MECHANICAL CALCULATION REPORT

PROJECT NAME: World Energy Renewables Project

ITEM NO. ： 18-X-356

PROJECT NUMBER: EN207119

PURCHASE ORDER NO.: 4505600572

SERVICE ： Vapor Cooler

VENDOR DOC. NO: WXCE6709-CAL-1

DRAWING No.: WXCE6709-00

DRAWING REV. No.: 03

03	18/10/2022	FOR REVIEW	Lei Zhiwei	Zhao Shengfang	Kevin Yang
02	10/08/2022	FOR REVIEW	Lei Zhiwei	Zhao Shengfang	Kevin Yang
01	24/05/2022	FOR REVIEW	Lei Zhiwei	Zhao Shengfang	Kevin Yang
00	05/03/2022	FOR REVIEW	Lei Zhiwei	Zhao Shengfang	Kevin Yang
REV.	**DATE**	**REASON FOR ISSUE**	**PREPARED**	**REVIEWED**	**APPROVED**

WUXI CHEMICAL EQUIPMENT CO., LTD.

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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

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ASME Code Version     : 2021

Analysis Performed by : WUXI CHEMICAL EQUIPMENT CO.,LTD.

Job File              : F:\2022 设计\2022.2.10 AP\18-X-356\输入\2022.10.13\18-X-356.pvdb

Date of Analysis      : Oct 19,2022   9:00am
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PV Elite 24 SP1, March 2022

Vessel Design Summary:

ASME Code, Section VIII Division 1, 2021

Diameter Spec : 22.624 in ID		
Vessel Design Length, Tangent to Tangent	239.60	in
Specified Datum Line Distance	0.00	in
Shell Side Design Temperature	490	F
Channel Side Design Temperature	150	F
Shell Side Design Pressure	550.000	psig
Channel Side Design Pressure	425.000	psig
Shop Shell Side Test Pressure	961.356	psig
Field Shell Side Test Pressure	789.674	psig
Shop Channel Side Test Pressure	961.356	psig
Field Channel Side Test Pressure	921.932	psig
Wind Design Code	ASCE/SEI 7-16	
Earthquake Design Code	ASCE/SEI 7-16	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normal ized	Impact Tested
Shell	SA-516 70	...	...	K02700	Yes	No
Head	SA-516 70	...	...	K02700	Yes	No
Flange	SA-266 2	...	...	K03506	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-105	...	...	K03504	Yes	No
Nozzle	SA-266 2	...	...	K03506	No	No
Re-Pad	SA-516 70	...	...	K02700	Yes	No
Nozzle Flg	SA-105	...	...	K03504	Yes	No
Tubes	SA-179	...	...	K01200	No	No
Tubesheet	SA-266 2	...	...	K03506	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Hrz Bolting		...	...		No	No
Saddles	SA-516 70	...	...	K02700	Yes	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 (psig & in):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Total Corrosion Allowance	Str. Flg. Gov.	In Creep Range
BLIND	425.817	15.00	808.900	0.1250	N/A	No
CHANNEL FLANGE 1	425.817	15.00	990.100	0.1250	N/A	No
CHANNEL SHELL	425.822	15.00	990.100	0.1250	N/A	No
CHANNEL FLANGE 2	425.817	15.00	990.100	0.1250	N/A	No
SHELL FLANGE	550.555	15.00	1123.000	0.1250	N/A	No
SHELL	550.558	15.00	1247.000	0.1250	N/A	No
HEAD	550.558	15.00	613.200	0.1250	No	No

Liquid Level: 22.62 in   Dens.: 42.407 lbm/ft^3   Sp. Gr.: 0.680

Element Types and Properties:

Element Type	"To" Elev in	Element Length in	Nominal Thickness in	Finished Thickness in	Reqd Thk Internal in	Reqd Thk External in	Long Eff	Circ Eff
Body Flg	4.02	3.614	3.937	3.614	3.135	3.002	1.00	1.00
Body Flg	11.07	6.764	5.512	5.189	3.521	5.189	1.00	1.00
Cylinder	30.75	19.685	0.709	0.709	0.372	0.213	1.00	1.00
Body Flg	37.52	6.764	5.512	5.189	3.665	5.189	1.00	1.00
Body Flg	48.65	6.764	5.512	5.189	3.317	5.189	1.00	1.00
Cylinder	237.63	188.976	0.866	0.866	0.445	0.317	1.00	1.00
Ellipse	239.60	1.969	0.551	0.472	0.436	0.186	1.00	1.00

Saddle Parameters:

Saddle Width	8.606	in
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	32.000	in
Wear Pad Width	13.000	in
Wear Pad Thickness	0.804	in
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	30.000	in
Baseplate Length	22.000	in
Baseplate Thickness	0.804	in
Baseplate Width	9.000	in
Number of Ribs (including outside ribs)	1	
Rib Thickness	0.568	in
Web Thickness	0.568	in
Height of Center Web	17.244	in
Number of Bolts in Baseplate	2	

Baseplate Sketch

```
|------------------ 22.000 in ---------------------|
---------------------------------------------------- ---
|                                                  |
|                                                  | 9.000 in
|                                                  |
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Baseplate Plan View

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---------------------------------------------------- ---
|                                                  | 0.804 in
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Baseplate Side View

Maximum Tensile Bolt Load	3627.	lbf

Summary of Maximum Saddle Loads, Operating Case:

Maximum Vertical Saddle Load	25006.32	lbf
Maximum Transverse Saddle Shear Load	3476.98	lbf
Maximum Longitudinal Saddle Shear Load	6953.97	lbf

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

Maximum Vertical Saddle Load	31508.73	lbf
Maximum Transverse Saddle Shear Load	4967.12	lbf
Maximum Longitudinal Saddle Shear Load	9934.24	lbf

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	10275.60	lbf

Maximum Transverse Saddle Shear Load	161.71	lbf
Maximum Longitudinal Saddle Shear Load	74.47	lbf

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	High Stress Location	Pass Fail
T2	WRC-297	0.854	Shell	Passed
T1	WRC-297	0.854	Shell	Passed
S1	WRC-297	0.947	Shell	Passed
S2	WRC-297	0.947	Shell	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	11492.8	lbm
Shop Test	- Fabricated + Water (Full)	14619.3	lbm
Shipping	- Fab. + Rem. Intls.+ Shipping App.	11492.8	lbm
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	11492.8	lbm
Empty	- Fab. + Intls. + Details + Wghts.	11492.8	lbm
Operating	- Empty + Operating Liquid (No CA)	13413.7	lbm
Field Test	- Empty Weight + Water (Full)	14619.3	lbm

Nozzle Calculation Summary (psig & in):

Description	MAWP	Ext	MAPNC	UG-45	[tr]	Weld Path	Areas or Stresses
T2	926.2	OK	1120	OK	0.370	OK	Passed
T2	990.1	OK	...	OK	0.370	OK	Passed
T1	926.2	OK	1120	OK	0.370	OK	Passed
T1	990.1	OK	...	OK	0.370	OK	Passed
V	990.1	OK	1208	OK	0.314	OK	Passed
D	990.1	OK	1208	OK	0.314	OK	Passed
AUX1	2359	OK	3112	OK	0.247	OK	Passed
AUX2	2359	OK	3112	OK	0.247	OK	Passed
S1	893.2	OK	1376	OK	0.453	OK	Passed
S2	893.2	OK	1376	OK	0.453	OK	Passed
AUX3	1410	OK	1933	OK	0.283	OK	Passed
AUX4	1410	OK	1933	OK	0.283	OK	Passed

Nozzle MAWP Summary:

```
Minimum MAWP Nozzles      :      893.2 Nozzle  : S2  [Shellside]
Minimum MAPnc Nozzles     :       1376 Nozzle  : S1  [Shellside]
Minimum MAWP Nozzles      :      926.2 Nozzle  : T1  [Tubeside]
Minimum MAPnc Nozzles     :       1120 Nozzle  : T2  [Tubeside]
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Multiple output lines for the same nozzle indicates required Code calculations in both the longitudinal and circumferential planes of reinforcement where applicable.

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	X Coordinate in	Layout Angle deg	Dia. Limit in
30	T2	20.910	31.601	11.502
30	T1	20.907	148.399	11.502
30	V	20.910	-23.140	4.500
30	D	20.910	203.140	4.500
30	AUX1	0.000	270.000	4.500
30	AUX2	0.000	90.000	4.500
60	S1	58.379	0.000	19.996
60	S2	207.395	180.000	19.996
60	AUX3	0.000	90.000	4.500
60	AUX4	0.000	270.000	4.500

The nozzle spacing is computed by the following:

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

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

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

No interference violations have been detected!

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk in	Reinforcing Pad Diameter	Reinforcing Pad Thk in	Cut Length in	Flg Class
V	2.000 in	Actual	LWN	3.308	0.654	...	...	7.49	300
D	2.000 in	Actual	LWN	3.308	0.654	...	...	7.49	300
AUX1	2.000 in	Actual	LWN	3.308	0.654	...	...	7.02	300
AUX2	2.000 in	Actual	LWN	3.308	0.654	...	...	7.02	300
AUX3	2.000 in	Actual	LWN	3.308	0.654	...	...	6.69	300
AUX4	2.000 in	Actual	LWN	3.308	0.654	...	...	6.69	300
T2	6.000 in	120	WNF	6.625	0.562	10.24	0.71	15.42	600
T1	6.000 in	120	WNF	6.625	0.562	10.24	0.71	15.42	600
S1	9.748 in	Actual	WNF	10.748	0.500	...	...	18.44	600
S2	9.748 in	Actual	WNF	10.748	0.500	...	...	18.44	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 (in):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
V	SA-105	0.709	0.354	...	...	...
D	SA-105	0.709	0.354	...	...	...
AUX1	SA-105	0.562	0.354	...	...	...
AUX2	SA-105	0.562	0.354	...	...	...
AUX3	SA-105	0.500	0.354	...	...	...
AUX4	SA-105	0.500	0.354	...	...	...
T2	SA-106 B	0.709	0.354	0.551	0.709	...
T1	SA-106 B	0.709	0.354	0.551	0.709	...
S1	SA-266 2	0.866	0.354	...	...	...
S2	SA-266 2	0.866	0.354	...	...	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum in	Layout Angle deg	Proj Outside in	Proj Inside in	Installed in Component
V	20.910	-23.1	5.78	0.00	CHANNEL SHELL
D	20.910	203.1	5.78	0.00	CHANNEL SHELL
AUX1	16.067	270.0	5.91	0.00	T1
AUX2	16.067	90.0	5.91	0.00	T2
AUX3	55.335	90.0	5.91	0.00	S1
AUX4	55.335	270.0	5.91	0.00	S2
T2	20.910	31.6	11.14	0.00	CHANNEL SHELL
T1	20.907	148.4	11.14	0.00	CHANNEL SHELL
S1	58.379	0.0	15.82	0.00	SHELL

S2		207.395	180.0	15.82	0.00	SHELL

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	BODY FLANGE: 3.937" THK X 31.299" OD	SA-266 2
3	BODY FLANGE: 5.512" THK X 31.299" OD	SA-266 2
1	CYLINDER: 0.709" THK X 22.624" ID X 1'-7.69"	SA-516 70
1	CYLINDER: 0.866" THK X 22.624" ID X 15'-8.98"	SA-516 70
1	ELLIPTICAL HEAD: 2.0 X 1, 0.551" THK X 22.624" ID X 1.97"	SA-516 70
16	BAFFLES: 22.600" DIA X 0.394" THK	SA-516 70
6	TIE RODS: 0.472" DIA X 176.378"	SA-36
6	SPACERS: 0.750" DIA X 176.378"	SA-179
1	TUBESHEET: 24.803" X 3.685" THK	SA-266 2
278	TUBES: 180.000" X 0.750" DIA X 0.083" THK	SA-179
2	SADDLE: 8.606" X 120 DEG	SA-516 70
6	CLASS 300 GR 1.1,2.0" BLIND FLANGE(S)	SA-105
2	GASKET: 24.803" OD X 23.228" ID	...
64	BODY FLANGE BOLTS: 1.250" DIA	SA-193 B7
128	NUTS FOR BODY FLANGE BOLTS: 1.250" DIA	...
1	NAMEPLATE	...

Minimum Design Metal Temperature Results Summary (F):

Description Notes		Curve	Basic MDMT	Reduced MDMT	UG-20(f) MDMT	Thickness ratio	Gov Thk in	E*	PWHT reqd
SHELL FLANGE	[11]	C	-11	-11	-20	0.546	0.866	1.00	No
SHELL	[8]	D	-36	-36	-20	0.482	0.866	1.00	No
HEAD	[10]	D	-55	-55	-20	0.999	0.472	1.00	No
HEAD	[7]	D	-55	-55	-20	0.839	0.551	1.00	No
Right Sdl	[24]	D	-39	-39	-20	0.482	0.804	1.00	No
Right Sdl	[24]	D	-39	-39	-20	0.482	0.804	1.00	No
S1	[1]	B	-6	-20	-20	0.412	0.500	1.00	No
Nozzle Flg	[4]	B	-20	-20					
S2	[1]	B	-6	-20	-20	0.413	0.500	1.00	No
Nozzle Flg	[4]	B	-20	-20					
AUX3	[1]	B	-6	-20	-20	0.412	0.500	1.00	No
Nozzle Flg	[4]	B	-20	-20					
AUX4	[1]	B	-6	-20	-20	0.413	0.500	1.00	No
Nozzle Flg	[4]	B	-20	-20					
Nozl. Bolting	[22]		-55			1.000	2.500	1.00	No
Tubesheet: SS	[13]	C	-9	-9	-20	0.590	0.921	1.00	No
Warmest MDMT:			-6	-9					
BLIND	[11]	C	-9	-9	-20	0.877	0.904	1.00	No
CHANNEL FLANG	[11]	C	-21	-21	-20	0.668	0.709	1.00	No
CHANNEL FLANG	[11]	C	-21	-21	-20	0.668	0.709	1.00	No
CHANNEL SHELL	[8]	D	-45	-45	-20	0.710	0.709	1.00	No
T2	[1]	C	-7	-20	-20	0.368	0.492	1.00	No
Nozzle Flg	[4]	B	-20	-20					
T1	[1]	C	-7	-20	-20	0.369	0.492	1.00	No
Nozzle Flg	[4]	B	-20	-20					
V	[1]	B	9	-20	-20	0.077	0.654	1.00	No
Nozzle Flg	[4]	B	-20	-20					
D	[1]	B	9	-20	-20	0.077	0.654	1.00	No
Nozzle Flg	[4]	B	-20	-20					
AUX1	[1]	B	0	-20	-20	0.280	0.562	1.00	No
Nozzle Flg	[4]	B	0	0					
AUX2	[1]	B	0	-20	-20	0.280	0.562	1.00	No
Nozzle Flg	[4]	B	-20	-20					
Nozl. Bolting	[22]		-55			1.000	2.500	1.00	No
Tubesheet: CS	[14]	C	-9	-9	-20	0.590	0.921	1.00	No
Bolting	[21]		-55						
Bolting	[21]		-55						
Warmest MDMT:			9	0					

Exchanger Side	Computed MDMT	Required MDMT	Pass/Fail
Shell	-20.0	32.0	Pass
Channel/Tube	0.0	32.0	Pass

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ASME Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ASME 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] - Body Flange Bolting Material
[22] - Nozzle Flange Bolting Material
[23] - Stiffening Ring to Shell Weld
[24] - Saddle to Shell Weld

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.

Units used in this Analysis (Inches_Unicode):

Name	System Unit	Constant	User Unit
Length	Feet	12.0000	in
Force	Pounds	1.0000	lbf
Mass	Pounds	1.0000	lbm
Area	sq. inches	1.0000	in^2
Moment	ft. lbs.	12.0000	in-lb
Stress	lbs./sq.in.	1.0000	psi
Temperature	Degrees F	1.0000	F
Pressure	psig	1.0000	psig
Elast. Modulus	lbs./sq.in.	1.0000	psi
Pipe Density	lbs./cu.in.	1.0000	lbm/in^3
Ins. Density	lbs./cu.ft.	1.0000	lbm/ft^3
Fluid Density	lbs./cu.ft.	1.0000	lbm/ft^3
Wind Speed	miles/hr	1.0000	mile/hr
Tray Weight	lbs./sq.ft.	1.0000	lb/ft^2
Inertia	in.**4	1.0000	in**4
G Load	G's	1.0000	g's
Wind Load	lbs./sq.ft.	1.0000	psf
Elevation	Feet	12.0000	in
Volume	in.**3	0.0043	gal
Diameter	inches	1.0000	in
Thickness	inches	1.0000	in

PV Elite Vessel Analysis Program: Input Data

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	550	psig
Channel Side Design Pressure	425	psig
Shell Side Design Temperature	490.0	F
Channel Side Design Temperature	150.0	F
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	None	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	32.0	F
MDMT (CET), Tube Side	32.0	F
User defined MAWP, Shell Side	0	psig
User defined MAWP, Channel Side	0	psig
User defined MAPnc, Shell Side	0	psig
User defined MAPnc, Channel Side	0	psig
User defined Test Pres., Shell Side	0	psig
User defined Test Pres., Channel Side	0	psig

Projection of Nozzle from Vessel Top	17.822	in
Projection of Nozzle from Vessel Bottom	17.822	in
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	

Shop Pressure Test:

Type of Pressure Test	UG-99(c)
Pressure Test Position	Horizontal

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 Test Performed in Corroded Condition                      No
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Field Pressure Test:

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 Type of Pressure Test                                UG-99(b)
 Pressure Test Position                             Horizontal
 Test Performed in Corroded Condition                      Yes

 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/SEI 7-16
 Wind Load Reduction Scale Factor                        0.600
 Basic Wind Speed                    [V]                   101  mile/hr
 Surface Roughness Category                    C: Open Terrain
 Importance Factor                                         1.0
 Type of Surface                             Moderately Smooth
 Base Elevation                                           1380  in
 Percent Wind for Hydrotest                               50.0
 Using User defined Wind Press. Vs Elev.                     N
 Height of Hill or Escarpment     H or Hh                    0  in
 Distance Upwind of Crest              Lh                    0  in
 Distance from Crest to the Vessel      x                    0  in
 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
 Site Elevation above Sea Level                            927  in

 Seismic Design Code                             ASCE/SEI 7-16
 Seismic Load Reduction Scale Factor                     0.700
 Importance Factor                                       1.500
 Table Value Fa                                          1.000
 Table Value Fv                                          1.721
 Max. Mapped Res. Acceleration       [Ss]                1.616
 Max. Eff. Ground Acceleration        [S]                0.579
 Force Modification Factor R                             2.500
 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 )                        1.077
 User Value of Sd1 (used if > 0 )                        0.996
 Moment Reduction Factor Tau                             1.000

 M.A.W.P + Static Head to Nozzle                             Y
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Consider MAP New and Cold in Noz. Design	Y
Consider External Loads for Nozzle Des.	Y
Use ASME VIII-1 Appendix 1-9	N
Perform Blast Load Analysis	No
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	No
Consider Longitudinal Stress in MDMT Calculations	Yes

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Flange	
Description	BLIND	
Distance "FROM" to "TO"	3.614	in
Flange Outside Diameter	31.299	in
Element Thickness	3.614	in
Internal Corrosion Allowance	0.125	in
Nominal Thickness	3.937	in
External Corrosion Allowance	0	in
Design Internal Pressure	425.82	psig
Design Temperature Internal Pressure	150	F
Design External Pressure	15	psig
Design Temperature External Pressure	300	F
Effective Diameter Multiplier	1.5	
Material Name	SA-266 2	
Allowable Stress, Ambient	20000	psi
Allowable Stress, Operating	20000	psi
Allowable Stress, Hydrotest	32400	psi
Material Density	0.28	lbm/in^3
P Number Thickness	1.25	in
Yield Stress, Operating	33800	psi
UCS-66 Chart Curve Designation	C	
External Pressure Chart Name	CS-2	
UNS Number	K03506	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weld is pre-Heated	No	

Element From Node	20	
Element To Node	30	
Element Type	Flange	
Description	CHANNEL FLANGE 1	
Distance "FROM" to "TO"	6.764	in
Flange Inside Diameter	22.624	in
Element Thickness	5.189	in
Internal Corrosion Allowance	0.125	in

```
Nominal Thickness                                  5.512  in
External Corrosion Allowance                           0  in
Design Internal Pressure                             425  psig
Design Temperature Internal Pressure                 150  F
Design External Pressure                              15  psig
Design Temperature External Pressure                 300  F
Effective Diameter Multiplier                        1.5
Material Name                                   SA-266 2
Perform Flange Stress Calculation (Y/N)                Y
Weld is pre-Heated                                    No

    Element From Node                                 20
    Detail Type                                   Liquid
    Detail ID                                 Liquid: 20
    Dist. from "FROM" Node / Offset dist               0  in
    Height/Length of Liquid                       22.624  in
    Liquid Density                                  62.4  lbm/ft^3

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

Element From Node                                     30
Element To Node                                       40
Element Type                                    Cylinder
Description                                CHANNEL SHELL
Distance "FROM" to "TO"                           19.685  in
Inside Diameter                                   22.624  in
Element Thickness                                  0.709  in
Internal Corrosion Allowance                       0.125  in
Nominal Thickness                                  0.709  in
External Corrosion Allowance                           0  in
Design Internal Pressure                             425  psig
Design Temperature Internal Pressure                 150  F
Design External Pressure                              15  psig
Design Temperature External Pressure                 300  F
Effective Diameter Multiplier                        1.5
Material Name                                  SA-516 70 [Normalized]
    Allowable Stress, Ambient                      20000  psi
    Allowable Stress, Operating                    20000  psi
    Allowable Stress, Hydrotest                    34199  psi
    Material Density                                0.28  lbm/in^3
    P Number Thickness                             1.142  in
    Yield Stress, Operating                        35707  psi
    UCS-66 Chart Curve Designation                     D
    External Pressure Chart Name                    CS-2
    UNS Number                                    K02700
    Product Form                                   Plate
Efficiency, Longitudinal Seam                        1.0
Efficiency, Circumferential Seam                     1.0
Weld is pre-Heated                                    No

    Element From Node                                 30
    Detail Type                                   Liquid
    Detail ID                                 Liquid: 30
    Dist. from "FROM" Node / Offset dist               0  in
    Height/Length of Liquid                       22.624  in
    Liquid Density                                  62.4  lbm/ft^3

    Element From Node                                 30
    Detail Type                                   Nozzle
    Detail ID                                         T2
    Dist. from "FROM" Node / Offset dist           9.843  in
    Nozzle Diameter                                    6  in.
    Nozzle Schedule                                  120
    Nozzle Class                                     600
```

```
     Layout Angle                                31.600901
     Blind Flange (Y/N)                                  N
     Weight of Nozzle ( Used if > 0 )                    0  lbf
     Grade of Attached Flange                       GR 1.1
     Nozzle Matl                                  SA-106 B

     Element From Node                                  30
     Detail Type                                    Nozzle
     Detail ID                                          T1
     Dist. from "FROM" Node / Offset dist             9.84  in
     Nozzle Diameter                                     6  in.
     Nozzle Schedule                                   120
     Nozzle Class                                      600
     Layout Angle                                  148.399
     Blind Flange (Y/N)                                  N
     Weight of Nozzle ( Used if > 0 )                    0  lbf
     Grade of Attached Flange                       GR 1.1
     Nozzle Matl                                  SA-106 B

     Element From Node                                  30
     Detail Type                                    Nozzle
     Detail ID                                           V
     Dist. from "FROM" Node / Offset dist            9.843  in
     Nozzle Diameter                                     2  in.
     Nozzle Schedule                                  None
     Nozzle Class                                      300
     Layout Angle                               -23.139999
     Blind Flange (Y/N)                                  Y
     Weight of Nozzle ( Used if > 0 )                    0  lbf
     Grade of Attached Flange                       GR 1.1
     Nozzle Matl                                    SA-105 [Normalized]

     Element From Node                                  30
     Detail Type                                    Nozzle
     Detail ID                                           D
     Dist. from "FROM" Node / Offset dist            9.843  in
     Nozzle Diameter                                     2  in.
     Nozzle Schedule                                  None
     Nozzle Class                                      300
     Layout Angle                                   203.14
     Blind Flange (Y/N)                                  Y
     Weight of Nozzle ( Used if > 0 )                    0  lbf
     Grade of Attached Flange                       GR 1.1
     Nozzle Matl                                    SA-105 [Normalized]

     Element From Node                                  30
     Detail Type                                    Nozzle
     Detail ID                                        AUX1
     Dist. from "FROM" Node / Offset dist                5  in
     Nozzle Diameter                                     2  in.
     Nozzle Schedule                                  None
     Nozzle Class                                      300
     Layout Angle                                    270.0
     Blind Flange (Y/N)                                  Y
     Weight of Nozzle ( Used if > 0 )                    0  lbf
     Grade of Attached Flange                       GR 1.1
     Nozzle Matl                                    SA-105 [Normalized]

     Element From Node                                  30
     Detail Type                                    Nozzle
     Detail ID                                        AUX2
     Dist. from "FROM" Node / Offset dist                5  in
     Nozzle Diameter                                     2  in.
     Nozzle Schedule                                  None
```

```
    Nozzle Class                                      300
    Layout Angle                                     90.0
    Blind Flange (Y/N)                                  Y
    Weight of Nozzle ( Used if > 0 )                    0  lbf
    Grade of Attached Flange                       GR 1.1
    Nozzle Matl                                    SA-105 [Normalized]

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

 Element From Node                                     40
 Element To Node                                       50
 Element Type                                      Flange
 Description                             CHANNEL FLANGE 2
 Distance "FROM" to "TO"                            6.764  in
 Flange Inside Diameter                            22.624  in
 Element Thickness                                  5.189  in
 Internal Corrosion Allowance                       0.125  in
 Nominal Thickness                                  5.512  in
 External Corrosion Allowance                           0  in
 Design Internal Pressure                             425  psig
 Design Temperature Internal Pressure                 150  F
 Design External Pressure                              15  psig
 Design Temperature External Pressure                 300  F
 Effective Diameter Multiplier                        1.5
 Material Name                                   SA-266 2
    Allowable Stress, Ambient                       20000  psi
    Allowable Stress, Operating                     20000  psi
    Allowable Stress, Hydrotest                     32400  psi
    Material Density                                 0.28  lbm/in^3
    P Number Thickness                               1.22  in
    Yield Stress, Operating                         33800  psi
    UCS-66 Chart Curve Designation                      C
    External Pressure Chart Name                     CS-2
    UNS Number                                     K03506
    Product Form                                 Forgings
 Perform Flange Stress Calculation (Y/N)                Y
 Weld is pre-Heated                                    No

    Element From Node                                  40
    Detail Type                                    Liquid
    Detail ID                                  Liquid: 40
    Dist. from "FROM" Node / Offset dist                0  in
    Height/Length of Liquid                        22.624  in
    Liquid Density                                   62.4  lbm/ft^3

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

 Element From Node                                     50
 Element To Node                                       60
 Element Type                                      Flange
 Description                                 SHELL FLANGE
 Distance "FROM" to "TO"                            6.764  in
 Flange Inside Diameter                            22.624  in
 Element Thickness                                  5.189  in
 Internal Corrosion Allowance                       0.125  in
 Nominal Thickness                                  5.512  in
 External Corrosion Allowance                           0  in
 Design Internal Pressure                             550  psig
 Design Temperature Internal Pressure                 490  F
 Design External Pressure                              15  psig
 Design Temperature External Pressure                 300  F
 Effective Diameter Multiplier                        1.5
 Material Name                                   SA-266 2
 Perform Flange Stress Calculation (Y/N)                Y
```

```
 Weld is pre-Heated                                        No

     Element From Node                                     50
     Detail Type                                       Liquid
     Detail ID                                     Liquid: 50
     Dist. from "FROM" Node / Offset dist                   0  in
     Height/Length of Liquid                           22.624  in
     Liquid Density                                    42.407  lbm/ft^3

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

 Element From Node                                         60
 Element To Node                                           70
 Element Type                                        Cylinder
 Description                                            SHELL
 Distance "FROM" to "TO"                               188.98  in
 Inside Diameter                                       22.624  in
 Element Thickness                                      0.866  in
 Internal Corrosion Allowance                           0.125  in
 Nominal Thickness                                      0.866  in
 External Corrosion Allowance                               0  in
 Design Internal Pressure                                 550  psig
 Design Temperature Internal Pressure                     490  F
 Design External Pressure                                  15  psig
 Design Temperature External Pressure                     300  F
 Effective Diameter Multiplier                            1.5
 Material Name                                      SA-516 70 [Normalized]
     Allowable Stress, Ambient                          20000  psi
     Allowable Stress, Operating                        20000  psi
     Allowable Stress, Hydrotest                        34200  psi
     Material Density                                    0.28  lbm/in^3
     P Number Thickness                                  1.25  in
     Yield Stress, Operating                            31150  psi
     UCS-66 Chart Curve Designation                         D
     External Pressure Chart Name                        CS-2
     UNS Number                                        K02700
     Product Form                                       Plate
 Efficiency, Longitudinal Seam                            1.0
 Efficiency, Circumferential Seam                         1.0
 Weld is pre-Heated                                        No

     Element From Node                                     60
     Detail Type                                       Saddle
     Detail ID                                        Lft Sdl
     Dist. from "FROM" Node / Offset dist              17.716  in
     Width of Saddle                                    8.606  in
     Height of Saddle at Bottom                            32  in
     Saddle Contact Angle                               120.0
     Height of Composite Ring Stiffener                     0  in
     Width of Wear Plate                                   13  in
     Thickness of Wear Plate                            0.804  in
     Contact Angle, Wear Plate (degrees)                132.0
     Friction coefficient                          0.40000001
     Moment Factor                                        3.0
     Dimension E at base (optional)                         0  in
     Circumferential Eff. over Saddle                     1.0
     Circumferential Eff. at Midspan                      1.0
     Tangent to Tangent dist. (optional)                    0  in

     Element From Node                                     60
     Detail Type                                       Saddle
     Detail ID                                      Right Sdl
     Dist. from "FROM" Node / Offset dist              126.72  in
     Width of Saddle                                    8.606  in
```

```
     Height of Saddle at Bottom                        32  in
     Saddle Contact Angle                           120.0
     Height of Composite Ring Stiffener                 0  in
     Width of Wear Plate                               13  in
     Thickness of Wear Plate                        0.804  in
     Contact Angle, Wear Plate (degrees)            132.0
     Friction coefficient                             0.0
     Moment Factor                                    3.0
     Dimension E at base (optional)                     0  in
     Circumferential Eff. over Saddle                 1.0
     Circumferential Eff. at Midspan                  1.0
     Tangent to Tangent dist. (optional)                0  in

     Element From Node                                 60
     Detail Type                                   Liquid
     Detail ID                                 Liquid: 60
     Dist. from "FROM" Node / Offset dist               0  in
     Height/Length of Liquid                       22.624  in
     Liquid Density                                42.407  lbm/ft^3

     Element From Node                                 60
     Detail Type                                   Nozzle
     Detail ID                                         S1
     Dist. from "FROM" Node / Offset dist           9.724  in
     Nozzle Diameter                                9.748  in.
     Nozzle Schedule                                 None
     Nozzle Class                                     600
     Layout Angle                                     0.0
     Blind Flange (Y/N)                                 N
     Weight of Nozzle ( Used if > 0 )                   0  lbf
     Grade of Attached Flange                      GR 1.1
     Nozzle Matl                                 SA-266 2

     Element From Node                                 60
     Detail Type                                   Nozzle
     Detail ID                                         S2
     Dist. from "FROM" Node / Offset dist          158.74  in
     Nozzle Diameter                                9.748  in.
     Nozzle Schedule                                 None
     Nozzle Class                                     600
     Layout Angle                                   180.0
     Blind Flange (Y/N)                                 N
     Weight of Nozzle ( Used if > 0 )                   0  lbf
     Grade of Attached Flange                      GR 1.1
     Nozzle Matl                                 SA-266 2

     Element From Node                                 60
     Detail Type                                   Nozzle
     Detail ID                                       AUX3
     Dist. from "FROM" Node / Offset dist            6.68  in
     Nozzle Diameter                                    2  in.
     Nozzle Schedule                                 None
     Nozzle Class                                     300
     Layout Angle                                    90.0
     Blind Flange (Y/N)                                 Y
     Weight of Nozzle ( Used if > 0 )                   0  lbf
     Grade of Attached Flange                      GR 1.1
     Nozzle Matl                                   SA-105 [Normalized]

     Element From Node                                 60
     Detail Type                                   Nozzle
     Detail ID                                       AUX4
     Dist. from "FROM" Node / Offset dist            6.68  in
     Nozzle Diameter                                    2  in.
```

Nozzle Schedule	None
Nozzle Class	300
Layout Angle	270.0
Blind Flange (Y/N)	Y
Weight of Nozzle (Used if > 0)	0 lbf
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-105 [Normalized]

Element From Node	70
Element To Node	80
Element Type	Elliptical
Description	HEAD
Distance "FROM" to "TO"	1.969 in
Inside Diameter	22.624 in
Element Thickness	0.472 in
Internal Corrosion Allowance	0.125 in
Nominal Thickness	0.551 in
External Corrosion Allowance	0 in
Design Internal Pressure	550 psig
Design Temperature Internal Pressure	490 F
Design External Pressure	15 psig
Design Temperature External Pressure	300 F
Effective Diameter Multiplier	1.5
Material Name	SA-516 70 [Normalized]
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Elliptical Head Factor	2.0
Weld is pre-Heated	No

Element From Node	70
Detail Type	Liquid
Detail ID	Liquid: 70
Dist. from "FROM" Node / Offset dist	0 in
Height/Length of Liquid	22.624 in
Liquid Density	42.407 lbm/ft^3

XY Coordinate Calculations:

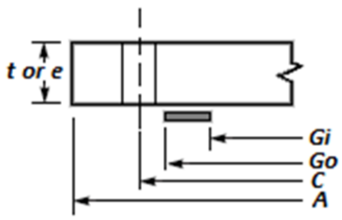
From	To	X (Horiz.) in	Y (Vert.) in	DX (Horiz.) in	DY (Vert.) in
	BLIND	4.021	...	3.614	...
	CHANNEL FLANGE	11.067	...	6.764	...
	CHANNEL SHELL	30.752	...	19.685	...
	CHANNEL FLANGE	37.516	...	6.764	...
	SHELL FLANGE	48.655	...	6.764	...
	SHELL	237.631	...	188.976	...
	HEAD	239.6	...	1.969	...

PV Elite includes an 1/8 inch (3.175mm) raised face and gasket thicknesses for girth flanges and tubesheet thicknesses where applicable in the Tangent to Tangent length calculation. The calculated dimensions are based on the given element lengths. Due to variability in manufacturing (weld gaps etc.), the Tangent to Tangent length may not be exact.

Flange Input Data Values **Description:** BLIND :

BLIND

```
 Flange Type                                TEMA Channel Cover

 Design Pressure                              P        425.82  psig
 Design Temperature                                       150  F
 Internal Corrosion Allowance                ci        0.1250  in
 External Corrosion Allowance                ce        0.0000  in
 Use Corrosion Allowance in Thickness Calcs.              Yes

 Flange Outside Diameter                      A        31.299  in
 Flange Thickness                             t        3.6140  in

 Flange Material                                     SA-266 2
 Flange Material UNS number                            K03506
 Flange Allowable Stress At Temperature     Sfo      20000.00  psi
 Flange Allowable Stress At Ambient         Sfa      20000.00  psi

 Bolt Material                                      SA-193 B7
 Bolt Allowable Stress At Temperature        Sb      25000.00  psi
 Bolt Allowable Stress At Ambient            Sa      25000.00  psi

 Diameter of the Load Reaction, Long  Span  D           0.000  in
 Diameter of the Load Reaction, Short Span  d           0.000  in
 Perimeter along the Center of the Bolts    L          90.289  in
 Youngs Modulus for Blind Flange Matl.      Sy    29030770.00  psi
 Allowed Channel Cover Deflection      dfAllow         0.0300  in

 Diameter of Bolt Circle                      C        28.740  in
 Nominal Bolt Diameter                        a        1.2500  in
 Type of Threads                            TEMA Thread Series
 Number of Bolts                                           32

 Flange Face Outside Diameter               Fod        24.803  in
 Flange Face Inside Diameter                Fid        22.506  in
 Flange Facing Sketch                         1, Code Sketch 1a

 Gasket Outside Diameter                     Go        24.803  in
 Gasket Inside Diameter                      Gi        23.228  in
 Gasket Factor                                m        4.2500
 Gasket Design Seating Stress                 y      10100.00  psi

 Column for Gasket Seating                    2, Code Column II
 Gasket Thickness                            tg        0.1570  in

 Length of Partition Gasket                  lp       23.2280  in
 Width  of Partition Gasket                  tp        0.3940  in
 Partition Gasket Factor                  mPart        4.2500
 Partition Gasket Design Seating Stress yPart      10100.00  psi
```



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```
Gasket Contact Width,       N = (Go - Gi) / 2          0.787  in
Basic Gasket Width,        bo = N / 2                  0.394  in
Effective Gasket Width,     b = sqrt(bo)/2             0.314  in
Gasket Reaction Diameter,   G = Go - 2 * b            24.176  in
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 24.18² * 425.8
  = 195462.750 lbf
```

Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 0.314 * pi * 24.18 * 4.25 * 425.8
    + 2 * 23.23 * 0.197 * 4.25 * 425.8
  = 102809.969 lbf
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 195463 + 102810 + 0, 0 )
  = 298272.719 lbf
```

Gasket Seating Bolt Load [Wm2]:
```
  = y * b * pi * G  + yPart * bPart * lp
  = 10100*0.314*pi*24.18+10100*0.197*23.23
  = 286889.500 lbf
```

Required Bolt Area [Am]:
```
  = max( Wm1/Sb, Wm2/Sa )
  = max( 298273/25000, 286890/25000 )
  = 11.931 in^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 1.25 + 6 * 3.489/(4.25 + 0.5)
  = 6.907 in
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 28.74 * sin( pi/32 )
  = 2.817 in
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 2.817/( 2 * 1.25 + 3.489 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area:	11.931	29.728	
Radial Distance between Bolts and Edge:	1.250	1.280	
Circ. Spacing between the Bolts:	2.813	2.817	6.907

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * pi(Go + Gi) )
  = 29.73 * 25000/(10100 * pi(24.8 + 23.23 ) )
  = 0.488 in
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa( Am + Ab ) / 2
  = 25000( 11.93 + 29.73 )/2
  = 520736.38 lbf
```

Gasket Load for the Operating Condition [HG]:
```
  = Wm1
  = 298272.72 lbf
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 28.74 - 24.18 )/2
  = 2.2822 in
```

Tangential Flange Stress, Flat Head (UG-34), Operating [STo]:
```
  = 1.9 * Wm1 * hG * Bsc/(t² * G) + C * Z * Peq * G²/t²
  = 1.9*298273*2.282*1/(3.489²*24.18)+0.3*1*425.8*24.18²/3.489²
  = 10528.22 psi
```

Tangential Flange Stress, Flat Head (UG-34), Seating [STa]:
```
  = 1.9 * W * hG * Bsc/ (t² * G)
  = 1.9*520736*2.282*1/(3.489²*24.18)
  = 7672.85 psi
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 298273/29.73
  = 10033.39 psi
```

Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (286890/29.73)
  = 9650.48 psi
```

Flange Stress Analysis Results: psi

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Tangential Flange	10528.22	20000.00	7672.85	20000.00
Bolting	10033.39	25000.00	9650.48	25000.00

TEMA Channel Cover Deflection Calculations:
```
 Actual deflection at center per TEMA formula        0.0218  in
 Allowed deflection at center of Cover               0.0300  in

 Reqd. Blind Flange Thickness at Center               2.656 in
 Reqd. Blind Flange Thickness at Gasket               2.286 in
 Min. Required Flange Thickness per TEMA              3.135 in
 Estimated M.A.W.P. ( Operating )                     808.9 psig
 Estimated Finished Weight of Flange at given Thk.    778.6 lbm
 Estimated Unfinished Weight of Forging at given Thk  778.6 lbm
```

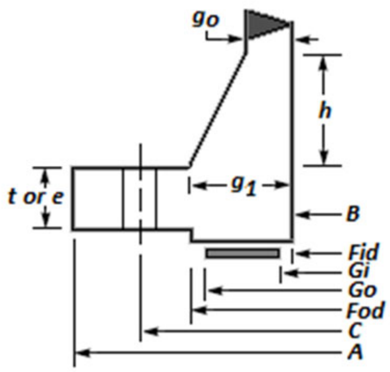
Minimum Design Metal Temperature Results:
Thickness Ratio = 0.877, Temperature Reduction per Fig. UCS 66.1 = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C          -9 F
 Min Metal Temp. w/o impact per UG-20(f)                -20 F
```

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

CHANNEL FLANGE 1

```
Flange Type                          Integral Weld Neck

Design Pressure                      P          425.82  psig
Design Temperature                                 150  F
Internal Corrosion Allowance         ci         0.1250  in
External Corrosion Allowance         ce         0.0000  in
Use Corrosion Allowance in Thickness Calcs.        Yes

Flange Inside Diameter               B          22.624  in
Flange Outside Diameter              A          31.299  in
Flange Thickness                     t          5.1890  in
Thickness of Hub at Small End        go         0.7090  in
Thickness of Hub at Large End        g1         1.1810  in
Length of Hub                        h          1.5750  in

Flange Material                               SA-266 2
Flange Material UNS number                      K03506
Flange Allowable Stress At Temperature  Sfo   20000.00  psi
Flange Allowable Stress At Ambient      Sfa   20000.00  psi

Bolt Material                                SA-193 B7
Bolt Allowable Stress At Temperature    Sb    25000.00  psi
Bolt Allowable Stress At Ambient        Sa    25000.00  psi

Diameter of Bolt Circle              C          28.740  in
Nominal Bolt Diameter                a          1.2500  in
Type of Threads                      TEMA Thread Series
Number of Bolts                                     32

Flange Face Outside Diameter         Fod        24.921  in
Flange Face Inside Diameter          Fid        22.624  in
Flange Facing Sketch                  1, Code Sketch 1a

Gasket Outside Diameter              Go         24.803  in
Gasket Inside Diameter               Gi         23.228  in
Gasket Factor                        m          4.2500
Gasket Design Seating Stress         y        10100.00  psi

Column for Gasket Seating             2, Code Column II
Gasket Thickness                     tg         0.1570  in

Length of Partition Gasket           lp        23.2280  in
Width  of Partition Gasket           tp         0.3940  in
Partition Gasket Factor            mPart        4.2500
Partition Gasket Design Seating Stress yPart  10100.00  psi
```



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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)
  = (425.8*(22.62/2+0.125))/(20000*1-0.6*425.8)+Ca
  = 0.3717 in
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000 * 1 * 0.584 )/(11.44 + 0.6 * 0.584 )
  = 990.889 psig
```

```
 Corroded Flange Thickness, tc = T-ci                      5.064  in
 Corroded Flange ID,      Bcor = B+2*Fcor                 22.874  in
 Corroded Large Hub,     g1Cor = g1-ci                     1.056  in
 Corroded Small Hub,     g0Cor = go-ci                     0.584  in
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor        1.877  in

 Gasket Contact Width,       N = (Go - Gi) / 2             0.787  in
 Basic Gasket Width,        bo = N / 2                     0.394  in
 Effective Gasket Width,     b = sqrt(bo)/2                0.314  in
 Gasket Reaction Diameter,   G = Go - 2 * b               24.176  in
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 24.18² * 425.8
  = 195462.750 lbf
```

Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 0.314 * pi * 24.18 * 4.25 * 425.8
    + 2 * 23.23 * 0.197 * 4.25 * 425.8
  = 102809.969 lbf
```

Hydrostatic End Load at Flange ID [Hd]:
```
  = pi * Bcor² * P  / 4
  = pi * 22.87² *425.8/4
  = 174983.516 lbf
```

Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 195463 - 174984
  = 20479.234 lbf
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 195463 + 102810 + 0, 0 )
  = 298272.719 lbf
```

Gasket Seating Bolt Load [Wm2]:
```
  = y * b * pi * G  + yPart * bPart * lp
  = 10100*0.314*pi*24.18+10100*0.197*23.23
  = 286889.500 lbf
```

Required Bolt Area [Am]:
```
  = max( Wm1/Sb, Wm2/Sa )
  = max( 298273/25000, 286890/25000 )
  = 11.931 in^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 1.25 + 6 * 5.064/(4.25 + 0.5)
  = 8.897 in
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 28.74 * sin( pi/32 )
  = 2.817 in
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 2.817/( 2 * 1.25 + 5.064 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area:	11.931	29.728	
Radial Distance between Hub and Bolts:	1.750	1.877	
Radial Distance between Bolts and Edge:	1.250	1.280	
Circ. Spacing between the Bolts:	2.813	2.817	8.897

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * pi(Go + Gi) )
  = 29.73 * 25000/(10100 * pi(24.8 + 23.23 ) )
  = 0.488 in
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa( Am + Ab ) / 2
  = 25000( 11.93 + 29.73 )/2
  = 520736.38 lbf
```

Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 298273 - 195463
  = 102809.97 lbf
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 28.74 - 24.18 )/2
  = 2.2822 in
```

Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
```

```
  = ( 1.877 + 1.056 + 2.282 )/2
  = 2.6076 in
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 1.877 +( 1.056/2.0 )
  = 2.4050 in
```

Summary of Moments for Internal Pressure: (in-lb)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	174984.	2.4050	1.0000	420835.
Face Pressure, Mt	20479.	2.6076	1.0000	53402.
Gasket Load, Mg	102810.	2.2822	1.0000	234638.
Gasket Seating, Matm	520736.	2.2822	1.0000	1188449.

```
 Total Moment for Operation,      Mop                              708875. in-lb
 Total Moment for Gasket seating, Matm                            1188449. in-lb

 Effective Hub Length, ho = sqrt(Bcor*goCor)           3.655 in
 Hub Ratio,          h/h0 = HL / H0                    0.431
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.808
```

Flange Factors for Integral Flange:

```
 Factor F                                              0.846
 Factor V                                              0.272
 Factor f                                              1.198
 Factors from Figure 2-7.1                    K =      1.368
                    T =      1.768            U =      6.980
                    Y =      6.352            Z =      3.293
                    e =     0.2314 1/in       d =     31.985 in^3
 Stress Factors                           Alpha =      2.172
                 Beta =      2.563        Gamma =      1.228
                Delta =      4.060       Lambda =      5.289
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.198*708875/22.87)/(5.289*1.056²)
  = 6293.40 psi
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.198*1188449/22.87)/(5.289*1.056²)
  = 10551.07 psi
```

Radial Flange Stress, Operating [SRo]:

```
  = ( beta * Mop / Bcor ) / ( L * t² )
  = (2.563*708875/22.87)/(5.289*5.064²)
  = 585.58 psi
```

Radial Flange Stress, Seating [SRa]:

```
  = ( beta * Matm/Bcor ) / ( L * t² )
  = (2.563*1188449/22.87)/(5.289*5.064²)
  = 981.75 psi
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (6.352*708875/(5.064²*22.87))-3.293*585.6
  = 5748.06 psi
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (6.352*1188449/(5.064²*22.87))-3.293*981.7
```

= 9636.78 psi

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (6293+max(585.6,5748))/2
= 6020.73 psi

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (10551+max(981.7,9637))/2
= 10093.92 psi

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 298273/29.73
= 10033.39 psi

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (286890/29.73)
= 9650.48 psi

Flange Stress Analysis Results: psi

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	6293.40	30000.00	10551.07	30000.00
Radial Flange	585.58	20000.00	981.75	20000.00
Tangential Flange	5748.06	20000.00	9636.78	20000.00
Maximum Average	6020.73	20000.00	10093.92	20000.00
Bolting	10033.39	25000.00	9650.48	25000.00

Minimum Required Flange Thickness	3.521 in
Estimated M.A.W.P. (Operating)	1061 psig
Estimated Finished Weight of Flange at given Thk.	564.7 lbm
Estimated Unfinished Weight of Forging at given Thk	695.8 lbm

---

Flange Stress results per WRC-538 at computed Sfmax (psi):

		Operating		stress	Gasket Seating		stress
		Actual	Allowed	ratio	Actual	Allowed	ratio
Longitudinal Hub	Sh	59732.06	72000.00	0.830	59732.06	72000.00	0.830
Tangential Flange	St	54000.00	54000.00	1.000	54000.00	54000.00	1.000
Tangential Flange	Sto	22737.95	36000.00	0.632	22737.95	36000.00	0.632
Combined	Sh/f + St	103367.08	108000.00	0.957	103367.08	108000.00	0.957
Combined	Sr + St	59501.26	108000.00	0.551	59501.26	108000.00	0.551
Combined	Sh + Sto	82470.02	108000.00	0.764	82470.02	108000.00	0.764
Radial Flange	Sr	5501.26	72000.00	0.076	5501.26	72000.00	0.076
Maximum Stress Ratio				1.000			1.000

Coefficients for f and f2

	f	*f2*	*f3*
a	-0.71375912	-0.01447638	-0.06456312
b	-0.12846279	-0.27814745	-0.08232239
c	1.08037907	0.01035395	0.13691677
d	0.99766848	1.37984158	-0.77879888
e	1.21823466	-0.34346764	0.14909019
f	0.01024612	0.02536192	0.00660062
g	0.4262313	-0.0014508	0.0616252
h	1.4204976	2.25543162	0.74639834
i	-0.70278181	-0.60889597	-0.079595
j	-0.02483937	-0.15735462	0.09851673
k	-1.59460436	1.22516062	-0.1121436

$$f_n = \frac{\left[a + c\left(\frac{g1}{g0}\right) + e\left(\frac{h}{h0}\right) + g\left(\frac{g1}{g0}\right)^2 + i\left(\frac{h}{h0}\right)^2 + k\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}{\left[1 + b\left(\frac{g1}{g0}\right) + d\left(\frac{h}{h0}\right) + f\left(\frac{g1}{g0}\right)^2 + h\left(\frac{h}{h0}\right)^2 + j\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}$$

Hub Stress Correction Factor [f]:
```
  = max( 1, F1_(num) / F1_(den) )
  = max( 1, 1.785/1.476 )
  = 1.2100
```

Hub Stress Correction Factor [f2]:
```
  = max( 0.25, fn2 ) if h/ho < 0.35, else max ( 0.25, fn3 )
  = max( 0.25, 0.693/1.471 ) if h/ho < 0.35, else max( 0.25, 0.347/0.752 )
  = 0.4606
```

In this case, the hub ratio h/ho, 0.4309 was >= 0.35.

PV Elite iterates on the assembly bolt load stress, Sfmax, until it exceeds the limits provided by WRC 538.

Bolting and Gasket Calculations per ASME PCC-1 Appendix O:

Input Data:

```
 Maximum permissible bolt stress                            Sbmax     73500.0 psi
 Minimum permissible bolt stress                            Sbmin     42000.0 psi
 Max. permissible bolt stress prior to flange damage        Sfmax     98155.4 psi
 Target assembly gasket stress                                SgT     49500.0 psi
 Maximum permissible gasket stress                          Sgmax     55000.0 psi
 Minimum gasket operating stress                          Sgmin-O     14000.0 psi
 Minimum gasket seating stress                            Sgmin-S     20000.0 psi
 Nut Factor                                                     K       0.200
 Fraction of Gasket Load remaining after relaxation          Phig       0.700
```

```
 Root Area of a Single Bolt                                  Abs       0.9290 in^2
 Max. permissible single flange rotation for gasket    Thetagmax       1.000 deg
```

Calculated Results:

```
 Flange Material Ambient Yield Stress                        Sya     36000.0 psi
 Flange Material Operating Yield Stress                      Syo     33800.0 psi
 Single flange rotation at Sfmax
 Thetafmax  = 52.14 * (N*Ab*Sesbl*hg/12) / Bsc * Cnv_fac * V / ( Lambda * Eamb * go^2 * ho * Thetagmax )
    = 0.304 deg
```

Gasket Contact Area [Ag]:

```
  = pi/4( GO.D.^2 - GI.D.^2 ) + ( PartFactor * lp * bPart )
  = pi/4( 24.8^2 - 23.23^2 ) +( 0.5 * 23.23 * 0.197 )
  = 61.7 in^2
```

Target Bolt Stress [Sbsel]:

```
  = SGT * Ag / ( nb * Ab )          (O-1)
  = 49500 * 61.7/( 32 * 0.929 )
  = 102740.4 psi
```

Upper Bolt Stress Limit [Sbsel]:

```
  = min( Sbsel, Sbmax )             (O-4)
  = min( 73500, 73500 )
  = 73500.0 psi
```

Lower Bolt Stress Limit [Sbsel]:

```
  = max( Sbsel, Sbmin )             (O-5)
  = max( 73500, 42000 )
  = 73500.0 psi
```

Upper Bolt Stress Limit including the Flange [Sbsel]:

```
  = min( Sbsel, Sfmax )             (O-6)
  = min( 73500, 98155 )
  = 73500.0 psi
```

Gasket Assembly Stress [GAS]:

```
  = Sgmin-S( Ag / ( nb * Abs ) )    (O-7)
  = 20000( 61.7/( 32 * 0.929 ) )
  = 41511.3 psi
```

Since Sbsel >= GAS, check passes.

Gasket Operating Stress [GOS]:

```
  = (Sgmin-O * Ag + pi/4 * Pmax * GI.D.^2)/(PhiG * Abs * nb)  (O-8)
  = (14000*61.7+pi/4*425.8*23.23^2)/(0.7*0.929*32)
  = 50182.340 psi
```

Since Sbsel >= GOS, check passes.

Gasket Maximum Stress [GMS]:

```
  = Sgmax( Ag / ( nb * Abs ) )      (O-9)
  = 55000( 61.7/( 32 * 0.929 ) )
  = 114156.0 psi
```

Since Sbsel <= GMS, check passes.

Flange Rotation Limit [FRL]:

```
  = Sfmax( thetagmax / thetafmax )   (O-10)
  = 98155( 1/0.304 )
  = 323072.8 psi
```

Since Sbsel <= FRL, check passes.

Assembly Bolt Torque [Tb]:
```
  = Sbsel * K * Abs * Phib/12        (O-2)
  = 73500 * 0.2 * 0.929 * 1.25/12
  = 17070.4 in-lb

 Bolt Allowable Stress for: SA-193 B8 Cl. 2  SbB8  17750 psi
 Bolt Allowable Stress for: SA-193 B7          Sb  25000 psi
```

Note: Since Sb >= SbB8, bolt allowable stress comparison check Passes.

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 * go^2 * ho * Ki)
  = 52.14*1188449/1*1*0.272/(2.234*29200000*0.584^2*3.655*0.3)
  = 0.690 (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*708875/1*1*0.272/(2.234*28830770*0.584^2*3.655*0.3)
  = 0.417 (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*1188449/1*1*0.272/(5.289*29200000*0.584^2*3.655*0.3)
  = 0.291 (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*708875/1*1*0.272/(5.289*28830770*0.584^2*3.655*0.3)
  = 0.176 (should be <= 1)

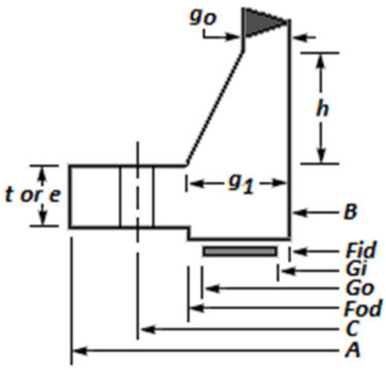
Minimum Design Metal Temperature Results:
Thickness Ratio = 0.668, Temperature Reduction per Fig. UCS 66.1 = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C             -21 F
```

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

CHANNEL FLANGE 2

```
Flange Type                              Integral Weld Neck

Design Pressure                           P          425.82  psig
Design Temperature                                      150  F
Internal Corrosion Allowance             ci          0.1250  in
External Corrosion Allowance             ce          0.0000  in
Use Corrosion Allowance in Thickness Calcs.             Yes

Flange Inside Diameter                    B          22.624  in
Flange Outside Diameter                   A          31.299  in
Flange Thickness                          t          5.1890  in
Thickness of Hub at Small End            go          0.7090  in
Thickness of Hub at Large End            g1          1.1810  in
Length of Hub                             h          1.5750  in

Flange Material                                    SA-266 2
Flange Material UNS number                           K03506
Flange Allowable Stress At Temperature  Sfo        20000.00  psi
Flange Allowable Stress At Ambient      Sfa        20000.00  psi

Bolt Material                                     SA-193 B7
Bolt Allowable Stress At Temperature     Sb        25000.00  psi
Bolt Allowable Stress At Ambient         Sa        25000.00  psi

Diameter of Bolt Circle                   C          28.740  in
Nominal Bolt Diameter                     a          1.2500  in
Type of Threads                          TEMA Thread Series
Number of Bolts                                          32

Flange Face Outside Diameter            Fod          24.921  in
Flange Face Inside Diameter             Fid          22.624  in
Flange Facing Sketch                      1, Code Sketch 1a

Gasket Outside Diameter                  Go          24.803  in
Gasket Inside Diameter                   Gi          23.228  in
Gasket Factor                             m          4.2500
Gasket Design Seating Stress              y        10100.00  psi

Column for Gasket Seating                 2, Code Column II
Gasket Thickness                         tg          0.1575  in

Length of Partition Gasket               lp         23.2280  in
Width  of Partition Gasket               tp          0.3940  in
Partition Gasket Factor               mPart          4.2500
Partition Gasket Design Seating Stress yPart       10100.00  psi
```



ASME Code, Section VIII Division 1, 2021

Hub Small End Required Thickness due to Internal Pressure:

```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (425.8*(22.62/2+0.125))/(20000*1-0.6*425.8)+Ca
  = 0.3717 in
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000 * 1 * 0.584 )/(11.44 + 0.6 * 0.584 )
  = 990.889 psig
```

```
 Corroded Flange Thickness, tc = T-ci                     5.064  in
 Corroded Flange ID,      Bcor = B+2*Fcor                22.874  in
 Corroded Large Hub,     g1Cor = g1-ci                    1.056  in
 Corroded Small Hub,     g0Cor = go-ci                    0.584  in
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor       1.877  in

 Gasket Contact Width,       N = (Go - Gi) / 2            0.787  in
 Basic Gasket Width,        bo = N / 2                    0.394  in
 Effective Gasket Width,     b = sqrt(bo)/2               0.314  in
 Gasket Reaction Diameter,   G = Go - 2 * b              24.176  in
```

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.785 * 24.18² * 425.8
  = 195462.750 lbf
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 0.314 * pi * 24.18 * 4.25 * 425.8
    + 2 * 23.23 * 0.197 * 4.25 * 425.8
  = 102809.969 lbf
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = pi * Bcor² * P  / 4
  = pi * 22.87² *425.8/4
  = 174983.516 lbf
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 195463 - 174984
  = 20479.234 lbf
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 195463 + 102810 + 0, 0 )
  = 298272.719 lbf
  = 364234.312 lbf, Mating Flange Load Governs
```

Gasket Seating Bolt Load [Wm2]:
```
  = y * b * pi * G  + yPart * bPart * lp
  = 10100*0.314*pi*24.18+10100*0.197*23.23
  = 286889.500 lbf
```

Required Bolt Area [Am]:
```
  = max( Wm1/Sb, Wm2/Sa )
  = max( 364234/25000, 286890/25000 )
  = 14.569 in^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 1.25 + 6 * 5.064/(4.25 + 0.5)
  = 8.897 in
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 28.74 * sin( pi/32 )
  = 2.817 in
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 2.817/( 2 * 1.25 + 5.064 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area:	14.569	29.728	
Radial Distance between Hub and Bolts:	1.750	1.877	
Radial Distance between Bolts and Edge:	1.250	1.280	
Circ. Spacing between the Bolts:	2.813	2.817	8.897

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * pi(Go + Gi) )
  = 29.73 * 25000/(10100 * pi(24.8 + 23.23 ) )
  = 0.488 in
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa( Am + Ab ) / 2
  = 25000( 14.57 + 29.73 )/2
  = 553717.12 lbf
```

Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 364234 - 195463
  = 168771.56 lbf
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 28.74 - 24.18 )/2
  = 2.2822 in
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 1.877 + 1.056 + 2.282 )/2
  = 2.6076 in
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 1.877 +( 1.056/2.0 )
  = 2.4050 in
```

Summary of Moments for Internal Pressure: (in-lb)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	174984.	2.4050	1.0000	420835.
Face Pressure, Mt	20479.	2.6076	1.0000	53402.
Gasket Load, Mg	168772.	2.2822	1.0000	385178.
Gasket Seating, Matm	553717.	2.2822	1.0000	1263720.

```
 Total Moment for Operation,      Mop                          859416. in-lb
 Total Moment for Gasket seating, Matm                        1263720. in-lb

 Effective Hub Length, ho = sqrt(Bcor*goCor)           3.655 in
 Hub Ratio,          h/h0 = HL / H0                    0.431
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.808
```

Flange Factors for Integral Flange:

```
 Factor F                                              0.846
 Factor V                                              0.272
 Factor f                                              1.198
 Factors from Figure 2-7.1                    K =      1.368
                    T =      1.768            U =      6.980
                    Y =      6.352            Z =      3.293
                    e =     0.2314 1/in       d =     31.985 in^3
 Stress Factors                           Alpha =      2.172
                 Beta =      2.563        Gamma =      1.228
                Delta =      4.060       Lambda =      5.289
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.198*859416/22.87)/(5.289*1.056²)
  = 7629.90 psi
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.198*1263719/22.87)/(5.289*1.056²)
  = 11219.32 psi
```

Radial Flange Stress, Operating [SRo]:

```
  = ( beta * Mop / Bcor ) / ( L * t² )
  = (2.563*859416/22.87)/(5.289*5.064²)
  = 709.94 psi
```

Radial Flange Stress, Seating [SRa]:

```
  = ( beta * Matm/Bcor ) / ( L * t² )
  = (2.563*1263719/22.87)/(5.289*5.064²)
  = 1043.93 psi
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (6.352*859416/(5.064²*22.87))-3.293*709.9
  = 6968.75 psi
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
```

= (6.352*1263719/(5.064²*22.87))-3.293*1044
= 10247.12 psi

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (7630+max(709.9,6969))/2
= 7299.33 psi

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (11219+max(1044,10247))/2
= 10733.22 psi

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 364234/29.73
= 12252.23 psi

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (286890/29.73)
= 9650.48 psi

Flange Stress Analysis Results: psi

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	7629.90	30000.00	11219.32	30000.00
Radial Flange	709.94	20000.00	1043.93	20000.00
Tangential Flange	6968.75	20000.00	10247.12	20000.00
Maximum Average	7299.33	20000.00	10733.22	20000.00
Bolting	12252.23	25000.00	9650.48	25000.00

Minimum Required Flange Thickness	3.665 in
Estimated M.A.W.P. (Operating)	1061 psig
Estimated Finished Weight of Flange at given Thk.	564.7 lbm
Estimated Unfinished Weight of Forging at given Thk	695.8 lbm

---

Flange Stress results per WRC-538 at computed Sfmax (psi):

		Operating		stress	Gasket Seating		stress
		Actual	Allowed	ratio	Actual	Allowed	ratio
Longitudinal Hub	Sh	59732.06	72000.00	0.830	59732.06	72000.00	0.830
Tangential Flange	St	54000.00	54000.00	1.000	54000.00	54000.00	1.000
Tangential Flange	Sto	22737.95	36000.00	0.632	22737.95	36000.00	0.632
Combined	Sh/f + St	103367.08	108000.00	0.957	103367.08	108000.00	0.957
Combined	Sr + St	59501.26	108000.00	0.551	59501.26	108000.00	0.551
Combined	Sh + Sto	82470.02	108000.00	0.764	82470.02	108000.00	0.764
Radial Flange	Sr	5501.26	72000.00	0.076	5501.26	72000.00	0.076
Maximum Stress Ratio				1.000			1.000

Coefficients for f and f2

	f	f2	f3
a	-0.71375912	-0.01447638	-0.06456312
b	-0.12846279	-0.27814745	-0.08232239
c	1.08037907	0.01035395	0.13691677
d	0.99766848	1.37984158	-0.77879888
e	1.21823466	-0.34346764	0.14909019
f	0.01024612	0.02536192	0.00660062
g	0.4262313	-0.0014508	0.0616252
h	1.4204976	2.25543162	0.74639834
i	-0.70278181	-0.60889597	-0.079595
j	-0.02483937	-0.15735462	0.09851673
k	-1.59460436	1.22516062	-0.1121436

$$f_n = \frac{\left[a + c\left(\frac{g1}{g0}\right) + e\left(\frac{h}{h0}\right) + g\left(\frac{g1}{g0}\right)^2 + i\left(\frac{h}{h0}\right)^2 + k\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}{\left[1 + b\left(\frac{g1}{g0}\right) + d\left(\frac{h}{h0}\right) + f\left(\frac{g1}{g0}\right)^2 + h\left(\frac{h}{h0}\right)^2 + j\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}$$

Hub Stress Correction Factor [f]:

```
  = max( 1, F1_(num) / F1_(den) )
  = max( 1, 1.785/1.476 )
  = 1.2100
```

Hub Stress Correction Factor [f2]:

```
  = max( 0.25, fn2 ) if h/ho < 0.35, else max ( 0.25, fn3 )
  = max( 0.25, 0.693/1.471 ) if h/ho < 0.35, else max( 0.25, 0.347/0.752 )
  = 0.4606
```

In this case, the hub ratio h/ho, 0.4309 was >= 0.35.

PV Elite iterates on the assembly bolt load stress, Sfmax, until it exceeds the limits provided by WRC 538.

Bolting and Gasket Calculations per ASME PCC-1 Appendix O:

Input Data:

```
 Maximum permissible bolt stress                          Sbmax     73500.0 psi
 Minimum permissible bolt stress                          Sbmin     42000.0 psi
 Max. permissible bolt stress prior to flange damage      Sfmax     98155.4 psi
 Target assembly gasket stress                              SgT     49500.0 psi
 Maximum permissible gasket stress                        Sgmax     55000.0 psi
 Minimum gasket operating stress                        Sgmin-O     14000.0 psi
 Minimum gasket seating stress                          Sgmin-S     20000.0 psi
 Nut Factor                                                   K       0.200
 Fraction of Gasket Load remaining after relaxation        Phig       0.700
```

```
 Root Area of a Single Bolt                              Abs      0.9290 in^2
 Max. permissible single flange rotation for gasket    Thetagmax    1.000 deg
```

Calculated Results:

```
 Flange Material Ambient Yield Stress                    Sya     36000.0 psi
 Flange Material Operating Yield Stress                  Syo     33800.0 psi
 Single flange rotation at Sfmax
 Thetafmax  = 52.14 * (N*Ab*Sesbl*hg/12) / Bsc * Cnv_fac * V / ( Lambda * Eamb * go^2 * ho * Thetagmax )
    = 0.304 deg
```

Gasket Contact Area [Ag]:
```
  = pi/4( GO.D.^2 - GI.D.^2 ) + ( PartFactor * lp * bPart )
  = pi/4( 24.8^2 - 23.23^2 ) +( 0.5 * 23.23 * 0.197 )
  = 61.7 in^2
```

Target Bolt Stress [Sbsel]:
```
  = SGT * Ag / ( nb * Ab )          (O-1)
  = 49500 * 61.7/( 32 * 0.929 )
  = 102740.4 psi
```

Upper Bolt Stress Limit [Sbsel]:
```
  = min( Sbsel, Sbmax )             (O-4)
  = min( 73500, 73500 )
  = 73500.0 psi
```

Lower Bolt Stress Limit [Sbsel]:
```
  = max( Sbsel, Sbmin )             (O-5)
  = max( 73500, 42000 )
  = 73500.0 psi
```

Upper Bolt Stress Limit including the Flange [Sbsel]:
```
  = min( Sbsel, Sfmax )             (O-6)
  = min( 73500, 98155 )
  = 73500.0 psi
```

Gasket Assembly Stress [GAS]:
```
  = Sgmin-S( Ag / ( nb * Abs ) )    (O-7)
  = 20000( 61.7/( 32 * 0.929 ) )
  = 41511.3 psi
```

Since Sbsel >= GAS, check passes.

Gasket Operating Stress [GOS]:
```
  = (Sgmin-O * Ag + pi/4 * Pmax * GI.D.^2)/(PhiG * Abs * nb)  (O-8)
  = (14000*61.7+pi/4*425.8*23.23^2)/(0.7*0.929*32)
  = 50182.340 psi
```

Since Sbsel >= GOS, check passes.

Gasket Maximum Stress [GMS]:
```
  = Sgmax( Ag / ( nb * Abs ) )      (O-9)
  = 55000( 61.7/( 32 * 0.929 ) )
  = 114156.0 psi
```

Since Sbsel <= GMS, check passes.

Flange Rotation Limit [FRL]:
```
  = Sfmax( thetagmax / thetafmax )   (O-10)
  = 98155( 1/0.304 )
  = 323072.8 psi
```

Since Sbsel <= FRL, check passes.

Assembly Bolt Torque [Tb]:
```
  = Sbsel * K * Abs * Phib/12        (O-2)
  = 73500 * 0.2 * 0.929 * 1.25/12
  = 17070.4 in-lb

 Bolt Allowable Stress for: SA-193 B8 Cl. 2  SbB8  17750 psi
 Bolt Allowable Stress for: SA-193 B7          Sb  25000 psi
```

Note: Since Sb >= SbB8, bolt allowable stress comparison check Passes.

Flange Rigidity Based on Required Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*1263719/1*1*0.272/(2.415*29200000*0.584^2*3.655*0.3)$
$= 0.679$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*859416/1*1*0.272/(2.415*28830770*0.584^2*3.655*0.3)$
$= 0.468$ (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*1263719/1*1*0.272/(5.289*29200000*0.584^2*3.655*0.3)$
$= 0.310$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*859416/1*1*0.272/(5.289*28830770*0.584^2*3.655*0.3)$
$= 0.213$ (should be <= 1)

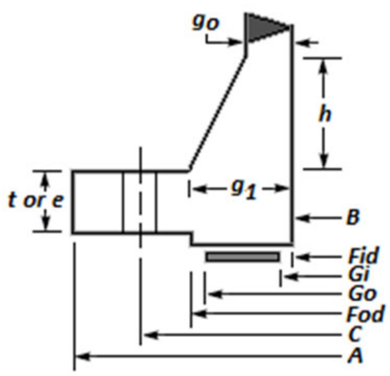
Minimum Design Metal Temperature Results:
Thickness Ratio = 0.668, Temperature Reduction per Fig. UCS 66.1 = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C            -21 F
```

Flange Input Data Values   **Description: Shell Flange   :**

SHELL FLANGE

Flange Type		Integral Weld Neck	
Design Pressure	P	550.56	psig
Design Temperature		490	F
Internal Corrosion Allowance	ci	0.1250	in
External Corrosion Allowance	ce	0.0000	in
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	22.624	in
Flange Outside Diameter	A	31.299	in
Flange Thickness	t	5.1890	in
Thickness of Hub at Small End	go	0.8660	in
Thickness of Hub at Large End	g1	1.2600	in
Length of Hub	h	1.5750	in
Flange Material		SA-266 2	
Flange Material UNS number		K03506	
Flange Allowable Stress At Temperature	Sfo	19640.00	psi
Flange Allowable Stress At Ambient	Sfa	20000.00	psi
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	25000.00	psi
Bolt Allowable Stress At Ambient	Sa	25000.00	psi
Diameter of Bolt Circle	C	28.740	in
Nominal Bolt Diameter	a	1.2500	in
Type of Threads		TEMA Thread Series	
Number of Bolts		32	
Flange Face Outside Diameter	Fod	24.921	in
Flange Face Inside Diameter	Fid	22.624	in
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	24.803	in
Gasket Inside Diameter	Gi	23.228	in
Gasket Factor	m	4.2500	
Gasket Design Seating Stress	y	10100.00	psi
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	0.1575	in



ASME Code, Section VIII Division 1, 2021

Hub Small End Required Thickness due to Internal Pressure:

```
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (550.6*(22.62/2+0.125))/(19640*1-0.6*550.6)+Ca
= 0.4511 in
```

Hub Small End Hub MAWP:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (19640 * 1 * 0.741 )/(11.44 + 0.6 * 0.741 )
= 1224.855 psig
```

```
Corroded Flange Thickness, tc = T-ci                      5.064  in
Corroded Flange ID,      Bcor = B+2*Fcor                 22.874  in
Corroded Large Hub,     g1Cor = g1-ci                     1.135  in
Corroded Small Hub,     g0Cor = go-ci                     0.741  in
Code R Dimension,           R = ((C-Bcor)/2)-g1cor        1.798  in

Gasket Contact Width,       N = (Go - Gi) / 2             0.787  in
Basic Gasket Width,        bo = N / 2                     0.394  in
Effective Gasket Width,     b = sqrt(bo)/2                0.314  in
Gasket Reaction Diameter,   G = Go - 2 * b               24.176  in
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

```
= 0.785 * G² * Peq
= 0.785 * 24.18² * 550.6
= 252721.344 lbf
```

Contact Load on Gasket Surfaces [Hp]:

```
= 2 * b * pi * G * m * P
= 2 * 0.314 * pi * 24.18 * 4.25 * 550.6
= 111512.977 lbf
```

Hydrostatic End Load at Flange ID [Hd]:

```
= pi * Bcor² * P  / 4
= pi * 22.87² *550.6/4
= 226242.953 lbf
```

Pressure Force on Flange Face [Ht]:

```
= H - Hd
= 252721 - 226243
= 26478.391 lbf
```

Operating Bolt Load [Wm1]:

```
= max( H + Hp + H'p, 0 )
= max( 252721 + 111513 + 0, 0 )
= 364234.312 lbf
```

Gasket Seating Bolt Load [Wm2]:

```
= y * b * pi * G  + yPart * bPart * lp
= 10100*0.314*pi*24.18+0*0*0
= 240672.766 lbf
= 286889.500 lbf, Mating Flange Load Governs
```

Required Bolt Area [Am]:

```
= max( Wm1/Sb, Wm2/Sa )
= max( 364234/25000, 286890/25000 )
= 14.569 in^2
```

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

```
= 2a + 6t/(m + 0.5)
= 2 * 1.25 + 6 * 5.064/(4.25 + 0.5)
= 8.897 in
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 28.74 * sin( pi/32 )
  = 2.817 in
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 2.817/( 2 * 1.25 + 5.064 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area:	14.569	29.728	
Radial Distance between Hub and Bolts:	1.750	1.798	
Radial Distance between Bolts and Edge:	1.250	1.280	
Circ. Spacing between the Bolts:	2.813	2.817	8.897

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * pi(Go + Gi) )
  = 29.73 * 25000/(10100 * pi(24.8 + 23.23 ) )
  = 0.488 in
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa( Am + Ab ) / 2
  = 25000( 14.57 + 29.73 )/2
  = 553717.12 lbf
```

Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 364234 - 252721
  = 111512.97 lbf
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 28.74 - 24.18 )/2
  = 2.2822 in
```

Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 1.798 + 1.135 + 2.282 )/2
  = 2.6076 in
```

Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 1.798 +( 1.135/2.0 )
  = 2.3655 in
```

Summary of Moments for Internal Pressure: (in-lb)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	226243.	2.3655	1.0000	535178.
Face Pressure, Mt	26478.	2.6076	1.0000	69046.
Gasket Load, Mg	111513.	2.2822	1.0000	254500.
Gasket Seating, Matm	553717.	2.2822	1.0000	1263720.

```
Total Moment for Operation,      Mop                        858724. in-lb
Total Moment for Gasket seating, Matm                      1263720. in-lb
```

```
 Effective Hub Length, ho = sqrt(Bcor*goCor)           4.117 in
 Hub Ratio,          h/h0 = HL / H0                    0.383
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.532
```

Flange Factors for Integral Flange:

```
 Factor F                                              0.865
 Factor V                                              0.336
 Factor f                                              1.000
 Factors from Figure 2-7.1                     K =     1.368
                    T =      1.768             U =     6.980
                    Y =      6.352             Z =     3.293
                    e =     0.2101 1/in        d =    47.015 in^3
 Stress Factors                            Alpha =     2.064
                 Beta =      2.418         Gamma =     1.167
                Delta =      2.762        Lambda =     3.929
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1*858724/22.87)/(3.929*1.135²)
  = 7416.33 psi
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1*1263719/22.87)/(3.929*1.135²)
  = 10914.07 psi
```

Radial Flange Stress, Operating [SRo]:

```
  = ( beta * Mop / Bcor ) / ( L * t² )
  = (2.418*858724/22.87)/(3.929*5.064²)
  = 901.00 psi
```

Radial Flange Stress, Seating [SRa]:

```
  = ( beta * Matm/Bcor ) / ( L * t² )
  = (2.418*1263719/22.87)/(3.929*5.064²)
  = 1325.93 psi
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (6.352*858724/(5.064²*22.87))-3.293*901
  = 6332.14 psi
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (6.352*1263719/(5.064²*22.87))-3.293*1326
  = 9318.54 psi
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (7416+max(901,6332))/2
  = 6874.24 psi
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (10914+max(1326,9319))/2
  = 10116.30 psi
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 364234/29.73
  = 12252.23 psi
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
```

= (286890/29.73)
= 9650.48 psi

Flange Stress Analysis Results: psi

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	7416.33	29460.00	10914.07	30000.00
Radial Flange	901.00	19640.00	1325.93	20000.00
Tangential Flange	6332.14	19640.00	9318.54	20000.00
Maximum Average	6874.24	19640.00	10116.30	20000.00
Bolting	12252.23	25000.00	9650.48	25000.00

Minimum Required Flange Thickness	3.317 in
Estimated M.A.W.P. (Operating)	1123 psig
Estimated Finished Weight of Flange at given Thk.	568.7 lbm
Estimated Unfinished Weight of Forging at given Thk	695.8 lbm

---

Flange Stress results per WRC-538 at computed Sfmax (psi):

		Operating Actual	Operating Allowed	stress ratio	Gasket Seating Actual	Gasket Seating Allowed	stress ratio
Longitudinal Hub	Sh	54466.99	67314.29	0.809	54466.99	72000.00	0.756
Tangential Flange	St	46504.46	50485.72	0.921	46504.46	54000.00	0.861
Tangential Flange	Sto	19348.06	33657.14	0.575	19348.06	36000.00	0.537
Combined	Sh/f + St	100971.45	100971.44	1.000	100971.45	108000.00	0.935
Combined	Sr + St	53121.57	100971.44	0.526	53121.57	108000.00	0.492
Combined	Sh + Sto	73815.05	100971.44	0.731	73815.05	108000.00	0.683
Radial Flange	Sr	6617.11	67314.29	0.098	6617.11	72000.00	0.092
Maximum Stress Ratio				1.000			0.935

Coefficients for f and f2

	f	f2	f3
a	-0.71375912	-0.01447638	-0.06456312
b	-0.12846279	-0.27814745	-0.08232239
c	1.08037907	0.01035395	0.13691677
d	0.99766848	1.37984158	-0.77879888
e	1.21823466	-0.34346764	0.14909019
f	0.01024612	0.02536192	0.00660062
g	0.4262313	-0.0014508	0.0616252
h	1.4204976	2.25543162	0.74639834
i	-0.70278181	-0.60889597	-0.079595
j	-0.02483937	-0.15735462	0.09851673
k	-1.59460436	1.22516062	-0.1121436

$$f_n = \frac{\left[a + c\left(\frac{g1}{g0}\right) + e\left(\frac{h}{h0}\right) + g\left(\frac{g1}{g0}\right)^2 + i\left(\frac{h}{h0}\right)^2 + k\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}{\left[1 + b\left(\frac{g1}{g0}\right) + d\left(\frac{h}{h0}\right) + f\left(\frac{g1}{g0}\right)^2 + h\left(\frac{h}{h0}\right)^2 + j\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}$$

Hub Stress Correction Factor [f]:

```
  = max( 1, F1_(num) / F1_(den) )
  = max( 1, 1.37/1.402 )
  = 1.0000
```

Hub Stress Correction Factor [f2]:

```
  = max( 0.25, fn2 ) if h/ho < 0.35, else max ( 0.25, fn3 )
  = max( 0.25, 0.495/1.399 ) if h/ho < 0.35, else max( 0.25, 0.269/0.758 )
  = 0.3552
```

In this case, the hub ratio h/ho, 0.3826 was >= 0.35.

PV Elite iterates on the assembly bolt load stress, Sfmax, until it exceeds the limits provided by WRC 538.

Bolting and Gasket Calculations per ASME PCC-1 Appendix O:

Input Data:

Maximum permissible bolt stress	Sbmax	73500.0 psi
Minimum permissible bolt stress	Sbmin	42000.0 psi
Max. permissible bolt stress prior to flange damage	Sfmax	92954.2 psi
Target assembly gasket stress	SgT	49500.0 psi
Maximum permissible gasket stress	Sgmax	55000.0 psi
Minimum gasket operating stress	Sgmin-O	14000.0 psi
Minimum gasket seating stress	Sgmin-S	20000.0 psi
Nut Factor	K	0.200
Fraction of Gasket Load remaining after relaxation	Phig	0.700

```
 Root Area of a Single Bolt                                  Abs      0.9290 in^2
 Max. permissible single flange rotation for gasket    Thetagmax       1.000 deg
```

Calculated Results:

```
 Flange Material Ambient Yield Stress                        Sya     36000.0 psi
 Flange Material Operating Yield Stress                      Syo     29450.0 psi
 Single flange rotation at Sfmax
 Thetafmax  = 52.14 * (N*Ab*Sesbl*hg/12) / Bsc * Cnv_fac * V / ( Lambda * Eamb * go^2 * ho * Thetagmax )
    = 0.290 deg
```

Gasket Contact Area [Ag]:

```
  = pi/4( GO.D.^2 - GI.D.^2 )
  = pi/4( 24.8^2 - 23.23^2 )
  = 59.4 in^2
```

Target Bolt Stress [Sbsel]:

```
  = SGT * Ag / ( nb * Ab )          (O-1)
  = 49500 * 59.41/( 32 * 0.929 )
  = 98930.7 psi
```

Upper Bolt Stress Limit [Sbsel]:

```
  = min( Sbsel, Sbmax )             (O-4)
  = min( 73500, 73500 )
  = 73500.0 psi
```

Lower Bolt Stress Limit [Sbsel]:

```
  = max( Sbsel, Sbmin )             (O-5)
  = max( 73500, 42000 )
  = 73500.0 psi
```

Upper Bolt Stress Limit including the Flange [Sbsel]:

```
  = min( Sbsel, Sfmax )             (O-6)
  = min( 73500, 92954 )
  = 73500.0 psi
```

Gasket Assembly Stress [GAS]:

```
  = Sgmin-S( Ag / ( nb * Abs ) )    (O-7)
  = 20000( 59.41/( 32 * 0.929 ) )
  = 39972.0 psi
```

Since Sbsel >= GAS, check passes.

Gasket Operating Stress [GOS]:

```
  = (Sgmin-O * Ag + pi/4 * Pmax * GI.D.^2)/(PhiG * Abs * nb)  (O-8)
  = (14000*59.41+pi/4*550.6*23.23^2)/(0.7*0.929*32)
  = 51183.164 psi
```

Since Sbsel >= GOS, check passes.

Gasket Maximum Stress [GMS]:

```
  = Sgmax( Ag / ( nb * Abs ) )      (O-9)
  = 55000( 59.41/( 32 * 0.929 ) )
  = 109923.0 psi
```

Since Sbsel <= GMS, check passes.

Flange Rotation Limit [FRL]:

```
  = Sfmax( thetagmax / thetafmax )   (O-10)
  = 92954( 1/0.29 )
  = 320811.4 psi
```

Since Sbsel <= FRL, check passes.

Assembly Bolt Torque [Tb]:
```
  = Sbsel * K * Abs * Phib/12        (O-2)
  = 73500 * 0.2 * 0.929 * 1.25/12
  = 17070.4 in-lb

 Bolt Allowable Stress for: SA-193 B8 Cl. 2  SbB8  16299 psi
 Bolt Allowable Stress for: SA-193 B7          Sb  25000 psi
```

Note: Since Sb >= SbB8, bolt allowable stress comparison check Passes.

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 * go^2 * ho * Ki)
  = 52.14*1263719/1*1*0.336/(1.636*29200000*0.741^2*4.117*0.3)
  = 0.682   (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*858724/1*1*0.336/(1.636*27160000*0.741^2*4.117*0.3)
  = 0.498   (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*1263719/1*1*0.336/(3.929*29200000*0.741^2*4.117*0.3)
  = 0.284   (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*858724/1*1*0.336/(3.929*27160000*0.741^2*4.117*0.3)
  = 0.207   (should be <= 1)

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.546, Temperature Reduction per Fig. UCS 66.1 = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C          -11 F
 Min Metal Temp. w/o impact per UG-20(f)                 -20 F
```


Internal Pressure Results Summary:

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd psig	Nominal Thickness in	Total Corr Allowance in	Element Diameter in	Allowable Stress(SE) psi
BLIND		425.817	3.937	0.125	31.299	20000
CHANNEL FLANGE 1		425.817	5.512	0.125	22.624	20000
CHANNEL SHELL		425.822	0.709	0.125	22.624	20000
CHANNEL FLANGE 2		425.817	5.512	0.125	22.624	20000
SHELL FLANGE		550.555	5.512	0.125	22.624	19640
SHELL		550.558	0.866	0.125	22.624	20000
HEAD		550.558	0.551	0.125	22.624	20000

Element Required Thickness and MAWP :

From	To	Design Pressure psig	M.A.W.P. Corroded psig	M.A.P. New & Cold psig	Minimum Thickness in	Required Thickness in
BLIND		425.817	808.9	867.9	3.614	3.13483
CHANNEL FLANGE 1		425	990.1	1061	5.189	3.521
CHANNEL SHELL		425	990.1	1208	0.709	0.37166
CHANNEL FLANGE 2		425	990.1	1061	5.189	3.665
SHELL FLANGE		550	1123	1123	5.189	3.317
SHELL		550	1247	1464	0.866	0.44512
HEAD		550	613.2	831	0.472	0.43618

Note: Shell Side MAWP governed by a standard Flange!

Shell Side Flange MAWP including Static Pres.: 607.4 = 608 - 0.558 psig

Note: Channel Side MAWP governed by a standard Flange!

Tube Side Flange MAWP including Static Pres.: 709.2 = 710 - 0.821 psig

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      =           607.4 psig
Shell Side MAPnc     =             740 psig
Channel Side  MAWP  =           709.2 psig
Channel Side  MAPnc =             740 psig
```

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

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Cylindrical Shell From 30 To 40 SA-516 70 , UCS-66 Crv. D at 150 F

CHANNEL SHELL

Longitudinal Joint: User Defined

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (425.8*11.44)/(20000*1-0.6*425.8)
  = 0.2467 + 0.1250 = 0.3717 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.821 psig
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*1*0.584)/(11.44+0.6*0.584)
  = 990.9 - 0.821 = 990.1  psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*1*0.709)/(11.31+0.6*0.709)
  = 1208 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (425.8*(11.44+0.6*0.584))/(1*0.584)
  = 8594.741 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 3.039 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.709, tr = 0.414, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.71, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -45 F
```

Cylindrical Shell From 60 To 70 SA-516 70 , UCS-66 Crv. D at 490 F

SHELL

Longitudinal Joint: User Defined

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (550.6*11.44)/(20000*1-0.6*550.6)
  = 0.3201 + 0.1250 = 0.4451 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.558 psig
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*1*0.741)/(11.44+0.6*0.741)
  = 1247 - 0.558 = 1247  psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*1*0.866)/(11.31+0.6*0.866)
  = 1464 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (550.6*(11.44+0.6*0.741))/(1*0.741)
  = 8827.954 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 3.687 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.866, tr = 0.357, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.482, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -36 F
```

Elliptical Head From 70 To 80 SA-516 70 , UCS-66 Crv. D at 490 F

HEAD

Longitudinal   Joint: User Defined

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (550.6*22.87*0.986)/(2*20000*1-0.2*550.6)
  = 0.3112 + 0.1250 = 0.4362 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.558 psig
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*20000*1*0.347)/(0.986*22.87+0.2*0.347)
  = 613.7 - 0.558 = 613.2  psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*20000*1*0.472)/(1*22.62+0.2*0.472)
  = 831 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (550.6*(0.986*22.87+0.2*0.347))/(2*1*0.347)
  = 17941.105 psi
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c     per UG-27 (c)(1)
  = (550.6*11.44)/(20000*1-0.6*550.6)+0.125
  = 0.445 in
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.558 psig
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000 * 1 * 0.426 )/(11.44 + 0.6 * 0.426 )
  = 728.7 - 0.558 = 728.1  psig
```

Factor K, corroded condition [Kcor]:

$= (2 + (\text{Inside Diameter}/(2 * \text{Inside Head Depth}))^2)/6$

$= (2 +(22.87/(2 * 5.781))^2)/6$

$= 0.985663$

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 10.026 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 0.472, tr = 0.347, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.999, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -55 F
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 0.551, tr = 0.357, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.839, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve D            -55 F
```

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        789.674  psig
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     715.000  psig
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     961.356  psig
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        668.186  psig
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   786.500  psig
Pressure per App 27-4  = M.A.W.P.                      607.442  psig
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S        921.932  psig
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     552.500  psig
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     961.356  psig
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        780.096  psig
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   607.750  psig
Pressure per App 27-4  = M.A.W.P.                      709.179  psig
```

Horizontal Test performed per: UG-99c

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 (psi & psig):

From To	Stress	Allowable	Ratio	Pressure
CHANNEL SHELL	15928.7	34198.7	0.466	962.17
SHELL	13145.6	34200.0	0.384	962.17
HEAD	23155.8	34200.0	0.677	962.17

Stress ratios for Nozzle and Pad Materials (psi):

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	17100.00	17100.00	1.000
T2	Pad	20000.00	20000.00	1.000
T1	Nozzle	17100.00	17100.00	1.000
T1	Pad	20000.00	20000.00	1.000
V	Nozzle	20000.00	20000.00	1.000
D	Nozzle	20000.00	20000.00	1.000
AUX1	Nozzle	20000.00	19637.42	1.018
AUX2	Nozzle	20000.00	19637.40	1.018
S1	Nozzle	20000.00	19640.00	1.018
S2	Nozzle	20000.00	19640.00	1.018
AUX3	Nozzle	20000.00	19640.00	1.018
AUX4	Nozzle	20000.00	19640.00	1.018

Minimum 1.000

Stress ratios for Pressurized Vessel Elements (psi):

Description	Ambient	Operating	Ratio
BLIND	20000.00	20000.00	1.000
CHANNEL FLANGE 1	20000.00	20000.00	1.000
CHANNEL SHELL	20000.00	20000.00	1.000
CHANNEL FLANGE 2	20000.00	20000.00	1.000
SHELL FLANGE	20000.00	19640.00	1.018
SHELL	20000.00	20000.00	1.000
HEAD	20000.00	20000.00	1.000
Minimum			1.000

Stress ratios for Exchanger Materials (psi):

Description	Ambient	Operating	Ratio
Tube Material	13400.00	13400.00	1.000
Tubesheet Material	20000.00	19640.00	1.018
Minimum			1.000

Hoop Stress in Nozzle Wall during Pressure Test (psi):

Description	Ambient	Operating	Ratio
T2	5286.30	31500.00	0.168
T1	5286.30	31500.00	0.168
V	2048.52	32400.00	0.063
D	2048.52	32400.00	0.063
AUX1	2048.52	32400.29	0.063
AUX2	2048.52	32400.30	0.063
S1	9956.57	32400.00	0.307
S2	9956.57	32400.00	0.307
AUX3	2048.52	32400.00	0.063
AUX4	2048.52	32400.00	0.063

Elements Suitable for Test Pressure.

Field Test Pressure Calculations:

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S        789.674  psig
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     715.000  psig
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     961.356  psig
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        668.186  psig
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   786.500  psig
Pressure per App 27-4  = M.A.W.P.                      607.442  psig
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S        921.932  psig
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     552.500  psig
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     961.356  psig
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        780.096  psig
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   607.750  psig
```

Pressure per App 27-4 = M.A.W.P.   709.179 psig

Horizontal Test performed per: UG-99b

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 (psi & psig):

From To	Stress	Allowable	Ratio	Pressure
CHANNEL SHELL	18637.7	34198.7	0.545	923.39
SHELL	12685.5	34200.0	0.371	791.13
HEAD	25780.8	34200.0	0.754	791.13

Stress ratios for Nozzle and Pad Materials (psi):

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	17100.00	17100.00	1.000
T2	Pad	20000.00	20000.00	1.000
T1	Nozzle	17100.00	17100.00	1.000
T1	Pad	20000.00	20000.00	1.000
V	Nozzle	20000.00	20000.00	1.000
D	Nozzle	20000.00	20000.00	1.000
AUX1	Nozzle	20000.00	19637.42	1.018
AUX2	Nozzle	20000.00	19637.40	1.018
S1	Nozzle	20000.00	19640.00	1.018
S2	Nozzle	20000.00	19640.00	1.018
AUX3	Nozzle	20000.00	19640.00	1.018
AUX4	Nozzle	20000.00	19640.00	1.018
Minimum				1.000

Stress ratios for Pressurized Vessel Elements (psi):

Description	Ambient	Operating	Ratio
BLIND	20000.00	20000.00	1.000
CHANNEL FLANGE 1	20000.00	20000.00	1.000
CHANNEL SHELL	20000.00	20000.00	1.000
CHANNEL FLANGE 2	20000.00	20000.00	1.000
SHELL FLANGE	20000.00	19640.00	1.018
SHELL	20000.00	20000.00	1.000
HEAD	20000.00	20000.00	1.000
Minimum			1.000

Stress ratios for Exchanger Materials (psi):

Description	Ambient	Operating	Ratio
Tube Material	13400.00	13400.00	1.000
Tubesheet Material	20000.00	19640.00	1.018
Minimum			1.000

Hoop Stress in Nozzle Wall during Pressure Test (psi):

Description	Ambient	Operating	Ratio

T2	5073.24	31500.00	0.161
T1	5073.24	31500.00	0.161
V	1965.95	32400.00	0.061
D	1965.95	32400.00	0.061
AUX1	1965.95	32400.29	0.061
AUX2	1965.95	32400.30	0.061
S1	8186.66	32400.00	0.253
S2	8186.66	32400.00	0.253
AUX3	1684.37	32400.00	0.052
AUX4	1684.37	32400.00	0.052

Elements Suitable for Test Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length in	Outside Diameter in	Corroded Thickness in	Factor A	Factor B psi
10	20	No Calc	...	3.489	No Calc	No Calc
20	30	No Calc	...	5.064	No Calc	No Calc
30	40	33.213	24.042	0.584	0.0036369	16692
40	50	No Calc	...	5.064	No Calc	No Calc
50	60	No Calc	...	5.064	No Calc	No Calc
60	70	199.595	24.356	0.741	0.0010945	12767
70	80	No Calc	23.568	0.347	0.0020449	15120.1

External Pressure Calculations:

From	To	External Actual T. in	External Required T. in	External Design Pressure psig	External M.A.W.P. psig
10	20	3.614	3.002	15	No Calc
20	30	5.189	5.189	15	No Calc
30	40	0.709	0.21315	15	540.6
40	50	5.189	5.189	15	No Calc
50	60	5.189	5.189	15	No Calc
60	70	0.866	0.31716	15	517.9
70	80	0.472	0.18602	15	247.4
Minimum					247.4

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners in	Allowable Length Bet. Stiffeners in	Ring Inertia Required in**4	Ring Inertia Available in**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	No Calc	No Calc	No Calc	No Calc
30	40	33.213	928.779	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	199.595	6833.59	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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Cylindrical Shell From 30 to 40 Ext. Chart: CS-2 at 300 F

CHANNEL SHELL
Elastic Modulus from Chart: CS-2 at 300 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure						MAEP
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.584	24.04	33.21	41.17	1.3815	0.0036369	16692.01

MAEP = (4*B)/(3*(Do/t)) = (4*16692)/(3*41.17) = 540.6 psig

Results for Required Thickness | Tca

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.088	24.04	33.21	272.73	1.3815	0.0002116	3068.29

MAEP = (4*B)/(3*(Do/t)) = (4*3068)/(3*272.7) = 15 psig

Results for Maximum Stiffened Length | Slen

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.584	24.04	928.78	41.17	38.6315	0.0006544	9488.82

MAEP = (4*B)/(3*(Do/t)) = (4*9489)/(3*41.17) = 307.3 psig

Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 300 F

SHELL
Elastic Modulus from Chart: CS-2 at 300 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure | MAEP

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.741	24.36	199.59	32.87	8.1949	0.0010945	12766.95

MAEP = (4*B)/(3*(Do/t)) = (4*12767)/(3*32.87) = 517.9 psig

Results for Required Thickness | Tca

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.192	24.36	199.59	126.75	8.1949	0.0000983	1426.03

MAEP = (4*B)/(3*(Do/t)) = (4*1426)/(3*126.8) = 15 psig

Results for Maximum Stiffened Length | Slen

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.741	24.36	6833.59	32.87	50.0000	0.0010422	12554.32

MAEP = (4*B)/(3*(Do/t)) = (4*12554)/(3*32.87) = 509.3 psig

Elliptical Head From 70 to 80 Ext. Chart: CS-2 at 300 F

HEAD
Elastic Modulus from Chart: CS-2 at 300 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure | MAEP

Tca	Outer Dia	Do/t	Factor A	Factor B
0.347	23.57	67.92	0.0020449	15120.11

MAEP = B/(K0*Do/t) = 15120/(0.9 *67.92) = 247.4 psig

Results for Required Thickness				Tca
Tca	Outer Dia	Do/t	Factor A	Factor B
0.061	23.57	386.22	0.0003596	5214.34

MAEP = B/(K0*Do/t) = 5214/(0.9 *386.2) = 15 psig

Element and Detail Weights:

From	To	Element Metal Wgt. lbf	Element ID Volume gal	Corroded Metal Wgt. lbf	Corroded ID Volume gal	Extra due Misc % lbf
10	20	848.153	...	848.153	...	...
20	30	597.881	12.5465	580.153	12.6074	...
30	40	286.458	34.2573	237.218	35.0185	...
40	50	597.881	12.5465	580.153	12.6074	...
50	60	601.907	12.5465	584.18	12.6074	...
60	70	3381.56	228.979	2908.85	236.288	...
70	80	121.289	9.98856	93.7734	10.2847	...
Total		6435	310.86	5832	319.41	0

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 lbf	X Offset, Dtl. Cent. in	Y Offset, Dtl. Cent. in	Z Offset Dtl. Cent. in	Description
20	Liqd	104.658	3.382	...	...	Liquid: 20
30	Liqd	285.763	9.84252	...	...	Liquid: 30
30	Nozl	127.513	9.843	12.456	7.66323	T2
30	Nozl	127.513	9.84	-12.4559	7.66325	T1
30	Nozl	28.0963	9.843	11.3215	-4.83836	V
30	Nozl	28.0963	9.843	-11.3215	-4.83836	D
30	Nozl	28.2826	5	...	-12.312	AUX1
30	Nozl	28.2826	5	...	12.312	AUX2
40	Liqd	104.658	3.382	...	...	Liquid: 40
50	Liqd	71.1259	3.382	...	...	Liquid: 50
60	Sadl	240.523	17.716	20.821	...	Lft Sdl
60	Sadl	240.523	126.717	20.821	...	Right Sdl
60	Liqd	1298.09	94.4882	...	...	Liquid: 60
60	Nozl	312.024	9.724	16.186	...	S1
60	Nozl	312.024	158.74	-16.186	...	S2
60	Nozl	28.5223	6.68	...	12.312	AUX3
60	Nozl	28.5223	6.68	...	-12.312	AUX4
70	Liqd	56.6252	3.85433	0.85831E-05	...	Liquid: 70
40	FTsh	371.811	8.9215	...	...	
40	Tube	2610.8	97.079	...	...	Tubes
50	Bafl	34.0598	22.441	...	...	Baffles
50	Bafl	34.0598	31.055	...	...	Baffles
50	Bafl	34.0598	39.669	...	...	Baffles
50	Bafl	34.0598	48.283	...	...	Baffles
50	Bafl	34.0598	56.897	...	...	Baffles
50	Bafl	34.0598	65.511	...	...	Baffles
50	Bafl	34.0598	74.125	...	...	Baffles
50	Bafl	34.0598	82.739	...	...	Baffles
50	Bafl	34.0598	91.353	...	...	Baffles
50	Bafl	34.0598	99.967	...	...	Baffles
50	Bafl	34.0598	108.581	...	...	Baffles
50	Bafl	34.0598	117.195	...	...	Baffles
50	Bafl	34.0598	125.809	...	...	Baffles
50	Bafl	34.0598	134.423	...	...	Baffles
50	Bafl	34.0598	143.037	...	...	Baffles
50	Bafl	34.2698	151.651	...	...	Baffles

Total Weight of Each Detail Type:

Saddles	481.0
Liquid	1920.9
Nozzles	1048.9
Exchanger Components	3527.8
Sum of the Detail Weights	6978.6 lbf

Weight Summation Results: (lbf)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	6435.1	6435.1	6435.1	6435.1	6435.1	6435.1
Saddles	481.0	481.0	481.0	481.0	481.0	481.0
Nozzles	1048.9	1048.9	1048.9	1048.9	1048.9	1048.9
Exchanger	3527.8	3527.8	3527.8	3527.8	3527.8	3527.8
Ope. Liquid	...	...	...	...	...	1920.9
Test Liquid	...	2593.1	...	...	...	...
Tube Tst Lqd	...	533.3	...	...	...	...
Totals	11492.8	14619.3	11492.8	11492.8	11492.8	13413.7

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	11492.8 lbf
Shop Test Wt.	- Fabricated Weight + Water (Full)	14619.3 lbf
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	11492.8 lbf
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	11492.8 lbf
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	11492.8 lbf
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	13413.7 lbf
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	12811.1 lbf
Field Test Wt.	- Empty Weight + Water (Full)	14619.3 lbf

Exchanger Tube Data

Volume of Exchanger tubes :	63.9 gal
Weight of Ope Liq in tubes :	0.0 lbf
Weight of Water in tubes :	533.3 lbf

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

Outside Surface Areas of Elements:

From	To	Surface Area in^2
10	20	1156.52
20	30	1033.01
30	40	1486.81
40	50	1033.01
50	60	1033.8
60	70	14459.8
70	80	756.965

Total 20959.957 in^2 [145.6 Square Feet]

Nozzle Flange MAWP Results: (psig & F)

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
T2	1420.0	1480.0	150	600	GR 1.1	1278.4	851.6	141.6	851.6
T1	1420.0	1480.0	150	600	GR 1.1	1278.4	851.6	141.6	851.6
V	710.0	740.0	150	300	GR 1.1	...	...	...	...
D	710.0	740.0	150	300	GR 1.1	...	...	...	...
AUX1	710.0	740.0	150	300	GR 1.1	...	...	...	...
AUX2	710.0	740.0	150	300	GR 1.1	...	...	...	...
S1	1211.0	1480.0	490	600	GR 1.1	917.0	899.5	1211.0	899.5
S2	1211.0	1480.0	490	600	GR 1.1	917.0	899.5	1211.0	899.5
AUX3	608.0	740.0	490	300	GR 1.1	...	...	...	...
AUX4	608.0	740.0	490	300	GR 1.1	...	...	...	...

Shellside Flange Rating

Lowest Flange Pressure Rating was (Ope)[ShellSide]:   608.000 psig
Lowest Flange Pressure Rating was (Amb)[ShellSide]:   740.000 psig

Channelside Flange Rating

Lowest Flange Pressure Rating was (Ope)[TubeSide]:   710.000 psig
Lowest Flange Pressure Rating was (Amb)[TubeSide]:   740.000 psig

Selected Method for Derating ASME B16.5 Flange MAWP: ASME UG-44(b)

The UG-44(b) Method is based on the paper PVP 2013-97814. PV Elite uses the maximum loads from each load category to determine ME and FE. In many cases, the computed maximum allowable pressure will be greater than the flange rating. In these cases, the minimum of the rating from the table and the UG-44(b) method will be used. SA-193 B8 Cl. 2 bolts or ones with higher allowable stresses at the specified bolt size shall be used.

The axial force FE must put the nozzle in tension (-P for 107/297; +Fr for PD 5500 AnnexG) to be considered.

Nozzle Description	Gasket Dimension G in	Fm Value	Resolved Moment ME in-lb	Axial Force FE lbf	MAWP PD psig	Maximum Pressure Pmax psig	Pass Fail
T2	7.565	0.50	103377	2800	709.1	851.6	Pass
T1	7.565	0.50	103377	2800	708.4	851.6	Pass
S1	11.655	0.50	271900	4520	607.4	899.5	Pass
S2	11.655	0.50	271900	4520	606.9	899.5	Pass

Evaluating Flange on Nozzle [T2]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(103377)+4*abs(2800)7.565 < pi*7.565^3[(1420.0-709.1)+.500*1420.000]
= 1738752.0 < 1932567.8   Check Passes
```

Maximum Pressure for Flange on Nozzle T2 [Pmax]:

```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 1420.000, 0.500 * 1420.000 + 1420.000 - 1738752.0/(pi * 7.565^3)
= min( 1420.000, 851.617 )
= 851.617 psig
```

Evaluating Flange on Nozzle [T1]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(103377)+4*abs(2800)7.565 < pi*7.565^3[(1420.0-708.4)+.500*1420.000]
= 1738752.0 < 1933514.0   Check Passes
```

Maximum Pressure for Flange on Nozzle T1 [Pmax]:
```
  = min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
  = min( 1420.000, 0.500 * 1420.000 + 1420.000 - 1738752.0/(pi * 7.565^3)
  = min( 1420.000, 851.617 )
  = 851.617 psig
```

Evaluating Flange on Nozzle [S1]:
```
  = 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
  = 16(271900)+4*abs(4520)11.655 < pi*11.655^3[(1211.0-607.4)+.500*1211.000]
  = 4561123.5 < 6013593.5  Check Passes
```

Maximum Pressure for Flange on Nozzle S1 [Pmax]:
```
  = min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
  = min( 1211.000, 0.500 * 1211.000 + 1211.000 - 4561123.5/(pi * 11.655^3)
  = min( 1211.000, 899.467 )
  = 899.467 psig
```

Evaluating Flange on Nozzle [S2]:
```
  = 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
  = 16(271900)+4*abs(4520)11.655 < pi*11.655^3[(1211.0-606.9)+.500*1211.000]
  = 4561123.5 < 6016355.0  Check Passes
```

Maximum Pressure for Flange on Nozzle S2 [Pmax]:
```
  = min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
  = min( 1211.000, 0.500 * 1211.000 + 1211.000 - 4561123.5/(pi * 11.655^3)
  = min( 1211.000, 899.467 )
  = 899.467 psig
```

Pressure Ratings are per ASME B16.5 2017 Edition

Wind Load Calculation Results:

Input Values:

```
Wind Design Code                                     ASCE/SEI 7-16
Wind Load Reduction Scale Factor                             0.600
Basic Wind Speed                         [V]                   101  mile/hr
Surface Roughness Category                        C: Open Terrain
Importance Factor                                              1.0
Type of Surface                                 Moderately Smooth
Base Elevation                                                1380  in
Percent Wind for Hydrotest                                    50.0
Using User defined Wind Press. Vs Elev.                          N
Height of Hill or Escarpment     H or Hh                         0  in
Distance Upwind of Crest              Lh                         0  in
Distance from Crest to the Vessel      x                         0  in
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
Site Elevation above Sea Level                                 927  in
```

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*0.177*0.902)/(1+1.7*3.4*0.177)))
  = min(0.85, 0.879 )
  = 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

User Entered Importance Factor is                     1.000
Force Coefficient                                [Cf] 0.619
Structure Height to Diameter ratio                    10.396
```

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 26.11-1
Alpha = 9.5 : Zg = 10800 in

Effective Height [z]:

```
  = Centroid Height + Vessel Base Elevation
  = 32 + 1380 = 1412 in
  = 117.7 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

Because z(117.7 ft.) > 15 ft.

$= 2.01(z / Zg)^{2/Alpha}$

$= 2.01(117.7/900)^{2/9.5}$

= 1.31

Type of Hill: No Hill

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

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

Topographical Factor [Kzt]:
$= (1 + K1 * K2 * K3)^2$
$= (1 + 0 * 0 * 0)^2$
= 1

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max(16, 0.00256 * Kz * Kzt * Kd * Ke * $V(mph)^2$)
= max(16, 0.00256 * 1.31 * 1 * 1 * 0.997 * 101^2)
= 34.1 psf

Force on the first element [F]:
= qz * G * Cf * WindArea
= 34.1 * 0.85 * 0.619 * 1.178
= 21.1 lbf

Element	Hgt (z) in	K1	K2	K3	Kz	Kzt	qz psf
BLIND	1412.0	0.000	0.000	0.000	1.310	1.000	34.097
CHANNEL FLANGE	1412.0	0.000	0.000	0.000	1.310	1.000	34.097
CHANNEL SHELL	1412.0	0.000	0.000	0.000	1.310	1.000	34.097
CHANNEL FLANGE	1412.0	0.000	0.000	0.000	1.310	1.000	34.097
SHELL FLANGE	1412.0	0.000	0.000	0.000	1.310	1.000	34.097
SHELL	1412.0	0.000	0.000	0.000	1.310	1.000	34.097
HEAD	1412.0	0.000	0.000	0.000	1.310	1.000	34.097

Wind Load Calculation:

From	To	Wind Height in	Wind Diameter in	Wind Area in^2	Wind Pressure psf	Element Wind Load lbf
10	20	1412	46.9485	169.672	34.097	12.6804
20	30	1412	33.936	229.543	34.097	17.1548
30	40	1412	36.063	709.902	34.097	53.0543
40	50	1412	33.936	229.543	34.097	17.1548
50	60	1412	33.936	229.543	34.097	17.1548
60	70	1412	36.534	6904.06	34.097	515.973
70	80	1412	35.352	183.039	34.097	13.6794

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 Results:

Earthquake Load Calculation:

Input Values:

```
Seismic Design Code                                         ASCE/SEI 7-16
Seismic Load Reduction Scale Factor                                 0.700
Importance Factor                                                   1.500
Table Value Fa                                                      1.000
Table Value Fv                                                      1.721
Max. Mapped Res. Acceleration        [Ss]                           1.616
Max. Eff. Ground Acceleration         [S]                           0.579
Force Modification Factor R                                         2.500
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 )                                    1.077
User Value of Sd1 (used if > 0 )                                    0.996
Moment Reduction Factor Tau                                         1.000
```

Seismic Analysis Results:

```
Sms = Fa * Ss = 1 * 1.616 = 1.616
Sm1 = Fv * S1 = 1.721 * 0.579 = 0.996
Sds = 2/3 * Sms = 2/3 * 1.616 = 1.077

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.862, 1.077 )
    = 1.077

Sd1 = 2/3 * Sm1 = 2/3 * 0.996 = 0.664

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.531, 0.996 )
    = 0.996
```

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 *($3.971^{0.75}$)
 = 0.056 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:
```
= ( 1/Natural Frequency ) = ( 1/33 )
= 0.030
```

Check the Value of T which is the smaller of Cu*Ta and T:
```
= Minimum Value of(1.4 * 0.0563, 0.0303 ) 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 * 1.077 * 12811 *( 1 + 2*1 )/( 2.5/1.5 )
= 9934.242 lbf
```

Check the Maximum value of Fp per equation 13.3-2:
```
= 1.6 * Sds * I * W
= 1.6 * 1.077 * 1.5 * 12811 = 33114 lbf
```

Check the Minimum value of Fp per equation 13.3-3:
  = 0.3 * 1.077 * 1.5 * 12811
  = 6208.902 lbf

Compute the Total Base Shear V = Fp, [V]:
  = 9934.242 lbf

Vertical load per 12.4-4, [Ev]:
  = 0.2 * Sds * W
  = 0.2 * 1.077 * 12811
  = 2759.5 lbf

Final Base Shear,   V = 6953.97 lbf
Final Vertical Load, Ev = 1931.66 lbf

Earthquake Load Calculation:

From	To	Earthquake Height in	Earthquake Weight lbf	Element Ope Load lbf
10	20	15.6495	1423.46	1025.25
20	30	11.312	1423.46	741.089
30	40	11.312	1423.46	741.089
40	50	11.312	1423.46	741.089
50	60	11.312	1423.46	741.089
60	Sadl	11.312	1423.46	741.089
Sadl	70	11.312	1423.46	741.089
60	70	11.312	1423.46	741.089
70	80	11.312	1423.46	741.089

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 :

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

Center of Gravity of the Saddles	120.872 in
Center of Gravity of the Liquid	110.915 in
Center of Gravity of the Nozzles	89.144 in
Center of Gravity of the Tubesheet(s)	39.674 in
Center of Gravity of the Tubes	127.831 in
Center of Gravity of the Baffles	128.962 in
Center of Gravity of Bare Shell New and Cold	89.112 in
Center of Gravity of Bare Shell Corroded	85.138 in
Vessel CG in the Operating Condition	99.919 in
Vessel CG in the Fabricated (Shop/Empty) Condition	99.531 in
Vessel CG in the Test Condition	104.019 in

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 VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Note:
Wear Pad Width (13.00) 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( 8.606 + 1.56*sqrt( 11.75 * 0.866 ), 2 * 42.31 )
  = 13.5812 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       11.75  in
 Shell Thickness used in this Case                t       0.866  in
 Stiffened Vessel Length per 4.15.6               L      197.71  in
 Distance from Saddle to Vessel tangent      a1 or a      42.31  in

 Saddle Width                                b1 or b       8.61  in
 Saddle Bearing Angle                 delta or theta     120.00  degrees

 Inside or Mean Depth of Head               Hi or hm       5.89  in

 Shell Allowable Stress used in Calculation            20000.00  psi
 Head Allowable Stress used in Calculation             20000.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B       32.00  in
 Coefficient of Friction                         mu        0.00

 Tube Bundle Pull out Force                             3748.00  lbf
 Tube Bundle Pull out Force Impact Factor                 1.500
 Apply Bundle Pull out Force to Fixed Saddle only           Yes

 Saddle Force Q, + Bundle Pull, Force                   3218.71  lbf

 Pressure used in Analysis                        P       0.000  psig

 Horizontal Vessel Analysis Results:       Actual |    Allowable |
                                              psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan         -46.95 |    -34200.00 |
 Long. Stress at Top    of Midspan          46.95 |     20000.00 |
 Long. Stress at Bottom of Midspan          46.95 |     20000.00 |
 Long. Stress at Top    of Saddles         810.61 |     20000.00 |
 Long. Stress at Bottom of Saddles        -449.29 |    -34200.00 |
 Long. Stress at Bottom of Saddles         449.29 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                 203.79 |     16000.00 |
 Circ. Stress at Horn of Saddle            408.67 |     30000.00 |
 Circ. Compressive Stress in Shell          20.81 |     20000.00 |
 ----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Bundle pull out Force:

Saddle Reaction Force due to Bundle Pull out Force [Fwl]:

```
  = Bundle Pull Out Force * Impact Factor * B / Ls
```

```
  = 3748 * 1.5 * 32/109
  = 1650.5 lbf
```

Load Combination Results for Tube Bundle Pull Out [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 1568 + max( 1650, 0, 0, 0 )
  = 3218.7 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	3459.23	lbf
Transverse Shear Load Saddle	0.00	lbf
Longitudinal Shear Load Saddle	5622.00	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 22.000 in
```

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 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-hm²)/(2a*L))/(1+(4h2)/3L)]
  = -3219*42.31[1-(1-42.31/197.7+(11.75²-5.892²)/
    (2*42.31*197.7))/(1+(4*5.892)/(3*197.7))]
  = -32433.2 in-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-hi²)/(L²))/(1+(4hi)/( 3L))-4a/L
  = 3219*197.7/4(1+2(11.75²-5.892²)/(197.7²))/(1+(4*5.892)/
    (3*197.7))-4*42.31/197.7
  = 17620.8 in-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 0 * 11.75/(2*0.866 ) - 17621/(pi*11.75²*0.866 )
  = -46.95 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 0 * 11.75/(2 * 0.866 ) + 17621/(pi * 11.75² * 0.866 )
  = 46.95 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 0*11.75/(2*0.866)--32433/(0.107*pi*11.75²*0.866)
  = 810.61 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:

```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 0*11.75/(2*0.866)+-32433/(0.192*pi*11.75²*0.866)
  = -449.29 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:

```
  = Q(L-2a)/(L+(4*hm/3))
  = 3219( 197.7 - 2 * 42.31 )/(197.7 +( 4 * 5.892/3))
```

```
  = 1770.6 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:

```
  = K2 * T / ( Rm * t )
  = 1.171 * 1771/( 11.75 * 0.866 )
  = 203.79 psi
```

Decay Length (4.15.20) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 11.75 * 0.866 )
  = 2.488 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:

```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.76 * 3219 * 0.1/( 0.866( 8.606 + 2.488 + 2.488 ) )
  = -20.81 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:

```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -3219/(4 * 0.866(8.606 + 2.488 + 2.488 )) -
     3 * 0.0529 * 3219/(2*0.866²)
  = -408.67 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 8.606 + 1.56 * sqrt( 11.75 * 0.866 ), 2 * 42.31 )
  = 13.58 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in
Baseplate Thickness	Bpthk	0.8040	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	1	
Rib Thickness	Ribtk	0.5680	in
Web Thickness	Webtk	0.5680	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.2	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:

$$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$$
$$= ((1.56 * sqrt(11.31 * 0.866) + 13)0.866^3)/12$$
$$= 0.968 \text{ in**4}$$

Resolved Inertia for the Shell [I,shell]:

$$= ShellInertia + AShell(C1 - Y)^2$$
$$= 0.968 + 15.49(6.393 - 0.433)^2$$
$$= 551.150 \text{ in**4}$$

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	17.8826	0.8660	0.4330	15.4864	6.7056	551.1504
Wearplate	13.0000	0.8040	1.2680	10.4520	13.2531	275.1393
Web	0.5680	18.2140	10.7770	10.3456	111.4940	484.8065
BasePlate	9.0000	0.8040	20.2860	7.2360	146.7895	1396.9595
Totals	...	...	...	43.5199	278.2422	2708.0557

Distance to Centroid [C1]:

```
  = AY / A
```

```
  = 278.2/43.52
  = 6.393 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.094 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.204 * 3219
  = 655.0773 lbf

 Tension Stress, St = ( Fh/As )       =        23.3676  psi
 Allowed Stress, Sa = 0.6 * Yield Str =     22800.0117  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 32 - 11.31 * sin(120/2)/1.047
  = 22.645 in

 Bending Moment, M  = Fh * d          =     14834.2588  in-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        35.0222  psi
 Allowed Stress, Sa = 2/3 * Yield Str =     25333.3477  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(3219 + 240.5 )9/( 2 * 22 * 25333 ))
  = 0.289 in
```

Check of Center Rib:

Inertia of Saddle, Center Rib - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5680	8.0380	4.5870	4.5656	20.9423	53.3249
Web	11.2427	0.5680	0.2840	6.3859	1.8136	20.7217
Totals	...	...	...	10.9515	22.7559	74.0466

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 22.76/10.95
  = 2.078 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 2.078, abs( 8.606 - 2.078 ) )
  = 6.528 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 32 - cos( 12.98/2 )( 0.804 + 0 + 0 ) - 0
  = 18.214 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 74.05/10.95 )
  = 2.600 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 18.21/2.6
  = 7.005
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 5622/( 2 * 22 )
  = 127.773 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 127.8 * 11.24 * 18.21
  = 26164.695 in-lb
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 26165/11.34
  = 2306.737 psi
```

Compressive Allowable, KL/r < Cc(7.005 < 122.7) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 7.005 )²/(2 * 122.7² ))38000/
    ( 5/3+3*(7.005 )/(8* 122.7 )-( 7.005³)/(8*122.7³)
  = 22475 psi
```

AISC Unity Check of Center Rib (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 155.1/22475 +( 26165 * 6.528/74.05 )/25333
  = 0.098
```

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		ASTM F1554 Grade 55	
Bolt Allowable Stress	Stba	24800.00	psi
Bolt Corrosion Allowance	Bca	0.0590	in
Distance from Bolts to Edge	Edgedis	5.0000	in
Nominal Bolt Diameter	Bnd	0.8750	in
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.2946	in^2
Saddle Load QO (Weight)	QO	3459.2	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	1650.5	lbf
Maximum Transverse Force	Ft	0.0	lbf
Maximum Longitudinal Force	Fl	1650.5	lbf
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 1650/( 0.295 * 2 )
  = 2801.7 psi.  Must be less than 14880.0 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 0/( 0.295 * 2 )
  = 0.0 psi.  Must be less than 14880.0 psi.
```

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 )
  = 1650/(14880 * 2 )
  = 0.0555 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 32 * 0 + 0
  = 0.00 in-lb
```

Eccentricity (e):
```
  = Rmom / QO
  = 0/3459
  = 0.00 in < 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, 0.0555, 0 ]
  = 0.0555 in^2
```

Warning:
Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.

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 VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Note:
Wear Pad Width (13.00) 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( 8.606 + 1.56*sqrt( 11.81 * 0.741 ), 2 * 42.31 )
  = 13.2204 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       11.81  in
 Shell Thickness used in this Case                t       0.866  in
 Stiffened Vessel Length per 4.15.6               L      197.71  in
 Distance from Saddle to Vessel tangent     a1 or a       42.31  in

 Saddle Width                               b1 or b        8.61  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Inside or Mean Depth of Head              Hi or hm        5.83  in

 Shell Allowable Stress used in Calculation          20000.00  psi
 Head Allowable Stress used in Calculation           20000.00  psi
 Circumferential Efficiency in Plane of Saddle           1.00
 Circumferential Efficiency at Mid-Span                  1.00

 Distance from Saddle Base to Centerline        B       32.00  in
 Coefficient of Friction                       mu        0.00

 Tube Bundle Pull out Force                           3748.00  lbf
 Tube Bundle Pull out Force Impact Factor               1.500
 Apply Bundle Pull out Force to Fixed Saddle only         Yes

 Saddle Force Q, + Bundle Pull, Force                 2917.39  lbf

 Pressure used in Analysis                      P       0.000  psig
```

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	-49.43	-34200.00
Long. Stress at Top of Midspan	49.43	20000.00
Long. Stress at Bottom of Midspan	49.43	20000.00
Long. Stress at Top of Saddles	848.05	20000.00
Long. Stress at Bottom of Saddles	-470.04	-34200.00
Long. Stress at Bottom of Saddles	470.04	20000.00
Tangential Shear in Shell	214.82	16000.00
Circ. Stress at Horn of Saddle	495.67	30000.00
Circ. Compressive Stress in Shell	22.64	20000.00

Intermediate Results: Saddle Reaction Q due to Bundle pull out Force:

Saddle Reaction Force due to Bundle Pull out Force [Fwl]:

```
  = Bundle Pull Out Force * Impact Factor * B / Ls
```

```
  = 3748 * 1.5 * 32/109
  = 1650.5 lbf
```

Load Combination Results for Tube Bundle Pull Out [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 1267 + max( 1650, 0, 0, 0 )
  = 2917.4 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	3157.91	lbf
Transverse Shear Load Saddle	0.00	lbf
Longitudinal Shear Load Saddle	5622.00	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 22.000 in
```

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 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-hm²)/(2a*L))/(1+(4h2)/3L)]
  = -2917*42.31[1-(1-42.31/197.7+(11.81²-5.83²)/
    (2*42.31*197.7))/(1+(4*5.83)/(3*197.7))]
  = -29343.2 in-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-hi²)/(L²))/(1+(4hi)/( 3L))-4a/L
  = 2917*197.7/4(1+2(11.81²-5.83²)/(197.7²))/(1+(4*5.83)/
    (3*197.7))-4*42.31/197.7
  = 16043.4 in-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 0 * 11.81/(2*0.741 ) - 16043/(pi*11.81²*0.741 )
  = -49.43 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 0 * 11.81/(2 * 0.741 ) + 16043/(pi * 11.81² * 0.741 )
  = 49.43 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 0*11.81/(2*0.741)--29343/(0.107*pi*11.81²*0.741)
  = 848.05 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:

```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 0*11.81/(2*0.741)+-29343/(0.192*pi*11.81²*0.741)
  = -470.04 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:

```
  = Q(L-2a)/(L+(4*hm/3))
  = 2917( 197.7 - 2 * 42.31 )/(197.7 +( 4 * 5.83/3))
```

= 1605.5 lbf

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
= K2 * T / (Rm * t)
= 1.171 * 1605/(11.81 * 0.741)
= 214.82 psi

Decay Length (4.15.20) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(11.81 * 0.741)
= 2.307 in

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
= -K5 * Q * k / (t(b + X1 + X2))
= -0.76 * 2917 * 0.1/(0.741(8.606 + 2.307 + 2.307))
= -22.64 psi

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
= -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
= -2917/(4 * 0.741(8.606 + 2.307 + 2.307)) -
3 * 0.0529 * 2917/(2*0.741²)
= -495.67 psi

Effective reinforcing plate width (4.15.24) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(8.606 + 1.56 * sqrt(11.81 * 0.741), 2 * 42.31)
= 13.22 in

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in
Baseplate Thickness	Bpthk	0.8040	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	1	
Rib Thickness	Ribtk	0.5680	in
Web Thickness	Webtk	0.5680	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.2	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12
= ((1.56 * sqrt(11.44 * 0.741) + 13)0.741^3)/12
= 0.595 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y)^2
= 0.595 + 13(6.65 - 0.37)^2
= 513.090 in**4

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	17.5414	0.7410	0.3705	12.9982	4.8158	513.0898
Wearplate	13.0000	0.8040	1.1430	10.4520	11.9466	317.5056
Web	0.5680	18.2140	10.6520	10.3456	110.2008	451.7313
BasePlate	9.0000	0.8040	20.1610	7.2360	145.8850	1321.3612
Totals	...	...	...	41.0317	272.8483	2603.6880

Distance to Centroid [C1]:
= AY / A

```
  = 272.8/41.03
  = 6.650 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.094 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.204 * 2917
  = 593.7521 lbf

 Tension Stress, St = ( Fh/As )       =         21.1801  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0117  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 32 - 11.44 * sin(120/2)/1.047
  = 22.542 in

 Bending Moment, M  = Fh * d          =      13384.1680  in-lb

 Bending Stress, Sb = ( M * C1 / I  ) =         34.1825  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3477  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(2917 + 240.5 )9/( 2 * 22 * 25333 ))
  = 0.277 in
```

Check of Center Rib:

Inertia of Saddle, Center Rib - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5680	8.0380	4.5870	4.5656	20.9423	53.3249
Web	11.2427	0.5680	0.2840	6.3859	1.8136	20.7217
Totals	...	...	...	10.9515	22.7559	74.0466

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 22.76/10.95
  = 2.078 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 2.078, abs( 8.606 - 2.078 ) )
  = 6.528 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 32 - cos( 12.98/2 )( 0.804 + 0 + 0 ) - 0
  = 18.214 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 74.05/10.95 )
  = 2.600 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 18.21/2.6
  = 7.005
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 5622/( 2 * 22 )
  = 127.773 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 127.8 * 11.24 * 18.21
  = 26164.695 in-lb
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 26165/11.34
  = 2306.737 psi
```

Compressive Allowable, KL/r < Cc(7.005 < 122.7) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 7.005 )²/(2 * 122.7² ))38000/
    ( 5/3+3*(7.005 )/(8* 122.7 )-( 7.005³)/(8*122.7³)
  = 22475 psi
```

AISC Unity Check of Center Rib (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 140.6/22475 +( 26165 * 6.528/74.05 )/25333
  = 0.097
```

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		ASTM F1554 Grade 55	
Bolt Allowable Stress	Stba	24800.00	psi
Bolt Corrosion Allowance	Bca	0.0590	in
Distance from Bolts to Edge	Edgedis	5.0000	in
Nominal Bolt Diameter	Bnd	0.8750	in
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.2946	in^2
Saddle Load QO (Weight)	QO	3157.9	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	1650.5	lbf
Maximum Transverse Force	Ft	0.0	lbf
Maximum Longitudinal Force	Fl	1650.5	lbf
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 1650/( 0.295 * 2 )
  = 2801.7 psi.  Must be less than 14880.0 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 0/( 0.295 * 2 )
  = 0.0 psi.  Must be less than 14880.0 psi.
```

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 )
  = 1650/(14880 * 2 )
  = 0.0555 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 32 * 0 + 0
  = 0.00 in-lb
```

Eccentricity (e):
```
  = Rmom / QO
  = 0/3158
  = 0.00 in < 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, 0.0555, 0 ]
  = 0.0555 in^2
```

Warning:
Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Width (13.00) 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( 8.606 + 1.56*sqrt( 11.81 * 0.741 ), 2 * 30 )
  = 13.2204 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       11.81  in
 Shell Thickness used in this Case                t       0.866  in
 Stiffened Vessel Length per 4.15.6               L      197.71  in
 Distance from Saddle to Vessel tangent      a1 or a      30.00  in

 Saddle Width                                b1 or b       8.61  in
 Saddle Bearing Angle                 delta or theta     120.00  degrees

 Shell Allowable Stress used in Calculation            20000.00  psi
 Head Allowable Stress used in Calculation             19640.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B       32.00  in
 Coefficient of Friction                         mu        0.40

 Saddle Force Q, Operating Case                        24765.80  lbf

 Pressure used in Analysis                        P     550.278  psig

 Horizontal Vessel Analysis Results:       Actual |    Allowable |
                                              psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan        2874.85 |     20000.00 |
 Long. Stress at Bottom of Midspan        5893.57 |     20000.00 |
 Long. Stress at Top    of Saddles        7390.08 |     20000.00 |
 Long. Stress at Bottom of Saddles        2718.18 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                2308.11 |     16000.00 |
 Circ. Stress at Horn of Saddle           4207.76 |     25000.00 |
 Circ. Compressive Stress in Shell         192.20 |     20000.00 |
 ----------------------------------------------------------------
```

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( 646.9/2 + 0 ) * 32/22
  = 1411.3 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 148.9, 0 ) * 32/109
  = 43.7 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:
```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 6954, 0 ) * 32/109
```

= 2041.5 lbf

Saddle Reaction Force due to Earthquake Ft [Fst]:
= Ftr(Ft/Num of Saddles + Z Force Load) * B / E
= 3(6954/2 + 0) * 32/22
= 15172.3 lbf

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + max(Fwl, Fwt, Fsl, Fst)
= 9594 + max(43.72, 1411, 2042, 15172)
= 24765.8 lbf

Longitudinal Wind Force [Fl]:
= WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))
= 0.6 * 34.1(0 + pi/4(2.03 * 1.5)^2)
= 148.932 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	25006.32	lbf
Transverse Shear Load Saddle	3476.98	lbf
Longitudinal Shear Load Saddle	6953.97	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
= Baseplate Length
= 22.000 in

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 4.15.1 [M1]:
= -Q*a [1 - (1- a/L + (Rm²-hm²)/(2a*L))/(1+(4h2)/3L)]
= -24766*30[1-(1-30/197.7+(11.81²-0²)/
(2*30*197.7))/(1+(4*0)/(3*197.7))]
= -104005.4 in-lb

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm²-hi²)/(L²))/(1+(4hi)/(3L))-4a/L
= 24766*197.7/4(1+2(11.81²-0²)/(197.7²))/(1+(4*0)/
(3*197.7))-4*30/197.7
= 489865.8 in-lb

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 550.3 * 11.81/(2*0.741) - 489866/(pi*11.81²*0.741)
= 2874.85 psi

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 550.3 * 11.81/(2 * 0.741) + 489866/(pi * 11.81² * 0.741)
= 5893.57 psi

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 550.3*11.81/(2*0.741)--104005/(0.107*pi*11.81²*0.741)
= 7390.08 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 550.3*11.81/(2*0.741)+-104005/(0.192*pi*11.81²*0.741)
  = 2718.18 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*hm/3))
  = 24766( 197.7 - 2 * 30 )/(197.7 +( 4 * 0/3))
  = 17250.0 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.171 * 17250/( 11.81 * 0.741 )
  = 2308.11 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 11.81 * 0.741 )
  = 2.307 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.76 * 24766 * 0.1/( 0.741( 8.606 + 2.307 + 2.307 ) )
  = -192.20 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -24766/(4 * 0.741(8.606 + 2.307 + 2.307 )) -
     3 * 0.0529 * 24766/(2*0.741²)
  = -4207.76 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 8.606 + 1.56 * sqrt( 11.81 * 0.741 ), 2 * 30 )
  = 13.22 in
```

Distance between Saddle Supports [Ls]:
```
  = 109.0 in
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls( Design Temperature - Ambient Temperature )
  = 0.72800E-05 * 109( 490 - 70 )
  = 0.333 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in
Baseplate Thickness	Bpthk	0.8040	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	1	
Rib Thickness	Ribtk	0.5680	in
Web Thickness	Webtk	0.5680	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.2	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:

$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$

$= ((1.56 * sqrt(11.44 * 0.741) + 13)0.741^3)/12$

= 0.595 in**4

Resolved Inertia for the Shell [I,shell]:

$= ShellInertia + AShell(C1 - Y)^2$
$= 0.595 + 13(6.65 - 0.37)^2$
= 513.090 in**4

	B in	D in	Y in	A in^2	AY in^3	$I + AD^2$ in**4
Shell	17.5414	0.7410	0.3705	12.9982	4.8158	513.0898
Wearplate	13.0000	0.8040	1.1430	10.4520	11.9466	317.5056
Web	0.5680	18.2140	10.6520	10.3456	110.2008	451.7313
BasePlate	9.0000	0.8040	20.1610	7.2360	145.8850	1321.3612
Totals	...	...	...	41.0317	272.8483	2603.6880

Distance to Centroid [C1]:
= AY / A
= 272.8/41.03
= 6.650 in

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120) - 0.5*sin(120)²)/(pi - 2.094 + sin(120)cos(120))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 24766
= 5040.3770 lbf

Tension Stress, St = (Fh/As) = 179.7980 psi
Allowed Stress, Sa = 0.6 * Yield Str = 22800.0117 psi

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 32 - 11.44 * sin(120/2)/1.047
= 22.542 in

Bending Moment, M = Fh * d = 113618.5469 in-lb

Bending Stress, Sb = (M * C1 / I) = 290.1761 psi
Allowed Stress, Sa = 2/3 * Yield Str = 25333.3477 psi

Minimum Thickness of Baseplate per Moss:
= sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
= sqrt(3(24766 + 240.5)9/(2 * 22 * 25333))
= 0.778 in

Check of Center Rib:

Inertia of Saddle, Center Rib - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5680	8.0380	4.5870	4.5656	20.9423	53.3249
Web	11.2427	0.5680	0.2840	6.3859	1.8136	20.7217
Totals	...	...	...	10.9515	22.7559	74.0466

Distance to Centroid from Datum [ytot]:
= AY / A
= 22.76/10.95
= 2.078 in

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 2.078, abs( 8.606 - 2.078 ) )
  = 6.528 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 32 - cos( 12.98/2 )( 0.804 + 0 + 0 ) - 0
  = 18.214 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 74.05/10.95 )
  = 2.600 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 18.21/2.6
  = 7.005
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 6954/( 2 * 22 )
  = 158.045 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 158 * 11.24 * 18.21
  = 32363.656 in-lb
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 32364/11.34
  = 2853.251 psi
```

Compressive Allowable, KL/r < Cc(7.005 < 122.7) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 7.005 )²/(2 * 122.7² ))38000/
    ( 5/3+3*(7.005 )/(8* 122.7 )-( 7.005³)/(8*122.7³)
  = 22475 psi
```

AISC Unity Check of Center Rib (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1193/22475 +( 32364 * 6.528/74.05 )/25333
  = 0.166
```

<u>Input Data for Base Plate Bolting Calculations:</u>

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		ASTM F1554 Grade 55	
Bolt Allowable Stress	Stba	24800.00	psi
Bolt Corrosion Allowance	Bca	0.0590	in
Distance from Bolts to Edge	Edgedis	5.0000	in
Nominal Bolt Diameter	Bnd	0.8750	in
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.2946	in^2
Saddle Load QO (Weight)	QO	9834.0	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	2041.5	lbf
Maximum Transverse Force	Ft	3477.0	lbf
Maximum Longitudinal Force	Fl	6954.0	lbf
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 6954/( 0.295 * 2 )
  = 11804.3 psi.  Must be less than 14880.0 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 3477/( 0.295 * 2 )
  = 5902.1 psi.  Must be less than 14880.0 psi.
```

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 )
  = 6954/(14880 * 2 )
  = 0.2337 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 32 * 3477 + 0
  = 111263.51 in-lb
```

Eccentricity (e):
```
  = Rmom / QO
  = 111264/9834
  = 11.31 in > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 22/2 - 5
   = 6.00 in

 K1 = 3 (e - 0.5 * Bplen)
    = 3(11.31 - 0.5*22 )
    = 0.94 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1 * 0.295/9 *(6 + 11.31 )
    = 3.40 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -3.4 *(0.5 * 22 + 6 )
    = -57.80 in ³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 0.942 * Y² + 3.4 * Y + -57.8 = 0
 Y  = 3.31 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (22/2 - 3.309/3 - 11.31 )
     = -1.42

 Denom = (Bplen / 2 - Y / 3 + f)
       = (22/2 - 3.309/3 + 6 )
       = 15.90
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 9834 * -1.417/15.9
  = 876.64 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 876.6/( 24800 * 1 )
  = 0.0353 in^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.234, 0.0353 ]
  = 0.2337 in^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(9834 + 876.6 )/(3.309 * 9 )
  = 719.31 psig
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (22 - 20 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 876.6 * 1
  = 876.64 in-lb
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 719.3 *(3.309 - 1 )/3.309
  = 501.92 psig
```

Overturning Moment due to Bearing Pressure [Mc]:

```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (1² * 9/6) *(501.9 + 2 * 719.3 )
  = 2910.80 in-lb
```

Baseplate Required Thickness [Treq]:

```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(876.6,2911 )/(9 * 30000 ))
  = 0.2543 in
```

MDMT Calculations for: Right Sdl, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.804, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.482, Temp. Reduction = 0 F
Attachment governing, Attachment stress = Shell stress per Code

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -39 F
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Note:
Wear Pad Width (13.00) 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( 8.606 + 1.56*sqrt( 11.81 * 0.741 ), 2 * 42.31 )
  = 13.2204 in
```

Input and Calculated Values:

Vessel Mean Radius	Rm	11.81	in
Shell Thickness used in this Case	t	0.866	in
Stiffened Vessel Length per 4.15.6	L	197.71	in
Distance from Saddle to Vessel tangent	a1 or a	42.31	in
Saddle Width	b1 or b	8.61	in
Saddle Bearing Angle	delta or theta	120.00	degrees
Inside or Mean Depth of Head	Hi or hm	5.83	in
Shell Allowable Stress used in Calculation		20000.00	psi
Head Allowable Stress used in Calculation		20000.00	psi
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	32.00	in
Coefficient of Friction	mu	0.00	
Saddle Force Q, Operating Case		19840.51	lbf
Pressure used in Analysis	P	550.278	psig

Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	4048.03	20000.00
Long. Stress at Bottom of Midspan	4720.39	20000.00
Long. Stress at Top of Saddles	10151.59	20000.00
Long. Stress at Bottom of Saddles	1187.58	20000.00
Tangential Shear in Shell	1460.93	16000.00
Circ. Stress at Horn of Saddle	3370.95	25000.00
Circ. Compressive Stress in Shell	153.98	20000.00

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( 646.9/2 + 0 ) * 32/22
  = 1411.3 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 148.9, 0 ) * 32/109
  = 43.7 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:

```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 6954, 0 ) * 32/109
  = 2041.5 lbf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 6954/2 + 0 ) * 32/22
  = 15172.3 lbf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 4668 + max( 43.72, 1411, 2042, 15172 )
  = 19840.5 lbf
```

Longitudinal Wind Force [Fl]:

```
  = WindScalar * WindPress( Platform Area + ( pi/4( OD * WindDiaMult )² ) )
  = 0.6 * 34.1( 0 + pi/4( 2.03 * 1.5 )² )
  = 148.932 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	20081.03	lbf
Transverse Shear Load Saddle	3476.98	lbf
Longitudinal Shear Load Saddle	6953.97	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 22.000 in
```

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 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-hm²)/(2a*L))/(1+(4h2)/3L)]
  = -19841*42.31[1-(1-42.31/197.7+(11.81²-5.83²)/
    (2*42.31*197.7))/(1+(4*5.83)/(3*197.7))]
  = -199556.2 in-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-hi²)/(L²))/(1+(4hi)/( 3L))-4a/L
  = 19841*197.7/4(1+2(11.81²-5.83²)/(197.7²))/(1+(4*5.83)/
    (3*197.7))-4*42.31/197.7
  = 109107.8 in-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 550.3 * 11.81/(2*0.741 ) - 109108/(pi*11.81²*0.741 )
  = 4048.03 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 550.3 * 11.81/(2 * 0.741 ) + 109108/(pi * 11.81² * 0.741 )
  = 4720.39 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 550.3*11.81/(2*0.741)--199556/(0.107*pi*11.81²*0.741)
  = 10151.59 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:

```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 550.3*11.81/(2*0.741)+-199556/(0.192*pi*11.81²*0.741)
  = 1187.58 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:

```
  = Q(L-2a)/(L+(4*hm/3))
```

```
  = 19841( 197.7 - 2 * 42.31 )/(197.7 +( 4 * 5.83/3))
  = 10918.5 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:

```
  = K2 * T / ( Rm * t )
  = 1.171 * 10918/( 11.81 * 0.741 )
  = 1460.93 psi
```

Decay Length (4.15.20) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 11.81 * 0.741 )
  = 2.307 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:

```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.76 * 19841 * 0.1/( 0.741( 8.606 + 2.307 + 2.307 ) )
  = -153.98 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:

```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -19841/(4 * 0.741(8.606 + 2.307 + 2.307 )) -
     3 * 0.0529 * 19841/(2*0.741²)
  = -3370.95 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 8.606 + 1.56 * sqrt( 11.81 * 0.741 ), 2 * 42.31 )
  = 13.22 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in
Baseplate Thickness	Bpthk	0.8040	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	1	
Rib Thickness	Ribtk	0.5680	in
Web Thickness	Webtk	0.5680	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.2	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:

$$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$$
$$= ((1.56 * sqrt(11.44 * 0.741) + 13)0.741^3)/12$$
$$= 0.595 \ in**4$$

Resolved Inertia for the Shell [I,shell]:

$$= ShellInertia + AShell(C1 - Y)^2$$
$$= 0.595 + 13(6.65 - 0.37)^2$$
$$= 513.090 \ in**4$$

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	17.5414	0.7410	0.3705	12.9982	4.8158	513.0898
Wearplate	13.0000	0.8040	1.1430	10.4520	11.9466	317.5056
Web	0.5680	18.2140	10.6520	10.3456	110.2008	451.7313
BasePlate	9.0000	0.8040	20.1610	7.2360	145.8850	1321.3612
Totals	...	...	...	41.0317	272.8483	2603.6880

Distance to Centroid [C1]:

```
  = AY / A
  = 272.8/41.03
  = 6.650 in
```

Angle [beta]:

```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:

```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.094 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:

```
  = K1 * Q
  = 0.204 * 19841
  = 4037.9736 lbf

 Tension Stress, St = ( Fh/As )       =       144.0407  psi
 Allowed Stress, Sa = 0.6 * Yield Str =     22800.0117  psi
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 32 - 11.44 * sin(120/2)/1.047
  = 22.542 in

 Bending Moment, M  = Fh * d          =     91022.6953  in-lb

 Bending Stress, Sb = ( M * C1 / I  ) =       232.4674  psi
 Allowed Stress, Sa = 2/3 * Yield Str =     25333.3477  psi
```

Minimum Thickness of Baseplate per Moss:

```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(19841 + 240.5 )9/( 2 * 22 * 25333 ))
  = 0.697 in
```

Check of Center Rib:

Inertia of Saddle, Center Rib - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5680	8.0380	4.5870	4.5656	20.9423	53.3249
Web	11.2427	0.5680	0.2840	6.3859	1.8136	20.7217
Totals	...	...	...	10.9515	22.7559	74.0466

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 22.76/10.95
  = 2.078 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 2.078, abs( 8.606 - 2.078 ) )
  = 6.528 in
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 32 - cos( 12.98/2 )( 0.804 + 0 + 0 ) - 0
  = 18.214 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 74.05/10.95 )
```

= 2.600 in

Slenderness ratio [KL/r]:
= KL/r
= 1 * 18.21/2.6
= 7.005

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 6954/(2 * 22)
= 158.045 lbf/in

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 158 * 11.24 * 18.21
= 32363.656 in-lb

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 32364/11.34
= 2853.251 psi

Compressive Allowable, KL/r < Cc(7.005 < 122.7) per AISC E2-1 [Sca]:
= (1-$(Klr)^2/(2*Cc^2)$)Fy/(5/3+3*(Klr)/(8*Cc)-$(Klr^3)/(8*Cc^3)$)
= (1-(7.005 $)^2/(2 * 122.7^2$))38000/
(5/3+3*(7.005)/(8* 122.7)-($7.005^3)/(8*122.7^3)$
= 22475 psi

AISC Unity Check of Center Rib (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 955.9/22475 +(32364 * 6.528/74.05)/25333
= 0.155

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		ASTM F1554 Grade 55	
Bolt Allowable Stress	Stba	24800.00	psi
Bolt Corrosion Allowance	Bca	0.0590	in
Distance from Bolts to Edge	Edgedis	5.0000	in
Nominal Bolt Diameter	Bnd	0.8750	in
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.2946	in^2
Saddle Load QO (Weight)	QO	4908.7	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	2041.5	lbf
Maximum Transverse Force	Ft	3477.0	lbf
Maximum Longitudinal Force	Fl	6954.0	lbf
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
= Fl / (Bolt Area * Number of Bolts)
= 6954/(0.295 * 2)
= 11804.3 psi. Must be less than 14880.0 psi.

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
= Ft / (Bolt Area * Number of Bolts)
= 3477/(0.295 * 2)
= 5902.1 psi. Must be less than 14880.0 psi.

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)
= 6954/(14880 * 2)
= 0.2337 in^2

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 32 * 3477 + 0
= 111263.51 in-lb

Eccentricity (e):
= Rmom / QO
= 111264/4909
= 22.67 in > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis
= 22/2 - 5
= 6.00 in

K1 = 3 (e - 0.5 * Bplen)
= 3(22.67 - 0.5*22)
= 35.00 in

K2 = 6 * n1 * At / Bpwid * (f + e)
= 6 * 1 * 0.295/9 *(6 + 22.67)
= 5.63 in ^{2}

K3 = -K2 * (0.5 * Bplen + f)
= -5.629 *(0.5 * 22 + 6)
= -95.70 in ^{3}

Iteratively Solving for the Effective Bearing Length:
Y^3 + K1 * Y^2 + K2 * Y + K3 = 0
Y^3 + 35 * Y^2 + 5.629 * Y + -95.7 = 0
Y = 1.54 in

Num = (Bplen / 2 - Y / 3 - e)
= (22/2 - 1.543/3 - 22.67)
= -12.18

Denom = (Bplen / 2 - Y / 3 + f)
= (22/2 - 1.543/3 + 6)
= 16.49

Total Bolt Tension Force [Tforce]:
= - QO * Num / Denom
= - 4909 * -12.18/16.49
= 3626.93 lbf

Bolt Area Required due to Transverse Load [Bltareart]:
= Tforce / (Stba * Nbt)
= 3627/(24800 * 1)
= 0.1462 in^2

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0, 0.234, 0.146]
= 0.2337 in^2

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(4909 + 3627 )/(1.543 * 9 )
  = 1229.25 psig
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (22 - 20 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 3627 * 1
  = 3626.93 in-lb
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 1229 *(1.543 - 1 )/1.543
  = 432.62 psig
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (1² * 9/6) *(432.6 + 2 * 1229 )
  = 4336.67 in-lb
```

Baseplate Required Thickness [Treq]:
```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(3627,4337 )/(9 * 30000 ))
  = 0.3104 in
```

MDMT Calculations for: Right Sdl, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.804, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.482, Temp. Reduction = 0 F
Attachment governing, Attachment stress = Shell stress per Code

```
 Min Metal Temp. w/o impact per UCS-66, Curve D           -39 F
```

Warning:
Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Test Case

Note:
Wear Pad Width (13.00) 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( 8.606 + 1.56*sqrt( 11.75 * 0.866 ), 2 * 30 )
  = 13.5812 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       11.75  in
 Shell Thickness used in this Case                t       0.866  in
 Stiffened Vessel Length per 4.15.6               L      197.71  in
 Distance from Saddle to Vessel tangent      a1 or a      30.00  in

 Saddle Width                                b1 or b       8.61  in
 Saddle Bearing Angle                 delta or theta     120.00  degrees

 Shell Allowable Stress used in Calculation            34200.00  psi
 Head Allowable Stress used in Calculation             34200.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B       32.00  in
 Coefficient of Friction                         mu        0.40

 Saddle Force Q, Test Case, no Ext. Forces             10035.08  lbf

 Pressure used in Analysis                        P     790.098  psig

 Horizontal Vessel Analysis Results:       Actual |    Allowable |
                                              psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan        4829.00 |     34200.00 |
 Long. Stress at Bottom of Midspan        5886.60 |     34200.00 |
 Long. Stress at Top    of Saddles        6412.02 |     34200.00 |
 Long. Stress at Bottom of Saddles        4773.48 |     34200.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                 804.51 |     20254.00 |
 Circ. Stress at Horn of Saddle           1274.11 |     51300.00 |
 Circ. Compressive Stress in Shell          64.87 |     34200.00 |
 ----------------------------------------------------------------
```

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( 323.4/2 + 0 ) * 32/22
  = 705.7 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 74.47, 0 ) * 32/109
  = 21.9 lbf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 9329 + max( 21.86, 705.7, 0, 0 )
```

  = 10035.1 lbf

Longitudinal Wind Force [Fl]:
  = WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))
  = 0.6 * 34.1(0 + pi/4(2.03 * 1.5)^2)
  = 148.932 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	10275.60	lbf
Transverse Shear Load Saddle	161.71	lbf
Longitudinal Shear Load Saddle	74.47	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
  = Baseplate Length
  = 22.000 in

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 4.15.1 [M1]:
  = -Q*a [1 - (1- a/L + (Rm²-hm²)/(2a*L))/(1+(4h2)/3L)]
  = -10035*30[1-(1-30/197.7+(11.75²-0²)/
    (2*30*197.7))/(1+(4*0)/(3*197.7))]
  = -42180.2 in-lb

Moment per Equation 4.15.4 [M2]:
  = Q*L/4(1+2(Rm²-hi²)/(L²))/(1+(4hi)/(3L))-4a/L
  = 10035*197.7/4(1+2(11.75²-0²)/(197.7²))/(1+(4*0)/
    (3*197.7))-4*30/197.7
  = 198455.7 in-lb

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 790.1 * 11.75/(2*0.866) - 198456/(pi*11.75²*0.866)
  = 4829.00 psi

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 790.1 * 11.75/(2 * 0.866) + 198456/(pi * 11.75² * 0.866)
  = 5886.60 psi

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma*3]:
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 790.1*11.75/(2*0.866)--42180/(0.107*pi*11.75²*0.866)
  = 6412.02 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma*4]:
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 790.1*11.75/(2*0.866)+-42180/(0.192*pi*11.75²*0.866)
  = 4773.48 psi

Maximum Shear Force in the Saddle (4.15.3) [T]:
  = Q(L-2a)/(L+(4*hm/3))
  = 10035(197.7 - 2 * 30)/(197.7 +(4 * 0/3))
  = 6989.7 lbf

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.171 * 6990/( 11.75 * 0.866 )
  = 804.51 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 11.75 * 0.866 )
  = 2.488 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.76 * 10035 * 0.1/( 0.866( 8.606 + 2.488 + 2.488 ) )
  = -64.87 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -10035/(4 * 0.866(8.606 + 2.488 + 2.488 )) -
     3 * 0.0529 * 10035/(2*0.866²)
  = -1274.11 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 8.606 + 1.56 * sqrt( 11.75 * 0.866 ), 2 * 30 )
  = 13.58 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in
Baseplate Thickness	Bpthk	0.8040	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	1	
Rib Thickness	Ribtk	0.5680	in
Web Thickness	Webtk	0.5680	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.2	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:
```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t³ )/12
  = (( 1.56 * sqrt( 11.31 * 0.866 ) + 13 )0.866³ )/12
  = 0.968 in**4
```

Resolved Inertia for the Shell [I,shell]:
```
  = ShellInertia + AShell( C1 - Y )²
  = 0.968 + 15.49( 6.393 - 0.433 )²
  = 551.150 in**4
```

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	17.8826	0.8660	0.4330	15.4864	6.7056	551.1504
Wearplate	13.0000	0.8040	1.2680	10.4520	13.2531	275.1393
Web	0.5680	18.2140	10.7770	10.3456	111.4940	484.8065
BasePlate	9.0000	0.8040	20.2860	7.2360	146.7895	1396.9595
Totals	...	...	...	43.5199	278.2422	2708.0557

Distance to Centroid [C1]:
```
  = AY / A
  = 278.2/43.52
  = 6.393 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.094 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.204 * 10035
  = 2042.3556 lbf

 Tension Stress, St = ( Fh/As )       =         72.8540  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0117  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 32 - 11.31 * sin(120/2)/1.047
  = 22.645 in

 Bending Moment, M  = Fh * d          =      46249.2461  in-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        109.1898  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3477  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(10035 + 240.5 )9/( 2 * 22 * 25333 ))
  = 0.499 in
```

Check of Center Rib:

Inertia of Saddle, Center Rib - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5680	8.0380	4.5870	4.5656	20.9423	53.3249
Web	11.2427	0.5680	0.2840	6.3859	1.8136	20.7217
Totals	...	...	...	10.9515	22.7559	74.0466

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 22.76/10.95
  = 2.078 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 2.078, abs( 8.606 - 2.078 ) )
  = 6.528 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 32 - cos( 12.98/2 )( 0.804 + 0 + 0 ) - 0
  = 18.214 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 74.05/10.95 )
  = 2.600 in
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 18.21/2.6
  = 7.005
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 74.47/( 2 * 22 )
  = 1.692 lbf/in
```

Moment at base of inner Rib [Mbase,c]:

```
  = Unit Force * e * L
  = 1.692 * 11.24 * 18.21
  = 346.564 in-lb
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

```
  = Bending Moment / Section Modulus
  = 346.6/11.34
  = 30.554 psi
```

Compressive Allowable, KL/r < Cc(7.005 < 122.7) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 7.005 )²/(2 * 122.7² ))38000/
    ( 5/3+3*(7.005 )/(8* 122.7 )-( 7.005³)/(8*122.7³)
  = 22475 psi
```

AISC Unity Check of Center Rib (must be <= 1)

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 483.5/22475 +( 346.6 * 6.528/74.05 )/25333
  = 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		ASTM F1554 Grade 55	
Bolt Allowable Stress	Stba	24800.00	psi
Bolt Corrosion Allowance	Bca	0.0590	in
Distance from Bolts to Edge	Edgedis	5.0000	in
Nominal Bolt Diameter	Bnd	0.8750	in
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.2946	in^2
Saddle Load QO (Weight)	QO	9569.9	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	21.9	lbf
Maximum Transverse Force	Ft	161.7	lbf
Maximum Longitudinal Force	Fl	74.5	lbf
Saddle Bolted to Steel Foundation		Yes	

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

```
  = Fl / ( Bolt Area * Number of Bolts )
  = 74.47/( 0.295 * 2 )
  = 126.4 psi.  Must be less than 14880.0 psi.
```

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

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 161.7/( 0.295 * 2 )
  = 274.5 psi.  Must be less than 14880.0 psi.
```

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 )
  = 74.47/(14880 * 2 )
  = 0.0025 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 32 * 161.7 + 0
  = 5174.81 in-lb
```

Eccentricity (e):

```
  = Rmom / QO
  = 5175/9570
  = 0.54 in < 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, 0.0025, 0 ]
  = 0.0025 in^2
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Note:
Wear Pad Width (13.00) 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( 8.606 + 1.56*sqrt( 11.75 * 0.866 ), 2 * 42.31 )
  = 13.5812 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       11.75  in
 Shell Thickness used in this Case                t       0.866  in
 Stiffened Vessel Length per 4.15.6               L      197.71  in
 Distance from Saddle to Vessel tangent     a1 or a       42.31  in

 Saddle Width                               b1 or b        8.61  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Inside or Mean Depth of Head              Hi or hm        5.89  in

 Shell Allowable Stress used in Calculation            34200.00  psi
 Head Allowable Stress used in Calculation             34200.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B       32.00  in
 Coefficient of Friction                         mu        0.00

 Saddle Force Q, Test Case, no Ext. Forces              5514.46  lbf

 Pressure used in Analysis                        P     790.098  psig

 Horizontal Vessel Analysis Results:       Actual |    Allowable |
                                              psi |          psi |
 ----------------------------------------------------------------
```

Long. Stress at Top of Midspan	5277.36	34200.00
Long. Stress at Bottom of Midspan	5438.24	34200.00
Long. Stress at Top of Saddles	6746.58	34200.00
Long. Stress at Bottom of Saddles	4588.05	34200.00
Tangential Shear in Shell	349.15	20254.00
Circ. Stress at Horn of Saddle	700.15	51300.00
Circ. Compressive Stress in Shell	35.65	34200.00

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( 323.4/2 + 0 ) * 32/22
  = 705.7 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 74.47, 0 ) * 32/109
  = 21.9 lbf
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 4809 + max( 21.86, 705.7, 0, 0 )
  = 5514.5 lbf
```

Longitudinal Wind Force [Fl]:

= WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult $)^2$))

= 0.6 * 34.1(0 + pi/4(2.03 * 1.5 $)^2$)

= 148.932 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	5754.99	lbf
Transverse Shear Load Saddle	161.71	lbf
Longitudinal Shear Load Saddle	74.47	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = Baseplate Length
  = 22.000 in
```

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 4.15.1 [M1]:
```
  = -Q*a [1 - (1- a/L + (Rm²-hm²)/(2a*L))/(1+(4h2)/3L)]
  = -5514*42.31[1-(1-42.31/197.7+(11.75²-5.892²)/
    (2*42.31*197.7))/(1+(4*5.892)/(3*197.7))]
  = -55566.3 in-lb
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(Rm²-hi²)/(L²))/(1+(4hi)/( 3L))-4a/L
  = 5514*197.7/4(1+2(11.75²-5.892²)/(197.7²))/(1+(4*5.892)/
    (3*197.7))-4*42.31/197.7
  = 30188.9 in-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 790.1 * 11.75/(2*0.866 ) - 30189/(pi*11.75²*0.866 )
  = 5277.36 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 790.1 * 11.75/(2 * 0.866 ) + 30189/(pi * 11.75² * 0.866 )
  = 5438.24 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 790.1*11.75/(2*0.866)--55566/(0.107*pi*11.75²*0.866)
  = 6746.58 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 790.1*11.75/(2*0.866)+-55566/(0.192*pi*11.75²*0.866)
  = 4588.05 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*hm/3))
  = 5514( 197.7 - 2 * 42.31 )/(197.7 +( 4 * 5.892/3))
  = 3033.5 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.171 * 3033/( 11.75 * 0.866 )
  = 349.15 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 11.75 * 0.866 )
  = 2.488 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.76 * 5514 * 0.1/( 0.866( 8.606 + 2.488 + 2.488 ) )
  = -35.65 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -5514/(4 * 0.866(8.606 + 2.488 + 2.488 )) -
     3 * 0.0529 * 5514/(2*0.866²)
  = -700.15 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 8.606 + 1.56 * sqrt( 11.75 * 0.866 ), 2 * 42.31 )
  = 13.58 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in
Baseplate Thickness	Bpthk	0.8040	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	1	
Rib Thickness	Ribtk	0.5680	in
Web Thickness	Webtk	0.5680	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.2	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12
= ((1.56 * sqrt(11.31 * 0.866) + 13)0.866^3)/12
= 0.968 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y $)^2$
= 0.968 + 15.49(6.393 - 0.433 $)^2$
= 551.150 in**4

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	17.8826	0.8660	0.4330	15.4864	6.7056	551.1504
Wearplate	13.0000	0.8040	1.2680	10.4520	13.2531	275.1393
Web	0.5680	18.2140	10.7770	10.3456	111.4940	484.8065
BasePlate	9.0000	0.8040	20.2860	7.2360	146.7895	1396.9595
Totals	...	...	...	43.5199	278.2422	2708.0557

Distance to Centroid [C1]:
= AY / A
= 278.2/43.52
= 6.393 in

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120) - 0.5*sin(120)²)/(pi - 2.094 + sin(120)cos(120))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 5514
= 1122.3131 lbf

```
Tension Stress, St = ( Fh/As )       =        40.0346  psi
Allowed Stress, Sa = 0.6 * Yield Str =     22800.0117  psi
```

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 32 - 11.31 * sin(120/2)/1.047
= 22.645 in

```
Bending Moment, M  = Fh * d          =     25414.8359  in-lb

Bending Stress, Sb = ( M * C1 / I  ) =        60.0019  psi
Allowed Stress, Sa = 2/3 * Yield Str =     25333.3477  psi
```

Minimum Thickness of Baseplate per Moss:
= sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
= sqrt(3(5514 + 240.5)9/(2 * 22 * 25333))
= 0.373 in

Check of Center Rib:

Inertia of Saddle, Center Rib - Axial Direction

B	D	Y	A	AY	Io

Rib	0.5680	8.0380	4.5870	4.5656	20.9423	53.3249
Web	11.2427	0.5680	0.2840	6.3859	1.8136	20.7217
Totals	...	...	...	10.9515	22.7559	74.0466

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 22.76/10.95
  = 2.078 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 2.078, abs( 8.606 - 2.078 ) )
  = 6.528 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 32 - cos( 12.98/2 )( 0.804 + 0 + 0 ) - 0
  = 18.214 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 74.05/10.95 )
  = 2.600 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 18.21/2.6
  = 7.005
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 74.47/( 2 * 22 )
  = 1.692 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 1.692 * 11.24 * 18.21
  = 346.564 in-lb
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 346.6/11.34
  = 30.554 psi
```

Compressive Allowable, KL/r < Cc(7.005 < 122.7) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 7.005 )²/(2 * 122.7² ))38000/
    ( 5/3+3*(7.005 )/(8* 122.7 )-( 7.005³)/(8*122.7³)
  = 22475 psi
```

AISC Unity Check of Center Rib (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 265.7/22475 +( 346.6 * 6.528/74.05 )/25333
  = 0.013
```

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		ASTM F1554 Grade 55	
Bolt Allowable Stress	Stba	24800.00	psi
Bolt Corrosion Allowance	Bca	0.0590	in
Distance from Bolts to Edge	Edgedis	5.0000	in

Nominal Bolt Diameter	Bnd	0.8750	in
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.2946	in^2
Saddle Load QO (Weight)	QO	5049.3	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	21.9	lbf
Maximum Transverse Force	Ft	161.7	lbf
Maximum Longitudinal Force	Fl	74.5	lbf
Saddle Bolted to Steel Foundation		Yes	

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

```
= Fl / ( Bolt Area * Number of Bolts )
= 74.47/( 0.295 * 2 )
= 126.4 psi.  Must be less than 14880.0 psi.
```

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

```
= Ft / ( Bolt Area * Number of Bolts )
= 161.7/( 0.295 * 2 )
= 274.5 psi.  Must be less than 14880.0 psi.
```

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 )
= 74.47/(14880 * 2 )
= 0.0025 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
= B * Ft + Sum of X Moments
= 32 * 161.7 + 0
= 5174.81 in-lb
```

Eccentricity (e):

```
= Rmom / QO
= 5175/5049
= 1.02 in < 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, 0.0025, 0 ]
= 0.0025 in^2
```

Warning:
Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.

Input, Nozzle Desc: T2   From: 30

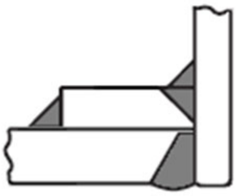
Pressure for Reinforcement Calculations	P	709.239	psig
Temperature for Internal Pressure	Temp	150	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		740.00	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	22.6240	in
Design Length of Section	L	33.2130	in
Shell Finished (Minimum) Thickness	t	0.7090	in
Shell Internal Corrosion Allowance	c	0.1250	in
Shell External Corrosion Allowance	co	0.0000	in
Distance from Cylinder/Cone Centerline	L1	6.2990	in
Distance from Bottom/Left Tangent		20.91	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		Outside	
Layout Angle		31.60	deg
Diameter		6.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness		120	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	11.1415	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3540	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.7090	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	20000.00	psi
Pad Allowable Stress At Ambient	Spa	20000.00	psi
Diameter of Pad along vessel surface	Dp	10.2370	in
Thickness of Pad	te	0.7090	in
Weld leg size between Pad and Shell	Wp	0.5510	in
Groove weld depth between Pad and Nozzle	Wgpn	0.7090	in
Reinforcing Pad Width		1.8060	in
Flange Class		600	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: T2

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          6.625  in.
 Actual Thickness Used in Calculation                 0.562  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 709.2*11.44/(20000*1-0.6*709.2)
  = 0.4144 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 709.2*3.312/(17100*1+0.4*709.2)
  = 0.1351 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 740*3.312/(17100*1+0.4*740)
  = 0.1409 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0264 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)           Dl    14.1772  in
 Parallel to Vessel Wall, opening length             d     7.0886  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.4600  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)           Dl    13.5609  in
 Parallel to Vessel Wall, opening length             d     6.7804  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.7725  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
```

```
  = min( 1, 17100/20000 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 17100/20000 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 20000/20000 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	2.990	0.318	2.972
Area in Shell	A1	1.181	3.452	1.859
Area in Nozzle Wall	A2	0.780	1.061	1.321
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.411	0.411	0.411
Area in Element	A5	2.561	2.561	2.561
TOTAL AREA AVAILABLE	Atot	4.933	7.485	6.152

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 54.22 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	7.5000	0.7090	in
Based on given Pad Diameter:	10.2370	0.1875	in
Based on Shell or Nozzle Thickness:	9.3125	0.5625	in

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (7.089*0.414*1+2*0.437*0.414*1*(1-0.855))
  = 2.990 in^2
```

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 )
  = 7.089( 1 * 0.584 - 1 * 0.414 ) - 2 * 0.437
    ( 1 * 0.584 - 1 * 0.414 ) *( 1 - 0.855 )
  = 1.181 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 1.46 ) *( 0.437 - 0.135 ) * 0.855/sin( 75 )
  = 0.780 in^2
```

See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Welds [A41 + A42 + A43]:

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
```

= $0.354^2 * 0.855 + (0)^2 * 0.855 + 0.551^2 * 1$
= 0.411 in^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (11.78 - 8.166) * 0.709 * 1
= 2.561 in^2

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:C, Curve:B)

Govrn. thk, tg = 0.492, tr = 0.135, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.368, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve B	-7 F
Min Metal Temp. w/o impact per UG-20(f)	-20 F

Nozzle Neck to Pad Weld for the Nozzle, Curve: C

Govrn. thk, tg = 0.492, tr = 0.135, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.368, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve C   -37 F

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 0.492, tr = 0.135, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.368, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve D   -55 F

Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 0.709, tr = 0.414, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.71, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve D   -45 F

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

Govrn. thk, tg = 0.492, tr = 0.135, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.368, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve C   -37 F

Gov. MDMT of the Nozzle :	-20 F
Gov. MDMT of the Reinforcement Pad :	-45 F
Gov. MDMT of the nozzle to shell joint welded assembly :	-20 F

Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)	-20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)	-20 F

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 709.24/1480.00 = 0.479

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: T2

Intermediate Calc. for nozzle/shell Welds   Tmin   0.4370   in

```
 Intermediate Calc. for pad/shell Welds   TminPad      0.5840  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2503 = 0.7 * Wo in
 Pad Weld             0.2920 = 0.5*TminPad  0.3896 = 0.7 * Wp in
```

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,(2.99 - 1.181 + 2 * 0.437 * 0.855 *
    (1 * 0.584 - 0.414 ) )20000 )
  = 38719.45 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.78 + 2.561 + 0.411 - 0 * 0.855 ) * 20000
  = 75036.98 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.78 + 0 + 0.107 +( 0.436 ) ) * 20000
  = 26474.91 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.78 + 0 + 0.411 + 2.561 +( 0.436 ) ) * 20000
  = 83765.09 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 8.166 * 0.354 * 0.49 * 17100
  = 38047. lbf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.142/2.0 ) * 10.24 * 0.551 * 0.49 * 20000
  = 86830. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 3.814 ) *( 0.562 - 0.125 ) * 0.7 * 17100
  = 62670. lbf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.142/2 ) * 8.166 * 0.709 * 0.74 * 20000
  = 134595. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 8.166 *( 0.709 - 0.125 ) * 0.74 * 20000
  = 110866. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SPEW + SNW ) = ( 86830 + 62670 ) = 149500 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 38047 + 134595 + 110866 + 0 ) = 283508 lbf
```

Failure Path [Path 3-3]:

```
  = ( Spew + Tngw + Sinw )
  = ( 86830 + 110866 + 0 ) = 197696 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 149500  lbf, must exceed W = 38719 lbf    or W1 = 75036 lbf
 Path 2-2 = 283507  lbf, must exceed W = 38719 lbf    or W2 = 26474 lbf
 Path 3-3 = 197695  lbf, must exceed W = 38719 lbf    or W3 = 83765 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 926.2 psig

 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 1120 psig
```

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: T2

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation            6.625  in.
 Actual Thickness Used in Calculation                   0.562  in.
```

Nozzle input data check completed without errors.

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

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 709.2*11.44/(20000*1-0.6*709.2)
  = 0.4144 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]

```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 709.2*3.312/(17100*1+0.4*709.2)
  = 0.1351 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]

```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 740*3.312/(17100*1+0.4*740)
  = 0.1409 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0264 in

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     11.5020  in
 Parallel to Vessel Wall, opening length              d      5.7510  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.4600  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     11.0020  in
 Parallel to Vessel Wall, opening length              d      5.5010  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.7725  in
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	2.436	0.259	2.424
Area in Shell	A1	0.954	2.789	1.500
Area in Nozzle Wall	A2	0.754	1.025	1.276
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.411	0.411	0.382
Area in Element	A5	2.561	2.561	2.561
TOTAL AREA AVAILABLE	Atot	4.679	6.785	5.719

The MAWP Case Governs the Analysis.

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

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	7.1250	0.7090	in
Based on given Pad Diameter:	10.2370	0.1250	in
Based on Shell or Nozzle Thickness:	7.2500	0.5625	in

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (5.751*0.414*1+2*0.437*0.414*1*(1-0.855))
  = 2.436 in^2
```

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 )
  = 5.751( 1 * 0.584 - 1 * 0.414 ) - 2 * 0.437
    ( 1 * 0.584 - 1 * 0.414 ) *( 1 - 0.855 )
  = 0.954 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 1.46 ) *( 0.437 - 0.135 ) * 0.855
  = 0.754 in^2
```

Area Available in Welds [A41 + A42 + A43]:

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 0.354² * 0.855 +(0 )² * 0.855 + 0.551² * 1
  = 0.411 in^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 10.24 - 6.625 ) * 0.709 * 1
  = 2.561 in^2
```

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

```
 Wall Thickness for Internal/External pressures       ta = 0.2601 in
 Wall Thickness per UG16(b),                        tr16b = 0.1875 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.5394 in
 Wall Thickness                   tb1 = max(trb1, tr16b) = 0.5394 in
 Wall Thickness                   tb2 = max(trb2, tr16b) = 0.1875 in
 Wall Thickness per table UG-45                      tb3 = 0.3699 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.37, max( 0.539, 0.188 ) ]
```

```
  = 0.3699 in
```

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

```
  = max( ta, tb )
  = max( 0.26, 0.37 )
  = 0.3699 in
```

Available Nozzle Neck Thickness = 0.875 * 0.562 = 0.492 in --> 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   :  10218.7,  Allowable :  17100.0 psi  Passed
 Expansion   :      0.0,  Allowable :  32531.3 psi  Passed
 Occasional :   2168.6,  Allowable :  22743.0 psi  Passed
 Shear       :   5810.0,  Allowable :  11970.0 psi  Passed
```

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

Weld Size Calculations, Description: T2

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.4370  in
 Intermediate Calc. for pad/shell Welds   TminPad      0.5840  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2503 = 0.7 * Wo in
 Pad Weld             0.2920 = 0.5*TminPad  0.3896 = 0.7 * Wp in
```

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,(2.436 - 0.954 + 2 * 0.437 * 0.855 *
    (1 * 0.584 - 0.414 ) )20000 )
  = 32170.87 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.754 + 2.561 + 0.411 - 0 * 0.855 ) * 20000
  = 74505.21 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.754 + 0 + 0.107 +( 0.436 ) ) * 20000
  = 25943.14 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.754 + 0 + 0.411 + 2.561 +( 0.436 ) ) * 20000
  = 83233.33 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 6.625 * 0.354 * 0.49 * 17100
  = 30867. lbf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.142/2.0 ) * 10.24 * 0.551 * 0.49 * 20000
```

```
  = 86830. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 3.094 ) *( 0.562 - 0.125 ) * 0.7 * 17100
  = 50845. lbf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.142/2 ) * 6.625 * 0.709 * 0.74 * 20000
  = 109198. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 6.625 *( 0.709 - 0.125 ) * 0.74 * 20000
  = 89946. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SPEW + SNW ) = ( 86830 + 50845 ) = 137675 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 30867 + 109198 + 89946 + 0 ) = 230011 lbf
```

Failure Path [Path 3-3]:

```
  = ( Spew + Tngw + Sinw )
  = ( 86830 + 89946 + 0 ) = 176776 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 137674  lbf, must exceed W = 32170 lbf    or W1 = 74505 lbf
 Path 2-2 = 230010  lbf, must exceed W = 32170 lbf    or W2 = 25943 lbf
 Path 3-3 = 176775  lbf, must exceed W = 32170 lbf    or W3 = 83233 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 990.1 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 3.4310 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 15.4151 in

Warning:
The equations for nozzle local stress analysis pertain to radial nozzles only and this nozzle is not specified as radial. Please check the specific analysis code for all assumptions and limitations.

Input Echo, WRC297 Item 1, Description: T2 :

```
 Diameter Basis for Cylindrical Shell                   ID
 Shell Corrosion Allowance                              0.1250  in
 Shell Diameter                                         22.624  in
 Shell Thickness                                        0.7090  in
 Shell Stress Concentration Factor                       1.000
 Vessel Material                                     SA-516 70
 Vessel Cold S.I. Allowable                  Smc     20000.00  psi
 Vessel Hot  S.I. Allowable                  Smh     20000.00  psi
```

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-516 70

Diameter Basis for Nozzle		OD	
Nozzle Corrosion Allowance		0.1250	in
Nozzle Diameter		6.625	in
Nozzle Thickness		0.5620	in
Nozzle Stress Concentration Factor		1.000	
Nozzle Material		SA-106 B	
Nozzle Cold S.I. Allowable	SNmc	17100.00	psi
Nozzle Hot S.I. Allowable	SNmh	17100.00	psi

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

Diameter of Reinforcing Pad	10.237	in
Thickness of Reinforcing Pad	0.7090	in

Note:
External Forces and Moments in WRC 107/537 Convention:
These loads are assumed to be SUStained loads.

Design Internal Pressure	Dp	709.24	psig
Radial Load	P	-2800.00	lbf
Circumferential Shear	Vc	3500.00	lbf
Longitudinal Shear	Vl	3500.00	lbf
Circumferential Moment	Mc	64080.00	in-lb
Longitudinal Moment	Ml	81120.00	in-lb
Torsional Moment	Mt	103440.00	in-lb

Include Axial Pressure Thrust	No
Include Pressure Stress Indices per Div. 2	No
Local Loads applied at end of Nozzle/Attachment	No

Stress Computations at the Edge of the Nozzle:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 6.625 + 2 * 1.65 * sqrt( 12.083( 0.709 - 0.125 ) )
  = 15.391 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     24.167 in
 Nozzle Outside Diameter   (d) =      6.625 in
 Vessel Thickness used     (T) =      1.293 in
 Nozzle Thickness used     (t) =      0.437 in
 T / t                         =      2.959
 d / t                         =     15.160

Lambda = [(d/D) * sqrt(D/T)]  = 1.185

 Nr/P     =       0.122
 Mr/P     =       0.108
 M0/P     =       0.112
 N0/P     =       0.197
 MrD/Mc   =       0.177
 NrDL/Mc  =       0.158
 M0d/Mc   =       0.193
 N0DL/Mc  =       0.082
```

```
 MrD/Ml  =      0.141
 NrDL/Ml =      0.131
 M0D/Ml  =      0.160
 N0DL/Ml =      0.212
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Stresses Normal to           Top      Top   Bottom   Bottom
 longitudinal plane)       Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Outplane Membrane (P )        330      330      330      330
 Outplane Bending  (P )       1124    -1124     1124    -1124
 Outplane Membrane (Mc)          0        0        0        0
 Outplane Bending  (Mc)          0        0        0        0
 Outplane Membrane (ML)      -1553    -1553     1553     1553
 Outplane Bending  (ML)      -7029     7029     7029    -7029
 Normal Pressure Stress       5937     6647     5937     6647
 ---------------------- -------- -------- -------- --------
 Outplane Stress Summary     -1191    11329    15973      377
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Stresses parallel to         Top      Top   Bottom   Bottom
 longitudinal plane)       Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Inplane Membrane (P )         203      203      203      203
 Inplane Bending  (P )        1080    -1080     1080    -1080
 Inplane Membrane (Mc)           0        0        0        0
 Inplane Bending  (Mc)           0        0        0        0
 Inplane Membrane (ML)        -959     -959      959      959
 Inplane Bending  (ML)       -6211     6211     6211    -6211
 Inplane Pressure Stress      2968     2968     2968     2968
 ---------------------- -------- -------- -------- --------
 Inplane Stress Summary      -2919     7343    11421    -3161
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Shear stress normal to       Top      Top   Bottom   Bottom
 longitudinal plane)       Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Outplane  Shear  (Vc)         260      260     -260     -260
 Outplane  Shear  (Vl)           0        0        0        0
 Outplane  Shear  (Mt)        1160     1160     1160     1160
 ---------------------- -------- -------- -------- --------
 Shear Stress Summary         1420     1420      900      900
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Stress Intensities           Top      Top   Bottom   Bottom
                           Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Two * Max Shear Stress       3717    11783    16144     3969
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE          Cu       Cl       Du       Dl
 (Stresses Normal to          Left     Left    Right    Right
 circumferential plane)    Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Outplane Membrane (P )        330      330      330      330
 Outplane Bending  (P )       1124    -1124     1124    -1124
 Outplane Membrane (Mc)       -472     -472      472      472
 Outplane Bending  (Mc)      -6716     6716     6716    -6716
 Outplane Membrane (ML)          0        0        0        0
 Outplane Bending  (ML)          0        0        0        0
```

Normal Pressure Stress	2968	2968	2968	2968
Outplane Stress Summary	-2766	8418	11610	-4070

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	203	203	203	203
Inplane Bending (P)	1080	-1080	1080	-1080
Inplane Membrane (Mc)	-913	-913	913	913
Inplane Bending (Mc)	-6128	6128	6128	-6128
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	5937	6647	5937	6647
Inplane Stress Summary	179	10985	14261	555

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-260	-260	260	260
Torsional Shear (Mt)	1160	1160	1160	1160
Shear Stress Summary	900	900	1420	1420

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	3451	11269	14878	5427

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses in the hoop direction)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Hoop Membrane (P)	330	330	330	330
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	0	0	0	0
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	-1553	-1553	1553	1553
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	5204	6055	5204	6055
Hoop Stress Summary	3981	4832	7087	7938

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to pipe cross-section)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Axial Membrane (P)	329	329	329	329
Axial Bending (P)	4108	-4108	4108	-4108
Axial Membrane (Mc)	0	0	0	0
Axial Bending (Mc)	0	0	0	0
Axial Membrane (ML)	-6575	-6575	6575	6575
Axial Bending (ML)	-29178	29178	29178	-29178
Axial Pressure Stress	2602	2602	2602	2602

Axial Stress Summary	-28714	21426	42792	-23780

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
Shear due to (Vc)	769	769	-769	-769
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	3433	3433	3433	3433
Shear Stress Summary	4202	4202	2664	2664

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
Two * Max Shear Stress	33757	22429	42989	32162

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Hoop Membrane (P)	330	330	330	330
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-472	-472	472	472
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	5204	6055	5204	6055
Hoop Stress Summary	5062	5913	6006	6857

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Axial Membrane (P)	329	329	329	329
Axial Bending (P)	4108	-4108	4108	-4108
Axial Membrane (Mc)	-5194	-5194	5194	5194
Axial Bending (Mc)	-29651	29651	29651	-29651
Axial Membrane (ML)	0	0	0	0
Axial Bending (ML)	0	0	0	0
Axial Pressure Stress	2602	2602	2602	2602
Axial Stress Summary	-27806	23280	41884	-25634

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress)	Cu Outside	Cl Inside	Du Outside	Dl Inside
Shear due to (Vc)	0	0	0	0
Shear due to (Vl)	-769	-769	769	769
Shear due to Torsion	3433	3433	3433	3433
Shear Stress Summary	2664	2664	4202	4202

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Outside	Cl Inside	Du Outside	Dl Inside
Two * Max Shear Stress	33297	23679	42369	33560

Stress Computations at the Edge of the Reinforcing Pad:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 6.625 + 2 * 1.65 * sqrt( 11.729( 0.709 - 0.125 ) )
  = 15.262 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     23.458 in
 Nozzle Outside Diameter   (d) =     10.237 in
 Vessel Thickness used     (T) =      0.584 in
 Nozzle Thickness used     (t) =      2.243 in
 T / t                         =      0.260
 d / t                         =     10.000

Lambda = [(d/D) * sqrt(D/T)]  = 2.766
```

Note: Re-pad thickness is added to nozzle thickness to simulate the Re-pad.

```
 Nr/P     =       0.060
 Mr/P     =       0.113
 M0/P     =       0.034
 N0/P     =       0.070
 MrD/Mc   =       0.271
 NrDL/Mc  =       0.093
 M0d/Mc   =       0.082
 N0DL/Mc  =       0.085
 MrD/Ml   =       0.090
 NrDL/Ml  =       0.066
 M0D/Ml   =       0.026
 N0DL/Ml  =       0.086
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	572	572	572	572
Outplane Bending (P)	1690	-1690	1690	-1690
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-1994	-1994	1994	1994
Outplane Bending (ML)	-3605	3605	3605	-3605
Normal Pressure Stress	13543	14253	13543	14253
Outplane Stress Summary	10206	14746	21404	11524

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	496	496	496	496
Inplane Bending (P)	5561	-5561	5561	-5561
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-1525	-1525	1525	1525
Inplane Bending (ML)	-12592	12592	12592	-12592
Inplane Pressure Stress	6771	6771	6771	6771
Inplane Stress Summary	-1289	12773	26945	-9361

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Shear (Vc)	372	372	-372	-372
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	1075	1075	1075	1075
Shear Stress Summary	1447	1447	703	703

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	11853	15510	27032	20932

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	572	572	572	572
Outplane Bending (P)	1690	-1690	1690	-1690
Outplane Membrane (Mc)	-1555	-1555	1555	1555
Outplane Bending (Mc)	-8988	8988	8988	-8988
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	6771	6771	6771	6771
Outplane Stress Summary	-1510	13086	19576	-1780

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	496	496	496	496
Inplane Bending (P)	5561	-5561	5561	-5561
Inplane Membrane (Mc)	-1707	-1707	1707	1707
Inplane Bending (Mc)	-29874	29874	29874	-29874
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	13543	14253	13543	14253
Inplane Stress Summary	-11981	37355	51181	-18979

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-372	-372	372	372
Torsional Shear (Mt)	1075	1075	1075	1075
Shear Stress Summary	703	703	1447	1447

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside

Two * Max Shear Stress	12027	37375	51247	19099

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	5937	6647	5937	6647	5937	6647	5937	6647
Circ. Pl (SUS)	-1223	-1223	1883	1883	-710	-710	1116	1116
Circ. Q (SUS)	-5905	5905	8153	-8153	-5048	5048	7208	-7208
Long. Pm (SUS)	2968	2968	2968	2968	2968	2968	2968	2968
Long. Pl (SUS)	-756	-756	1162	1162	-142	-142	802	802
Long. Q (SUS)	-5131	5131	7291	-7291	-5592	5592	7840	-7840
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	260	260	-260	-260	-260	-260	260	260
Shear Q (SUS)	1160	1160	1160	1160	1160	1160	1160	1160
Pm (SUS)	5937	6647	5937	6647	5937	6647	5937	6647
Pm+Pl (SUS)	4740	5444	7838	8545	5254	5958	7073	7779
Pm+Pl+Q (Total)	3717	11783	16144	3969	3451	11269	14878	5427

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	6647	20000	Passed
Pm+Pl (SUS)	8545	30000	Passed
Pm+Pl+Q (TOTAL)	16144	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Reinforcing Pad Edge (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	13543	14253	13543	14253	13543	14253	13543	14253
Circ. Pl (SUS)	-1422	-1422	2566	2566	-1211	-1211	2203	2203
Circ. Q (SUS)	-1915	1915	5295	-5295	-24313	24313	35435	-35435
Long. Pm (SUS)	6771	6771	6771	6771	6771	6771	6771	6771
Long. Pl (SUS)	-1029	-1029	2021	2021	-983	-983	2127	2127
Long. Q (SUS)	-7031	7031	18153	-18153	-7298	7298	10678	-10678
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	372	372	-372	-372	-372	-372	372	372
Shear Q (SUS)	1075	1075	1075	1075	1075	1075	1075	1075
Pm (SUS)	13543	14253	13543	14253	13543	14253	13543	14253
Pm+Pl (SUS)	12142	12850	16127	16836	12353	13061	15766	16474

Pm+Pl+Q (Total)	11853	15510	27032	20932	12027	37375	51247	19099

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	14253	20000	Passed
Pm+Pl (SUS)	16836	30000	Passed
Pm+Pl+Q (TOTAL)	51247	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Stress Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	5204	6055	5204	6055	5204	6055	5204	6055
Circ. Pl (SUS)	-1223	-1223	1883	1883	-142	-142	802	802
Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	2602	2602	2602	2602	2602	2602	2602	2602
Long. Pl (SUS)	-6246	-6246	6904	6904	-4865	-4865	5523	5523
Long. Q (SUS)	-25070	25070	33286	-33286	-25543	25543	33759	-33759
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	769	769	-769	-769	-769	-769	769	769
Shear Q (SUS)	3433	3433	3433	3433	3433	3433	3433	3433
Pm (SUS)	5204	6055	5204	6055	5204	6055	5204	6055
Pm+Pl (SUS)	7778	8614	9729	9820	7484	8319	8374	8487
Pm+Pl+Q (Total)	33757	22429	42989	32162	33297	23679	42369	33560

Nozzle Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	6055	17100	Passed
Pm+Pl (SUS)	9820	25650	Passed
Pm+Pl+Q (TOTAL)	42989	51300	Passed

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

Input, Nozzle Desc: T1   From: 30

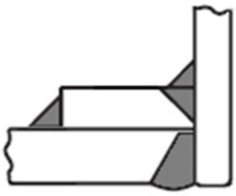
```
Pressure for Reinforcement Calculations        P     709.935  psig
Temperature for Internal Pressure           Temp         150  F
Design External Pressure                    Pext       15.00  psig
Temperature for External Pressure         Tempex         300  F
Maximum Allowable Pressure New & Cold                 740.00  psig

Parent Material [Normalized]                        SA-516 70
Parent Allowable Stress at Temperature        Sv    20000.00  psi
Parent Allowable Stress At Ambient           Sva    20000.00  psi

Inside Diameter of Cylindrical Shell           D     22.6240  in
Design Length of Section                       L     33.2130  in
Shell Finished (Minimum) Thickness             t      0.7090  in
Shell Internal Corrosion Allowance             c      0.1250  in
Shell External Corrosion Allowance            co      0.0000  in

Distance from Cylinder/Cone Centerline        L1      6.2990  in

Distance from Bottom/Left Tangent                      20.91  in

User Entered Minimum Design Metal Temperature          32.00  F
```

Type of Element Connected to the Parent : Nozzle

```
Material                                             SA-106 B
Material UNS Number                                    K03006
Material Specification/Type                        Smls. pipe
Allowable Stress at Temperature               Sn    17100.00  psi
Allowable Stress At Ambient                  Sna    17100.00  psi

Diameter Basis (for tr calc only)                     Outside
Layout Angle                                          148.40  deg
Diameter                                              6.0000  in.

Size and Thickness Basis                              Nominal
Nominal Thickness                                         120

Flange Material                                        SA-105
Flange Type                                  Weld Neck Flange

Corrosion Allowance                          can      0.1250  in
Joint Efficiency of Shell Seam at Nozzle      E1        1.00
Joint Efficiency of Nozzle Neck               En        1.00

Outside Projection                            ho     11.1415  in
Weld leg size between Nozzle and Pad/Shell    Wo      0.3540  in
Groove weld depth between Nozzle and Vessel Wgnv      0.7090  in
Inside Projection                              h      0.0000  in
Weld leg size, Inside Element to Shell        Wi      0.0000  in

Pad Material    [Normalized]                        SA-516 70
Pad Allowable Stress at Temperature           Sp    20000.00  psi
Pad Allowable Stress At Ambient              Spa    20000.00  psi
Diameter of Pad along vessel surface          Dp     10.2370  in
Thickness of Pad                              te      0.7090  in
Weld leg size between Pad and Shell           Wp      0.5510  in
Groove weld depth between Pad and Nozzle    Wgpn      0.7090  in
Reinforcing Pad Width                                 1.8060  in

Flange Class                                              600
Flange Grade                                           GR 1.1
```

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: T1

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation            6.625  in.
 Actual Thickness Used in Calculation                   0.562  in.
```

Nozzle input data check completed without errors.

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

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 709.9*11.44/(20000*1-0.6*709.9)
  = 0.4148 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]

```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 709.9*3.312/(17100*1+0.4*709.9)
  = 0.1353 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]

```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 740*3.312/(17100*1+0.4*740)
  = 0.1409 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0264 in

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    14.1772  in
 Parallel to Vessel Wall, opening length              d     7.0886  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.4600  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    13.5609  in
 Parallel to Vessel Wall, opening length              d     6.7804  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.7725  in
```

Weld Strength Reduction Factor [fr1]:

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

```
  = min( 1, 17100/20000 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 17100/20000 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 20000/20000 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	2.993	0.318	2.972
Area in Shell	A1	1.178	3.452	1.859
Area in Nozzle Wall	A2	0.780	1.061	1.321
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.411	0.411	0.411
Area in Element	A5	2.561	2.561	2.561
TOTAL AREA AVAILABLE	Atot	4.929	7.485	6.152

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 54.22 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	7.5625	0.7090	in
Based on given Pad Diameter:	10.2370	0.1875	in
Based on Shell or Nozzle Thickness:	9.3125	0.5625	in

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (7.089*0.415*1+2*0.437*0.415*1*(1-0.855))
  = 2.993 in^2
```

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 )
  = 7.089( 1 * 0.584 - 1 * 0.415 ) - 2 * 0.437
    ( 1 * 0.584 - 1 * 0.415 ) *( 1 - 0.855 )
  = 1.178 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 1.46 ) *( 0.437 - 0.135 ) * 0.855/sin( 75 )
  = 0.780 in^2
```

See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Welds [A41 + A42 + A43]:

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
```

```
  = 0.354² * 0.855 +(0 )² * 0.855 + 0.551² * 1
  = 0.411 in^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 11.78 - 8.166 ) * 0.709 * 1
  = 2.561 in^2
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:C, Curve:B)

Govrn. thk, tg = 0.492, tr = 0.135, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.369, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -7 F
 Min Metal Temp. w/o impact per UG-20(f)                    -20 F
```

Nozzle Neck to Pad Weld for the Nozzle, Curve: C

Govrn. thk, tg = 0.492, tr = 0.135, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.369, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C             -37 F
```

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 0.492, tr = 0.135, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.369, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -55 F
```

Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 0.709, tr = 0.415, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.71, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -45 F
```

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

Govrn. thk, tg = 0.492, tr = 0.135, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.369, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C             -37 F

 Gov. MDMT of the Nozzle                                :   -20 F
 Gov. MDMT of the Reinforcement Pad                     :   -45 F
 Gov. MDMT of the nozzle to shell joint welded assembly :   -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

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

```
 Design Pressure/Ambient Rating = 709.93/1480.00 = 0.480
```

Note: The MDMT was not reduced based on lower stress per user request.

<u>Weld Size Calculations, Description: T1</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.4370  in
```

```
 Intermediate Calc. for pad/shell Welds   TminPad      0.5840  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2503 = 0.7 * Wo in
 Pad Weld             0.2920 = 0.5*TminPad  0.3896 = 0.7 * Wp in
```

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,(2.993 - 1.178 + 2 * 0.437 * 0.855 *
    (1 * 0.584 - 0.415 ) )20000 )
  = 38831.04 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.78 + 2.561 + 0.411 - 0 * 0.855 ) * 20000
  = 75030.24 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.78 + 0 + 0.107 +( 0.436 ) ) * 20000
  = 26468.17 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.78 + 0 + 0.411 + 2.561 +( 0.436 ) ) * 20000
  = 83758.35 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 8.166 * 0.354 * 0.49 * 17100
  = 38047. lbf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.142/2.0 ) * 10.24 * 0.551 * 0.49 * 20000
  = 86830. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 3.814 ) *( 0.562 - 0.125 ) * 0.7 * 17100
  = 62670. lbf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.142/2 ) * 8.166 * 0.709 * 0.74 * 20000
  = 134595. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 8.166 *( 0.709 - 0.125 ) * 0.74 * 20000
  = 110866. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SPEW + SNW ) = ( 86830 + 62670 ) = 149500 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 38047 + 134595 + 110866 + 0 ) = 283508 lbf
```

Failure Path [Path 3-3]:

```
  = ( Spew + Tngw + Sinw )
  = ( 86830 + 110866 + 0 ) = 197696 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 149500  lbf, must exceed W = 38831 lbf    or W1 = 75030 lbf
 Path 2-2 = 283507  lbf, must exceed W = 38831 lbf    or W2 = 26468 lbf
 Path 3-3 = 197695  lbf, must exceed W = 38831 lbf    or W3 = 83758 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 926.2 psig

 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 1120 psig
```

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: T1

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation            6.625  in.
 Actual Thickness Used in Calculation                   0.562  in.
```

Nozzle input data check completed without errors.

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

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 709.9*11.44/(20000*1-0.6*709.9)
  = 0.4148 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]

```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 709.9*3.312/(17100*1+0.4*709.9)
  = 0.1353 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]

```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 740*3.312/(17100*1+0.4*740)
  = 0.1409 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0264 in

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     11.5020  in
 Parallel to Vessel Wall, opening length              d      5.7510  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.4600  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     11.0020  in
 Parallel to Vessel Wall, opening length              d      5.5010  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.7725  in
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	2.438	0.259	2.424
Area in Shell	A1	0.952	2.789	1.500
Area in Nozzle Wall	A2	0.753	1.025	1.276
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.411	0.411	0.382
Area in Element	A5	2.561	2.561	2.561
TOTAL AREA AVAILABLE	Atot	4.676	6.785	5.719

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations   90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	7.1250	0.7090	in
Based on given Pad Diameter:	10.2370	0.1250	in
Based on Shell or Nozzle Thickness:	7.2500	0.5625	in

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (5.751*0.415*1+2*0.437*0.415*1*(1-0.855))
  = 2.438 in^2
```

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 )
  = 5.751( 1 * 0.584 - 1 * 0.415 ) - 2 * 0.437
    ( 1 * 0.584 - 1 * 0.415 ) *( 1 - 0.855 )
  = 0.952 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 1.46 ) *( 0.437 - 0.135 ) * 0.855
  = 0.753 in^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 0.354² * 0.855 +(0 )² * 0.855 + 0.551² * 1
  = 0.411 in^2
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 10.24 - 6.625 ) * 0.709 * 1
  = 2.561 in^2
```

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

Wall Thickness for Internal/External pressures	ta =	0.2603 in
Wall Thickness per UG16(b),	tr16b =	0.1875 in
Wall Thickness, shell/head, internal pressure	trb1 =	0.5398 in
Wall Thickness	tb1 = max(trb1, tr16b) =	0.5398 in
Wall Thickness	tb2 = max(trb2, tr16b) =	0.1875 in
Wall Thickness per table UG-45	tb3 =	0.3699 in

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.37, max( 0.54, 0.188 ) ]
```

```
  = 0.3699 in
```

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

```
  = max( ta, tb )
  = max( 0.26, 0.37 )
  = 0.3699 in
```

Available Nozzle Neck Thickness = 0.875 * 0.562 = 0.492 in --> 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   :  10220.8,  Allowable :  17100.0 psi  Passed
 Expansion   :      0.0,  Allowable :  32529.2 psi  Passed
 Occasional  :   2170.8,  Allowable :  22743.0 psi  Passed
 Shear       :   5810.0,  Allowable :  11970.0 psi  Passed
```

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

Weld Size Calculations, Description: T1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.4370  in
 Intermediate Calc. for pad/shell Welds   TminPad      0.5840  in
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2503 = 0.7 * Wo in
 Pad Weld             0.2920 = 0.5*TminPad  0.3896 = 0.7 * Wp in
```

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,(2.438 - 0.952 + 2 * 0.437 * 0.855 *
    (1 * 0.584 - 0.415 ) )20000 )
  = 32260.23 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.753 + 2.561 + 0.411 - 0 * 0.855 ) * 20000
  = 74498.70 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.753 + 0 + 0.107 +( 0.436 ) ) * 20000
  = 25936.63 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.753 + 0 + 0.411 + 2.561 +( 0.436 ) ) * 20000
  = 83226.81 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 6.625 * 0.354 * 0.49 * 17100
  = 30867. lbf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.142/2.0 ) * 10.24 * 0.551 * 0.49 * 20000
```

```
  = 86830. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 3.094 ) *( 0.562 - 0.125 ) * 0.7 * 17100
  = 50845. lbf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.142/2 ) * 6.625 * 0.709 * 0.74 * 20000
  = 109198. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 6.625 *( 0.709 - 0.125 ) * 0.74 * 20000
  = 89946. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SPEW + SNW ) = ( 86830 + 50845 ) = 137675 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 30867 + 109198 + 89946 + 0 ) = 230011 lbf
```

Failure Path [Path 3-3]:

```
  = ( Spew + Tngw + Sinw )
  = ( 86830 + 89946 + 0 ) = 176776 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 137674  lbf, must exceed W = 32260 lbf    or W1 = 74498 lbf
 Path 2-2 = 230010  lbf, must exceed W = 32260 lbf    or W2 = 25936 lbf
 Path 3-3 = 176775  lbf, must exceed W = 32260 lbf    or W3 = 83226 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 990.1 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 3.4310 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 15.4151 in

Warning:
The equations for nozzle local stress analysis pertain to radial nozzles only and this nozzle is not specified as radial. Please check the specific analysis code for all assumptions and limitations.

Input Echo, WRC297 Item 1, Description: T1 :

```
 Diameter Basis for Cylindrical Shell                   ID
 Shell Corrosion Allowance                              0.1250  in
 Shell Diameter                                         22.624  in
 Shell Thickness                                        0.7090  in
 Shell Stress Concentration Factor                       1.000
 Vessel Material                                     SA-516 70
 Vessel Cold S.I. Allowable                  Smc      20000.00  psi
 Vessel Hot  S.I. Allowable                  Smh      20000.00  psi
```

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-516 70

Diameter Basis for Nozzle		OD	
Nozzle Corrosion Allowance		0.1250	in
Nozzle Diameter		6.625	in
Nozzle Thickness		0.5620	in
Nozzle Stress Concentration Factor		1.000	
Nozzle Material		SA-106 B	
Nozzle Cold S.I. Allowable	SNmc	17100.00	psi
Nozzle Hot S.I. Allowable	SNmh	17100.00	psi

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

Diameter of Reinforcing Pad	10.237	in
Thickness of Reinforcing Pad	0.7090	in

Note:
External Forces and Moments in WRC 107/537 Convention:
These loads are assumed to be SUStained loads.

Design Internal Pressure	Dp	709.93	psig
Radial Load	P	-2800.00	lbf
Circumferential Shear	Vc	3500.00	lbf
Longitudinal Shear	Vl	3500.00	lbf
Circumferential Moment	Mc	64080.00	in-lb
Longitudinal Moment	Ml	81120.00	in-lb
Torsional Moment	Mt	103440.00	in-lb

Include Axial Pressure Thrust	No
Include Pressure Stress Indices per Div. 2	No
Local Loads applied at end of Nozzle/Attachment	No

Stress Computations at the Edge of the Nozzle:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 6.625 + 2 * 1.65 * sqrt( 12.083( 0.709 - 0.125 ) )
  = 15.391 in
```

WRC 297 Curve Access Parameters:

Vessel Mean Diameter	(D) =	24.167	in
Nozzle Outside Diameter	(d) =	6.625	in
Vessel Thickness used	(T) =	1.293	in
Nozzle Thickness used	(t) =	0.437	in
T / t	=	2.959	
d / t	=	15.160	

Lambda = [(d/D) * sqrt(D/T)] = 1.185

Nr/P	=	0.122
Mr/P	=	0.108
M0/P	=	0.112
N0/P	=	0.197
MrD/Mc	=	0.177
NrDL/Mc	=	0.158
M0d/Mc	=	0.193
N0DL/Mc	=	0.082

```
MrD/Ml  =      0.141
NrDL/Ml =      0.131
M0D/Ml  =      0.160
N0DL/Ml =      0.212
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	330	330	330	330
Outplane Bending (P)	1124	-1124	1124	-1124
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-1553	-1553	1553	1553
Outplane Bending (ML)	-7029	7029	7029	-7029
Normal Pressure Stress	5943	6653	5943	6653
Outplane Stress Summary	-1185	11335	15979	383

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	203	203	203	203
Inplane Bending (P)	1080	-1080	1080	-1080
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-959	-959	959	959
Inplane Bending (ML)	-6211	6211	6211	-6211
Inplane Pressure Stress	2971	2971	2971	2971
Inplane Stress Summary	-2916	7346	11424	-3158

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Shear (Vc)	260	260	-260	-260
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	1160	1160	1160	1160
Shear Stress Summary	1420	1420	900	900

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	3713	11788	16150	3972

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	330	330	330	330
Outplane Bending (P)	1124	-1124	1124	-1124
Outplane Membrane (Mc)	-472	-472	472	472
Outplane Bending (Mc)	-6716	6716	6716	-6716
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0

```
 Normal Pressure Stress      2971     2971     2971     2971
 ---------------------- -------- -------- -------- --------
 Outplane Stress Summary    -2763     8421    11613    -4067
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stresses parallel to       Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Inplane Membrane (P )        203      203      203      203
 Inplane Bending  (P )       1080    -1080     1080    -1080
 Inplane Membrane (Mc)       -913     -913      913      913
 Inplane Bending  (Mc)      -6128     6128     6128    -6128
 Inplane Membrane (ML)          0        0        0        0
 Inplane Bending  (ML)          0        0        0        0
 Inplane Pressure Stress     5943     6653     5943     6653
 ---------------------- -------- -------- -------- --------
 Inplane Stress Summary       185    10991    14267      561
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Shear stress normal to     Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Outplane  Shear  (Vc)          0        0        0        0
 Outplane  Shear  (Vl)       -260     -260      260      260
 Torsional Shear  (Mt)       1160     1160     1160     1160
 ---------------------- -------- -------- -------- --------
 Shear Stress Summary         900      900     1420     1420
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stress Intensities         Left     Left    Right    Right
                          Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Two * Max Shear Stress      3454    11274    14883     5429
```

Nozzle Stresses (psi):

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Stresses in the             Top      Top   Bottom   Bottom
 hoop direction)          Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Hoop Membrane (P )           330      330      330      330
 Hoop Bending  (P )             0        0        0        0
 Hoop Membrane (Mc)             0        0        0        0
 Hoop Bending  (Mc)             0        0        0        0
 Hoop Membrane (ML)         -1553    -1553     1553     1553
 Hoop Bending  (ML)             0        0        0        0
 Hoop Pressure Stress        5209     6061     5209     6061
 ---------------------- -------- -------- -------- --------
 Hoop Stress Summary         3986     4838     7092     7944
```

Nozzle Stresses (psi):

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Stresses Normal to          Top      Top   Bottom   Bottom
 pipe cross-section)      Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Axial Membrane (P )          329      329      329      329
 Axial Bending  (P )         4108    -4108     4108    -4108
 Axial Membrane (Mc)            0        0        0        0
 Axial Bending  (Mc)            0        0        0        0
 Axial Membrane (ML)        -6575    -6575     6575     6575
 Axial Bending  (ML)       -29178    29178    29178   -29178
 Axial Pressure Stress       2604     2604     2604     2604
```

Axial Stress Summary	-28712	21428	42794	-23778

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
Shear due to (Vc)	769	769	-769	-769
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	3433	3433	3433	3433
Shear Stress Summary	4202	4202	2664	2664

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
Two * Max Shear Stress	33760	22431	42991	32166

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Hoop Membrane (P)	330	330	330	330
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-472	-472	472	472
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	5209	6061	5209	6061
Hoop Stress Summary	5067	5919	6011	6863

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Axial Membrane (P)	329	329	329	329
Axial Bending (P)	4108	-4108	4108	-4108
Axial Membrane (Mc)	-5194	-5194	5194	5194
Axial Bending (Mc)	-29651	29651	29651	-29651
Axial Membrane (ML)	0	0	0	0
Axial Bending (ML)	0	0	0	0
Axial Pressure Stress	2604	2604	2604	2604
Axial Stress Summary	-27804	23282	41886	-25632

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress)	Cu Outside	Cl Inside	Du Outside	Dl Inside
Shear due to (Vc)	0	0	0	0
Shear due to (Vl)	-769	-769	769	769
Shear due to Torsion	3433	3433	3433	3433
Shear Stress Summary	2664	2664	4202	4202

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Outside	Cl Inside	Du Outside	Dl Inside
Two * Max Shear Stress	33300	23681	42371	33564

Stress Computations at the Edge of the Reinforcing Pad:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 6.625 + 2 * 1.65 * sqrt( 11.729( 0.709 - 0.125 ) )
  = 15.262 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     23.458 in
 Nozzle Outside Diameter   (d) =     10.237 in
 Vessel Thickness used     (T) =      0.584 in
 Nozzle Thickness used     (t) =      2.243 in
 T / t                         =      0.260
 d / t                         =     10.000

Lambda = [(d/D) * sqrt(D/T)]  = 2.766
```

Note: Re-pad thickness is added to nozzle thickness to simulate the Re-pad.

```
 Nr/P     =      0.060
 Mr/P     =      0.113
 M0/P     =      0.034
 N0/P     =      0.070
 MrD/Mc   =      0.271
 NrDL/Mc  =      0.093
 M0d/Mc   =      0.082
 N0DL/Mc  =      0.085
 MrD/Ml   =      0.090
 NrDL/Ml  =      0.066
 M0D/Ml   =      0.026
 N0DL/Ml  =      0.086
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	572	572	572	572
Outplane Bending (P)	1690	-1690	1690	-1690
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-1994	-1994	1994	1994
Outplane Bending (ML)	-3605	3605	3605	-3605
Normal Pressure Stress	13557	14267	13557	14267
Outplane Stress Summary	10220	14760	21418	11538

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	496	496	496	496
Inplane Bending (P)	5561	-5561	5561	-5561
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-1525	-1525	1525	1525
Inplane Bending (ML)	-12592	12592	12592	-12592
Inplane Pressure Stress	6778	6778	6778	6778
Inplane Stress Summary	-1282	12780	26952	-9354

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Shear (Vc)	372	372	-372	-372
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	1075	1075	1075	1075
Shear Stress Summary	1447	1447	703	703

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	11860	15523	27039	20939

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	572	572	572	572
Outplane Bending (P)	1690	-1690	1690	-1690
Outplane Membrane (Mc)	-1555	-1555	1555	1555
Outplane Bending (Mc)	-8988	8988	8988	-8988
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	6778	6778	6778	6778
Outplane Stress Summary	-1503	13093	19583	-1773

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	496	496	496	496
Inplane Bending (P)	5561	-5561	5561	-5561
Inplane Membrane (Mc)	-1707	-1707	1707	1707
Inplane Bending (Mc)	-29874	29874	29874	-29874
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	13557	14267	13557	14267
Inplane Stress Summary	-11967	37369	51195	-18965

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-372	-372	372	372
Torsional Shear (Mt)	1075	1075	1075	1075
Shear Stress Summary	703	703	1447	1447

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside

Two * Max Shear Stress	12014	37389	51261	19085

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	5943	6653	5943	6653	5943	6653	5943	6653
Circ. Pl (SUS)	-1223	-1223	1883	1883	-710	-710	1116	1116
Circ. Q (SUS)	-5905	5905	8153	-8153	-5048	5048	7208	-7208
Long. Pm (SUS)	2971	2971	2971	2971	2971	2971	2971	2971
Long. Pl (SUS)	-756	-756	1162	1162	-142	-142	802	802
Long. Q (SUS)	-5131	5131	7291	-7291	-5592	5592	7840	-7840
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	260	260	-260	-260	-260	-260	260	260
Shear Q (SUS)	1160	1160	1160	1160	1160	1160	1160	1160
Pm (SUS)	5943	6653	5943	6653	5943	6653	5943	6653
Pm+Pl (SUS)	4746	5450	7844	8551	5260	5964	7079	7785
Pm+Pl+Q (Total)	3713	11788	16150	3972	3454	11274	14883	5429

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	6653	20000	Passed
Pm+Pl (SUS)	8551	30000	Passed
Pm+Pl+Q (TOTAL)	16150	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Reinforcing Pad Edge (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	13557	14267	13557	14267	13557	14267	13557	14267
Circ. Pl (SUS)	-1422	-1422	2566	2566	-1211	-1211	2203	2203
Circ. Q (SUS)	-1915	1915	5295	-5295	-24313	24313	35435	-35435
Long. Pm (SUS)	6778	6778	6778	6778	6778	6778	6778	6778
Long. Pl (SUS)	-1029	-1029	2021	2021	-983	-983	2127	2127
Long. Q (SUS)	-7031	7031	18153	-18153	-7298	7298	10678	-10678
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	372	372	-372	-372	-372	-372	372	372
Shear Q (SUS)	1075	1075	1075	1075	1075	1075	1075	1075
Pm (SUS)	13557	14267	13557	14267	13557	14267	13557	14267
Pm+Pl (SUS)	12156	12864	16141	16850	12367	13075	15780	16488

Pm+Pl+Q (Total)	11860	15523	27039	20939	12014	37389	51261	19085

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	14267	20000	Passed
Pm+Pl (SUS)	16850	30000	Passed
Pm+Pl+Q (TOTAL)	51261	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	5209	6061	5209	6061	5209	6061	5209	6061
Circ. Pl (SUS)	-1223	-1223	1883	1883	-142	-142	802	802
Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	2604	2604	2604	2604	2604	2604	2604	2604
Long. Pl (SUS)	-6246	-6246	6904	6904	-4865	-4865	5523	5523
Long. Q (SUS)	-25070	25070	33286	-33286	-25543	25543	33759	-33759
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	769	769	-769	-769	-769	-769	769	769
Shear Q (SUS)	3433	3433	3433	3433	3433	3433	3433	3433
Pm (SUS)	5209	6061	5209	6061	5209	6061	5209	6061
Pm+Pl (SUS)	7781	8618	9732	9822	7487	8323	8376	8490
Pm+Pl+Q (Total)	33760	22431	42991	32166	33300	23681	42371	33564

Nozzle Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	6061	17100	Passed
Pm+Pl (SUS)	9822	25650	Passed
Pm+Pl+Q (TOTAL)	42991	51300	Passed

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

Input, Nozzle Desc: V **From: 30**

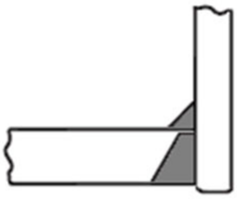
Pressure for Reinforcement Calculations	P	709.211	psig
Temperature for Internal Pressure	Temp	150	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		740.00	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	22.6240	in
Design Length of Section	L	33.2130	in
Shell Finished (Minimum) Thickness	t	0.7090	in
Shell Internal Corrosion Allowance	c	0.1250	in
Shell External Corrosion Allowance	co	0.0000	in
Distance from Cylinder/Cone Centerline	L1	4.7240	in
Distance from Bottom/Left Tangent		20.91	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		-23.14	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Material [Normalized]		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.1250	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.7831	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3540	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.7090	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: V

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 709.2*11.44/(20000*1-0.6*709.2)
  = 0.4144 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 709.2*1.125/(20000*1-0.6*709.2)
  = 0.0408 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([740/(20000*1]-1)
  = 0.0377 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0134 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)           Dl     4.9375  in
 Parallel to Vessel Wall, opening length             d     2.4688  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    1.3225  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)           Dl     4.9205  in
 Parallel to Vessel Wall                      Rn+tn+t     2.4602  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    1.6350  in
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.512	0.109	0.470
Area in Shell	A1	0.930	1.224	1.349
Area in Nozzle Wall	A2	1.363	1.440	2.127

Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.125	0.125	0.125
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	2.419	2.789	3.602

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations   65.70 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.469*0.414*0.5+2*0.529*0.414*0.5*(1-1))
  = 0.512 in^2
```

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 )
  = 2.469( 1 * 0.584 - 0.5 * 0.414 ) - 2 * 0.529
    ( 1 * 0.584 - 0.5 * 0.414 ) *( 1 - 1 )
  = 0.930 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 1.322 )( 0.529 - 0.0408 )1/sin( 71.33 )
  = 1.363 in^2
```

See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 1 +( 0 )² * 1
  = 0.125 in^2
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.654, tr = 0.0408, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.0771, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            9 F
Min Metal Temp. w/o impact per UG-20(f)                 -20 F

Gov. MDMT of the nozzle to shell joint welded assembly :   -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 709.21/740.00 = 0.958

Note: The MDMT was not reduced based on lower stress per user request.

<u>Weld Size Calculations, Description: V</u>

Intermediate Calc. for nozzle/shell Welds   Tmin   0.5290 in

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
 Nozzle Weld           0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(0.512 - 0.93 + 2 * 0.529 * 1 *
    (1 * 0.584 - 0.207 ) )20000 )
  = max( 0, -401.76) lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.363 + 0 + 0.125 - 0 * 1 ) * 20000
  = 29769.51 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.363 + 0 + 0.125 +( 0.618 ) ) * 20000
  = 42126.95 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.363 + 0 + 0.125 + 0 +( 0.618 ) ) * 20000
  = 42126.95 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 3.63 * 0.354 * 0.49 * 20000
  = 19779. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 1.525 ) *( 0.654 - 0.125 ) * 0.7 * 20000
  = 35472. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 3.63 *( 0.709 - 0.125 ) * 0.74 * 20000
  = 49278. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 19779 + 35472 ) = 55252 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 19779 + 0 + 49278 + 0 ) = 69058 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 19779 + 49278 + 0 ) = 69058 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 55251   lbf, must exceed W = 0 lbf        or W1 = 29769 lbf
 Path 2-2 = 69057   lbf, must exceed W = 0 lbf        or W2 = 42126 lbf
 Path 3-3 = 69057   lbf, must exceed W = 0 lbf        or W3 = 42126 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Maximum Allowable Pressure in the Operating case: 990.1 psig

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

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 1208 psig

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: V

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          2.000  in.
Actual Thickness Used in Calculation                0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 709.2*11.44/(20000*1-0.6*709.2)
  = 0.4144 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 709.2*1.125/(20000*1-0.6*709.2)
  = 0.0408 in
```

Reqd thk per App. 1 of Nozzle Wall, trn   [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([740/(20000*1]-1)
  = 0.0377 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0134 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.5000  in
Parallel to Vessel Wall, opening length              d     2.2500  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.3225  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.7260  in
Parallel to Vessel Wall                       Rn+tn+t     2.3630  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.6350  in
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.932	0.099	0.856
Area in Shell	A1	0.382	1.116	0.766
Area in Nozzle Wall	A2	1.291	1.364	2.015
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.125	0.125	0.125

Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	1.798	2.605	2.907

The MAWP 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)
  = (2.25*0.414*1+2*0.529*0.414*1*(1-1))
  = 0.932 in^2
```

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 )
  = 2.25( 1 * 0.584 - 1 * 0.414 ) - 2 * 0.529
    ( 1 * 0.584 - 1 * 0.414 ) *( 1 - 1 )
  = 0.382 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.322 )( 0.529 - 0.0408 )1
  = 1.291 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 1 +( 0 )² * 1
  = 0.125 in^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 0.1658 in
 Wall Thickness per UG16(b),                       tr16b = 0.1875 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.5394 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.5394 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.1875 in
 Wall Thickness per table UG-45                      tb3 = 0.3140 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.314, max( 0.539, 0.188 ) ]
  = 0.3140 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.166, 0.314 )
  = 0.3140 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Weld Size Calculations, Description: V

Intermediate Calc. for nozzle/shell Welds   Tmin   0.5290 in

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2503 = 0.7 * Wo in

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
```

```
  = max( 0,(0.932 - 0.382 + 2 * 0.529 * 1 *
    (1 * 0.584 - 0.414 ) )20000 )
  = 14603.29 lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.291 + 0 + 0.125 - 0 * 1 ) * 20000
  = 28334.20 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.291 + 0 + 0.125 +( 0.618 ) ) * 20000
  = 40691.63 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.291 + 0 + 0.125 + 0 +( 0.618 ) ) * 20000
  = 40691.63 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 3.308 * 0.354 * 0.49 * 20000
  = 18027. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 1.39 ) *( 0.654 - 0.125 ) * 0.7 * 20000
  = 32329. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 3.308 *( 0.709 - 0.125 ) * 0.74 * 20000
  = 44912. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 18027 + 32329 ) = 50356 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 18027 + 0 + 44912 + 0 ) = 62938 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 18027 + 44912 + 0 ) = 62938 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 50355   lbf, must exceed W = 14603 lbf   or W1 = 28334 lbf
 Path 2-2 = 62938   lbf, must exceed W = 14603 lbf   or W2 = 40691 lbf
 Path 3-3 = 62938   lbf, must exceed W = 14603 lbf   or W3 = 40691 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Maximum Allowable Pressure in the Operating case: 990.1 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

Approximate Maximum Allowable Pressure New & Cold: 1208 psig

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.9359 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.4945 in

Input, Nozzle Desc: D   From: 30

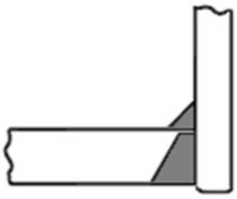
Pressure for Reinforcement Calculations	P	709.963	psig
Temperature for Internal Pressure	Temp	150	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		740.00	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	22.6240	in
Design Length of Section	L	33.2130	in
Shell Finished (Minimum) Thickness	t	0.7090	in
Shell Internal Corrosion Allowance	c	0.1250	in
Shell External Corrosion Allowance	co	0.0000	in
Distance from Cylinder/Cone Centerline	L1	4.7240	in
Distance from Bottom/Left Tangent		20.91	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		203.14	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Material [Normalized]		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.1250	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.7831	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3540	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.7090	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: D

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 710*11.44/(20000*1-0.6*710)
  = 0.4148 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 710*1.125/(20000*1-0.6*710)
  = 0.0408 in
```

Reqd thk per App. 1 of Nozzle Wall, trn   [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([740/(20000*1]-1)
  = 0.0377 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0134 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.9375  in
Parallel to Vessel Wall, opening length              d     2.4688  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.3225  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.9205  in
Parallel to Vessel Wall                       Rn+tn+t     2.4602  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.6350  in
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.512	0.109	0.470
Area in Shell	A1	0.930	1.224	1.349
Area in Nozzle Wall	A2	1.363	1.440	2.127

Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.125	0.125	0.125
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	2.418	2.789	3.602

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations   65.70 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.469*0.415*0.5+2*0.529*0.415*0.5*(1-1))
  = 0.512 in^2
```

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 )
  = 2.469( 1 * 0.584 - 0.5 * 0.415 ) - 2 * 0.529
    ( 1 * 0.584 - 0.5 * 0.415 ) *( 1 - 1 )
  = 0.930 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 1.322 )( 0.529 - 0.0408 )1/sin( 71.33 )
  = 1.363 in^2
```

See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 1 +( 0 )² * 1
  = 0.125 in^2
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.654, tr = 0.0408, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.0771, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B                 9 F
 Min Metal Temp. w/o impact per UG-20(f)                      -20 F

 Gov. MDMT of the nozzle to shell joint welded assembly :     -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)       -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)         -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 709.96/740.00 = 0.959

Note: The MDMT was not reduced based on lower stress per user request.

<u>Weld Size Calculations, Description: D</u>

Intermediate Calc. for nozzle/shell Welds   Tmin   0.5290 in

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(0.512 - 0.93 + 2 * 0.529 * 1 *
    (1 * 0.584 - 0.207 ) )20000 )
  = max( 0, -384.36) lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.363 + 0 + 0.125 - 0 * 1 ) * 20000
  = 29767.04 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.363 + 0 + 0.125 +( 0.618 ) ) * 20000
  = 42124.48 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.363 + 0 + 0.125 + 0 +( 0.618 ) ) * 20000
  = 42124.48 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 3.63 * 0.354 * 0.49 * 20000
  = 19779. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 1.525 ) *( 0.654 - 0.125 ) * 0.7 * 20000
  = 35472. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 3.63 *( 0.709 - 0.125 ) * 0.74 * 20000
  = 49278. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 19779 + 35472 ) = 55252 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 19779 + 0 + 49278 + 0 ) = 69058 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 19779 + 49278 + 0 ) = 69058 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 55251   lbf, must exceed W = 0 lbf        or W1 = 29767 lbf
 Path 2-2 = 69057   lbf, must exceed W = 0 lbf        or W2 = 42124 lbf
 Path 3-3 = 69057   lbf, must exceed W = 0 lbf        or W3 = 42124 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Maximum Allowable Pressure in the Operating case: 990.1 psig

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

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 1208 psig

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: D

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

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

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 710*11.44/(20000*1-0.6*710)
  = 0.4148 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]

```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 710*1.125/(20000*1-0.6*710)
  = 0.0408 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([740/(20000*1]-1)
  = 0.0377 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0134 in

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.5000  in
Parallel to Vessel Wall, opening length              d     2.2500  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.3225  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.7260  in
Parallel to Vessel Wall                       Rn+tn+t      2.3630  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.6350  in
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.933	0.099	0.856
Area in Shell	A1	0.381	1.116	0.766
Area in Nozzle Wall	A2	1.291	1.364	2.015
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.125	0.125	0.125

```
 Area in Element           A5 |    0.000|    0.000|    0.000|
 TOTAL AREA AVAILABLE    Atot |    1.797|    2.605|    2.907|
```

The MAWP 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)
  = (2.25*0.415*1+2*0.529*0.415*1*(1-1))
  = 0.933 in^2
```

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 )
  = 2.25( 1 * 0.584 - 1 * 0.415 ) - 2 * 0.529
    ( 1 * 0.584 - 1 * 0.415 ) *( 1 - 1 )
  = 0.381 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.322 )( 0.529 - 0.0408 )1
  = 1.291 in^2
```

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

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 1 +( 0 )² * 1
  = 0.125 in^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 0.1658 in
 Wall Thickness per UG16(b),                       tr16b = 0.1875 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.5398 in
 Wall Thickness                tb1 = max(trb1, tr16b) = 0.5398 in
 Wall Thickness                tb2 = max(trb2, tr16b) = 0.1875 in
 Wall Thickness per table UG-45                    tb3 = 0.3140 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.314, max( 0.54, 0.188 ) ]
  = 0.3140 in
```

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

```
  = max( ta, tb )
  = max( 0.166, 0.314 )
  = 0.3140 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Weld Size Calculations, Description: D

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.5290  in
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
 Nozzle Weld           0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
```

```
  = max( 0,(0.933 - 0.381 + 2 * 0.529 * 1 *
    (1 * 0.584 - 0.415 ) )20000 )
  = 14634.17 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.291 + 0 + 0.125 - 0 * 1 ) * 20000
  = 28331.86 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.291 + 0 + 0.125 +( 0.618 ) ) * 20000
  = 40689.30 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.291 + 0 + 0.125 + 0 +( 0.618 ) ) * 20000
  = 40689.30 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 3.308 * 0.354 * 0.49 * 20000
  = 18027. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 1.39 ) *( 0.654 - 0.125 ) * 0.7 * 20000
  = 32329. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 3.308 *( 0.709 - 0.125 ) * 0.74 * 20000
  = 44912. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 18027 + 32329 ) = 50356 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 18027 + 0 + 44912 + 0 ) = 62938 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 18027 + 44912 + 0 ) = 62938 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 50355   lbf, must exceed W = 14634 lbf    or W1 = 28331 lbf
 Path 2-2 = 62938   lbf, must exceed W = 14634 lbf    or W2 = 40689 lbf
 Path 3-3 = 62938   lbf, must exceed W = 14634 lbf    or W3 = 40689 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 990.1 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

Approximate Maximum Allowable Pressure New & Cold: 1208 psig

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.9359 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.4945 in

Input, Nozzle Desc: AUX1   Parent: T1

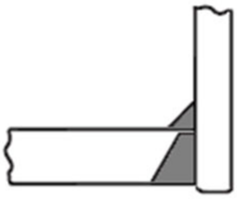
Pressure for Reinforcement Calculations	P	710.115	psig
Temperature for Internal Pressure	Temp	150	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		740.00	psig
Parent Material		SA-106 B	
Parent Allowable Stress at Temperature	Sv	17100.00	psi
Parent Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	5.5010	in
Design Length of Section	L	11.1415	in
Shell Finished (Minimum) Thickness	t	0.5620	in
Shell Internal Corrosion Allowance	c	0.1250	in
Shell External Corrosion Allowance	co	0.0000	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19637.42	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Material [Normalized]		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.1250	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.9050	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3540	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.5620	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Reinforcement CALCULATION, Description: AUX1

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          2.000  in.
Actual Thickness Used in Calculation                0.654  in.
```

Nozzle input data check completed without errors.

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

```
= P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
= 710.1*2.875/(17100*1-0.6*710.1)
= 0.1225 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]

```
= P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
= 740*2.75/(17100*1-0.6*740)
= 0.1222 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]

```
= P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
= 710.1*1.125/(19637*1-0.6*710.1)
= 0.0416 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]

```
= R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
= 1(exp([740/(20000*1]-1)
= 0.0377 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0135 in

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

```
Parallel to Vessel Wall (Diameter Limit)             Dl     4.5000  in
Parallel to Vessel Wall, opening length               d     2.2500  in
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     1.0925  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
Parallel to Vessel Wall (Diameter Limit)             Dl     4.4320  in
Parallel to Vessel Wall                        Rn+tn+t      2.2160  in
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     1.4050  in
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 19637/17100 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 19637/17100 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.276	0.030	0.244
Area in Shell	A1	0.708	0.924	1.070
Area in Nozzle Wall	A2	1.065	1.126	1.732
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.125	0.125	0.125
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	1.898	2.175	2.927

The MAWP 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)
  = (2.25*0.122*1+2*0.529*0.122*1*(1-1))
  = 0.276 in^2
```

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 )
  = 2.25( 1 * 0.437 - 1 * 0.122 ) - 2 * 0.529
    ( 1 * 0.437 - 1 * 0.122 ) *( 1 - 1 )
  = 0.708 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.092 )( 0.529 - 0.0416 )1
  = 1.065 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 1 +( 0 )² * 1
  = 0.125 in^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 0.1666 in
 Wall Thickness per UG16(b),                       tr16b = 0.1875 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.2475 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.2475 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.1875 in
 Wall Thickness per table UG-45                      tb3 = 0.3140 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.314, max( 0.247, 0.188 ) ]
  = 0.2475 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.167, 0.247 )
  = 0.2475 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

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 = 0.562, tr = 0.122, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.28, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B             0 F
Min Metal Temp. w/o impact per UG-20(f)                  -20 F

Gov. MDMT of the nozzle to shell joint welded assembly :   -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)       0 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)         0 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 710.12/740.00 = 0.960
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: AUX1

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.4370  in
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld           0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(0.276 - 0.708 + 2 * 0.529 * 1 *
    (1 * 0.437 - 0.122 ) )17100 )
  = max( 0, -1699.52) lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.065 + 0 + 0.125 - 0 * 1 ) * 17100
  = 20354.48 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.065 + 0 + 0.125 +( 0.462 ) ) * 17100
  = 28260.60 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.065 + 0 + 0.125 + 0 +( 0.462 ) ) * 17100
  = 28260.60 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 3.308 * 0.354 * 0.49 * 17100
```

```
  = 15413. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 1.39 ) *( 0.654 - 0.125 ) * 0.7 * 19637
  = 31743. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 3.308 *( 0.562 - 0.125 ) * 0.74 * 19637
  = 32998. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 15413 + 31743 ) = 47156 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 15413 + 0 + 32998 + 0 ) = 48410 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 15413 + 32998 + 0 ) = 48410 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 47155   lbf, must exceed W = 0 lbf        or W1 = 20354 lbf
 Path 2-2 = 48410   lbf, must exceed W = 0 lbf        or W2 = 28260 lbf
 Path 3-3 = 48410   lbf, must exceed W = 0 lbf        or W3 = 28260 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 2359 psig

 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 3112 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.5529 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.0199 in

Input, Nozzle Desc: AUX2   **Parent: T2**

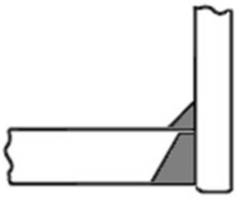
Pressure for Reinforcement Calculations	P	709.420	psig
Temperature for Internal Pressure	Temp	150	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		740.00	psig
Parent Material		SA-106 B	
Parent Allowable Stress at Temperature	Sv	17100.00	psi
Parent Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	5.5010	in
Design Length of Section	L	11.1415	in
Shell Finished (Minimum) Thickness	t	0.5620	in
Shell Internal Corrosion Allowance	c	0.1250	in
Shell External Corrosion Allowance	co	0.0000	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19637.40	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Material [Normalized]		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.1250	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.9050	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3540	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.5620	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Reinforcement CALCULATION, Description: AUX2

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

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

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 709.4*2.875/(17100*1-0.6*709.4)
  = 0.1223 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*2.75/(17100*1-0.6*740)
  = 0.1222 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]

```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 709.4*1.125/(19637*1-0.6*709.4)
  = 0.0415 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([740/(20000*1]-1)
  = 0.0377 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0135 in

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.5000  in
 Parallel to Vessel Wall, opening length              d     2.2500  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.0925  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.4320  in
 Parallel to Vessel Wall                       Rn+tn+t     2.2160  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.4050  in
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 19637/17100 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 19637/17100 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.275	0.030	0.244
Area in Shell	A1	0.708	0.924	1.070
Area in Nozzle Wall	A2	1.065	1.126	1.732
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.125	0.125	0.125
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	1.898	2.175	2.927

The MAWP 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)
  = (2.25*0.122*1+2*0.529*0.122*1*(1-1))
  = 0.275 in^2
```

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 )
  = 2.25( 1 * 0.437 - 1 * 0.122 ) - 2 * 0.529
    ( 1 * 0.437 - 1 * 0.122 ) *( 1 - 1 )
  = 0.708 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.092 )( 0.529 - 0.0415 )1
  = 1.065 in^2
```

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

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 1 +( 0 )² * 1
  = 0.125 in^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 0.1665 in
 Wall Thickness per UG16(b),                       tr16b = 0.1875 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.2473 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.2473 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.1875 in
 Wall Thickness per table UG-45                      tb3 = 0.3140 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.314, max( 0.247, 0.188 ) ]
  = 0.2473 in
```

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

```
  = max( ta, tb )
  = max( 0.167, 0.247 )
  = 0.2473 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

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 = 0.562, tr = 0.122, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.28, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              0 F
Min Metal Temp. w/o impact per UG-20(f)                   -20 F

Gov. MDMT of the nozzle to shell joint welded assembly :   -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 709.42/740.00 = 0.959
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: AUX2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.4370  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld           0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(0.275 - 0.708 + 2 * 0.529 * 1 *
    (1 * 0.437 - 0.122 ) )17100 )
  = max( 0, -1706.76) lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.065 + 0 + 0.125 - 0 * 1 ) * 17100
  = 20356.03 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.065 + 0 + 0.125 +( 0.462 ) ) * 17100
  = 28262.15 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.065 + 0 + 0.125 + 0 +( 0.462 ) ) * 17100
  = 28262.15 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 3.308 * 0.354 * 0.49 * 17100
```

```
  = 15413. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 1.39 ) *( 0.654 - 0.125 ) * 0.7 * 19637
  = 31743. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 3.308 *( 0.562 - 0.125 ) * 0.74 * 19637
  = 32998. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 15413 + 31743 ) = 47156 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 15413 + 0 + 32998 + 0 ) = 48410 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 15413 + 32998 + 0 ) = 48410 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 47155   lbf, must exceed W = 0 lbf        or W1 = 20356 lbf
 Path 2-2 = 48410   lbf, must exceed W = 0 lbf        or W2 = 28262 lbf
 Path 3-3 = 48410   lbf, must exceed W = 0 lbf        or W3 = 28262 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 2359 psig

 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 3112 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.5529 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.0199 in

Input, Nozzle Desc: S1 From: 60

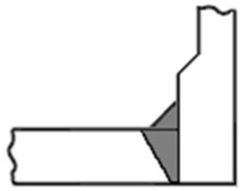
Pressure for Reinforcement Calculations	P	607.442	psig
Temperature for Internal Pressure	Temp	490	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		740.00	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	22.6240	in
Design Length of Section	L	199.5947	in
Shell Finished (Minimum) Thickness	t	0.8660	in
Shell Internal Corrosion Allowance	c	0.1250	in
Shell External Corrosion Allowance	co	0.0000	in
Distance from Bottom/Left Tangent		58.38	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material		SA-266 2	
Material UNS Number		K03506	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19640.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		0.00	deg
Diameter		9.7480	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.5000	in
Flange Material		SA-105	
Hub Height of Integral Nozzle	h	3.7400	in
Height of Beveled Transition	L'	0.6810	in
Hub Thickness of Integral Nozzle	(tn or x+tp)	1.1810	in
Corrosion Allowance	can	0.1250	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	15.8220	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3540	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.8660	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		600	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: S1

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation            9.748  in.
 Actual Thickness Used in Calculation                  0.500  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 607.4*11.44/(20000*1-0.6*607.4)
  = 0.3538 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 607.4*4.999/(19640*1-0.6*607.4)
  = 0.1575 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 740*4.874/(20000*1-0.6*740)
  = 0.1844 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0405 in

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 1.056, less than the hub height, use(e-2)
  = 2.6400 in
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)          Dl    19.9960  in
 Parallel to Vessel Wall, opening length            d     9.9980  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp   1.8525  in
```

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 1.181, less than the hub height, use(e-2)
  = 2.9525 in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    19.4960  in
 Parallel to Vessel Wall, opening length              d     9.7480  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     2.1650  in
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 19640/20000 )
  = 0.982
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 19640/20000 )
  = 0.982
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.982, 1 )
  = 0.982
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	3.551	0.964	4.173
Area in Shell	A1	3.856	5.466	4.269
Area in Nozzle Wall	A2	3.269	3.695	4.315
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.123	0.123	0.125
Area in Element	A5	0.000	0.000	0.000
Area in Hub	A6	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	7.248	9.284	8.710

The MAWP 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)
  = (9.998*0.354*1+2*1.056*0.354*1*(1-0.982))
  = 3.551 in^2
```

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 )
  = 9.998( 1 * 0.741 - 1 * 0.354 ) - 2 * 1.056
    ( 1 * 0.741 - 1 * 0.354 ) *( 1 - 0.982 )
  = 3.856 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.852 )( 1.056 - 0.158 )0.982
  = 3.269 in^2
```

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

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 0.982 +( 0 )² * 0.982
  = 0.123 in^2
```

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 = 0.2825 in
Wall Thickness per UG16(b),                       tr16b = 0.1875 in
Wall Thickness, shell/head, internal pressure      trb1 = 0.4788 in
Wall Thickness                  tb1 = max(trb1, tr16b) = 0.4788 in
Wall Thickness                  tb2 = max(trb2, tr16b) = 0.1875 in
Wall Thickness per table UG-45                      tb3 = 0.4530 in
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 0.453, max( 0.479, 0.188 ) ]
= 0.4530 in
```

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

```
= max( ta, tb )
= max( 0.283, 0.453 )
= 0.4530 in
```

Available Nozzle Neck Thickness = 1.1810 in --> 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   :  4089.9,  Allowable :  19640.0 psi  Passed
Expansion   :     0.0,  Allowable :  45460.1 psi  Passed
Occasional  :  1300.4,  Allowable :  26121.2 psi  Passed
Shear       :  2122.6,  Allowable :  13748.0 psi  Passed
```

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 = 0.5, tr = 0.155, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.412, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -6 F
Min Metal Temp. w/o impact per UG-20(f)                    -20 F
```

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

Govrn. thk, tg = 0.866, tr = 0.354, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.477, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              24 F
Min Metal Temp. w/o impact per UG-20(f)                    -20 F

Gov. MDMT of the nozzle to shell joint welded assembly :   -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

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

```
Design Pressure/Ambient Rating = 607.44/1480.00 = 0.410
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: S1

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.7410  in
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
 Nozzle Weld            0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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,(3.551 - 3.856 + 2 * 1.056 * 0.982 *
    (1 * 0.741 - 0.354 ) )20000 )
  = 9950.38 lbf
```

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
  = ( 3.269 + 0.123 - 0 * 0.982 ) * 20000
  = 67838.98 lbf
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 3.269 + 0 + 0.123 +( 1.537 ) ) * 20000
  = 98575.42 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 3.269 + 0 + 0.123 + 0 ) * 20000
  = 98575.42 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 12.11 * 0.354 * 0.49 * 19640
  = 64804. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 5.527 ) *( 1.181 - 0.125 ) * 0.7 * 19640
  = 252083. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 12.11 *( 0.866 - 0.125 ) * 0.74 * 20000
  = 208614. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 64804 + 252083 ) = 316887 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 64804 + 0 + 208614 + 0 ) = 273419 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 64804 + 208614 + 0 ) = 273419 lbf
```

Summary of Failure Path Calculations:

```
Path 1-1 = 316887  lbf, must exceed W = 9950 lbf     or W1 = 67838 lbf
Path 2-2 = 273418  lbf, must exceed W = 9950 lbf     or W2 = 98575 lbf
Path 3-3 = 273418  lbf, must exceed W = 9950 lbf     or W3 = 98575 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Maximum Allowable Pressure in the Operating case: 893.2 psig

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 1376 psig

The Drop for this Nozzle is : 1.7570 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 18.4450 in

Input Echo, WRC297 Item 1, Description: S1 :

Diameter Basis for Cylindrical Shell		ID	
Shell Corrosion Allowance		0.1250	in
Shell Diameter		22.624	in
Shell Thickness		0.8660	in
Shell Stress Concentration Factor		1.000	
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	20000.00	psi
Vessel Hot S.I. Allowable	Smh	20000.00	psi

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-516 70

Diameter Basis for Nozzle		ID	
Nozzle Corrosion Allowance		0.1250	in
Nozzle Diameter		9.748	in
Nozzle Thickness		1.1810	in
Nozzle Stress Concentration Factor		1.000	
Nozzle Material		SA-266 2	
Nozzle Cold S.I. Allowable	SNmc	20000.00	psi
Nozzle Hot S.I. Allowable	SNmh	19640.00	psi

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-266 2

Note:
External Forces and Moments in WRC 107/537 Convention:
These loads are assumed to be SUStained loads.

Design Internal Pressure	Dp	607.44	psig
Radial Load	P	-4520.00	lbf
Circumferential Shear	Vc	5660.00	lbf
Longitudinal Shear	Vl	5660.00	lbf
Circumferential Moment	Mc	168240.00	in-lb
Longitudinal Moment	Ml	213600.00	in-lb
Torsional Moment	Mt	271920.00	in-lb

Include Axial Pressure Thrust	No
Include Pressure Stress Indices per Div. 2	No
Local Loads applied at end of Nozzle/Attachment	No

Stress Computations at the Edge of the Nozzle:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 12.11 + 2 * 1.65 * sqrt( 11.808( 0.866 - 0.125 ) )
  = 21.871 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     23.615 in
 Nozzle Outside Diameter   (d) =     12.110 in
 Vessel Thickness used     (T) =      0.741 in
 Nozzle Thickness used     (t) =      1.056 in
 T / t                         =      0.702
 d / t                         =     11.468

Lambda = [(d/D) * sqrt(D/T)]  = 2.895

 Nr/P    =      0.068
 Mr/P    =      0.110
 M0/P    =      0.035
 N0/P    =      0.095
 MrD/Mc  =      0.256
 NrDL/Mc =      0.112
 M0d/Mc  =      0.083
 N0DL/Mc =      0.077
 MrD/Ml  =      0.102
 NrDL/Ml =      0.055
 M0D/Ml  =      0.032
 N0DL/Ml =      0.111
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	779	779	779	779
Outplane Bending (P)	1744	-1744	1744	-1744
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-3568	-3568	3568	3568
Outplane Bending (ML)	-6152	6152	6152	-6152
Normal Pressure Stress	9081	9688	9081	9688
Outplane Stress Summary	1884	11307	21324	6139

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	556	556	556	556
Inplane Bending (P)	5438	-5438	5438	-5438
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-1774	-1774	1774	1774
Inplane Bending (ML)	-19690	19690	19690	-19690
Inplane Pressure Stress	4540	4540	4540	4540
Inplane Stress Summary	-10930	17574	31998	-18258

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside

Outplane Shear (Vc)	401	401	-401	-401
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	1592	1592	1592	1592
Shear Stress Summary	1993	1993	1191	1191

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	13419	18154	32129	24513

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	779	779	779	779
Outplane Bending (P)	1744	-1744	1744	-1744
Outplane Membrane (Mc)	-1946	-1946	1946	1946
Outplane Bending (Mc)	-12606	12606	12606	-12606
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	4540	4540	4540	4540
Outplane Stress Summary	-7489	14235	21615	-7085

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	556	556	556	556
Inplane Bending (P)	5438	-5438	5438	-5438
Inplane Membrane (Mc)	-2840	-2840	2840	2840
Inplane Bending (Mc)	-38796	38796	38796	-38796
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	9081	9688	9081	9688
Inplane Stress Summary	-26561	40762	56711	-31150

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-401	-401	401	401
Torsional Shear (Mt)	1592	1592	1592	1592
Shear Stress Summary	1191	1191	1993	1993

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	26635	40815	56823	31313

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses in the	Au Top	Al Top	Bu Bottom	Bl Bottom

hoop direction)	Outside	Inside	Outside	Inside
Hoop Membrane (P)	779	779	779	779
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	0	0	0	0
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	-3568	-3568	3568	3568
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	3121	3849	3121	3849
Hoop Stress Summary	332	1060	7468	8196

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to pipe cross-section)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Axial Membrane (P)	123	123	123	123
Axial Bending (P)	1856	-1856	1856	-1856
Axial Membrane (Mc)	0	0	0	0
Axial Bending (Mc)	0	0	0	0
Axial Membrane (ML)	-2288	-2288	2288	2288
Axial Bending (ML)	-7073	7073	7073	-7073
Axial Pressure Stress	1560	1560	1560	1560
Axial Stress Summary	-5822	4612	12900	-4958

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
Shear due to (Vc)	281	281	-281	-281
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	1117	1117	1117	1117
Shear Stress Summary	1398	1398	836	836

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
Two * Max Shear Stress	6759	5096	13025	13259

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Hoop Membrane (P)	779	779	779	779
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-1946	-1946	1946	1946
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	3121	3849	3121	3849
Hoop Stress Summary	1954	2682	5846	6574

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Axial Membrane (P)	123	123	123	123

Axial Bending (P)	1856	-1856	1856	-1856
Axial Membrane (Mc)	-1802	-1802	1802	1802
Axial Bending (Mc)	-14907	14907	14907	-14907
Axial Membrane (ML)	0	0	0	0
Axial Bending (ML)	0	0	0	0
Axial Pressure Stress	1560	1560	1560	1560
Axial Stress Summary	-13170	12932	20248	-13278

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress)	Cu Outside	Cl Inside	Du Outside	Dl Inside
Shear due to (Vc)	0	0	0	0
Shear due to (Vl)	-281	-281	281	281
Shear due to Torsion	1117	1117	1117	1117
Shear Stress Summary	836	836	1398	1398

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Outside	Cl Inside	Du Outside	Dl Inside
Two * Max Shear Stress	15216	12999	20382	20047

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	9081	9688	9081	9688	9081	9688	9081	9688
Circ. Pl (SUS)	-2789	-2789	4347	4347	-2284	-2284	3396	3396
Circ. Q (SUS)	-4408	4408	7896	-7896	-33358	33358	44234	-44234
Long. Pm (SUS)	4540	4540	4540	4540	4540	4540	4540	4540
Long. Pl (SUS)	-1218	-1218	2330	2330	-1167	-1167	2725	2725
Long. Q (SUS)	-14252	14252	25128	-25128	-10862	10862	14350	-14350
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	401	401	-401	-401	-401	-401	401	401
Shear Q (SUS)	1592	1592	1592	1592	1592	1592	1592	1592
Pm (SUS)	9081	9688	9081	9688	9081	9688	9081	9688
Pm+Pl (SUS)	6345	6943	13452	14057	6843	7443	12507	13111
Pm+Pl+Q (Total)	13419	18154	32129	24513	26635	40815	56823	31313

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	9688	20000	Passed
Pm+Pl (SUS)	14057	30000	Passed
Pm+Pl+Q (TOTAL)	56823	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	3121	3849	3121	3849	3121	3849	3121	3849
Circ. Pl (SUS)	-2789	-2789	4347	4347	-1167	-1167	2725	2725
Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	1560	1560	1560	1560	1560	1560	1560	1560
Long. Pl (SUS)	-2165	-2165	2411	2411	-1679	-1679	1925	1925
Long. Q (SUS)	-5217	5217	8929	-8929	-13051	13051	16763	-16763
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	281	281	-281	-281	-281	-281	281	281
Shear Q (SUS)	1117	1117	1117	1117	1117	1117	1117	1117
Pm (SUS)	3121	3849	3121	3849	3121	3849	3121	3849
Pm+Pl (SUS)	1092	1757	7490	8214	2147	2856	5878	6599
Pm+Pl+Q (Total)	6759	5096	13025	13259	15216	12999	20382	20047

Nozzle Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	3849	19640	Passed
Pm+Pl (SUS)	8214	29460	Passed
Pm+Pl+Q (TOTAL)	20382	58920	Passed

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

Input, Nozzle Desc: S2 From: 60

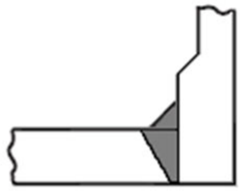
```
Pressure for Reinforcement Calculations        P       607.997  psig
Temperature for Internal Pressure           Temp          490   F
Design External Pressure                    Pext        15.00   psig
Temperature for External Pressure         Tempex          300   F
Maximum Allowable Pressure New & Cold                  740.00   psig

Parent Material [Normalized]                          SA-516 70
Parent Allowable Stress at Temperature        Sv     20000.00   psi
Parent Allowable Stress At Ambient           Sva     20000.00   psi

Inside Diameter of Cylindrical Shell           D      22.6240   in
Design Length of Section                       L     199.5947   in
Shell Finished (Minimum) Thickness             t       0.8660   in
Shell Internal Corrosion Allowance             c       0.1250   in
Shell External Corrosion Allowance            co       0.0000   in

Distance from Bottom/Left Tangent                      207.40   in

User Entered Minimum Design Metal Temperature           32.00   F
```

Type of Element Connected to the Parent : Nozzle

```
Material                                               SA-266 2
Material UNS Number                                      K03506
Material Specification/Type                            Forgings
Allowable Stress at Temperature               Sn     19640.00   psi
Allowable Stress At Ambient                  Sna     20000.00   psi

Diameter Basis (for tr calc only)                        Inside
Layout Angle                                           180.00   deg
Diameter                                               9.7480   in.

Size and Thickness Basis                                 Actual
Actual Thickness                              tn       0.5000   in

Flange Material                                          SA-105

Hub Height of Integral Nozzle                  h       3.7400   in
Height of Beveled Transition                  L'       0.6810   in
Hub Thickness of Integral Nozzle  ( tn or x+tp )       1.1810   in

Corrosion Allowance                          can       0.1250   in
Joint Efficiency of Shell Seam at Nozzle      E1         1.00
Joint Efficiency of Nozzle Neck               En         1.00

Outside Projection                            ho      15.8220   in
Weld leg size between Nozzle and Pad/Shell    Wo       0.3540   in
Groove weld depth between Nozzle and Vessel Wgnv       0.8660   in
Inside Projection                              h       0.0000   in
Weld leg size, Inside Element to Shell        Wi       0.0000   in

Flange Class                                              600
Flange Grade                                           GR 1.1
```

The Pressure Design option was MAWP + static head (to the nozzle).

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



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: S2

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation            9.748  in.
 Actual Thickness Used in Calculation                  0.500  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 608*11.44/(20000*1-0.6*608)
  = 0.3541 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*11.31/(20000*1-0.6*740)
  = 0.4280 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 608*4.999/(19640*1-0.6*608)
  = 0.1577 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 740*4.874/(20000*1-0.6*740)
  = 0.1844 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0405 in

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 1.056, less than the hub height, use(e-2)
  = 2.6400 in
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    19.9960  in
 Parallel to Vessel Wall, opening length              d     9.9980  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.8525  in
```

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 1.181, less than the hub height, use(e-2)
  = 2.9525 in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
Parallel to Vessel Wall (Diameter Limit)            Dl     19.4960  in
Parallel to Vessel Wall, opening length              d      9.7480  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      2.1650  in
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 19640/20000 )
= 0.982
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 19640/20000 )
= 0.982
```

Weld Strength Reduction Factor [fr3]:

```
= min( fr2, fr4 )
= min( 0.982, 1 )
= 0.982
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	3.554	0.964	4.173
Area in Shell	A1	3.853	5.466	4.269
Area in Nozzle Wall	A2	3.268	3.695	4.315
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.123	0.123	0.125
Area in Element	A5	0.000	0.000	0.000
Area in Hub	A6	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	7.245	9.284	8.710

The MAWP 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)
= (9.998*0.354*1+2*1.056*0.354*1*(1-0.982))
= 3.554 in^2
```

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 )
= 9.998( 1 * 0.741 - 1 * 0.354 ) - 2 * 1.056
  ( 1 * 0.741 - 1 * 0.354 ) *( 1 - 0.982 )
= 3.853 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 1.852 )( 1.056 - 0.158 )0.982
= 3.268 in^2
```

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 0.354² * 0.982 +( 0 )² * 0.982
= 0.123 in^2
```

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 = 0.2827 in
 Wall Thickness per UG16(b),                       tr16b = 0.1875 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.4791 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.4791 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.1875 in
 Wall Thickness per table UG-45                     tb3 = 0.4530 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.453, max( 0.479, 0.188 ) ]
  = 0.4530 in
```

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

```
  = max( ta, tb )
  = max( 0.283, 0.453 )
  = 0.4530 in
```

Available Nozzle Neck Thickness = 1.1810 in --> 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  :   4091.1,  Allowable :  19640.0 psi  Passed
 Expansion  :      0.0,  Allowable :  45458.9 psi  Passed
 Occasional :   1301.6,  Allowable :  26121.2 psi  Passed
 Shear      :   2122.6,  Allowable :  13748.0 psi  Passed
```

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 = 0.5, tr = 0.155, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.413, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -6 F
 Min Metal Temp. w/o impact per UG-20(f)                    -20 F
```

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

Govrn. thk, tg = 0.866, tr = 0.354, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.478, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              24 F
 Min Metal Temp. w/o impact per UG-20(f)                    -20 F

 Gov. MDMT of the nozzle to shell joint welded assembly :   -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

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

```
 Design Pressure/Ambient Rating = 608.00/1480.00 = 0.411
```

Note: The MDMT was not reduced based on lower stress per user request.

<u>Weld Size Calculations, Description: S2</u>

```
 Intermediate Calc. for nozzle/shell Welds    Tmin      0.7410   in
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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,(3.554 - 3.853 + 2 * 1.056 * 0.982 *
    (1 * 0.741 - 0.354 ) )20000 )
  = 10068.47 lbf
```

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
  = ( 3.268 + 0.123 - 0 * 0.982 ) * 20000
  = 67828.30 lbf
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 3.268 + 0 + 0.123 +( 1.537 ) ) * 20000
  = 98564.74 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 3.268 + 0 + 0.123 + 0 ) * 20000
  = 98564.74 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 12.11 * 0.354 * 0.49 * 19640
  = 64804. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 5.527 ) *( 1.181 - 0.125 ) * 0.7 * 19640
  = 252083. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 12.11 *( 0.866 - 0.125 ) * 0.74 * 20000
  = 208614. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 64804 + 252083 ) = 316887 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 64804 + 0 + 208614 + 0 ) = 273419 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 64804 + 208614 + 0 ) = 273419 lbf
```

Summary of Failure Path Calculations:

```
Path 1-1 = 316887  lbf, must exceed W = 10068 lbf    or W1 = 67828 lbf
Path 2-2 = 273418  lbf, must exceed W = 10068 lbf    or W2 = 98564 lbf
Path 3-3 = 273418  lbf, must exceed W = 10068 lbf    or W3 = 98564 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Maximum Allowable Pressure in the Operating case: 893.2 psig

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 1376 psig

The Drop for this Nozzle is : 1.7570 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 18.4450 in

Input Echo, WRC297 Item 1, Description: S2 :

Diameter Basis for Cylindrical Shell		ID	
Shell Corrosion Allowance		0.1250	in
Shell Diameter		22.624	in
Shell Thickness		0.8660	in
Shell Stress Concentration Factor		1.000	
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	20000.00	psi
Vessel Hot S.I. Allowable	Smh	20000.00	psi

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-516 70

Diameter Basis for Nozzle		ID	
Nozzle Corrosion Allowance		0.1250	in
Nozzle Diameter		9.748	in
Nozzle Thickness		1.1810	in
Nozzle Stress Concentration Factor		1.000	
Nozzle Material		SA-266 2	
Nozzle Cold S.I. Allowable	SNmc	20000.00	psi
Nozzle Hot S.I. Allowable	SNmh	19640.00	psi

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-266 2

Note:
External Forces and Moments in WRC 107/537 Convention:
These loads are assumed to be SUStained loads.

Design Internal Pressure	Dp	608.00	psig
Radial Load	P	-4520.00	lbf
Circumferential Shear	Vc	5660.00	lbf
Longitudinal Shear	Vl	5660.00	lbf
Circumferential Moment	Mc	168240.00	in-lb
Longitudinal Moment	Ml	213600.00	in-lb
Torsional Moment	Mt	271920.00	in-lb

Include Axial Pressure Thrust	No
Include Pressure Stress Indices per Div. 2	No
Local Loads applied at end of Nozzle/Attachment	No

Stress Computations at the Edge of the Nozzle:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 12.11 + 2 * 1.65 * sqrt( 11.808( 0.866 - 0.125 ) )
  = 21.871 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     23.615 in
 Nozzle Outside Diameter   (d) =     12.110 in
 Vessel Thickness used     (T) =      0.741 in
 Nozzle Thickness used     (t) =      1.056 in
 T / t                         =      0.702
 d / t                         =     11.468

Lambda = [(d/D) * sqrt(D/T)]  = 2.895

 Nr/P    =      0.068
 Mr/P    =      0.110
 M0/P    =      0.035
 N0/P    =      0.095
 MrD/Mc  =      0.256
 NrDL/Mc =      0.112
 M0d/Mc  =      0.083
 N0DL/Mc =      0.077
 MrD/Ml  =      0.102
 NrDL/Ml =      0.055
 M0D/Ml  =      0.032
 N0DL/Ml =      0.111
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	779	779	779	779
Outplane Bending (P)	1744	-1744	1744	-1744
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-3568	-3568	3568	3568
Outplane Bending (ML)	-6152	6152	6152	-6152
Normal Pressure Stress	9089	9697	9089	9697
Outplane Stress Summary	1892	11316	21332	6148

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	556	556	556	556
Inplane Bending (P)	5438	-5438	5438	-5438
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-1774	-1774	1774	1774
Inplane Bending (ML)	-19690	19690	19690	-19690
Inplane Pressure Stress	4544	4544	4544	4544
Inplane Stress Summary	-10926	17578	32002	-18254

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside

Outplane Shear (Vc)	401	401	-401	-401
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	1592	1592	1592	1592
Shear Stress Summary	1993	1993	1191	1191

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	13423	18158	32133	24517

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	779	779	779	779
Outplane Bending (P)	1744	-1744	1744	-1744
Outplane Membrane (Mc)	-1946	-1946	1946	1946
Outplane Bending (Mc)	-12606	12606	12606	-12606
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	4544	4544	4544	4544
Outplane Stress Summary	-7485	14239	21619	-7081

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	556	556	556	556
Inplane Bending (P)	5438	-5438	5438	-5438
Inplane Membrane (Mc)	-2840	-2840	2840	2840
Inplane Bending (Mc)	-38796	38796	38796	-38796
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	9089	9697	9089	9697
Inplane Stress Summary	-26553	40771	56719	-31141

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-401	-401	401	401
Torsional Shear (Mt)	1592	1592	1592	1592
Shear Stress Summary	1191	1191	1993	1993

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	26627	40824	56831	31304

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses in the	Au Top	Al Top	Bu Bottom	Bl Bottom

hoop direction)	Outside	Inside	Outside	Inside
Hoop Membrane (P)	779	779	779	779
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	0	0	0	0
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	-3568	-3568	3568	3568
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	3123	3853	3123	3853
Hoop Stress Summary	334	1064	7470	8200

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to pipe cross-section)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Axial Membrane (P)	123	123	123	123
Axial Bending (P)	1856	-1856	1856	-1856
Axial Membrane (Mc)	0	0	0	0
Axial Bending (Mc)	0	0	0	0
Axial Membrane (ML)	-2288	-2288	2288	2288
Axial Bending (ML)	-7073	7073	7073	-7073
Axial Pressure Stress	1561	1561	1561	1561
Axial Stress Summary	-5821	4613	12901	-4957

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
Shear due to (Vc)	281	281	-281	-281
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	1117	1117	1117	1117
Shear Stress Summary	1398	1398	836	836

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
Two * Max Shear Stress	6760	5097	13026	13262

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Hoop Membrane (P)	779	779	779	779
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-1946	-1946	1946	1946
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	3123	3853	3123	3853
Hoop Stress Summary	1956	2686	5848	6578

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Axial Membrane (P)	123	123	123	123

Axial Bending (P)	1856	-1856	1856	-1856
Axial Membrane (Mc)	-1802	-1802	1802	1802
Axial Bending (Mc)	-14907	14907	14907	-14907
Axial Membrane (ML)	0	0	0	0
Axial Bending (ML)	0	0	0	0
Axial Pressure Stress	1561	1561	1561	1561
Axial Stress Summary	-13169	12933	20249	-13277

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress)	Cu Outside	Cl Inside	Du Outside	Dl Inside
Shear due to (Vc)	0	0	0	0
Shear due to (Vl)	-281	-281	281	281
Shear due to Torsion	1117	1117	1117	1117
Shear Stress Summary	836	836	1398	1398

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Outside	Cl Inside	Du Outside	Dl Inside
Two * Max Shear Stress	15217	13000	20383	20050

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	9089	9697	9089	9697	9089	9697	9089	9697
Circ. Pl (SUS)	-2789	-2789	4347	4347	-2284	-2284	3396	3396
Circ. Q (SUS)	-4408	4408	7896	-7896	-33358	33358	44234	-44234
Long. Pm (SUS)	4544	4544	4544	4544	4544	4544	4544	4544
Long. Pl (SUS)	-1218	-1218	2330	2330	-1167	-1167	2725	2725
Long. Q (SUS)	-14252	14252	25128	-25128	-10862	10862	14350	-14350
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	401	401	-401	-401	-401	-401	401	401
Shear Q (SUS)	1592	1592	1592	1592	1592	1592	1592	1592
Pm (SUS)	9089	9697	9089	9697	9089	9697	9089	9697
Pm+Pl (SUS)	6353	6952	13460	14066	6851	7452	12515	13120
Pm+Pl+Q (Total)	13423	18158	32133	24517	26627	40824	56831	31304

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	9697	20000	Passed
Pm+Pl (SUS)	14066	30000	Passed
Pm+Pl+Q (TOTAL)	56831	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	3123	3853	3123	3853	3123	3853	3123	3853
Circ. Pl (SUS)	-2789	-2789	4347	4347	-1167	-1167	2725	2725
Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	1561	1561	1561	1561	1561	1561	1561	1561
Long. Pl (SUS)	-2165	-2165	2411	2411	-1679	-1679	1925	1925
Long. Q (SUS)	-5217	5217	8929	-8929	-13051	13051	16763	-16763
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	281	281	-281	-281	-281	-281	281	281
Shear Q (SUS)	1117	1117	1117	1117	1117	1117	1117	1117
Pm (SUS)	3123	3853	3123	3853	3123	3853	3123	3853
Pm+Pl (SUS)	1093	1760	7492	8218	2148	2859	5880	6603
Pm+Pl+Q (Total)	6760	5097	13026	13262	15217	13000	20383	20050

Nozzle Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	3853	19640	Passed
Pm+Pl (SUS)	8218	29460	Passed
Pm+Pl+Q (TOTAL)	20383	58920	Passed

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

Input, Nozzle Desc: AUX3 **Parent: S1**

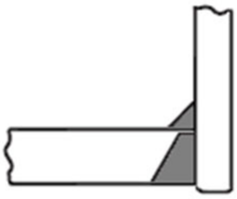
Pressure for Reinforcement Calculations	P	607.442	psig
Temperature for Internal Pressure	Temp	490	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		740.00	psig
Parent Material		SA-266 2	
Parent Allowable Stress at Temperature	Sv	19640.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	9.7480	in
Design Length of Section	L	15.8220	in
Shell Finished (Minimum) Thickness	t	0.5000	in
Shell Internal Corrosion Allowance	c	0.1250	in
Shell External Corrosion Allowance	co	0.0000	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19640.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Material [Normalized]		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.1250	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.9050	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3540	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.5000	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Reinforcement CALCULATION, Description: AUX3

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 607.4*4.999/(19640*1-0.6*607.4)
  = 0.1575 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*4.874/(20000*1-0.6*740)
  = 0.1844 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 607.4*1.125/(19640*1-0.6*607.4)
  = 0.0355 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([740/(20000*1]-1)
  = 0.0377 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0135 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.5000  in
 Parallel to Vessel Wall, opening length              d     2.2500  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9375  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.3080  in
 Parallel to Vessel Wall                       Rn+tn+t     2.1540  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.2500  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 19640/19640 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 19640/19640 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.354	0.046	0.369
Area in Shell	A1	0.489	0.753	0.728
Area in Nozzle Wall	A2	0.925	0.967	1.541
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.125	0.125	0.125
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	1.540	1.845	2.394

The MAWP 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)
  = (2.25*0.158*1+2*0.529*0.158*1*(1-1))
  = 0.354 in^2
```

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 )
  = 2.25( 1 * 0.375 - 1 * 0.158 ) - 2 * 0.529
    ( 1 * 0.375 - 1 * 0.158 ) *( 1 - 1 )
  = 0.489 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.938 )( 0.529 - 0.0355 )1
  = 0.925 in^2
```

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

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 1 +( 0 )² * 1
  = 0.125 in^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 0.1605 in
 Wall Thickness per UG16(b),                       tr16b = 0.1875 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.2825 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.2825 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.1875 in
 Wall Thickness per table UG-45                      tb3 = 0.3140 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.314, max( 0.283, 0.188 ) ]
  = 0.2825 in
```

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

```
  = max( ta, tb )
  = max( 0.16, 0.283 )
  = 0.2825 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.5, tr = 0.155, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.412, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -6 F
Min Metal Temp. w/o impact per UG-20(f)                    -20 F

Gov. MDMT of the nozzle to shell joint welded assembly :   -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 607.44/740.00 = 0.821

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: AUX3

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.3750  in
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(0.354 - 0.489 + 2 * 0.529 * 1 *
    (1 * 0.375 - 0.158 ) )19640 )
  = 1870.53 lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.925 + 0 + 0.125 - 0 * 1 ) * 19640
  = 20636.08 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.925 + 0 + 0.125 +( 0.397 ) ) * 19640
  = 28428.25 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.925 + 0 + 0.125 + 0 +( 0.397 ) ) * 19640
  = 28428.25 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 3.308 * 0.354 * 0.49 * 19640
```

```
  = 17702. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 1.39 ) *( 0.654 - 0.125 ) * 0.7 * 19640
  = 31747. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 3.308 *( 0.5 - 0.125 ) * 0.74 * 19640
  = 28320. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 17702 + 31747 ) = 49449 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 17702 + 0 + 28320 + 0 ) = 46022 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 17702 + 28320 + 0 ) = 46022 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 49449   lbf, must exceed W = 1870 lbf     or W1 = 20636 lbf
 Path 2-2 = 46021   lbf, must exceed W = 1870 lbf     or W2 = 28428 lbf
 Path 3-3 = 46021   lbf, must exceed W = 1870 lbf     or W3 = 28428 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 1410 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 1933 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2892 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.6942 in

Input, Nozzle Desc: AUX4 **Parent: S2**

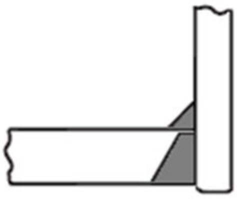
Pressure for Reinforcement Calculations	P	607.997	psig
Temperature for Internal Pressure	Temp	490	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		740.00	psig
Parent Material		SA-266 2	
Parent Allowable Stress at Temperature	Sv	19640.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	9.7480	in
Design Length of Section	L	15.8220	in
Shell Finished (Minimum) Thickness	t	0.5000	in
Shell Internal Corrosion Allowance	c	0.1250	in
Shell External Corrosion Allowance	co	0.0000	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	19640.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Material [Normalized]		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.1250	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	5.9050	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3540	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.5000	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Reinforcement CALCULATION, Description: AUX4

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 608*4.999/(19640*1-0.6*608)
  = 0.1577 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 740*4.874/(20000*1-0.6*740)
  = 0.1844 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 608*1.125/(19640*1-0.6*608)
  = 0.0355 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([740/(20000*1]-1)
  = 0.0377 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0135 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.5000  in
 Parallel to Vessel Wall, opening length              d     2.2500  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9375  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.3080  in
 Parallel to Vessel Wall                       Rn+tn+t      2.1540  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.2500  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 19640/19640 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 19640/19640 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (in^2)

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.355	0.046	0.369
Area in Shell	A1	0.489	0.753	0.728
Area in Nozzle Wall	A2	0.925	0.967	1.541
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.125	0.125	0.125
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	1.540	1.845	2.394

The MAWP 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)
  = (2.25*0.158*1+2*0.529*0.158*1*(1-1))
  = 0.355 in^2
```

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 )
  = 2.25( 1 * 0.375 - 1 * 0.158 ) - 2 * 0.529
    ( 1 * 0.375 - 1 * 0.158 ) *( 1 - 1 )
  = 0.489 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.938 )( 0.529 - 0.0355 )1
  = 0.925 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.354² * 1 +( 0 )² * 1
  = 0.125 in^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 0.1605 in
 Wall Thickness per UG16(b),                       tr16b = 0.1875 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.2827 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.2827 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.1875 in
 Wall Thickness per table UG-45                       tb3 = 0.3140 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.314, max( 0.283, 0.188 ) ]
  = 0.2827 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.16, 0.283 )
  = 0.2827 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.5, tr = 0.155, c = 0.125 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.413, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B               -6 F
Min Metal Temp. w/o impact per UG-20(f)                     -20 F

Gov. MDMT of the nozzle to shell joint welded assembly :    -20 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 608.00/740.00 = 0.822
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: AUX4

```
Intermediate Calc. for nozzle/shell Welds    Tmin      0.3750  in
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(0.355 - 0.489 + 2 * 0.529 * 1 *
    (1 * 0.375 - 0.158 ) )19640 )
  = 1880.45 lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.925 + 0 + 0.125 - 0 * 1 ) * 19640
  = 20634.87 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.925 + 0 + 0.125 +( 0.397 ) ) * 19640
  = 28427.03 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.925 + 0 + 0.125 + 0 +( 0.397 ) ) * 19640
  = 28427.03 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 3.308 * 0.354 * 0.49 * 19640
```

```
  = 17702. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 1.39 ) *( 0.654 - 0.125 ) * 0.7 * 19640
  = 31747. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 3.308 *( 0.5 - 0.125 ) * 0.74 * 19640
  = 28320. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 17702 + 31747 ) = 49449 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 17702 + 0 + 28320 + 0 ) = 46022 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 17702 + 28320 + 0 ) = 46022 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 49449   lbf, must exceed W = 1880 lbf     or W1 = 20634 lbf
 Path 2-2 = 46021   lbf, must exceed W = 1880 lbf     or W2 = 28427 lbf
 Path 3-3 = 46021   lbf, must exceed W = 1880 lbf     or W3 = 28427 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 1410 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 1933 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2892 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.6942 in

Input Echo, Tubesheet Number 1, Description:

Shell Data:

Main Shell Description: SHELL

Shell Maximum Design Pressure	Psd,max	550.00	psig
Shell Maximum Operating Pressure	Psox,max	550.00	psig
Shell Minimum Operating Pressure	Psox,min	0.00	psig
Shell Thickness	ts	0.8660	in
Shell Internal Corrosion Allowance	cas	0.1250	in
Shell External Corrosion Allowance	caext	0.0000	in
Inside Diameter of Shell	Ds	22.624	in
Shell Temperature for Internal Pressure	Ts	490.00	F
Shell Material		SA-516 70	

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-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	20000.00	psi
Shell Allowable Stress at Ambient		20000.00	psi

Channel Description: CHANNEL SHELL

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	425.00	psig
Channel Maximum Operating Pressure	Ptox,max	425.00	psig
Channel Minimum Operating Pressure	Ptox,min	0.00	psig
Channel Thickness	tc	0.7090	in
Channel Corrosion Allowance	cac	0.1250	in
Inside Diameter of Channel	Dc	22.624	in
Channel Design Temperature	TEMPC	150.00	F
Channel Material		SA-516 70	

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-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	20000.00	psi
Channel Allowable Stress at Ambient		20000.00	psi

Tube Data:

Number of Tube Holes	Nt	278	
Tube Wall Thickness	et	0.0830	in
Tube Outside Diameter	D	0.7500	in
Total Straight Tube Length	Lt	180.00	in
Straight Tube Length (bet. inner tubsht faces)	L	175.945	in
Design Temperature of the Tubes		490.00	F
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		13400.00	psi
Tube Allowable Stress At Ambient		13400.00	psi
Tube Yield Stress At design Temperature	Syt	21300.00	psi
Tube Pitch (Center to Center Spacing)	P	1.0000	in
Tube Layout Pattern		Square	

Fillet Weld Leg	af	0.1180	in
Groove Weld Leg	ag	0.1180	in
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	
Is the Tube Inset		No	

Radius to Outermost Tube Hole Center	ro	10.543	in
Largest Center-to-Center Tube Distance	Ul	2.2500	in
Length of Expanded Portion of Tube	ltx	0.0000	in
Tube-side pass partition groove depth	hg	0.1970	in

Tubesheet Data:

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

Tubesheet Design Metal Temperature	T	490.00	F
Tubesheet Material		SA-266 2	

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	19640.00	psi
Tubesheet Allowable Stress at Ambient	Tt	20000.00	psi
Thickness of Tubesheet	h	3.6850	in
Tubesheet Corr. Allowance (Shell side)	Cats	0.1250	in
Tubesheet Corr. Allowance (Channel side)	Catc	0.1250	in
Tubesheet Outside Diameter	A	24.803	in
Dimension G for the Channel Side	Gc	24.176	in
Area of the Untubed Lanes	AL	64.615	in^2
Junction Stress Reduction option		Perform Plastic Calculation	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	15.0000	psig
Channel Side Min. Design Pressure	Ptd,min	15.0000	psig

Additional Data for Gasketed Tubesheets:

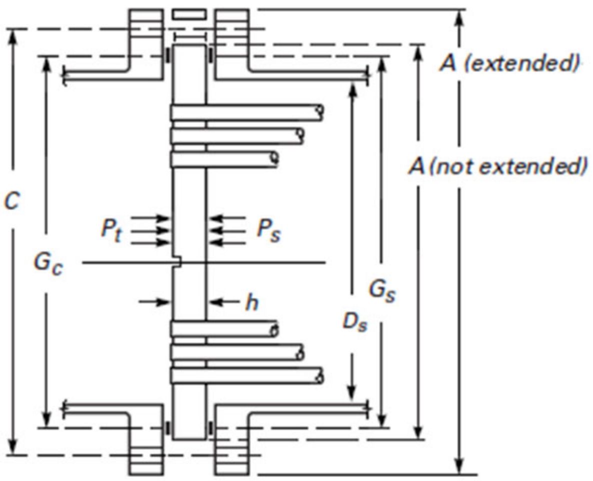
Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	31.299	in
Flange Inside Diameter	B	22.624	in
Flange Face Outside Diameter	Fod	24.921	in
Flange Face Inside Diameter	Fid	22.624	in
Gasket Outside Diameter	Go	24.803	in
Gasket Inside Diameter	Gi	23.228	in
Small end Hub thk.	g0	0.8660	in
Large end Hub thk.	g1	1.2600	in
Gasket Factor,	m	4.25	
Gasket Design Seating Stress	y	10100.00	psi
Flange Facing Sketch		Code Sketch 1a	
Column for Gasket Seating		Code Column II	
Gasket Thickness	tg	0.1575	in
Full face Gasket Flange Option		Program Selects	

Bolting Information:

Diameter of Bolt Circle	C	28.740	in
Nominal Bolt Diameter	dB	1.2500	in
Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	32	
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	25000.00	psi
Bolt Allowable Stress At Ambient	Sa	25000.00	psi
Weld between Flange and Shell/Channel		0.0000	in
Alternate Flange Operating Bolt Load, Wm1		364234.31	lbf
Alternate Flange Seating Bolt Load, Wm2		286889.50	lbf
Alternate Flange Design Bolt Load, W		553717.12	lbf

```
Tubesheet Integral with                                  None
Tubesheet Extended as Flange                               No
```

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2021

Elasticity/Expansion Material Properties :

Shell - TM-1 Carbon Steels with C<= 0.3%

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      490.0 F       0.27360E+08 psi
Elastic Mod. at Ambient Temperature      70.0 F       0.29400E+08 psi
```

Channel - TM-1 Carbon Steels with C<= 0.3%

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      150.0 F       0.29031E+08 psi
Elastic Mod. at Ambient Temperature      70.0 F       0.29400E+08 psi
```

Tubes - TM-1 Carbon Steels with C<= 0.3%

```
-----------------------------------------------------------------
Elastic Mod. at Tubsht. Design Temp.    490.0 F       0.27360E+08 psi
Elastic Mod. at Ambient Temperature      70.0 F       0.29400E+08 psi
```

TubeSheet - TM-1 Carbon Steels with C<= 0.3%

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      490.0 F       0.27360E+08 psi
Elastic Mod. at Ambient Temperature      70.0 F       0.29400E+08 psi
```

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)
  = (440*(0.75/2-0)/(13400*1+0.4*440)
  = 0.0122 + 0.0000 = 0.0122 in
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
External Pressure Chart     CS-1             at       490.00  F
Elastic Modulus for Material                    27100000.00  psi
```

Results for Max. Allowable External Pressure (Emawp):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.0830	0.75	186.86	9.04	50.0000	0.0134718	12701.92

EMAWP = (2.167/(D/T)-0.0833)*B = 1988 psig

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

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.0319	0.75	186.86	23.51	50.0000	0.0019907	9962.36

EMAWP = (4*B)/(3*(D/T)) = (4 *9962)/(3 *23.51) = 565.1 psig

Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.0319	in
Allowable Internal Pressure at Corroded thickness	3253.95	psig
Required Internal Design Pressure	440.00	psig
Allowable External Pressure at Corroded thickness	1988.04	psig
Required External Design Pressure	565.00	psig
Required Thickness due to Shell Side pressure	0.0319	in

U-Tube Tubesheet results per ASME UHX-12 2021

Results for 6 Load Cases:

	--Reqd. Thk. + CA		---- Tubesheet Stresses				Case	Pass/
Case#	Tbsht	Extnsn	Bend	Allwd	Shear	Allwd	Type	Fail
D1uc	2.621	0.163	18890	39280	2607	15697	Ps+Pt D1	Ok
D2uc	2.941	0.209	24257	39280	3348	15697	Ps+Pt D2	Ok
D3uc	1.487	0.046	5367	39280	741	15697	Ps+Pt D3	Ok
D1c	2.741	0.163	20321	39280	2797	15697	Ps+Pt-c D1	Ok
D2c	3.063	0.209	26094	39280	3592	15697	Ps+Pt-c D2	Ok
D3c	1.614	0.046	5773	39280	795	15697	Ps+Pt-c D3	Ok
Max:	3.0634	0.209	in	0.664		0.229	(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 (in)	Required	Actual	P/F
Tubesheet Thickness :	3.0634	3.6850	Ok
Tube Thickness :	0.0319	0.0830	Ok
Tube-Tubesheet Fillet Weld Leg :	0.0504	0.1180	Ok
Tube-Tubesheet Groove Weld Leg :	0.0504	0.1180	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	850.50	1.000	850.50	1.000
Tubesheet Shear Stress	2469.25	1.000	2469.25	1.000
Tube Pressure Stress	3253.94	1.000	1988.03	1.000
Minimum MAWP	850.50		850.50	

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	931.68	1.000	931.68	1.000
Tubesheet Shear Stress	2700.12	1.000	2700.12	1.000
Tube Pressure Stress	3253.94	1.000	2175.54	1.000
Minimum MAPnc	931.68		931.68	

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

Tubesheet MDMT Calculations:

Determine the governing MDMT considering the governing condition:

Governing thickness on the shell side per figure UCS-66.3 (c):

```
  = tubesheet thickness/4
  = 3.685/4
  = 0.921 in
```

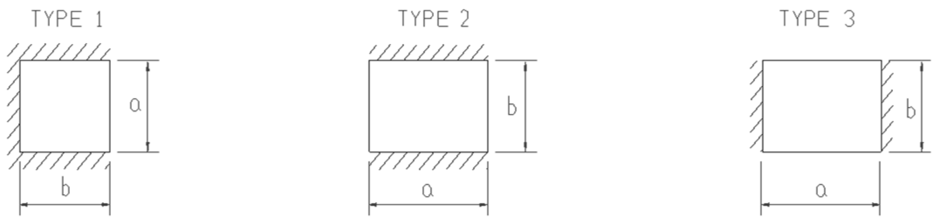
Thickness Ratio = 0.59, Temperature Reduction per Fig. UCS 66.1 = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C              -9 F
 Min Metal Temp. w/o impact per UG-20(f)                    -20 F
```

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:

```
  = max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1
  = max( 425/931.7, 550/931.7 )
  = 0.590
```

Appendix 1

PASS PARTITION PLATE THICKNESS CALCULATION					
(For part no.16)					
CODE: TEMA TENTH ED.-2019 (RCB-9.13)					
DESIGN DATA [PASS PARITION PLATE]					
PRESS.DROP ACROSS PLATE q	7.06	psig	DESIGN TEMPERATURE T		150
PLATE a	33.386	in	PASS PARTITION TYPE		2
PLATE b	22.624	in	MAX. ALLOWABLE STRESS S		20000 psig
MATERIAL OF PLATE		SA-516 Gr.70N			
TABLE RCB-9.132 PASS PARTITION FACTOR					
					
THREE SIDE FIXED		LONG SIDE FIXED		SHORT SIDE FIXED	
a/b	B	a/b	B	a/b	B
0.25	0.02	1	0.4182	1	0.4182
0.5	0.081	1.2	0.4626	1.2	0.5208
0.75	0.173	1.4	0.486	1.4	0.5988
1	0.307	1.6	0.4968	1.6	0.654
1.5	0.539	1.8	0.4971	1.8	0.6912
2	0.657	2	0.4973	2	0.7146
3	0.718	∞	0.5	∞	0.75
PASS PARTITION PLATE FORMULA(TEMA RBC-9.132)					
From a/b =1.476, Get B = 0.4901					
1. DESIGN THICKNESS		$t = b\sqrt{\frac{qB}{1.5S}}$ =0. 243			in
2. CODE MIN.THICKNESS		t_m = 0.375			in
3. REQUIRED THICKNESS		t_r = MAX(t, t_m)+2X0.118 = 0.611			in
USED NOMINAL PASS PARTITION THICKNESS t_u = 0.63≥ t_r =0.611, O.K. !!					

Appendix 2 Checking the bend portion before bending as per TEMA RCB-2.3.1

Checking the bend portion before bending as per TEMA RCB-2.3.1

Parameters	**Unit**	**Value**
d_0-- Outside tube diameter	In	0.75
R-- Mean radius of bend (considering the smallest radius)	In	1.125
t_n-- Tube normal thickness	In	0.083
Tube thickness maximum down tolerance	%	0
tm-- Tube minimum thickness (consider down tolerance)	in	0.083
t_1-- Minimum tube wall thickness calculated by Code rules for a straight tube subjected to the same pressure and metal temperature, it can be read from the Pvelite calculation result: ASME TS Calc: Summary of thickness comparisons	in	0.0319
t_0-- Required tube wall thickness prior to bending $t_0 = t_1\left[1+\dfrac{d_0}{4R}\right]$	in	0.037
$t_0 < t_m$		OK
Calculated thickness reducing ration, shall be less than 17%	%	14.3
Conculsion: The tube wall thickness can meet with the requirements of RCB-2.3.1 U-Tubes of TEMA standard.		

FLANGE ANALYSIS WORKSHEET

Flange Inputs

Design Pressure	P	425	psig
Design Temperature	T	150	F
Corrosion Allowance	ci	0.125	in
Flange Material		SA-266 Gr.2	
Flange Allowable Stress at Ambient	S_fa	20000	psi
Flange Allowable Stress at Operating Temperature	S_fo	20000	psi
Flange Yield Stress at Ambient	S_ya	36000	psi
Flange Yield Stress at Operating Temperature	S_yo	33800	psi
Flange Modulus of Elasticity, Ambient	Eamb	2.92E+07	psi
Flange Modulus of Elasticity, Operating	Eop	2.81E+07	psi
Flange Thickness	t	5.189	in
Flange ID	B	22.624	in
Flange OD	A	31.299	in
Thickenss of Hub at Small End	g0	0.709	in
Thickenss of Hub at Large End	g1	1.181	in
Length of Hub	h	1.575	in
Rigidity Factor	K_I	0.3	
Bolt Material		SA-193 B7	
Bolt Allowable Stress at Ambient	S_ba	25000	psi
Bolt Allowable Stress At Operating Temperature	S_bo	25000	psi
Bolt Yield Stress at Ambient Temperature	S_ya	105000	psi
Bolt Yield Stress at Operating Temperature	S_yo	94500	psi
Diameter of Bolt Circle	C	28.74	in
Nominal Bolt Diameter	a	1-1/4	in
Number of Bolts	n	32	
Flange Face OD	F_od	24.921	in
Flange Face ID	F_id	22.624	in
Gasket OD	G_o	24.803	in
Gasket ID	G_i	23.228	in
Gasket Factor	m	4.25	
Gasket Design Seating Stress	y	10000	psi
Gasket thickness	tg	0.157	in
Gasket Partition Width	W	0.394	in
Gasket Partition Length	L	34.842	in
Minimum Gasket Seating Stress	Sg_min_s	20000	psi
Minimum Gasket Operating Stress	Sg_min_o	14000	psi
Max Gasket Stress	Sg_max	55000	psi
Target Gasket Stress	Sg_t	41250	psi
Maximum Allowable Flange Rotation	θ_g	1	degrees
Gasket Relaxation Fraction	ф_g	0.7	
Nut Factor (K = Friction + 0.04)	K	0.2	
Corroded Flange ID	Bcor	22.874	in
Corroded Large Hub	g1cor	1.0560	in
Corroded Small Hub	g0cor	0.584	in
Gasket Contact Width	N	0.788	in
Basic Gasket Width	b0	0.394	in
Effective Gasket Width	b	0.3137	in
Effective Partition Width	b_part	0.197	in
Gasket Reaction Diameter	G	24.176	in
Hub Small End Required Thickenss	t_min	0.2462	in
Hydro End Load Due to Pressure	H	195087.4	lb
Contact Load on Gasket Surface	Hp	110878.0	lb
Hydro End Load at Flange ID	Hd	174647.5	lb
Pressure Force on Flange Face	Ht	20439.9	lb
Operating Bolt Load	Wm1	305965.4	lb
Gasket Sealing Bolt Load	Wm2	306928.7	lb
Required Bolt Area	Am	12.277	in^2
Bolt Root Area	Ab	0.9289	in^2
Actual Bolt Area	Ab_tot	29.725	in^2
Moment Multiplier of Bolt Spacing	Bsc	1.000	
Flange Design Bolt Load, Seating	W	525024.3	lb
Gasket Seating Force	Hg	110878.0	lb
Distance to Hub Large End	R	1.8770	in
Distance to Gasket Load Reaction	hg	2.2822	in
Distance to Face Pressure Reaction	ht	2.6076	in
Distance to End Pressure Reaction	hd	2.4050	in
Effective Hub Length	ho	3.6549	in
Hub Ratio	h/ho	0.4309	
Thickenss Ratio	g1/go	1.808	
Area of Gasket	Ag	66.28	in^2

Flange Anaylsis Results Per ASME Section VIII, Div 1, App. 2

Summary of Bolting Information

	Minimum	Actual	Maximum	
Bolt Area	12.277	29.725	-	in^2
Circ. Spacing Between Bolts	2.8125	2.817	9.0545	in

Summary of Moments for Internal Pressure

Loading		Force	Distance	Moment	
End Pressure	Md	174648	2.4050	35002	ft-lb
Face Pressure	Mt	20440	2.6076	4442	ft-lb
Gasket Load	Mg	110878	2.2822	21088	ft-lb
Total Operating	Mo			60531	ft-lb
Gasket Seating	Ma	525024	2.2822	99853	ft-lb

Stress Computation Results

		Gasket Seating		Operating		
		Actual	**Allowed**	**Actual**	**Allowed**	psi
Longitudinal Hub	Sh	9986.5	30000	6053.9	30000	psi
Radial Flange	Sr	898.3	20000	544.6	20000	psi
Tangential Flange	St	9357.0	20000	5672.3	20000	psi
Maximum Average	Savg	9671.7	20000	5863.1	20000	psi
Bolting		10325.7	25000	10293.3	25000	psi

Flange Rigidity Check

	Gasket Seating		Operating	
	Actual	**Allowed**	**Actual**	**Allowed**
Flange Rigidity Index	0.276	1.0	0.174	1.0

WRC Bulletin 538 & ASME PCC-1 Appendix O Analysis

WRC Bulletin 538 Analysis

Max. Bolt Stress for Flange	S_fmax	92954	psi
Hub Stress Correction Factor	f	1.209957361	
Hub Stress Correction Factor #2	f_2	0.46059	
Modified Moment	Mo_mod	525496	ft-lb
Elevated Yield Stress Reduction	S_yo'	38629	psi
Modified Yield Stress	S_y	36000	psi

WRC Bulletin 538 Stress Computation Results

		Actual	**Seating**	**Operating**	
Longitudinal Hub Stress	Sh	52556	72000	72000	psi
Tangential Stress at Hub/Flang	St	49243	54000	54000	psi
Tangential Stress at Hub/Shell	Sto	20006	36000	36000	psi
Combined Stress at Hub/Flange	Sh/f +St	92679	108000	108000	psi
Combined Stress at Hub/Flange	Sr + St	53971	108000	108000	psi
Combined Stress at Hub/Shell	Sh + Sto	72562	108000	108000	psi
Radial Stress at Hub/Flange	Sr	4728	72000	72000	psi

Flange Rotation Check

Bolt Load, Seating	W_mod	2184773	lb
Gasket Seating Moment	Ma_mod	415516	ft-lb
Actual Flange Rotation	θ_f	0.3449	degrees

ASME PCC-1 Appendix O Analysis

Step 1:	Target Bolt Stress (O-1)	S_bsel	91976	psi
Step 2:	Maximum Bolt Stress	S_bmax	73500	psi
	Upper Control Limit (O-4)	S_bsel	73500	psi
Step 3:	Minimum Bolt Stress	S_bmin	42000	psi
	Lower Control Limit (O-5)	S_bsel	73500	psi
Step 4:	Max. Bolt Stress for Flange	S_fmax	92954	psi
	Flange Limit Control (O-6)	S_bsel	73500	psi
Step 5a:	Actual Gasket Seating Stress	Sg_s	32964	psi
Step 5b:	Is the gasket seated?	S_bsel ≥	44595	
Step 6a:	Actual Gasket Op. Stress	Sg_o	20357	psi
Step 6b:	Is gasket operating stress maintained?	S_bsel ≥	53250	
Step 7:	Is the gasket maximum stress exceeded?	S_bsel ≤	122635	
Step 8:	Is the flange rotation limit exceeded?	S_bsel ≤	269510	

Bolt Tension/Torque Value Selection

Selected Bolt Stress	Tension	73500	psi
Applied Bolt Torque (O-2)	Torque	1422	ft-lbs

Notes & Assumptions:

1. This sheet is for integral type flanges with standard serrated finishes (facing sketch 1a or 1b - no nubbins) with DJ, flat metal, spiral wound, or cammprofile style gaskets.
2. To use this sheet, input values in the yellow highlighted cells. Ensure flange and bolt temperatures reflect design temperature, especially if temperature reductions were included for uninsulated components per B31.3 allowances.
3. Use the solver to maximize the flange assembly stress (orange highlighted cell).
4. The bolting limits utilized in the PCC-1 Appendix O calculations are a minimum of 40% and a maximum of 70% of the ambient yield. Differing limits may be input manually into the cells highlighted in purple if analysis warrants.
5. Cells with comments provide additional analysis options and commentary.

Revision 0 - 2018.03.27 - MAB - Initial Issue.Revision 1 - 2018.04.17 - MAB - Reformatted and added flange rotation calculation.Revision 2 - 2018.04.18 - MAB - Corrected partition gasket effective width calculation.

FLANGE ANALYSIS WORKSHEET

Flange Inputs

Design Pressure	P	550	psig
Design Temperature	T	490	F
Corrosion Allowance	ci	0.125	in
Flange Material		SA-266 Gr.2	
Flange Allowable Stress at Ambient	S_fa	20000	psi
Flange Allowable Stress at Operating Temperature	S_fo	19640	psi
Flange Yield Stress at Ambient	S_ya	36000	psi
Flange Yield Stress at Operating Temperature	S_yo	29450	psi
Flange Modulus of Elasticity, Ambient	Eamb	2.92E+07	psi
Flange Modulus of Elasticity, Operating	Eop	2.72E+07	psi
Flange Thickness	t	5.189	in
Flange ID	B	22.624	in
Flange OD	A	31.299	in
Thickenss of Hub at Small End	g0	0.866	in
Thickenss of Hub at Large End	g1	1.26	in
Length of Hub	h	1.575	in
Rigidity Factor	K_I	0.3	
Bolt Material		SA - 193 B7	
Bolt Allowable Stress at Ambient	S_ba	25000	psi
Bolt Allowable Stress At Operating Temperature	S_bo	25000	psi
Bolt Yield Stress at Ambient Temperature	S_ya	105000	psi
Bolt Yield Stress at Operating Temperature	S_yo	89700	psi
Diameter of Bolt Circle	C	28.74	in
Nominal Bolt Diameter	a	1-1/4	in
Number of Bolts	n	32	
Flange Face OD	F_od	24.921	in
Flange Face ID	F_id	22.624	in
Gasket OD	G_o	24.803	in
Gasket ID	G_i	23.228	in
Gasket Factor	m	4.25	
Gasket Design Seating Stress	y	10000	psi
Gasket thickness	tg	0.157	in
Gasket Partition Width	W	0	in
Gasket Partition Length	L	0	in
Minimum Gasket Seating Stress	Sg_min_s	20000	psi
Minimum Gasket Operating Stress	Sg_min_o	14000	psi
Max Gasket Stress	Sg_max	55000	psi
Target Gasket Stress	Sg_t	41250	psi
Maximum Allowable Flange Rotation	θ_g	1	degrees
Gasket Relaxation Fraction	ϕ_g	0.7	
Nut Factor (K = Friction + 0.04)	K	0.2	
Corroded Flange ID	Bcor	22.874	in
Corroded Large Hub	g1cor	1.1350	in
Corroded Small Hub	g0cor	0.741	in
Gasket Contact Width	N	0.788	in
Basic Gasket Width	b0	0.394	in
Effective Gasket Width	b	0.3137	in
Effective Partition Width	b_part	0.000	in
Gasket Reaction Diameter	G	24.176	in
Hub Small End Required Thickenss	t_min	0.3258	in
Hydro End Load Due to Pressure	H	252466.1	lb
Contact Load on Gasket Surface	Hp	111400.5	lb
Hydro End Load at Flange ID	Hd	226014.4	lb
Pressure Force on Flange Face	Ht	26451.7	lb
Operating Bolt Load	Wm1	363866.6	lb
Gasket Sealing Bolt Load	Wm2	238289.9	lb
Required Bolt Area	Am	14.555	in^2
Bolt Root Area	Ab	0.9289	in^2
Actual Bolt Area	Ab_tot	29.725	in^2
Moment Multiplier of Bolt Spacing	Bsc	1.000	
Flange Design Bolt Load, Seating	W	553493.3	lb
Gasket Seating Force	Hg	111400.5	lb
Distance to Hub Large End	R	1.7980	in
Distance to Gasket Load Reaction	hg	2.2822	in
Distance to Face Pressure Reaction	ht	2.6076	in
Distance to End Pressure Reaction	hd	2.3655	in
Effective Hub Length	ho	4.1170	in
Hub Ratio	h/ho	0.3826	
Thickenss Ratio	g1/go	1.532	
Area of Gasket	Ag	59.41	in^2

Flange Anaylsis Results Per ASME Section VIII, Div 1, App. 2

Summary of Bolting Information				
	Minimum	Actual	Maximum	
Bolt Area	14.555	29.725	-	in^2
Circ. Spacing Between Bolts	2.8125	2.817	9.0545	in

Summary of Moments for Internal Pressure					
Loading		Force	Distance	Moment	
End Pressure	Md	226014	2.3655	44553	ft-lb
Face Pressure	Mt	26452	2.6076	5748	ft-lb
Gasket Load	Mg	111401	2.2822	21187	ft-lb
Total Operating	Mo			71488	ft-lb
Gasket Seating	Ma	553493	2.2822	105267	ft-lb

Stress Computation Results						
		Gasket Seating		Operating		
		Actual	**Allowed**	**Actual**	**Allowed**	psi
Longitudinal Hub	Sh	10285.2	30000	6984.8	29460	psi
Radial Flange	Sr	1207.3	20000	819.9	19640	psi
Tangential Flange	St	9011.1	20000	6119.5	19640	psi
Maximum Average	Savg	9648.2	20000	6552.2	19640	psi
Bolting		8016.5	25000	12241.2	25000	psi

Flange Rigidity Check				
	Gasket Seating		Operating	
	Actual	**Allowed**	**Actual**	**Allowed**
Flange Rigidity Index	0.268	1.0	0.196	1.0

WRC Bulletin 538 & ASME PCC-1 Appendix O Analysis

WRC Bulletin 538 Analysis			
Max. Bolt Stress for Flange	S_fmax	92954	psi
Hub Stress Correction Factor	f	1	
Hub Stress Correction Factor #2	f_2	0.35523	
Modified Moment	Mo_mod	525496	ft-lb
Elevated Yield Stress Reduction	S_yo'	33657	psi
Modified Yield Stress	S_y	33657	psi

WRC Bulletin 538 Stress Computation Results					
		Actual	**Seating**	**Operating**	
Longitudinal Hub Stress	Sh	51344	72000	67314	psi
Tangential Stress at Hub/Flange	St	44984	54000	50486	psi
Tangential Stress at Hub/Shell	Sto	18239	36000	33657	psi
Combined Stress at Hub/Flange	Sh/f +St	96327	108000	100971	psi
Combined Stress at Hub/Flange	Sr + St	51010	108000	100971	psi
Combined Stress at Hub/Shell	Sh + Sto	69582	108000	100971	psi
Radial Stress at Hub/Flange	Sr	6027	72000	67314	psi

Flange Rotation Check			
Bolt Load, Seating	W_mod	2184773	lb
Gasket Seating Moment	Ma_mod	415516	ft-lb
Actual Flange Rotation	θ_f	0.3171	degrees

ASME PCC-1 Appendix O Analysis				
Step 1:	Target Bolt Stress (O-1)	S_bsel	82451	psi
Step 2:	Maximum Bolt Stress	S_bmax	73500	psi
	Upper Control Limit (O-4)	S_bsel	73500	psi
Step 3:	Minimum Bolt Stress	S_bmin	42000	psi
	Lower Control Limit (O-5)	S_bsel	73500	psi
Step 4:	Max. Bolt Stress for Flange	S_fmax	92954	psi
	Flange Limit Control (O-6)	S_bsel	73500	psi
Step 5a:	Actual Gasket Seating Stress	Sg_s	36772	psi
Step 5b:	Is the gasket seated?	S_bsel ≥	39976	
Step 6a:	Actual Gasket Op. Stress	Sg_o	21818	psi
Step 6b:	Is gasket operating stress maintained?	S_bsel ≥	51177	
Step 7:	Is the gasket maximum stress exceeded?	S_bsel ≤	109935	
Step 8:	Is the flange rotation limit exceeded?	S_bsel ≤	293099	

Bolt Tension/Torque Value Selection			
Selected Bolt Stress	Tension	73500	psi
Applied Bolt Torque (O-2)	Torque	1422	ft-lbs

Notes & Assumptions:

1. This sheet is for integral type flanges with standard serrated finishes (facing sketch 1a or 1b - no nubbins) with DJ, flat metal, spiral wound, or cammprofile style gaskets.
2. To use this sheet, input values in the yellow highlighted cells. Ensure flange and bolt temperatures reflect design temperature, especially if temperature reductions were included for uninsulated components per B31.3 allowances.
3. Use the solver to maximize the flange assembly stress (orange highlighted cell).
4. The bolting limits utilized in the PCC-1 Appendix O calculations are a minimum of 40% and a maximum of 70% of the ambient yield. Differing limits may be input manually into the cells highlighted in purple if analysis warrants.
5. Cells with comments provide additional analysis options and commentary.

Revision 0 - 2018.03.27 - MAB - Initial Issue.Revision 1 - 2018.04.17 - MAB - Reformatted and added flange rotation calculation.Revision 2 - 2018.04.18 - MAB - Corrected partition gasket effective width calculation.

	鞍座热膨胀计算	项目号 ITEM NO.
	Saddle Thermal Expansion calculation	文件号 DOC. NO.

输入数据 Input Data

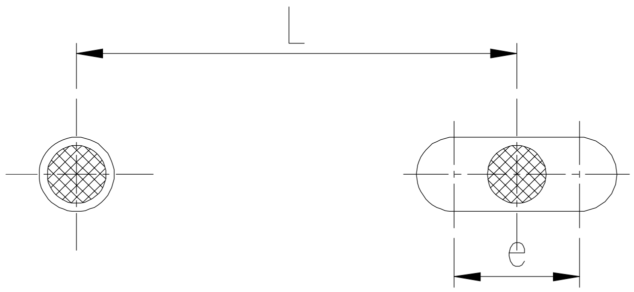


FIG: saddle base plate anchor bolt hole

设备材料The material of vessel		SA-516 Gr.70N	
最高设计温度The max. design temperature	T_1=	254.4	°C
最低设计温度The min. design temperature	T_2=	0	°C
设备材料在最高设计温度下的热膨胀系数 The expansion coefficient at the max. design temperature	a_1=	1.26E-05	mm/mm°C
设备材料在最低设计温度下的热膨胀系数 The expansion coefficient at the min. design temperature	a_2=	1.08E-05	mm/mm°C
鞍座间距The distance of saddle	L=	2768.6	mm
鞍座底板长圆孔长度 The slot hole of saddle base plate	e=	35	mm

设计计算 Checking strength

设备的安装温度 The install temperature	t=	21.1	°C
最高设计温度下热膨胀长度 The expansion length at max. temp.	$\Delta L_1=a_1L(T_1\text{-}t)=$	8.11	mm
最低设计温度下热膨胀长度 The expansion length at min. temp.	$\Delta L_2=a_2L(T_2\text{-}t)=$	-0.63	mm
最大热膨胀长度 The max. expansion length	$\Delta L=\max(\vert\Delta L_1\vert,\vert\Delta L_2\vert)=$	8.11	mm

判别依据 Evaluate ΔL <= e/2

The slot hole length is OK!

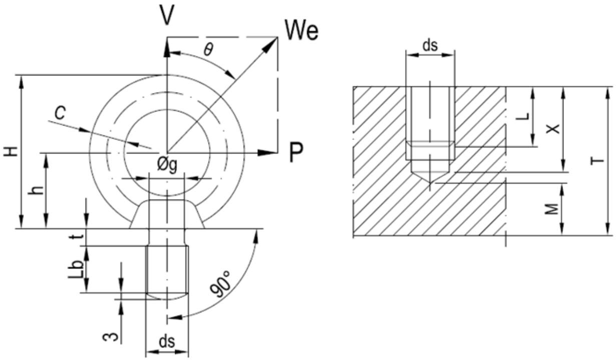
APPENDIX 5

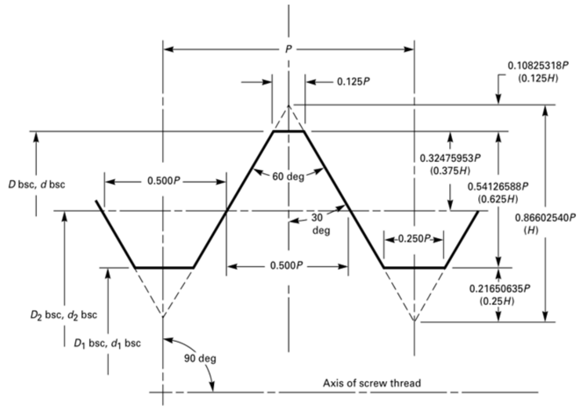
TEST RING CALCULATION FOR FRONT TUBESHEET END

Bolt material	SA-193 Gr.B7	
Bolt yield stress	724	Mpa
Bolt tensile stress	862	Mpa
Bolt allowable stress when test	172.4	Mpa
Applied bolt tension stress coefficient	100	%
Bolt stress when test St	172.4	Mpa
Bolt diameter	1 1/4"	
Bolt root area Ab	599.29	mm^2
Bolt number N	32	
Total bolt load when test W=St*Ab*N	3306158.24	N
Test ring OD A	795	mm
Test ring ID B	574.6	mm
Bolt circle diameter C	730	mm
Test ring material	SA-266 Gr.2N	
Test ring yield stress Sy	248.2	Mpa
Test ring allowable stress S=0.9*Sy	223.38	Mpa
Value H=(C-B)/2	77.7	mm
Value K=A/B	1.38	
Value Y	6.14	
Required test ring thickness as per TEMA RCB-5.14 $T=\left[\frac{(W)(H)(Y)}{(B)(S)}\right]^{1/2}$	110.88	mm
Test ring thickness in drawing	115	mm

CALCULATION OF PULLING EYE BOLT

Eye bolt Uint		
Bolt Nominal Diameter ds =	0.625	in
Allowable Stress Of Eye Bolt Material Se =	20000	psi
Allowable Stress Of Tubesheet Material St =	20000	psi
Yield Stress Of Eye Bolt Material Syb =	36000	psi
Yield Stress Of Tubesheet Material Syt =	36000	psi
Tubesheet Shell Side Corrosion Allowance CA =	0.125	in
C =	0.5	in
h =	1.53	in
Min Diameter g =	0.512	in
Eye bolt Thread Length Lb =	1.102	in
Depth Of Hole X=	1.126	in
Tubesheet thickness T =	3.937	in
Eye bolt Numble N=	4	
Max Load Angle θ =	15	°
P =	0.091	in
Root Min Diameter d1 =	0.5264925	in
Root Max Diameter d =	0.625	in
Dm (Average Diameter) = (d1+d) / 2 =	0.57574625	in
Min Ss = Minimum Value 0.4xSyb or 0.4xSyt =	14400	psi
Bundle Pulling Load Fp = IF x Wb =	5622	Ib
Impact Factor IF =	1.5	
Bundle Weight We =	3748	Ib

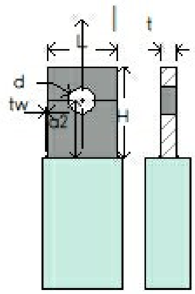




Stress			Material & Load			
Sy(Min.Yield Strength) =	36000	psi	Material:	SA-105N		
SLt= 0.6 Sy =	21600	psi	Applicable Load per eye bolt			
SLs= 0.4 Sy =	14400	psi	We = Fp/4 =	1405.5	Ib	
SLb= 0.66 Sy =	23760	psi	V = We x Cos θ =	1357.713	Ib	
			P= We x Sin θ =	364.0245	Ib	
A. EYE BOLT THREAD LENGTH						
1.Per UG-43 (g) of ASME VIII-1						
Lb1= max (ds, 0.75 x ds x (Se/St)) =	0.625	in				
2.Per Machine design 2002 Edition, Auchor: CHARLES WILSON						
Lb2= (3 x We) / (π x Dm x min Ss x N) =	0.04047134	in				
Thus. Lb=	1.102	in	≥ max (Lb1, Lb2) =	0.625	in	OK
B.tubesheet thk. Margin						
M = T-X-CA -(g/2 x tan30°) =	2.538288	in	≥ min M =	0.236	in	OK
C: Eye Bolt Strength						
1.Shear Stress: S1						
S1= 4We / (π x g^2) =	7158.13598	psi	≤ SLs =	14400	psi	OK
2.Tension Stress: S2						
S2= 4V / (π x g^2) =	6594.4284	Psi	≤ SLt =	21600	psi	OK
3.Bending Stress S3						
Section Modulus of eye bolts, Z= π x g3 =	0.42165841	in3				
S3= (Px h) /Z	1320.87364	psi	≤ SLb =	23760	psi	OK
4.Shear Stress at thickness of "C" part: S4						
S4= We / (π x C^2/4) =	7158.1	psi	≤ SLs =	14400	psi	OK
Note: 1.SLt: allowable tensile or compressive stress of eye bolt						
2.SLs: allowable shear stress of eye bolt						
3.SLb: allowable bending stress of eye bolt						

Table of Contents

Lifting Lug for Blind

Geometry Inputs	
	
Attached To	Blind
Material	SA-516 Gr.70N
Orientation	Circumferential
Distance of Lift Point From Datum	1.968"
Angular Position	0 deg
Length, L	5.118"
Height, H	6.89"
Thickness, t	0.63"
Hole Diameter, d	1.969"
Pin Diameter, Dp	1.1811"
Load Eccentricity, a_1	0"
Distance from Load to Shell or Pad, a_2	4.331"
Load Angle Normal to Vessel, β	0 deg
Load Angle from Vertical, ϕ	0 deg
Welds	
Size, t_w	0.236"

Intermediate Values	
Load Factor	1.3500
Vessel Weight (new, incl. Load Factor), W	1,041.3 lb
Lug Weight (new), W_{lug}	5.8 lb
Allowable Stress, Tensile, σ_t	14,968 psi
Allowable Stress, Shear, σ_s	9,979 psi
Allowable Stress, Bearing, σ_p	19,957 psi
Allowable Stress, Bending, σ_b	16,465 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	9,979 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values	
Required Lift Pin Diameter, d_{reqd}	0.2578"
Required Lug Thickness, t_{reqd}	0.0442"
Lug Stress Ratio, σ_{ratio}	0.02
Weld Shear Stress Ratio, τ_{ratio}	0.05
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

`F_r` = `text(force on vessel at lug)`
`F_r` = `W* text(LoadFactor)`
= 1,041 lb_f

Lug Pin Diameter - Shear stress

`d_(text(reqd))` = `sqrt((2*F_v) / (pi * sigma_s))`
= `sqrt((2*"1,041" ) / (pi * "9,979"))` = 0.2578"

`d_(reqd) / D_p` = `0.2578 / 1.1811` = `0.22` Acceptable

`sigma` = `F_v / A`
= `F_v / (2*(0.25*pi*D_p^(2)))`
= `"1,041" / (2*(0.25*pi*1.1811^2))` = `475 text( psi)`

`sigma / sigma_s` = `475 / "9,979"` = `0.05` Acceptable

Lug Thickness - Tensile stress

`t_(text(reqd))` = `F_v / ((L - d)* sigma_t)`
= `"1,041" / ((5.118 - 1.969)*"14,968")` = 0.0221"

`t_(text(reqd)) / t` = `0.0221 / 0.63` = `0.04`

`sigma` = `F_v / A`
= `F_v / ((L - d)*t)`
= `"1,041" / ((5.118 - 1.969)*0.63)` = `525 text( psi)`

`sigma / sigma_(t` = `525 / "14,968"` = `0.04` Acceptable

Lug Thickness - Bearing stress

`t_(text(reqd))` = `F_v / (D_p * sigma_p)`
= `"1,041" / (1.1811*"19,957")` = 0.0442"

`t_(text(reqd))/ t` = `0.0442 / 0.63` = `0.07` Acceptable

σ = `F_v / A_(text(bearing))`
= `F_v / (D_p *(t))`
= `"1,041" / (1.1811*(0.63))` = `"1,399" text( psi)`

`sigma / sigma_(p` = `"1,399" / "19,957"` = `0.07` Acceptable

Lug Thickness - Shear stress

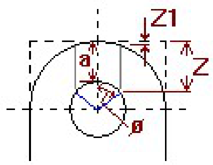
`t_(text(reqd))` = `[F_v / sigma_s] / (2*L_(text(shear)))`
= `("1,041" / "9,979") / (2*1.6697)` = 0.0312"

`t_(text(reqd)) / t` = `0.0312 / 0.63` = `0.05` Acceptable

`tau` = `F_v / A_(text(shear))`
= `F_v / (2*t*L_(text(shear)))`
= `"1,041" / (2*0.63*1.6697)` = `495 text( psi)`

`tau / sigma_s` = `495 / "9,979"` = `0.05` Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



`phi` = `55*D_p / d`
= `55*1.1811 / 1.969`
= `32.9917 deg`
`L_(text(shear))` = `(H - a2 - 0.5*d) + 0.5* D_p *(1 - cos(phi))`
= `(6.89 - 4.331 - 0.5*1.969) + 0.5*1.1811*(1 - cos(32.9917))`
= 1.6697"

Lug Plate Stress

Lug stress tensile + bending during lift:
`sigma_(text(ratio))` = `[F_(text(ten))/ (A_(text(ten)) * sigma_t)] + [M_(text(bend)) / (Z_(text(bend)) * sigma_b)] le 1`
= `[(F_r * cos( beta ) ) / (t * L * sigma_t)] + [(6 * abs(F_r * sin(beta) * text(Hght) - F_r * cos(beta) * a_1) ) / (t * L_2 * sigma_b)] le 1`
= `"1,041" * cos(0.0) / (0.63*5.118*"14,968") + 6*abs("1,041"*sin(0.0)*4.331 - "1,041"*cos(0.0)*0) / (0.63*5.118^2 * "16,465")`
= 0.02 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 0.00 deg; lift force = 1,041 lb_f

`A_(text(weld))` = `2*(0.707) * t_w *(L + t)`
= `2*(0.707)*0.236*(5.118 + 0.63)` `= 1.9181 text( in)^2`

`tau_t` = `F_(text(lug)) * cos(beta) / A_(text(weld))`
= `"1,041"*cos(0.0) / 1.9181` `= 543 text( psi)`

`tau_s` = `F_(text(lug)) * sin(beta) / A_(text(weld))`
= `"1,041"*sin(0.0) / 1.9181` `= 0 text( psi)`

`tau_b` = `M * c / I`
= `3*(F_(text(lug)) * sin(beta)*Hght - F_(text(lug)) * cos(beta)*a_1) / (0.707*h*L*(3*t + L))`
= `3*abs("1,041"*sin(0.0)*4.331 - "1,041"*cos(0.0)*(0)) / (5.9845)`
= `0 text( psi)`

`tau_(text(ratio))` = `sqrt( (tau_t + tau_b)^2 + tau_s^2 ) / tau_(text(allowable)) le 1`
= `sqrt ( (543 + 0)^2 + (0)^2 ) / "9,979"`
= 0.05 Acceptable

WRC 537 Analysis

Geometry	
Height (radial)	6.89"
Width (circumferential)	5.118"
Length	0.63"
Fillet Weld Size:	0.236"
Located On	Blind (2.284" from left end)
Location Angle	0.00 deg

Applied Loads	
Radial load, P_r	-1,041.33 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	0 lb_f-in
Longitudinal shear, V_L	0 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	10.6495"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

`gamma = R_(m) / T = 10.6495 / 10 = 1.065`

WRC 537: R_m / t < 5 (ratio not covered by WRC 537; R_m / t = 5 used)

`C_(1) = 2.204, C_(2) = 0.551 text( in)`

Note: Actual lug
`C_(1) / C_(2) gt 4, C_(1) / C_(2) = 4`
used as this is the maximum ratio covered by WRC 537.

Local circumferential pressure stress
`= (P*R_(i)) / T =0 text( psi)`

Local longitudinal pressure stress
`= (P*R_(i)) / (2*T) =0 text( psi)`

Maximum combined stress
`(P_(L)+P_(b)+Q) = 21 text( psi)`

Allowable combined stress
`(P_(L)+P_(b)+Q) = ±3*S = ±60,000 text( psi)`

The maximum combined stress
`(P_(L)+P_(b)+Q)`
is within allowable limits.

Maximum local primary membrane stress
`(P_(L)) = 10 text( psi)`

Allowable local primary membrane stress
`(P_(L)) = ±1.5*S = ±30,000 text( psi)`

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 537										
Figure	Y	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.0168	0.0942	0	0	0	0	10	10	10	10
4C*	0.9949	0.1738	10	10	10	10	0	0	0	0
1C	0.1546	0.1821	0	0	0	0	10	-10	10	-10
2C-1	0.1288	0.1821	8	-8	8	-8	0	0	0	0
3A*	0.0711	0.1304	0	0	0	0	0	0	0	0
1A	0.1031	0.1917	0	0	0	0	0	0	0	0
3B*	0.1536	0.0821	0	0	0	0	0	0	0	0
1B-1	0.0618	0.1478	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			18	2	18	2	20	0	20	0
Primary membrane circumferential stress*			10	10	10	10	10	10	10	10
3C*	0.9535	0.1738	9	9	9	9	0	0	0	0
4C*	1.0514	0.0942	0	0	0	0	10	10	10	10
1C-1	0.1966	0.1242	12	-12	12	-12	0	0	0	0
2C	0.1689	0.1242	0	0	0	0	11	-11	11	-11
4A*	0.0949	0.1304	0	0	0	0	0	0	0	0
2A	0.0637	0.1408	0	0	0	0	0	0	0	0
4B*	0.0342	0.0821	0	0	0	0	0	0	0	0
2B-1	0.1045	0.1018	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			21	-3	21	-3	21	-1	21	-1
Primary membrane longitudinal stress*			9	9	9	9	10	10	10	10
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			21	-5	21	-5	21	-1	21	-1
* denotes primary stress.										

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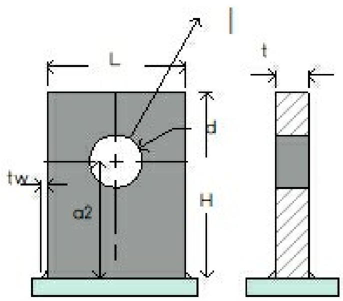
Lifting Lug #1

Geometry Inputs	
	
Attached To	Channel
Material	SA-516 Gr.70N
Orientation	Circumferential
Distance of Lift Point From Datum	31.102"
Angular Position	0 deg
Length, L	5.118"
Height, H	6.89"
Thickness, t	0.63"
Hole Diameter, d	1.969"
Pin Diameter, Dp	1.1811"
Load Eccentricity, a_1	0"
Distance from Load to Shell or Pad, a_2	4.331"
Load Angle Normal to Vessel, β	-30 deg
Load Angle from Vertical, ϕ	-30 deg
Welds	
Size, t_w	0.236"

Intermediate Values	
Load Factor	1.3500
Vessel Weight (new, incl. Load Factor), W	3,388 lb
Lug Weight (new), W_{lug}	5.8 lb
Distance from Center of Gravity to this lug, x_1	14.173"
Distance from Center of Gravity to second lug, x_2	14.173"
Allowable Stress, Tensile, σ_t	14,968 psi
Allowable Stress, Shear, σ_s	9,979 psi
Allowable Stress, Bearing, σ_p	19,957 psi
Allowable Stress, Bending, σ_b	16,465 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	9,979 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values	
Required Lift Pin Diameter, d_{reqd}	0.3533"
Required Lug Thickness, t_{reqd}	0.083"
Lug Stress Ratio, σ_{ratio}	0.13
Weld Shear Stress Ratio, τ_{ratio}	0.31
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

`F_r = text(force on vessel at lug)`
`F_r = [W / cos(phi_1 )]*(1 - x_1 / (x_1 + x_2)) = ("3,388") / cos(-30)*(1 - 14.173/ (14.173 + 14.173)) =`
1,956 lb_f

where 'x_1' is the distance between this lug and the center of gravity
'x_2' is the distance between the second lift lug and the center of gravity

Lug Pin Diameter - Shear stress

`d_(text(reqd))` = `sqrt((2*F_v) / (pi * sigma_s))`
= `sqrt((2*"1,956" ) / (pi * "9,979"))` = 0.3533"

`d_(reqd) / D_p` = `0.3533 / 1.1811` = `0.30` Acceptable

`sigma` = `F_v / A`
= `F_v / (2*(0.25*pi*D_p^(2)))`
= `"1,956" / (2*(0.25*pi*1.1811^2))` = `893 text( psi)`

`sigma / sigma_s` = `893 / "9,979"` = `0.09` Acceptable

Lug Thickness - Tensile stress

`t_(text(reqd))` = `F_v / ((L - d)* sigma_t)`
= `"1,956" / ((5.118 - 1.969)*"14,968")` = 0.0415"

`t_(text(reqd)) / t` = `0.0415 / 0.63` = `0.07`

`sigma` = `F_v / A`
= `F_v / ((L - d)*t)`
= `"1,956" / ((5.118 - 1.969)*0.63)` = `986 text( psi)`

`sigma / sigma_(t` = `986 / "14,968"` = `0.07` Acceptable

Lug Thickness - Bearing stress

`t_(text(reqd))` = `F_v / (D_p * sigma_p)`
= `"1,956" / (1.1811*"19,957")` = 0.083"

`t_(text(reqd))/ t` = `0.083 / 0.63` = `0.13` Acceptable

σ = `F_v / A_(text(bearing))`
= `F_v / (D_p *(t))`
= `"1,956" / (1.1811*(0.63))` = `"2,629" text( psi)`

`sigma / sigma_(p` = `"2,629" / "19,957"` = `0.13` Acceptable

Lug Thickness - Shear stress

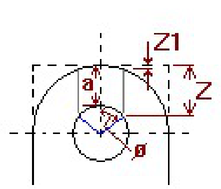
`t_(text(reqd))` = `[F_v / sigma_s] / (2*L_(text(shear)))`
= `("1,956" / "9,979") / (2*1.6697)` = 0.0587"

`t_(text(reqd)) / t` = `0.0587 / 0.63` = `0.09` Acceptable

`tau` = `F_v / A_(text(shear))`
= `F_v / (2*t*L_(text(shear)))`
= `"1,956" / (2*0.63*1.6697)` = `930 text( psi)`

`tau / sigma_s` = `930 / "9,979"` = `0.09` Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



`phi` = `55*D_p / d`
= `55*1.1811 / 1.969`
= `32.9917 deg`
`L_(text(shear))` = `(H - a2 - 0.5*d) + 0.5* D_p *(1 - cos(phi))`
= `(6.89 - 4.331 - 0.5*1.969) + 0.5*1.1811*(1 - cos(32.9917))`
= 1.6697"

Lug Plate Stress

Lug stress tensile + bending during lift:
`sigma_(text(ratio))` = `[F_(text(ten))/ (A_(text(ten)) * sigma_t)] + [M_(text(bend)) / (Z_(text(bend)) * sigma_b)] le 1`
= `[(F_r * cos( beta ) ) / (t * L * sigma_t)] + [(6 * abs(F_r * sin(beta) * text(Hght) - F_r * cos(beta) * a_1) ) / (t * L_2 * sigma_b)] le 1`
= `"1,956" * cos(-30.0) / (0.63*5.118*"14,968") + 6*abs("1,956"*sin(-30.0)*4.331 - "1,956"*cos(-30.0)*0) / (0.63*5.118^2 * "16,465")`
= 0.13 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle -30.00 deg; lift force = 1,956 lb_f

`A_(text(weld))` = `2*(0.707) * t_w *(L + t)`
= `2*(0.707)*0.236*(5.118 + 0.63)` `= 1.9181 text( in)^2`

`tau_t` = `F_(text(lug)) * cos(beta) / A_(text(weld))`
= `"1,956"*cos(-30.0) / 1.9181` `= 883 text( psi)`

`tau_s` = `F_(text(lug)) * sin(beta) / A_(text(weld))`
= `"1,956"*sin(-30.0) / 1.9181` `= -510 text( psi)`

`tau_b` = `M * c / I`
= `3*(F_(text(lug)) * sin(beta)*Hght - F_(text(lug)) * cos(beta)*a_1) / (0.707*h*L*(3*t + L))`
= `3*abs("1,956"*sin(-30.0)*4.331 - "1,956"*cos(-30.0)*(0)) / (5.9845)`
= `"2,123" text( psi)`

`tau_(text(ratio))` = `sqrt( (tau_t + tau_b)^2 + tau_s^2 ) / tau_(text(allowable)) le 1`
= `sqrt ( (883 + "2,123")^2 + (-510)^2 ) / "9,979"`
= 0.31 Acceptable

WRC 537 Analysis

Geometry	
Height (radial)	6.89"
Width (circumferential)	0.63"
Length	5.118"
Fillet Weld Size:	0.236"
Located On	Channel (5.315" from left end)
Location Angle	0.00 deg

Applied Loads	
Radial load, P_r	-1,694.02 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	-4,235.9 lb_f-in
Longitudinal shear, V_L	-978.04 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	11.6665"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

$\gamma = R_m / T = 11.6665 / 0.709 = 16.4549$

$C_1 = 0.551, C_2 = 2.204 \text{ in}$

Note: Actual lug
$C_1 / C_2 < 1 / 4, C_1 / C_2 = 1 / 4$
used as this is the minimum ratio covered by WRC 537.

Local circumferential pressure stress
$= (P \cdot R_i) / T = 0 \text{ psi}$

Local longitudinal pressure stress
$= (P \cdot R_i) / (2 \cdot T) = 0 \text{ psi}$

Maximum combined stress
$(P_L+P_b+Q) = 6{,}214 \text{ psi}$

Allowable combined stress
$(P_L+P_b+Q) = \pm 3 \cdot S = \pm 60{,}000 \text{ psi}$

The maximum combined stress
(P_L+P_b+Q)
is within allowable limits.

Maximum local primary membrane stress
$(P_L) = 935 \text{ psi}$

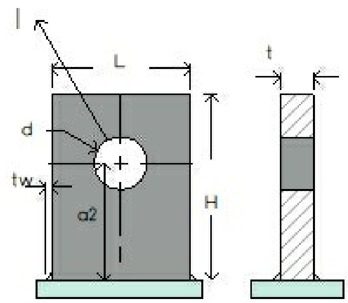
Allowable local primary membrane stress
$(P_L) = \pm 1.5 \cdot S = \pm 30{,}000 \text{ psi}$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 537										
Figure	**Y**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	2.5846	0.1398	0	0	0	0	529	529	529	529
4C*	2.9004	0.1134	594	594	594	594	0	0	0	0
1C	0.1762	0.0831	0	0	0	0	3,562	-3,562	3,562	-3,562
2C-1	0.1514	0.0831	3,061	-3,061	3,061	-3,061	0	0	0	0
3A*	0.2043	0.075	0	0	0	0	0	0	0	0
1A	0.1036	0.098	0	0	0	0	0	0	0	0
3B*	1.367	0.119	341	341	-341	-341	0	0	0	0
1B-1	0.0547	0.1069	2,218	-2,218	-2,218	2,218	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			6,214	-4,344	1,096	-590	4,091	-3,033	4,091	-3,033
Primary membrane circumferential stress*			935	935	253	253	529	529	529	529
3C*	2.8032	0.1134	574	574	574	574	0	0	0	0
4C*	2.7914	0.1398	0	0	0	0	572	572	572	572
1C-1	0.1456	0.1181	2,944	-2,944	2,944	-2,944	0	0	0	0
2C	0.1137	0.1181	0	0	0	0	2,298	-2,298	2,298	-2,298
4A*	0.2755	0.075	0	0	0	0	0	0	0	0
2A	0.0557	0.1373	0	0	0	0	0	0	0	0
4B*	0.3854	0.119	170	170	-170	-170	0	0	0	0
2B-1	0.0718	0.1473	2,113	-2,113	-2,113	2,113	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			5,801	-4,313	1,235	-427	2,870	-1,726	2,870	-1,726
Primary membrane longitudinal stress*			744	744	404	404	572	572	572	572
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	156	156	-156	-156
Total Shear stress			0	0	0	0	156	156	-156	-156
Combined stress (P_L+P_b+Q)			6,214	-4,344	1,235	-590	4,111	-3,051	4,111	-3,051

* denotes primary stress.

Lifting Lug #2

Geometry Inputs	
	
Attached To	Channel
Material	SA-516 Gr.70N
Orientation	Circumferential
Distance of Lift Point From Datum	2.756"
Angular Position	0 deg
Length, L	5.118"
Height, H	6.89"
Thickness, t	0.63"
Hole Diameter, d	1.969"
Pin Diameter, Dp	1.1811"
Load Eccentricity, a_1	0"
Distance from Load to Shell or Pad, a_2	4.331"
Load Angle Normal to Vessel, β	30 deg
Load Angle from Vertical, ϕ	30 deg
Welds	
Size, t_w	0.236"

Intermediate Values	
Load Factor	1.3500
Vessel Weight (new, incl. Load Factor), W	3,388 lb
Lug Weight (new), W_{lug}	5.8 lb
Distance from Center of Gravity to this lug, x_1	14.173"
Distance from Center of Gravity to second lug, x_2	14.173"
Allowable Stress, Tensile, σ_t	14,968 psi
Allowable Stress, Shear, σ_s	13,320 psi
Allowable Stress, Bearing, σ_p	29,970 psi
Allowable Stress, Bending, σ_b	22,201 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	13,320 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values	
Required Lift Pin Diameter, d_{reqd}	0.3058"
Required Lug Thickness, t_{reqd}	0.0553"
Lug Stress Ratio, σ_{ratio}	0.1
Weld Shear Stress Ratio, τ_{ratio}	0.23
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

`F_r = text(force on vessel at lug)`
`F_r = [W / cos(phi_1 )]*(1 - x_1 / (x_1 + x_2)) = ("3,388") / cos(30)*(1 - 14.173/ (14.173 + 14.173)) =` 1,956 lb_f

where 'x_1' is the distance between this lug and the center of gravity
'x_2' is the distance between the second lift lug and the center of gravity

Lug Pin Diameter - Shear stress

`d_(text(reqd))` = `sqrt((2*F_v) / (pi * sigma_s))`
= `sqrt((2*"1,956" ) / (pi * "13,320"))` = 0.3058"

`d_(reqd) / D_p` = `0.3058 / 1.1811` = `0.26` Acceptable

`sigma` = `F_v / A`
= `F_v / (2*(0.25*pi*D_p^(2)))`
= `"1,956" / (2*(0.25*pi*1.1811^2))` = `893 text( psi)`

`sigma / sigma_s` = `893 / "13,320"` = `0.07` Acceptable

Lug Thickness - Tensile stress

`t_(text(reqd))` = `F_v / ((L - d)* sigma_t)`
= `"1,956" / ((5.118 - 1.969)*"14,968")` = 0.0415"

`t_(text(reqd)) / t` = `0.0415 / 0.63` = `0.07`

`sigma` = `F_v / A`
= `F_v / ((L - d)*t)`
= `"1,956" / ((5.118 - 1.969)*0.63)` = `986 text( psi)`

`sigma / sigma_(t` = `986 / "14,968"` = `0.07` Acceptable

Lug Thickness - Bearing stress

`t_(text(reqd))` = `F_v / (D_p * sigma_p)`
= `"1,956" / (1.1811*"29,970")` = 0.0553"

`t_(text(reqd))/ t` = `0.0553 / 0.63` = `0.09` Acceptable

σ = `F_v / A_(text(bearing))`
= `F_v / (D_p *(t))`
= `"1,956" / (1.1811*(0.63))` = `"2,629" text( psi)`

`sigma / sigma_(p` = `"2,629" / "29,970"` = `0.09` Acceptable

Lug Thickness - Shear stress

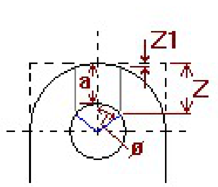
t_{reqd} = $[F_v / \sigma_s] / (2 \cdot L_{\text{shear}})$
= $(\text{1,956} / \text{13,320}) / (2 \cdot 1.6697)$ = 0.044"

t_{reqd} / t = $0.044 / 0.63$ = 0.07 Acceptable

τ = F_v / A_{shear}
= $F_v / (2 \cdot t \cdot L_{\text{shear}})$
= $\text{1,956} / (2 \cdot 0.63 \cdot 1.6697)$ = 930 psi

τ / σ_s = $930 / \text{13,320}$ = 0.07 Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



ϕ = $55 \cdot D_p / d$
= $55 \cdot 1.1811 / 1.969$
= 32.9917 deg
L_{shear} = $(H - a2 - 0.5 \cdot d) + 0.5 \cdot D_p \cdot (1 - \cos(\phi))$
= $(6.89 - 4.331 - 0.5 \cdot 1.969) + 0.5 \cdot 1.1811 \cdot (1 - \cos(32.9917))$
= 1.6697"

Lug Plate Stress

Lug stress tensile + bending during lift:
σ_{ratio} = $[F_{\text{ten}} / (A_{\text{ten}} \cdot \sigma_t)] + [M_{\text{bend}} / (Z_{\text{bend}} \cdot \sigma_b)] \le 1$
= $[(F_r \cdot \cos(\beta)) / (t \cdot L \cdot \sigma_t)] + [(6 \cdot |F_r \cdot \sin(\beta) \cdot \text{Hght} - F_r \cdot \cos(\beta) \cdot a_1|) / (t \cdot L_2 \cdot \sigma_b)] \le 1$
= $\text{1,956} \cdot \cos(30.0) / (0.63 \cdot 5.118 \cdot \text{14,968}) + 6 \cdot |\text{1,956} \cdot \sin(30.0) \cdot 4.331 - \text{1,956} \cdot \cos(30.0) \cdot 0| / (0.63 \cdot 5.118^2 \cdot \text{22,201})$
= 0.10 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 30.00 deg; lift force = 1,956 lb_f

A_{weld} = $2 \cdot (0.707) \cdot t_w \cdot (L + t)$
= $2 \cdot (0.707) \cdot 0.236 \cdot (5.118 + 0.63) = 1.9181 \text{ in}^2$

τ_t = $F_{\text{lug}} \cdot \cos(\beta) / A_{\text{weld}}$
= $\text{1,956} \cdot \cos(30.0) / 1.9181$ $= 883 \text{ psi}$

τ_s = $F_{\text{lug}} \cdot \sin(\beta) / A_{\text{weld}}$
= $\text{1,956} \cdot \sin(30.0) / 1.9181$ $= 510 \text{ psi}$

τ_b = $M \cdot c / I$
= $3 \cdot (F_{\text{lug}} \cdot \sin(\beta) \cdot Hght - F_{\text{lug}} \cdot \cos(\beta) \cdot a_1) / (0.707 \cdot h \cdot L \cdot (3 \cdot t + L))$
= $3 \cdot |\text{1,956} \cdot \sin(30.0) \cdot 4.331 - \text{1,956} \cdot \cos(30.0) \cdot (0)| / (5.9845)$
= $\text{2,123} \text{ psi}$

τ_{ratio} = $\sqrt{(\tau_t + \tau_b)^2 + \tau_s^2} / \tau_{\text{allowable}} \le 1$
= $\sqrt{(883 + \text{2,123})^2 + (510)^2} / \text{13,320}$
= 0.23 Acceptable

WRC 537 Analysis

Geometry	
Height (radial)	6.89"
Width (circumferential)	0.63"
Length	5.118"
Fillet Weld Size:	0.236"
Located On	Channel (0.197" from right end)
Location Angle	0.00 deg

Applied Loads	
Radial load, P_r	-1,694.02 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	4,235.9 lb_f-in
Longitudinal shear, V_L	978.04 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	11.6665"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

$\gamma = R_m / T = 11.6665 / 0.709 = 16.4549$

$C_1 = 0.551, C_2 = 2.204 \text{ in}$

Note: Actual lug
$C_1 / C_2 < 1 / 4, C_1 / C_2 = 1 / 4$
used as this is the minimum ratio covered by WRC 537.

Local circumferential pressure stress
$= (P \cdot R_i) / T = 0 \text{ psi}$

Local longitudinal pressure stress
$= (P \cdot R_i) / (2 \cdot T) = 0 \text{ psi}$

Maximum combined stress
$(P_L+P_b+Q) = 6{,}214 \text{ psi}$

Allowable combined stress
$(P_L+P_b+Q) = \pm 3 \cdot S = \pm 60{,}000 \text{ psi}$

The maximum combined stress
(P_L+P_b+Q)
is within allowable limits.

Maximum local primary membrane stress
$(P_L) = 935 \text{ psi}$

Allowable local primary membrane stress
$(P_L) = \pm 1.5 \cdot S = \pm 30{,}000 \text{ psi}$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 537										
Figure	**Y**	**β**	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	2.5846	0.1398	0	0	0	0	529	529	529	529
4C*	2.9004	0.1134	594	594	594	594	0	0	0	0
1C	0.1762	0.0831	0	0	0	0	3,562	-3,562	3,562	-3,562
2C-1	0.1514	0.0831	3,061	-3,061	3,061	-3,061	0	0	0	0
3A*	0.2043	0.075	0	0	0	0	0	0	0	0
1A	0.1036	0.098	0	0	0	0	0	0	0	0
3B*	1.367	0.119	-341	-341	341	341	0	0	0	0
1B-1	0.0547	0.1069	-2,218	2,218	2,218	-2,218	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			1,096	-590	6,214	-4,344	4,091	-3,033	4,091	-3,033
Primary membrane circumferential stress*			253	253	935	935	529	529	529	529
3C*	2.8032	0.1134	574	574	574	574	0	0	0	0
4C*	2.7914	0.1398	0	0	0	0	572	572	572	572
1C-1	0.1456	0.1181	2,944	-2,944	2,944	-2,944	0	0	0	0
2C	0.1137	0.1181	0	0	0	0	2,298	-2,298	2,298	-2,298
4A*	0.2755	0.075	0	0	0	0	0	0	0	0
2A	0.0557	0.1373	0	0	0	0	0	0	0	0
4B*	0.3854	0.119	-170	-170	170	170	0	0	0	0
2B-1	0.0718	0.1473	-2,113	2,113	2,113	-2,113	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			1,235	-427	5,801	-4,313	2,870	-1,726	2,870	-1,726
Primary membrane longitudinal stress*			404	404	744	744	572	572	572	572
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	-156	-156	156	156
Total Shear stress			0	0	0	0	-156	-156	156	156
Combined stress (P_L+P_b+Q)			1,235	-590	6,214	-4,344	4,111	-3,051	4,111	-3,051

* denotes primary stress.

Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Wed Aug 10 10:25:32 2022.

Model Notes

Model Notes

```
Input Echo:

Model Type                    : Cylindrical Shell

Parent Geometry
        Parent Outside Diam.  :      24.042 in.
        Thickness             :       0.584 in.
        Fillet Along Shell    :       0.375 in.

Parent Properties:
        Cold Allowable        :     20000.0 psi
        Hot  Allowable        :     20000.0 psi
        Material ID #2        :  Low Alloy Steel
        Ultimate Tensile (Amb) :    70000.0 psi
        Yield Strength (Amb)  :     38000.0 psi
        Yield Strength (Hot)  :     35700.0 psi
        Elastic Modulus (Amb) :  29452900.0 psi
        Poissons Ratio        :       0.300
        Weight Density        :  0.2830E+00 lb./cu.in.

Hillside Offset Distance      :       6.299 in.

Nozzle Geometry
        Nozzle Outside Diam.  :       6.626 in.
        Thickness             :       0.437 in.
        Length                :      16.053 in.
        Nozzle Weld Length    :       0.375 in.
        RePad Width           :       2.593 in.
        RePad Thickness       :       0.709 in.
        RePad Weld Leg        :       0.551 in.
        Nozzle Tilt Angle     :       0.000 deg.
        Distance from Top     :       9.842 in.
        Distance from Bottom  :       9.843 in.

Nozzle Properties
        Cold Allowable        :     17100.0 psi
        Hot  Allowable        :     17100.0 psi
        Material ID #2        :  Low Alloy Steel
        Ultimate Tensile (Amb) :    60000.0 psi
        Yield Strength (Amb)  :     35000.0 psi
        Yield Strength (Hot)  :     32900.0 psi
        Elastic Modulus (Amb) :  29452900.0 psi
        Poissons Ratio        :       0.300
        Weight Density        :  0.2830E+00 lb./cu.in.

Design Operating Cycles       :          0.
Ambient Temperature (Deg.)    :       70.00

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    :      150.00 deg.
Nozzle Outside Temperature    :      150.00 deg.
Vessel Inside  Temperature    :      150.00 deg.
```

Nozzle T1,T2 FEA Calculation

WRC 537 Convention		Global	
Pr	2800.0 lbf	Fx	3500.0 lbf
Vc	3500.0 lbf	Fy	-2800.0 lbf
Vl	3500.0 lbf	Fz	3500.0 lbf
Mt	103440.0 lbf-in	Mx	742.9 ft-lbf
Ml	64080.0 lbf-in	My	8620.0 ft-lbf
Mc	81120.0 lbf-in	Mz	-2162.9 ft-lbf

```
Vessel Outside Temperature    :     150.00 deg.

Nozzle Pressure               :      425.0 psi
Vessel Pressure               :      425.0 psi


FEA Model Loads:
These are the user defined loads applied to the FEA model
at the end of the nozzle in global coordinates.

Forces( lb.)  Moments (ft-lb)

Load Case        FX          FY          FZ          MX          MY          MZ
--------------------------------------------------------------------------------
   OPER:     3500.0     -2800.0      3500.0       742.9      8620.0     -2162.9

Both ends of the model are "fixed," except that one end
is free axially so that longitudinal pressure stresses
may be developed in the geometry.

Stresses are NOT averaged.

Vessel Centerline  Vector    :  0.000   0.000   1.000
Nozzle Orientation Vector    :  0.000   1.000   0.000
```

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```
Load Case Report
FEPipe Version 14.0           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   7  LOAD CASES ANALYZED ARE:

  1   SUSTAINED       (Pr Only)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.

      /-------- Loads in Case    1
        Pressure Case     1

  2   OPERATING       (Fatigue Calc Performed)

      Case run to compute the operating stresses used in
      secondary, peak and range calculations as needed.

      /-------- Loads in Case    2
        Pressure Case     1
        Loads from (Operating)

  3   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case    3
        Loads from (Axial)

  4   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case    4
        Loads from (Inplane)

  5   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case    5
        Loads from (Outplane)

  6   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
```

/-------- Loads in Case 6
Loads from (Torsion)

7 Program Generated -- Force Only

Case run to compute sif's and flexibilities.
/-------- Loads in Case 7
Pressure Case 1

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Solution Data
FEPipe Version 14.0 Jobname: NOZZLE $P
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Solution Data

Maximum Solution Row Size = 636
Number of Nodes = 2123
Number of Elements = 684
Number of Solution Cases = 7

Summation of Loads per Case

Case #	FX	FY	FZ
1	0.	-1742.	174648.
2	3500.	-4842.	178149.
3	1.	169935.	0.
4	0.	0.	3.
5	-2.	0.	0.
6	0.	0.	0.
7	0.	-1742.	174648.

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ASME Code Stress Output Plots
FEPipe Version 14.0 Jobname: NOZZLE $P
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ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 1

2) Qb < SPS (SUS,Bending) Case 1

3) Pl+Pb+Q < SPS (SUS,Inside) Case 1

4) Pl+Pb+Q < SPS (SUS,Outside) Case 1

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

6) Pl+Pb+Q < SPS (OPE,Inside) Case 2

7) Pl+Pb+Q < SPS (OPE,Outside) Case 2

8) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2

9) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

10) Membrane < User (OPE,Membrane) Case 2

11) Bending < User (OPE,Bending) Case 2

12) Pl+Pb+Q+F < Sa (SIF,Outside) Case 3

13) Pl+Pb+Q+F < Sa (SIF,Outside) Case 4

14) Pl+Pb+Q+F < Sa (SIF,Outside) Case 5

15) Pl+Pb+Q+F < Sa (SIF,Outside) Case 6

16) Pl+Pb+Q+F < Sa (SIF,Outside) Case 7

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```
Stress Results - Notes
FEPipe Version 14.0          Jobname: NOZZLE              $P
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```

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.
- Using 2013-2017 ASME Section VIII Division 2
- Use Polished Bar fatigue curve.
- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.
- Primary bending stresses at discontinuities are treated like secondary stresses.
- Use Equivalent Stress (Von Mises).
- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.
- Use local tensor values for averaged and not averaged stresses.

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```
ASME Overstressed Areas
FEPipe Version 14.0          Jobname: NOZZLE              $P
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```

ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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```
Highest Primary Stress Ratios
FEPipe Version 14.0          Jobname: NOZZLE              $P
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```

Highest Primary Stress Ratios $X

Header/Pad at Junction

Pl SPL Primary Membrane Load Case 1

```
     6,184          35,700     Plot Reference:
       psi             psi     1) Pl < SPL (SUS,Membrane) Case 1

             17%


Branch at Junction

        Pl             SPL     Primary Membrane Load Case 1
     4,106          32,900     Plot Reference:
       psi             psi     1) Pl < SPL (SUS,Membrane) Case 1

             12%


Branch Transition

        Pl             SPL     Primary Membrane Load Case 1
     3,278          32,900     Plot Reference:
       psi             psi     1) Pl < SPL (SUS,Membrane) Case 1

              9%


Pad Outer Edge Weld

        Pl             SPL     Primary Membrane Load Case 1
     8,841          35,700     Plot Reference:
       psi             psi     1) Pl < SPL (SUS,Membrane) Case 1

             24%


Header/Pad removed from Junction

        Pl             SPL     Primary Membrane Load Case 1
     9,138          35,700     Plot Reference:
       psi             psi     1) Pl < SPL (SUS,Membrane) Case 1

             25%


Branch removed from Junction

        Pl             SPL     Primary Membrane Load Case 1
     3,220          32,900     Plot Reference:
       psi             psi     1) Pl < SPL (SUS,Membrane) Case 1

              9%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 14.0            Jobname: NOZZLE              $P
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Highest Secondary Stress Ratios                       $X


Header/Pad at Junction

  Pl+Pb+Q              SPS     Primary+Secondary (Inner) Load Case 2
    16,147          73,700     Plot Reference:
       psi             psi     6) Pl+Pb+Q < SPS (OPE,Inside) Case 2

             21%


Branch at Junction

  Pl+Pb+Q              SPS     Primary+Secondary (Outer) Load Case 2
    24,475          67,900     Plot Reference:
       psi             psi     7) Pl+Pb+Q < SPS (OPE,Outside) Case 2

             36%
```

```
Branch Transition

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
   11,214        67,900     Plot Reference:
      psi           psi     7) Pl+Pb+Q < SPS (OPE,Outside) Case 2

            16%

Pad Outer Edge Weld

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
   26,981        73,700     Plot Reference:
      psi           psi     7) Pl+Pb+Q < SPS (OPE,Outside) Case 2

            36%

Header/Pad removed from Junction

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
   12,808        73,700     Plot Reference:
      psi           psi     6) Pl+Pb+Q < SPS (OPE,Inside) Case 2

            17%

Branch removed from Junction

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
   13,327        67,900     Plot Reference:
      psi           psi     7) Pl+Pb+Q < SPS (OPE,Outside) Case 2

            19%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 14.0           Jobname: NOZZLE              $P
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Highest Fatigue Stress Ratios                        $X


Header/Pad at Junction

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 2
   10,899     0.000 Life    Stress Concentration Factor = 1.350
      psi     0.006 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 10,273,540.
Allowable                   "B31" Fatigue Stress Allowable = 50000.0
1,805,334                   Markl Fatigue Stress Allowable = 245000.0
      psi                   WRC 474 Mean Cycles to Failure = 1,980,289.
                            WRC 474 99% Probability Cycles = 460,048.
       0%                   WRC 474 95% Probability Cycles = 638,728.
                            BS5500 Allowed Cycles(Curve F) = 368,047.
                            Membrane-to-Bending Ratio = 0.747
                            Bending-to-PL+PB+Q Ratio = 0.572
                            Plot Reference:
                            8) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2


Branch at Junction

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 2
   16,521     0.000 Life    Stress Concentration Factor = 1.350
      psi     0.009 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 187,395.
Allowable                   "B31" Fatigue Stress Allowable = 42750.0
1,805,334                   Markl Fatigue Stress Allowable = 245000.0
      psi                   WRC 474 Mean Cycles to Failure = 1,189,072.
                            WRC 474 99% Probability Cycles = 276,237.
       0%                   WRC 474 95% Probability Cycles = 383,526.
                            BS5500 Allowed Cycles(Curve F) = 142,734.
                            Membrane-to-Bending Ratio = 0.515
                            Bending-to-PL+PB+Q Ratio = 0.660
                            Plot Reference:
```

```
                             9) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2


Branch Transition

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
    5,607     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.003 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 42750.0
1,805,334                    Markl Fatigue Stress Allowable = 245000.0
      psi                    WRC 474 Mean Cycles to Failure = 12,279,100.
                             WRC 474 99% Probability Cycles = 2,852,598.
       0%                    WRC 474 95% Probability Cycles = 3,960,530.
                             BS5500 Allowed Cycles(Curve F) = 1,483,805.
                             Membrane-to-Bending Ratio = 7.952
                             Bending-to-PL+PB+Q Ratio = 0.112
                             Plot Reference:
                             9) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2


Pad Outer Edge Weld

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
   18,213     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.010 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 131,888.
Allowable                    "B31" Fatigue Stress Allowable = 50000.0
1,805,334                    Markl Fatigue Stress Allowable = 245000.0
      psi                    WRC 474 Mean Cycles to Failure = 710,409.
                             WRC 474 99% Probability Cycles = 165,038.
       1%                    WRC 474 95% Probability Cycles = 229,137.
                             BS5500 Allowed Cycles(Curve F) = 106,540.
                             Membrane-to-Bending Ratio = 0.490
                             Bending-to-PL+PB+Q Ratio = 0.671
                             Plot Reference:
                             9) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2


Header/Pad removed from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 2
    6,404     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.004 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 50000.0
1,805,334                    Markl Fatigue Stress Allowable = 245000.0
      psi                    WRC 474 Mean Cycles to Failure = 6,782,998.
                             WRC 474 99% Probability Cycles = 1,575,782.
       0%                    WRC 474 95% Probability Cycles = 2,187,806.
                             BS5500 Allowed Cycles(Curve F) = 995,984.
                             Membrane-to-Bending Ratio = 1.782
                             Bending-to-PL+PB+Q Ratio = 0.359
                             Plot Reference:
                             8) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2


Branch removed from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
    6,664     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.004 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 42750.0
1,805,334                    Markl Fatigue Stress Allowable = 245000.0
      psi                    WRC 474 Mean Cycles to Failure = 7,182,235.
                             WRC 474 99% Probability Cycles = 1,668,530.
       0%                    WRC 474 95% Probability Cycles = 2,316,577.
                             BS5500 Allowed Cycles(Curve F) = 884,104.
                             Membrane-to-Bending Ratio = 5.313
                             Bending-to-PL+PB+Q Ratio = 0.158
                             Plot Reference:
                             9) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2
```

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```
Stress Intensification Factors
FEPipe Version 14.0          Jobname: NOZZLE             $P
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```

Stress Intensification Factors $X

Branch/Nozzle Sif Summary

	Peak	Primary	Secondary	SSI
Axial :	2.449	1.814	3.628	1.229
Inplane :	1.575	1.167	2.334	1.163
Outplane:	1.960	1.452	2.904	1.167
Torsion :	1.038	0.965	1.538	1.019
Pressure:	1.349	1.045	1.998	1.071

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 :	6.626	in.
Pipe Thk:	0.437	in.
Z approx:	13.147	cu.in.
Z exact :	12.341	cu.in.

(SSI = SIF^x)	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.665	0.340	0.554	-0.947	0.146

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor = 7.841
Header Pressure i-factor = 2.765

The B31.3 pressure i-factors should be used with with F/A, where F is the axial force due to pressure, and A is the area of the pipe wall. This is equivalent to finding the pressure stress from (ip)(PD/4T).

B31.3 (Branch)		
Peak Stress Sif	0.000	Axial
	1.880	Inplane
	2.257	Outplane
	1.000	Torsional
B31.1 (Branch)		
Peak Stress Sif	0.000	Axial
	2.257	Inplane
	2.257	Outplane
	2.257	Torsional
WRC 330 (Branch)		
Peak Stress Sif	0.000	Axial
	3.016	Inplane
	2.257	Outplane
	3.016	Torsional

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Allowable Loads
FEPipe Version 14.0 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 (lb.)	159012.	48047.	72070.
Inplane Moment (in. lb.)	359004.	76704.	162715.
Outplane Moment (in. lb.)	288589.	61660.	130800.
Torsional Moment (in. lb.)	544825.	164624.	246936.

Pressure	(psi)	1791.91	425.00	425.00

PRIMARY Load Type:		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(lb.)	154094.	43026.	64538.
Inplane Moment	(in. lb.)	347901.	71767.	152241.
Outplane Moment	(in. lb.)	279663.	57691.	122381.
Torsional Moment	(in. lb.)	420664.	122722.	184082.
Pressure	(psi)	1660.37	425.00	425.00

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.

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Flexibilities
FEPipe Version 14.0 Jobname: NOZZLE $P
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Flexibilities $X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiffnesses 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 = 6.626 in.
Wall Thickness = 0.437 in.

Axial Translational Stiffness	=	10992307.	lb./in.
Inplane Rotational Stiffness	=	2863321.	in.lb./deg
Outplane Rotational Stiffness	=	1390201.	in.lb./deg
Torsional Rotational Stiffness	=	13309852.	in.lb./deg

Intersection Flexibility Factors for Branch/Nozzle :

Find axial stiffness: K = 3EI/(kd)^3 lb./in.
Find bending and torsional stiffnesses: K = EI/(kd) in.lb.per radian.
The EI product is 0.12061E+10 lb.in.^2
The value of (d) to use is: 6.189 in..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor	(k) =	1.116
Inplane Flexibility Factor	(k) =	1.188
Outplane Flexibility Factor	(k) =	2.447
Torsional Flexibility Factor	(k) =	0.256

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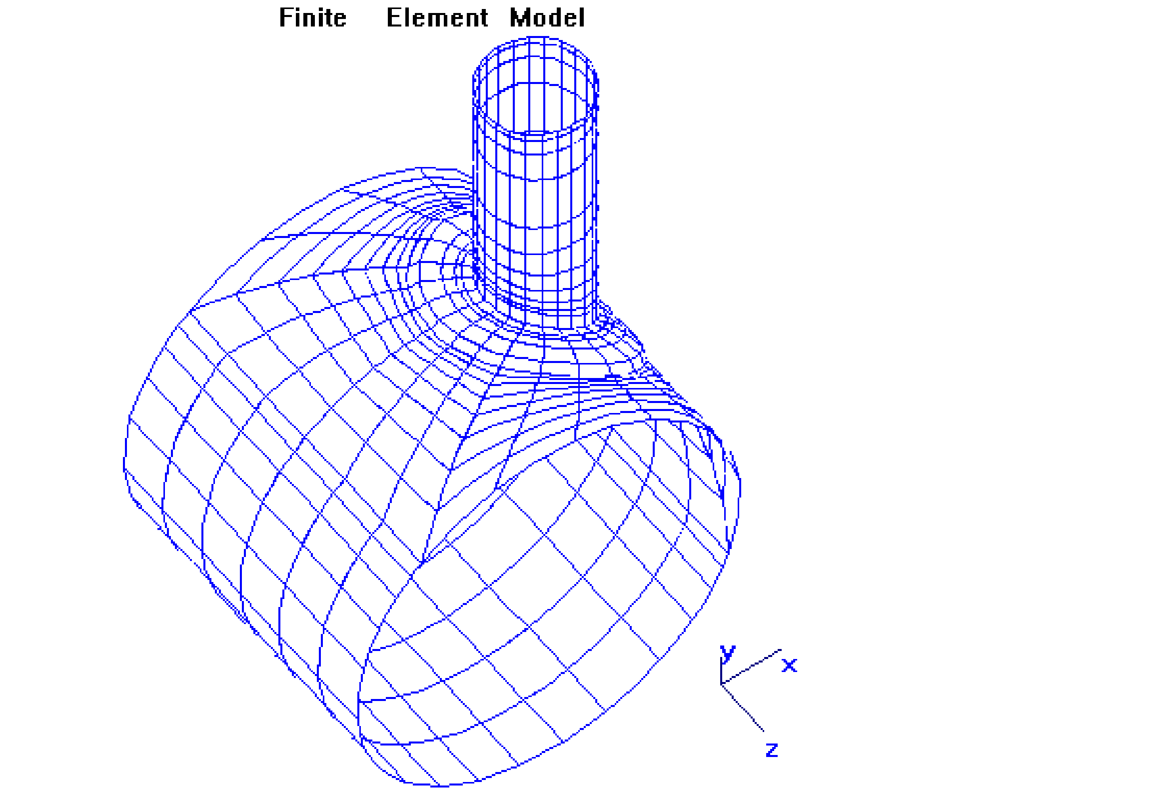
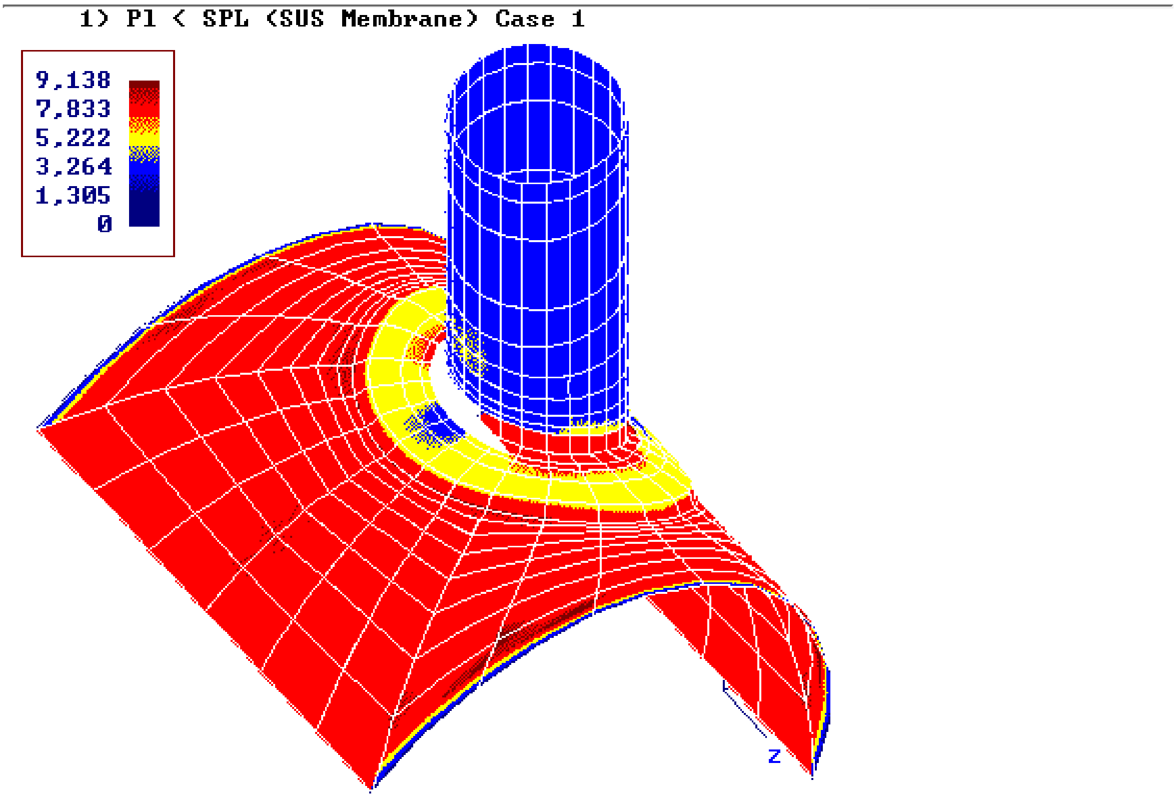
Nozzle T1,T2 FEA Calculation

Nozzle T1,T2 FEA Calculation

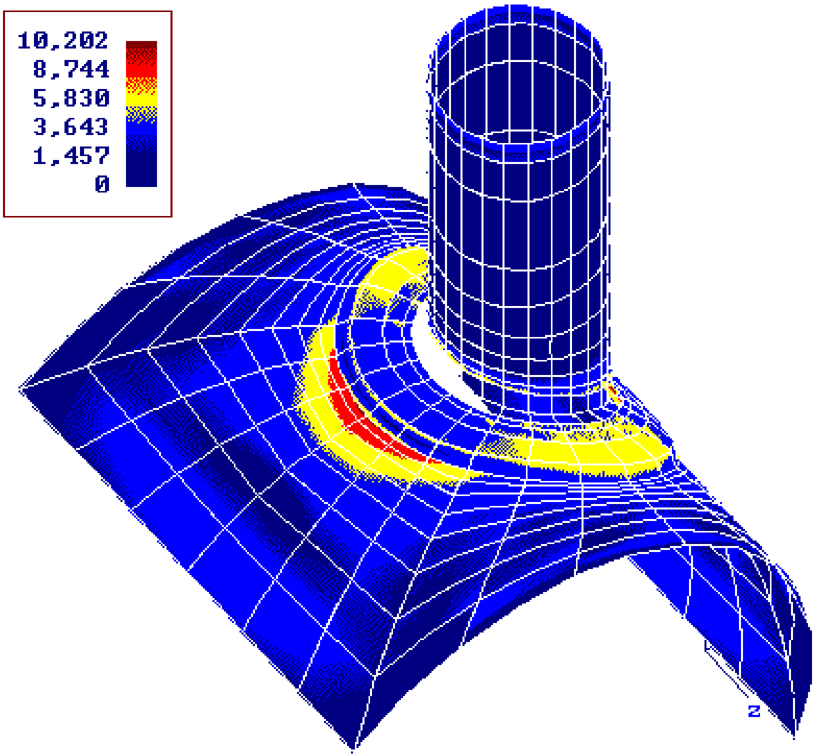
Finite Element Model

Elements at Discontinuity

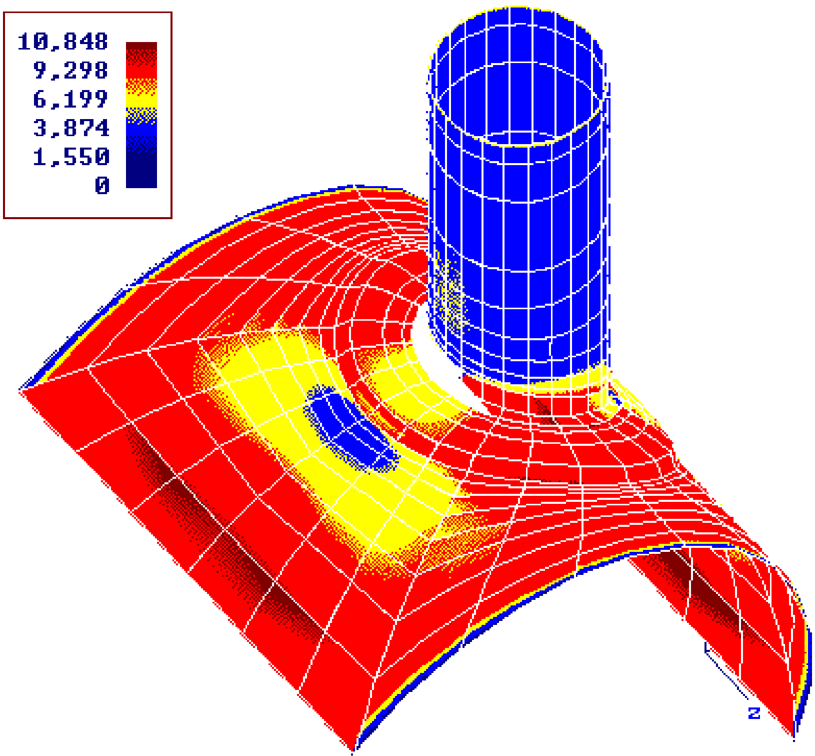

Finite Element Model
y
x
z


1) Pl < SPL (SUS Membrane) Case 1
9,138
7,833
5,222
3,264
1,305
0
z

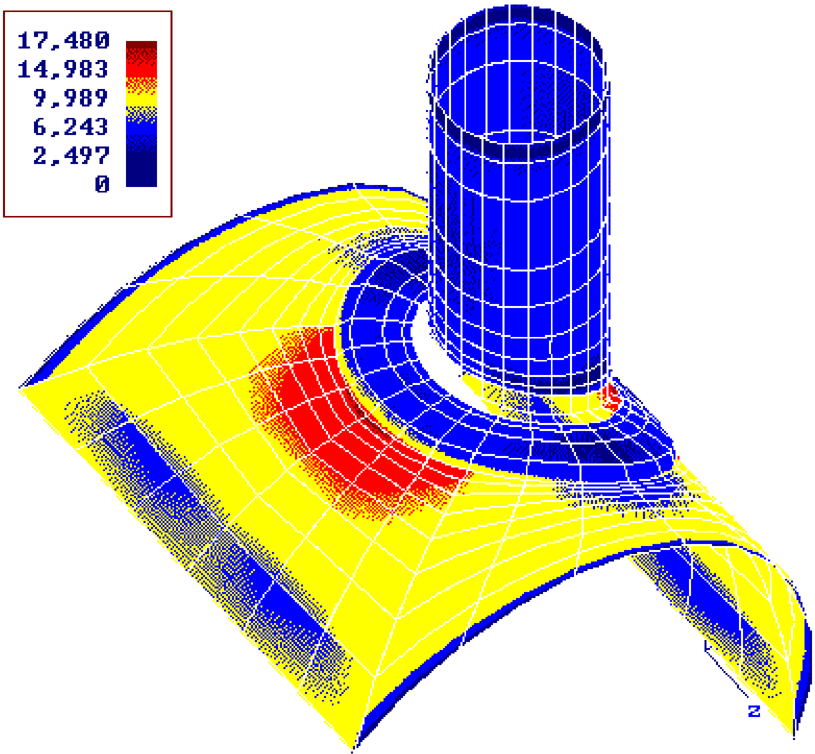
2) Qb < SPS (SUS Bending) Case 1



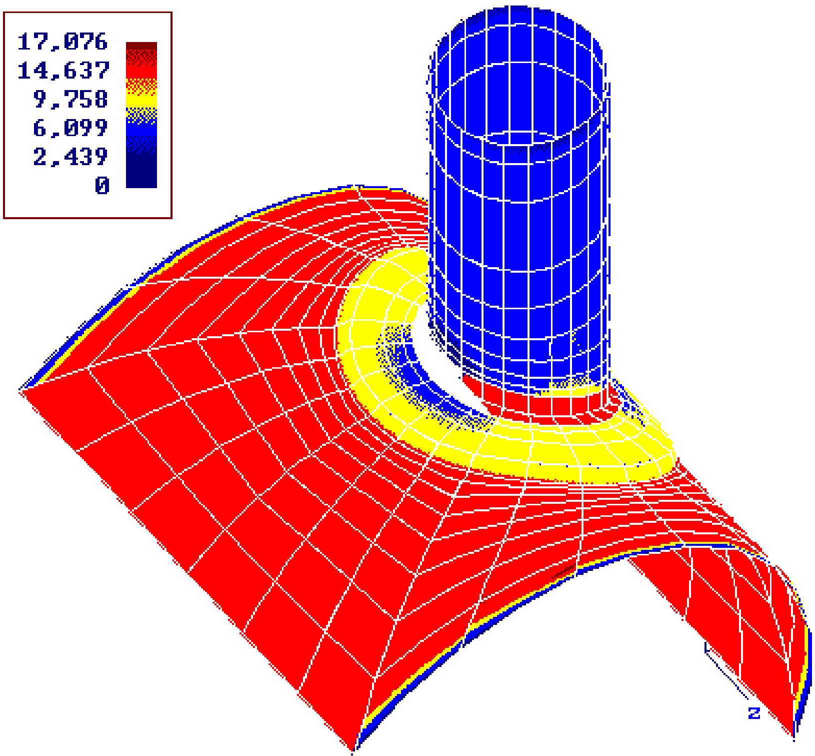
3) Pl+Pb+Q < SPS (SUS Inside) Case 1



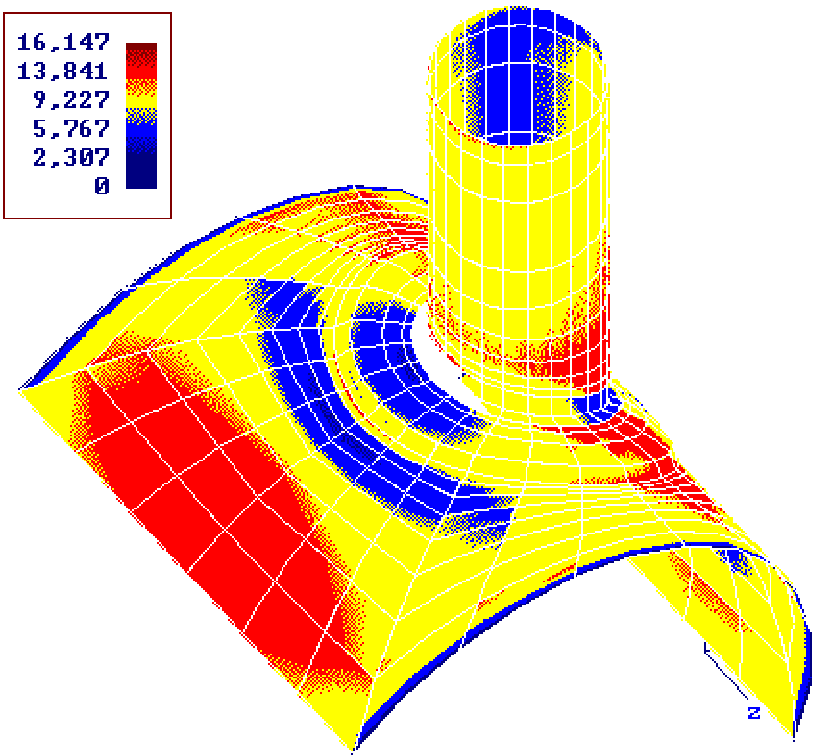
4) Pl+Pb+Q < SPS (SUS Outside) Case 1



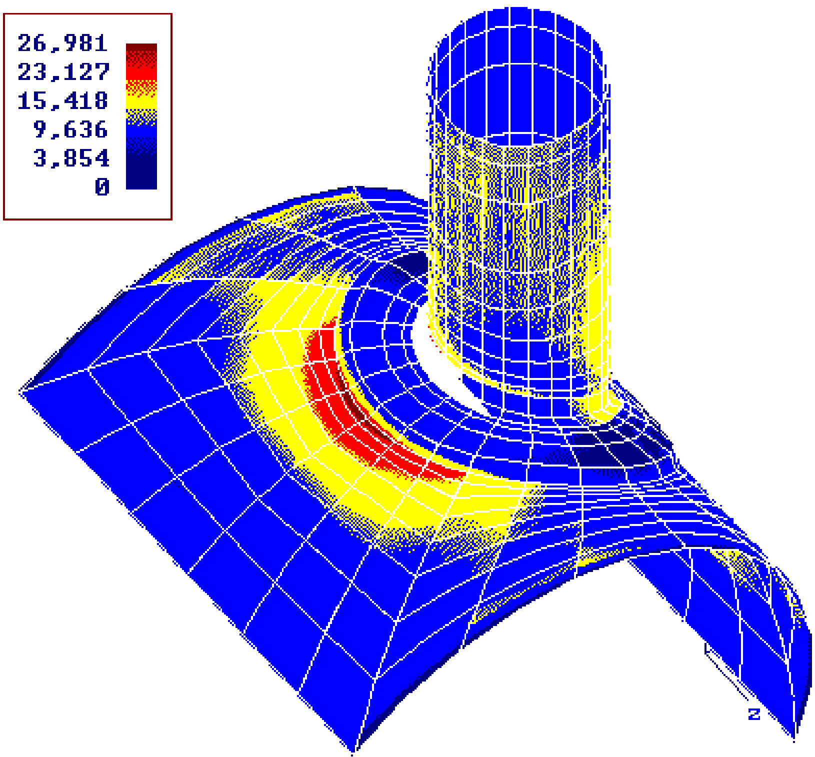
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 1



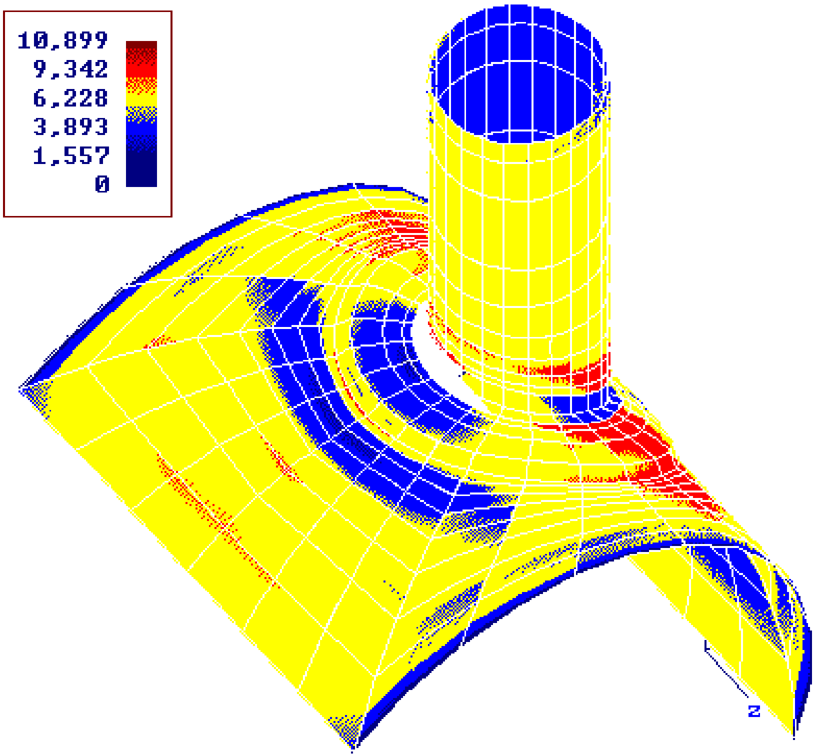
6) Pl+Pb+Q < SPS (OPE Inside) Case 2



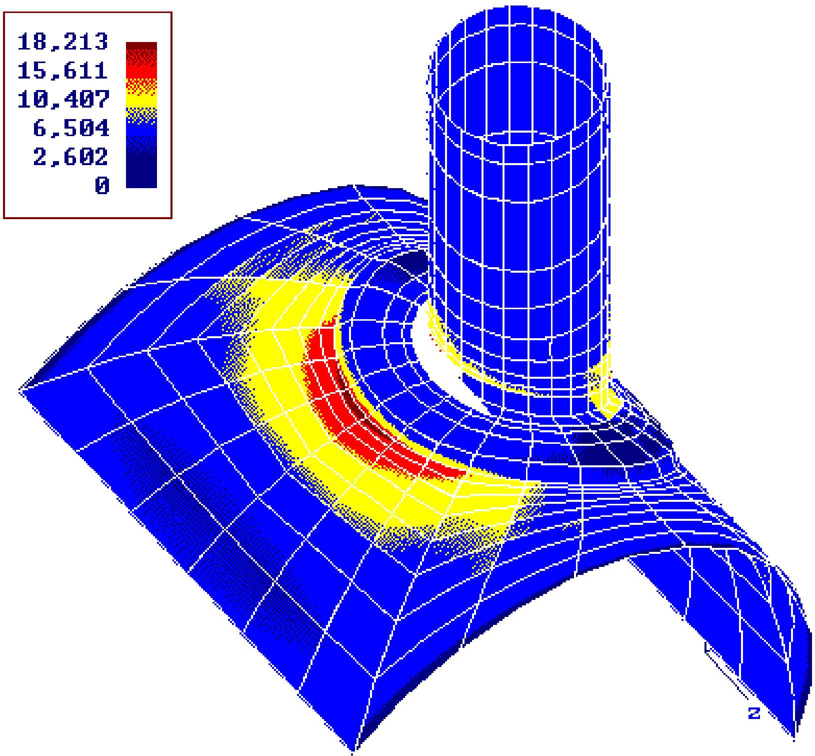
7) Pl+Pb+Q < SPS (OPE Outside) Case 2



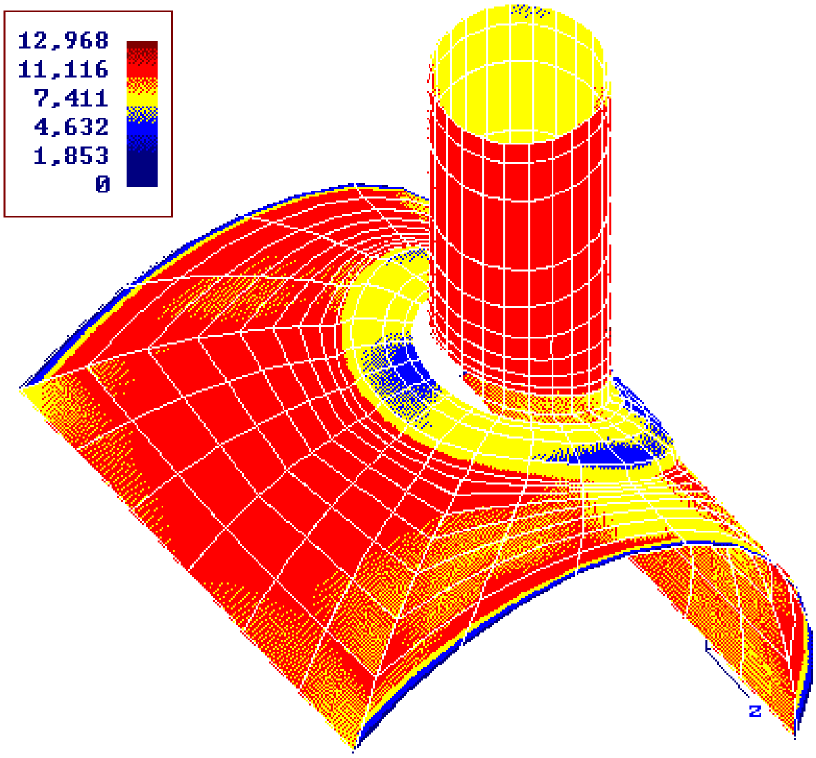
8) Pl+Pb+Q+F < Sa (EXP Inside) Case 2



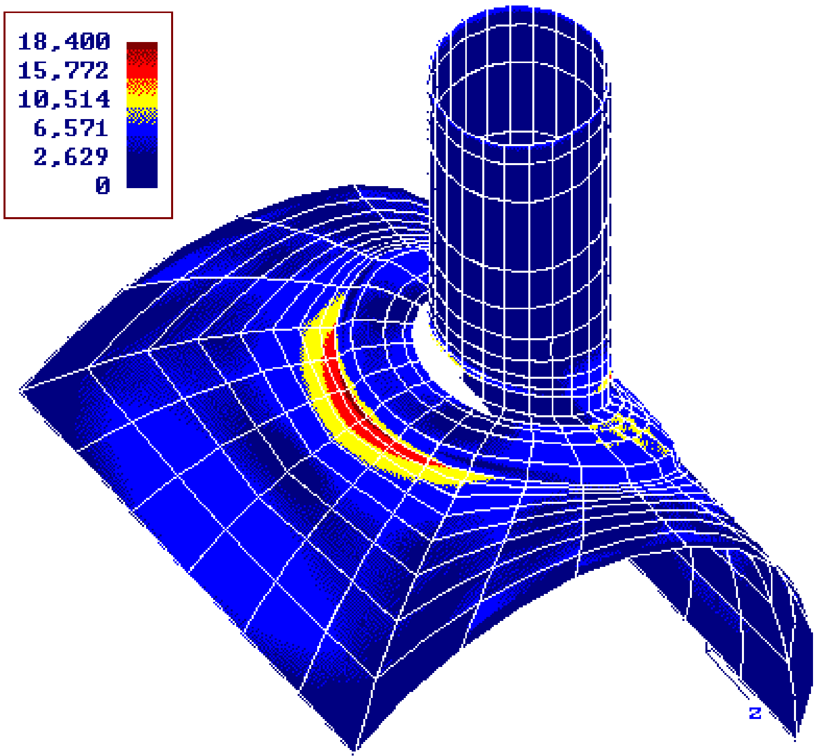
9) Pl+Pb+Q+F < Sa (EXP Outside) Case 2



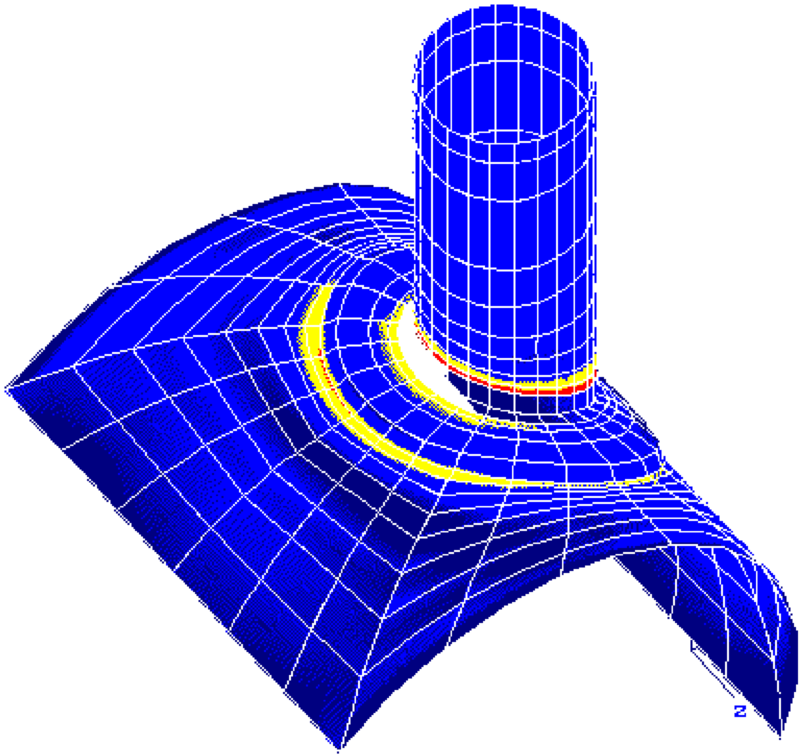
10) Membrane < User (OPE Membrane) Case 2



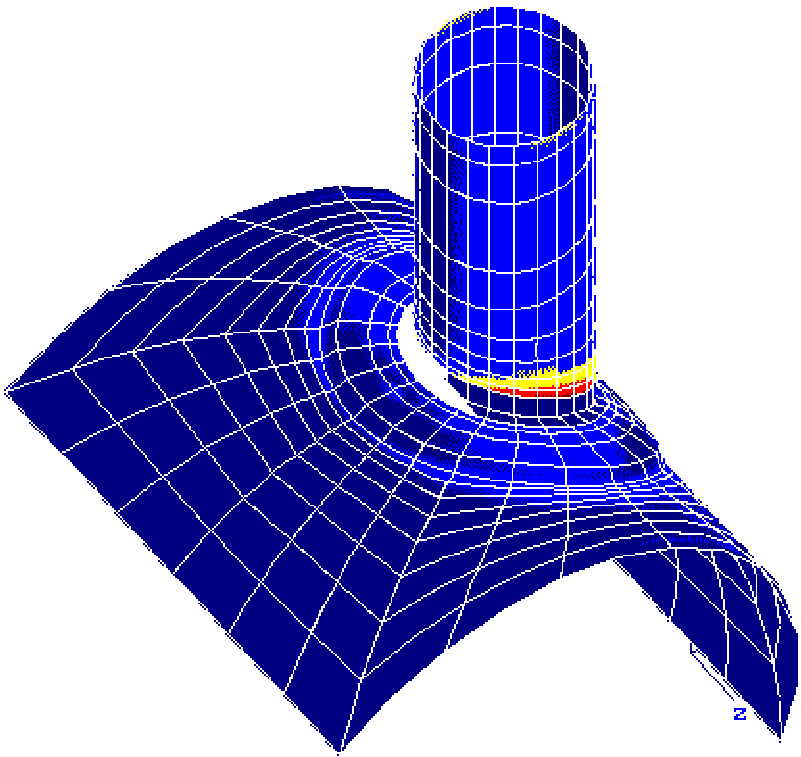
11) Bending < User (OPE Bending) Case 2



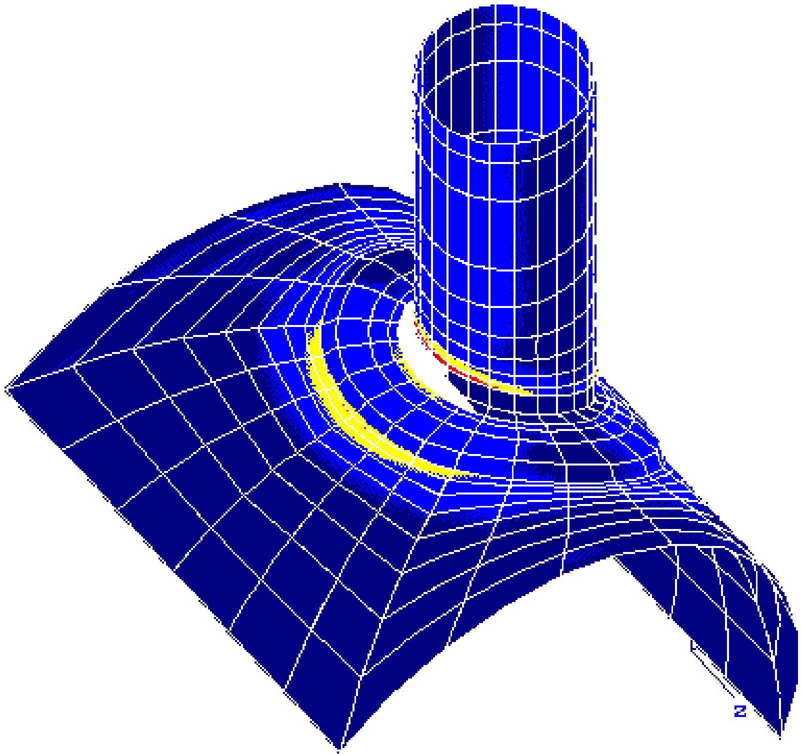
12) Pl+Pb+Q+F < Sa (SIF Outside) Case 3



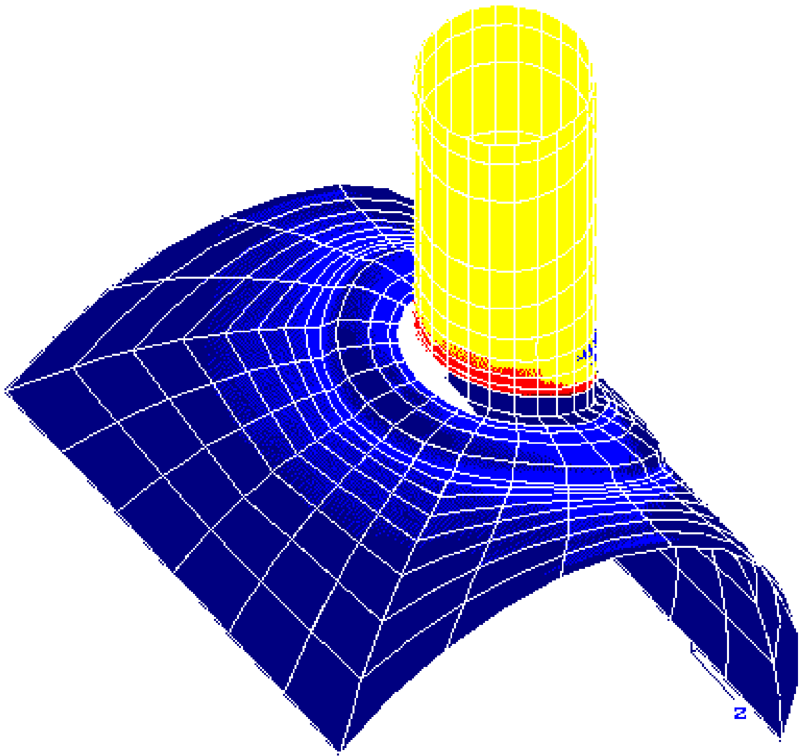
13) Pl+Pb+Q+F < Sa (SIF Outside) Case 4



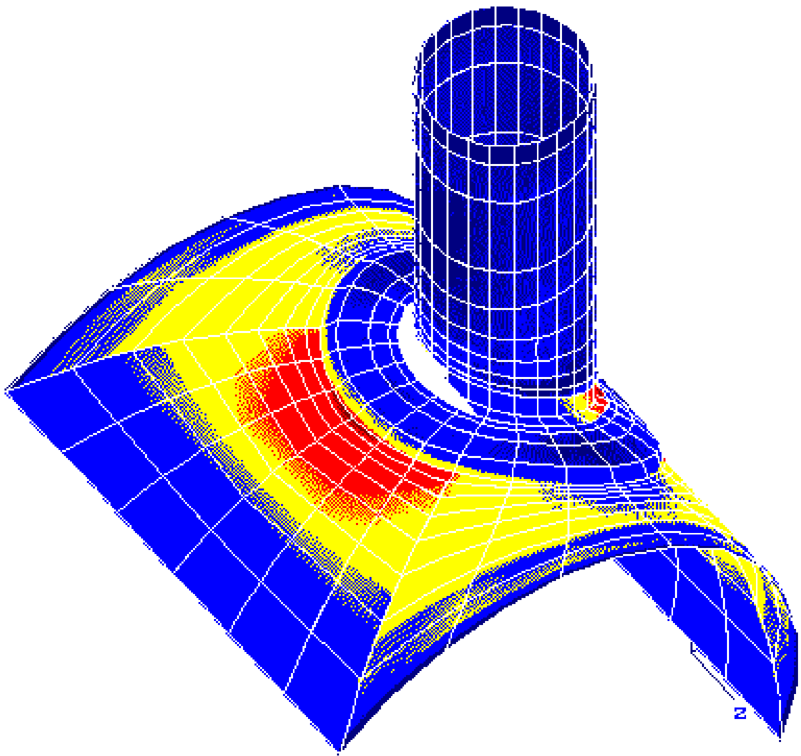
14) Pl+Pb+Q+F < Sa (SIF Outside) Case 5



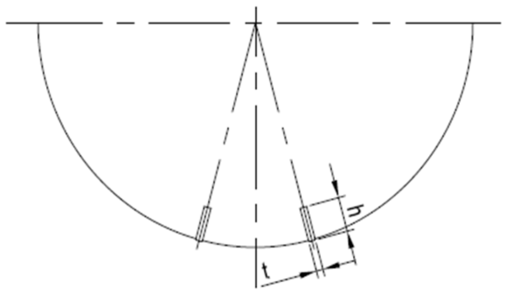
15) Pl+Pb+Q+F < Sa (SIF Outside) Case 6

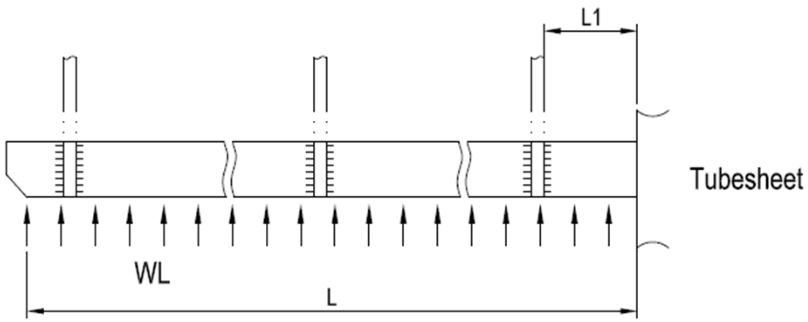


16) Pl+Pb+Q+F < Sa (SIF Outside) Case 7



Sliding strip Calculation





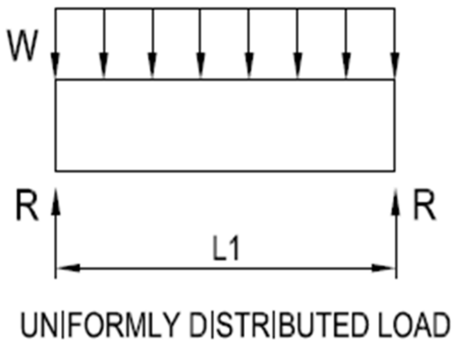
Material		Design Data	
Material of Sliding shoe	SA-516 Gr.70N	Bundle Weight, Wb =	3748 Ib
Quantity of Sliding shoe N =	2	Design temperature, T =	32 ℉
Eff. Quantity of Sliding shoe Ne =	2	Corrosion allowance, CA =	0.125 in
Sliding shoe Thk. t =	0.63 in	Sy(Min.Yield Strength)@ DT =	36000 Psi
Sliding shoe eff. Width. h=	2.362 in	Ss(allowable shear stress)=0.4 x Sy =	14400 Psi
Sliding shoe length. L=	174.763 in	Sb(allowable bending stress)=0.66 x Sy =	23760 Psi
L1=	22.441 in		

Calculation for Max. unsup't length of Sliding shoe

1. Load & Moment

1.) Uniform load

W= F/L =Wb / (6 * L) = 3.57 Ib/in



2.) Total Equiv. Uniform load = W * L1 = 80.2123142 Ib

3) Reaction or shear load

R=V= (W* L1)/2 = 40.1061571 Ib

2. Stress check

1.) Shear Stress

Ss = V/A = 26.95197579 psi < Ss = 14400 psi OK

Where, Section area A = t*h = 1.48806 in^2

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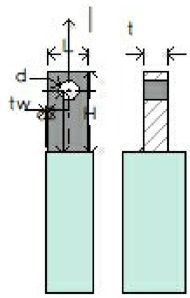
Lifting Lug

Geometry Inputs	
	
Attached To	Tubesheet
Material	SA-516 Gr.70N
Orientation	Longitudinal
Distance of Lift Point From Datum	1.968"
Angular Position	0 deg
Length, L	2.756"
Height, H	5.709"
Thickness, t	0.866"
Hole Diameter, d	1.378"
Pin Diameter, Dp	1.1811"
Load Eccentricity, a_1	0"
Distance from Load to Shell or Pad, a_2	4.331"
Load Angle Normal to Vessel, β	0 deg
Load Angle from Vertical, ϕ	0 deg
Welds	
Size, t_w	0.236"

Intermediate Values	
Load Factor	1.3500
Vessel Weight (new, incl. Load Factor), W	2,189.3 lb
Lug Weight (new), W_{lug}	3.5 lb
Allowable Stress, Tensile, σ_t	14,968 psi
Allowable Stress, Shear, σ_s	9,979 psi
Allowable Stress, Bearing, σ_p	19,957 psi
Allowable Stress, Bending, σ_b	16,465 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	9,979 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values	
Required Lift Pin Diameter, d_{reqd}	0.3737"
Required Lug Thickness, t_{reqd}	0.125"
Lug Stress Ratio, σ_{ratio}	0.06
Weld Shear Stress Ratio, τ_{ratio}	0.18
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

`F_r` = `text(force on vessel at lug)`
`F_r` = `W* text(LoadFactor)`
= 2,189 lb_f

Lug Pin Diameter - Shear stress

`d_(text(reqd))` = `sqrt((2*F_v) / (pi * sigma_s))`
= `sqrt((2*"2,189" ) / (pi * "9,979"))` = 0.3737"

`d_(reqd) / D_p` = `0.3737 / 1.1811` = `0.32` Acceptable

`sigma` = `F_v / A`
= `F_v / (2*(0.25*pi*D_p^(2)))`
= `"2,189" / (2*(0.25*pi*1.1811^2))` = `999 text( psi)`

`sigma / sigma_s` = `999 / "9,979"` = `0.1` Acceptable

Lug Thickness - Tensile stress

`t_(text(reqd))` = `F_v / ((L - d)* sigma_t)`
= `"2,189" / ((2.756 - 1.378)*"14,968")` = 0.1061"

`t_(text(reqd)) / t` = `0.1061 / 0.866` = `0.12`

`sigma` = `F_v / A`
= `F_v / ((L - d)*t)`
= `"2,189" / ((2.756 - 1.378)*0.866)` = `"1,835" text( psi)`

`sigma / sigma_(t` = `"1,835" / "14,968"` = `0.12` Acceptable

Lug Thickness - Bearing stress

`t_(text(reqd))` = `F_v / (D_p * sigma_p)`
= `"2,189" / (1.1811*"19,957")` = 0.0929"

`t_(text(reqd))/ t` = `0.0929 / 0.866` = `0.11` Acceptable

σ = `F_v / A_(text(bearing))`
= `F_v / (D_p *(t))`
= `"2,189" / (1.1811*(0.866))` = `"2,140" text( psi)`

`sigma / sigma_(p` = `"2,140" / "19,957"` = `0.11` Acceptable

Lug Thickness - Shear stress

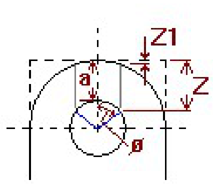
`t_(text(reqd))` = `[F_v / sigma_s] / (2*L_(text(shear)))`
= `("2,189" / "9,979") / (2*0.8779)` = 0.125"

`t_(text(reqd)) / t` = `0.125 / 0.866` = `0.14` Acceptable

`tau` = `F_v / A_(text(shear))`
= `F_v / (2*t*L_(text(shear)))`
= `"2,189" / (2*0.866*0.8779)` = `"1,440" text( psi)`

`tau / sigma_s` = `"1,440" / "9,979"` = `0.14` Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



`phi` = `55*D_p / d`
= `55*1.1811 / 1.378`
= `47.1412 deg`
`L_(text(shear))` = `(H - a2 - 0.5*d) + 0.5* D_p *(1 - cos(phi))`
= `(5.709 - 4.331 - 0.5*1.378) + 0.5*1.1811*(1 - cos(47.1412))`
= 0.8779"

Lug Plate Stress

Lug stress tensile + bending during lift:
`sigma_(text(ratio))` = `[F_(text(ten))/ (A_(text(ten)) * sigma_t)] + [M_(text(bend)) / (Z_(text(bend)) * sigma_b)] le 1`
= `[(F_r * cos( beta ) ) / (t * L * sigma_t)] + [(6 * abs(F_r * sin(beta) * text(Hght) - F_r * cos(beta) * a_1) ) / (t * L_2 * sigma_b)] le 1`
= `"2,189" * cos(0.0) / (0.866*2.756*"14,968") + 6*abs("2,189"*sin(0.0)*4.331 - "2,189"*cos(0.0)*0) / (0.866*2.756^2 * "16,465")`
= 0.06 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 0.00 deg; lift force = 2,189 lb_f

`A_(text(weld))` = `2*(0.707) * t_w *(L + t)`
= `2*(0.707)*0.236*(2.756 + 0.866)` `= 1.2087 text( in)^2`

`tau_t` = `F_(text(lug)) * cos(beta) / A_(text(weld))`
= `"2,189"*cos(0.0) / 1.2087` `= "1,811" text( psi)`

`tau_s` = `F_(text(lug)) * sin(beta) / A_(text(weld))`
= `"2,189"*sin(0.0) / 1.2087` `= 0 text( psi)`

`tau_b` = `M * c / I`
= `3*(F_(text(lug)) * sin(beta)*Hght - F_(text(lug)) * cos(beta)*a_1) / (0.707*h*L*(3*t + L))`
= `3*abs("2,189"*sin(0.0)*4.331 - "2,189"*cos(0.0)*(0)) / (2.4620)`
= `0 text( psi)`

`tau_(text(ratio))` = `sqrt( (tau_t + tau_b)^2 + tau_s^2 ) / tau_(text(allowable)) le 1`
= `sqrt ( ("1,811" + 0)^2 + (0)^2 ) / "9,979"`
= 0.18 Acceptable

WRC 537 Analysis

Geometry	
Height (radial)	5.709"
Width (circumferential)	0.866"
Length	2.756"
Fillet Weld Size:	0.236"
Located On	Tubesheet (3.347" from left end)
Location Angle	0.00 deg

Applied Loads	
Radial load, P_r	-2,189.29 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	0 lb_f-in
Longitudinal shear, V_L	0 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	7.4015"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

`gamma = R_(m) / T = 7.4015 / 10 = 0.7402`

WRC 537: R_m / t < 5 (ratio not covered by WRC 537; R_m / t = 5 used)

`C_(1) = 0.669, C_(2) = 1.614 text( in)`

Local circumferential pressure stress
`= (P*R_(i)) / T =0 text( psi)`

Local longitudinal pressure stress
`= (P*R_(i)) / (2*T) =0 text( psi)`

Maximum combined stress
`(P_(L)+P_(b)+Q) = 53 text( psi)`

Allowable combined stress
`(P_(L)+P_(b)+Q) = ±3*S = ±60,000 text( psi)`

The maximum combined stress
`(P_(L)+P_(b)+Q)`
is within allowable limits.

Maximum local primary membrane stress
`(P_(L)) = 30 text( psi)`

Allowable local primary membrane stress
`(P_(L)) = ±1.5*S = ±30,000 text( psi)`

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 537										
Figure	**Y**	**β**	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	0.9357	0.193	0	0	0	0	28	28	28	28
4C*	1.0034	0.1623	30	30	30	30	0	0	0	0
1C	0.192	0.1272	0	0	0	0	25	-25	25	-25
2C-1	0.1693	0.1272	22	-22	22	-22	0	0	0	0
3A*	0.0641	0.1212	0	0	0	0	0	0	0	0
1A	0.1059	0.1413	0	0	0	0	0	0	0	0
3B*	0.3401	0.1626	0	0	0	0	0	0	0	0
1B-1	0.0614	0.1515	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			52	8	52	8	53	3	53	3
Primary membrane circumferential stress*			30	30	30	30	28	28	28	28
3C*	0.9638	0.1623	29	29	29	29	0	0	0	0
4C*	0.9807	0.193	0	0	0	0	29	29	29	29
1C-1	0.1651	0.1678	22	-22	22	-22	0	0	0	0
2C	0.136	0.1678	0	0	0	0	18	-18	18	-18
4A*	0.0846	0.1212	0	0	0	0	0	0	0	0
2A	0.0619	0.1848	0	0	0	0	0	0	0	0
4B*	0.0889	0.1626	0	0	0	0	0	0	0	0
2B-1	0.0914	0.1861	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			51	7	51	7	47	11	47	11
Primary membrane longitudinal stress*			29	29	29	29	29	29	29	29
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			52	8	52	8	53	11	53	11

* denotes primary stress.

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Earthquake Load Calculation Results:

Earthquake Load Calculation:

Input Values:

```
Seismic Design Code                                  ASCE/SEI 7-16
Seismic Load Reduction Scale Factor                          0.700
Importance Factor                                            1.500
Table Value Fa                                               1.000
Table Value Fv                                               1.721
Max. Mapped Res. Acceleration       [Ss]                     1.616
Max. Eff. Ground Acceleration        [S]                     0.579
Force Modification Factor R                                  2.500
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 )                             1.077
User Value of Sd1 (used if > 0 )                             0.996
Moment Reduction Factor Tau                                  1.000
```

Seismic Analysis Results:

```
Sms = Fa * Ss = 1 * 1.616 = 1.616
Sm1 = Fv * S1 = 1.721 * 0.579 = 0.996
Sds = 2/3 * Sms = 2/3 * 1.616 = 1.077

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.862, 1.077 )
    = 1.077

Sd1 = 2/3 * Sm1 = 2/3 * 0.996 = 0.664

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.531, 0.996 )
    = 0.996
```

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 *($3.971^{0.75}$)
= 0.056 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

```
= ( 1/Natural Frequency ) = ( 1/33 )
= 0.030
```

Check the Value of T which is the smaller of Cu*Ta and T:

```
= Minimum Value of(1.4 * 0.0563, 0.0303 ) 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 * 1.077 * 13454 *( 1 + 2*1 )/( 2.5/1.5 )
= 10432.489 lbf
```

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

```
= 1.6 * Sds * I * W
= 1.6 * 1.077 * 1.5 * 13454 = 34775 lbf
```

Check the Minimum value of Fp per equation 13.3-3:
= 0.3 * 1.077 * 1.5 * 13454
= 6520.307 lbf

Compute the Total Base Shear V = Fp, [V]:
= 10432.489 lbf

Vertical load per 12.4-4, [Ev]:
= 0.2 * Sds * W
= 0.2 * 1.077 * 13454
= 2897.9 lbf

Final Base Shear, V = 7302.74 lbf
Final Vertical Load, Ev = 2028.54 lbf

Earthquake Load Calculation:

From	To	Earthquake Height in	Earthquake Weight lbf	Element Ope Load lbf
10	20	15.6495	1494.85	1076.68
20	30	11.312	1494.85	778.258
30	40	11.312	1494.85	778.258
40	50	11.312	1494.85	778.258
50	60	11.312	1494.85	778.258
60	Sadl	11.312	1494.85	778.258
Sadl	70	11.312	1494.85	778.258
60	70	11.312	1494.85	778.258
70	80	11.312	1494.85	778.258

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.

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Width (13.00) 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( 8.606 + 1.56*sqrt( 11.75 * 0.866 ), 2 * 30 )
  = 13.5812 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm        11.75  in
 Shell Thickness used in this Case                t        0.866  in
 Stiffened Vessel Length per 4.15.6               L       197.71  in
 Distance from Saddle to Vessel tangent      a1 or a       30.00  in

 Saddle Width                                 b1 or b        8.61  in
 Saddle Bearing Angle                  delta or theta      120.00  degrees

 Shell Allowable Stress used in Calculation           20000.00  psi
 Head Allowable Stress used in Calculation            19640.00  psi
 Circumferential Efficiency in Plane of Saddle            1.00
 Circumferential Efficiency at Mid-Span                   1.00

 Distance from Saddle Base to Centerline         B        32.00  in
 Coefficient of Friction                        mu         0.40

 Saddle Force Q, Operating Case                       25833.00  lbf

 Pressure used in Analysis                       P      550.278  psig

 Horizontal Vessel Analysis Results:       Actual |    Allowable |
                                              psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan        2370.26 |     20000.00 |
 Long. Stress at Bottom of Midspan        5092.80 |     20000.00 |
 Long. Stress at Top    of Saddles        6445.38 |     20000.00 |
 Long. Stress at Bottom of Saddles        2227.35 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                2071.02 |     16000.00 |
 Circ. Stress at Horn of Saddle           3279.91 |     25000.00 |
 Circ. Compressive Stress in Shell         166.99 |     20000.00 |
 ----------------------------------------------------------------
```

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( 646.9/2 + 0 ) * 32/22
  = 1411.3 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 148.9, 0 ) * 32/109
  = 43.7 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:
```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 7303, 0 ) * 32/109
```

```
  = 2143.9 lbf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 7303/2 + 0 ) * 32/22
  = 15933.3 lbf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 9900 + max( 43.72, 1411, 2144, 15933 )
  = 25833.0 lbf
```

Longitudinal Wind Force [Fl]:

  = WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))
  = 0.6 * 34.1(0 + pi/4(2.03 * 1.5)^2)
  = 148.932 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	26095.85	lbf
Transverse Shear Load Saddle	3651.37	lbf
Longitudinal Shear Load Saddle	7302.74	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 22.000 in
```

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 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-hm²)/(2a*L))/(1+(4h2)/3L)]
  = -25833*30[1-(1-30/197.7+(11.75²-0²)/
    (2*30*197.7))/(1+(4*0)/(3*197.7))]
  = -108583.2 in-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-hi²)/(L²))/(1+(4hi)/( 3L))-4a/L
  = 25833*197.7/4(1+2(11.75²-0²)/(197.7²))/(1+(4*0)/
    (3*197.7))-4*30/197.7
  = 510878.6 in-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 550.3 * 11.75/(2*0.866 ) - 510879/(pi*11.75²*0.866 )
  = 2370.26 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 550.3 * 11.75/(2 * 0.866 ) + 510879/(pi * 11.75² * 0.866 )
  = 5092.80 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 550.3*11.75/(2*0.866)--108583/(0.107*pi*11.75²*0.866)
  = 6445.38 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 550.3*11.75/(2*0.866)+-108583/(0.192*pi*11.75²*0.866)
  = 2227.35 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*hm/3))
  = 25833( 197.7 - 2 * 30 )/(197.7 +( 4 * 0/3))
  = 17993.3 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.171 * 17993/( 11.75 * 0.866 )
  = 2071.02 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 11.75 * 0.866 )
  = 2.488 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.76 * 25833 * 0.1/( 0.866( 8.606 + 2.488 + 2.488 ) )
  = -166.99 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -25833/(4 * 0.866(8.606 + 2.488 + 2.488 )) -
     3 * 0.0529 * 25833/(2*0.866²)
  = -3279.91 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 8.606 + 1.56 * sqrt( 11.75 * 0.866 ), 2 * 30 )
  = 13.58 in
```

Distance between Saddle Supports [Ls]:
```
  = 109.0 in
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls( Design Temperature - Ambient Temperature )
  = 0.72800E-05 * 109( 490 - 70 )
  = 0.333 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in
Baseplate Thickness	Bpthk	0.8660	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	1	
Rib Thickness	Ribtk	0.6300	in
Web Thickness	Webtk	0.6300	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.2	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:

$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$

$= ((1.56 * sqrt(11.31 * 0.866) + 13)0.866^3)/12$

= 0.968 in**4

Resolved Inertia for the Shell [I,shell]:

$= \text{ShellInertia} + \text{AShell}(C1 - Y)^2$
$= 0.968 + 15.49(6.575 - 0.433)^2$
= 585.163 in**4

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	17.8826	0.8660	0.4330	15.4864	6.7056	585.1630
Wearplate	13.0000	0.8660	1.2990	11.2580	14.6241	314.0742
Web	0.6300	18.0900	10.7770	11.3967	122.8223	512.0325
BasePlate	9.0000	0.8660	20.2550	7.7940	157.8675	1459.0917
Totals	...	...	...	45.9351	302.0195	2870.3618

Distance to Centroid [C1]:
= AY / A
= 302/45.94
= 6.575 in

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
$= (1 + \cos(\beta) - 0.5\sin(\beta)^2)/(\pi - \beta + \sin(\beta)\cos(\beta))$
$= (1 + \cos(120) - 0.5\sin(120)^2)/(\pi - 2.094 + \sin(120)\cos(120))$
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 25833
= 5257.5747 lbf

Tension Stress, St = (Fh/As) = 172.6699 psi
Allowed Stress, Sa = 0.6 * Yield Str = 22800.0117 psi

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 32 - 11.31 * sin(120/2)/1.047
= 22.645 in

Bending Moment, M = Fh * d = 119058.0312 in-lb

Bending Stress, Sb = (M * C1 / I) = 272.7174 psi
Allowed Stress, Sa = 2/3 * Yield Str = 25333.3477 psi

Minimum Thickness of Baseplate per Moss:
= sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
= sqrt(3(25833 + 262.9)9/(2 * 22 * 25333))
= 0.795 in

Check of Center Rib:

Inertia of Saddle, Center Rib - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.6300	7.9760	4.6180	5.0249	23.2049	58.6040
Web	11.2964	0.6300	0.3150	7.1168	2.2418	22.8049
Totals	...	...	...	12.1416	25.4467	81.4089

Distance to Centroid from Datum [ytot]:
= AY / A
= 25.45/12.14
= 2.096 in

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 2.096, abs( 8.606 - 2.096 ) )
  = 6.510 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 32 - cos( 13.04/2 )( 0.866 + 0 + 0 ) - 0
  = 18.090 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 81.41/12.14 )
  = 2.589 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 18.09/2.589
  = 6.986
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 7303/( 2 * 22 )
  = 165.971 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 166 * 11.3 * 18.09
  = 33916.676 in-lb
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 33917/12.5
  = 2712.279 psi
```

Compressive Allowable, KL/r < Cc(6.986 < 122.7) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 6.986 )²/(2 * 122.7² ))38000/
    ( 5/3+3*(6.986 )/(8* 122.7 )-( 6.986³)/(8*122.7³)
  = 22476 psi
```

AISC Unity Check of Center Rib (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1128/22476 +( 33917 * 6.51/81.41 )/25333
  = 0.157
```

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		ASTM F1554 Grade 55	
Bolt Allowable Stress	Stba	24800.00	psi
Bolt Corrosion Allowance	Bca	0.0590	in
Distance from Bolts to Edge	Edgedis	5.0000	in
Nominal Bolt Diameter	Bnd	0.8750	in
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.2946	in^2
Saddle Load QO (Weight)	QO	10162.6	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	2143.9	lbf
Maximum Transverse Force	Ft	3651.4	lbf
Maximum Longitudinal Force	Fl	7302.7	lbf
Saddle Bolted to Steel Foundation		Yes	

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

```
  = Fl / ( Bolt Area * Number of Bolts )
  = 7303/( 0.295 * 2 )
  = 12396.3 psi.  Must be less than 14880.0 psi.
```

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

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 3651/( 0.295 * 2 )
  = 6198.2 psi.  Must be less than 14880.0 psi.
```

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 )
  = 7303/(14880 * 2 )
  = 0.2454 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 32 * 3651 + 0
  = 116843.88 in-lb
```

Eccentricity (e):

```
  = Rmom / QO
  = 116844/10163
  = 11.50 in > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 22/2 - 5
   = 6.00 in

 K1 = 3 (e - 0.5 * Bplen)
    = 3(11.5 - 0.5*22 )
    = 1.49 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1 * 0.295/9 *(6 + 11.5 )
    = 3.44 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -3.436 *(0.5 * 22 + 6 )
    = -58.41 in ³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 1.492 * Y² + 3.436 * Y + -58.41 = 0
 Y  = 3.19 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (22/2 - 3.185/3 - 11.5 )
     = -1.56

 Denom = (Bplen / 2 - Y / 3 + f)
       = (22/2 - 3.185/3 + 6 )
       = 15.94
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 10163 * -1.559/15.94
  = 994.23 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 994.2/( 24800 * 1 )
  = 0.0401 in^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.245, 0.0401 ]
  = 0.2454 in^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(10163 + 994.2 )/(3.185 * 9 )
  = 778.32 psig
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (22 - 20 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 994.2 * 1
  = 994.23 in-lb
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 778.3 *(3.185 - 1 )/3.185
  = 533.98 psig
```

Overturning Moment due to Bearing Pressure [Mc]:

```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (1² * 9/6) *(534 + 2 * 778.3 )
  = 3135.93 in-lb
```

Baseplate Required Thickness [Treq]:

```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(994.2,3136 )/(9 * 30000 ))
  = 0.2640 in
```

MDMT Calculations for: Right Sdl, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.866, tr = 0.482, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.556, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -36 F
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Note:
Wear Pad Width (13.00) 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( 8.606 + 1.56*sqrt( 11.75 * 0.866 ), 2 * 42.31 )
  = 13.5812 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                             Rm       11.75  in
 Shell Thickness used in this Case               t       0.866  in
 Stiffened Vessel Length per 4.15.6              L      197.71  in
 Distance from Saddle to Vessel tangent   a1 or a       42.31  in

 Saddle Width                             b1 or b        8.61  in
 Saddle Bearing Angle              delta or theta      120.00  degrees

 Inside or Mean Depth of Head            Hi or hm        5.89  in

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline       B       32.00  in
 Coefficient of Friction                      mu        0.00

 Saddle Force Q, Operating Case                     20989.99  lbf

 Pressure used in Analysis                     P     550.278  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan       3425.35 |     20000.00 |
 Long. Stress at Bottom of Midspan       4037.71 |     20000.00 |
 Long. Stress at Top    of Saddles       9017.73 |     20000.00 |
 Long. Stress at Bottom of Saddles        801.59 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               1328.98 |     16000.00 |
 Circ. Stress at Horn of Saddle          2665.01 |     25000.00 |
 Circ. Compressive Stress in Shell        135.68 |     20000.00 |
 ----------------------------------------------------------------
```

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( 646.9/2 + 0 ) * 32/22
  = 1411.3 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 148.9, 0 ) * 32/109
  = 43.7 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:

```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 7303, 0 ) * 32/109
  = 2143.9 lbf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 7303/2 + 0 ) * 32/22
  = 15933.3 lbf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
```

```
  = 5057 + max( 43.72, 1411, 2144, 15933 )
  = 20990.0 lbf
```

Longitudinal Wind Force [Fl]:

```
  = WindScalar * WindPress( Platform Area + ( pi/4( OD * WindDiaMult )^2 ) )
  = 0.6 * 34.1( 0 + pi/4( 2.03 * 1.5 )^2 )
  = 148.932 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	21252.84	lbf
Transverse Shear Load Saddle	3651.37	lbf
Longitudinal Shear Load Saddle	7302.74	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 22.000 in
```

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 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-hm²)/(2a*L))/(1+(4h2)/3L)]
  = -20990*42.31[1-(1-42.31/197.7+(11.75²-5.892^2)/
    (2*42.31*197.7))/(1+(4*5.892)/(3*197.7))]
  = -211504.7 in-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-hi²)/(L²))/(1+(4hi)/( 3L))-4a/L
  = 20990*197.7/4(1+2(11.75²-5.892²)/(197.7²))/(1+(4*5.892)/
    (3*197.7))-4*42.31/197.7
  = 114909.6 in-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 550.3 * 11.75/(2*0.866 ) - 114910/(pi*11.75²*0.866 )
  = 3425.35 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 550.3 * 11.75/(2 * 0.866 ) + 114910/(pi * 11.75² * 0.866 )
  = 4037.71 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 550.3*11.75/(2*0.866)--211505/(0.107*pi*11.75²*0.866)
  = 9017.73 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:

```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 550.3*11.75/(2*0.866)+-211505/(0.192*pi*11.75²*0.866)
  = 801.59 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:

```
  = Q(L-2a)/(L+(4*hm/3))
  = 20990( 197.7 - 2 * 42.31 )/(197.7 +( 4 * 5.892/3))
```

= 11546.4 lbf

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:

```
= K2 * T / ( Rm * t )
= 1.171 * 11546/( 11.75 * 0.866 )
= 1328.98 psi
```

Decay Length (4.15.20) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 11.75 * 0.866 )
= 2.488 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:

```
= -K5 * Q * k / ( t( b + X1 + X2 ) )
= -0.76 * 20990 * 0.1/( 0.866( 8.606 + 2.488 + 2.488 ) )
= -135.68 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:

```
= -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
= -20990/(4 * 0.866(8.606 + 2.488 + 2.488 )) -
   3 * 0.0529 * 20990/(2*0.866²)
= -2665.01 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 8.606 + 1.56 * sqrt( 11.75 * 0.866 ), 2 * 42.31 )
= 13.58 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	22.0000	in
Baseplate Thickness	Bpthk	0.8660	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	1	
Rib Thickness	Ribtk	0.6300	in
Web Thickness	Webtk	0.6300	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.2	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:

$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$

$= ((1.56 * sqrt(11.31 * 0.866) + 13)0.866^3)/12$

= 0.968 in**4

Resolved Inertia for the Shell [I,shell]:

$= ShellInertia + AShell(C1 - Y)^2$

$= 0.968 + 15.49(6.575 - 0.433)^2$

= 585.163 in**4

	B in	D in	Y in	A in^2	AY in^3	$I + AD^2$ in**4
Shell	17.8826	0.8660	0.4330	15.4864	6.7056	585.1630
Wearplate	13.0000	0.8660	1.2990	11.2580	14.6241	314.0742
Web	0.6300	18.0900	10.7770	11.3967	122.8223	512.0325
BasePlate	9.0000	0.8660	20.2550	7.7940	157.8675	1459.0917
Totals	...	...	...	45.9351	302.0195	2870.3618

Distance to Centroid [C1]:

= AY / A

```
  = 302/45.94
  = 6.575 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.094 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.204 * 20990
  = 4271.9175 lbf

 Tension Stress, St = ( Fh/As )       =       140.2988  psi
 Allowed Stress, Sa = 0.6 * Yield Str =     22800.0117  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 32 - 11.31 * sin(120/2)/1.047
  = 22.645 in

 Bending Moment, M  = Fh * d          =     96737.7812  in-lb

 Bending Stress, Sb = ( M * C1 / I  ) =       221.5900  psi
 Allowed Stress, Sa = 2/3 * Yield Str =     25333.3477  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(20990 + 262.9 )9/( 2 * 22 * 25333 ))
  = 0.717 in
```

Check of Center Rib:

Inertia of Saddle, Center Rib - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.6300	7.9760	4.6180	5.0249	23.2049	58.6040
Web	11.2964	0.6300	0.3150	7.1168	2.2418	22.8049
Totals	...	...	...	12.1416	25.4467	81.4089

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 25.45/12.14
  = 2.096 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 2.096, abs( 8.606 - 2.096 ) )
  = 6.510 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 32 - cos( 13.04/2 )( 0.866 + 0 + 0 ) - 0
  = 18.090 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 81.41/12.14 )
  = 2.589 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 18.09/2.589
  = 6.986
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 7303/( 2 * 22 )
  = 165.971 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 166 * 11.3 * 18.09
  = 33916.676 in-lb
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 33917/12.5
  = 2712.279 psi
```

Compressive Allowable, KL/r < Cc(6.986 < 122.7) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 6.986 )²/(2 * 122.7² ))38000/
    ( 5/3+3*(6.986 )/(8* 122.7 )-( 6.986³)/(8*122.7³)
  = 22476 psi
```

AISC Unity Check of Center Rib (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 916.5/22476 +( 33917 * 6.51/81.41 )/25333
  = 0.148
```

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		ASTM F1554 Grade 55	
Bolt Allowable Stress	Stba	24800.00	psi
Bolt Corrosion Allowance	Bca	0.0590	in
Distance from Bolts to Edge	Edgedis	5.0000	in
Nominal Bolt Diameter	Bnd	0.8750	in
Thread Series	Series	UNC	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	0.2946	in^2
Saddle Load QO (Weight)	QO	5319.6	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	2143.9	lbf
Maximum Transverse Force	Ft	3651.4	lbf
Maximum Longitudinal Force	Fl	7302.7	lbf
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 7303/( 0.295 * 2 )
  = 12396.3 psi.  Must be less than 14880.0 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 3651/( 0.295 * 2 )
  = 6198.2 psi.  Must be less than 14880.0 psi.
```

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 )
  = 7303/(14880 * 2 )
  = 0.2454 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 32 * 3651 + 0
  = 116843.88 in-lb
```

Eccentricity (e):
```
  = Rmom / QO
  = 116844/5320
  = 21.96 in > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 22/2 - 5
   = 6.00 in

 K1 = 3 (e - 0.5 * Bplen)
    = 3(21.96 - 0.5*22 )
    = 32.89 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1 * 0.295/9 *(6 + 21.96 )
    = 5.49 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -5.491 *(0.5 * 22 + 6 )
    = -93.35 in ³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 32.89 * Y² + 5.491 * Y + -93.35 = 0
 Y  = 1.57 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (22/2 - 1.568/3 - 21.96 )
     = -11.49

 Denom = (Bplen / 2 - Y / 3 + f)
       = (22/2 - 1.568/3 + 6 )
       = 16.48
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 5320 * -11.49/16.48
  = 3708.68 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 3709/( 24800 * 1 )
  = 0.1495 in^2
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.245, 0.15 ]
  = 0.2454 in^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
= 2(QO + Tforce) / (Y * Bpwid)
= 2(5320 + 3709 )/(1.568 * 9 )
= 1279.42 psig
```

Distance from Baseplate Edge to the Web [ADIST]:
```
= (Bplen - Weblngth) / 2
= (22 - 20 )/2
= 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:
```
= Tforce * Adist
= 3709 * 1
= 3708.68 in-lb
```

Equivalent Bearing Pressure (f1):
```
= fc * (Y - Adist) / Y
= 1279 *(1.568 - 1 )/1.568
= 463.52 psig
```

Overturning Moment due to Bearing Pressure [Mc]:
```
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (1² * 9/6) *(463.5 + 2 * 1279 )
= 4533.56 in-lb
```

Baseplate Required Thickness [Treq]:
```
= sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
= sqrt(6 * max(3709,4534 )/(9 * 30000 ))
= 0.3174 in
```

MDMT Calculations for: Right Sdl, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.866, tr = 0.482, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.556, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve D            -36 F
```

Warning:
Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.