 158.3 *100.0, 4*278.616 *23.8 )
  (3.141* 278.616²) )
= 27.6603 mm.
```

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

```
= (p* - d*)/p* = (27.6603 - 16.7273 )/27.6603 = 0.39526
```

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

```
 h/p =   3.529412 ;  mu* =   0.395259
E*/E =   0.407128 ;  nu* =   0.311853 ;  E* = 79536152. KPa.
```

Note: As h/p (3.529) is > 2, data values for h/p = 2 were used.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:
= A/Do = 377.8/278.616 = 1.356

Determine Coefficient [F]:
= (1 - nu*)/E* * (E * ln(K))
= (1 - 0.31)/79536152 * (0.19536E+09 * ln(1.36))
= 0.5147

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 228364.1 + 1070682 * (357.283 - 357.283)/(2 * pi * 278.616)
= 228364.0938 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)
= ((228364.09) - 278.616²/32 * 0.515 * (62.0 - -1.03))/(1 + 0.51)
= 98800.4688 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 98800.47 + 278.616²/64 * (3 + 0.312)(62.0 - -1.03)
= 352008.8750 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(98800.469), abs(352008.875))
= 352008.8750 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 352008.875/((0.3953) * (84.0 - 5.0)²)
= 85.6238 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 137.9 = 275.8 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 356116.156/((0.4135) * (48.2879 - 5.0)²
= 275.7684 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 48.2879 + 0.0 + 0.0 = 48.2879 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(48.2879, 19.9423) = 48.2879 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(62.0 - -1.03) = 63.034 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 137.9 * 0.2 * 84.0/278.62 = 265.51 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(278.62/84.0)*[62.0--1.03]N./mm²
= 26.19 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 2.11)2.11
= 1.123 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.11 * (19.05 - 2.11) * 92.4 = 10374.825 N

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) * 92.4
= 6510.2075 N

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) * 92.4
= 10061.2305 N

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10374.8252 N

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5620 mm.

Minimum Required Fillet Weld Leg	afr	1.2810	mm.
Minimum Required Groove Weld Leg	agr	1.2810	mm.

Tube-Tubesheet Jt allowable, 10374.83 is >= tube strength 10374.83 N
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	85.6	<=	275.8 N./mm²	Ok
Tubesheet shear stress	26.2	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	48.288	84.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	23.749	mm.
Basic Gasket Width,	b0 = N / 2.0	11.874	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.680	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	357.289	mm.

Flange Design Bolt Load, Seating Condition	W :	1362104.12	N
Flange Design Bolt Load, Operating Condition	Wm1:	1070682.12	N

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 * 0.2) * (278.62/(0.8 * 137.9)) * [62.0 - 59.0] + 0.0
= 0.9491 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 129.783 + 19.05 = 278.616 mm.

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

```
= (23.8 - 19.05 )/23.8 = 0.2
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:

```
= Gs / Do (Configurations d, e, f)
= 357.2894/278.616 = 1.2824
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 357.283/278.616 = 1.2823
```

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

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 278.616²/16 * [ (1.282 - 1) * (1.282² + 1) * 62.0 -
  (1.282 - 1) * (1.282² + 1) * 59.0 ]
= 10890.5684 bars*mm.²
```

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

Compute the Ratio [rho]:

```
= ltx/h = 69.0/84.0 = 0.8214 ( 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*2.11 *(.19536E+09/.19536E+09)*
     ( 92/137 )*( 0.821 ), 19.05 -2*2.11 )
= 16.7273 mm.
```

Compute the Effective Tube Pitch [p*]:

```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 23.8/sqrt( 1 - 4 * min( 158.3 *100.0, 4*278.616 *23.8 )
  (3.141* 278.616²) )
= 27.6603 mm.
```

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

```
= (p* - d*)/p* = (27.6603 - 16.7273 )/27.6603 = 0.39526
```

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

```
 h/p =   3.529412 ;  mu* =   0.395259
E*/E =   0.407128 ;  nu* =   0.311853 ;  E* = 79536152. KPa.
```

Note: As h/p (3.529) is > 2, data values for h/p = 2 were used.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
= A/Do = 377.8/278.616 = 1.356
```

Determine Coefficient [F]:

```
= (1 - nu*)/E* * ( E * ln(K) )
= (1 - 0.31 )/79536152 * ( 0.19536E+09 * ln(1.36 ) )
```

= 0.5147

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 10890.6 + 1071331 * (357.283 - 357.283)/(2 * pi * 278.616)
= 10890.5684 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)
= ((10890.57) - 278.616²/32 * 0.515 * (62.0 - 59.0))/(1 + 0.51)
= 4716.7432 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 4716.74 + 278.616²/64 * (3 + 0.312)(62.0 - 59.0)
= 16767.7695 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(4716.743), abs(16767.77))
= 16767.7695 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 16767.77/((0.3953) * (84.0 - 5.0)²)
= 4.0786 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 137.9 = 275.8 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 16963.283/((0.4135) * (14.4642 - 5.0)²
= 274.8070 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 14.4642 + 0.0 + 0.0 = 14.4642 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(14.4642, 0.9491) = 14.4642 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(62.0 - 59.0) = 3.0 bars

Shear Stress check [Tau_limit]:

```
  = 3.2 * S * mu * h/Do
  = 3.2 * 137.9 * 0.2 * 84.0/278.62 = 265.51 bars
```

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

```
  = 1/(4* Mu) * (Do/h) * [Ps - Pt]
  = 1/(4*0.2)*(278.62/84.0)*[62.0-59.0]N./mm²
  = 1.25 N./mm²
```

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:

```
  = pi( do - t )t
  = pi( 19.05 - 2.11 )2.11
  = 1.123 cm²
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.11 * ( 19.05 - 2.11 ) * 92.4 = 10374.825 N
```

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 ) * 92.4
  = 6510.2075  N
```

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 ) * 92.4
  = 10061.2305  N

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 10374.8252 N
```

Design Strength Ratio [fd]:

```
  = 1.0000
```

Weld Strength Factor [fw]:

```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:

```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.5620  mm.

 Minimum Required Fillet Weld Leg             afr      1.2810  mm.
 Minimum Required Groove Weld Leg             agr      1.2810  mm.

 Tube-Tubesheet Jt allowable, 10374.83 is >= tube strength 10374.83 N
```

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	4.1	<=	275.8 N./mm²	Ok
Tubesheet shear stress	1.2	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	14.464	84.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	23.749	mm.
Basic Gasket Width,	b0 = N / 2.0	11.874	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.680	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	357.289	mm.

Flange Design Bolt Load, Seating Condition	W :	1362104.12	N
Flange Design Bolt Load, Operating Condition	Wm1:	1018874.94	N

Required Tubesheet Flanged Extension thk. per UHX-9 (operating) [hr_opr]:
= sqrt(1.9 * WM1 * hg / (S * G))
= sqrt(1.9 * 1018874 * 65.83/(137.9 * 357.283))
= 50.860 mm.

Required Tubesheet Flanged Extension thk. per UHX-9 (seating) [hr_seat]:
= sqrt(1.9 * W * hg / (Sa * G))
= sqrt(1.9 * 1362104 * 65.83/(137.9 * 357.283))
= 58.806 mm.

Gasket Reaction Diameter (Gc or Gs as applicable): 357.289 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 * 0.2) * (278.62/(0.8 * 137.9)) * [-1.03 - 59.0] + 6.0
= 24.9932 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
= 2 * ro + dt
= 2 * 129.783 + 19.05 = 278.616 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:
```
= (p - dt) / p
= (23.8 - 19.05 )/23.8 = 0.2
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
```
= Gs / Do (Configurations d, e, f)
= 357.2894/278.616 = 1.2824
```

Compute the Ratio [Rhoc]:
```
= Gc / Do (Configurations d)
= 357.283/278.616 = 1.2823
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 278.616²/16 * [ (1.282 - 1) * (1.282² + 1) * -1.034 -
  (1.282 - 1) * (1.282² + 1) * 59.0 ]
= -217473.9219 bars*mm.²
```

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

Compute the Ratio [rho]:
```
= ltx/h = 69.0/78.0 = 0.8846 ( 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*2.11 *(.19536E+09/.19536E+09)*
     ( 92/137 )*( 0.885 ), 19.05 -2*2.11 )
= 16.5486 mm.
```

Compute the Effective Tube Pitch [p*]:
```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 23.8/sqrt( 1 - 4 * min( 158.3 *100.0, 4*278.616 *23.8 )
  (3.141* 278.616²) )
= 27.6603 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
= (p* - d*)/p* = (27.6603 - 16.5486 )/27.6603 = 0.40172
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
 h/p =   3.277311 ;  mu* =   0.401718
E*/E =   0.415658 ;  nu* =   0.310375 ;  E* = 81202672. KPa.
```

Note: As h/p (3.277) is > 2, data values for h/p = 2 were used.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:
```
= A/Do = 377.8/278.616 = 1.356
```

Determine Coefficient [F]:
```
= (1 - nu*)/E* * ( E * ln(K) )
= (1 - 0.31 )/81202672 * ( 0.19536E+09 * ln(1.36 ) )
= 0.5053
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
```
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= -217473.9 + 1018874 * (357.283 - 357.283 )/(2 * pi * 278.616 )
= -217473.9219 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)
= ((-217473.92) - 278.616²/32 * 0.505 * (-1.03 - 59.0 ) )/(1 + 0.51 )
= -95593.7656 bars*mm.²
```

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
```
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= -95593.77 + 278.616²/64 * (3 + 0.31 )(-1.03 - 59.0 )
= -336643.4688 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:
```
= Max( abs(Mp), abs(Mo) )
= Max( abs(-95593.766), abs(-336643.46) )
= 336643.4688 bars*mm.²
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
```
= 6 * M / ( (mu*) * ( h - hg')² )
= 6 * 336643.469/( ( 0.4017 ) * ( 78.0 - 2.0 )² )
= 87.0558 N./mm²
```

The Allowable Tubesheet Bending Stress [SigmaAll]:
```
= 2 * S = 2 * 137.9 = 275.8 N./mm²
```

Tubesheet Bending Stress at Final Thickness [Sigma]:
```
= 6 * M / ( (mu*) * ( h - hg')²
= 6 * 339660.531/( ( 0.4135 ) * ( 44.2998 - 2.0 )²
= 275.4573 N./mm²
```

Required Tubesheet Thickness, for Bending Stress [HreqB]:
```
= H + CATS + CATC = 44.2998 + 3.0 + 3.0 = 50.2998 mm.
```

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(50.2998, 24.9932) = 50.2998 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(-1.03 - 59.0) = 60.034 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 137.9 * 0.2 * 78.0/278.62 = 246.54 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(278.62/78.0)*[-1.03-59.0]N./mm²
= 26.86 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 2.11)2.11
= 1.123 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.11 * (19.05 - 2.11) * 92.4 = 10374.825 N

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) * 92.4
= 6510.2075 N

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) * 92.4
= 10061.2305 N

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10374.8252 N

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5620 mm.

Minimum Required Fillet Weld Leg	afr	1.2810	mm.
Minimum Required Groove Weld Leg	agr	1.2810	mm.

Tube-Tubesheet Jt allowable, 10374.83 is >= tube strength 10374.83 N
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	87.1	<=	275.8 N./mm²	Ok
Tubesheet shear stress	26.9	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	50.300	84.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	23.749	mm.
Basic Gasket Width,	b0 = N / 2.0	11.874	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.680	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	357.289	mm.

Flange Design Bolt Load, Seating Condition W : 1362104.12 N
Flange Design Bolt Load, Operating Condition Wm1: 1070682.12 N

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 * 0.2) * (278.62/(0.8 * 137.9)) * [62.0 - -1.03] + 6.0
= 25.9423 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 129.783 + 19.05 = 278.616 mm.

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

```
= (23.8 - 19.05 )/23.8 = 0.2
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:

```
= Gs / Do (Configurations d, e, f)
= 357.2894/278.616 = 1.2824
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 357.283/278.616 = 1.2823
```

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

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 278.616²/16 * [ (1.282 - 1) * (1.282² + 1) * 62.0 -
  (1.282 - 1) * (1.282² + 1) * -1.034 ]
= 228364.0938 bars*mm.²
```

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

Compute the Ratio [rho]:

```
= ltx/h = 69.0/78.0 = 0.8846 ( 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*2.11 *(.19536E+09/.19536E+09)*
     ( 92/137 )*( 0.885 ), 19.05 -2*2.11 )
= 16.5486 mm.
```

Compute the Effective Tube Pitch [p*]:

```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 23.8/sqrt( 1 - 4 * min( 158.3 *100.0, 4*278.616 *23.8 )
  (3.141* 278.616²) )
= 27.6603 mm.
```

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

```
= (p* - d*)/p* = (27.6603 - 16.5486 )/27.6603 = 0.40172
```

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

```
 h/p =   3.277311 ;  mu* =   0.401718
E*/E =   0.415658 ;  nu* =   0.310375 ;  E* = 81202672. KPa.
```

Note: As h/p (3.277) is > 2, data values for h/p = 2 were used.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
= A/Do = 377.8/278.616 = 1.356
```

Determine Coefficient [F]:

```
= (1 - nu*)/E* * ( E * ln(K) )
= (1 - 0.31 )/81202672 * ( 0.19536E+09 * ln(1.36 ) )
```

= 0.5053

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 228364.1 + 1070682 * (357.283 - 357.283)/(2 * pi * 278.616)
= 228364.0938 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)
= ((228364.09) - 278.616²/32 * 0.505 * (62.0 - -1.03))/(1 + 0.51)
= 100385.7969 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 100385.8 + 278.616²/64 * (3 + 0.31)(62.0 - -1.03)
= 353481.1875 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(100385.797), abs(353481.188))
= 353481.1875 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 353481.188/((0.4017) * (78.0 - 2.0)²)
= 91.4101 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 137.9 = 275.8 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 356484.312/((0.4135) * (45.331 - 2.0)²
= 275.5058 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 45.331 + 3.0 + 3.0 = 51.331 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(51.331, 25.9423) = 51.331 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(62.0 - -1.03) = 63.034 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 137.9 * 0.2 * 78.0/278.62 = 246.54 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(278.62/78.0)*[62.0--1.03]N./mm²
= 28.21 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19.05 - 2.11)2.11
= 1.123 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.11 * (19.05 - 2.11) * 92.4 = 10374.825 N

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) * 92.4
= 6510.2075 N

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) * 92.4
= 10061.2305 N

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10374.8252 N

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5620 mm.

Minimum Required Fillet Weld Leg afr 1.2810 mm.
Minimum Required Groove Weld Leg agr 1.2810 mm.

Tube-Tubesheet Jt allowable, 10374.83 is >= tube strength 10374.83 N
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	91.4	<=	275.8 N./mm²	Ok
Tubesheet shear stress	28.2	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	51.331	84.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	23.749	mm.
Basic Gasket Width,	b0 = N / 2.0	11.874	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.680	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	357.289	mm.

Flange Design Bolt Load, Seating Condition	W :	1362104.12	N
Flange Design Bolt Load, Operating Condition	Wm1:	1070682.12	N

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 * 0.2) * (278.62/(0.8 * 137.9)) * [62.0 - 59.0] + 6.0
= 6.9491 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 129.783 + 19.05 = 278.616 mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
= (p - dt) / p
= (23.8 - 19.05)/23.8 = 0.2

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
= Gs / Do (Configurations d, e, f)
= 357.2894/278.616 = 1.2824

Compute the Ratio [Rhoc]:
= Gc / Do (Configurations d)
= 357.283/278.616 = 1.2823

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

```
  = Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
  = 278.616²/16 * [ (1.282 - 1) * (1.282² + 1) * 62.0 -
    (1.282 - 1) * (1.282² + 1) * 59.0 ]
  = 10890.5684 bars*mm.²
```

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

Compute the Ratio [rho]:

```
  = ltx/h = 69.0/78.0 = 0.8846 ( 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*2.11 *(.19536E+09/.19536E+09)*
       ( 92/137 )*( 0.885 ), 19.05 -2*2.11 )
  = 16.5486 mm.
```

Compute the Effective Tube Pitch [p*]:

```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 23.8/sqrt( 1 - 4 * min( 158.3 *100.0, 4*278.616 *23.8 )
    (3.141* 278.616²) )
  = 27.6603 mm.
```

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

```
  = (p* - d*)/p* = (27.6603 - 16.5486 )/27.6603 = 0.40172
```

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

```
   h/p =   3.277311 ;  mu* =   0.401718
  E*/E =   0.415658 ;  nu* =   0.310375 ;  E* = 81202672. KPa.
```

Note: As h/p (3.277) is > 2, data values for h/p = 2 were used.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
  = A/Do = 377.8/278.616 = 1.356
```

Determine Coefficient [F]:

```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.31 )/81202672 * ( 0.19536E+09 * ln(1.36 ) )
  = 0.5053
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
  = Mts + W* * (Gc - Gs)/(2 * pi * Do)
  = 10890.6 + 1071331 * (357.283 - 357.283 )/(2 * pi * 278.616 )
  = 10890.5684 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)
= ((10890.57) - 278.616²/32 * 0.505 * (62.0 - 59.0))/(1 + 0.51)
= 4792.2842 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 4792.28 + 278.616²/64 * (3 + 0.31)(62.0 - 59.0)
= 16837.9297 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(4792.284), abs(16837.93))
= 16837.9297 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 16837.93/((0.4017) * (78.0 - 2.0)²)
= 4.3543 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 137.9 = 275.8 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 16904.219/((0.4135) * (11.4464 - 2.0)²
= 274.8853 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 11.4464 + 3.0 + 3.0 = 17.4464 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(17.4464, 6.9491) = 17.4464 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(62.0 - 59.0) = 3.0 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 137.9 * 0.2 * 78.0/278.62 = 246.54 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(278.62/78.0)*[62.0-59.0]N./mm²
= 1.34 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:

```
  = pi( do - t )t
  = pi( 19.05 - 2.11 )2.11
  = 1.123 cm²
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.11 * ( 19.05 - 2.11 ) * 92.4 = 10374.825 N
```

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 ) * 92.4
  = 6510.2075  N
```

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 ) * 92.4
  = 10061.2305  N

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 10374.8252 N
```

Design Strength Ratio [fd]:

```
  = 1.0000
```

Weld Strength Factor [fw]:

```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:

```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.5620  mm.

 Minimum Required Fillet Weld Leg             afr      1.2810  mm.
 Minimum Required Groove Weld Leg             agr      1.2810  mm.

 Tube-Tubesheet Jt allowable, 10374.83 is >= tube strength 10374.83 N
```

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	4.4	<=	275.8 N./mm²	Ok
Tubesheet shear stress	1.3	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	17.446	84.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

U-Tube Tubesheet results per ASME UHX-12 2019

Results for 6 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht	Extnsn	---- Tubesheet Stresses Bend	Allwd	Shear	Allwd	Case Type	Pass/ Fail
D1uc	47.249	58.806	82	276	25	110	Ps+Pt D1	Ok
D2uc	48.288	...	86	276	26	110	Ps+Pt D2	Ok
D3uc	14.464	...	4	276	1	110	Ps+Pt D3	Ok
D1c	50.300	58.806	87	276	27	110	Ps+Pt-c D1	Ok
D2c	51.331	...	91	276	28	110	Ps+Pt-c D2	Ok
D3c	17.446	...	4	276	1	110	Ps+Pt-c D3	Ok
Max:	51.3310	58.806	mm.	0.331		0.256	(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 :	51.331	84.000	Ok
Tubesheet Thickness Flanged Extension :	58.806	60.000	Ok
Tube Thickness :	0.981	2.110	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	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	190.192	1.000	190.183	1.000
Tubesheet Shear Stress	265.508	1.000	290.894	0.998
Tube Pressure Stress	224.573	1.000	150.191	1.000
Tubesheet Extension Stress	68.505	...	No Calc	No Calc
Minimum MAWP	68.505		150.191	

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	203.045	1.000	203.045	1.000
Tubesheet Shear Stress	265.508	1.000	313.912	1.000
Tube Pressure Stress	224.573	1.000	150.191	1.000
Tubesheet Extension Stress	68.505	...	No Calc	No Calc
Minimum MAPnc	68.505		150.191	

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

Tubesheet MDMT Calculations:

Note: The loading conditions from this case will be used to determine the tubesheet MDMT.

Determine the governing MDMT considering the governing condition:

Governing thickness on the shell side per figure UCS-66.3 (c):

```
= tubesheet thickness/4
= 84.0/4
= 21.000 mm.
```

Thickness Ratio = 0.861, Temperature Reduction per Fig. UCS 66.1 = 8 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve C            -25 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit       -42 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -48 °C
```

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:

```
= max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1
= max( 59.0/68.5, 62.0/150.19 )
= 0.861
```

FEA T1,T2 Nozzle

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: Tue Feb 25 10:22:44 2025.

Model Notes
Model Notes

Input Echo:

Model Type : Cylindrical Shell

Parent Geometry
Parent Outside Diam. : 323.800 mm.
Thickness : 12.200 mm.

Parent Properties:
Cold Allowable : 117.9 MPa
Hot Allowable : 117.9 MPa
Material DB # 1009922.
Ultimate Tensile (Amb) : 413.7 MPa
Yield Strength (Amb) : 241.3 MPa
Yield Strength (Hot) : 221.3 MPa
Elastic Modulus (Amb) : 202720.0 MPa
Poissons Ratio : 0.300
Expansion Coefficient : 0.1207E-04 mm./mm./deg.
Weight Density : 0.0000E+00 N /cu.mm.(NOT USED)

Nozzle Geometry
Nozzle Reinforced OD : 219.100 mm.
Reinforced Thickness : 32.000 mm.
Reinforced Length : 200.000 mm.

```
        Transition Length      :      18.000 mm.
        Neck OD                :     168.300 mm.
        Neck Thickness         :       6.600 mm.
        Neck Length            :       0.000 mm.
        Nozzle Tilt Angle      :       0.000 deg.
        Distance from Top      :       0.000 mm.
        Distance from Bottom   :       0.000 mm.

Nozzle Properties
        Cold Allowable         :       117.9 MPa
        Hot  Allowable         :       117.9 MPa
        Material DB # 1009922.
        Ultimate Tensile (Amb) :       413.7 MPa
        Yield Strength (Amb)   :       241.3 MPa
        Yield Strength (Hot)   :       221.3 MPa
        Elastic Modulus (Amb)  :    202720.0 MPa
        Poissons Ratio         :       0.300
        Expansion Coefficient  :  0.1207E-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     :       95.00 deg.
Nozzle Outside Temperature     :       95.00 deg.
Vessel Inside  Temperature     :       95.00 deg.
Vessel Outside Temperature     :       95.00 deg.

Nozzle Pressure                :       5.900 MPa
Vessel Pressure                :       5.900 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:     9600.0    -9600.0    -7200.0        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:     9600.0    -9600.0    -7200.0        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.

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.

The cylinder length or nozzle/branch location was adjusted
so that a better mesh could be generated at each end of the
cylinder. The nozzle is now located 647.60 mm.
down the length of the cylinder and the total cylinder length
is 1295.20 mm.

Vessel Centerline Vector : 1.000 0.000 0.000
Nozzle Orientation Vector : 0.000 1.000 0.000

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Load Case Report
FEPipe Version 15.0 Jobname: NOZZLE $P
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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
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Solution Data


Maximum Solution Row Size =    1176
Number of Nodes           =    2620
Number of Elements        =     860
Number of Solution Cases  =       8

Summation of Loads per Case

Case #               FX                FY                FZ

   1              9600.            -9600.            -7200.
   2            459594.           -19289.            -7200.
   3            449994.            -9689.                0.
   4                 0.           462333.                0.
   5                 1.                0.                0.
   6                 0.                0.                1.
   7                 0.                0.                0.
   8            449994.            -9689.                0.
```

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ASME Code Stress Output Plots
FEPipe Version 15.0 Jobname: NOZZLE $P
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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
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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
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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

Header Next to Nozzle Weld

Pl	SPL	Primary Membrane Load Case 2
96	221	Min Prin. Stress = -7. (16% Neg, 0% NegHi)
MPa	MPa	Plot Reference:

1) Pl < SPL (SUS,Membrane) Case 2
43%

Branch Next to Header Weld

Pl	SPL	Primary Membrane Load Case 2
87	221	Min Prin. Stress = -18. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
39%		

Branch Transition

Pl	SPL	Primary Membrane Load Case 2
74	221	Min Prin. Stress = -14. (59% Neg, 58% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
33%		

Header away from Junction

Pl	SPL	Primary Membrane Load Case 2
75	221	Min Prin. Stress = -5. (53% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
34%		

Branch away from Junction

Pl	SPL	Primary Membrane Load Case 2
49	221	Min Prin. Stress = -20. (56% Neg, 55% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
22%		

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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 1.90. 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 Case	Combined/Max (Inside)	Combined/Max (Outside)
4	1.778	1.896

Header Next to Nozzle Weld

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
161	463	Min Prin. Stress = -10. (28% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
34%		

Branch Next to Header Weld

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
127	463	Min Prin. Stress = -15. (65% Neg, 61% NegHi)
MPa	MPa	Plot Reference:
		15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
27%		

Branch Transition

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
96	463	Min Prin. Stress = -11. (53% Neg, 53% NegHi)
MPa	MPa	Plot Reference:
		16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
20%		

Header away from Junction

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
106	463	Min Prin. Stress = -7. (58% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
22%		

Branch away from Junction

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
97	463	Min Prin. Stress = -18. (53% Neg, 51% NegHi)
MPa	MPa	Plot Reference:
		15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
21%		

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Highest Fatigue Stress Ratios
FEPipe Version 15.0 Jobname: NOZZLE $P
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Highest Fatigue Stress Ratios $X

Header Next to Nozzle Weld

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
217	0.031 Life	Stress Concentration Factor = 1.350
MPa	0.374 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 228,958.

Allowable	"B31" Fatigue Stress Allowable = 589.5
579.9	Markl Fatigue Stress Allowable = 575.0
MPa	WRC 474 Mean Cycles to Failure = 1,261,194.
	WRC 474 99% Probability Cycles = 292,987.
37%	WRC 474 95% Probability Cycles = 406,775.
	BS5500 Allowed Cycles(Curve F) = 166,830.
	Membrane-to-Bending Ratio = 0.768
	Bending-to-PL+PB+Q Ratio = 0.566
	Plot Reference:
	18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch Next to Header Weld

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
171	0.008 Life	Stress Concentration Factor = 1.350
MPa	0.296 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 884,457.
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 1,269,251.
		WRC 474 99% Probability Cycles = 294,858.
29%		WRC 474 95% Probability Cycles = 409,374.
		BS5500 Allowed Cycles(Curve F) = 254,451.
		Membrane-to-Bending Ratio = 1.794
		Bending-to-PL+PB+Q Ratio = 0.358
		Plot Reference:
		17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Branch Transition

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
96	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.166 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 7.1959E10
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 9,113,523.
		WRC 474 99% Probability Cycles = 2,117,154.
16%		WRC 474 95% Probability Cycles = 2,939,402.
		BS5500 Allowed Cycles(Curve F) = 771,480.
		Membrane-to-Bending Ratio = 1.724
		Bending-to-PL+PB+Q Ratio = 0.367
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Header away from Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
106	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.183 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.1984E10
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 4,343,737.
		WRC 474 99% Probability Cycles = 1,009,090.
18%		WRC 474 95% Probability Cycles = 1,400,994.
		BS5500 Allowed Cycles(Curve F) = 581,628.
		Membrane-to-Bending Ratio = 2.368
		Bending-to-PL+PB+Q Ratio = 0.297
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

```
Branch away from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       97     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.168 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 5.8374E10
Allowable                    "B31" Fatigue Stress Allowable = 589.5
    579.9                    Markl Fatigue Stress Allowable = 575.0
      MPa                    WRC 474 Mean Cycles to Failure = 9,244,370.
                             WRC 474 99% Probability Cycles = 2,147,551.
      16%                    WRC 474 95% Probability Cycles = 2,981,604.
                             BS5500 Allowed Cycles(Curve F) = 746,459.
                             Membrane-to-Bending Ratio = 0.594
                             Bending-to-PL+PB+Q Ratio = 0.627
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
```

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```
Highest Stress Ratios Per Region
FEPipe Version 15.0          Jobname: NOZZLE                $P
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Highest Stress Ratios Per Region                        $X


Header Next to Nozzle Weld

       Pl             SPL     Primary Membrane Load Case 2
       96             221     Min Prin. Stress = -7. (16% Neg, 0% NegHi)
      MPa             MPa     Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
            43%

       Qb             SPS     Primary Bending Load Case 2
       72             463     Min Prin. Stress = -7. (16% Neg, 0% NegHi)
      MPa             MPa     Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 2
            15%

  Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 2
      115             463     Min Prin. Stress = -7. (16% Neg, 0% NegHi)
      MPa             MPa     Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            24%

  Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 2
      130             463     Min Prin. Stress = -7. (16% Neg, 0% NegHi)
      MPa             MPa     Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            28%

 S1+S2+S3             4S      Part 5 (5.3.2) Load Case 2
      165             472     Min Prin. Stress = -7. (16% Neg, 0% NegHi)
      MPa             MPa     Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            34%

  Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 3
```

```
      101                463      Min Prin. Stress = -3. (17% Neg, 0% NegHi)
      MPa                MPa      Plot Reference:
                                     6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
              21%

   Pl+Pb+Q                SPS      Primary+Secondary (Outer) Load Case 3
       90                 463      Min Prin. Stress = -3. (17% Neg, 0% NegHi)
      MPa                MPa      Plot Reference:
                                     7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
              19%

  Membrane               User     Component Evaluation Load Case 3
       92                 463      Min Prin. Stress = -3. (17% Neg, 0% NegHi)
      MPa                MPa      Plot Reference:
                                     8) Membrane < User (OPE,Membrane) Case 3
              19%

   Bending               User     Component Evaluation Load Case 3
       32                 463      Min Prin. Stress = -3. (17% Neg, 0% NegHi)
      MPa                MPa      Plot Reference:
                                     9) Bending < User (OPE,Bending) Case 3
               6%

   Pl+Pb+Q                SPS      Primary+Secondary (Inner) Load Case 4
      113                 463      Min Prin. Stress = -10. (28% Neg, 0% NegHi)
      MPa                MPa      Plot Reference:
                                     15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
              24%

   Pl+Pb+Q                SPS      Primary+Secondary (Outer) Load Case 4
      161                 463      Min Prin. Stress = -10. (28% Neg, 0% NegHi)
      MPa                MPa      Plot Reference:
                                     16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
              34%

 Pl+Pb+Q+F    Damage Ratio         Primary+Secondary+Peak (Inner) Load Case 4
      152     0.001 Life           Stress Concentration Factor = 1.350
      MPa     0.262 Stress         Strain Concentration Factor = 1.000
                                   Cycles Allowed for this Stress = 7,778,560.
 Allowable                         "B31" Fatigue Stress Allowable = 589.5
    579.9                          Markl Fatigue Stress Allowable = 575.0
      MPa                          WRC 474 Mean Cycles to Failure = 3,582,214.
                                   WRC 474 99% Probability Cycles = 832,181.
      26%                          WRC 474 95% Probability Cycles = 1,155,378.
                                   BS5500 Allowed Cycles(Curve F) = 482,454.
                                   Membrane-to-Bending Ratio = 2.447
                                   Bending-to-PL+PB+Q Ratio = 0.290
                                   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
      217     0.031 Life           Stress Concentration Factor = 1.350
      MPa     0.374 Stress         Strain Concentration Factor = 1.000
                                   Cycles Allowed for this Stress = 228,958.
 Allowable                         "B31" Fatigue Stress Allowable = 589.5
    579.9                          Markl Fatigue Stress Allowable = 575.0
      MPa                          WRC 474 Mean Cycles to Failure = 1,261,194.
                                   WRC 474 99% Probability Cycles = 292,987.
      37%                          WRC 474 95% Probability Cycles = 406,775.
                                   BS5500 Allowed Cycles(Curve F) = 166,830.
                                   Membrane-to-Bending Ratio = 0.768
                                   Bending-to-PL+PB+Q Ratio = 0.566
                                   Plot Reference:
                                   18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

Branch Next to Header Weld

Pl	SPL	Primary Membrane Load Case 2
87	221	Min Prin. Stress = -18. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
39%		
Qb	SPS	Primary Bending Load Case 2
44	463	Min Prin. Stress = -18. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
9%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
122	463	Min Prin. Stress = -18. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
26%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
67	463	Min Prin. Stress = -18. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
14%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
104	472	Min Prin. Stress = -18. (66% Neg, 62% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
21%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
124	463	Min Prin. Stress = -12. (65% Neg, 61% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
26%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
59	463	Min Prin. Stress = -12. (65% Neg, 61% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
12%		
Membrane	User	Component Evaluation Load Case 3
84	463	Min Prin. Stress = -12. (65% Neg, 61% NegHi)
MPa	MPa	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
18%		
Bending	User	Component Evaluation Load Case 3
41	463	Min Prin. Stress = -12. (65% Neg, 61% NegHi)
MPa	MPa	Plot Reference:
		9) Bending < User (OPE,Bending) Case 3
8%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
127	463	Min Prin. Stress = -15. (65% Neg, 61% NegHi)
MPa	MPa	Plot Reference:
		15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
27%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
63	463	Min Prin. Stress = -15. (65% Neg, 61% NegHi)
MPa	MPa	Plot Reference:
		16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

13%

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
171	0.008 Life	Stress Concentration Factor = 1.350
MPa	0.296 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 884,457.
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 1,269,251.
		WRC 474 99% Probability Cycles = 294,858.
29%		WRC 474 95% Probability Cycles = 409,374.
		BS5500 Allowed Cycles(Curve F) = 254,451.
		Membrane-to-Bending Ratio = 1.794
		Bending-to-PL+PB+Q Ratio = 0.358
		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
86	0.000 Life	Stress Concentration Factor = 1.350
MPa	0.147 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 11,901,131.
		WRC 474 99% Probability Cycles = 2,764,738.
14%		WRC 474 95% Probability Cycles = 3,838,491.
		BS5500 Allowed Cycles(Curve F) = 2,051,204.
		Membrane-to-Bending Ratio = 0.565
		Bending-to-PL+PB+Q Ratio = 0.639
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch Transition

Pl	SPL	Primary Membrane Load Case 2
74	221	Min Prin. Stress = -14. (59% Neg, 58% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
33%		
Qb	SPS	Primary Bending Load Case 2
44	463	Min Prin. Stress = -14. (59% Neg, 58% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
9%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
83	463	Min Prin. Stress = -14. (59% Neg, 58% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
17%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
94	463	Min Prin. Stress = -14. (59% Neg, 58% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
20%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
122	472	Min Prin. Stress = -14. (59% Neg, 58% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
25%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3

```
      78              463     Min Prin. Stress = -10. (57% Neg, 56% NegHi)
     MPa              MPa     Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             16%

  Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 3
      92              463     Min Prin. Stress = -10. (57% Neg, 56% NegHi)
     MPa              MPa     Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             19%

 Membrane            User     Component Evaluation Load Case 3
      71              463     Min Prin. Stress = -10. (57% Neg, 56% NegHi)
     MPa              MPa     Plot Reference:
                              8) Membrane < User (OPE,Membrane) Case 3
             15%

   Bending            User     Component Evaluation Load Case 3
      43              463     Min Prin. Stress = -10. (57% Neg, 56% NegHi)
     MPa              MPa     Plot Reference:
                              9) Bending < User (OPE,Bending) Case 3
              9%

  Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 4
      80              463     Min Prin. Stress = -11. (53% Neg, 53% NegHi)
     MPa              MPa     Plot Reference:
                              15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
             17%

  Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 4
      96              463     Min Prin. Stress = -11. (53% Neg, 53% NegHi)
     MPa              MPa     Plot Reference:
                              16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             20%

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 4
      80     0.000 Life       Stress Concentration Factor = 1.000
     MPa     0.138 Stress     Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 589.5
    579.9                     Markl Fatigue Stress Allowable = 575.0
     MPa                      WRC 474 Mean Cycles to Failure = 16,202,319.
                              WRC 474 99% Probability Cycles = 3,763,942.
      13%                     WRC 474 95% Probability Cycles = 5,225,760.
                              BS5500 Allowed Cycles(Curve F) = 1,338,310.
                              Membrane-to-Bending Ratio = 2.040
                              Bending-to-PL+PB+Q Ratio = 0.329
                              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
      96     0.000 Life       Stress Concentration Factor = 1.000
     MPa     0.166 Stress     Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 7.1959E10
Allowable                     "B31" Fatigue Stress Allowable = 589.5
    579.9                     Markl Fatigue Stress Allowable = 575.0
     MPa                      WRC 474 Mean Cycles to Failure = 9,113,523.
                              WRC 474 99% Probability Cycles = 2,117,154.
      16%                     WRC 474 95% Probability Cycles = 2,939,402.
                              BS5500 Allowed Cycles(Curve F) = 771,480.
                              Membrane-to-Bending Ratio = 1.724
                              Bending-to-PL+PB+Q Ratio = 0.367
                              Plot Reference:
                              18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

Header away from Junction

Pl	SPL	Primary Membrane Load Case 2
75	221	Min Prin. Stress = -5. (53% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
34%		
Qb	SPS	Primary Bending Load Case 2
35	463	Min Prin. Stress = -5. (53% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
7%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
96	463	Min Prin. Stress = -5. (53% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
20%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
101	463	Min Prin. Stress = -5. (53% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
21%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
137	472	Min Prin. Stress = -5. (53% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
29%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
83	463	Min Prin. Stress = -5. (54% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
18%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
89	463	Min Prin. Stress = -5. (54% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
19%		
Membrane	User	Component Evaluation Load Case 3
70	463	Min Prin. Stress = -5. (54% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
15%		
Bending	User	Component Evaluation Load Case 3
26	463	Min Prin. Stress = -5. (54% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		9) Bending < User (OPE,Bending) Case 3
5%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
93	463	Min Prin. Stress = -7. (58% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
20%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
106	463	Min Prin. Stress = -7. (58% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

22%

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
93	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.160 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 6,521,111.
		WRC 474 99% Probability Cycles = 1,514,913.
15%		WRC 474 95% Probability Cycles = 2,103,266.
		BS5500 Allowed Cycles(Curve F) = 864,725.
		Membrane-to-Bending Ratio = 3.376
		Bending-to-PL+PB+Q Ratio = 0.229
		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
106	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.183 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.1984E10
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 4,343,737.
		WRC 474 99% Probability Cycles = 1,009,090.
18%		WRC 474 95% Probability Cycles = 1,400,994.
		BS5500 Allowed Cycles(Curve F) = 581,628.
		Membrane-to-Bending Ratio = 2.368
		Bending-to-PL+PB+Q Ratio = 0.297
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch away from Junction

Pl	SPL	Primary Membrane Load Case 2
49	221	Min Prin. Stress = -20. (56% Neg, 55% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
22%		
Qb	SPS	Primary Bending Load Case 2
64	463	Min Prin. Stress = -20. (56% Neg, 55% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
13%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
93	463	Min Prin. Stress = -20. (56% Neg, 55% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
20%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
49	463	Min Prin. Stress = -20. (56% Neg, 55% 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
83	472	Min Prin. Stress = -20. (56% Neg, 55% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
17%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3

90		463	Min Prin. Stress = -15. (54% Neg, 52% NegHi)
MPa		MPa	Plot Reference:
			6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
	19%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 3
45		463	Min Prin. Stress = -15. (54% Neg, 52% NegHi)
MPa		MPa	Plot Reference:
			7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
	9%		
Membrane		User	Component Evaluation Load Case 3
45		463	Min Prin. Stress = -15. (54% Neg, 52% NegHi)
MPa		MPa	Plot Reference:
			8) Membrane < User (OPE,Membrane) Case 3
	9%		
Bending		User	Component Evaluation Load Case 3
61		463	Min Prin. Stress = -15. (54% Neg, 52% NegHi)
MPa		MPa	Plot Reference:
			9) Bending < User (OPE,Bending) Case 3
	13%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 4
97		463	Min Prin. Stress = -18. (53% Neg, 51% NegHi)
MPa		MPa	Plot Reference:
			15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
	21%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 4
50		463	Min Prin. Stress = -18. (53% Neg, 51% NegHi)
MPa		MPa	Plot Reference:
			16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
	10%		
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 4
97	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.168 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 5.8374E10
Allowable			"B31" Fatigue Stress Allowable = 589.5
579.9			Markl Fatigue Stress Allowable = 575.0
MPa			WRC 474 Mean Cycles to Failure = 9,244,370.
			WRC 474 99% Probability Cycles = 2,147,551.
16%			WRC 474 95% Probability Cycles = 2,981,604.
			BS5500 Allowed Cycles(Curve F) = 746,459.
			Membrane-to-Bending Ratio = 0.594
			Bending-to-PL+PB+Q Ratio = 0.627
			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
50	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.087 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 1.0000E11
Allowable			"B31" Fatigue Stress Allowable = 589.5
579.9			Markl Fatigue Stress Allowable = 575.0
MPa			WRC 474 Mean Cycles to Failure = 66,537,580.
			WRC 474 99% Probability Cycles = 15,457,283.
8%			WRC 474 95% Probability Cycles = 21,460,494.
			BS5500 Allowed Cycles(Curve F) = 5,389,172.
			Membrane-to-Bending Ratio = 10.995
			Bending-to-PL+PB+Q Ratio = 0.083
			Plot Reference:
			18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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Stress Intensification Factors
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             10:22am  FEB 25,2025



Stress Intensification Factors                          $X


Branch/Nozzle Sif Summary

                   Peak      Primary    Secondary      SSI
Axial    :        4.233        3.135        6.271    1.394
Inplane  :        0.918        0.900        1.360    0.972
Outplane:         2.700        2.000        4.001    1.257
Torsion  :        0.465        0.911        0.931    0.682
Pressure:         1.071        1.169        1.587    1.016

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 :       168.300  mm.
Pipe Thk:         6.600  mm.
Z approx:    135535.625  cu.mm.
Z exact :    130437.461  cu.mm.

  (SSI = SIF^x)         Axial    Inpl    Outpl    Tors    Pres
SIF/SSI Exponents:      0.792    1.227    0.698    0.122    2.268

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =         2.321
      Header Pressure i-factor =         2.227

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
                         2.130         Inplane
                         2.660         Outplane
                         1.000         Torsional
B31.1   (Branch)
Peak Stress Sif ....     0.000         Axial
                         2.660         Inplane
                         2.660         Outplane
                         2.660         Torsional
WRC 330   (Branch)
```

```
Peak Stress Sif ....    0.000        Axial
                        1.823        Inplane
                        2.071        Outplane
                        1.075        Torsional
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Allowable Loads
FEPipe Version 15.0          Jobname: NOZZLE                $P
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Allowable Loads $X

SECONDARY Load Type (Range):		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	229686.	60455.	90683.
Inplane Moment	(mm. N)	41203472.	7668644.	16267651.
Outplane Moment	(mm. N)	14006932.	2606921.	5530114.
Torsional Moment	(mm. N)	64829248.	17315446.	25973168.
Pressure	(MPa)	20.39	5.90	5.90

PRIMARY Load Type:		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	236638.	46243.	69364.
Inplane Moment	(mm. N)	32060454.	4992833.	10591398.
Outplane Moment	(mm. N)	14430867.	1994064.	4230049.
Torsional Moment	(mm. N)	31679134.	7174378.	10761567.
Pressure	(MPa)	14.26	5.90	5.90

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
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:22am FEB 25,2025

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.	960	16%	0%	Header Next to Nozzle Weld
2	OPERATING	3	-3.	960	17%	0%	Header Next to Nozzle Weld
3	EXPANSION	4	-10.	960	28%	0%	Header Next to Nozzle Weld
4	SUSTAINED	2	-5.	1600	53%	0%	Header away from Junction
5	OPERATING	3	-5.	1600	54%	0%	Header away from Junction
6	EXPANSION	4	-7.	1600	58%	0%	Header away from Junction
7	SUSTAINED	2	-18.	760	66%	62%	Branch Next to Header Weld
8	OPERATING	3	-12.	760	65%	61%	Branch Next to Header Weld
9	EXPANSION	4	-15.	760	65%	61%	Branch Next to Header Weld
10	SUSTAINED	2	-20.	520	56%	55%	Branch away from Junction
11	OPERATING	3	-15.	520	54%	52%	Branch away from Junction
12	EXPANSION	4	-18.	520	53%	51%	Branch away from Junction
13	SUSTAINED	2	-14.	960	59%	58%	Branch Transition
14	OPERATING	3	-10.	960	57%	56%	Branch Transition
15	EXPANSION	4	-11.	960	53%	53%	Branch Transition

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Flexibilities
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:22am FEB 25,2025

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 =  168.300  mm.
Wall Thickness   =    6.600  mm.

Axial Translational Stiffness   =        905408.   N /mm.
Outplane Rotational Stiffness   =      96500712.  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.

Inplane Rotational Stiffness
Torsional Rotational Stiffness


Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (mm.) =  0.254  In-Plane (mm.) =  0.000  Out-Plane (mm.) =  0.205

PRIMARY
Axial (mm.) =  0.261  In-Plane (mm.) =  0.000  Out-Plane (mm.) =  0.211

Secondary Conservative Displacement =  0.105 mm.
Secondary Realistic    Displacement =  0.181 mm.

Primary Conservative Displacement =  0.080 mm.
Primary Realistic Displacement    =  0.138 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   0.22282E+13    N mm.^2
The value of (d) to use is: 161.700  mm..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor     (k) =     1.204
Outplane Flexibility Factor  (k) =     2.492
```

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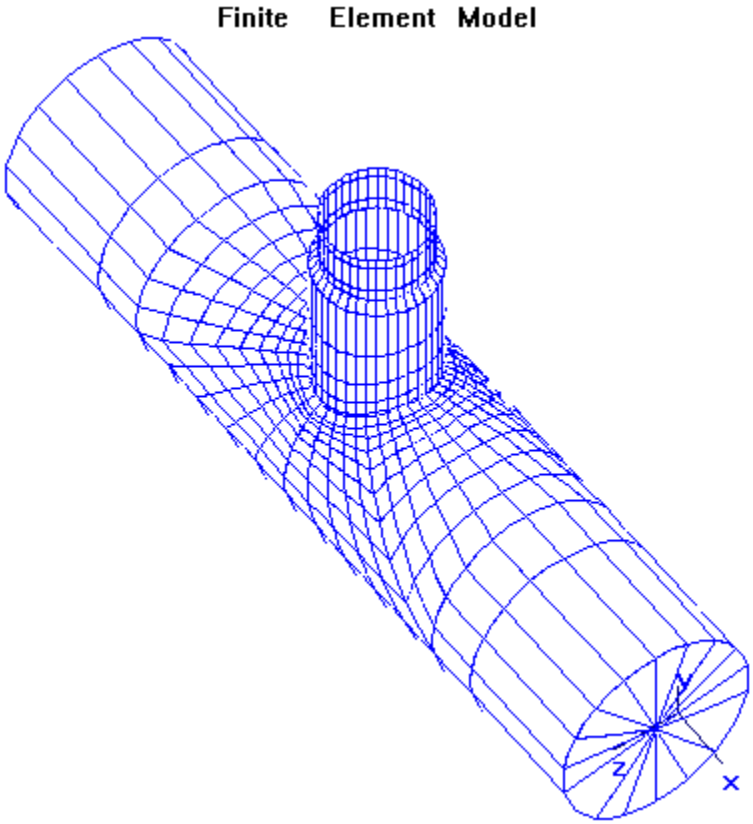
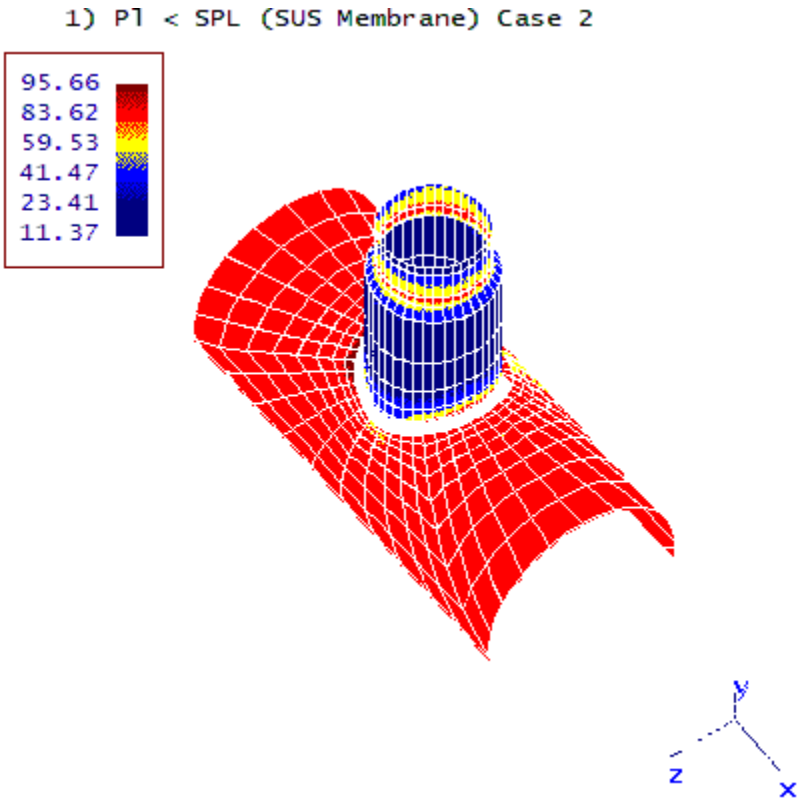
Finite Element Model

- 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
-

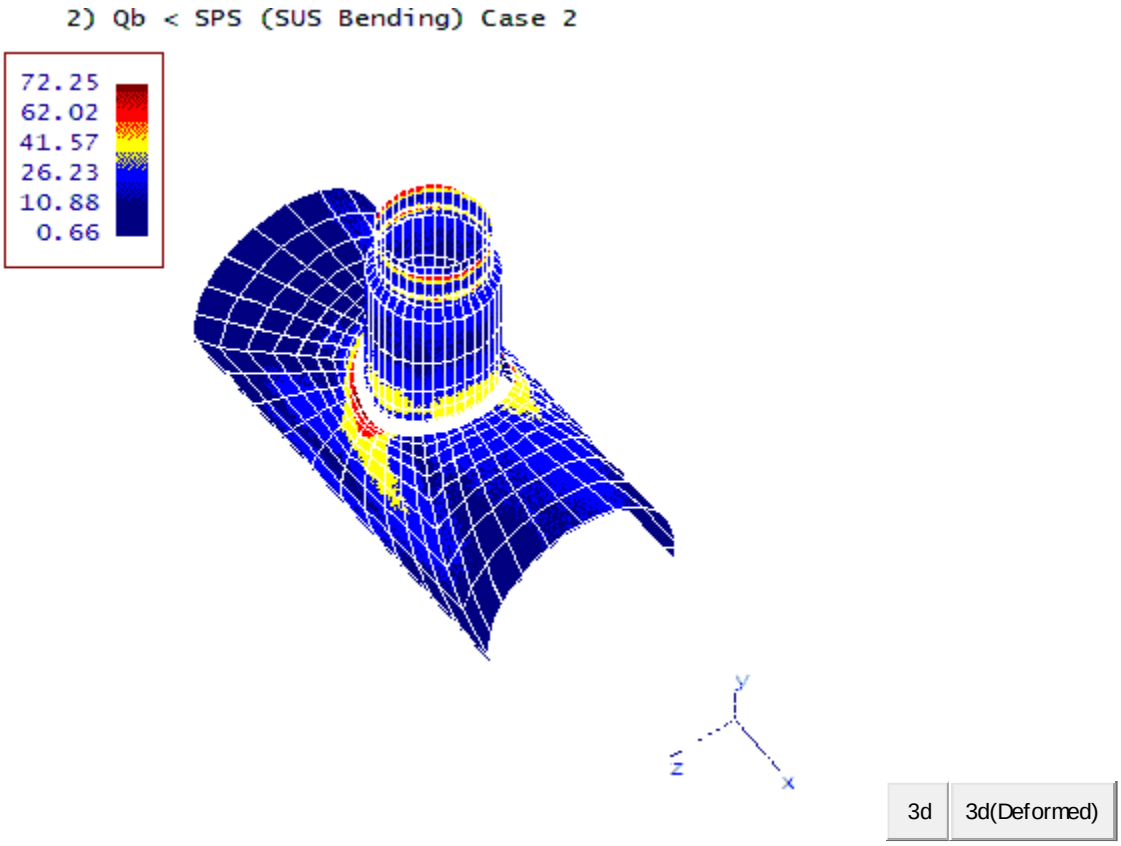


3d

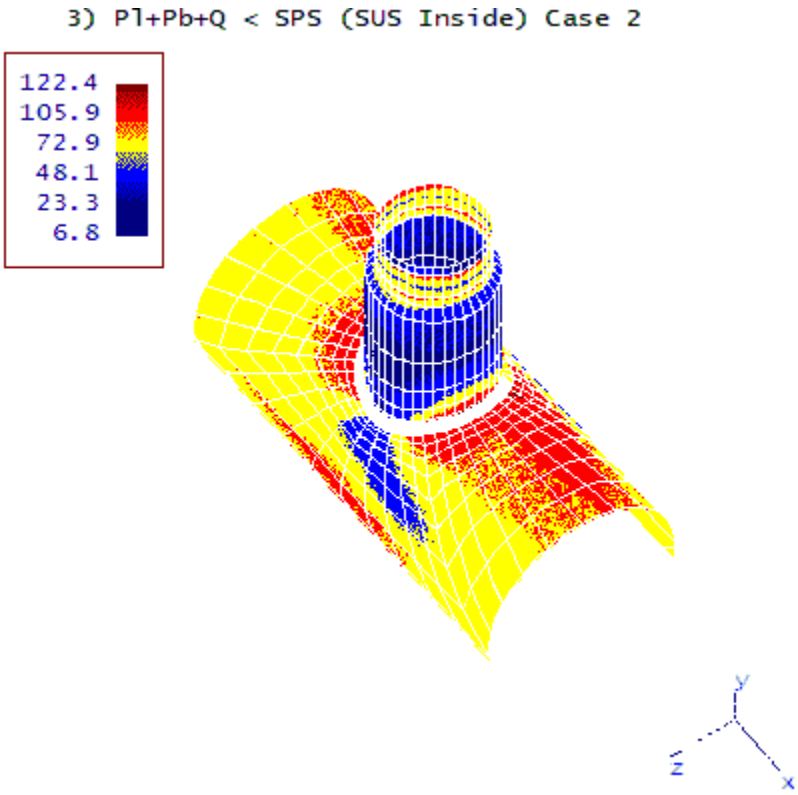
-


1) Pl < SPL (SUS Membrane) Case 2
95.66
83.62
59.53
41.47
23.41
11.37
Y
Z
X
3d
3d(Deformed)

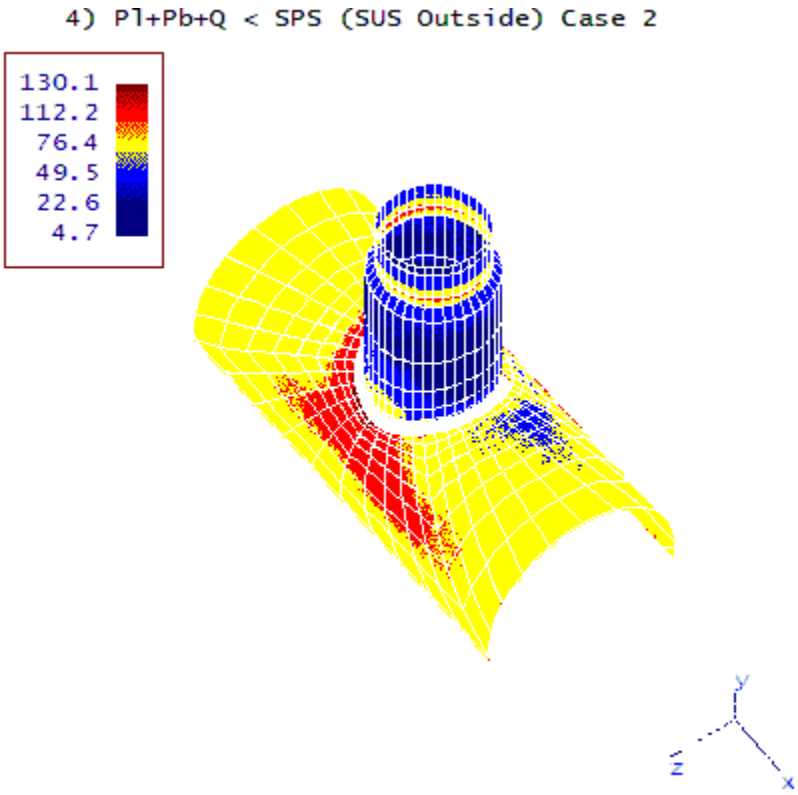
-
-


2) Qb < SPS (SUS Bending) Case 2
72.25
62.02
41.57
26.23
10.88
0.66
Y
Z
X
3d
3d(Deformed)

-
-

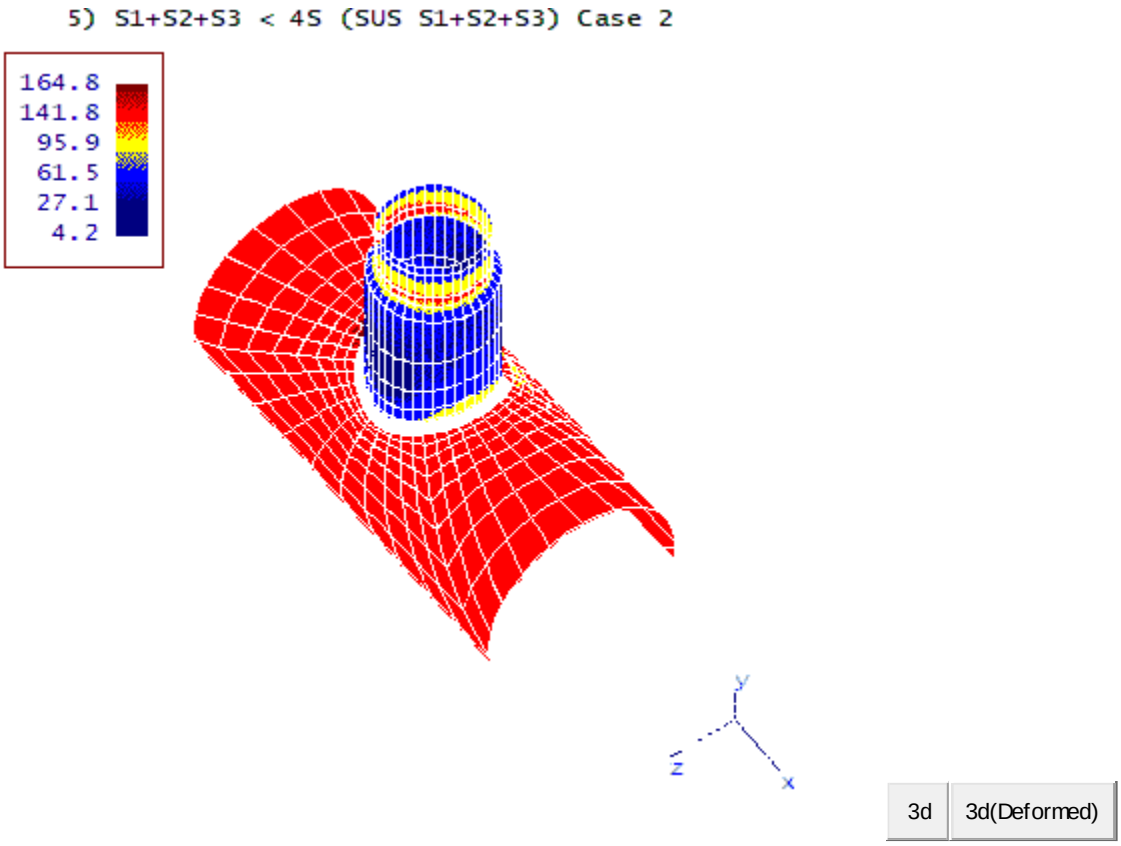

3) Pl+Pb+Q < SPS (SUS Inside) Case 2
122.4
105.9
72.9
48.1
23.3
6.8
Y
Z
X
3d
3d(Deformed)

-
-

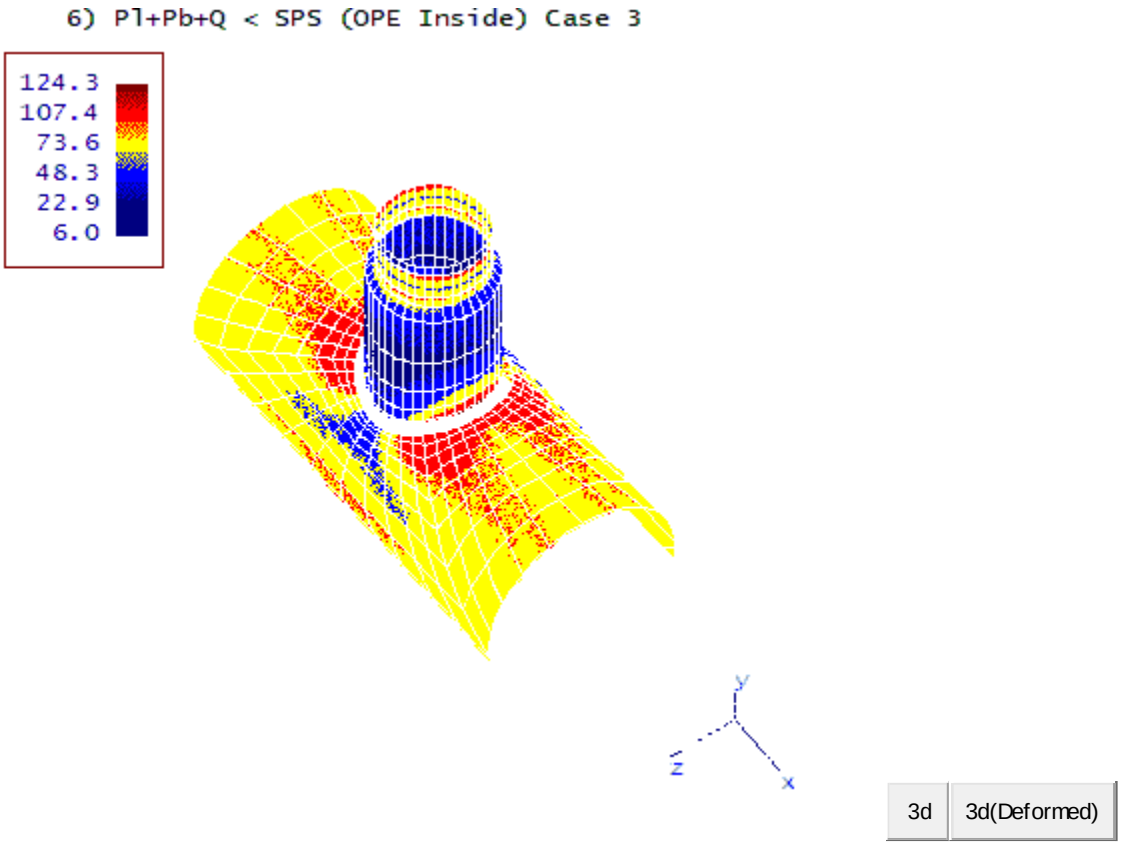


3d | 3d(Deformed)

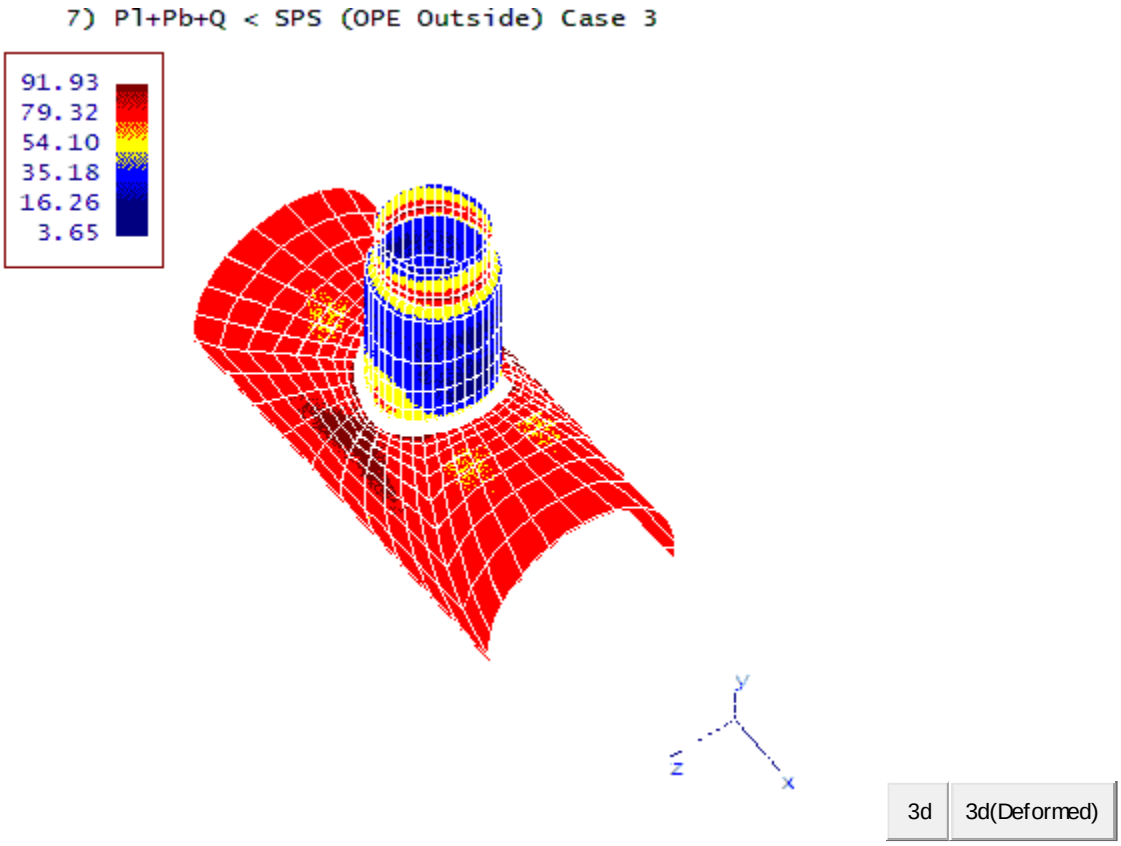
-
-


5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2
164.8
141.8
95.9
61.5
27.1
4.2
Y
Z
X
3d
3d(Deformed)

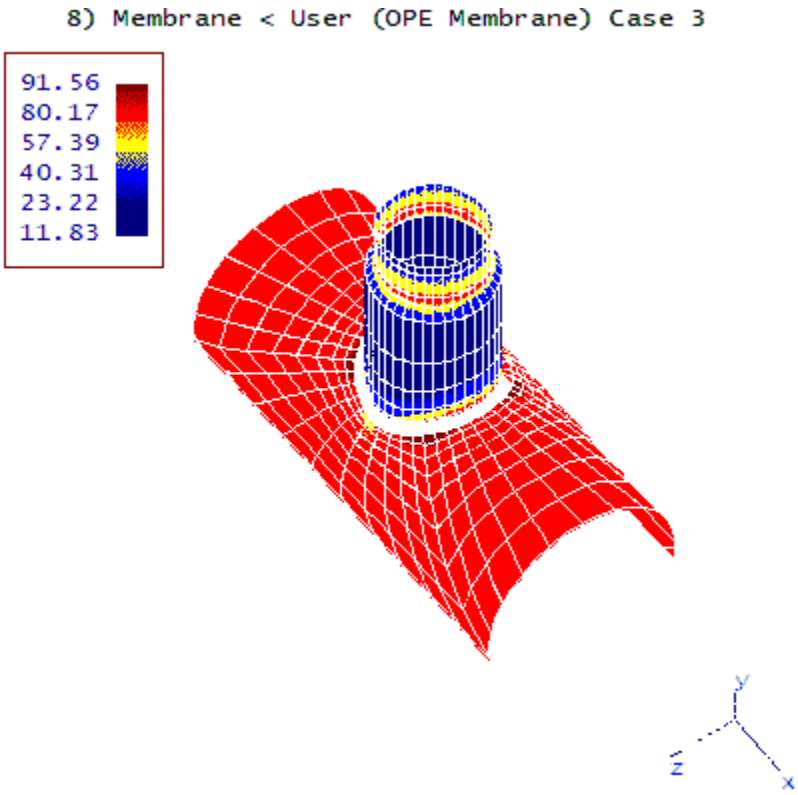
-
-


6) Pl+Pb+Q < SPS (OPE Inside) Case 3
124.3
107.4
73.6
48.3
22.9
6.0
Y
Z
X
3d
3d(Deformed)

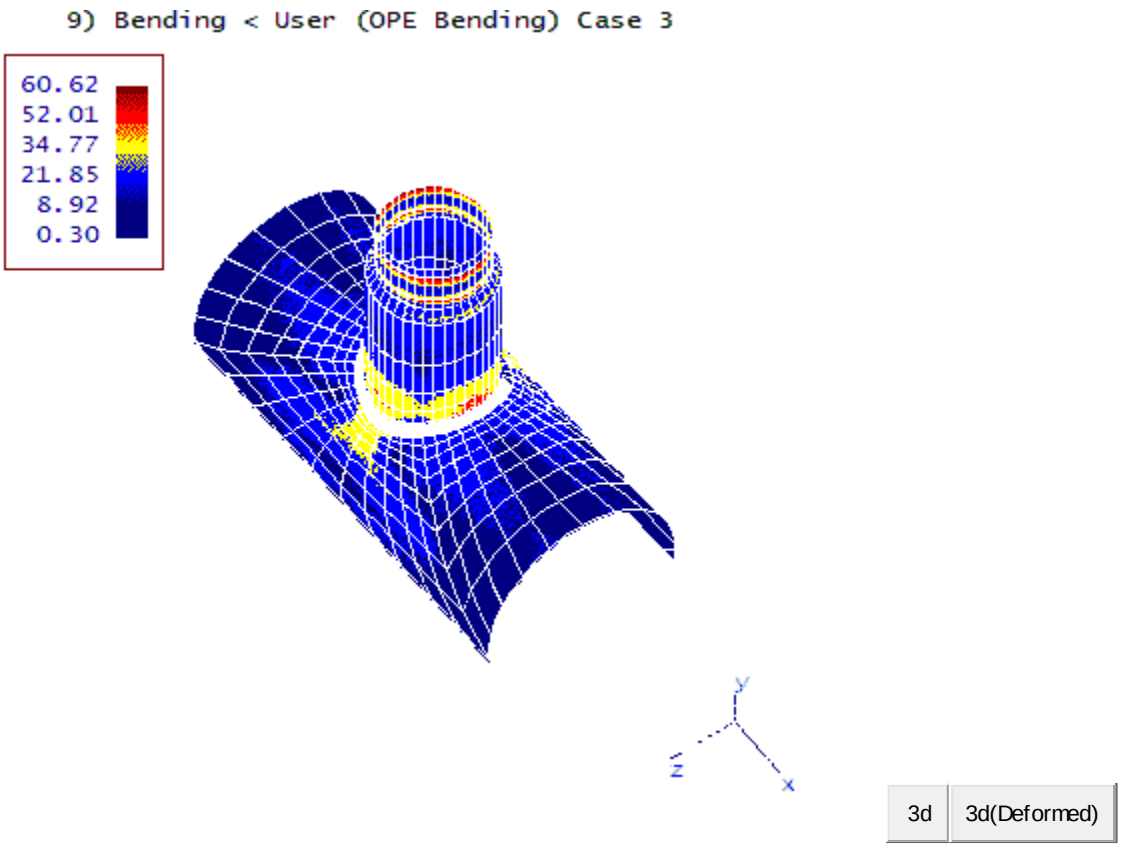
-
-


7) Pl+Pb+Q < SPS (OPE Outside) Case 3
91.93
79.32
54.10
35.18
16.26
3.65
Y
Z
X
3d
3d(Deformed)

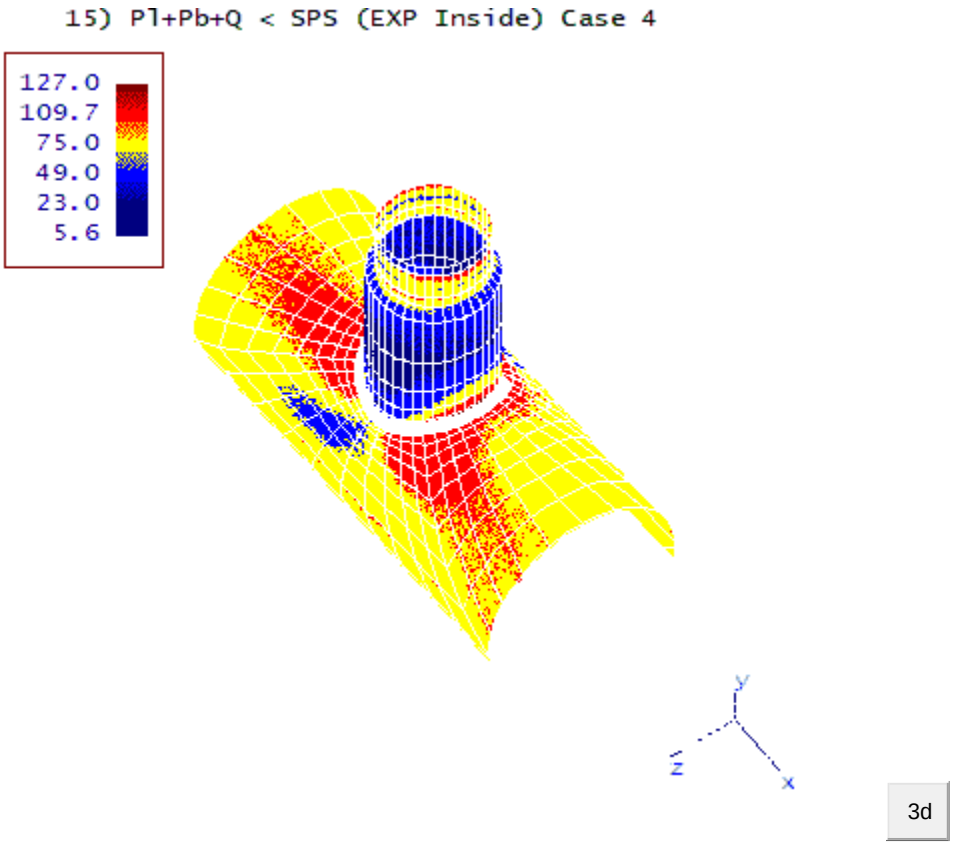
-
-


8) Membrane < User (OPE Membrane) Case 3
91.56
80.17
57.39
40.31
23.22
11.83
Y
Z
X
3d
3d(Deformed)

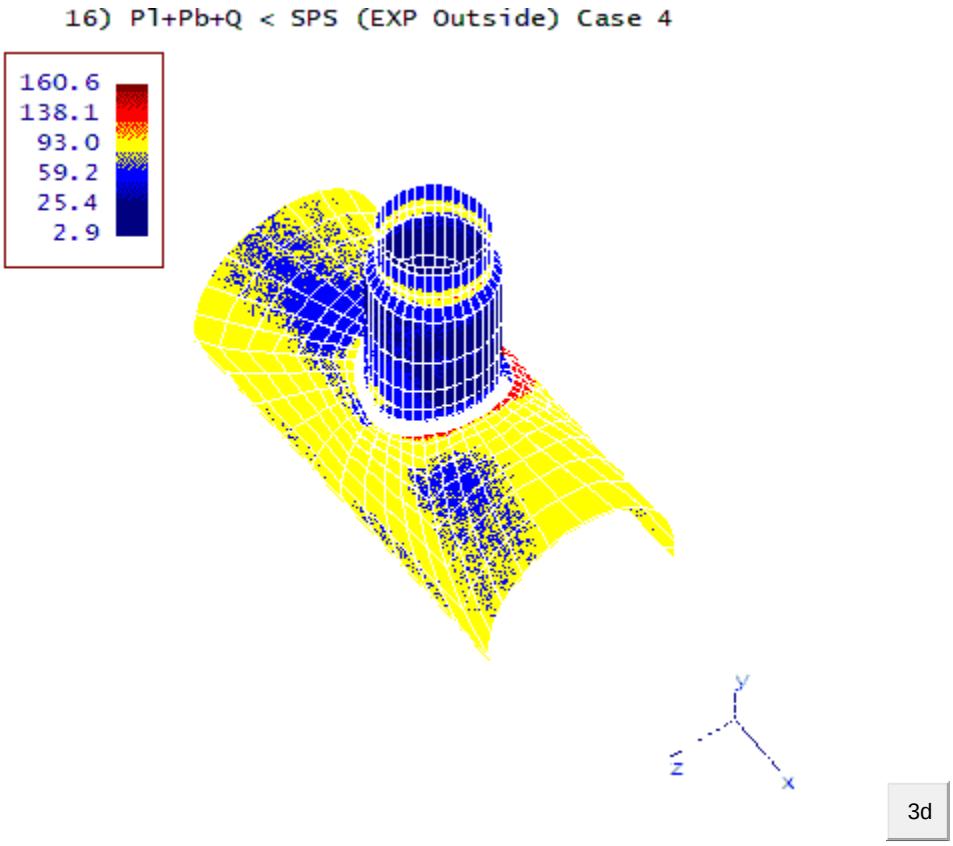
-
-


9) Bending < User (OPE Bending) Case 3
60.62
52.01
34.77
21.85
8.92
0.30
Y
Z
X
3d
3d(Deformed)

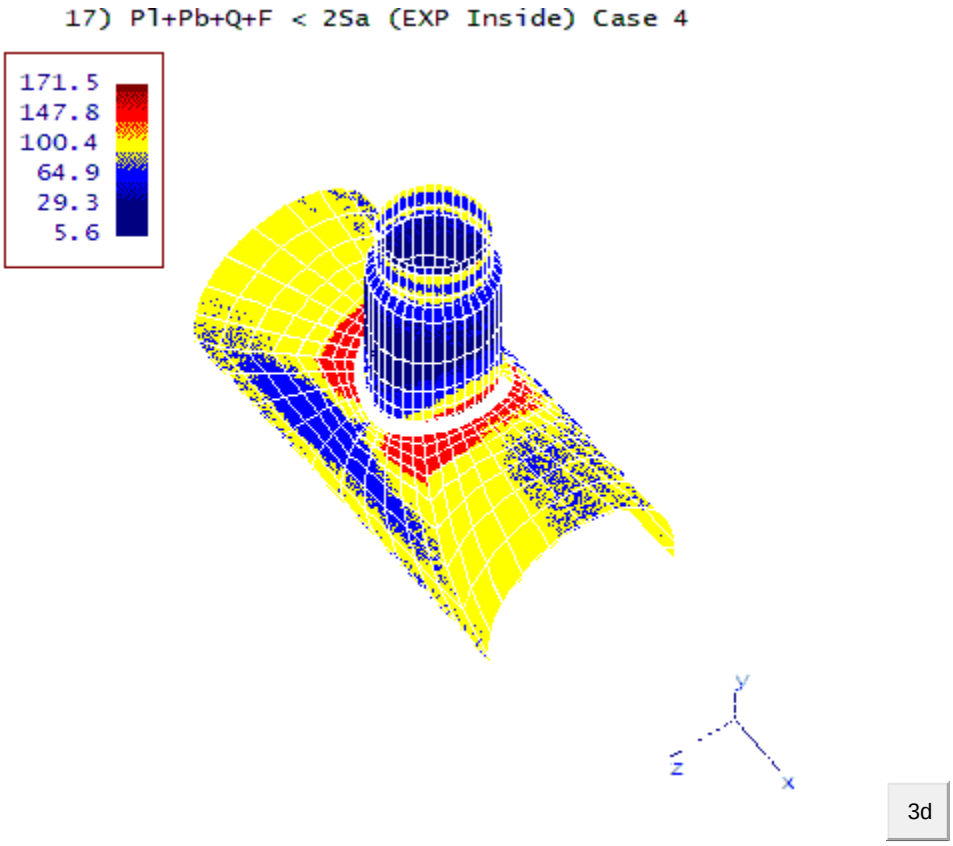
-
-


15) Pl+Pb+Q < SPS (EXP Inside) Case 4
127.0
109.7
75.0
49.0
23.0
5.6
Y
Z
X
3d

-
-

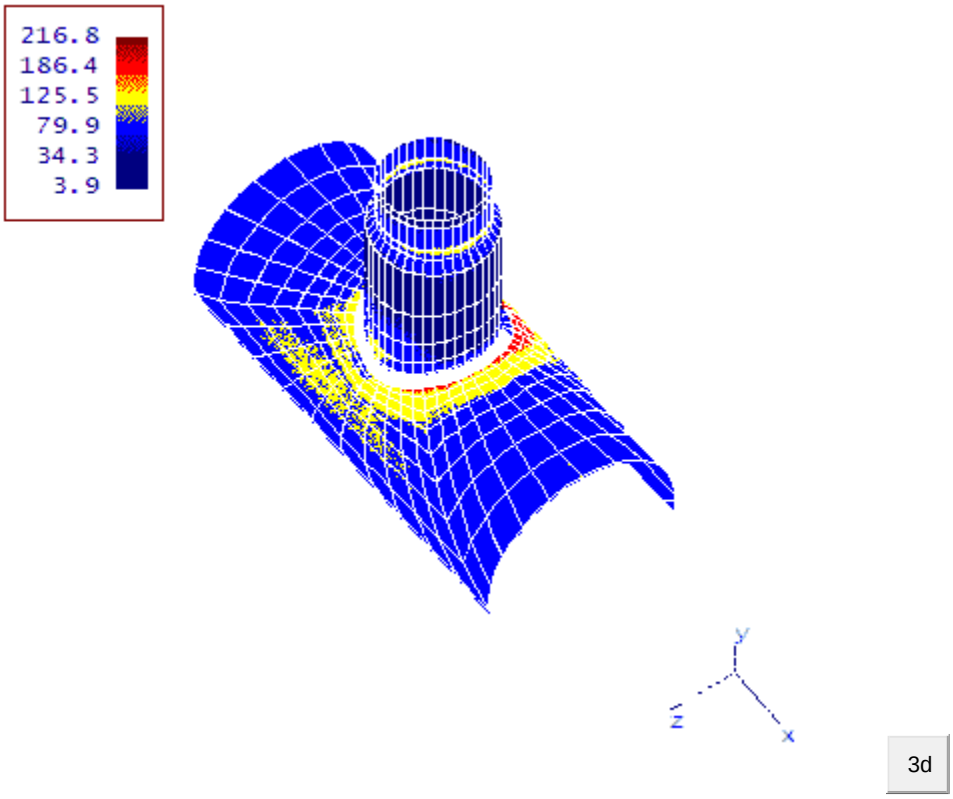

16) Pl+Pb+Q < SPS (EXP Outside) Case 4
160.6
138.1
93.0
59.2
25.4
2.9
Y
Z
X
3d

-
-


17) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4
171.5
147.8
100.4
64.9
29.3
5.6
Y
Z
X
3d

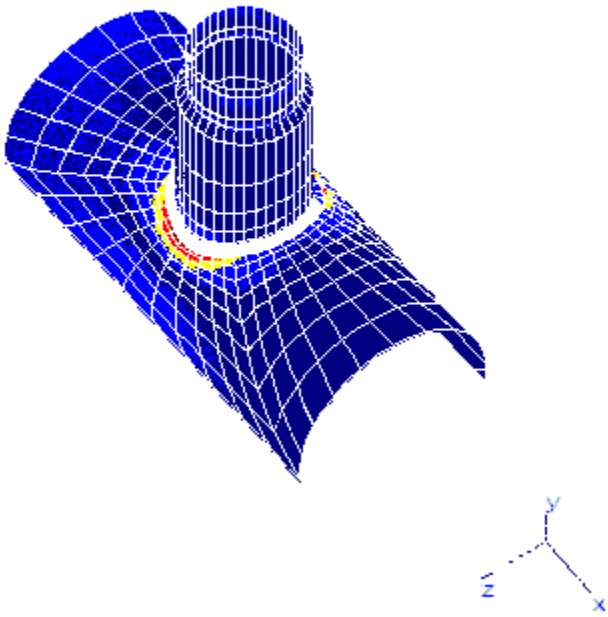
-
-

18) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4



-
-

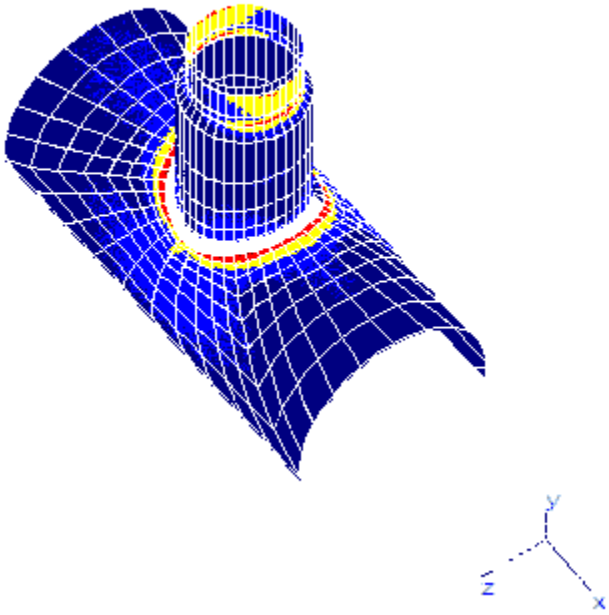
10) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5



3d | 3d(Deformed)

-
-

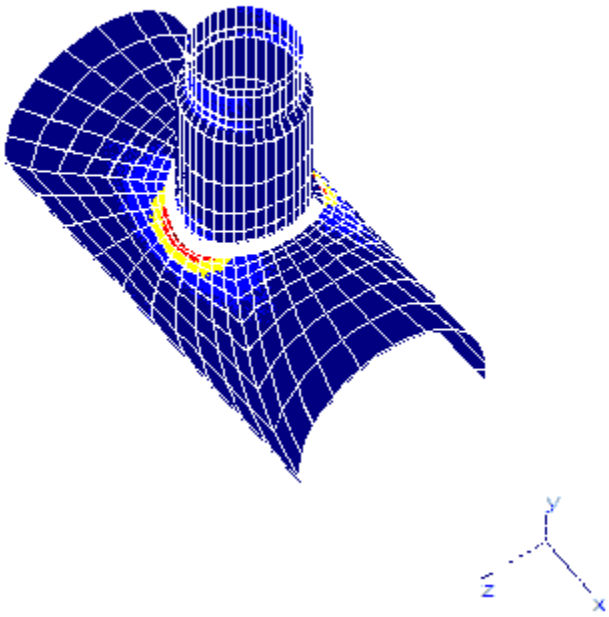
11) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6



3d | 3d(Deformed)

-
-

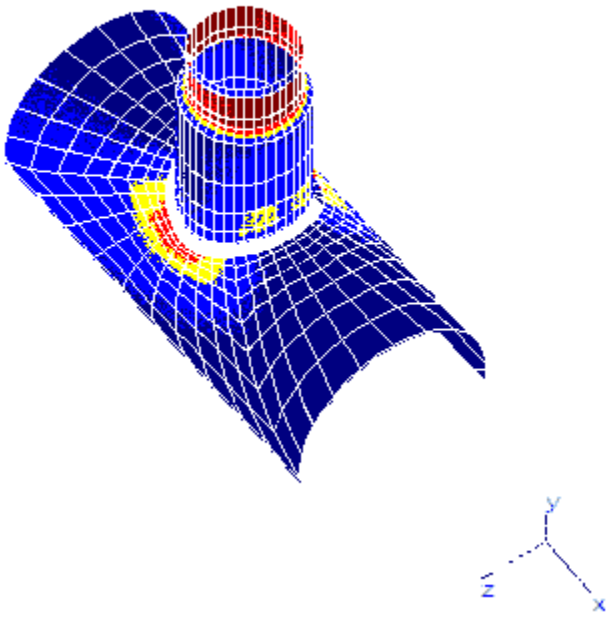
12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7



3d | 3d(Deformed)

-
-

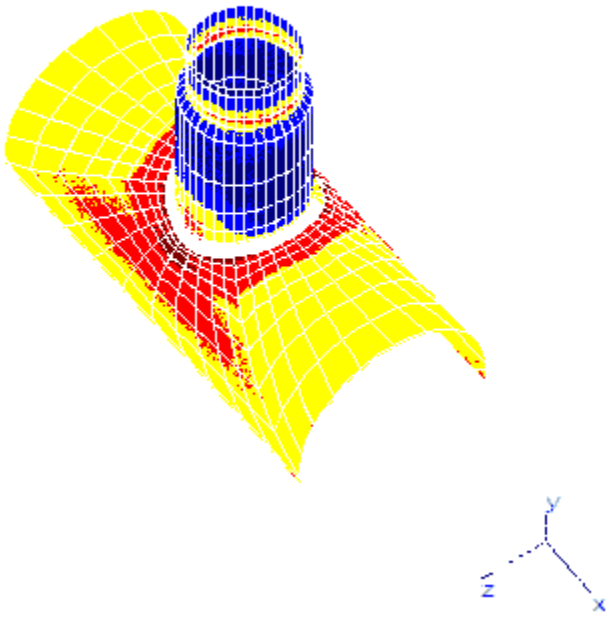
13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 8



3d | 3d(Deformed)

-
-

14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 9



3d | 3d(Deformed)

•

LIFTING WRC

Input Echo, 107/537 Item 1, Description: New WRC 107/537

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	288.900	mm.
Vessel Thickness	Tv	17.400	mm.
Design Temperature		85.00	C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2

*Note: Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps. Make sure that material properties at this temperature are not time-dependent for Material: SA-106 B*

Attachment Type	Type	Rectangular	
Parameter C11	C11	10.00	mm.
Parameter C22	C22	110.00	mm.
Thickness of Reinforcing Pad	Tpad	8.000	mm.
Pad Parameter C11P	C11p	85.000	mm.
Pad Parameter C22P	C22p	165.000	mm.
Design Internal Pressure	Dp	0.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	0.0	Kgf
Longitudinal Shear	(SUS)	Vl	1427.0	Kgf
Circumferential Shear	(SUS)	Vc	0.0	Kgf
Circumferential Moment	(SUS)	Mc	0.0	Kg-m.
Longitudinal Moment	(SUS)	Ml	171.2	Kg-m.
Torsional Moment	(SUS)	Mt	0.0	Kg-m.

Use Interactive Control		No
WRC107 Version	Version	March 1979 (B1 & B2)
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	0.0	Kgf
Circumferential Shear	VC	0.0	Kgf
Longitudinal Shear	VL	1427.0	Kgf
Circumferential Moment	MC	0.0	Kg-m.
Longitudinal Moment	ML	171.2	Kg-m.
Torsional Moment	MT	0.0	Kg-m.

Dimensionless Parameters used : Gamma = 7.08

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979 B1/B2	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.165	4C		1.321	(A,B)
N(PHI) / (P/Rm)	0.165	3C		1.230	(C,D)
M(PHI) / (P)	0.089	2C1		0.186	(A,B)
M(PHI) / (P)	0.089	1C		0.213	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.070	3A	!	0.040	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.092	1A		0.105	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.156	3B	!	0.541	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.140	1B1		0.058	(A,B,C,D)
N(x) / (P/Rm)	0.130	3C		1.315	(A,B)
N(x) / (P/Rm)	0.130	4C		1.363	(C,D)
M(x) / (P)	0.136	1C1		0.172	(A,B)
M(x) / (P)	0.136	2C		0.138	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.070	4A	!	0.063	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.129	2A		0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.156	4B	!	0.139	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.193	2B1		0.083	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	-7.0	-7.0	7.0	7.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-52.5	52.5	52.5	-52.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-59.5	45.5	59.5	-45.5	0.0	0.0	0.0	0.0

Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-54.3	54.3	54.3	-54.3	0.0	0.0	0.0	0.0
Tot. Long. Str.	-57.4	51.1	57.4	-51.1	0.0	0.0	0.0	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.8	-2.8	2.8	2.8
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-2.8	-2.8	2.8	2.8
Str. Int.	59.5	51.1	59.5	51.1	5.7	5.7	5.7	5.7

Dimensionless Parameters used : Gamma = 10.74

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979 B1/B2	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.502	4C	!	1.302	(A,B)
N(PHI) / (P/Rm)	0.502	3C	!	0.768	(C,D)
M(PHI) / (P)	0.353	2C1		0.039	(A,B)
M(PHI) / (P)	0.353	1C	!	0.061	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.343	3A	!	0.446	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.374	1A		0.083	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.428	3B	!	1.121	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.404	1B1		0.023	(A,B,C,D)
N(x) / (P/Rm)	0.432	3C		0.904	(A,B)
N(x) / (P/Rm)	0.432	4C		1.408	(C,D)
M(x) / (P)	0.445	1C1		0.045	(A,B)
M(x) / (P)	0.445	2C	!	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.343	4A	!	0.900	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.465	2A		0.037	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.428	4B	!	0.473	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.478	2B1		0.032	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	-11.1	-11.1	11.1	11.1	0.0	0.0	0.0	0.0
Circ. Bend. ML	-17.6	17.6	17.6	-17.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-28.7	6.4	28.7	-6.4	0.0	0.0	0.0	0.0
Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	-6.9	-6.9	6.9	6.9	0.0	0.0	0.0	0.0
Long. Bend. ML	-21.3	21.3	21.3	-21.3	0.0	0.0	0.0	0.0
Tot. Long. Str.	-28.2	14.4	28.2	-14.4	0.0	0.0	0.0	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.9	-2.9	2.9	2.9
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-2.9	-2.9	2.9	2.9
Str. Int.	28.7	14.4	28.7	14.4	5.9	5.9	5.9	5.9

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)	-7.0	-7.0	7.0	7.0	0.0	0.0	0.0	0.0
Circ. Q (SUS)	-52.5	52.5	52.5	-52.5	0.0	0.0	0.0	0.0
Long. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)	-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Long. Q (SUS)	-54.3	54.3	54.3	-54.3	0.0	0.0	0.0	0.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.0	0.0	0.0	0.0	-2.8	-2.8	2.8	2.8
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)	7.0	7.0	7.0	7.0	5.7	5.7	5.7	5.7
Pm+Pl+Q (Total)	59.5	51.1	59.5	51.1	5.7	5.7	5.7	5.7

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	117.90	Passed
Pm+Pl (SUS)	7.03	176.86	Passed
Pm+Pl+Q (TOTAL)	59.53	353.71	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)	-11.1	-11.1	11.1	11.1	0.0	0.0	0.0	0.0
Circ. Q (SUS)	-17.6	17.6	17.6	-17.6	0.0	0.0	0.0	0.0
Long. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)	-6.9	-6.9	6.9	6.9	0.0	0.0	0.0	0.0
Long. Q (SUS)	-21.3	21.3	21.3	-21.3	0.0	0.0	0.0	0.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.0	0.0	0.0	0.0	-2.9	-2.9	2.9	2.9
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)	11.1	11.1	11.1	11.1	5.9	5.9	5.9	5.9
Pm+Pl+Q (Total)	28.7	14.4	28.7	14.4	5.9	5.9	5.9	5.9

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	117.90	Passed
Pm+Pl (SUS)	11.13	176.86	Passed
Pm+Pl+Q (TOTAL)	28.71	353.71	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Lifting Lug Calculation - E-300

Lifting Lug Calculation

Tag No.: E-300
Equipment: Gas/Lean Glycol Exchanger
Reference: Pressure Vessel Design Manual By Dennis R.Moss

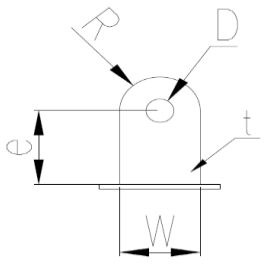
A: Lifting Lug For Hairpin

A1: Loads

Wt. of Exchanger =	1197	Kg
Material =	SA-283 C	
Yield Stress =	207	Mpa
Allowable Stress =	108	Mpa
Impact Factor =	2	
Sling Angle (θ) =	60	
NO. of Lifting Points =	2	
Total Vertical Wt. (Fv) =	23	KN
Total Load at Lifting Point (Ft) =	14	KN

A2: Dimentions

Lug Thickness (t) =	10	mm
Plate Thickness =	6	mm
Radius (R) =	55	mm
e =	120	mm
Lug Width (W) =	110	mm
Hole (D) =	38	mm



A3: Stress Analysis

Bearing Stress:

Bearing Area =	3.8	cm^2	Ab=Dxt
Alowable Bearing Stress =	186.3	Mpa	0.9xFy
Bearing Stess (fp) =	35.7	Mpa	(O.K !!)

Shear Stress: (At Top of Lug)

Shear Area =	3.6	cm^2	As=(R-D/2)xt
Alloawable Shear Stress =	82.8	Mpa	0.4xFy
Actual shear streess(fv) =	37.7	Mpa	**(O.K !!)**

Shear Stress: (At Pin Hole)

Shear Area =	7.2	cm^2	As=2x(R-D/2)xt
Alloawable Shear Stress =	82.8	Mpa	0.4xFy
Actual shear streess(fv) =	18.8	Mpa	**(O.K !!)**

Tensile Stress:

Tensile Area =	7.2	cm^2	At=2x(R-D/2)xt
Alloawable Tensile Stress =	124.2	Mpa	0.6xFy
Actual Tensile streess(ft) =	18.8	Mpa	**(O.K !!)**

Bending Stress:

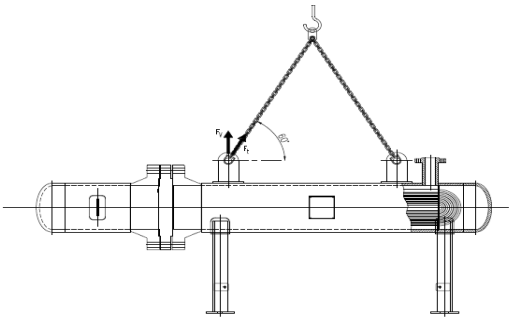
Section Modulus =	20.2	cm^3	Z=t*W^2/6
Alloawable Bending Stress =	124.2	Mpa	0.6xFy
Bending moment (M) =	162.7	KN.cm	
Actual Bending streess(fb) =	80.7	Mpa	**(O.K !!)**

Combined Stress:

Combined Tensile & Bending Stress			
Stress Ratio, [(ft/Ft) + (fb/Fb)] ≤ 1	0.80		**(O.K !!)**
Combined Tensile & Shear Stress	67.9	Mpa	fcr = √(ft^2 + 3fv^2)
fc ≤ S allowable	108.0		**(O.K !!)**

A4: Weld Calculation

Weld leg Size =	7	mm	**(OK !!)**
Shear Load Due Fv	61.63	N/mm	
Shear Load Due M	403.4	N/mm	
Total Load	408.1	N/mm	
Allowable Shear	113.9	Mpa	
Require Weld Size	5.1	mm	



Pass Partition Plate Calculation - E-300

Item No.:	E-300

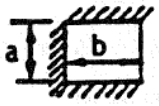
Stationary Pass Partition Input Data Values

Shell Inside Diameter,	ID= 289	mm
Pressure Drop across Pass Partition,	q= .50	bar
Design Temperature,	T= 95	°C
Three / Two Sides Fixed	Three	
Pass Partition Length	L= 559	mm
Pass Partition Dimension,	a= 289	mm
Pass Partition Dimension,	b= 559	mm
Corrosion allowance,	C= 3	mm
(TEMA RCB-1.518 Pass partition plates are not required to have corrosion allowance.)		
Pass Partition Material,	SA-516 70	C.S.
Allowable Stress in Tension, at Design Temperature,	S = 137.9	N/mm²

TEMA TABLE RCB-9.1.3.1M NOMINAL PASS PARTITION PLATE THICKNESS

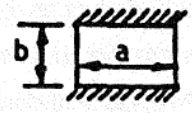
Shell ID	Min. Thk. (mm)	
	Carbon Steel	Alloy Mat.
Up to 600	10	6
600-1500	12	10
1500-2500	16	12

TEMA TABLE RCB-9.1.3.2 PASS PARTITION DIMENSION FACTORS



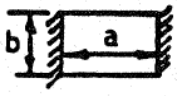
Three sides fixed
One side simply supported

a/b	Beta
0.25	0.02
0.5	0.081
0.75	0.173
1	0.307
1.5	0.539
2	0.657
3	0.718



Long sides fixed
Short sides simply supported

a/b	Beta
1	0.4182
1.2	0.4626
1.4	0.486
1.6	0.4968
1.8	0.4971
2	0.4973
infi.	0.5



Short sides fixed
Long sides simply supported

a/b	Beta
1	0.4182
1.2	0.5208
1.4	0.5988
1.6	0.654
1.8	0.6912
2	0.7146
infi.	0.75

Stationary Pass Partition Plate Calculation For Item No.:E-300		
Pass Partition Input Data Values		
Shell Inside Diameter,	ID =	288.8 mm
Pressure Drop across Pass Partition,	q =	0.5 bar
Design Temperature,	T =	95 °C
Pass Partition Dimension,	a =	288.8 mm
Pass Partition Dimension,	b =	559 mm
Corrosion allowance,	c =	3 mm
Pass Partition Material,		SA-516 70
Allowable Stress in Tension, at Design Temperature,	S	137.9 N/mm²
TEMA RCB-9.131 Minimum Thickness of Pass Partition Plate		
t min,	tmin	10 mm
TEMA RCB-9.132 Pass Partition Plate Formula		
Pass Partition Dimension,	a/b	0.52
Three sides fixed One side simply supported	Beta	0.0871
tmin, tmin = b*(q*Beta/(1.5*S))1/2 + C	tmin	5.57 mm
Pass partition minimum weld size, w = 0.75*t	w	7.50
The pass partition plate thickness of 10 mm is adequate.		
The pass partition fillet weld size of 8 mm is adequate.		