



پتروشیمی توسعه پارک
سناستی گوهر آفری



BINA EPC Contractor Co.

(Executor of Oil, Gas, Petrochemical & Power Industries)

Toase-eh Park Sanati Gohar Ofoh Petrochemical Co.

**CONCEPTUAL, BASIC and DETAIL DESIGN
ENGINEERING OF STYRENE PARK OFFSITE**

Document Title: Strength Calculation-Cartridge Filter

Document No.: EI027-HRC-VD-ME-CAL-004

ENBR
TEKNOLOJI



Rev.: 01

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STYRENE PARK OFFSITE

Document Title:

Strength Calculation-Cartridge Filter

Rev.	Issued Date	DESCRIPTION	PREPARED	CHECKED	APPROVED
01	08 / Apr. / 2024	Issued for Approval	A. Azodi	E. Malek	M. Shariati
00	27 / Feb. / 2024	Issued for Approval	A. Azodi	E. Malek	M. Shariati



پتروشیمی توسعه پارک
مستقبل امروز ما



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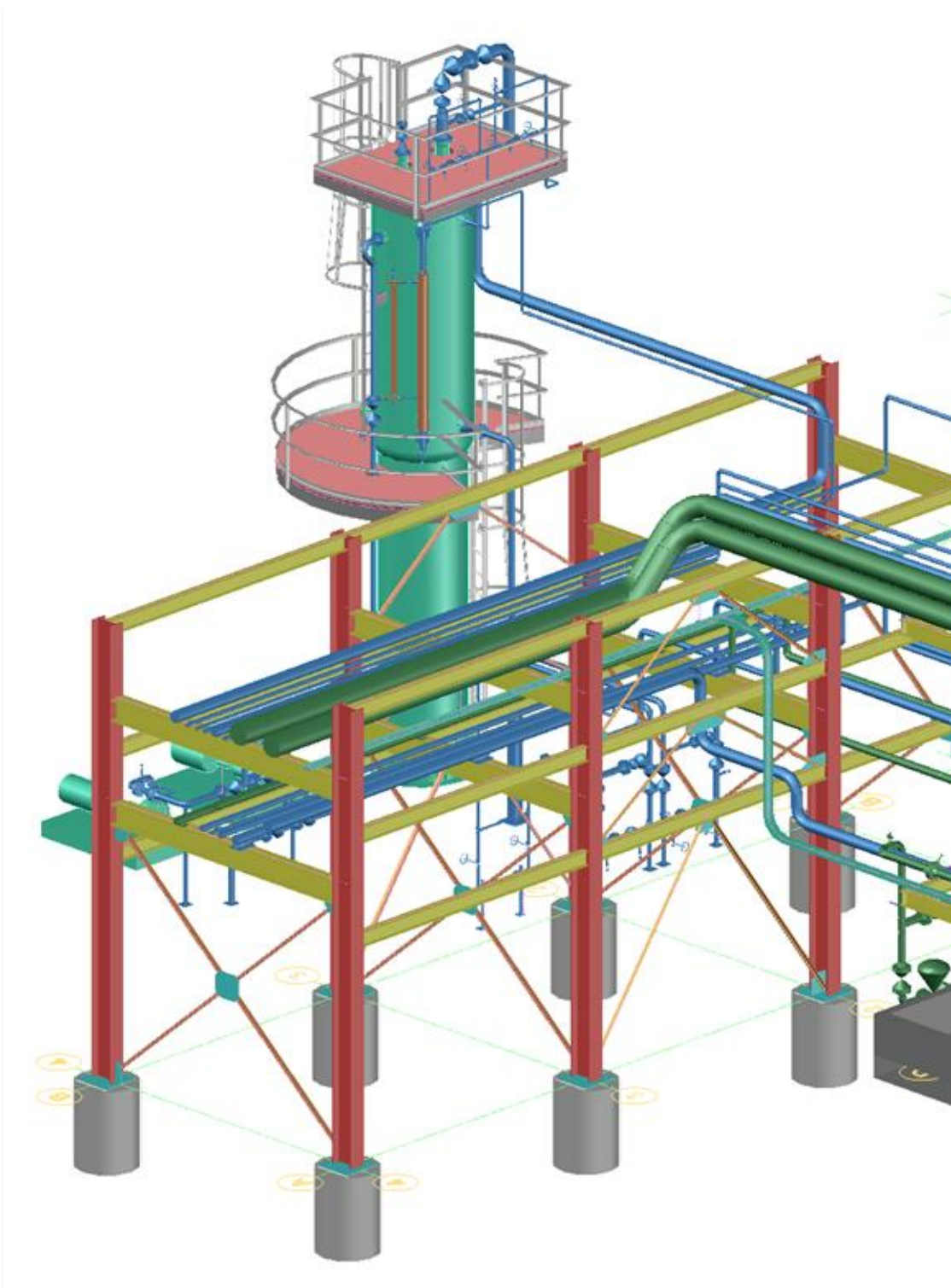
Rev.: 01

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121	X						
122	X						

Project Data Page:

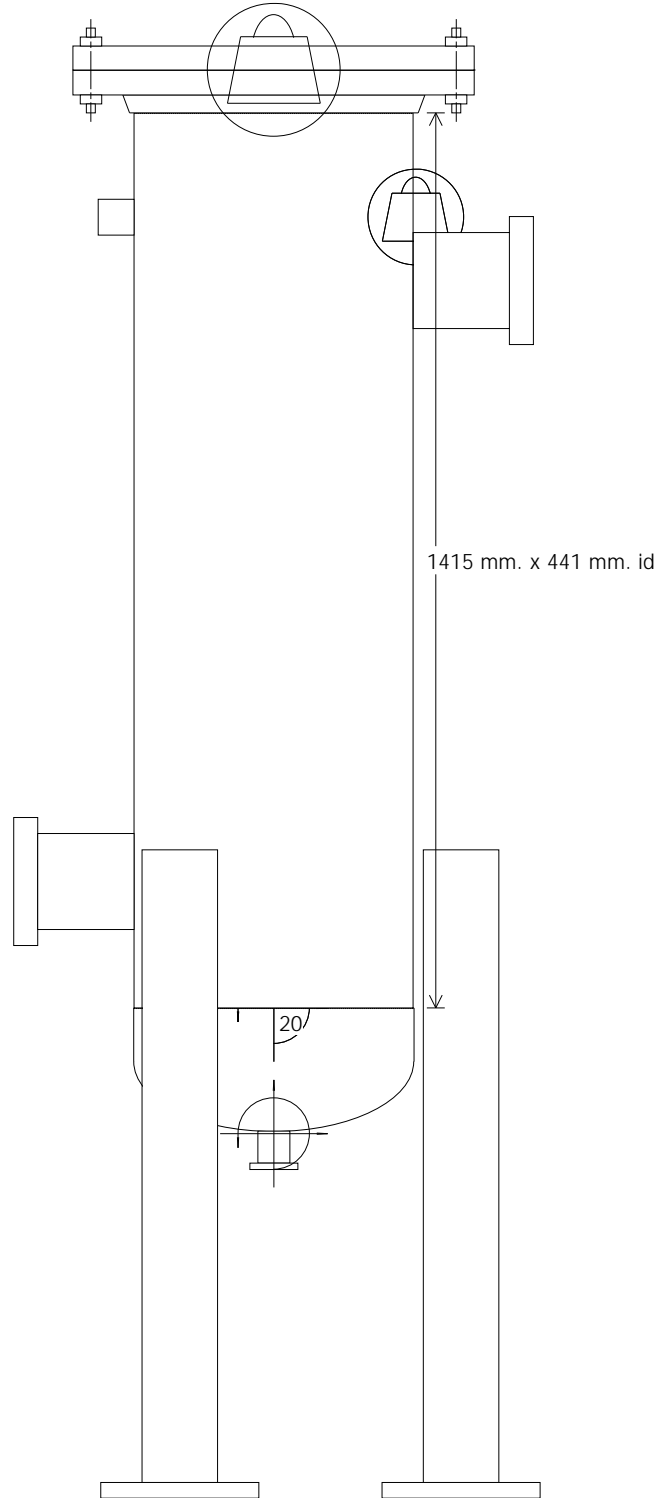




PV Elite[®] **2019**



HEXAGON
PPM





Strength Calculation-Cartridge Filter
Design by A. Azodi
Rev.01

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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File : C:\USERS\A.AZODI\DESKTOP\EI027-HRC-VD-ME-CAL-004

Date of Analysis : Apr 8,2024 1:17pm

PV Elite 2019 SP1, March 2019



Note:
PV Elite performs all calculations internally in Imperial Units to remain compliant with the ASME Code and any built in assumptions in the ASME Code formulas. The finalized results are reflected to show the user's set of selected units.



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Warnings and Errors:

Step: 0

1:17pm

Apr 8, 2024

Class From To : Basic Element Checks.

=====

Class From To: Check of Additional Element Data

=====

There were no geometry errors or warnings.

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Input Echo:

Step: 1 1:17pm Apr 8,2024

• PV Elite Vessel Analysis Program: Input Data

Strength Calculation-Cartridge Filter
Design by A. Azodi
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Design Internal Pressure (for Hydrotest) 3.5 bars
Design Internal Temperature 85.0 °C
Type of Hydrotest UG-99(b)
Hydrotest Position Vertical
Projection of Nozzle from Vessel Top 0 mm.
Projection of Nozzle from Vessel Bottom 0 mm.
Minimum Design Metal Temperature -5.0 °C
Type of Construction Welded
Special Service Air/Water/Steam
Degree of Radiography RT-1
Use Higher Longitudinal Stresses (Flag) Y
Select t for Internal Pressure (Flag) N
Select t for External Pressure (Flag) N
Select t for Axial Stress (Flag) N
Select Location for Stiff. Rings (Flag) N
Consider Vortex Shedding N
Perform a Corroded Hydrotest Y

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

Wind Design Code UBC-94/97
UBC Design Wind Speed 125 Km/hr
UBC Exposure Constant C: Open Terrain
UBC Importance Factor 1.15
UBC Base Elevation 0 mm.
UBC Percent Wind for Hydrotest 33.0
Using User defined Wind Press. Vs Elev. N
Damping Factor (Beta) for Wind (Ope) 0.0100
Damping Factor (Beta) for Wind (Empty) 0.0000
Damping Factor (Beta) for Wind (Filled) 0.0000

Seismic Design Code ASCE/SEI 7-16



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Input Echo:

Step: 1 1:17pm Apr 8,2024

Table with 2 columns: Parameter and Value. Parameters include Seismic Load Reduction Scale Factor (0.700), Importance Factor (1.250), Table Value Fa (1.050), Table Value Fv (1.100), Max. Mapped Res. Acceleration [Ss] (1.310), Max. Eff. Ground Acceleration [S] (0.460), Force Modification Factor R (2.000), Site Class (C), Component Elevation Ratio z/h (0.000), Amplification Factor Ap (0.000), Force Factor (0.000), Consider Vertical Acceleration (No), Minimum Acceleration Multiplier (0.000), User Value of Sds (used if > 0) (0.920), User Value of Sd1 (used if > 0) (0.340), Moment Reduction Factor Tau (1.000).

Table with 2 columns: Parameter and Value. Parameters include Design Pressure + Static Head (Y), Consider MAP New and Cold in Noz. Design (N), Consider External Loads for Nozzle Des. (Y), Use ASME VIII-1 Appendix 1-9 (N).

Material Database Year Current w/Addenda or Code Year

Configuration Directives:

Table with 2 columns: Directive and Value. Directives include Do not use Nozzle MDMT Interpretation VIII-1 01-37 (No), Use Table G instead of exact equation for "A" (Yes), Shell Head Joints are Tapered (Yes), Compute "K" in corroded condition (Yes), Use Code Case 2286 (No), Use the MAWP to compute the MDMT (Yes), For thickness ratios <= 0.35, MDMT will be -155F (-104C) (Yes), For PWHT & P1 Materials the MDMT can be < -55F (-48C) (No), Using Metric Material Databases, ASME II D (No), Calculate B31.3 type stress for Nozzles with Loads (Yes), Reduce the MDMT due to lower membrane stress (Yes), Consider Longitudinal Stress in MDMT calcs. (Div. 1) (Yes).

Complete Listing of Vessel Elements and Details:

Table with 2 columns: Parameter and Value. Parameters include Element From Node (10), Element To Node (20), Element Type (Elliptical), Description (Cap - 18" (sch.10)), Distance "FROM" to "TO" (85 mm.), Element Outside Diameter (457.2 mm.), Element Thickness (5.5563 mm.), Internal Corrosion Allowance (3 mm.), Nominal Thickness (6.35 mm.), External Corrosion Allowance (0 mm.), Design Internal Pressure (3.5 bars), Design Temperature Internal Pressure (85 °C), Design External Pressure (1 bars), Design Temperature External Pressure (85 °C), Effective Diameter Multiplier (1.2).



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Input Echo:

Step: 1 1:17pm Apr 8,2024

Material Name	SA-234 WPB
Allowable Stress, Ambient	117.9 N./mm ²
Allowable Stress, Operating	117.9 N./mm ²
Allowable Stress, Hydrotest	217.19 N./mm ²
Material Density	0.00775 kg./cm ³
P Number Thickness	31.75 mm.
Yield Stress, Operating	222.99 N./mm ²
UCS-66 Chart Curve Designation	B
External Pressure Chart Name	CS-2
UNS Number	K03006
Product Form	Smls. & wld. fittings
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	0.85
Elliptical Head Factor	2.0
Weld is pre-Heated	No

Element From Node	10
Detail Type	Liquid
Detail ID	Liquid: 10
Dist. from "FROM" Node / Offset dist	-111.52 mm.
Height/Length of Liquid	196.52 mm.
Liquid Density	0.11996E-05 kg./cm ³

Element From Node	10
Detail Type	Nozzle
Detail ID	Drain - 2in
Dist. from "FROM" Node / Offset dist	0 mm.
Nozzle Diameter	2 in.
Nozzle Schedule	160
Nozzle Class	150
Layout Angle	0.0
Blind Flange (Y/N)	Y
Weight of Nozzle (Used if > 0)	11.052 Kgf
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-106 B

Element From Node	10
Detail Type	For./Mom.
Detail ID	Drain - 2"
Dist. from "FROM" Node / Offset dist	-114 mm.
Force in X Direction	0 Kgf
Force in Y Direction	-51.805 Kgf
Force in Z Direction	0 Kgf
Moment about X Axis	0 Kg-m.
Moment about Y Axis	0 Kg-m.
Moment about Z Axis	0 Kg-m.
Force/Moment Combination Method	SRSS

Element From Node	10
Detail Type	For./Mom.
Detail ID	Gas In - 6"
Dist. from "FROM" Node / Offset dist	85 mm.
Force in X Direction	180.71 Kgf
Force in Y Direction	-180.71 Kgf
Force in Z Direction	180.71 Kgf
Moment about X Axis	172.37 Kg-m.
Moment about Y Axis	0 Kg-m.



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Input Echo:

Step: 1 1:17pm Apr 8,2024

Moment about Z Axis	172.37	Kg-m.
Force/Moment Combination Method	SRSS	
Element From Node	10	
Detail Type	For./Mom.	
Detail ID	Gas Out - 6"	
Dist. from "FROM" Node / Offset dist	85	mm.
Force in X Direction	180.71	Kgf
Force in Y Direction	-180.71	Kgf
Force in Z Direction	180.71	Kgf
Moment about X Axis	344.04	Kg-m.
Moment about Y Axis	0	Kg-m.
Moment about Z Axis	344.04	Kg-m.
Force/Moment Combination Method	SRSS	

Element From Node	20	
Element To Node	40	
Element Type	Cylinder	
Description	Shell - 18"	
Distance "FROM" to "TO"	1415	mm.
Element Outside Diameter	457.2	mm.
Element Thickness	6	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	6	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	3.5	bars
Design Temperature Internal Pressure	85	°C
Design External Pressure	1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	137.9	N./mm ²
Allowable Stress, Operating	137.9	N./mm ²
Allowable Stress, Hydrotest	235.81	N./mm ²
Material Density	0.00775	kg./cm ³
P Number Thickness	31.75	mm.
Yield Stress, Operating	241.81	N./mm ²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Weld is pre-Heated	No	

Element From Node	20	
Detail Type	Liquid	
Detail ID	Liquid: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1415	mm.
Liquid Density	0.11996E-05	kg./cm ³

Element From Node	20	
Detail Type	Nozzle	
Detail ID	Gas In - 6in	



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Input Echo:

Step: 1 1:17pm Apr 8,2024

Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	STD	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	26.071	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	Gas Out - 6in	
Dist. from "FROM" Node / Offset dist	1150	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	STD	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	26.071	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	Vent - 1in	
Dist. from "FROM" Node / Offset dist	1250	mm.
Nozzle Diameter	2.25	in.
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.685	Kgf
Grade of Attached Flange	None	
Nozzle Matl	SA-105	

Element From Node	20	
Detail Type	Leg	
Detail ID	LEGS	
Dist. from "FROM" Node / Offset dist	250	mm.
Diameter at Leg Centerline	589.2	mm.
Leg Orientation	1	
Number of Legs	3	
Section Identifier	IPE120	
Length of Legs	1000	mm.

Element From Node	20	
Detail Type	Weight	
Detail ID	LIFTING-L	
Dist. from "FROM" Node / Offset dist	1250	mm.
Miscellaneous Weight	20	Kgf
Offset from Element Centerline	225	mm.

Element From Node	20	
Detail Type	Weight	
Detail ID	LIFTING-R	
Dist. from "FROM" Node / Offset dist	1250	mm.



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Input Echo:

Step: 1 1:17pm Apr 8,2024

Miscellaneous Weight	20	Kgf
Offset from Element Centerline	225	mm.
Element From Node	20	
Detail Type	Weight	
Detail ID	CARTRIDGE	
Dist. from "FROM" Node / Offset dist	675	mm.
Miscellaneous Weight	300	Kgf
Offset from Element Centerline	0	mm.

Element From Node	40	
Element To Node	50	
Element Type	Flange	
Description	Body Flange - 18"	
Distance "FROM" to "TO"	68.072	mm.
Flange Inside Diameter	457.2	mm.
Element Thickness	39.624	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	6.35	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	3.5	bars
Design Temperature Internal Pressure	85	°C
Design External Pressure	1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-105	
Allowable Stress, Ambient	137.9	N./mm ²
Allowable Stress, Operating	137.9	N./mm ²
Allowable Stress, Hydrotest	223.4	N./mm ²
Material Density	0.00775	kg./cm ³
P Number Thickness	31.75	mm.
Yield Stress, Operating	229.19	N./mm ²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03504	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	Kgf
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		
Weld is pre-Heated	No	

Element From Node	50	
Element To Node	60	
Element Type	Flange	
Description	Blind Flange - 18"	
Distance "FROM" to "TO"	38	mm.
Flange Inside Diameter	635	mm.
Element Thickness	38	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	6.35	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	3.5	bars



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Input Echo:

Step: 1 1:17pm Apr 8,2024

Design Temperature Internal Pressure	85	°C
Design External Pressure	1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516	70
Allowable Stress, Ambient	137.9	N./mm ²
Allowable Stress, Operating	137.9	N./mm ²
Allowable Stress, Hydrotest	235.81	N./mm ²
Material Density	0.00775	kg./cm ³
P Number Thickness	31.75	mm.
Yield Stress, Operating	241.81	N./mm ²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	Kgf
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		
Weld is pre-Heated	No	
Element From Node	50	
Detail Type	Weight	
Detail ID	DAVIT	
Dist. from "FROM" Node / Offset dist	0	mm.
Miscellaneous Weight	50	Kgf
Offset from Element Centerline	0	mm.



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XY Coordinate Calculations: Step: 2 1:17pm Apr 8,2024

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
Cap - 18" (sch.		...	85	...	85
Shell - 18"		...	1500	...	1415
Body Flange - 1		...	1500	...	-68.072
Blind Flange -		...	1547.53	...	38



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Flg Calc [Int P]: Body Flg

Flng: 3

1:17pm

Apr 8,2024

Flange Input Data Values

Description: Body Flg :

Body Flange - 18"

Description of Flange Geometry (Type)		Loose Slip On	
Design Pressure	P	3.50	bars
Design Temperature		85	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	457.200	mm.
Flange Outside Diameter	A	635.000	mm.
Flange Thickness	t	39.6240	mm.
Thickness of Hub at Small End	go	18.0970	mm.
Thickness of Hub at Large End	gl	21.5900	mm.
Length of Hub	h	28.4480	mm.
Flange Material		SA-105	
Flange Material UNS number		K03504	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm ²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm ²
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm ²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm ²
Diameter of Bolt Circle	C	577.850	mm.
Nominal Bolt Diameter	a	28.5750	mm.
Type of Threads	TEMA Thread Series		
Number of Bolts		16	
Flange Face Outside Diameter	Fod	533.400	mm.
Flange Face Inside Diameter	Fid	457.200	mm.
Flange Facing Sketch	1, Code Sketch 1a		
Gasket Outside Diameter	Go	527.050	mm.
Gasket Inside Diameter	Gi	457.200	mm.
Gasket Factor	m	2.5000	
Gasket Design Seating Stress	y	68.95	N./mm ²
Column for Gasket Seating	2, Code Column II		
Gasket Thickness	tg	3.1750	mm.
Flange Class		150	
Flange Grade		GR 1.1	



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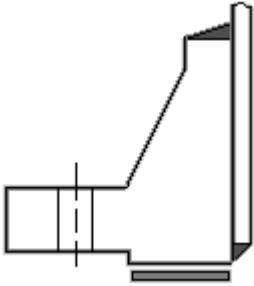
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Flg Calc [Int P]: Body Flg

Flng: 3

1:17pm

Apr 8,2024



ASME Code, Section VIII Division 1, 2017

Corroded Flange Thickness, $t_c = T - c_i$ 36.624 mm.
Code R Dimension, $R = (C - B) / 2 - g_1$ 38.735 mm.

Gasket Contact Width, $N = (G_o - G_i) / 2$ 34.925 mm.
Basic Gasket Width, $bo = N / 2$ 17.462 mm.
Effective Gasket Width, $b = C_b \sqrt{bo}$ 10.530 mm.
Gasket Reaction Diameter, $G = G_o - 2 * b$ 505.989 mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * P_{eq}$$
$$= 0.785 * 506^2 * 3.5$$
$$= 7176.907 \text{ Kgf}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * P_i * G * m * P$$
$$= 2 * 10.53 * 3.142 * 506 * 2.5 * 3.5$$
$$= 2987.212 \text{ Kgf}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= P_i * B_{cor}^2 * P / 4$$
$$= 3.142 * 457.2^2 * 3.5 / 4$$
$$= 5859.586 \text{ Kgf}$$

Pressure Force on Flange Face [Ht]:

$$= H - H_d$$
$$= 7177 - 5860$$
$$= 1317.321 \text{ Kgf}$$

Operating Bolt Load [Wm1]:

$$= \max(H + H_p + H'p, 0)$$
$$= \max(7177 + 2987 + 0, 0)$$
$$= 10164.119 \text{ Kgf}$$

Gasket Seating Bolt Load [Wm2]:

$$= y * b * P_i * G + y_{Part} * b_{Part} * l_p$$
$$= 68.95 * 10.53 * 3.141 * 506 + 0 * 0 * 0$$
$$= 117689.297 \text{ Kgf}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } W_{m1} / S_b, W_{m2} / S_a$$
$$= \text{Maximum of } 10164 / 172.4, 117689 / 172.4$$
$$= 66.956 \text{ cm}^2$$

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsm_{ax}]:

$$= 2a + 6t / (m + 0.5)$$
$$= 2 * 28.57 + 6 * 36.62 / (2.5 + 0.5)$$
$$= 130.398 \text{ mm.}$$



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Flg Calc [Int P]: Body Flg

Flng: 3

1:17pm

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Actual Circumferential Bolt Spacing [Bs]:

$$= C * \sin(\pi / n)$$
$$= 577.8 * \sin(3.142/16)$$
$$= 112.733 \text{ mm.}$$

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

$$= \max(\sqrt{ Bs / (2a + t) }, 1)$$
$$= \max(\sqrt{ 112.7 / (2 * 28.57 + 36.62) }, 1)$$
$$= 1.0964$$

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

	Minimum	Actual	Maximum
Bolt Area, cm ²	66.956	75.148	
Radial Distance between Hub and Bolts:	38.100	38.735	
Radial Distance between Bolts and Edge:	28.575	28.575	
Circ. Spacing between the Bolts:	63.500	112.733	130.398

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

$$= Ab * Sa / (y * \pi * (Go + Gi))$$
$$= 75.15 * 172.4 / (68.95 * 3.142 * (527 + 457.2))$$
$$= 6.076 \text{ mm.}$$

Flange Design Bolt Load, Gasket Seating [W]:

$$= Sa * (Am + Ab) / 2$$
$$= 172.4 * (66.96 + 75.15) / 2$$
$$= 124888.80 \text{ Kgf}$$

Gasket Load for the Operating Condition [HG]:

$$= Wm1 - H$$
$$= 10164 - 7177$$
$$= 2987.21 \text{ Kgf}$$

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

$$= (C - G) / 2$$
$$= (577.8 - 506) / 2$$
$$= 35.9303 \text{ mm.}$$

Distance to Face Pressure Reaction [ht]:

$$= (hD + hG) / 2$$
$$= (60.33 + 35.93) / 2$$
$$= 48.1276 \text{ mm.}$$

Distance to End Pressure Reaction [hd]:

$$= (C - Bcor) / 2$$
$$= (577.8 - 457.2) / 2$$
$$= 60.3250 \text{ mm.}$$

Summary of Moments for Internal Pressure: (Kg-m.)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	5860.	60.3250	1.0964	388.
Face Pressure, Mt	1317.	48.1276	1.0964	70.
Gasket Load, Mg	2987.	35.9303	1.0964	118.
Gasket Seating, Matm	124889.	35.9303	1.0964	4920.



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Flg Calc [Int P]: Body Flg

Flng: 3

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Total Moment for Operation, Mop	575. Kg-m.
Total Moment for Gasket seating, Matm	4920. Kg-m.

*Note: User choose not to perform Stress Calculations on this Standard Flange.
Pressure rating of the flange will be used to check code compliance.*

Estimated Finished Weight of Flange at given Thk.	53.4 kg.
Estimated Unfinished Weight of Forging at given Thk	80.5 kg.

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)	-29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)	-104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)	-42 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 3.50/19.60 = 0.179

*Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.*

Minimum Attachment Weld Size for Slip on Flanges, UW-21, [xmin]:
= min(1.4 * tn, G0)
= min(1.4 * 3, 18.1)
= 4.200 mm.

Minimum Attachment Weld Size for Slip on Flanges, UW-21, [ymin]:
= min(tn, (6 mm or 1/4 inch))
= min(3, 6)
= 3.000 mm.



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Flg Calc [Int P]: Blind Flg

Flng: 4

1:17pm

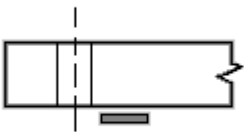
Apr 8, 2024

Flange Input Data Values

Description: Blind Flg :

Blind Flange - 18"

Description of Flange Geometry (Type)			Blind
Design Pressure	P	3.50	bars
Design Temperature		85	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Outside Diameter	A	635.000	mm.
Flange Thickness	t	38.0000	mm.
Flange Material		SA-516 70	
Flange Material UNS number		K02700	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm ²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm ²
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm ²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm ²
Diameter of the Load Reaction, Long Span	D	0.000	mm.
Diameter of the Load Reaction, Short Span	d	0.000	mm.
Perimeter along the Center of the Bolts	L	1815.369	mm.
Diameter of Bolt Circle	C	577.850	mm.
Nominal Bolt Diameter	a	28.5750	mm.
Type of Threads	TEMA Thread Series		
Number of Bolts		16	
Flange Face Outside Diameter	Fod	533.400	mm.
Flange Face Inside Diameter	Fid	438.150	mm.
Flange Facing Sketch	1, Code Sketch 1a		
Gasket Outside Diameter	Go	527.050	mm.
Gasket Inside Diameter	Gi	474.726	mm.
Gasket Factor	m	2.5000	
Gasket Design Seating Stress	y	68.95	N./mm ²
Column for Gasket Seating	2, Code Column II		
Gasket Thickness	tg	3.1750	mm.





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Flg Calc [Int P]: Blind Flg Flng: 4 1:17pm Apr 8,2024

Gasket Contact Width,	$N = (Go - Gi) / 2$	26.162	mm.
Basic Gasket Width,	$bo = N / 2$	13.081	mm.
Effective Gasket Width,	$b = Cb \sqrt{bo}$	9.114	mm.
Gasket Reaction Diameter,	$G = Go - 2 * b$	508.822	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * Peq$$

$$= 0.785 * 508.8^2 * 3.5$$

$$= 7257.490 \text{ Kgf}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * Pi * G * m * P$$

$$= 2 * 9.114 * 3.142 * 508.8 * 2.5 * 3.5$$

$$= 2599.906 \text{ Kgf}$$

Operating Bolt Load [Wm1]:

$$= \max(H + Hp + H'p, 0)$$

$$= \max(7257 + 2600 + 0, 0)$$

$$= 9857.396 \text{ Kgf}$$

Gasket Seating Bolt Load [Wm2]:

$$= y * b * Pi * G + yPart * bPart * lp$$

$$= 68.95 * 9.114 * 3.141 * 508.8 + 0 * 0 * 0$$

$$= 102430.352 \text{ Kgf}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } Wm1/Sb, Wm2/Sa$$

$$= \text{Maximum of } 9857/172.4, 102430/172.4$$

$$= 58.275 \text{ cm}^2$$

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

$$= 2a + 6t / (m + 0.5)$$

$$= 2 * 28.57 + 6 * 35 / (2.5 + 0.5)$$

$$= 127.150 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

$$= C * \sin(pi / n)$$

$$= 577.8 * \sin(3.142/16)$$

$$= 112.733 \text{ mm.}$$

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

$$= \max(\sqrt{Bs / (2a + t)}, 1)$$

$$= \max(\sqrt{112.7 / (2 * 28.57 + 35)}, 1)$$

$$= 1.1061$$

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

	Minimum	Actual	Maximum
Bolt Area, cm ²	58.275	75.148	
Radial Distance between Bolts and Edge:	28.575	28.575	
Circ. Spacing between the Bolts:	63.500	112.733	127.150

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

$$= Ab * Sa / (y * Pi * (Go + Gi))$$

$$= 75.15 * 172.4 / (68.95 * 3.142 * (527 + 474.7))$$

$$= 5.970 \text{ mm.}$$



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Flg Calc [Int P]: Blind Flg

Flng: 4

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Flange Design Bolt Load, Gasket Seating [W]:

$$= Sa * (Am + Ab) / 2$$

$$= 172.4 * (58.28 + 75.15) / 2$$

$$= 117259.34 \text{ Kgf}$$

Gasket Load for the Operating Condition [HG]:

$$= Wm1$$

$$= 9857.40 \text{ Kgf}$$

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

$$= (C - G) / 2$$

$$= (577.8 - 508.8) / 2$$

$$= 34.5140 \text{ mm.}$$

Tangential Flange Stress, Flat Head (UG-34), Operating [STo]:

$$= 1.9 * Wm1 * hg * Bsc / (t^2 * G) + C * Z * Peq * G^2 / t^2$$

$$= 1.9 * 9857 * 34.51 * 1.106 / (35^2 * 508.8) +$$

$$0.3 * 1 * 3.5 * 508.8^2 / 35^2$$

$$= 33.44 \text{ N./mm}^2$$

Tangential Flange Stress, Flat Head (UG-34), Seating [STa]:

$$= 1.9 * W * hg * Bsc / (t^2 * G)$$

$$= 1.9 * 117259 * 34.51 * 1.106 / (35^2 * 508.8)$$

$$= 133.81 \text{ N./mm}^2$$

Bolt Stress, Operating [BSo]:

$$= Wm1 / Ab$$

$$= 9857 / 75.15$$

$$= 12.86 \text{ N./mm}^2$$

Bolt Stress, Seating [BSa]:

$$= (Wm2 / Ab)$$

$$= (102430 / 75.15)$$

$$= 133.67 \text{ N./mm}^2$$

Flange Stress Analysis Results: N./mm²

	Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Tangential Flange	33.	138.	134.	138.
Bolting	13.	172.	134.	172.

Reqd. Blind Flange Thickness at Center 37.478 mm.
 Reqd. Blind Flange Thickness at Gasket 37.478 mm.
 Estimated M.A.W.P. (Operating) 14.432 bars
 Estimated Finished Weight of Flange at given Thk. 93.3 kg.
 Estimated Unfinished Weight of Forging at given Thk 93.3 kg.

Minimum Design Metal Temperature Results:

Thickness Ratio = 0.939, Temperature Reduction per Fig. UCS 66.1 = 3 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1) -32 °C



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Internal Pressure Calculations: Step: 5 1:17pm Apr 8,2024

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm ²
Cap - 18" (sch.1		3.5002	6.35	3	457.2	117.9
Shell - 18"		3.5002	6	3	457.2	117.22
Body Flange - 18		3.5	6.35	3	457.2	137.9
Blind Flange - 1		3.5	6.35	3	635	137.9

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
Cap - 18" (sch.1		3.5	13.5523	29.2965	5.55625	5.5
Shell - 18"		3.5	15.4627	31.0897	6	5.5
Body Flange - 18		3.5	18.1501	19.6001	39.624	No Calc
Blind Flange - 1		3.5	14.4325	17.1041	38	37.4775

Minimum 13.552 17.104

MAWP: 13.552 bars, limited by: Cap - 18" (sch.10).

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 To 20 SA-234 WPB , UCS-66 Crv. B at 85 °C

Cap - 18" (sch.10)

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

$$= (P \cdot D_o \cdot K_{cor}) / (2 \cdot S \cdot E + 2 \cdot P \cdot (K_{cor} - 0.1)) \text{ per Appendix 1-4 (c)}$$

$$= (3.5 \cdot 457.2 \cdot 0.983) / (2 \cdot 117.9 \cdot 1 + 2 \cdot 3.5 \cdot (0.983 - 0.1))$$

$$= 0.6652 + 3.0000 = 3.6652 \text{ mm.}$$

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 2.5000 mm. per UG-16 will be used.

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

Less Operating Hydrostatic Head Pressure of 0.000 bars

$$= (2 \cdot S \cdot E \cdot t) / (K \cdot D_o - 2 \cdot t \cdot (K - 0.1)) \text{ per Appendix 1-4 (c)}$$

$$= (2 \cdot 117.9 \cdot 1 \cdot 2.556) / (0.983 \cdot 457.2 - 2 \cdot 2.556 \cdot (0.983 - 0.1))$$

$$= 13.552 - 0.000 = 13.552 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (2 \cdot S \cdot E \cdot t) / (K \cdot D_o - 2 \cdot t \cdot (K - 0.1)) \text{ per Appendix 1-4 (c)}$$

$$= (2 \cdot 117.9 \cdot 1 \cdot 5.556) / (1 \cdot 457.2 - 2 \cdot 5.556 \cdot (1 - 0.1))$$

$$= 29.297 \text{ bars}$$



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Internal Pressure Calculations: Step: 5 1:17pm Apr 8,2024

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
= (3.5*(0.983*457.2-2*2.556*(0.983-0.1)))/(2*1*2.556)
= 30.451 N./mm²

Straight Flange Required Thickness:
= (P*Ro)/(S*E+0.4*P) + ca per Appendix 1-1 (a)(1)
= (3.5*228.6)/(117.9*1+0.4*3.5)+3
= 3.678 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.000 bars
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (117.9 * 1 * 3.35)/(228.6 - 0.4 * 3.35)
= 17.379 - 0.000 = 17.379 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^(2))/6
= (2 + (452.1/(2 * 114.5))^(2))/6
= 0.982651

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 5.556, tr = 2.556, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 1, Temp. Reduction = 0 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 6.35, tr = 2.616, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.781, Temp. Reduction = 12 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -41 °C

Cylindrical Shell From 20 To 40 SA-516 70 , UCS-66 Crv. B at 85 °C

Shell - 18"

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (3.5*228.6)/(137.9*0.85+0.4*3.5)
= 0.6818 + 3.0000 = 3.6818 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 2.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.000 bars
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (137.9*0.85*3)/(228.6-0.4*3)
= 15.463 - 0.000 = 15.463 bars



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Internal Pressure Calculations: Step: 5 1:17pm Apr 8,2024

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (137.9*0.85*6)/(228.6-0.4*6)
= 31.090 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Ro-0.4*t))/(E*t)
= (3.5*((228.6-0.4*3))/(0.85*3)
= 31.215 N./mm²

% Elongation per Table UG-79-1 (50*t_{nom}/R_f*(1-R_f/R_o)) 1.330 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 6, tr = 2.631, c = 3 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.745, Temp. Reduction = 14 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -43 °C

Note: Heads and Shells Exempted to -20F (-29C) by paragraph UG-20F

Hydrostatic Test Pressure Results:

Pressure per UG99b = 1.30 * M.A.W.P. * Sa/S 17.618 bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S 4.550 bars
Pressure per UG99c = 1.30 * M.A.P. - Head(Hyd) 22.232 bars
Pressure per UG100 = 1.10 * M.A.W.P. * Sa/S 14.907 bars
Pressure per PED = max(1.43*DP, 1.25*DP*ratio) 5.005 bars
Pressure per App 27-4 = M.A.W.P. 13.552 bars

UG-99(b), Test Pressure Calculation:
= Test Factor * MAWP * Stress Ratio
= 1.3 * 13.55 * 1
= 17.618 bars

Vertical 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 (N./mm² & bars):

From To	Stress	Allowable	Ratio	Pressure
Cap - 18" (sch.10)	154.7	217.2	0.712	17.78
Shell - 18"	158.4	235.8	0.672	17.76

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
Drain - 2in	Nozzle	117.90	117.90	1.000



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Internal Pressure Calculations: Step: 5 1:17pm Apr 8,2024

Drain - 2in	Pad	137.90	137.90	1.000
Gas In - 6in	Nozzle	117.90	117.90	1.000
Gas In - 6in	Pad	137.90	137.90	1.000
Gas Out - 6in	Nozzle	117.90	117.90	1.000
Gas Out - 6in	Pad	137.90	137.90	1.000
Vent - 1in	Nozzle	137.90	137.90	1.000

Minimum 1.000

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

Description	Ambient	Operating	Ratio
Cap - 18" (sch.10)	117.90	117.90	1.000
Shell - 18"	137.90	137.90	1.000
Body Flange - 18"	137.90	137.90	1.000
Blind Flange - 18"	137.90	137.90	1.000

Minimum 1.000

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

Description	Ambient	Operating	Ratio
Drain - 2in	10.83	217.19	0.050
Gas In - 6in	45.61	217.19	0.210
Gas Out - 6in	45.37	217.19	0.209
Vent - 1in	4.97	223.40	0.022

Elements Suitable for Internal Pressure.

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External Pressure Calculations: Step: 6 1:17pm Apr 8,2024

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm ²
10	20	No Calc	457.2	2.55625	0.00077654	77.1443
20	40	1537.17	457.2	3	0.00019777	19.7722
40	50	No Calc	...	36.624	No Calc	No Calc
50	60	No Calc	...	35	No Calc	No Calc

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	5.55625	5.5	1	4.79218
20	40	6	5.39662	1	1.72975
40	50	39.624	No Calc	1	No Calc
50	60	38	37.5412	1	No Calc

Minimum 1.730

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	40	1537.17	2555.37	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 85 °C

Cap - 18" (sch.10)

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
2.556	457.20	178.86	0.0007765	77.14

EMAP = B/(K0*D/t) = 77.14/(0.9 *178.9) = 4.792 bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
-----	----	-----	----------	---



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External Pressure Calculations: Step: 6 1:17pm Apr 8,2024

1.164 457.20 392.77 0.0003536 35.35
EMAP = B/(K0*D/t) = 35.35/(0.9 *392.8) = 1 bars

Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (1.67*452.1*0.983)/(2*117.9*1-0.2*1.67)
= 0.3147 + 3.0000 = 3.3147 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*117.9*1*2.556)/(0.983*452.1+0.2*2.556))/1.67
= 8.115 bars

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(4.792, 8.115)
= 4.792 bars

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

Cylindrical Shell From 20 to 40 Ext. Chart: CS-2 at 85 °C

Shell - 18"

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	457.20	1537.17	152.40	3.3621	0.0001978	19.77

EMAP = (4*B)/(3*(D/t)) = (4*19.77)/(3*152.4) = 1.73 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.397	457.20	1537.17	190.77	3.3621	0.0001431	14.31

EMAP = (4*B)/(3*(D/t)) = (4*14.31)/(3*190.8) = 1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	457.20	2555.37	152.40	5.5892	0.0001144	11.44

EMAP = (4*B)/(3*(D/t)) = (4*11.44)/(3*152.4) = 1 bars



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Element and Detail Weights: Step: 7 1:17pm Apr 8,2024

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm.	Corroded Metal Wgt. kg.	Corroded ID Volume Cm.	Extra due Misc % kg.
10	20	18.0037	24908.9	9.49802	25744	0.90019
20	40	93.2731	220310	46.9464	226288	4.66366
40	50	53.3965	...	53.3965	...	2.66983
50	60	93.2719	...	93.2719	...	4.6636
Total		257	245219.02	203	252032.45	12

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	0.029872	...	-55.761	Liquid: 10
10	Nozl	11.6046	...	-246.522	Drain - 2in
10	Forc	...	...	-114	Drain - 2"
10	Forc	...	...	85	Gas In - 6"
10	Forc	...	...	85	Gas Out - 6"
20	Liqd	0.26421	...	707.5	Liquid: 20
20	Nozl	27.3742	306.737	200	Gas In - 6in
20	Nozl	27.3742	306.737	1150	Gas Out - 6in
20	Nozl	0.71921	251.175	1250	Vent - 1in
20	Legs	80.5908	...	-250	LEGS
20	Wght	20	225	1250	LIFTING-L
20	Wght	20	225	1250	LIFTING-R
20	Wght	300	...	675	CARTRIDGE
50	Wght	50	...	...	DAVIT

Total Weight of Each Detail Type:

Liquid	0.3
Nozzles	67.1
Legs	80.6
Weights	390.0

Sum of the Detail Weights 538.0 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	270.8	270.8	270.8	270.8	270.8	270.8
Nozzles	67.1	67.1	67.1	67.1	67.1	67.1
Legs	80.6	80.6	80.6	80.6	80.6	80.6
Wld Weights	390.0	390.0	390.0	390.0	390.0	390.0
Ope. Liquid	0.3
Test Liquid	...	245.1
Totals	808.5	1053.6	808.5	808.5	808.5	808.8



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Element and Detail Weights: Step: 7 1:17pm Apr 8,2024

Miscellaneous Weight Percent: 5.0 %

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

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	808.5 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	1053.6 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	808.5 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	808.5 kg.
Op. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	808.5 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	808.8 kg.
Field Test Wt.	- Empty Weight + Water (Full)	1002.8 kg.
Mass of the Upper 1/3 of the Vertical Vessel		288.5 kg.

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

Outside Surface Areas of Elements:

From	To	Surface Area cm ²
10	20	3506.76
20	40	20324.2
40	50	2762.85
50	60	3924.99

Total 30518.762 cm²

Element and Detail Weights:

From	To	Total Ele. Empty Wgt. kg.	Total. Ele. Oper. Wgt. kg.	Total. Ele. Hydro. Wgt. kg.	Total Dtl. Offset Mom. Kg-m.	Oper. Wgt. No Liquid kg.
10	20	30.5085	30.5384	47.3058	...	30.5085
20	Legs	87.1739	87.2206	118.536	4.58915	87.1739
Legs	40	406.231	406.448	552.376	21.3854	406.231
40	50	56.0663	56.0663	56.0663	...	56.0663
50	60	147.936	147.936	147.936	...	147.936

Empty Support Force + the Sum of the Y forces	1141.13	Kgf
Operating Support Force + the Sum of the Y forces	1141.43	Kgf
Hydro Support Force + the Sum of the Y forces	1335.44	Kgf

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20



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Element and Detail Weights: Step: 7 1:17pm Apr 8,2024

20	Legs	-30.5085	-30.5384	-47.3058
Legs	40	610.232	610.45	756.378
40	50	204.002	204.002	204.002
50	60	147.936	147.936	147.936

Note: The cumulative operating weights no liquid in the column above are the cumulative operating weights minus the operating liquid weight minus any weights absent in the empty condition.

Cumulative Vessel Moment

From	To	Cumulative Empty Mom. Kg-m.	Cumulative Oper. Mom. Kg-m.	Cumulative Hydro. Mom. Kg-m.
10	20
20	Legs	4.58915	4.58915	4.58915
Legs	40	21.3854	21.3854	21.3854
40	50
50	60



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Nozzle Flange MAWP:

Step: 8 1:17pm Apr 8,2024

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating		Design Temp °C	Class	Grade/Group	Equiv. Press	Max Pressure		
	Op. bars	Ambient bars					PVP	50%	DNV bars
Drain - 2in	18.15	19.60	85	150	GR 1.1	...	...	...	...
Gas In - 6in	18.15	19.60	85	150	GR 1.1	...	...	...	...
Gas Out - 6in	18.15	19.60	85	150	GR 1.1	...	...	...	...
Min Rating	18.150	19.600 bars [for Core Elements]					0.000	0.000	0.000

Selected Method for Derating ANSI B16.5 Flange MAWP: None Selected

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

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Natural Frequency Calculation: Step: 9 1:17pm Apr 8, 2024

The Natural Frequencies for the vessel have been computed iteratively by solving a system of matrices. These matrices describe the mass and the stiffness of the vessel. This is the generalized eigenvalue/eigenvector problem and is referenced in some mathematical texts.

The Natural Frequency for the Vessel (Empty.) is 22.0608 Hz.

The Natural Frequency for the Vessel (Ope...) is 22.0578 Hz.

The Natural Frequency for the Vessel (Filled) is 20.3316 Hz.

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Forces/Moments Applied to Vessel Step: 10 1:17pm Apr 8,2024

Forces/Moments Applied to Vessel (Combined w/Wind Loads)

From	To	X and Z Dir Force Res. Kgf	X,Z Moment and For Res Kg-m.
10	20	511.114	730.313
20	40	...	...
40	50	...	...
50	60	...	...

Forces/Moments Applied to Vessel (Combined w/Seismic Loads)

From	To	X and Z Dir Force Res. Kgf	X,Z Moment and For Res Kg-m.
10	20	511.114	730.313
20	40	...	...
40	50	...	...
50	60	...	...

User Input Forces and Moments:

From Node	Distance From	----- Forces Fx	----- Fy	----- Fz	----- Moments Mx	----- My	----- Mz
10	-114.00		-52.				
10	85.00	181.	-181.	181.	172.		172.
10	85.00	181.	-181.	181.	344.		344.



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Wind Load Calculation: Step: 11 1:17pm Apr 8,2024

Wind Analysis Results per UBC 1994 or UBC 1997

Importance Factor as Entered by the User is	1.150	
Wind Stagnation Pressure (qs) from Table 16-F	75.6	Kgs/m ²
Pressure Coefficient from Table 16-H	Cq 0.800	
User Entered Basic Wind Speed	125.0	Km/hr

$P(\text{height}) = C_e(\text{height,Exp}) * C_q * q_s * \text{Imp Fact. [18-1](1994) or [20-1](1997)}$

The values of Ce are shown as the in the table below:

Element	Ce
Cap - 18" (sch.1	1.0600
Shell - 18"	1.0600
Body Flange - 18	1.0600
Blind Flange - 1	1.0600

Wind Vibration Calculations

This evaluation is based on work by Kanti Mahajan and Ed Zorilla

Nomenclature

- Cf - Correction factor for natural frequency
- D - Average internal diameter of vessel mm.
- Df - Damping Factor < 0.75 Unstable, > 0.95 Stable
- Dr - Average internal diameter of top half of vessel mm.
- f - Natural frequency of vibration (Hertz)
- f1 - Natural frequency of bare vessel based on a unit value of $(D/L^2)(10^{(4)})$
- L - Total height of structure mm.
- Lc - Total length of conical section(s) of vessel mm.
- tb - Uncorroded plate thickness at bottom of vessel mm.
- V30 - Design Wind Speed provided by user Km/hr
- Vc - Critical wind velocity Km/hr
- Vw - Maximum wind speed at top of structure Km/hr
- W - Total corroded weight of structure Kgf
- Ws - Cor. vessel weight excl. weight of parts which do not effect stiff. Kgf
- Z - Maximum amplitude of vibration at top of vessel mm.
- Dl - Logarithmic decrement (taken as 0.03 for Welded Structures)
- Vp - Vib. Chance, $\leq 0.32037E-06$ (High); $0.32037E-06 < 0.40047E-06$ (Probable)
- P30 - wind pressure 30 feet above the base

Check other Conditions and Basic Assumptions:

- #1 - Total Cone Length / Total Length < 0.5
 $0/1548 = 0$
- #2 - $(D / L^2) * 10^{(4)} < 8.0$ (English Units)
 $- (1.571/5.077^2) * 10^{(4)} = 609.5$ [Geometry Violation]

Compute the vibration possibility. If $V_p > 0.40047E-06$ no chance. [Vp]:

$$= W / (L * D_r^2)$$

$$= 751.2 / (1548 * 460.8^2)$$

$$= 0.22857E-05$$



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Wind Load Calculation: Step: 11 1:17pm Apr 8,2024

Since Vp is > 0.40047E-06 no further vibration analysis is required !

Platform Load Calculations

ID	Wind Area cm ²	Elevation mm.	Pressure Kgs/m ²	Force Kgf	Cf
----	------------------------------	------------------	--------------------------------	--------------	----

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm ²	Elevation mm.	Pressure Kgs/m ²	Force Kgf
LIFTING-L	0.00	1335.00	73.70	0.00
LIFTING-R	0.00	1335.00	73.70	0.00
CARTRIDGE	0.00	760.00	73.70	0.00
DAVIT	0.00	1509.53	73.70	0.00

The Natural Frequency for the Vessel (Ope...) is 22.0578 Hz.

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm ²	Wind Pressure Kgs/m ²	Element Wind Load Kgf
10	20	111.672	548.64	970.835	73.6976	7.15483
20	40	904.022	548.64	7763.26	73.6976	57.2134
40	50	1577.49	548.64	373.47	73.6976	2.75239
50	60	1640.05	762	289.56	73.6976	2.13399



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Earthquake Load Calculation: Step: 12 1:17pm Apr 8, 2024

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE/SEI 7-16
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.250
Table Value Fa		1.050
Table Value Fv		1.100
Max. Mapped Res. Acceleration	[Ss]	1.310
Max. Eff. Ground Acceleration	[S]	0.460
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.920
User Value of Sd1 (used if > 0)		0.340
Moment Reduction Factor Tau		1.000

Seismic Analysis Results:

$$Sms = Fa * Ss = 1.05 * 1.31 = 1.375$$

$$Sm1 = Fv * S1 = 1.1 * 0.46 = 0.506$$

$$Sds = 2/3 * Sms = 2/3 * 1.375 = 0.917$$

$$Sds = \text{Max}(0.8 * Sds, SdsUser)$$

$$= \text{Max}(0.734, 0.92)$$

$$= 0.920$$

$$Sd1 = 2/3 * Sm1 = 2/3 * 0.506 = 0.337$$

$$Sd1 = \text{Max}(0.8 * Sd1, Sd1User)$$

$$= \text{Max}(0.27, 0.34)$$

$$= 0.340$$

Check Approximate Fundamental Period from 12.8-7 [Ta]:

$$= Ct * hn^{(x)} \text{ where } Ct = 0.020, x = 0.75 \text{ and } hn = \text{Structural Height (ft.)}$$

$$= 0.020 * (7.004^{(0.75)})$$

$$= 0.086 \text{ seconds}$$

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

$$= (1/\text{Natural Frequency}) = (1/22.06)$$

$$= 0.045$$

Check the Value of T which is the smaller of Cu*Ta and T:

$$= \text{Minimum Value of } (1.4 * 0.0861, 0.0453) \text{ per 12.8.2}$$

$$= 0.045$$

As the time period is < 0.06 second, use section 15.4.2.

Compute the Base Shear per equation 15.4-5, [V]:



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Earthquake Load Calculation: Step: 12 1:17pm Apr 8,2024

$$= 0.3 * Sds * W * I$$

$$= 0.3 * 0.92 * 728.2 * 1.25$$

$$= 251.232 \text{ Kgf}$$

Final Base Shear, V = 175.86 Kgf

Distribute the Base shear force to each element according to the equations

$F_x = C_{vx} * V$ (eqn. 12.8-11) and the vertical distribution factor

$C_{vx} = \frac{W_x * h_x^k}{\sum (W_i * h_i^k)}$ and k is an exponent which is related to the period of Vibration.

In this case, the value of k was 1

The Natural Frequency for the Vessel (Ope...) is 22.0578 Hz.

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight Kgf	Element Ope Load Kgf	Element Emp Load Kgf
10	20	42.5	30.5384	0.31898	0.31863
20	Legs	335	87.2206	7.18106	7.17649
Legs	40	917.5	406.448	91.6507	91.5924
40	50	1534.04	56.0663	21.1379	21.1358
50	60	1528.53	147.936	55.5738	55.5681

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.



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User Force/Moment Shear and Bending Step: 13 1:17pm Apr 8,2024

Bending Moments due to user defined forces and moments.

User Force/Moment Shear and Bending

From	To	Distance to Support mm.	Cumulative Shr Wind Cas Kg-f	Cumulative Shr Eqk Cas Kg-f	Wind Bending Kg-m.	Earthquake Bending Kg-m.
10	20	340.406	...	...	...	...
20	Legs	125	511.114	511.114	730.313	730.313
Legs	40	582.5	511.114	511.114	858.094	858.094
40	50	1130.96	...	...	...	...
50	60	1193.53	...	...	...	...

Note:
The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of;
Wind: 1.000; Earthquake: 0.700.

Note:
Review the Vessel Design Summary for the cumulative shear force and bending moment on the support.

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Wind/Earthquake Shear, Bending: Step: 14 1:17pm Apr 8,2024

The following table is for the Operating Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support mm.	Cumulative Wind Shear Kgf	Earthquake Shear Kgf	Wind Bending Kg-m.	Earthquake Bending Kg-m.
10	20	340.406	...	...	...	...
20	Legs	125	7.15483	0.31898	0.64685	0.028838
Legs	40	582.5	59.1463	168.681	29.4	142.618
40	50	1130.96	4.88638	76.7117	0.29982	6.08783
50	60	1193.53	2.13399	55.5738	0.040547	1.05592

Note:

The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of; Wind: 1.000; Earthquake: 0.700.

Note:

Review the Vessel Design Summary for the cumulative shear force and bending moment on the support.

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Wind Deflection:

Step: 15 1:17pm Apr 8,2024

Wind Deflection Calculations:

The following table is for the Applied Forces Case.

Wind Deflection:

From	To	Cumulative Wind Shear Kgf	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	2.18689	2.18689	0.0031983
20	Legs	511.114	2.1902	2.19987	0.0032998
Legs	40	511.114	2.27474	2.3626	0.0033507
40	50	...	2.35741	2.35223	0.0033507
50	60	...	2.35512	2.35802	0.0033507

Allowable deflection at the Tower Top (For)(6.000"/100ft. Criteria)
Allowable deflection : 7.738 Actual deflection : 2.363 mm.

The following table is for the Operating Case.

Wind Deflection:

From	To	Cumulative Wind Shear Kgf	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	0.25407	0.25407	0.00037799
20	Legs	7.15483	0.2542	0.25457	0.00038185
Legs	40	59.1463	0.2589	0.2651	0.00038897
40	50	4.88638	0.26473	0.26435	0.00038897
50	60	2.13399	0.26456	0.26477	0.00038897

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed Km/hr	2nd Crit. Wind Speed Km/hr
10	20	217.246	1357.79
20	40	217.246	1357.79
40	50	217.246	1357.79
50	60	301.73	1885.81

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 7.738 Actual deflection : 0.265 mm.

Total Deflection in the Operating Condition + Applied Forces :
Allowable deflection : 7.738 Actual deflection : 2.628 mm.



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Longitudinal Stress Constants: Step: 16 1:17pm Apr 8,2024

Longitudinal Stress Constants:

From	To	Metal Area New cm ²	Metal Area Corroded cm ²	Section Modulus New mm. ³	Section Modulus Corroded mm. ³
10	20	78.8366	36.5108	879466	412679
20	40	85.0492	42.8071	946932	482907
40	50	85.0492	42.8071	946932	482907
50	60	85.0492	42.8071	946932	482907

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Longitudinal Allowable Stresses: Step: 17 1:17pm Apr 8,2024

Longitudinal Allowable Stresses:

From	To	Tensile N./mm ²	Hydrotest Tensile N./mm ²	Compressive N./mm ²	Hydrotest Compressive N./mm ²
10	20	120.263	221.536	-113.916	-113.916
20	Legs	140.658	240.525	-118.874	-118.874
Legs	40	140.658	240.525	-118.874	-118.874
40	50	165.48	268.078	-118.874	-118.874
50	60	165.48	282.971	-118.874	-118.874



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Longitudinal Stresses due to: Step: 18 1:17pm Apr 8,2024

Longitudinal Stress Report

Note: Longitudinal Operating and Empty Stresses are computed in the corroded condition. Stresses due to loads in the hydrostatic test cases have also been computed in the corroded condition.

Longitudinal Pressure Stresses due to:

From	To	Longitudinal Stress Internal Pressure N./mm ²	Longitudinal Stress External Pressure N./mm ²	Longitudinal Stress Hydrotest Pressure N./mm ²
10	20	15.4058	-4.49682	77.5479
20	40	13.0908	-3.83541	65.8949
40	50	...	...	...
50	60	...	...	...

Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty N./mm ²	Wght. Str. Operating N./mm ²	Wght. Str. Hydrotest N./mm ²	Wght. Str. Emp. Mom. N./mm ²	Wght. Str. Opr. Mom. N./mm ²
10	20	...	...	...	...	...
20	Legs	0.069893	0.069961	0.10837	0.093194	0.093194
Legs	40	-1.398	-1.3979	-1.398	0.43428	0.43428
40	50	-0.46736	-0.46736	-0.46736	...	...
50	60	-0.33891	-0.33891	-0.33891	...	...

Longitudinal Stresses due to Weight Loads and Bending for these Conditions:

From	To	Wght. Str. Hyd. Mom. N./mm ²	Bend. Str. Oper. Wind N./mm ²	Bend. Str. Oper. Equ. N./mm ²	Bend. Str. Hyd. Wind N./mm ²	Bend. Str. Hyd. Equ. N./mm ²
10	20	...	...	...	...	...
20	Legs	0.093194	0.013136	0.00058563	0.0043349	...
Legs	40	0.43428	0.59704	2.89622	0.19702	...
40	50	...	0.0060887	0.12363	0.0020093	...
50	60	...	0.0008234	0.021443	0.00027172	...

Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case N./mm ²	Vortex Shedding Empty Case N./mm ²	Vortex Shedding Test Case N./mm ²	Earthquake Empty Case N./mm ²
10	20
20	Legs	0.000585
Legs	40	2.89536
40	50	0.12362
50	60	0.021441



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Longitudinal Stresses due to: Step: 18 1:17pm Apr 8,2024

Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind N./mm ²	Longitudinal Stress Y Forces Seismic N./mm ²
10	20	1.1099	1.1099
20	Legs	0.94665	0.94665
Legs	40	...	...
40	50	...	...
50	60	...	...

Longitudinal Stresses due to User Forces and Moments:

From	To	Wind For/Mom Corroded N./mm ²	Earthquake For/Mom Corroded N./mm ²	Wind For/Mom No Corrosion N./mm ²	Earthquake For/Mom No Corrosion N./mm ²
10	20	...	...	...	...
20	Legs	14.8308	14.8308	7.56328	7.56328
Legs	40	17.4257	17.4257	8.8866	8.8866
40	50
50	60



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Stress due to Combined Loads: Step: 19 1:17pm Apr 8,2024

Stress Combination Load Cases for Vertical Vessels:

Load Case Definition Key

- IP = Longitudinal Stress due to Internal Pressure
EP = Longitudinal Stress due to External Pressure
HP = Longitudinal Stress due to Hydrotest Pressure
NP = No Pressure
EW = Longitudinal Stress due to Weight (No Liquid)
OW = Longitudinal Stress due to Weight (Operating)
HW = Longitudinal Stress due to Weight (Hydrotest)
WI = Bending Stress due to Wind Moment (Operating)
EQ = Bending Stress due to Earthquake Moment (Operating)
EE = Bending Stress due to Earthquake Moment (Empty)
HI = Bending Stress due to Wind Moment (Hydrotest)
HE = Bending Stress due to Earthquake Moment (Hydrotest)
WE = Bending Stress due to Wind Moment (Empty) (no CA)
WF = Bending Stress due to Wind Moment (Filled) (no CA)
CW = Longitudinal Stress due to Weight (Empty) (no CA)
VO = Bending Stress due to Vortex Shedding Loads (Ope)
VE = Bending Stress due to Vortex Shedding Loads (Emp)
VF = Bending Stress due to Vortex Shedding Loads (Test No CA.)
FW = Axial Stress due to Vertical Forces for the Wind Case
FS = Axial Stress due to Vertical Forces for the Seismic Case
BW = Bending Stress due to Lat. Forces for the Wind Case, Corroded
BS = Bending Stress due to Lat. Forces for the Seismic Case, Corroded
BN = Bending Stress due to Lat. Forces for the Wind Case, UnCorroded
BU = Bending Stress due to Lat. Forces for the Seismic Case, UnCorroded

General Notes:

Case types HI and HE are in the Corroded condition.

Case types WE, WF, and CW are in the Un-Corroded condition.

A blank stress and stress ratio indicates that the corresponding stress comprising those components that did not contribute to that type of stress.

An asterisk (*) in the final column denotes overstress.

Analysis of Load Case 1 : NP+EW+WI+FW+BW

Table with 7 columns: From Node, Tensile Stress, All. Tens. Stress, Comp. Stress, All. Comp. Stress, Tens. Ratio, Comp. Ratio. Rows for nodes 10, 20, 20.

Analysis of Load Case 2 : NP+EW+EE+FS+BS

Table with 7 columns: From Node, Tensile Stress, All. Tens. Stress, Comp. Stress, All. Comp. Stress, Tens. Ratio, Comp. Ratio. Rows for nodes 10, 20, 20.

Analysis of Load Case 3 : NP+OW+WI+FW+BW



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Stress due to Combined Loads: Step: 19 1:17pm Apr 8,2024

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	1.11	120.26		113.92	0.0092	
20	15.95	140.66	-13.92	118.87	0.1134	0.1171
20	17.06	140.66	-19.85	118.87	0.1213	0.1670

Analysis of Load Case 4 : NP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	1.11	120.26		113.92	0.0092	
20	15.94	140.66	-13.91	118.87	0.1133	0.1170
20	19.36	140.66	-22.15	118.87	0.1376	0.1864

Analysis of Load Case 5 : NP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	221.54	0.00	113.92	0.0000	0.0000
20	0.21	240.53		118.87	0.0009	
20		240.53	-2.03	118.87		0.0171

Analysis of Load Case 6 : NP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	221.54	0.00	113.92	0.0000	0.0000
20	0.20	240.53		118.87	0.0008	
20		240.53	-1.83	118.87		0.0154

Analysis of Load Case 7 : IP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	16.52	120.26		113.92	0.1373	
20	29.04	140.66	-0.83	118.87	0.2065	0.0070
20	30.15	140.66	-6.76	118.87	0.2143	0.0569

Analysis of Load Case 8 : IP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	16.52	120.26		113.92	0.1373	
20	29.03	140.66	-0.82	118.87	0.2064	0.0069
20	32.45	140.66	-9.06	118.87	0.2307	0.0762

Analysis of Load Case 9 : EP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		120.26	-3.39	113.92		0.0297
20	12.12	140.66	-17.76	118.87	0.0862	0.1494
20	13.22	140.66	-23.69	118.87	0.0940	0.1993

Analysis of Load Case 10 : EP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		120.26	-3.39	113.92		0.0297
20	12.11	140.66	-17.74	118.87	0.0861	0.1493
20	15.52	140.66	-25.99	118.87	0.1104	0.2186

Analysis of Load Case 11 : HP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
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Stress due to Combined Loads: Step: 19 1:17pm Apr 8,2024

Node	Stress	Stress	Stress	Stress	Ratio	Ratio
10	77.55	221.54		113.92	0.3500	
20	66.10	240.53		118.87	0.2748	
20	65.13	240.53		118.87	0.2708	

Analysis of Load Case 12 : HP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	77.55	221.54		113.92	0.3500	
20	66.10	240.53		118.87	0.2748	
20	64.93	240.53		118.87	0.2700	

Analysis of Load Case 13 : IP+WE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	15.41	120.26		113.92	0.1281	
20	13.25	140.66		118.87	0.0942	
20	12.13	140.66		118.87	0.0862	

Analysis of Load Case 14 : IP+WF+CW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	15.41	120.26		113.92	0.1281	
20	13.13	140.66		118.87	0.0933	
20	12.39	140.66		118.87	0.0881	

Analysis of Load Case 15 : IP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	15.41	120.26		113.92	0.1281	
20	13.25	140.66		118.87	0.0942	
20	12.13	140.66		118.87	0.0862	

Analysis of Load Case 16 : IP+VE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	15.41	120.26		113.92	0.1281	
20	13.25	140.66		118.87	0.0942	
20	12.13	140.66		118.87	0.0862	

Analysis of Load Case 17 : NP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	120.26	0.00	113.92	0.0000	0.0000
20	0.16	140.66	-0.02	118.87	0.0012	0.0002
20		140.66	-1.83	118.87		0.0154

Analysis of Load Case 18 : FS+BS+IP+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	16.52	120.26		113.92	0.1373	
20	29.03	140.66	-0.82	118.87	0.2064	0.0069
20	29.55	140.66	-6.17	118.87	0.2101	0.0519

Analysis of Load Case 19 : FS+BS+EP+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
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Stress due to Combined Loads: Step: 19 1:17pm Apr 8,2024

10		120.26	-3.39	113.92		0.0297
20	12.11	140.66	-17.74	118.87	0.0861	0.1493
20	12.63	140.66	-23.09	118.87	0.0898	0.1943

Absolute Maximum of the all of the Stress Ratio's 0.3500

Governing Element: Cap - 18" (sch.10)
Governing Load Case 11 : HP+HW+HI

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Center of Gravity Calculation: Step: 20 1:17pm Apr 8,2024

Shop/Field Installation Options :

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

Center of Gravity of Liquid	706.335 mm.
Center of Gravity of Nozzles	592.021 mm.
Center of Gravity of Legs	-165.000 mm.
Center of Gravity of Added Weights (Operating)	915.067 mm.
Center of Gravity of Added Weights (Empty)	915.067 mm.
Center of Gravity of Bare Shell New and Cold	1141.929 mm.
Center of Gravity of Bare Shell Corroded	1269.936 mm.
Vessel CG in the Operating Condition	871.019 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	856.605 mm.
Vessel CG in the Test Condition	822.693 mm.

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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

RESULTS FOR LEGS : Operating Case Description: LEGS

Legs attached to: Shell - 18"

Section Properties : I Beam IPE120

European Structural Steel Data

Overall Leg Length		1000.000	mm.
Effective Leg Length	Leglen	800.000	mm.
Distance Leg Up Side of Vessel		250.000	mm.
Number of Legs	Nleg	3	
Cross Sectional Area for IPE120	Aleg	13.200	cm ²
Section Inertia (strong axis)		317.998	cm ^{*4}
Section Inertia (weak axis)		27.700	cm ^{*4}
Section Modulus (strong axis)		53000.219	mm. ³
Section Modulus (weak axis)		8650.034	mm. ³
Radius of Gyration (strong axis)		49.000	mm.
Radius of Gyration (weak axis)		14.500	mm.

Leg Orientation - Strong Axis

Overturning Moment at top of Legs		1009.7	Kg-m.
Total Weight Load at top of Legs	W	1145.3	Kgf
Total Shear force at top of Legs		687.0	Kgf
Additional force in Leg due to Bracing	Fadd	0.0	Kgf
Occasional Load Factor	Occfac	1.000	
Effective Leg End Condition Factor	k	0.650	

Note: The Legs are Not Cross Braced
The Leg Shear Force includes Wind and Seismic Effects

Pad Width along Circumference	C11P	150.000	mm.
Pad Length along Vessel Axis	C22P	250.000	mm.
Pad Thickness	Tpad	6.000	mm.

Maximum Shear at top of one Leg [Vleg]:
= (max(Wind, Seismic) + applied forces) (Imax / Itot)
= (687) (316.9/372.4)
= 584.59 Kgf

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 11231/3 + (9901107/(1 * 294.6))/1320
= 28.30 N./mm²

Axial Compression, Leg closest to the Neutral Axis [Sva]:
= (W / Nleg) / Aleg
= (1145/3)/13.2
= 2.84 N./mm²

Allowable Comp. for the Selected Leg (KL/r < Cc) [Sa]:
= Occfac * (1-(kl/r)²/(2*Cc²))*Fy /
(5/3+3*(KL/r)/(8*Cc)-(KL/r³)/(8*Cc³)
= 1 * (1-(35.86)²/(2 * 127.2²)) * 248.2/
(5/3+3*(35.86)/(8* 127.2)-(35.86³)/(8* 127.2³)



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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

= 134.69 N./mm²

Bending at the Bottom of the Leg closest to the N.A. [S]:

= (Vleg * Leglen / Smdsa)
= (584.6 * 800/53000)
= 86.54 N./mm²

Allowable Bending Stress[Sb]:

= (0.6 * Fy * Occfac)
= (0.6 * 248.2 * 1)
= 148.93 N./mm²

AISC Unity Check [Sc](must be < or = to 1.00) :

= (Sma/Sa)+(0.85*S)/((1-Sma/Spex)*Sb)
= (28.3/134.7)+(0.85 *86.54)/((1 -28.3/814.4) *148.9)
= 0.7218

WRC 107 Stress Analysis for Leg to Shell Junction, Ope Condition

Table with 3 columns: Parameter, ID, Value. Rows: Rectangular Attachment Parameter C11 (64.000 mm), Rectangular Attachment Parameter C22 (230.950 mm).

Input Echo, WRC107/537 Item 1, Description: LEGS

Table with 3 columns: Parameter, ID, Value. Rows: Diameter Basis for Vessel (Vbasis, ID, Cylsph, Cylindrical), Internal Corrosion Allowance (Cas, 3.0000 mm), Vessel Diameter (Dv, 445.200 mm), Vessel Thickness (Tv, 6.000 mm).

Table with 3 columns: Parameter, ID, Value. Row: Design Temperature (T1, 85.0 °C).

Table with 3 columns: Parameter, Type, Value. Rows: Attachment Type (Rectangular), Parameter C11 (64.00 mm), Parameter C22 (230.95 mm).

Table with 3 columns: Parameter, ID, Value. Rows: Thickness of Reinforcing Pad (Tpad, 6.000 mm), Pad Parameter C11P (C11p, 150.000 mm), Pad Parameter C22P (C22p, 250.000 mm).

Table with 3 columns: Parameter, ID, Value. Rows: Design Internal Pressure (Dp, 3.500 bars), Include Pressure Thrust (No).

Table with 3 columns: Parameter, ID, Value. Rows: Vessel Centerline Direction Cosine (Vx, Vy, Vz, 0.000, 1.000, 0.000), Nozzle Centerline Direction Cosine (Nx, Ny, Nz, 1.000, 0.000, 0.000).

Table with 3 columns: Parameter, ID, Value. Rows: Global Force (SUS) (Fx, Fy, Fz, 307.5 Kg, 381.8 Kg, 307.5 Kg), Global Moment (SUS) (Mx, My, Mz, 0.0 Kg-m, 0.0 Kg-m, 199.2 Kg-m).



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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

Internal Pressure (SUS) P 3.50 bars
Include Pressure Thrust No

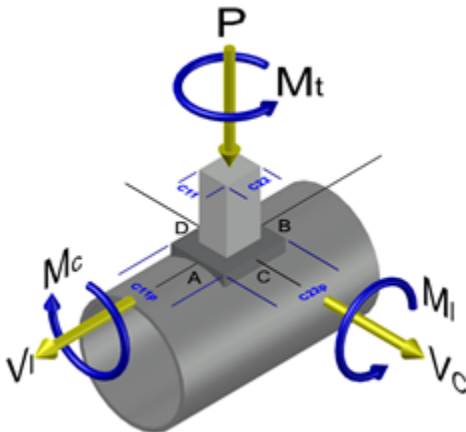
Global Force (OCC) Fx 584.6 Kgf
Global Force (OCC) Fy 3427.3 Kgf
Global Force (OCC) Fz 0.0 Kgf
Global Moment (OCC) Mx 0.0 Kg-m.
Global Moment (OCC) My 0.0 Kg-m.
Global Moment (OCC) Mz 460.1 Kg-m.

Occasional Internal Pressure (OCC) Pvar 0.00 bars

Use Interactive Control No
WRC107 Version Version March 1979

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

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



WRC 107 Stress Calculation for SUStained loads:

Radial Load P 307.5 Kgf
Circumferential Shear VC -307.5 Kgf
Longitudinal Shear VL 381.8 Kgf
Circumferential Moment MC 0.0 Kg-m.
Longitudinal Moment ML -199.2 Kg-m.
Torsional Moment MT 0.0 Kg-m.

Dimensionless Parameters used : Gamma = 25.57

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979 Beta Figure Value Location



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Leg Check, (Operating Case):

Step: 21

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Table with 5 columns: Parameter, Value, Curve, Value, and Location. Rows include N(PHI) / (P/Rm), M(PHI) / (P), N(x) / (P/Rm), etc.

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Table with 10 columns: Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, Dl. Rows include Circ. Memb. P, Long. Memb. P, Tot. Circ. Str., etc.



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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

Dimensionless Parameters used : Gamma = 75.70

Dimensionless Loads for Cylindrical Shells at Pad edge:

Table with 5 columns: Curves read for 1979, Beta, Figure, Value, Location. It lists various stress curves like N(PHI) / (P/Rm) and M(PHI) / (P) with their respective values and locations.

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Table titled 'Stress Intensity Values at' with columns for Type of Stress, Load, and stress intensity values (Au, Al, Bu, Bl, Cu, Cl, Du, Dl) for various vessel components like Circ. Memb. P, Long. Memb. P, etc.



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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

Table with 9 columns: Tot. Shear, Str. Int., and numerical values for various stress components.

WRC 107 Stress Calculation for OCCasional loads:

Table listing radial load, circumferential shear, longitudinal shear, and torsional moment with corresponding values in Kg-f and Kg-m.

Dimensionless Parameters used : Gamma = 25.57
Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Large table showing Stress Intensity Values at various points (Au, Al, Bu, Bl, Cu, Cl, Du, Dl) for different types of stress and loads.

Dimensionless Parameters used : Gamma = 75.70
Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Table showing Stress Intensity Values at the edge of reinforcing pad for different types of stress and loads.



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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

Table with 9 columns and multiple rows showing stress calculations for various components like Circ. Bend. P, Long. Memb. P, etc.

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N/mm²)

Table with 10 columns (Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, D1) and multiple rows showing stress intensity values for different load types and components.



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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-2.6	-2.6	2.6	2.6	-0.9	-0.9	0.9	0.9	0.9
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-8.1	-8.1	8.1	8.1	8.1
Shear Pl(TOTAL)	-2.6	-2.6	2.6	2.6	-9.0	-9.0	9.0	9.0	9.0
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	8.6	9.0	8.6	9.0	8.6	9.0	8.6	9.0	9.0
Pm (SUS+OCC)	8.6	9.0	8.6	9.0	8.6	9.0	8.6	9.0	9.0
Pm+Pl (SUS)	24.2	24.5	16.3	16.1	7.1	7.4	7.1	7.4	7.4
Pm+Pl (SUS+OCC)	59.4	59.7	65.0	64.6	21.4	21.6	21.4	21.6	21.6
Pm+Pl+Q (Total)	176.7	58.9	229.4	101.3	44.7	48.2	44.7	48.2	48.2

Vessel Stress Summation Comparison (N/mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	8.95	137.90	Passed
Pm (SUS+OCC)	8.95	165.48	Passed
Pm+Pl (SUS)	24.54	206.85	Passed
Pm+Pl (SUS+OCC)	64.97	248.22	Passed
Pm+Pl+Q (TOTAL)	229.41	413.70	Passed

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature. This allowable is computed per ASME VIII-2, 5.5.6.1(1) Part 5, 3((Smc + Smh)/2).

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N/mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		26.1	26.5	26.1	26.5	26.1	26.5	26.1	26.5
Circ. Pm (OCC)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pm(TOTAL)		26.1	26.5	26.1	26.5	26.1	26.5	26.1	26.5
Circ. Pl (SUS)		32.5	32.5	-63.8	-63.8	-4.8	-4.8	-4.8	-4.8
Circ. Pl (OCC)		81.4	81.4	-141.0	-141.0	-9.1	-9.1	-9.1	-9.1
Circ. Pl(TOTAL)		113.9	113.9	-204.8	-204.8	-13.9	-13.9	-13.9	-13.9
Circ. Q (SUS)		31.8	-31.8	-51.2	51.2	-136.8	136.8	-136.8	136.8
Circ. Q (OCC)		77.5	-77.5	-114.3	114.3	-260.0	260.0	-260.0	260.0
Circ. Q (TOTAL)		109.3	-109.3	-165.6	165.6	-396.8	396.8	-396.8	396.8
Long. Pm (SUS)		13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
Long. Pm (OCC)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pm(TOTAL)		13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
Long. Pl (SUS)		28.6	28.6	-39.2	-39.2	-17.1	-17.1	-17.1	-17.1
Long. Pl (OCC)		68.2	68.2	-88.3	-88.3	-32.5	-32.5	-32.5	-32.5



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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

Table with 9 columns and 20 rows showing stress calculations for Long. Pl, Shear Pm, Shear Pl, Shear Q, and Pm (SUS) under various conditions (TOTAL, SUS, OCC).

Vessel Stress Summation Comparison (N/mm²):

Table with 4 columns: Type of Stress Int., Max. S.I., S.I. Allowable, and Result. Rows include Pm (SUS), Pm (SUS+OCC), Pm+Pl (SUS), Pm+Pl (SUS+OCC), and Pm+Pl+Q (TOTAL).

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature. This allowable is computed per ASME VIII-2, 5.5.6.1(1) Part 5, 3((Smc + Smh)/2).

Bolting Size Requirement for Leg Baseplates :

Table with 4 columns: Parameter, Code, Value, and Unit. Rows include Baseplate Material (SA-283 C), Baseplate Allowable Stress (SBA), Baseplate Length (B), Baseplate Width (D), Baseplate Thickness (BTHK), Leg Dimension Along Baseplate Length (d), Leg Dimension Along Baseplate Width (b), Dist. from the Leg Edge to Bolt Hole Center (z), Bolt Material (SA-36), Bolt Allowable Tensile Stress (STBA), Bolt Allowable Shear Stress (SBShear), Anchor Bolt Nominal Diameter (BOD), Number of Anchor Bolts in Tension per Leg (NB), Total Number of Anchors Bolt per Leg (NBT), and Ultimate 28-day Concrete Strength (FCPRIME).



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Shear Stress in a Single Bolt [taub]:

$$\begin{aligned}
 &= \text{Shear Force} / (2 * \text{Bolt Area} * \text{Number of Bolts}) \\
 &= 687 / (2 * 1.383 * 4) \\
 &= 6.1 \text{ N./mm}^2. \text{ Must be less than } 68.7 \text{ N./mm}^2.
 \end{aligned}$$

LEG BASEPLATE and BOLTING Analysis, including Moments

I-Beam Leg

Base Plate Available Area (AA):

$$\begin{aligned}
 &= B * D \\
 &= 280 * 280 \\
 &= 784.00 \text{ cm}^2
 \end{aligned}$$

Clearance Between The Bolt And The Leg Edge (BCL):

$$\begin{aligned}
 &= z - \text{BOD} / 2 \\
 &= 50 - 16/2 \\
 &= 42.00 \text{ mm.}
 \end{aligned}$$

Moment at Baseplate (MOMENT):

$$\begin{aligned}
 &= V_{\text{leg}} * L_{\text{leg}} \\
 &= 584.6 * 1000 \\
 &= 584.60 \text{ Kg-m.}
 \end{aligned}$$

Axial Load on the baseplate (P):

$$\begin{aligned}
 &= \text{Operating Weight per leg (as Seismic + Operating case is controlling)} \\
 &= 269.60 \text{ Kgf}
 \end{aligned}$$

Eccentricity (e):

$$\begin{aligned}
 &= \text{MOMENT} * \text{Conv_Factor} / P \\
 &= 584.6 * 9806.64 / 269.6 \\
 &= 2168.37 \text{ mm.} > D/6 \text{ [Plate Uplift Condition]}
 \end{aligned}$$

$$\begin{aligned}
 a &= (D - d) / 2 \\
 &= (280 - 120) / 2 \\
 &= 80.00 \text{ mm.}
 \end{aligned}$$

Modular Ratio Of Steel/Concrete (n):

$$\begin{aligned}
 &= E_S / E_C \\
 &= 203402 / 21526 \\
 &= 9.45
 \end{aligned}$$

$$\begin{aligned}
 F &= 0.5 * d + z \\
 &= 0.5 * 120 + 50 \\
 &= 110.00 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 K1 &= 3.0 (e - 0.5 * D) \\
 &= 3.0 (2168 - 0.5 * 280) \\
 &= 6085.12
 \end{aligned}$$

$$\begin{aligned}
 K2 &= 6 * n * A_{st} / B * (F + e) \\
 &= 6 * 9.449 * 2.766 / 280 * (110 + 2168) \\
 &= 1276.24
 \end{aligned}$$

$$\begin{aligned}
 K3 &= -K2 * (0.5 * D + F) \\
 &= -1276 * (0.5 * 280 + 110)
 \end{aligned}$$



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= -319059.73

Solving For The Effective Bearing Length Using Iteration:

$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$

$Y^3 + 239.6 * Y^2 + 197.8 * Y - 1947 = 0$

$Y = 62.41 \text{ mm.}$

NUM = (D / 2 - Y / 3 - e)
= (280/2 - 62.41/3 - 2168)
= -2049.18

DENOM = (D / 2 - Y / 3 + F)
= (280/2 - 62.41/3 + 110)
= 229.20

Total Bolt Tension Force (T):

= - P * NUM / DENOM
= - 269.6 * -2049/229.2
= 2410.39 Kgf

Overturing Moment Due To Bolt In Tension (Mt):

= T * (0.5 * D + F - Y)
= 2410 * (0.5 * 280 + 110 - 62.41)
= 452.18 Kg-m.

Bearing Pressure (FC):

= 2 * (P + T) / (Y * B)
= 2 * (269.6 + 2410)/(62.41 * 280)
= 30.08 bars [<= FCPRIME (206.84)]

Equivalent Bearing Pressure (f1):

= FC * (Y - a) / Y
= 30.08 * (62.41 - 80)/62.41
= -8.48 bars

Overturing Moment Due To Bearing Pressure (Mc):

= (a² * B / 6) * (f1 + 2 * FC)
= (80² * 280/6) * (-8.481 + 2 * 30.08)
= 157.40 Kg-m.

The Baseplate Required Thickness (TREQ):

= (6 * MAX(Mt,Mc) / (B * 1.5 * SBA))^{1/2}
= (6 * 452.2/(280 * 162.4))^{1/2}
= 24.19 mm.

Required bolt area (ABREQM): per D. Moss

= T / STBA
= 2410/114.5
= 2.0653 cm² [< Ast (2.77) --> PASSED]

Distance from Top of Legs to Vessel CG (CD_DIST):

= 536 mm.

Total Overturing Moment at Baseplate (Mbb):

= (Mleg / max([CD_DIST], minDist)) * (CD_DIST + Lleg)
= (1010/max(536, 38.1)) * (536 + 1000)
= 2893.44 Kg-m.



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Leg Check, (Operating Case): Step: 21 1:17pm Apr 8,2024

Required Total Bolt Area per Leg (ABREQB): per H. Bednar

$$= (1 / (Nleg * STBA)) * ((4 * Mbb / (Rn * 2)) - W)$$

$$= (1 / (3 * 114.5)) * ((4 * 2893 / (589.2)) - 808.8)$$

$$= 5.3791 \text{ cm}^2$$

Available Total Bolt Corr. Area per Leg (ABAVL):

$$= As * NBT$$

$$= 1.383 * 4$$

$$= 5.5330 \text{ cm}^2 [> ABREQB (5.38) --> PASSED]$$

Summary of Results:

		Actual	Required	Pass/Fail
Baseplate Thickness	(mm.):	25.000	24.191	Pass
Bolt Root Area (Bednar)	(cm ²):	5.53	5.38	Pass
Bolt Root Area (D. Moss)	(cm ²):	2.77	2.07	Pass

Note: The required thickness calculation is performed based on:
Strong axis orientation of the beam leg
Even number of bolts installed only on the B dimension sides



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Leg Check, (Filled w/Water): Step: 22 1:17pm Apr 8,2024

RESULTS FOR LEGS : HydroTest Case Description: LEGS

Legs attached to: Shell - 18"

Section Properties : I Beam IPE120

European Structural Steel Data

Overall Leg Length		1000.000	mm.
Effective Leg Length	Leglen	800.000	mm.
Distance Leg Up Side of Vessel		250.000	mm.
Number of Legs	Nleg	3	
Cross Sectional Area for IPE120	Aleg	13.200	cm ²
Section Inertia (strong axis)		317.998	cm ^{*4}
Section Inertia (weak axis)		27.700	cm ^{*4}
Section Modulus (strong axis)		53000.219	mm. ³
Section Modulus (weak axis)		8650.034	mm. ³
Radius of Gyration (strong axis)		49.000	mm.
Radius of Gyration (weak axis)		14.500	mm.

Leg Orientation - Strong Axis

Overturning Moment at top of Legs		18.7	Kg-m.
Total Weight Load at top of Legs	W	976.8	Kgf
Total Shear force at top of Legs		22.9	Kgf
Additional force in Leg due to Bracing	Fadd	0.0	Kgf
Occasional Load Factor	Occfac	1.000	
Effective Leg End Condition Factor	k	0.650	

Note: The Legs are Not Cross Braced
The Leg Shear Force includes Wind and Seismic Effects

Pad Width along Circumference	C11P	150.000	mm.
Pad Length along Vessel Axis	C22P	250.000	mm.
Pad Thickness	Tpad	6.000	mm.

Maximum Shear at top of one Leg [Vleg]:
= (max(Wind, Seismic) + applied forces) (Imax / Itot)
= (22.85) (316.9/372.4)
= 19.45 Kgf

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 9579/3 + (183391/(1 * 294.6))/1320
= 2.89 N./mm²

Axial Compression, Leg closest to the Neutral Axis [Sva]:
= (W / Nleg) / Aleg
= (976.8/3) /13.2
= 2.42 N./mm²

Allowable Comp. for the Selected Leg (KL/r < Cc) [Sa]:
= Occfac * (1-(kl/r)²/(2*Cc²))*Fy /
(5/3+3*(KL/r)/(8*Cc)-(KL/r³)/(8*Cc³)
= 1 * (1-(35.86)²/(2 * 127.2²)) * 248.2/
(5/3+3*(35.86)/(8* 127.2)-(35.86³)/(8* 127.2³)



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= 134.69 N./mm²

Bending at the Bottom of the Leg closest to the N.A. [S]:

= (Vleg * Leglen / Smdsa)
= (19.45 * 800/53000)
= 2.88 N./mm²

Allowable Bending Stress[Sb]:

= (0.6 * Fy * Occfac)
= (0.6 * 248.2 * 1)
= 148.93 N./mm²

AISC Unity Check [Sc](must be < or = to 1.00) :

= (Sma/Sa)+(0.85*S)/((1-Sma/Spex)*Sb)
= (2.891/134.7)+(0.85 *2.879)/((1 -2.891/814.4) *148.9)
= 0.0380

WRC 107 Stress Analysis for Leg to Shell Junction, Test Condition

Table with 3 columns: Parameter, ID, Value. Rows: Rectangular Attachment Parameter C11 (64.000 mm), Rectangular Attachment Parameter C22 (230.950 mm).

Input Echo, WRC107/537 Item 1, Description: LEGS

Table with 3 columns: Parameter, ID, Value. Rows: Diameter Basis for Vessel (Vbasis, ID, Cylsph, Cylindrical), Internal Corrosion Allowance (Cas, 0.0000 mm), Vessel Diameter (Dv, 445.200 mm), Vessel Thickness (Tv, 6.000 mm).

Table with 3 columns: Parameter, ID, Value. Row: Design Temperature (T1, 85.0 °C).

Table with 3 columns: Parameter, Type, Value. Rows: Attachment Type (Type, Rectangular), Parameter C11 (C11, 64.00 mm), Parameter C22 (C22, 230.95 mm).

Table with 3 columns: Parameter, ID, Value. Rows: Thickness of Reinforcing Pad (Tpad, 6.000 mm), Pad Parameter C11P (C11p, 150.000 mm), Pad Parameter C22P (C22p, 250.000 mm).

Table with 3 columns: Parameter, ID, Value. Rows: Design Internal Pressure (Dp, 3.500 bars), Include Pressure Thrust (No).

Table with 3 columns: Parameter, ID, Value. Rows: Vessel Centerline Direction Cosine (Vx, Vy, Vz, 0.000, 1.000, 0.000), Nozzle Centerline Direction Cosine (Nx, Ny, Nz, 1.000, 0.000, 0.000).

Table with 3 columns: Parameter, ID, Value. Rows: Global Force (SUS) (Fx, Fy, Fz, 307.5 Kg, 325.6 Kg, 307.5 Kg), Global Moment (SUS) (Mx, My, Mz, 0.0 Kg-m, 0.0 Kg-m, 195.5 Kg-m).



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Internal Pressure (SUS) P 3.50 bars
Include Pressure Thrust No

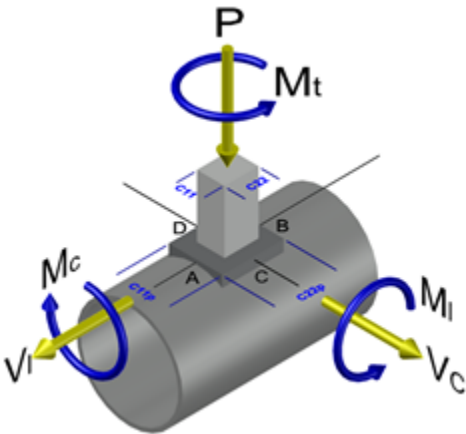
Global Force (OCC) Fx 19.4 Kgf
Global Force (OCC) Fy 63.5 Kgf
Global Force (OCC) Fz 0.0 Kgf
Global Moment (OCC) Mx 0.0 Kg-m.
Global Moment (OCC) My 0.0 Kg-m.
Global Moment (OCC) Mz 12.0 Kg-m.

Occasional Internal Pressure (OCC) Pvar 0.00 bars

Use Interactive Control No
WRC107 Version Version March 1979

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

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



WRC 107 Stress Calculation for SUStained loads:

Radial Load P 307.5 Kgf
Circumferential Shear VC -307.5 Kgf
Longitudinal Shear VL 325.6 Kgf
Circumferential Moment MC 0.0 Kg-m.
Longitudinal Moment ML -195.5 Kg-m.
Torsional Moment MT 0.0 Kg-m.

Dimensionless Parameters used : Gamma = 19.05

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979 Beta Figure Value Location



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Leg Check, (Filled w/Water):

Step: 22

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Table with 6 columns: Parameter, Value, Code, Value, Code, Value. Rows include N(PHI) / (P/Rm), M(PHI) / (P), N(PHI) / (MC/(Rm**2 * Beta)), etc.

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Table with 10 columns: Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, Dl. Rows include Circ. Memb. P, Long. Memb. P, Tot. Circ. Str., Shear VC, etc.



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Leg Check, (Filled w/Water):

Step: 22

1:17pm

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Dimensionless Parameters used : Gamma = 37.60

Dimensionless Loads for Cylindrical Shells at Pad edge:

Table with 5 columns: Curves read for 1979, Beta, Figure, Value, Location. Rows include N(PHI) / (P/Rm), M(PHI) / (P), N(PHI) / (MC/(Rm**2 * Beta)), etc.

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Table with 10 columns: Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, D1. Rows include Circ. Memb. P, Long. Memb. P, Tot. Circ. Str., etc.



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Leg Check, (Filled w/Water): Step: 22 1:17pm Apr 8,2024

Table with 9 columns: Tot. Shear, Str. Int., and numerical values for each.

WRC 107 Stress Calculation for OCCasional loads:

Table listing stress types (Radial Load, Circumferential Shear, etc.) and their corresponding values in Kg-f and Kg-m.

Dimensionless Parameters used : Gamma = 19.05

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Large table with columns for Type of Stress, Load, and Stress Intensity Values at various points (Au, Al, Bu, Bl, Cu, Cl, Du, Dl).

Dimensionless Parameters used : Gamma = 37.60

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Table with columns for Type of Stress, Load, and Stress Intensity Values at various points (Au, Al, Bu, Bl, Cu, Cl, Du, Dl).



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Leg Check, (Filled w/Water): Step: 22 1:17pm Apr 8,2024

Table with 10 columns and multiple rows showing stress values for various components like Circ. Bend. P, Long. Memb. P, Shear VC, etc.

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N/mm²)

Table with 10 columns (Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, D1) and multiple rows showing stress intensity values for different load types and components.



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Leg Check, (Filled w/Water): Step: 22 1:17pm Apr 8,2024

Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-2.0	-2.0	2.0	2.0	-0.6	-0.6	0.6	0.6	0.6
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-0.1	-0.1	0.1	0.1	0.1
Shear Pl(TOTAL)	-2.0	-2.0	2.0	2.0	-0.7	-0.7	0.7	0.7	0.7
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	6.3	6.7	6.3	6.7	6.3	6.7	6.3	6.7	6.7
Pm (SUS+OCC)	6.3	6.7	6.3	6.7	6.3	6.7	6.3	6.7	6.7
Pm+Pl (SUS)	16.3	16.6	9.6	9.4	5.0	5.3	5.0	5.3	5.3
Pm+Pl (SUS+OCC)	16.8	17.2	10.4	10.2	4.9	5.3	4.9	5.3	5.3
Pm+Pl+Q (Total)	40.7	10.0	45.9	28.9	5.5	15.2	5.5	15.2	15.2

Vessel Stress Summation Comparison (N/mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	6.67	235.81	Passed
Pm (SUS+OCC)	6.67	282.97	Passed
Pm+Pl (SUS)	16.61	353.71	Passed
Pm+Pl (SUS+OCC)	17.17	424.46	Passed
Pm+Pl+Q (TOTAL)	45.93	707.43	Passed

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature. This allowable is computed per ASME VIII-2, 5.5.6.1(1) Part 5, 3((Smc + Smh)/2).

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N/mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		12.8	13.2	12.8	13.2	12.8	13.2	12.8	13.2
Circ. Pm (OCC)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pm(TOTAL)		12.8	13.2	12.8	13.2	12.8	13.2	12.8	13.2
Circ. Pl (SUS)		12.2	12.2	-24.0	-24.0	-2.2	-2.2	-2.2	-2.2
Circ. Pl (OCC)		0.7	0.7	-1.5	-1.5	-0.1	-0.1	-0.1	-0.1
Circ. Pl(TOTAL)		12.9	12.9	-25.5	-25.5	-2.3	-2.3	-2.3	-2.3
Circ. Q (SUS)		15.2	-15.2	-24.9	24.9	-31.1	31.1	-31.1	31.1
Circ. Q (OCC)		0.9	-0.9	-1.5	1.5	-2.0	2.0	-2.0	2.0
Circ. Q (TOTAL)		16.2	-16.2	-26.4	26.4	-33.1	33.1	-33.1	33.1
Long. Pm (SUS)		6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Long. Pm (OCC)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pm(TOTAL)		6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Long. Pl (SUS)		12.1	12.1	-16.8	-16.8	-6.3	-6.3	-6.3	-6.3
Long. Pl (OCC)		0.7	0.7	-1.0	-1.0	-0.4	-0.4	-0.4	-0.4



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Leg Check, (Filled w/Water): Step: 22 1:17pm Apr 8,2024

Table with 10 columns and 20 rows showing stress calculations for Long. Pl, Shear Pm, and Pm+Pl+Q across various conditions like (TOTAL), (SUS), and (OCC).

Vessel Stress Summation Comparison (N/mm²):

Table with 4 columns: Type of Stress Int., Max. S.I., S.I. Allowable, and Result. Rows include Pm (SUS), Pm (SUS+OCC), Pm+Pl (SUS), Pm+Pl (SUS+OCC), and Pm+Pl+Q (TOTAL).

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature. This allowable is computed per ASME VIII-2, 5.5.6.1(1) Part 5, 3((Smc + Smh)/2).

Bolting Size Requirement for Leg Baseplates :

Table with 5 columns: Parameter, Unit, Value, Unit, Value. Lists baseplate material (SA-283 C), allowable stress (108.25 N./mm²), dimensions (280.0000 mm), bolt material (SA-36), and concrete strength (20.685 N./mm²).



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Shear Stress in a Single Bolt [taub]:

$$\begin{aligned}
 &= \text{Shear Force} / (2 * \text{Bolt Area} * \text{Number of Bolts}) \\
 &= 687 / (2 * 1.383 * 4) \\
 &= 6.1 \text{ N./mm}^2. \text{ Must be less than } 68.7 \text{ N./mm}^2.
 \end{aligned}$$

LEG BASEPLATE and BOLTING Analysis, including Moments

I-Beam Leg

Base Plate Available Area (AA):

$$\begin{aligned}
 &= B * D \\
 &= 280 * 280 \\
 &= 784.00 \text{ cm}^2
 \end{aligned}$$

Clearance Between The Bolt And The Leg Edge (BCL):

$$\begin{aligned}
 &= z - \text{BOD} / 2 \\
 &= 50 - 16/2 \\
 &= 42.00 \text{ mm.}
 \end{aligned}$$

Moment at Baseplate (MOMENT):

$$\begin{aligned}
 &= V_{\text{leg}} * L_{\text{leg}} \\
 &= 19.45 * 1000 \\
 &= 19.45 \text{ Kg-m.}
 \end{aligned}$$

Axial Load on the baseplate (P):

$$\begin{aligned}
 &= \text{Operating Weight per leg (as Seismic + Operating case is controlling)} \\
 &= 269.60 \text{ Kgf}
 \end{aligned}$$

Eccentricity (e):

$$\begin{aligned}
 &= \text{MOMENT} * \text{Conv_Factor} / P \\
 &= 19.45 * 9806.64 / 269.6 \\
 &= 72.14 \text{ mm.} > D/6 \text{ [Plate Uplift Condition]}
 \end{aligned}$$

$$\begin{aligned}
 a &= (D - d) / 2 \\
 &= (280 - 120) / 2 \\
 &= 80.00 \text{ mm.}
 \end{aligned}$$

Modular Ratio Of Steel/Concrete (n):

$$\begin{aligned}
 &= E_S / E_C \\
 &= 203402 / 21526 \\
 &= 9.45
 \end{aligned}$$

$$\begin{aligned}
 F &= 0.5 * d + z \\
 &= 0.5 * 120 + 50 \\
 &= 110.00 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 K1 &= 3.0 (e - 0.5*D) \\
 &= 3.0 (72.14 - 0.5*280) \\
 &= -203.59
 \end{aligned}$$

$$\begin{aligned}
 K2 &= 6 * n * A_{st} / B * (F + e) \\
 &= 6 * 9.449 * 2.766 / 280 * (110 + 72.14) \\
 &= 102.02
 \end{aligned}$$

$$\begin{aligned}
 K3 &= -K2 * (0.5 * D + F) \\
 &= -102 * (0.5 * 280 + 110)
 \end{aligned}$$



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Leg Check, (Filled w/Water):

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= -25506.09

Solving For The Effective Bearing Length Using Iteration:

$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$

$Y^3 + -8.015 * Y^2 + 15.81 * Y - 155.6 = 0$

$Y = 212.17 \text{ mm.}$

$NUM = (D / 2 - Y / 3 - e)$

$= (280/2 - 212.2/3 - 72.14)$

$= -2.86$

$DENOM = (D / 2 - Y / 3 + F)$

$= (280/2 - 212.2/3 + 110)$

$= 179.28$

Total Bolt Tension Force (T):

$= - P * NUM / DENOM$

$= - 269.6 * -2.858/179.3$

$= 4.30 \text{ Kgf}$

Overturing Moment Due To Bolt In Tension (Mt):

$= T * (0.5 * D + F - Y)$

$= 4.298 * (0.5 * 280 + 110 - 212.2)$

$= 0.16 \text{ Kg-m.}$

Bearing Pressure (FC):

$= 2 * (P + T) / (Y * B)$

$= 2 * (269.6 + 4.298) / (212.2 * 280)$

$= 0.90 \text{ bars [} \leq \text{ FCPRIME (} 206.84 \text{)]}$

Equivalent Bearing Pressure (f1):

$= FC * (Y - a) / Y$

$= 0.904 * (212.2 - 80) / 212.2$

$= 0.56 \text{ bars}$

Overturing Moment Due To Bearing Pressure (Mc):

$= (a^2 * B / 6) * (f1 + 2 * FC)$

$= (80^2 * 280/6) * (0.563 + 2 * 0.904)$

$= 7.22 \text{ Kg-m.}$

The Baseplate Required Thickness (TREQ):

$= (6 * \text{MAX}(Mt,Mc) / (B * 1.5 * SBA))^{1/2}$

$= (6 * 7.224 / (280 * 162.4))^{1/2}$

$= 3.06 \text{ mm.}$

Required bolt area (ABREQM): per D. Moss

$= T / STBA$

$= 4.298/114.5$

$= 0.0037 \text{ cm}^2 [< \text{Ast (} 2.77 \text{) --> PASSED]}$

Distance from Top of Legs to Vessel CG (CD_DIST):

$= 487.7 \text{ mm.}$

Total Overturing Moment at Baseplate (Mbb):

$= (Mleg / \text{max}([CD_DIST], \text{minDist})) * (CD_DIST + Lleg)$

$= (18.7 / \text{max}(487.7, 38.1)) * (487.7 + 1000)$

$= 57.05 \text{ Kg-m.}$



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Leg Check, (Filled w/Water): Step: 22 1:17pm Apr 8,2024

Required Total Bolt Area per Leg (ABREQB): per H. Bednar

$$= (1 / (Nleg * STBA)) * ((4 * Mbb / (Rn * 2)) - W)$$

$$= (1 / (3 * 114.5)) * ((4 * 57.05 / (589.2)) - 808.8)$$

$$= -0.1204 \text{ cm}^2 \text{ --> (No tension in bolts)}$$

Summary of Results:

		Actual	Required	Pass/Fail
Baseplate Thickness	(mm.):	25.000	3.058	Pass
Bolt Root Area (D. Moss)	(cm ²):	2.77	0.00	Pass

Note: The required thickness calculation is performed based on:
Strong axis orientation of the beam leg
Even number of bolts installed only on the B dimension sides



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Nozzle Summary:

Step: 28

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Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
Drain - 2in	13.55	...	...	OK	5.50	OK	No Calc[*]
Gas In - 6in		...	...	OK	5.50	OK	No Calc[*]
Gas Out - 6in		...	...	OK	5.50	OK	No Calc[*]
Vent - 1in		...	...	OK	5.50	OK	No Calc[*]

MAWP Summary:

Minimum MAWP Nozzles : 13.552 Nozzle : Drain - 2in
 Minimum MAWP Shells/Flanges : 13.552 Element : Cap - 18" (sch.10)
 Minimum MAPnc Shells/Flanges : 17.104 Element : Blind Flange - 18"

Computed Vessel M.A.W.P. : 13.552 bars

[*] - This was a small opening and the areas were not computed or the MAWP of this connection could not be computed because the longitudinal bending stress was greater than the hoop stress.

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

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	Y Coordinate mm.	Layout Angle deg	Dia. Limit mm.
10	Drain - 2in	0.000	0.000	102.068
20	Gas In - 6in	285.000	180.000	323.658
20	Gas Out - 6in	1235.000	0.000	323.658
20	Vent - 1in	1335.000	180.000	78.802

The nozzle spacing is computed by the following:

= Sqrt(ll² + lc²) 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 !



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Nozzle Calcs.: Drain - 2in

Nozl: 5

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Input, Nozzle Desc: Drain - 2in

From: 10

Pressure for Reinforcement Calculations	P	3.500	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	1.00	bars
Temperature for External Pressure	Tempex	85	°C

Shell Material		SA-234	WPB
Shell Allowable Stress at Temperature	Sv	117.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm ²

Inside Diameter of Elliptical Head	D	446.09	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	5.5563	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.

Distance from Head Centerline L1 0.0000 mm.

User Entered Minimum Design Metal Temperature -5.00 °C

Type of Element Connected to the Shell : Nozzle

Material		SA-106	B
Material UNS Number		K03006	
Material Specification/Type		Smls.	pipe
Allowable Stress at Temperature	Sn	117.90	N./mm ²
Allowable Stress At Ambient	Sna	117.90	N./mm ²

Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		2.0000	in.

Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	

Flange Material		SA-105	
Flange Type		Slip on	

Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	

Outside Projection	ho	100.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	6.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	5.5563	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.

Pad Material		SA-516	70
Pad Allowable Stress at Temperature	Sp	137.90	N./mm ²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm ²
Diameter of Pad along vessel surface	Dp	160.0000	mm.
Thickness of Pad	te	6.0000	mm.
Weld leg size between Pad and Shell	Wp	6.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	6.0000	mm.



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Nozzle Calcs.: Drain - 2in

Nozl: 5

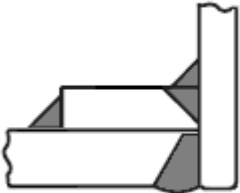
1:17pm

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Reinforcing Pad Width	49.8375 mm.
Class of attached Flange	150
Grade of attached Flange	GR 1.1

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: Drain - 2in

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	2.375 in.
Actual Thickness Used in Calculation	0.301 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, Tr [Int. Press]
 $= (P \cdot K_1 \cdot D) / (2 \cdot S_v \cdot E - 0.2 \cdot P)$ per UG-37(a)(3)
 $= (3.5 \cdot 0.889 \cdot 452.1) / (2 \cdot 117.9 \cdot 1 - 0.2 \cdot 3.5)$
 $= 0.5966 \text{ mm.}$

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$ per Appendix 1-1 (a)(1)
 $= (3.5 \cdot 30.16) / (117.9 \cdot 1 + 0.4 \cdot 3.5)$
 $= 0.0894 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.2358 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	102.0684 mm.
Parallel to Vessel Wall, opening length	d	51.0342 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		6.3906 mm.

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: Drain - 2in.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration



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Nozzle Calcs.: Drain - 2in

Noz1: 5

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and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.

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

Wall Thickness for Internal/External pressures	ta = 3.2358 mm.
Wall Thickness per UG16(b),	tr16b = 5.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 3.6596 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 5.5000 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 5.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

= min[tb3, max(tb1,tb2)]
= min[6.42, max(5.5, 5.5)]
= 5.5000 mm.

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

= max(ta, tb)
= max(3.236, 5.5)
= 5.5000 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 16.8,	Allowable	: 117.9 N./mm ²	Passed
Expansion	: 0.0,	Allowable	: 278.0 N./mm ²	Passed
Occasional	: 0.9,	Allowable	: 156.8 N./mm ²	Passed
Shear	: 11.5,	Allowable	: 82.5 N./mm ²	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 7.645, tr = 0.0894, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.0193, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 6, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.233, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 6, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.233, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).



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Nozzle Calcs.: Drain - 2in

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Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 5.556, tr = 0.597, c = 3 mm., E* = 1
Thickness Ratio = $tr * (E^*) / (tg - c) = 0.233$, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

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

Govrn. thk, tg = 5.556, tr = 0.597, c = 3 mm., E* = 1
Thickness Ratio = $tr * (E^*) / (tg - c) = 0.233$, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C
Governing MDMT of the Reinforcement Pad : -104 °C
Governing MDMT of all the sub-joints of this Junction : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = $3.50 / 19.60 = 0.179$

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: Drain - 2in

Intermediate Calc. for nozzle/shell Welds Tmin 4.6454 mm.
Intermediate Calc. for pad/shell Welds TminPad 3.3500 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$3.2518 = 0.7 * t_{min}$	$4.2420 = 0.7 * W_o$ mm.
Pad Weld	$1.6750 = 0.5 * T_{minPad}$	$4.2420 = 0.7 * W_p$ mm.

Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)
(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 13.552 bars

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

The Drop for this Nozzle is : 1.1222 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 106.6784 mm.



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Nozzle Calcs.: Drain - 2in

Nozl: 5

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Input Echo, WRC107/537 Item 1, Description: Drain - 2in :

Table with 4 columns: Parameter, Vbasis, ID, Value. Rows include Diameter Basis for Vessel, Internal Corrosion Allowance, Vessel Diameter, Vessel Thickness, Design Temperature, Vessel Material, Vessel UNS Number, Vessel Cold S.I. Allowable, Vessel Hot S.I. Allowable.

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-234 WPB

Table with 4 columns: Parameter, Type, Round, Value. Rows include Attachment Type, Diameter Basis for Nozzle, Corrosion Allowance for Nozzle, Nozzle Diameter, Nozzle Thickness, Nozzle Material, Nozzle UNS Number, Nozzle Cold S.I. Allowable, Nozzle Hot S.I. Allowable, Thickness of Reinforcing Pad, Diameter of Reinforcing Pad, Design Internal Pressure, Include Pressure Thrust.

External Forces and Moments in WRC 107/537 Convention:

Table with 5 columns: Parameter, (SUS), (V1), (Vc), (Mc), (M1), (M2), (Mt), Value, Unit. Rows include Radial Load, Longitudinal Shear, Circumferential Shear, Circumferential Moment, Longitudinal Moment, Torsional Moment.

Table with 4 columns: Use Interactive Control, WRC107 Version, Version, No, March 1979.

Table with 2 columns: Parameter, Value. Rows include Include Pressure Stress Indices per Div. 2, Compute Pressure Stress per WRC-368, Local Loads applied at end of Nozzle/Attachment.

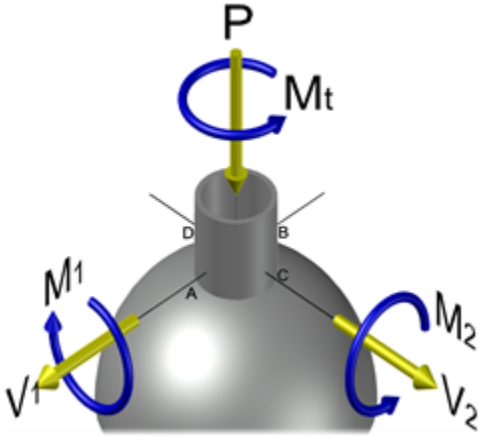
Note:
WRC Bulletin 537 provides equations for the dimensionless curves

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found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
 = NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
 = 60.325 + 2 * 1.65 * sqrt(405.757 (5.556 - 3.0))
 = 166.604 mm.

WRC 107 Stress Calculation for SUSstained loads:

Radial Load	(P)	-51.8	Kgf
Circumferential Shear	(VC) V2	64.9	Kgf
Longitudinal Shear	(VL) V1	64.9	Kgf
Circumferential Moment	(MC) M1	-11.0	Kg-m.
Longitudinal Moment	(ML) M2	13.9	Kg-m.
Torsional Moment	(MT)	17.5	Kg-m.

Dimensionless Parameters: U = 0.51 TAU = 5.99 RHO = 1.84

Dimensionless Loads for Spherical Shells at Attachment Junction:

Curves read for 1979	Figure	Value	Location
N(x) * T / P	SP 2	0.07465	(A,B,C,D)
M(x) / P	SP 2	0.05454	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / MC	SM 2	0.16607	(A,B,C,D)
M(x) * SQRT(Rm * T) / MC	SM 2	0.13675	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / ML	SM 2	0.16607	(A,B,C,D)
M(x) * SQRT(Rm * T) / ML	SM 2	0.13675	(A,B,C,D)
N(y) * T / P	SP 2	0.18590	(A,B,C,D)
M(y) / P	SP 2	0.04501	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / MC	SM 2	0.16250	(A,B,C,D)
M(y) * SQRT(Rm * T) / MC	SM 2	0.15789	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / ML	SM 2	0.16250	(A,B,C,D)
M(y) * SQRT(Rm * T) / ML	SM 2	0.15789	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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



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Table with 10 columns: Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, D1. Rows include Rad. Memb. P, Rad. Bend. P, Rad. Memb. MC, Rad. Memb. ML, Tot. Rad. Str., Tang. Memb. P, Tang. Bend. P, Tang. Memb. MC, Tang. Bend. ML, Tot. Tang. Str., Shear VC, Shear VL, Shear MT, Tot. Shear, Str. Int.

Unitless Prm: U = 2.48 TAU = 0.00 (16.72) RHO = 0.00 (0.55)

Dimensionless Loads for Spherical Shells at Pad edge:

Table with 4 columns: Curves read for 1979, Figure, Value, Location. Rows include N(x) * T / P, M(x) / P, N(x) * T * SQRT(Rm * T) / MC, M(x) * SQRT(Rm * T) / MC, N(x) * T * SQRT(Rm * T) / ML, M(x) * SQRT(Rm * T) / ML, N(y) * T / P, M(y) / P, N(y) * T * SQRT(Rm * T) / MC, M(y) * SQRT(Rm * T) / MC, N(y) * T * SQRT(Rm * T) / ML, M(y) * SQRT(Rm * T) / ML.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Table with 10 columns: Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, D1. This is a header row for a stress intensity values table.



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Rad. Memb. P	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Rad. Bend. P	4.6	-4.6	4.6	-4.6	4.6	-4.6	4.6	-4.6	4.6
Rad. Memb. MC	0.0	0.0	0.0	0.0	8.7	8.7	-8.7	-8.7	8.7
Rad. Memb. MC	0.0	0.0	0.0	0.0	32.4	-32.4	-32.4	32.4	32.4
Rad. Memb. ML	-10.9	-10.9	10.9	10.9	0.0	0.0	0.0	0.0	0.0
Rad. Bend. ML	-40.8	40.8	40.8	-40.8	0.0	0.0	0.0	0.0	0.0
Tot. Rad. Str.	-45.4	27.0	58.1	-32.8	47.4	-26.7	-34.8	20.8	20.8
Tang. Memb. P	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Tang. Bend. P	1.4	-1.4	1.4	-1.4	1.4	-1.4	1.4	-1.4	1.4
Tang. Memb. MC	0.0	0.0	0.0	0.0	2.6	2.6	-2.6	-2.6	2.6
Tang. Bend. MC	0.0	0.0	0.0	0.0	9.8	-9.8	-9.8	9.8	9.8
Tang. Memb. ML	-3.3	-3.3	3.3	3.3	0.0	0.0	0.0	0.0	0.0
Tang. Bend. ML	-12.3	12.3	12.3	-12.3	0.0	0.0	0.0	0.0	0.0
Tot. Tang. Str.	-13.7	8.1	17.5	-9.9	14.3	-8.1	-10.5	6.3	6.3
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0	1.0
Shear MT	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Tot. Shear	2.7	2.7	0.7	0.7	0.7	0.7	2.7	2.7	2.7
Str. Int.	45.7	27.3	58.1	32.8	47.4	26.7	35.1	21.3	21.3

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N/mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Pm (SUS)		8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Rad. Pl (SUS)		-4.7	-4.7	5.7	5.7	4.7	4.7	-3.6	-3.6
Rad. Q (SUS)		-23.5	23.5	28.0	-28.0	22.7	-22.7	-18.2	18.2
Long. Pm (SUS)		8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Long. Pl (SUS)		-3.8	-3.8	6.4	6.4	5.3	5.3	-2.8	-2.8
Long. Q (SUS)		-27.9	27.9	31.6	-31.6	25.5	-25.5	-21.8	21.8
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)		3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Pm (SUS)		8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Pm+Pl (SUS)		4.9	4.9	15.2	15.2	14.1	14.1	6.0	6.0
Pm+Pl+Q (Total)		26.3	34.8	47.6	18.6	40.6	13.8	19.4	29.9

Vessel Stress Summation Comparison (N/mm²):



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Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	8.28	117.90	Passed
Pm+Pl (SUS)	15.19	176.86	Passed
Pm+Pl+Q (TOTAL)	47.64	353.71	Passed

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

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N/mm²)

Type of Stress Load		Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad.	Pm (SUS)	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Rad.	Pl (SUS)	-9.2	-9.2	12.6	12.6	10.4	10.4	-7.0	-7.0
Rad.	Q (SUS)	-36.2	36.2	45.4	-45.4	37.0	-37.0	-27.8	27.8
Long.	Pm (SUS)	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Long.	Pl (SUS)	-2.8	-2.8	3.8	3.8	3.1	3.1	-2.1	-2.1
Long.	Q (SUS)	-10.9	10.9	13.7	-13.7	11.2	-11.2	-8.4	8.4
Shear	Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear	Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear	Q (SUS)	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Pm (SUS)		27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Pm+Pl (SUS)		25.1	25.1	40.4	40.4	38.2	38.2	25.8	25.8
Pm+Pl+Q (Total)		32.2	55.0	85.8	22.9	75.1	19.7	24.9	49.0

Vessel Stress Summation Comparison (N/mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	27.69	117.90	Passed
Pm+Pl (SUS)	40.43	176.86	Passed
Pm+Pl+Q (TOTAL)	85.76	353.71	Passed

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



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Input, Nozzle Desc: Gas In - 6in From: 20

Pressure for Reinforcement Calculations	P	3.500	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	1.00	bars
Temperature for External Pressure	Tempex	85	°C

Shell Material		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²

Inside Diameter of Cylindrical Shell	D	445.20	mm.
Design Length of Section	L	1537.1740	mm.
Shell Finished (Minimum) Thickness	t	6.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.

Distance from Bottom/Left Tangent 285.00 mm.

User Entered Minimum Design Metal Temperature -5.00 °C

Type of Element Connected to the Shell : Nozzle

Material		SA-106	B
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm ²
Allowable Stress At Ambient	Sna	117.90	N./mm ²

Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		6.0000	in.

Size and Thickness Basis		Minimum	
Nominal Thickness	tn	STD	

Flange Material		SA-105	
Flange Type		Slip on	

Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	

Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	6.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	6.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.

Pad Material		SA-516	70
Pad Allowable Stress at Temperature	Sp	137.90	N./mm ²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm ²
Diameter of Pad along vessel surface	Dp	250.0000	mm.
Thickness of Pad	te	6.0000	mm.
Weld leg size between Pad and Shell	Wp	6.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	6.0000	mm.



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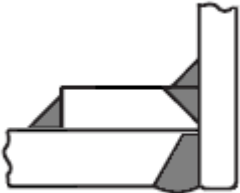
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Reinforcing Pad Width	40.8625 mm.
Class of attached Flange	150
Grade of attached Flange	GR 1.1

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: Gas In - 6in

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	6.625 in.
Actual Thickness Used in Calculation	0.245 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$ per UG-27 (c)(1)
 $= (3.5 \cdot 225.6) / (137.9 \cdot 1 - 0.6 \cdot 3.5)$
 $= 0.5735 \text{ mm.}$

The Longitudinal Stress Governs over the Hoop Stress on the shell course where this nozzle is located. The Maximum stress ratio times the Shell thickness will be used in the calculation of the Area required.

The Stress Ratio is 0.2065 and the shell thk. is 6.0000 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$ per Appendix 1-1 (a)(1)
 $= (3.5 \cdot 84.14) / (117.9 \cdot 1 + 0.4 \cdot 3.5)$
 $= 0.2495 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.5061 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	323.6580 mm.
Parallel to Vessel Wall, opening length	d	161.8290 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		7.5000 mm.

Weld Strength Reduction Factor [fr1]:

$= \min(1, S_n / S_v)$
 $= \min(1, 117.9 / 137.9)$



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Nozzle Calcs.: Gas In - 6in

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= 0.855

Weld Strength Reduction Factor [fr2]:

= min(1, Sn/Sv)

= min(1, 117.9/137.9)

= 0.855

Weld Strength Reduction Factor [fr4]:

= min(1, Sp/Sv)

= min(1, 137.9/137.9)

= 1.000

Weld Strength Reduction Factor [fr3]:

= min(fr2, fr4)

= min(0.855, 1)

= 0.855

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.008	1.950	NA
Area in Shell	A1	3.830	0.971	NA
Area in Nozzle Wall	A2	0.381	0.348	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.495	0.495	NA
Area in Element	A5	3.678	3.678	NA
TOTAL AREA AVAILABLE	Atot	8.384	5.492	NA

The External Pressure 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:	171.3085	6.0000	mm.
Based on given Pad Diameter:	250.0000	0.2227	mm.
Based on Shell or Nozzle Thickness:	171.3085	6.0000	mm.

Area Required [A]:

= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)

= 0.5(161.8*2.397*1+2*3.223*2.397*1(1-0.855))

= 1.950 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)

= 161.8 (1 * 3 - 1 * 2.397) - 2 * 3.223

(1 * 3 - 1 * 2.397) * (1 - 0.855)

= 0.971 cm²

Area Available in Nozzle Wall Projecting Outward [A2]:

= (2 * Tlwp) * (tn - trn) * fr2

= (2 * 7.5) * (3.223 - 0.506) * 0.855



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Nozzle Calcs.: Gas In - 6in Nozl: 6 1:17pm Apr 8,2024

= 0.348 cm²

Area Available in Welds [A41 + A42 + A43]:

= (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
= (0.158) * 0.855 + (0) * 0.855 + 152.4² * 1
= 0.495 cm²

Area Available in Element, also see UG-37(h) [A5]:

= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (250 - 168.3)6 * 1 * 0.75
= 3.678 cm²

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

Wall Thickness for Internal/External pressures	ta = 3.5061 mm.
Wall Thickness per UG16(b),	tr16b = 5.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 3.5735 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 5.5000 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 5.5000 mm.
Wall Thickness per table UG-45	tb3 = 9.2200 mm.

Determine Nozzle Thickness candidate [tb]:

= min[tb3, max(tb1,tb2)]
= min[9.22, max(5.5, 5.5)]
= 5.5000 mm.

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

= max(ta, tb)
= max(3.506, 5.5)
= 5.5000 mm.

Available Nozzle Neck Thickness = 6.2230 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 23.2,	Allowable	: 117.9 N./mm ²	Passed
Expansion	: 0.0,	Allowable	: 271.6 N./mm ²	Passed
Occasional	: 4.3,	Allowable	: 156.8 N./mm ²	Passed
Shear	: 13.1,	Allowable	: 82.5 N./mm ²	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 6.223, tr = 0.249, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.0774, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 6, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.191, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).



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Nozzle Calcs.: Gas In - 6in Nozl: 6 1:17pm Apr 8,2024

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govern. thk, tg = 6, c = 3 mm., E* = 1
Thickness Ratio = $tr * (E*) / (tg - c) = 0.191$, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Shell to Pad Weld Junction at Pad OD, Curve: B

Govern. thk, tg = 6, tr = 0.574, c = 3 mm., E* = 1
Thickness Ratio = $tr * (E*) / (tg - c) = 0.191$, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

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

Govern. thk, tg = 6, tr = 0.574, c = 3 mm., E* = 1
Thickness Ratio = $tr * (E*) / (tg - c) = 0.191$, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C
Governing MDMT of the Reinforcement Pad : -104 °C
Governing MDMT of all the sub-joints of this Junction : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 3.50/19.60 = 0.179

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: Gas In - 6in

Intermediate Calc. for nozzle/shell Welds Tmin 3.2230 mm.
Intermediate Calc. for pad/shell Welds TminPad 3.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.2561 = 0.7 * tmin.	4.2420 = 0.7 * Wo mm.
Pad Weld	1.5000 = 0.5 * TminPad	4.2420 = 0.7 * Wp mm.

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



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Nozzle Calcs.: Gas In - 6in Nozl: 6 1:17pm Apr 8,2024

Weld Load [W]:

$$= \max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)$$

$$= \max(0, (1.95 - 0.971 + 2 * 3.223 * 0.855 * (1 * 3 - 2.397))137.9)$$

$$= 1424.26 \text{ Kgf}$$

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

Weld Load [W1]:

$$= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv$$

$$= (0.348 + 3.678 + 0.495 - 0 * 0.855) * 137.9$$

$$= 6356.89 \text{ Kgf}$$

Weld Load [W2]:

$$= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$$

$$= (0.348 + 0 + 0.308 + (0.165)) * 137.9$$

$$= 1155.28 \text{ Kgf}$$

Weld Load [W3]:

$$= (A2+A3+A4+A5+(2*tn*t*fr1))*S$$

$$= (0.348 + 0 + 0.495 + 3.678 + (0.165)) * 137.9$$

$$= 6589.38 \text{ Kgf}$$

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= (3.142/2.0) * 168.3 * 6 * 0.49 * 117.9$$

$$= 9343. \text{ Kgf}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.142/2.0) * 250 * 6 * 0.49 * 137.9$$

$$= 16235. \text{ Kgf}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * (Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn$$

$$= (3.142 * 82.53) * (6.223 - 3) * 0.7 * 117.9$$

$$= 7032. \text{ Kgf}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgp * 0.74 * Seg$$

$$= (3.142/2) * 168.3 * 6 * 0.74 * 137.9$$

$$= 16503. \text{ Kgf}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= (3.142/2.0) * 168.3 * (6 - 3) * 0.74 * 137.9$$

$$= 8251. \text{ Kgf}$$

Strength of Failure Paths:

$$PATH11 = (SPEW + SNW) = (16235 + 7032) = 23267 \text{ Kgf}$$

$$PATH22 = (Sonw + Tpgw + Tngw + Sinw)$$

$$= (9343 + 16503 + 8251 + 0) = 34097 \text{ Kgf}$$

$$PATH33 = (Spew + Tngw + Sinw)$$

$$= (16235 + 8251 + 0) = 24486 \text{ Kgf}$$



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Nozzle Calcs.: Gas In - 6in

Nozl: 6

1:17pm

Apr 8,2024

Summary of Failure Path Calculations:

Path 1-1 = 23267 Kgf, must exceed W = 1424 Kgf or W1 = 6356 Kgf
Path 2-2 = 34097 Kgf, must exceed W = 1424 Kgf or W2 = 1155 Kgf
Path 3-3 = 24486 Kgf, must exceed W = 1424 Kgf or W3 = 6589 Kgf

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 15.463 bars

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

The Drop for this Nozzle is : 16.5135 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.5135 mm.

Input Echo, WRC107/537 Item 1, Description: Gas In - 6in :

Table with 4 columns: Parameter, Vbasis, ID, Value. Rows include Diameter Basis for Vessel, Internal Corrosion Allowance, Vessel Diameter, Vessel Thickness, Design Temperature, Vessel Material, Vessel UNS Number, Vessel Cold S.I. Allowable, Vessel Hot S.I. Allowable.

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-516 70

Table with 4 columns: Attachment Type, Type, Round, Value. Rows include Diameter Basis for Nozzle, Nozzle Diameter, Nozzle Thickness, Nozzle Material, Nozzle UNS Number, Nozzle Cold S.I. Allowable, Nozzle Hot S.I. Allowable, Thickness of Reinforcing Pad, Diameter of Reinforcing Pad, Design Internal Pressure, Include Pressure Thrust.

External Forces and Moments in WRC 107/537 Convention:

Table with 4 columns: Force/Moment, (SUS), Type, Value. Rows include Radial Load, Longitudinal Shear, Circumferential Shear, Circumferential Moment, Longitudinal Moment.



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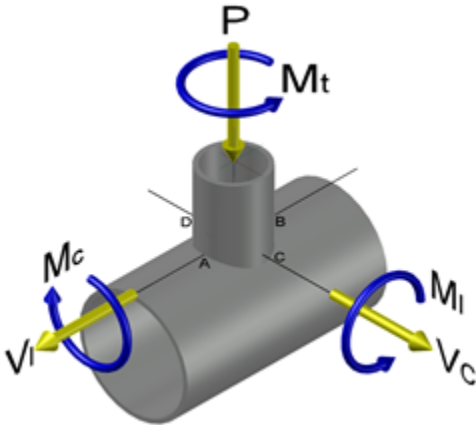
Nozzle Calcs.: Gas In - 6in Nozl: 6 1:17pm Apr 8,2024

Torsional Moment (SUS) Mt 136.2 Kg-m.

Use Interactive Control No
WRC107 Version Version March 1979

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 168.275 + 2 * 1.65 * sqrt(227.1 (6.0 - 3.0))
= 254.411 mm.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-144.4	Kgf
Circumferential Shear	VC	180.7	Kgf
Longitudinal Shear	VL	180.7	Kgf
Circumferential Moment	MC	-84.4	Kg-m.
Longitudinal Moment	ML	106.9	Kg-m.
Torsional Moment	MT	136.2	Kg-m.

Dimensionless Parameters used : Gamma = 25.57

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.320	4C	3.067	(A,B)
N(PHI) / (P/Rm)	0.320	3C	1.693	(C,D)
M(PHI) / (P)	0.320	2C1	0.021	(A,B)
M(PHI) / (P)	0.320	1C !	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.320	3A	1.075	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.320	1A	0.074	(A,B,C,D)



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Nozzle Calcs.: Gas In - 6in Nozl: 6 1:17pm Apr 8,2024

Table with 5 columns: Parameter, Value, Figure, Value, Location. Rows include N(PHI) / (ML/(Rm**2 * Beta)), M(PHI) / (ML/(Rm * Beta)), N(x) / (P/Rm), M(x) / (P), N(x) / (MC/(Rm**2 * Beta)), M(x) / (MC/(Rm * Beta)), N(x) / (ML/(Rm**2 * Beta)), M(x) / (ML/(Rm * Beta)).

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Table with 10 columns: Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, Dl. Rows include Circ. Memb. P, Circ. Bend. P, Circ. Memb. MC, Circ. Memb. ML, Tot. Circ. Str., Long. Memb. P, Long. Bend. P, Long. Memb. MC, Long. Bend. MC, Long. Memb. ML, Long. Bend. ML, Tot. Long. Str., Shear VC, Shear VL, Shear MT, Tot. Shear, Str. Int.

Dimensionless Parameters used : Gamma = 75.70

Dimensionless Loads for Cylindrical Shells at Pad edge:

Table with 5 columns: Curves read for 1979, Beta, Figure, Value, Location. Rows include N(PHI) / (P/Rm), N(PHI) / (P/Rm).



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Nozzle Calcs.: Gas In - 6in Nozl: 6 1:17pm Apr 8,2024

Table with 5 columns: Calculation, Value, Nozzle, Time, and Location. Rows include M(PHI) / (P), N(PHI) / (MC/(Rm**2 * Beta)), N(x) / (P/Rm), etc.

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Table with 10 columns: Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, Dl. Rows include Circ. Memb. P, Long. Memb. P, Tot. Circ. Str., Tot. Long. Str., Shear VC, etc.



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Nozzle Calcs.: Gas In - 6in Nozl: 6 1:17pm Apr 8,2024

Pm (SUS)	26.1	26.5	26.1	26.5	26.1	26.5	26.1	26.5
Pm+Pl (SUS)	7.0	7.3	61.3	61.6	85.2	85.2	59.7	60.0
Pm+Pl+Q (Total)	20.2	25.5	81.0	44.4	380.0	297.6	194.8	227.1

Vessel Stress Summation Comparison (N/mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	26.50	137.90	Passed
Pm+Pl (SUS)	85.24	206.85	Passed
Pm+Pl+Q (TOTAL)	379.96	413.70	Passed

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

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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

Input, Nozzle Desc: Gas Out - 6in From: 20

Pressure for Reinforcement Calculations	P	3.500	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	1.00	bars
Temperature for External Pressure	Tempex	85	°C

Shell Material		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²

Inside Diameter of Cylindrical Shell	D	445.20	mm.
Design Length of Section	L	1537.1740	mm.
Shell Finished (Minimum) Thickness	t	6.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.

Distance from Bottom/Left Tangent 1235.00 mm.

User Entered Minimum Design Metal Temperature -5.00 °C

Type of Element Connected to the Shell : Nozzle

Material		SA-106	B
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm ²
Allowable Stress At Ambient	Sna	117.90	N./mm ²

Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		6.0000	in.

Size and Thickness Basis		Minimum	
Nominal Thickness	tn	STD	

Flange Material		SA-105	
Flange Type		Slip on	

Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	

Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	6.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	6.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.

Pad Material		SA-516	70
Pad Allowable Stress at Temperature	Sp	137.90	N./mm ²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm ²
Diameter of Pad along vessel surface	Dp	250.0000	mm.
Thickness of Pad	te	6.0000	mm.
Weld leg size between Pad and Shell	Wp	6.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	6.0000	mm.



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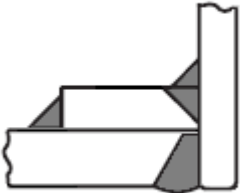
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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

Reinforcing Pad Width	40.8625 mm.
Class of attached Flange	150
Grade of attached Flange	GR 1.1

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: Gas Out - 6in

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	6.625 in.
Actual Thickness Used in Calculation	0.245 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$ per UG-27 (c)(1)
 $= (3.5 \cdot 225.6) / (137.9 \cdot 1 - 0.6 \cdot 3.5)$
 $= 0.5735 \text{ mm.}$

The Longitudinal Stress Governs over the Hoop Stress on the shell course where this nozzle is located. The Maximum stress ratio times the Shell thickness will be used in the calculation of the Area required.

The Stress Ratio is 0.2065 and the shell thk. is 6.0000 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$ per Appendix 1-1 (a)(1)
 $= (3.5 \cdot 84.14) / (117.9 \cdot 1 + 0.4 \cdot 3.5)$
 $= 0.2495 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.5061 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	323.6580 mm.
Parallel to Vessel Wall, opening length	d	161.8290 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		7.5000 mm.

Weld Strength Reduction Factor [fr1]:

$= \min(1, S_n / S_v)$
 $= \min(1, 117.9 / 137.9)$



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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

= 0.855

Weld Strength Reduction Factor [fr2]:

= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr4]:

= min(1, Sp/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr3]:

= min(fr2, fr4)
= min(0.855, 1)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.008	1.950	NA
Area in Shell	A1	3.830	0.971	NA
Area in Nozzle Wall	A2	0.381	0.348	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.495	0.495	NA
Area in Element	A5	3.678	3.678	NA
TOTAL AREA AVAILABLE	Atot	8.384	5.492	NA

The External Pressure 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:	171.3085	6.0000 mm.
Based on given Pad Diameter:	250.0000	0.2227 mm.
Based on Shell or Nozzle Thickness:	171.3085	6.0000 mm.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(161.8*2.397*1+2*3.223*2.397*1(1-0.855))
= 1.950 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 161.8 (1 * 3 - 1 * 2.397) - 2 * 3.223
(1 * 3 - 1 * 2.397) * (1 - 0.855)
= 0.971 cm²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 7.5) * (3.223 - 0.506) * 0.855



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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

= 0.348 cm²

Area Available in Welds [A41 + A42 + A43]:

= (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
= (0.158) * 0.855 + (0) * 0.855 + 152.4² * 1
= 0.495 cm²

Area Available in Element, also see UG-37(h) [A5]:

= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (250 - 168.3)6 * 1 * 0.75
= 3.678 cm²

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

Wall Thickness for Internal/External pressures	ta = 3.5061 mm.
Wall Thickness per UG16(b),	tr16b = 5.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 3.5735 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 5.5000 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 5.5000 mm.
Wall Thickness per table UG-45	tb3 = 9.2200 mm.

Determine Nozzle Thickness candidate [tb]:

= min[tb3, max(tb1,tb2)]
= min[9.22, max(5.5, 5.5)]
= 5.5000 mm.

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

= max(ta, tb)
= max(3.506, 5.5)
= 5.5000 mm.

Available Nozzle Neck Thickness = 6.2230 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 23.2,	Allowable	: 117.9 N./mm ²	Passed
Expansion	: 0.0,	Allowable	: 271.6 N./mm ²	Passed
Occasional	: 4.3,	Allowable	: 156.8 N./mm ²	Passed
Shear	: 13.1,	Allowable	: 82.5 N./mm ²	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 6.223, tr = 0.249, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.0774, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 6, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.191, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).



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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 6, c = 3 mm., E* = 1
Thickness Ratio = $tr * (E*) / (tg - c) = 0.191$, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 6, tr = 0.574, c = 3 mm., E* = 1
Thickness Ratio = $tr * (E*) / (tg - c) = 0.191$, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

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

Govrn. thk, tg = 6, tr = 0.574, c = 3 mm., E* = 1
Thickness Ratio = $tr * (E*) / (tg - c) = 0.191$, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C
Governing MDMT of the Reinforcement Pad : -104 °C
Governing MDMT of all the sub-joints of this Junction : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 3.50/19.60 = 0.179

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: Gas Out - 6in

Intermediate Calc. for nozzle/shell Welds Tmin 3.2230 mm.
Intermediate Calc. for pad/shell Welds TminPad 3.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.2561 = 0.7 * tmin.	4.2420 = 0.7 * Wo mm.
Pad Weld	1.5000 = 0.5 * TminPad	4.2420 = 0.7 * Wp mm.

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



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Nozzle Calcs.: Gas Out - 6in

Nozl: 7

1:17pm

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Weld Load [W]:

$$= \max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)$$

$$= \max(0, (1.95 - 0.971 + 2 * 3.223 * 0.855 * (1 * 3 - 2.397))137.9)$$

$$= 1424.26 \text{ Kgf}$$

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

Weld Load [W1]:

$$= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv$$

$$= (0.348 + 3.678 + 0.495 - 0 * 0.855) * 137.9$$

$$= 6356.89 \text{ Kgf}$$

Weld Load [W2]:

$$= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$$

$$= (0.348 + 0 + 0.308 + (0.165)) * 137.9$$

$$= 1155.28 \text{ Kgf}$$

Weld Load [W3]:

$$= (A2+A3+A4+A5+(2*tn*t*fr1))*S$$

$$= (0.348 + 0 + 0.495 + 3.678 + (0.165)) * 137.9$$

$$= 6589.38 \text{ Kgf}$$

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= (3.142/2.0) * 168.3 * 6 * 0.49 * 117.9$$

$$= 9343. \text{ Kgf}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.142/2.0) * 250 * 6 * 0.49 * 137.9$$

$$= 16235. \text{ Kgf}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * (Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn$$

$$= (3.142 * 82.53) * (6.223 - 3) * 0.7 * 117.9$$

$$= 7032. \text{ Kgf}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgp * 0.74 * Seg$$

$$= (3.142/2) * 168.3 * 6 * 0.74 * 137.9$$

$$= 16503. \text{ Kgf}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= (3.142/2.0) * 168.3 * (6 - 3) * 0.74 * 137.9$$

$$= 8251. \text{ Kgf}$$

Strength of Failure Paths:

$$PATH11 = (SPEW + SNW) = (16235 + 7032) = 23267 \text{ Kgf}$$

$$PATH22 = (Sonw + Tpgw + Tngw + Sinw)$$

$$= (9343 + 16503 + 8251 + 0) = 34097 \text{ Kgf}$$

$$PATH33 = (Spew + Tngw + Sinw)$$

$$= (16235 + 8251 + 0) = 24486 \text{ Kgf}$$



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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

Summary of Failure Path Calculations:

Path 1-1 = 23267 Kgf, must exceed W = 1424 Kgf or W1 = 6356 Kgf
Path 2-2 = 34097 Kgf, must exceed W = 1424 Kgf or W2 = 1155 Kgf
Path 3-3 = 24486 Kgf, must exceed W = 1424 Kgf or W3 = 6589 Kgf

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 15.463 bars

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

The Drop for this Nozzle is : 16.5135 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.5135 mm.

Input Echo, WRC107/537 Item 1, Description: Gas Out - 6in :

Table with 4 columns: Parameter, Vbasis, ID, Value. Rows include Diameter Basis for Vessel, Internal Corrosion Allowance, Vessel Diameter, Vessel Thickness, Design Temperature, Vessel Material, Vessel UNS Number, Vessel Cold S.I. Allowable, Vessel Hot S.I. Allowable.

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-516 70

Table with 4 columns: Attachment Type, Type, Round, Value. Rows include Diameter Basis for Nozzle, Nozzle Diameter, Nozzle Thickness, Nozzle Material, Nozzle UNS Number, Nozzle Cold S.I. Allowable, Nozzle Hot S.I. Allowable, Thickness of Reinforcing Pad, Diameter of Reinforcing Pad, Design Internal Pressure, Include Pressure Thrust.

External Forces and Moments in WRC 107/537 Convention:

Table with 4 columns: Force/Moment, (SUS), Code, Value. Rows include Radial Load, Longitudinal Shear, Circumferential Shear, Circumferential Moment, Longitudinal Moment.



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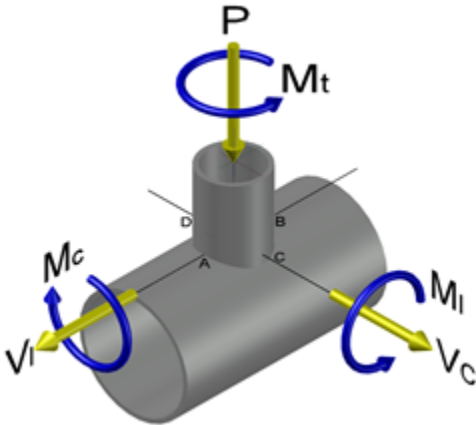
Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

Torsional Moment (SUS) Mt 136.2 Kg-m.

Use Interactive Control No
WRC107 Version Version March 1979

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 168.275 + 2 * 1.65 * sqrt(227.1 (6.0 - 3.0))
= 254.411 mm.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-144.4	Kgf
Circumferential Shear	VC	180.7	Kgf
Longitudinal Shear	VL	180.7	Kgf
Circumferential Moment	MC	-84.4	Kg-m.
Longitudinal Moment	ML	106.9	Kg-m.
Torsional Moment	MT	136.2	Kg-m.

Dimensionless Parameters used : Gamma = 25.57

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.320	4C	3.067	(A,B)
N(PHI) / (P/Rm)	0.320	3C	1.693	(C,D)
M(PHI) / (P)	0.320	2C1	0.021	(A,B)
M(PHI) / (P)	0.320	1C !	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.320	3A	1.075	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.320	1A	0.074	(A,B,C,D)



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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

Table with 5 columns: Parameter, Value, Figure, Value, Location. Rows include N(PHI) / (ML/(Rm**2 * Beta)), M(PHI) / (ML/(Rm * Beta)), N(x) / (P/Rm), M(x) / (P), N(x) / (MC/(Rm**2 * Beta)), M(x) / (MC/(Rm * Beta)), N(x) / (ML/(Rm**2 * Beta)), M(x) / (ML/(Rm * Beta)).

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Table with 10 columns: Type of Stress, Load, Au, Al, Bu, Bl, Cu, Cl, Du, Dl. Rows include Circ. Memb. P, Circ. Bend. P, Circ. Memb. MC, Circ. Memb. ML, Tot. Circ. Str., Long. Memb. P, Long. Bend. P, Long. Memb. MC, Long. Bend. MC, Long. Memb. ML, Long. Bend. ML, Tot. Long. Str., Shear VC, Shear VL, Shear MT, Tot. Shear, Str. Int.

Dimensionless Parameters used : Gamma = 75.70

Dimensionless Loads for Cylindrical Shells at Pad edge:

Table with 5 columns: Curves read for 1979, Beta, Figure, Value, Location. Rows include N(PHI) / (P/Rm), N(PHI) / (P/Rm).



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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

Table with columns for stress calculation formulas, values, nozzle numbers, and locations. Includes rows for M(PHI) and N(x) calculations.

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Table with columns for Type of Stress, Load, and Stress Intensity Values at various locations (Au, Al, Bu, Bl, Cu, Cl, Du, Dl). Includes rows for Circ. Memb., Long. Memb., and Shear.



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Nozzle Calcs.: Gas Out - 6in Nozl: 7 1:17pm Apr 8,2024

Pm (SUS)	26.1	26.5	26.1	26.5	26.1	26.5	26.1	26.5
Pm+Pl (SUS)	7.0	7.3	61.3	61.6	85.2	85.2	59.7	60.0
Pm+Pl+Q (Total)	20.2	25.5	81.0	44.4	380.0	297.6	194.8	227.1

Vessel Stress Summation Comparison (N/mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	26.50	137.90	Passed
Pm+Pl (SUS)	85.24	206.85	Passed
Pm+Pl+Q (TOTAL)	379.96	413.70	Passed

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

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Nozzle Calcs.: Vent - 1in

Nozl: 8

1:17pm

Apr 8,2024

Input, Nozzle Desc: Vent - 1in

From: 20

Pressure for Reinforcement Calculations	P	3.500	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	1.00	bars
Temperature for External Pressure	Tempex	85	°C

Shell Material		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²

Inside Diameter of Cylindrical Shell	D	445.20	mm.
Design Length of Section	L	1537.1740	mm.
Shell Finished (Minimum) Thickness	t	6.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.

Distance from Bottom/Left Tangent 1335.00 mm.

User Entered Minimum Design Metal Temperature -5.00 °C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm ²
Allowable Stress At Ambient	Sna	137.90	N./mm ²

Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		2.2500	in.

Size and Thickness Basis		Actual	
Actual Thickness	tn	11.8745	mm.

Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	

Outside Projection	ho	52.3250	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	6.0000	mm.
Groove weld depth between Nozzle and Vessel Wgnv		6.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.

The Pressure Design option was Design Pressure + static head.

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



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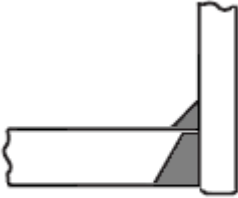
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Nozzle Calcs.: Vent - 1in

Nozl: 8

1:17pm

Apr 8,2024



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

Reinforcement CALCULATION, Description: Vent - 1in

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	2.250 in.
Actual Thickness Used in Calculation	0.468 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)
= (3.5*225.6)/(137.9*1-0.6*3.5)
= 0.5735 mm.

The Longitudinal Stress Governs over the Hoop Stress on the shell course where this nozzle is located. The Maximum stress ratio times the Shell thickness will be used in the calculation of the Area required.

The Stress Ratio is 0.2065 and the shell thk. is 6.0000 mm.

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)
= (3.5*28.57)/(137.9*1+0.4*3.5)
= 0.0725 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.1739 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	78.8020	mm.
Parallel to Vessel Wall, opening length	d	39.4010	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	7.5000	mm.

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: Vent - 1in. This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.

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

Wall Thickness for Internal/External pressures ta = 3.1739 mm.



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Nozzle Calcs.: Vent - 1in Nozl: 8 1:17pm Apr 8,2024

Wall Thickness per UG16(b),	tr16b = 5.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 3.5735 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 5.5000 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 5.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[6.42, max(5.5, 5.5)]
= 5.5000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.174, 5.5)
= 5.5000 mm.

Available Nozzle Neck Thickness = 11.8745 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 6, tr = 0.573, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.191, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of all the sub-joints of this Junction : -104 °C

Weld Size Calculations, Description: Vent - 1in

Intermediate Calc. for nozzle/shell Welds Tmin 3.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.1000 = 0.7 * tmin.	4.2420 = 0.7 * Wo mm.

Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)
(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 15.463 bars

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

The Drop for this Nozzle is : 1.8417 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 60.1667 mm.



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Nozzle Schedule:

Step: 27 1:17pm Apr 8,2024

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm.	Reinforcing Pad Diameter mm.	Pad Thk mm.	Cut Length mm.	Flg Class
Drain - 2in	2.000 in	160	SlipOn	2.375	8.738	160.00	6.00	106.68	150
Vent - 1in	2.250 in	Actual	None	2.250	11.875	...	...	60.17	...
Gas In - 6in	6.000 in	STD	SlipOn	6.625	7.112	250.00	6.00	172.51	150
Gas Out - 6in	6.000 in	STD	SlipOn	6.625	7.112	250.00	6.00	172.51	150

General Notes for the above table:

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

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

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

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

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
Drain - 2in	SA-106 B	5.556	6.000	6.000	6.000	...
Vent - 1in	SA-105	6.000	6.000	...	...	...
Gas In - 6i	SA-106 B	6.000	6.000	6.000	6.000	...
Gas Out - 6	SA-106 B	6.000	6.000	6.000	6.000	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
Drain - 2in	...	0.0	100.00	0.00	Cap - 18" (sch.1
Vent - 1in	1335.000	180.0	52.33	0.00	Shell - 18"
Gas In - 6in	285.000	180.0	150.00	0.00	Shell - 18"
Gas Out - 6in	1235.000	0.0	150.00	0.00	Shell - 18"

Weld Sizes for Slip On/Socket Weld Nozzle Flanges per UW-21:

Nozzle to Flange Fillet Weld Leg dimension [xmin]:
= min(1.4 * tn, Hub Thickness)

The Nozzle Wall thicknesses shown below are in the corroded condition. Hubs are considered to be straight.

Nominal or Actual	Schd	Flg	Noz.	Wall	Hub	Throat	xmin
-------------------	------	-----	------	------	-----	--------	------



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Nozzle Schedule:

Step: 27 1:17pm Apr 8,2024

Description	Size	or FVC Type	Type	O/Dia in	Thk mm.	Thk mm.	Thk mm.	Thk mm.
Drain - 2in	2.000 in	160	SlipOn	2.375	5.738	7.874	5.512	7.874
Gas In - 6in	6.000 in	STD	SlipOn	6.625	4.112	10.287	4.030	5.757
Gas Out - 6in	6.000 in	STD	SlipOn	6.625	4.112	10.287	4.030	5.757

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MDMT Summary:

Step: 29 1:17pm Apr 8,2024

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
Nozzle Flg	[5]	B	-29	-104					
Blind Flange	[11]	B	-29	-32	-29	0.939	9.500	1.00	No
Cap - 18" (sc[10]		B	-29	-29	-29	1.000	5.556	1.00	No
Cap - 18" (sch[7]		B	-29	-41	-29	0.781	6.350	1.00	No
Shell - 18" [8]		B	-29	-43	-29	0.745	6.000	0.85	No
Drain - 2in [1]		B	-29	-104		0.019	7.645	1.00	No
Nozzle Flg [4]		B	-29	-104					
Gas In - 6in [1]		B	-29	-104		0.077	6.223	1.00	No
Nozzle Flg [4]		B	-29	-104					
Gas Out - 6in [1]		B	-29	-104		0.077	6.223	1.00	No
Nozzle Flg [4]		B	-29	-104					
Vent - 1in [1]		B	-29	-104	-29	0.191	6.000	1.00	No
Bolting [21]			-48						

Warmest MDMT: -29 -29

Required Minimum Design Metal Temperature -5.0 °C
Warmest Computed Minimum Design Metal Temperature -29.0 °C

Notes:

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

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

Notes:

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



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MDMT Summary:

Step: 29

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Vessel Design Summary:

Step: 30

1:17pm

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ASME Code, Section VIII Division 1, 2017

Diameter Spec : 457.200 mm. OD	
Vessel Design Length, Tangent to Tangent	1547.53 mm.
Distance of Bottom Tangent above Grade	0.00 mm.
Specified Datum Line Distance	0.00 mm.
Internal Design Temperature	85 °C
Internal Design Pressure	3.500 bars
External Design Temperature	85 °C
External Design Pressure	1.000 bars
Maximum Allowable Working Pressure	13.552 bars
External Max. Allowable Working Pressure	1.730 bars
Hydrostatic Test Pressure	17.618 bars
Required Minimum Design Metal Temperature	-5.0 °C
Warmest Computed Minimum Design Metal Temperature	-29.0 °C
Wind Design Code	UBC
Earthquake Design Code	ASCE/SEI 7-16

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	No	No
Head	SA-234 WPB	...	...	K03006	No	No
Flange	SA-105	...	...	K03504	No	No
Flange	SA-516 70	...	...	K02700	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-105	...	...	K03504	No	No
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Leg Baseplate	SA-283 C	...	...	K02401	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Leg Bolting	SA-36	...	...	K02600	No	No

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

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Cap - 18" (sch.10)	3.500	1.00	13.552	3.0000	No	No
Shell - 18"	3.500	1.00	15.463	3.0000	N/A	No
Body Flange - 18"	3.500	1.00	18.150	3.0000	N/A	No
Blind Flange - 18"	3.500	1.00	14.432	3.0000	N/A	No

Liquid Level: 1611.52 mm. Dens.: 0.000 kg./cm³ Sp. Gr.: 0.001



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Vessel Design Summary:

Step: 30 1:17pm Apr 8,2024

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	85.0	85.0	6.3	5.6	5.5	5.5	1.00	0.85
Cylinder	1500.0	1415.0	6.0	6.0	5.5	5.4	0.85	0.85
Body Flg	1500.0	68.1	6.3	39.6	...	...	1.00	1.00
Body Flg	1547.5	38.0	6.3	38.0	37.5	37.5	1.00	1.00

Loads for Foundation/Support Design:

Factored Loads:

Total Wind Shear on top of all Legs	580.	Kgf
Total Earthquake Shear on top of all Legs	687.	Kgf
Total Wind Moment at top of all Legs	896.	Kg-m.
Total Earthquake Moment at top of all Legs	1010.	Kg-m.
Max. Wind Shear on one Leg (top & bottom)	494.	Kgf
Max. Earthq. Shear on one Leg (top & bottom)	585.	Kgf
Max. Wind Moment at base of one Leg	494.	Kg-m.
Max. Earthquake Moment at base of one Leg	585.	Kg-m.
Max. Vertical Load (Wt. + Wind) on one Leg	3425.	Kgf
Max. Vertical Load (Wt. + Eq.) on one Leg	3809.	Kgf

Un-Factored Loads:

Total Earthquake Shear on top of all Legs	981.	Kgf
Total Wind Moment at top of all Legs	896.	Kg-m.
Total Earthquake Moment at top of all Legs	1442.	Kg-m.
Max. Wind Shear on one Leg (top & bottom)	494.	Kgf
Max. Earthq. Shear on one Leg (top & bottom)	835.	Kgf
Max. Wind Moment at base of one Leg	494.	Kg-m.
Max. Earthquake Moment at base of one Leg	835.	Kg-m.
Max. Vertical Load (Wt. + Wind) on one Leg	3425.	Kgf
Max. Vertical Load (Wt. + Eq.) on one Leg	5442.	Kgf

Note:

Wind and Earthquake moments include the effects of user defined forces and moments if any exist in the job and were specified to act (compute loads and stresses) during these cases. Also included are moment effects due to eccentric weights if any are present in the input.

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	Pass Fail
LEGS	WRC-107/537	0.996	Passed
LEGS	WRC-107/537	0.073	Passed
Drain - 2in	WRC-107/537	0.242	Passed
Gas In - 6in	WRC-107/537	0.918	Passed
Gas Out - 6in	WRC-107/537	0.918	Passed



Strength Calculation-Cartridge Filter
Design by A. Azodi
Rev.01

PV Elite 2019 SP1 Licensee: SPLM Licensed User

FileName : EI027-HRC-VD-ME-CAL-004-01

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Vessel Design Summary: Step: 30 1:17pm Apr 8,2024

Weights:

Fabricated - Bare W/O Removable Internals	808.5	kg.
Shop Test - Fabricated + Water (Full)	1053.6	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	808.5	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	808.5	kg.
Empty - Fab. + Intls. + Details + Wghts.	808.5	kg.
Operating - Empty + Operating Liquid (No CA)	808.8	kg.
Field Test - Empty Weight + Water (Full)	1002.8	kg.

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