

 NISOC	نگهداشت و افزایش تولید میدان نفتی بینک سطح الارض و ابنیه تحت الارض خرید توپک ران و توپک گیر بسته خطوط لوله (قرارداد BK-HD-PPL-CO-0019_01)	 																								
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V02	0001	CN	ME	320	BV	PPL	BK																			

طرح نگهداشت و افزایش تولید ۲۷ مخزن

Mechanical Calculation Book for Pig Launcher Trap (PL-3201)

نگهداشت و افزایش تولید میدان نفتی بینک

V02	Mar.2024	IFI	Beh Koosh Vista	M.Fakharian	S.Faramarzpour	
V01	Dec.2023	IFI	Beh Koosh Vista	M.Fakharian	S.Faramarzpour	
V00	Aug.2023	IFI	Beh Koosh Vista	M.Fakharian	A.M.Mohseni	
Rev.	Date	Purpose of Issue/Status	Prepared by:	Checked by:	Approved by:	CLIENT Approval

Status:

IFA: Issued for Approval

IFR: Issued for Review

IFI: Issued for Information

AFC: Approved for Construction

 NISOC	نگهداشت و افزایش تولید میدان نفتی بینک سطح الارض و ابنیه تحت الارض خرید توپک ران و توپک گیر بسته خطوط لوله (قرارداد BK-HD-PPL-CO-0019_01)																									
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V02	0001	CN	ME	320	BV	PPL	BK																			

Revision Record Sheet

SHEET	V00	V01	V02	V03	V04	V05	V06	V07
1	X	X						
2	X	X						
3	X	X						
4	X	X						
5	X	X						
6	X	X						
7	X	X						
8	X	X						
9	X	X						
10	X	X						
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38	X	X	X					
39	X	X	X					
40	X	X	X					
41	X	X	X					
42	X	X	X					
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45	X	X	X					
46	X	X	X					
47	X	X	X					
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49	X	X	X					
50	X	X	X					

SHEET	V00	V01	V02	V03	V04	V05	V06	V07
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	BK	PPL	BV	320	ME	CN	0001	V02	

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	V02	0001	CN	ME	320	BV	PPL	
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1 INTRODUCTION:

ALL THE CALCULATIONS ARE ACCORDING TO ASME B31.8-2022

841.1. STEEL PIPING SYSTEMS DESIGN REQUIREMENTS.

841.1.1. Steel Pipe Design Formula

- (a) The design pressure for steel gas piping systems or the required wall thickness for a given design pressure shall be determined by the following formula:

$$t_r = t + A$$

$$t = \frac{PD}{2FETS}$$

- (b) The notations described below are used in the equations for the pressure design for Steel Pipe Design Formula.

t_r = Required wall thickness satisfying requirements for pressure and allowances

t = Pressure design wall thickness as calculated in inches (mm)

A = Corrosion allowances

P = Design gage pressure psi (bar)

D = Nominal outside diameter of pipe, in. (mm)

E = Joint factor obtained from Table 841.115A

F = Design factor obtained from Table 841.114A. In setting the values of the design factor, F, due consideration has been given and allowance has been made for the various under thickness tolerances provided for in the pipe specifications listed and approved for usage in this Code.

S = Specified minimum yield strength, psi (bar)

T = Temperature derating factor obtained from Table 841.116A

- (b) The design factor for pipelines in Location Class 1, Division 1 is based on gas pipeline operational experience at operation levels in excess of those previously recommended by this Code.

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Table 841.114A Basic Design Factor, F

Location Class	Design Factor, F
Location Class 1, Division 1	0.80
Location Class 1, Division 2	0.72
Location Class 2	0.60
Location Class 3	0.50
Location Class 4	0.40

Table 841.115A Longitudinal Joint Factor, E

Spec. No.	Pipe Class	E Factor
ASTM A 53	Seamless	1.00
	Electric Resistance Welded	1.00
	Furnace Butt Welded: Continuous Weld	0.60
ASTM A 106	Seamless	1.00
ASTM A 134	Electric Fusion Arc Welded	0.80
ASTM A 135	Electric Resistance Welded	1.00
ASTM A 139	Electric Fusion Welded	0.80
ASTM A 211	Spiral Welded Steel Pipe	0.80
ASTM A 333	Seamless	1.00
	Electric Resistance Welded	1.00
ASTM A 381	Double Submerged-Arc-Welded	1.00
ASTM A 671	Electric Fusion Welded	1.00
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A 672	Electric Fusion Welded	1.00
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
API 5L	Seamless	1.00
	Electric Resistance Welded	1.00
	Electric Flash Welded	1.00
	Submerged Arc Welded	1.00
	Furnace Butt Welded	0.60

GENERAL NOTE: Definitions for the various classes of welded pipe are given in para. 804.243.

Table 841.116A Temperature Derating Factor, T , for Steel Pipe

Temperature, °F	Temperature Derating Factor, T
250 or less	1.000
300	0.967
350	0.933
400	0.900
450	0.867

GENERAL NOTE: For intermediate temperatures, interpolate for derating factor.

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	BK	PPL	BV	320	ME	CN	0001	V02	

APPENDIX D

SPECIFIED MINIMUM YIELD STRENGTH FOR STEEL PIPE COMMONLY USED IN PIPING SYSTEMS¹

Table D-1 Specified Minimum Yield Strength for Steel Pipe Commonly Used in Piping Systems

Spec. No.	Grade	Type [Note (1)]	SMYS, psi
API 5L [Note (2)]	A25	BW, ERW, S	25,000
API 5L [Note (2)]	A	ERW, S, DSA	30,000
API 5L [Note (2)]	B	ERW, S, DSA	35,000
API 5L [Note (2)]	42	ERW, S, DSA	42,000
API 5L [Note (2)]	46	ERW, S, DSA	46,000
API 5L [Note (2)]	52	ERW, S, DSA	52,000
API 5L [Note (2)]	56	ERW, S, DSA	56,000
API 5L [Note (2)]	60	ERW, S, DSA	60,000
API 5L [Note (2)]	65	ERW, S, DSA	65,000
API 5L [Note (2)]	×70	ERW, S, DSA	70,000
API 5L [Note (2)]	80	ERW, S, DSA	80,000
ASTM A 53	Type F	BW	25,000
ASTM A 53	A	ERW, S	30,000
ASTM A 53	B	ERW, S	35,000
ASTM A 106	A	S	30,000
ASTM A 106	B	S	35,000
ASTM A 106	C	S	40,000
ASTM A 134	...	EFW	[Note (3)]
ASTM A 135	A	ERW	30,000
ASTM A 135	B	ERW	35,000
ASTM A 139	A	EFW	30,000
ASTM A 139	B	EFW	35,000
ASTM A 139	C	EFW	42,000
ASTM A 139	D	EFW	46,000
ASTM A 139	E	EFW	52,000
ASTM A 333	1	S, ERW	30,000
ASTM A 333	3	S, ERW	35,000
ASTM A 333	4	S	35,000
ASTM A 333	6	S, ERW	35,000
ASTM A 333	7	S, ERW	35,000
ASTM A 333	8	S, ERW	75,000
ASTM A 333	9	S, ERW	46,000

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V02	0001	CN	ME	320	BV	PPL	BK																	

2 Design Data

Design Pressure@ Temperature:	P= 62barg @ 85°C
Corrosion allowance (A):	3.2mm
Design Factor (F):	0.5
Weld efficiency(E):	1

3 Shell 10"-Barrel

Material specification:	API 5L-X52/PSL2
Outside diameter:	10" (273.1mm)
Nominal Wall Thickness:	9.27 mm (SCH.40)

Design thickness:

$$t = \frac{PD}{2FETS}$$

$$t = \frac{62 \times 273.1}{2(0.5 \times 1 \times 1 \times 3580)}$$

$$t = 4.73 \text{ mm}$$

The required wall thicknesses

$$t_r = t + A$$

$$t_r = 4.73 + 3.2 = 7.93 \text{ mm}$$

4 Shell 8"-Spool

Material specification:	API 5L-X52/PSL2
Outside diameter:	8" (219.1 mm)
Nominal Wall Thickness:	8.18 mm (SCH.40)

Design thickness:

$$t = \frac{PD}{2FETS}$$

$$t = \frac{62 \times 219.1}{2(0.5 \times 1 \times 1 \times 3580)}$$

$$t = 3.79 \text{ mm}$$

The required wall thicknesses

$$t_r = t + A$$

$$t_r = 3.79 + 3.2 = 6.99 \text{ mm}$$

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5 Nozzle Neck

5.1 Flange 8" (Outlet)

Material specification: A 694 F52
Outside diameter: 8" (219.1 mm)
Nominal Wall Thickness: 8.18 mm (SCH.40)

Design thickness:

$$t = \frac{PD}{2FETS}$$

$$t = \frac{62 \times 219.1}{2(0.5 \times 1 \times 1 \times 3580)}$$

$$t = 3.79 \text{ mm}$$

The required wall thicknesses

$$t_r = t + A$$

$$t_r = 3.79 + 3.2 = 6.99 \text{ mm}$$

5.2 Nozzle 2" (A, B, D1/2, V1/2)

Material specification: A 105N
Outside diameter: 2" (60.3 mm)
Nominal Wall Thickness: 5.54 mm (SCH.80)

Design thickness:

$$t = \frac{PD}{2FETS}$$

$$t = \frac{62 \times 60.3}{2(0.5 \times 1 \times 1 \times 2482)}$$

$$t = 1.51 \text{ mm}$$

The required wall thicknesses

$$t_r = t + A$$

$$t_r = 1.51 + 3.2 = 4.71 \text{ mm}$$

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5.3 Nozzle 1" (PSV, PG)

Material specification: A 105N
Outside diameter: 1" (33.4 mm)
Nominal Wall Thickness: 6.35 mm (SCH.160)

Design thickness:

$$t = \frac{PD}{2FETS}$$

$$t = \frac{62 \times 33.4}{2(0.5 \times 1 \times 1 \times 2482)}$$

$$t = 0.83 \text{ mm}$$

The required wall thicknesses

$$t_r = t + A$$

$$t_r = 0.83 + 3.2 = 4.03 \text{ mm}$$

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V02	0001	CN	ME	320	BV	PPL	BK																			

6. 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 %
10	20	54.7515	4417.86	52.6293	4577.49	2.73758
20	30	42.0098	32288.4	25.9637	34359.1	2.10049
30	40	9.92588	7221.66	6.59142	7651.96	0.49629
40	50	178.651	152711	118.4	160486	8.93256
Total		285	196638.55	203	207074.42	14

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
20	Sadl	23.8306	757	269.095	Lft Sdl
20	Liqd	1.33962	500	...	LIQUID
20	Nozl	6.49327	300	131.533	B
20	Nozl	6.40512	300	131.533	D2
20	Nozl	6.40512	700	131.533	V2
30	Liqd	0.29962	89	-13.9172	LIQUID
40	Sadl	26.3159	2100	289.505	Right Saddle
40	Liqd	6.33586	1500	...	LIQUID
40	Nozl	6.49327	600	157.442	V1
40	Nozl	2.64958	2400	143.98	PSV
40	Nozl	2.64958	2700	143.98	P
40	Nozl	6.49327	2400	157.442	A
40	Nozl	8.79809	2400	157.442	D1
40	Wght	80	3000	...	QOC

Total Weight of Each Detail Type

Total Weight of Saddles	50.1
Total Weight of Liquid	8.0
Total Weight of Nozzles	46.4
Total Weight of Weights	80.0

Sum of the Detail Weights 184.5 kg.

Weight Summation: kg.

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
299.6	396.1	299.6	396.1	299.6	476.1
50.1	196.5	50.1	...	50.1	8.0
46.4	80.0	46.4	...	...	...
...	...	...	...	...	80.0
...	...	...	...	...	-80.0
...	...	...	...	46.4	...
...	...	...	80.0	80.0	...
396.1	672.7	396.1	476.1	476.1	484.1

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V02	0001	CN	ME	320	BV	PPL	BK																			

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.

Note:

The shipping total has been modified because some items have been specified as being installed in the shop.

Weight Summary

Fabricated Wt.	- Bare Weight W/O Removable Internals	396.1 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	672.7 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	396.1 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	476.1 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	476.1 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	484.1 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	398.3 kg.
Field Test Wt.	- Empty Weight + Water (Full)	672.7 kg.

Note:

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

Outside Surface Areas of Elements:

From	To	Surface Area cm ²
10	20	2455.59
20	30	6883.23
30	40	1391.94
40	50	25739.1
Total		36469.836 cm ²

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2 7 Wind Load calculation

Input Values:

Wind Design Code	ASCE-7 2010
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed	232 Km/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0
Type of Surface	Moderately Smooth
Base Elevation	0 mm.
Percent Wind for Hydrotest	33.0
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 mm.
Distance Upwind of Crest Lh	0 mm.
Distance from Crest to the Vessel x	0 mm.
Type of Terrain (Hill, Escarpment)	Flat
Damping Factor (Beta) for Wind (Ope)	0.0100
Damping Factor (Beta) for Wind (Empty)	0.0000
Damping Factor (Beta) for Wind (Filled)	0.0000

Wind Analysis Results

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

$$\begin{aligned}
 &= \min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q)/(1 + 1.7 * gV * Izbar))) \\
 &= \min(0.85, 0.925((1+1.7*3.4*0.228*0.995)/(1+1.7*3.4*0.228))) \\
 &= \min(0.85, 0.922) \\
 &= 0.850
 \end{aligned}$$

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

Force Coefficient	[Cf] 0.654
Structure Height to Diameter ratio	16.809

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

Sample Calculation for the First Element

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

Value of [Alpha] and [Zg]:

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

Effective Height [z]:

$$\begin{aligned}
 &= \text{Centroid Height} + \text{Vessel Base Elevation} \\
 &= 471.0 + 0.0 = 471.0 \text{ mm.} \\
 &= 1.545 \text{ ft. Imperial Units}
 \end{aligned}$$

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z (1.545 \text{ ft.}) < 15 \text{ ft.} \\
 &= 2.01 * (15 / Zg) ^{(2 / Alpha)} \\
 &= 2.01 * (15/900.0) ^{(2/9.5)} \\
 &= 0.849
 \end{aligned}$$

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Type of Hill: No Hill

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

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

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

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= min(16, 0.00256 * Kz * Kzt * Kd * V(mph)²)
= min(16, 0.00256 * 0.849 * 1.0 * 0.95 * 144.162²)
= 42.9 psf [209.487] Kgs/m²

Force on the first element [F]:
= qz * G * Cf * WindArea
= 42.906 * 0.85 * 0.654 * 0.349
= 8.3 lbs. [3.8] Kgf

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m ²
end flange	471.0	0.000	0.000	0.000	0.849	1.000	209.487
spool	471.0	0.000	0.000	0.000	0.849	1.000	209.487
ECCENTRIC REDUC	471.0	0.000	0.000	0.000	0.849	1.000	209.487
BARREL	471.0	0.000	0.000	0.000	0.849	1.000	209.487

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm ²	Elevation mm.	Pressure Kgs/m ²	Force Kgf
QOC	0.00	3000.00	209.49	0.00

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	471	243.23	324.348	209.487	2.268
20	30	471	262.92	2629.2	209.487	18.3847
30	40	471	294.319	523.888	209.487	3.66329
40	50	471	327.72	9831.6	209.487	68.7475

Note:

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

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

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8 Earthquake Load Calculation:

Input Values:

Seismic Design Code	ASCE 7-2010
Seismic Load Reduction Scale Factor	0.700
Importance Factor	1.250
Table Value Fa	1.000
Table Value Fv	1.330
Short Period Acceleration value Ss	1.125
Long Period Acceleration Value S1	0.460
Moment Reduction Factor Tau	1.000
Force Modification Factor R	3.000
Site Class	C
Component Elevation Ratio	z/h
Amplification Factor	Ap
Force Factor	0.000
Consider Vertical Acceleration	No
Minimum Acceleration Multiplier	0.000
User Value of Sds (used if > 0)	0.000

Seismic Analysis Results:

$$\begin{aligned}
S_{ms} &= F_a * S_s = 1.0 * 1.125 = 1.125 \\
S_{m1} &= F_v * S_1 = 1.33 * 0.46 = 0.612 \\
S_{ds} &= 2/3 * S_{ms} = 2/3 * 1.125 = 0.75 \\
S_{d1} &= 2/3 * S_{m1} = 2/3 * 0.612 = 0.408
\end{aligned}$$

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

$$\begin{aligned}
&= C_t * h_n^{(x)} \text{ where } C_t = 0.020, x = 0.75 \text{ and } h_n = \text{Structural Height (ft.)} \\
&= 0.020 * (1.9629^{(0.75)}) \\
&= 0.033 \text{ seconds}
\end{aligned}$$

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

$$\begin{aligned}
&= (1/\text{Natural Frequency}) = (1/33.0) \\
&= 0.030
\end{aligned}$$

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

$$\begin{aligned}
&= \text{Minimum Value of } (1.4 * 0.033, 0.03) \text{ per 12.8.2} \\
&= 0.030
\end{aligned}$$

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

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

$$\begin{aligned}
&= 0.3 * S_{ds} * W * I \\
&= 0.3 * 0.75 * 398 * 1.25 \\
&= 112.014 \text{ Kgf}
\end{aligned}$$

Final Base Shear, $V = 78.41 \text{ Kgf}$

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight Kgf	Element Ope Load Kgf
Vista Engineering Dept.				

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10	20	101.346	66.3787	12.0675
20	30	101.37	66.3787	12.0703
20	30	101.37	66.3787	12.0703
30	40	99.8628	66.3787	11.8908
40	0	127.28	66.3787	15.1555
40	50	127.28	66.3787	15.1555

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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9 Lifting Lug

Lifting Lug Calculations: Lug(s) on Left End of Vessel

Input Values:

Lifting Lug Material		SA-283 C
Lifting Lug Yield Stress	Yield	206.85 N./mm ²
Total Height of Lifting Lug	w	100.0000 mm.
Thickness of Lifting Lug	t	10.0000 mm.
Diameter of Hole in Lifting Lug	dh	30.0000 mm.
Radius of Semi-Circular Arc of Lifting Lug	r	40.0000 mm.
Height of Lug from bottom to Center of Hole	h	50.0000 mm.
Offset from Vessel OD to Center of Hole	off	60.0000 mm.
Lug Fillet Weld Size	tw	10.0000 mm.
Length of weld along side of Lifting Lug	wl	120.0000 mm.
Length of Weld along Bottom of Lifting Lug	wb	10.0000 mm.
Thickness of Collar (if any)	tc	0.0000 mm.
Diameter of Collar (if any)	dc	0.0000 mm.
Impact Factor	Impfac	1.50
Sling Angle from Horizontal		90.0000 deg
Number of Lugs in Group		1

Lifting Lug Orientation to Vessel: Perpendicular
Lift Orientation : Horizontal Lift

PV Elite does not compute weak axis bending forces on the lugs. It is assumed that a spreader bar is used.

Computed Results:

Total vessel weight (No Liquid)		476.14 Kgf
Design Reaction force at the tailing lug		356.59 Kgf
Design Reaction force at the lifting lug		357.62 Kgf
Force Along Vessel Axis	Fax	0.00 Kgf
Force Normal to Vessel	Fn	356.59 Kgf
Force Tangential to Vessel	Ft	0.00 Kgf

Converting the weld leg dimension (tw) to the weld throat dimension.

Weld Group Inertia Calculations:

Weld Group Inertia about the Circumferential Axis	Ilc	260.754 cm**4
Weld Group Centroid distance in the Long. Direction	Yll	67.070 mm.
Dist. of Weld Group Centroid from Lug bottom	Yll_b	60.000 mm.
Weld Group Inertia about the Longitudinal Axis	Ill	1.189 cm**4
Weld Group Centroid Distance in the Circ. Direction	Ylc	5.000 mm.

Note: The Impact Factor is applied to the Forces acting on the Lug.

Primary Shear Stress in the Welds due to Shear Loads [Ssll]:

$$= \sqrt{Fax^2 + Ft^2 + Fn^2} / ((2 * (wl + wb)) * tw)$$

$$= \sqrt{0^2 + 0^2 + 357^2} / ((2 * (120.0 + 10.0)) * 7.07)$$

$$= 1.90 \text{ N./mm}^2$$

Shear Stress in the Welds due to Bending Loads [Sblf]:

$$= (Fn * (h - Yll_b)) * Yll / Ilc + (Fax * off * Yll / Ilc) + (Ft * off * Ylc / Ill)$$

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$$\begin{aligned}
 &= (357 * (50.0 - 60.0)) * 67.07 / 260.754 + \\
 &\quad (0 * 60.0 * 67.07 / 260.754) + \\
 &\quad (0 * 60.0 * 5.0 / 1.189) \\
 &= -0.90 \text{ N./mm}^2
 \end{aligned}$$

Total Shear Stress for Combined Loads [St]:

$$\begin{aligned}
 &= S_{s11} + S_{b1f} \\
 &= 1.902 + -0.899 \\
 &= 1.00 \text{ N./mm}^2
 \end{aligned}$$

Allowable Shear Stress for Combined Loads [Sta]:

$$\begin{aligned}
 &= 0.4 * \text{Yield} * \text{Occfac} \text{ (AISC Shear Allowable)} \\
 &= 0.4 * 207 * 1.0 \\
 &= 82.74 \text{ N./mm}^2
 \end{aligned}$$

Shear Stress in Lug above Hole [Shs]:

$$\begin{aligned}
 &= \sqrt{P_1^2 + F_{ax}^2} / S_{ha} \\
 &= \sqrt{357^2 + 0^2} / 5.0 \\
 &= 6.99 \text{ N./mm}^2
 \end{aligned}$$

Allowable Shear Stress in Lug above Hole [Sas]:

$$\begin{aligned}
 &= 0.4 * \text{Yield} * \text{Occfac} \\
 &= 0.4 * 207 * 1.0 \\
 &= 82.74 \text{ N./mm}^2
 \end{aligned}$$

Pin Hole Bearing Stress [Pbs]:

$$\begin{aligned}
 &= \sqrt{F_{ax}^2 + F_n^2} / (t * d_h) \\
 &= \sqrt{0^2 + 357^2} / (10.0 * 30.0) \\
 &= 11.66 \text{ N./mm}^2
 \end{aligned}$$

Allowable Bearing Stress [Pba]:

$$\begin{aligned}
 &= \min(0.75 * \text{Yield} * \text{Occfac}, 0.9 * \text{Yield}) \text{ AISC Bearing All.} \\
 &= \min(0.75 * 207 * 1.0, 186.2) \\
 &= 155.14 \text{ N./mm}^2
 \end{aligned}$$

Bending Stress at the Base of the Lug [Fbs]:

$$\begin{aligned}
 &= F_t * \text{off} / (w * t^2 / 6) + F_{ax} * \text{off} / (w^2 * t / 6) \\
 &= 0 * 60.0 / (100.0 * 10.0^2 / 6) + \\
 &\quad 0 * 60.0 / (100.0^2 * 10.0 / 6) \\
 &= 0.00 \text{ N./mm}^2
 \end{aligned}$$

Tensile Stress at the Base of the Lug [Fa]:

$$\begin{aligned}
 &= F_n / (w * t) \\
 &= 0 / (100.0 * 10.0) \\
 &= 3.50 \text{ N./mm}^2
 \end{aligned}$$

Total Combined Stress at the Base of the Lug:

$$\begin{aligned}
 &= F_{bs} + F_a \\
 &= 0.0 + 3.5 \\
 &= 3.50 \text{ N./mm}^2
 \end{aligned}$$

Lug Allowable Stress for Bending and Tension:

$$\begin{aligned}
 &= \min(0.66 * \text{Yield} * \text{Occfac}, 0.75 * \text{Yield}) \\
 &= \min(0.66 * 207 * 1.0, 155.1) \\
 &= 136.52 \text{ N./mm}^2
 \end{aligned}$$

Required Shackle Pin Diameter [Spd]:

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$$= \sqrt{(2 * \sqrt{F_n^2 + F_{ax}^2}) / (\pi * S_{ta})}$$

$$= \sqrt{2 * \sqrt{357^2 + 0^2}) / (\pi * 83)}$$

$$= 5.1871 \text{ mm.}$$

WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in the new and Cold Condition (no corrosion applied).

Note: Since Beta1/Beta2 >= 0.25, C22 (C22p) is adjusted per table 6 in paragraph 4.3 of WRC Bulletin 107.

Input Echo, WRC107/537 Item 1, Description: Lift Lug

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical
Internal Corrosion Allowance	Cas	0.0000 mm.
Vessel Diameter	Dv	202.740 mm.
Vessel Thickness	Tv	8.180 mm.
Design Temperature		37.78 °C
Attachment Type	Type	Rectangular
Parameter C11	C11	10.00 mm.
Parameter C22	C22	40.00 mm.
Thickness of Reinforcing Pad	Tpad	10.000 mm.
Pad Parameter C11P	C11p	120.000 mm.
Pad Parameter C22P	C22p	200.000 mm.
Design Internal Pressure	Dp	0.000 bars
Include Pressure Thrust		No
External Forces and Moments in WRC 107/537 Convention:		
Radial Load (SUS)	P	-356.6 Kg
Longitudinal Shear (SUS)	Vl	0.0 Kg
Circumferential Shear (SUS)	Vc	0.0 Kg
Circumferential Moment (SUS)	Mc	0.0 Kg-m.
Longitudinal Moment (SUS)	Ml	0.0 Kg-m.
Torsional Moment (SUS)	Mt	0.0 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

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	-356.6 Kg
Circumferential Shear	VC	0.0 Kg
Longitudinal Shear	VL	0.0 Kg
Circumferential Moment	MC	0.0 Kg-m.
Longitudinal Moment	ML	0.0 Kg-m.
Torsional Moment	MT	0.0 Kg-m.

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	BK	PPL	BV	320	ME	CN	0001	V02	

Dimensionless Parameters used : Gamma = 6.08

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.134	4C	1.186	(A,B)
N(PHI) / (P/Rm)	0.134	3C	1.148	(C,D)
M(PHI) / (P)	0.080	2C1	0.208	(A,B)
M(PHI) / (P)	0.080	1C	0.233	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.072	3A !	0.034	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.094	1A	0.105	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.114	3B !	0.307	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.103	1B	0.063	(A,B,C,D)
N(x) / (P/Rm)	0.109	3C	1.187	(A,B)
N(x) / (P/Rm)	0.109	4C	1.211	(C,D)
M(x) / (P)	0.113	1C1	0.199	(A,B)
M(x) / (P)	0.113	2C	0.167	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.072	4A !	0.050	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.132	2A	0.063	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.114	4B !	0.074	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.141	2B	0.095	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress		Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	Load	2.1	2.1	2.1	2.1	2.0	2.0	2.0	2.0
Circ. Bend. P		13.2	-13.2	13.2	-13.2	14.8	-14.8	14.8	-14.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. ML		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		15.2	-11.1	15.2	-11.1	16.8	-12.8	16.8	-12.8
Long. Memb. P		2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Long. Bend. P		12.7	-12.7	12.7	-12.7	10.6	-10.6	10.6	-10.6
Long. Memb. MC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		14.7	-10.6	14.7	-10.6	12.7	-8.5	12.7	-8.5
Shear VC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear MT		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Str. Int. | 15.2 | 11.1 | 15.2 | 11.1 | 16.8 | 12.8 | 16.8 | 12.8 |

Dimensionless Parameters used: Gamma = 12.89

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.923	4C !	1.455	(A,B)
N(PHI) / (P/Rm)	0.923	3C !	0.829	(C,D)
M(PHI) / (P)	0.687	2C1 !	0.017	(A,B)
M(PHI) / (P)	0.687	1C !	0.055	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.675	3A !	0.515	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.740	1A !	0.070	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.800	3B !	1.053	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.777	1B !	0.013	(A,B,C,D)
N(x) / (P/Rm)	0.813	3C !	0.829	(A,B)
N(x) / (P/Rm)	0.813	4C !	1.455	(C,D)
M(x) / (P)	0.832	1C1 !	0.034	(A,B)
M(x) / (P)	0.832	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.675	4A !	1.374	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.900	2A !	0.034	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.800	4B !	0.526	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.882	2B !	0.026	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load		Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		5.9	5.9	5.9	5.9	3.4	3.4	3.4	3.4
Circ. Bend. P		5.4	-5.4	5.4	-5.4	17.3	-17.3	17.3	-17.3
Circ. Memb. MC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. ML		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		11.3	0.5	11.3	0.5	20.6	-13.9	20.6	-13.9
Long. Memb. P		3.4	3.4	3.4	3.4	5.9	5.9	5.9	5.9
Long. Bend. P		10.5	-10.5	10.5	-10.5	10.0	-10.0	10.0	-10.0
Long. Memb. MC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		13.9	-7.2	13.9	-7.2	15.9	-4.1	15.9	-4.1
Shear VC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear MT		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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	BK	PPL	BV	320	ME	CN	0001	V02		

Tot. Shear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Str. Int.	13.9	7.7	13.9	7.7	20.6	13.9	20.6	13.9	

WRC 107/537 Stress Summations:

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

Type of Stress Load		Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)		2.1	2.1	2.1	2.1	2.0	2.0	2.0	2.0
Circ. Q (SUS)		13.2	-13.2	13.2	-13.2	14.8	-14.8	14.8	-14.8
Long. Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)		2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Long. Q (SUS)		12.7	-12.7	12.7	-12.7	10.6	-10.6	10.6	-10.6
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)		2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Pm+Pl+Q (Total)		15.2	11.1	15.2	11.1	16.8	12.8	16.8	12.8

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	151.70	Passed
Pm+Pl (SUS)	2.11	227.55	Passed
Pm+Pl+Q (TOTAL)	16.76	455.10	Passed

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)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)		5.9	5.9	5.9	5.9	3.4	3.4	3.4	3.4
Circ. Q (SUS)		5.4	-5.4	5.4	-5.4	17.3	-17.3	17.3	-17.3
Long. Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)		3.4	3.4	3.4	3.4	5.9	5.9	5.9	5.9
Long. Q (SUS)		10.5	-10.5	10.5	-10.5	10.0	-10.0	10.0	-10.0
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Mechanical Calculation Book for Pig Launcher Trap (PL-3201)																										
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V02	0001	CN	ME	320	BV	PPL	BK																			

Shear Pl (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Pm+Pl+Q (Total)	13.9	7.7	13.9	7.7	20.6	13.9	20.6	13.9

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	151.70	Passed
Pm+Pl (SUS)	5.90	227.55	Passed
Pm+Pl+Q (TOTAL)	20.64	455.10	Passed

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Lifting Lug Calculations: Lug(s) on Right End of Vessel

Input Values:

Lifting Lug Material	SA-283 C
Lifting Lug Yield Stress	Yield 206.85 N./mm ²
Total Height of Lifting Lug	w 100.0000 mm.
Thickness of Lifting Lug	t 10.0000 mm.
Diameter of Hole in Lifting Lug	dh 30.0000 mm.
Radius of Semi-Circular Arc of Lifting Lug	r 40.0000 mm.
Height of Lug from bottom to Center of Hole	h 50.0000 mm.
Offset from Vessel OD to Center of Hole	off 60.0000 mm.
Lug Fillet Weld Size	tw 10.0000 mm.
Length of weld along side of Lifting Lug	wl 120.0000 mm.
Length of Weld along Bottom of Lifting Lug	wb 10.0000 mm.
Thickness of Collar (if any)	tc 0.0000 mm.
Diameter of Collar (if any)	dc 0.0000 mm.
Impact Factor	Impfac 1.50
Sling Angle from Horizontal	90.0000 deg
Number of Lugs in Group	1

Lifting Lug Orientation to Vessel: Perpendicular
Lift Orientation: Horizontal Lift

PV Elite does not compute weak axis bending forces on the lugs. It is assumed that a spreader bar is used.

Computed Results:

Total vessel weight (No Liquid)	476.14 Kgf
Design Reaction force at the tailing lug	356.59 Kgf
Design Reaction force at the lifting lug	357.62 Kgf
Force Along Vessel Axis	Fax 0.00 Kgf
Force Normal to Vessel	Fn 357.62 Kgf
Force Tangential to Vessel	Ft 0.00 Kgf

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نسخه	سریال	نوع مدرک	رشته	تسهیلات	صادرکننده	بسته کاری	پروژه																	
V02	0001	CN	ME	320	BV	PPL	BK																	

Converting the weld leg dimension (tw) to the weld throat dimension.

Weld Group Inertia Calculations:

Weld Group Inertia about the Circumferential Axis	I _{lc}	260.754 cm**4
Weld Group Centroid distance in the Long. Direction	Y _{ll}	67.070 mm.
Dist. of Weld Group Centroid from Lug bottom	Y _{ll_b}	60.000 mm.
Weld Group Inertia about the Longitudinal Axis	I _{ll}	1.189 cm**4
Weld Group Centroid Distance in the Circ. Direction	Y _{lc}	5.000 mm.

Note: The Impact Factor is applied to the Forces acting on the Lug.

Primary Shear Stress in the Welds due to Shear Loads [S_{sl}]:

$$\begin{aligned}
 &= \sqrt{F_{ax}^2 + F_t^2 + F_n^2} / ((2 * (w_l + w_b)) * t_w) \\
 &= \sqrt{0^2 + 0^2 + 358^2} / ((2 * (120.0 + 10.0)) * 7.07) \\
 &= 1.91 \text{ N./mm}^2
 \end{aligned}$$

Shear Stress in the Welds due to Bending Loads [S_{blf}]:

$$\begin{aligned}
 &= (F_n * (h - Y_{ll_b})) * Y_{ll} / I_{lc} + (F_{ax} * off * Y_{ll} / I_{lc}) + (F_t * off * Y_{lc} / I_{ll}) \\
 &= (358 * (50.0 - 60.0)) * 67.07 / 260.754 + \\
 &\quad (0 * 60.0 * 67.07 / 260.754) + \\
 &\quad (0 * 60.0 * 5.0 / 1.189) \\
 &= -0.90 \text{ N./mm}^2
 \end{aligned}$$

Total Shear Stress for Combined Loads [S_t]:

$$\begin{aligned}
 &= S_{sl} + S_{blf} \\
 &= 1.908 + -0.902 \\
 &= 1.01 \text{ N./mm}^2
 \end{aligned}$$

Allowable Shear Stress for Combined Loads [S_a]:

$$\begin{aligned}
 &= 0.4 * \text{Yield} * \text{Occfac} \text{ (AISC Shear Allowable)} \\
 &= 0.4 * 207 * 1.0 \\
 &= 82.74 \text{ N./mm}^2
 \end{aligned}$$

Shear Stress in Lug above Hole [S_{hs}]:

$$\begin{aligned}
 &= \sqrt{P_l^2 + F_{ax}^2} / S_{ha} \\
 &= \sqrt{358^2 + 0^2} / 5.0 \\
 &= 7.01 \text{ N./mm}^2
 \end{aligned}$$

Allowable Shear Stress in Lug above Hole [S_{as}]:

$$\begin{aligned}
 &= 0.4 * \text{Yield} * \text{Occfac} \\
 &= 0.4 * 207 * 1.0 \\
 &= 82.74 \text{ N./mm}^2
 \end{aligned}$$

Pin Hole Bearing Stress [P_{bs}]:

$$\begin{aligned}
 &= \sqrt{F_{ax}^2 + F_n^2} / (t * d_h) \\
 &= \sqrt{0^2 + 358^2} / (10.0 * 30.0) \\
 &= 11.69 \text{ N./mm}^2
 \end{aligned}$$

Allowable Bearing Stress [P_{ba}]:

$$\begin{aligned}
 &= \min(0.75 * \text{Yield} * \text{Occfac}, 0.9 * \text{Yield}) \text{ AISC Bearing All.} \\
 &= \min(0.75 * 207 * 1.0, 186.2) \\
 &= 155.14 \text{ N./mm}^2
 \end{aligned}$$

Bending Stress at the Base of the Lug [F_{bs}]:

$$\begin{aligned}
 &= F_t * off / (w * t^3 / 6) + F_{ax} * off / (w^3 / 6) \\
 &= 0 * 60.0 / (100.0 * 10.0^3 / 6) +
 \end{aligned}$$

 NISOC	نگهداشت و افزایش تولید میدان نفتی بینک سطح الارض و ابنیه تحت الارض خرید توپک ران و توپک گیر بسته خطوط لوله (قرارداد BK-HD-PPL-CO-0019_01)							 شرکت توسعه و پیمانکاری  نام اوران به کوش	
شماره پیمان: ۰۵۳ - ۰۷۳ - ۹۱۸۴	Mechanical Calculation Book for Pig Launcher Trap (PL-3201)								شماره صفحه: ۲۴ از ۵۲
	پروژه	بسته کاری	صادر کننده	تسهیلات	رشته	نوع مدرک	سریال	نسخه	
	BK	PPL	BV	320	ME	CN	0001	V02	

$$0 * 60.0 / (100.0^{(2)} * 10.0 / 6)$$

$$= 0.00 \text{ N./mm}^2$$

Tensile Stress at the Base of the Lug [Fa]:

$$= F_n / (w * t)$$

$$= 0 / (100.0 * 10.0)$$

$$= 3.51 \text{ N./mm}^2$$

Total Combined Stress at the Base of the Lug:

$$= F_{bs} + F_a$$

$$= 0.0 + 3.5$$

$$= 3.51 \text{ N./mm}^2$$

Lug Allowable Stress for Bending and Tension:

$$= \min(0.66 * \text{Yield} * \text{Occfac}, 0.75 * \text{Yield})$$

$$= \min(0.66 * 207 * 1.0, 155.1)$$

$$= 136.52 \text{ N./mm}^2$$

Required Shackle Pin Diameter [Spd]:

$$= \sqrt{(2 * \sqrt{F_n^2 + F_{ax}^2}) / (\pi * \sigma_{ta})}$$

$$= \sqrt{2 * \sqrt{358^2 + 0^2} / (\pi * 83)}$$

$$= 5.1947 \text{ mm.}$$

WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in the new and Cold Condition (no corrosion applied).

Note: Since Beta1/Beta2 >= 0.25, C22 (C22p) is adjusted per table 6 in paragraph 4.3 of WRC Bulletin 107.

Input Echo, WRC107/537 Item 1, Description: Lift Lug

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical
Internal Corrosion Allowance	Cas	0.0000 mm.
Vessel Diameter	Dv	254.560 mm.
Vessel Thickness	Tv	9.270 mm.
Design Temperature		37.78 °C
Attachment Type	Type	Rectangular
Parameter C11	C11	10.00 mm.
Parameter C22	C22	40.00 mm.
Thickness of Reinforcing Pad	Tpad	10.000 mm.
Pad Parameter C11P	C11p	120.000 mm.
Pad Parameter C22P	C22p	200.000 mm.
Design Internal Pressure	Dp	0.000 bars
Include Pressure Thrust		No

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	-357.6	Kgf
Longitudinal Shear (SUS)	Vl	0.0	Kgf
Circumferential Shear (SUS)	Vc	0.0	Kgf
Circumferential Moment (SUS)	Mc	0.0	Kg-m.
Longitudinal Moment (SUS)	Ml	0.0	Kg-m.
Torsional Moment (SUS)	Mt	0.0	Kg-m.

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شماره پیمان: ۰۵۳ - ۰۷۳ - ۹۱۸۴	<table><tr><th colspan="8">Mechanical Calculation Book for Pig Launcher Trap (PL-3201)</th></tr><tr><th>نسخه</th><th>سریال</th><th>نوع مدرک</th><th>رشته</th><th>تسهیلات</th><th>صادر کننده</th><th>بسته کاری</th><th>پروژه</th></tr><tr><td>V02</td><td>0001</td><td>CN</td><td>ME</td><td>320</td><td>BV</td><td>PPL</td><td>BK</td></tr></table>	Mechanical Calculation Book for Pig Launcher Trap (PL-3201)								نسخه	سریال	نوع مدرک	رشته	تسهیلات	صادر کننده	بسته کاری	پروژه	V02	0001	CN	ME	320	BV	PPL	BK	شماره صفحه ۲۵: از ۵۲
Mechanical Calculation Book for Pig Launcher Trap (PL-3201)																										
نسخه	سریال	نوع مدرک	رشته	تسهیلات	صادر کننده	بسته کاری	پروژه																			
V02	0001	CN	ME	320	BV	PPL	BK																			

Use Interactive Control
WRC107 Version

No
Version March 1979

Include Pressure Stress Indices per Div. 2
Compute Pressure Stress per WRC-368

No
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 SUSained loads:

Radial Load	P	-357.6	Kgf
Circumferential Shear	VC	0.0	Kgf
Longitudinal Shear	VL	0.0	Kgf
Circumferential Moment	MC	0.0	Kg-m.
Longitudinal Moment	ML	0.0	Kg-m.
Torsional Moment	MT	0.0	Kg-m.

Dimensionless Parameters used : Gamma = 7.11

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.108	4C	1.394	(A,B)
N(PHI) / (P/Rm)	0.108	3C	1.364	(C,D)
M(PHI) / (P)	0.064	2C1	0.220	(A,B)
M(PHI) / (P)	0.064	1C	0.249	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.058	3A !	0.030	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.076	1A	0.106	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.092	3B !	0.306	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.083	1B	0.063	(A,B,C,D)
N(x) / (P/Rm)	0.088	3C	1.395	(A,B)
N(x) / (P/Rm)	0.088	4C	1.421	(C,D)
M(x) / (P)	0.091	1C1	0.218	(A,B)
M(x) / (P)	0.091	2C	0.181	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.058	4A !	0.047	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.107	2A	0.063	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.092	4B !	0.072	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.114	2B	0.098	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8
Circ. Bend. P		12.5	-12.5	12.5	-12.5	14.1	-14.1	14.1	-14.1

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شماره پیمان: ۰۵۳ - ۰۷۳ - ۹۱۸۴	Mechanical Calculation Book for Pig Launcher Trap (PL-3201)								شماره صفحه ۲۶: از ۵۲
	پروژه	بسته کاری	صادرکننده	تسهیلات	رشته	نوع مدرک	سریال	نسخه	
	BK	PPL	BV	320	ME	CN	0001	V02	

Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	14.3	-10.6	14.3	-10.6	15.9	-12.3	15.9	-12.3	
Long. Memb. P	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	
Long. Bend. P	12.3	-12.3	12.3	-12.3	10.3	-10.3	10.3	-10.3	
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Long. Memb. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Long. Bend. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Tot. Long. Str.	14.2	-10.5	14.2	-10.5	12.1	-8.4	12.1	-8.4	
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Shear VL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Tot. Shear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Str. Int.	14.3	10.6	14.3	10.6	15.9	12.3	15.9	12.3	

Dimensionless Parameters used : Gamma = 14.23

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.738	4C !	1.550	(A,B)
N(PHI) / (P/Rm)	0.738	3C !	0.868	(C,D)
M(PHI) / (P)	0.550	2C1 !	0.015	(A,B)
M(PHI) / (P)	0.550	1C !	0.055	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.539	3A !	0.542	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.592	1A !	0.067	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.639	3B !	1.095	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.621	1B !	0.013	(A,B,C,D)
N(x) / (P/Rm)	0.650	3C !	0.868	(A,B)
N(x) / (P/Rm)	0.650	4C !	1.550	(C,D)
M(x) / (P)	0.665	1C1 !	0.031	(A,B)
M(x) / (P)	0.665	2C !	0.031	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.539	4A !	1.523	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.719	2A !	0.032	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.639	4B !	0.556	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.705	2B !	0.024	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		4.4	4.4	4.4	4.4	2.5	2.5	2.5	2.5

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Mechanical Calculation Book for Pig Launcher Trap (PL-3201)																										
نسخه	سریال	نوع مدرک	رشته	تسهیلات	صادر کننده	بسته کاری	پروژه																			
V02	0001	CN	ME	320	BV	PPL	BK																			

Circ. Bend. P	3.8	-3.8	3.8	-3.8	13.5	-13.5	13.5	-13.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	8.2	0.7	8.2	0.7	16.0	-11.1	16.0	-11.1
Long. Memb. P	2.5	2.5	2.5	2.5	4.4	4.4	4.4	4.4
Long. Bend. P	7.6	-7.6	7.6	-7.6	7.5	-7.5	7.5	-7.5
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	10.1	-5.1	10.1	-5.1	12.0	-3.1	12.0	-3.1
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Str. Int.	10.1	5.8	10.1	5.8	16.0	11.1	16.0	11.1

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)		1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8
Circ. Q (SUS)		12.5	-12.5	12.5	-12.5	14.1	-14.1	14.1	-14.1
Long. Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)		1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Long. Q (SUS)		12.3	-12.3	12.3	-12.3	10.3	-10.3	10.3	-10.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)		1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Pm+Pl+Q (Total)		14.3	10.6	14.3	10.6	15.9	12.3	15.9	12.3

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	151.70	Passed

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Mechanical Calculation Book for Pig Launcher Trap (PL-3201)																										
نسخه	سریال	نوع مدرک	رشته	تسهیلات	صادر کننده	بسته کاری	پروژه																			
V02	0001	CN	ME	320	BV	PPL	BK																			

Pm+Pl (SUS)	1.89	227.55	Passed
Pm+Pl+Q (TOTAL)	15.90	455.10	Passed

WRC 107/537 Stress Summations:

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

Type of Stress		Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)		4.4	4.4	4.4	4.4	2.5	2.5	2.5	2.5
Circ. Q (SUS)		3.8	-3.8	3.8	-3.8	13.5	-13.5	13.5	-13.5
Long. Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)		2.5	2.5	2.5	2.5	4.4	4.4	4.4	4.4
Long. Q (SUS)		7.6	-7.6	7.6	-7.6	7.5	-7.5	7.5	-7.5
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)		4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Pm+Pl+Q (Total)		10.1	5.8	10.1	5.8	16.0	11.1	16.0	11.1

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	151.70	Passed
Pm+Pl (SUS)	4.45	227.55	Passed
Pm+Pl+Q (TOTAL)	16.03	455.10	Passed

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شماره پیمان: ۰۵۳ - ۰۷۳ - ۹۱۸۴	Mechanical Calculation Book for Pig Launcher Trap (PL-3201)								شماره صفحه ۲۹: از ۵۲
	پروژه	بسته کاری	صادرکننده	تسهیلات	رشته	نوع مدرک	سریال	نسخه	
	BK	PPL	BV	320	ME	CN	0001	V02	

2 10 Saddle

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

Horizontal Vessel Stress Calculations : Operating Case

Input and Calculated Values:

Vessel Mean Radius	Rm	107.06	mm.
Stiffened Vessel Length per 4.15.6	L	1178.00	mm.
Distance from Saddle to Vessel tangent	a	200.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	200.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm.
Wear Plate Allowable Stress	Sr	108.25	N./mm ²
Shell Allowable Stress used in Calculation		151.70	N./mm ²
Head Allowable Stress used in Calculation		151.70	N./mm ²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		479.13	Kgf

Horizontal Vessel Analysis Results:		Actual	Allowable
		N./mm ²	N./mm ²
Long. Stress at Top of Midspan		64.04	151.70
Long. Stress at Bottom of Midspan		69.25	151.70
Long. Stress at Top of Saddles		73.80	151.70
Long. Stress at Bottom of Saddles		62.69	151.70
Tangential Shear in Shell		6.81	121.36
Circ. Stress at Horn of Saddle		3.06	189.62
Circ. Stress at Tip of Wear Plate		13.61	189.62
Circ. Compressive Stress in Shell		0.39	151.70

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

$$\begin{aligned}
&= F_{tr} * (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E \\
&= 3.0 * (93.1/2 + 0) * 455.0/185.4334 \\
&= 342.5 \text{ Kgf}
\end{aligned}$$

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

$$\begin{aligned}
&= \max(F_l, \text{Friction Load, Sum of X Forces}) * B / L_s \\
&= \max(5.69, 0.0, 0) * 455.0/2521.0002 \\
&= 1.0 \text{ Kgf}
\end{aligned}$$

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

$$\begin{aligned}
&= \max(F_l, \text{Friction Force, Sum of X Forces}) * B / L_s \\
&= \max(78.41, 0.0, 0) * 455.0/2521.0002 \\
&= 14.2 \text{ Kgf}
\end{aligned}$$

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	BK	PPL	BV	320	ME	CN	0001	V02	

Saddle Reaction Force due to Earthquake Ft [Fst]:

$$= F_{tr} * (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E$$

$$= 3.0 * (78/2 + 0) * 455.0/185.4334$$

$$= 288.6 \text{ Kg}$$

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

$$= \text{Saddle Load} + \text{Max}(F_{wl}, F_{wt}, F_{sl}, F_{st})$$

$$= 137 + \text{Max}(1, 343, 14, 289)$$

$$= 479.1 \text{ Kg}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	502.96	Kgf
Transverse Shear Load Saddle	46.53	Kgf
Longitudinal Shear Load Saddle	78.41	Kgf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0434			

The suffix 'p' denotes the values for a wear plate if it exists.

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

Moment per Equation 4.15.3 [M1]:

$$= -Q * a [1 - (1 - a/L + (R^2 - h^2) / (2a * L)) / (1 + (4h^2) / (3L))]$$

$$= -479 * 200.0 [1 - (1 - 200.0/1178.0 + (107.06^2 - 0.0^2) / (2 * 200.0 * 1178.0)) / (1 + (4 * 0.0) / (3 * 1178.0))]$$

$$= -13.9 \text{ Kg-m.}$$

Moment per Equation 4.15.4 [M2]:

$$= Q * L / 4 (1 + 2(R^2 - h^2) / (L^2)) / (1 + (4h^2) / (3L)) - 4a/L$$

$$= 479 * 1178 / 4 (1 + 2(107^2 - 0^2) / (1178^2)) / (1 + (4 * 0) / (3 * 1178)) - 4 * 200 / 1178$$

$$= 47.6 \text{ Kg-m.}$$

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

$$= P * R_m / (2t) - M_2 / (\pi * R_m^2 * t)$$

$$= 62.0 * 107.06 / (2 * 4.98) - 47.6 / (\pi * 107.1^2 * 4.98)$$

$$= 64.04 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) + M_2 / (\pi * R_m^2 * t)$$

$$= 62.0 * 107.06 / (2 * 4.98) + 47.6 / (\pi * 107.1^2 * 4.98)$$

$$= 69.25 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) - M_1 / (K_1 * \pi * R_m^2 * t)$$

$$= 62.0 * 107.06 / (2 * 4.98) - 13.9 / (0.1066 * \pi * 107.1^2 * 4.98)$$

$$= 73.80 \text{ N./mm}^2$$

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V02	0001	CN	ME	320	BV	PPL	BK																			

Longitudinal Stress at Bottom of Shell at Support (4.15.11) $[\sigma_4]$:

$$= P \cdot R_m / (2t) + M_1 / (K_1 \cdot \pi \cdot R_m^2 \cdot t)$$

$$= 62.0 \cdot 107.06 / (2 \cdot 4.98) + 13.9 / (0.1923 \cdot \pi \cdot 107.1^2 \cdot 4.98)$$

$$= 62.69 \text{ N./mm}^2$$

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

$$= Q(L-2a) / (L + (4 \cdot h_2 / 3))$$

$$= 479(1178.0 - 2 \cdot 200.0) / (1178.0 + (4 \cdot 0.0 / 3))$$

$$= 316.4 \text{ Kg}$$

Shear Stress in the shell no rings, not stiffened (4.15.14) $[\tau_2]$:

$$= K_2 \cdot T / (R_m \cdot t)$$

$$= 1.1707 \cdot 316.44 / (107.06 \cdot 4.98)$$

$$= 6.81 \text{ N./mm}^2$$

Decay Length (4.15.22) $[x_1, x_2]$:

$$= 0.78 \cdot \sqrt{R_m \cdot t}$$

$$= 0.78 \cdot \sqrt{107.06 \cdot 4.98}$$

$$= 18.010 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) $[\sigma_6]$:

$$= -K_5 \cdot Q \cdot k / (t \cdot (b + X_1 + X_2))$$

$$= -0.7603 \cdot 479 \cdot 0.1 / (4.98 \cdot (150.0 + 18.01 + 18.01))$$

$$= -0.39 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) $[B_1]$:

$$= \min(b + 1.56 \cdot \sqrt{R_m \cdot t}, 2a)$$

$$= \min(150.0 + 1.56 \cdot \sqrt{107.06 \cdot 4.98}, 2 \cdot 200.0)$$

$$= 186.02 \text{ mm.}$$

Wear Plate/Shell Stress ratio (4.15.29) $[\eta]$:

$$= \min(S_r / S, 1)$$

$$= \min(108.252 / 151.7, 1)$$

$$= 0.7136$$

Circumferential Stress at wear plate (4.15.26) $[\sigma_6, r]$:

$$= -K_5 \cdot Q \cdot k / (B_1(t + \eta \cdot t_r))$$

$$= -0.7603 \cdot 479 \cdot 0.1 / (186.021(4.98 + 0.714 \cdot 10.0))$$

$$= -0.16 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, $L \geq 8R_m$ (4.15.27) $[\sigma_7, r]$:

$$= -Q / (4(t + \eta \cdot t_r) b_1) - 3 \cdot K_7 \cdot Q / (2(t + \eta \cdot t_r)^2)$$

$$= -479 / (4(4.98 + 0.714 \cdot 10.0) 186.021) -$$

$$3 \cdot 0.053 \cdot 479 / (2(4.98 + 0.714 \cdot 10.0)^2)$$

$$= -3.06 \text{ N./mm}^2$$

Circ. Comp. Stress at Tip of Wearplate, w/Pad $L \geq 8R_m$ (4.15.30) $[\sigma_7, 1]$:

$$= -Q / (4 \cdot t \cdot (b + X_1 + X_2)) - 3 \cdot K_7 \cdot Q / (2 \cdot t^2)$$

$$= -479 / (4 \cdot 4.98 \cdot (150.0 + 18.01 + 18.01)) -$$

$$3 \cdot 0.0434 \cdot 479 / (2 \cdot 4.98^2)$$

$$= -13.61 \text{ N./mm}^2$$

Free Un-Restrained Thermal Expansion between the Saddles $[Exp]$:

$$= \alpha \cdot L_s \cdot (\text{Design Temperature} - \text{Ambient Temperature})$$

$$= 0.000012 \cdot 2521.0 \cdot (85.0 - 21.1)$$

$$= 1.933 \text{ mm.}$$

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Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	250.0000	mm.
Baseplate Thickness	Bpthk	10.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	236.	5.	2.	12.	2921.	0.970
Wearplate	200.	10.	10.	20.	19960.	21.6
Web	10.	325.	178.	33.	578341.	0.131E+05
BasePlate	180.	10.	345.	18.	621774.	0.215E+05
Totals	...	...	...	82.	1222997.	0.347E+05

Value	C1 = Sumof (Ay) / Sumof (A)	=	149.	mm.
Value	I = Sumof (Io) - C1*Sumof (Ay)	=	0.165E+05	cm**4
Value	As = Sumof (A) - Ashell	=	70.5	cm ²

$$K1 = (1 + \cos(\beta) - 0.5 \sin(\beta)^2) / (\pi - \beta + \sin(\beta) \cos(\beta)) = 0.2035$$

$$Fh = K1 * Q = 0.2035 * 479.131 = 97.5136 \text{ Kgf}$$

Tension Stress, St = (Fh/As)	=	0.1356	N./mm ²
Allowed Stress, Sa = 0.6 * Yield Str	=	124.1100	N./mm ²

Saddle Splitting Dimension [d]:

$$= B - R * \sin(\theta) / \theta$$

$$= 455.0 - 104.57 * \sin(1.0472) / 1.0472$$

$$= 368.521 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 35.9366 \text{ Kg-m.}$$

Bending Stress, Sb = (M * C1 / I)	=	0.3180	N./mm ²
Allowed Stress, Sa = 2/3 * Yield Str	=	137.9000	N./mm ²

Minimum Thickness of Baseplate per Moss:

$$= (3 (Q + \text{Saddle_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress}))^{1/2}$$

$$= (3 (479 + 24) 180.0 / (2 * 250.0 * 137.9))^{1/2}$$

$$= 6.215 \text{ mm.}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

$$= \text{Web Length} / (\text{Nribs} - 1)$$

$$= 212.6092 / (2 - 1)$$

$$= 212.609 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

$$= e * \text{Bpwid} / 2$$

$$= 212.6092 * 180.0 / 2$$

$$= 191.348 \text{ cm}^2$$

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Axial Load [P]:

$$\begin{aligned}
 &= A_p * B_p \\
 &= 191.3 * 1.06 \\
 &= 203.736 \text{ Kgf}
 \end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned}
 &= \text{Rib Area} + \text{Web Area} \\
 &= 14.0 + 10.63 \\
 &= 24.630 \text{ cm}^2
 \end{aligned}$$

Compressive Stress [Sc]:

$$\begin{aligned}
 &= P/Ar \\
 &= 203.7/24.6305 \\
 &= 0.811 \text{ N./mm}^2
 \end{aligned}$$

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io	
Rib	10.0	140.0	80.0	14.0	112000.0	229.	
Web	106.3	10.0	5.0	10.6	5315.2	0.886	
Values	...	...	...	24.6	117315.3	230.	

Bending Moment [Rm]:

$$\begin{aligned}
 &= F_l / (2 * B_{plen}) * e * r_l / 2 \\
 &= 78.4 / (2 * 250.0) * 212.609 * 383.62 / 2 \\
 &= 6.395 \text{ Kg-m.}
 \end{aligned}$$

Compressive Allowable, $KL/R < C_c$ ($7.9785 < 138.1347$) per AISC E2-1 [Sca]:

$$\begin{aligned}
 &= (1 - (Kl/r)^2 / (2 * C_c^2)) * F_y / (5/3 + 3 * (Kl/r) / (8 * C_c) - (Kl/r)^3 / (8 * C_c^3)) \\
 &= (1 - (7.98)^2 / (2 * 138.13^2)) * 207 / \\
 &\quad (5/3 + 3 * (7.98) / (8 * 138.13) - (7.98^3) / (8 * 138.13^3)) \\
 &= 122.315 \text{ N./mm}^2
 \end{aligned}$$

AISC Unity Check of Outside Ribs (must be ≤ 1)

$$\begin{aligned}
 &= S_c / S_{ca} + (R_m * \text{Distance Side} / I) / S_{ba} \\
 &= 0.81 / 122.32 + (6.4 * 102.37 / 5694364) / 137.9 \\
 &= 0.015
 \end{aligned}$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm ²
Bolt Corrosion Allowance	Bca	0.0000	mm.
Distance from Bolts to Edge	Edgedis	80.0100	mm.
Nominal Bolt Diameter	Bnd	12.7000	mm.
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	108.25	N./mm ²
Area Available in a Single Bolt	BlArea	0.8129	cm ²
Saddle Load QO (Weight)	QO	160.4	Kgf
Saddle Load QL (Wind/Seismic contribution)	QL	14.2	Kgf
Maximum Transverse Force	Ft	46.5	Kgf
Maximum Longitudinal Force	Fl	78.4	Kgf
Saddle Bolted to Steel Foundation	No		

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Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ (} QO > QL \text{ --> No Uplift in Longitudinal direction)}$$

Bolt Area due to Shear Load [Bltarears]:

$$= F1 / (Stba * Nbolts)$$

$$= 78.41 / (172.38 * 2.0)$$

$$= 0.0223 \text{ cm}^2$$

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$= B * Ft + \text{Sum of X Moments}$$

$$= 455.0 * 46.53 + 0.0$$

$$= 21.17 \text{ Kg-m.}$$

Eccentricity (e):

$$= Rmom / QO$$

$$= 21.17 / 160.44$$

$$= 131.97 \text{ mm.} > Bplen / 6 \text{ --> Uplift in Transverse direction}$$

$f = Bplen / 2 - Edgedis$

$$= 250.0 / 2 - 80.01$$

$$= 44.99 \text{ mm.}$$

Modular Ratio Of Steel/Concrete (n1):

$$= ES / EC$$

$$= 203402.5 / 21526.32$$

$$= 9.45$$

$K1 = 3 (e - 0.5 * Bplen)$

$$= 3 (131.97 - 0.5 * 250.0)$$

$$= 20.90 \text{ mm.}$$

$K2 = 6 * n1 * At / Bpwid * (f + e)$

$$= 6 * 9.45 * 0.81 / 180.0 * (44.99 + 131.97)$$

$$= 4530.73 \text{ mm.}^2$$

$K3 = -K2 * (0.5 * Bplen + f)$

$$= -4530.73 * (0.5 * 250.0 + 44.99)$$

$$= -770177.98 \text{ mm.}^3$$

Iteratively Solving for the Effective Bearing Length:

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

$$Y^3 + 20.9 * Y^2 + 4530.73 * Y - 770178. = 0$$

$$Y = 70.34 \text{ mm.}$$

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

$$= (250.0 / 2 - 70.34 / 3 - 131.97)$$

$$= -30.41$$

$Denom = (Bplen / 2 - Y / 3 + f)$

$$= (250.0 / 2 - 70.34 / 3 + 44.99)$$

$$= 146.54$$

Total Bolt Tension Force [Tforce]:

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$$\begin{aligned}
 &= - QO * Num / Denom \\
 &= - 160.44 * -30.41/146.54 \\
 &= 33.30 \text{ Kgf}
 \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned}
 &= Tforce / (Stba * Nbt) \\
 &= 33.3 / (172.38 * 1.0) \\
 &= 0.0189 \text{ cm}^2
 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned}
 &= \max[Bltarearl, Bltarears, Bltareart] \\
 &= \max[0.0, 0.0223, 0.0189] \\
 &= 0.0223 \text{ cm}^2
 \end{aligned}$$

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

$$\begin{aligned}
 &= 2(QO + Tforce) / (Y * Bpwid) \\
 &= 2(160.44 + 33.3) / (70.34 * 180.0) \\
 &= 3.00 \text{ bars}
 \end{aligned}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$\begin{aligned}
 &= (Bplen - Weblngth) / 2 \\
 &= (250.0 - 199.2) / 2 \\
 &= 25.4000 \text{ mm.}
 \end{aligned}$$

Overturning Moment due To Bolt Tension [Mt]:

$$\begin{aligned}
 &= Tforce * Adist \\
 &= 33.3 * 25.4 \\
 &= 0.85 \text{ Kg-m.}
 \end{aligned}$$

Equivalent Bearing Pressure (f1):

$$\begin{aligned}
 &= fc * (Y - Adist) / Y \\
 &= 3.0 * (70.34 - 25.4) / 70.34 \\
 &= 1.92 \text{ bars}
 \end{aligned}$$

Overturning Moment due to Bearing Pressure [Mc]:

$$\begin{aligned}
 &= (Adist^2 * Bpwid / 6) * (f1 + 2 * fc) \\
 &= (25.4^2 * 180.0 / 6) * (1.92 + 2 * 3.0) \\
 &= 1.56 \text{ Kg-m.}
 \end{aligned}$$

Baseplate Required Thickness [Treq]:

$$\begin{aligned}
 &= (6 * \max(Mt, Mc) / (Bpwid * Sba))^{1/2} \\
 &= (6 * \max(0.85, 1.56) / (180.0 * 162.38))^{1/2} \\
 &= 1.7738 \text{ mm.}
 \end{aligned}$$

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle

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

Input and Calculated Values:

Vessel Mean Radius	Rm	133.52	mm.
Stiffened Vessel Length per 4.15.6	L	1178.00	mm.
Distance from Saddle to Vessel tangent	a	200.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees

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Wear Plate Width	b1	200.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm.
Wear Plate Allowable Stress	Sr	95.15	N./mm ²

Shell Allowable Stress used in Calculation	151.70	N./mm ²
Head Allowable Stress used in Calculation	0.00	N./mm ²
Circumferential Efficiency in Plane of Saddle	1.00	
Circumferential Efficiency at Mid-Span	1.00	

Saddle Force Q, Operating Case 495.84 Kgf

Horizontal Vessel Analysis Results:	Actual N./mm ²	Allowable N./mm ²
Long. Stress at Top of Midspan	81.34	151.70
Long. Stress at Bottom of Midspan	84.90	151.70
Long. Stress at Top of Saddles	71.73	151.70
Long. Stress at Bottom of Saddles	66.23	151.70
Tangential Shear in Shell	4.64	121.36
Circ. Stress at Horn of Saddle	3.04	189.62
Circ. Compressive Stress in Shell	0.31	151.70

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

$$= F_{tr} * (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E$$

$$= 3.0 * (93.1/2 + 0) * 471.0/231.2548$$

$$= 284.3 \text{ Kgf}$$

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

$$= \max(F_l, \text{Friction Load, Sum of X Forces}) * B / L_s$$

$$= \max(8.84, 0.0, 0) * 471.0/2521.0002$$

$$= 1.7 \text{ Kgf}$$

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

$$= \max(F_l, \text{Friction Force, Sum of X Forces}) * B / L_s$$

$$= \max(78.41, 0.0, 0) * 471.0/2521.0002$$

$$= 14.6 \text{ Kgf}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

$$= F_{tr} * (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E$$

$$= 3.0 * (78/2 + 0) * 471.0/231.2548$$

$$= 239.5 \text{ Kgf}$$

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

$$= \text{Saddle Load} + \max(F_{wl}, F_{wt}, F_{sl}, F_{st})$$

$$= 212 + \max(2, 284, 15, 240)$$

$$= 495.8 \text{ Kgf}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	522.15	Kgf
Transverse Shear Load Saddle	46.53	Kgf
Longitudinal Shear Load Saddle	78.41	Kgf

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Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0434			

The suffix 'p' denotes the values for a wear plate if it exists.

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

Moment per Equation 4.15.3 [M1]:

$$\begin{aligned}
 &= -Q \cdot a \left[1 - \left(1 - \frac{a}{L} + \frac{(R^2 - h^2)}{(2a \cdot L)} \right) / \left(1 + \frac{(4h^2)}{(3L)} \right) \right] \\
 &= -496 \cdot 200.0 \left[1 - \left(1 - \frac{200.0}{1178.0} + \frac{(133.515^2 - 0.0^2)}{(2 \cdot 200.0 \cdot 1178.0)} \right) / \left(1 + \frac{(4 \cdot 0.0^2)}{(3 \cdot 1178.0)} \right) \right] \\
 &= -13.1 \text{ Kg-m.}
 \end{aligned}$$

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= \frac{Q \cdot L}{4} \left(1 + 2 \frac{(R^2 - h^2)}{(L^2)} \right) / \left(1 + \frac{(4h^2)}{(3L)} \right) - 4 \frac{a}{L} \\
 &= \frac{496 \cdot 1178}{4} \left(1 + 2 \frac{(133.515^2 - 0^2)}{(1178^2)} \right) / \left(1 + \frac{(4 \cdot 0)}{(3 \cdot 1178)} \right) - 4 \cdot \frac{200}{1178} \\
 &= 50.6 \text{ Kg-m.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 62.001 \cdot 133.515 / (2 \cdot 4.98) - 50.6 / (\pi \cdot 133.5^2 \cdot 4.98) \\
 &= 81.34 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 62.001 \cdot 133.515 / (2 \cdot 4.98) + 50.6 / (\pi \cdot 133.5^2 \cdot 4.98) \\
 &= 84.90 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 62.001 \cdot 133.515 / (2 \cdot 6.07) - 13.1 / (0.1066 \cdot \pi \cdot 133.5^2 \cdot 6.07) \\
 &= 71.73 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 62.001 \cdot 133.515 / (2 \cdot 6.07) + 13.1 / (0.1923 \cdot \pi \cdot 133.5^2 \cdot 6.07) \\
 &= 66.23 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{Q(L - 2a)}{(L + (4 \cdot h^2 / 3))} \\
 &= \frac{496(1178.0 - 2 \cdot 200.0)}{(1178.0 + (4 \cdot 0.0^2 / 3))} \\
 &= 327.5 \text{ Kg}
 \end{aligned}$$

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

$$\begin{aligned}
 &= K2 \cdot T / (R_m \cdot t) \\
 &= 1.1707 \cdot 327.47 / (133.515 \cdot 6.07) \\
 &= 4.64 \text{ N./mm}^2
 \end{aligned}$$

Decay Length (4.15.22) [x1,x2]:

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$$= 0.78 * \sqrt{R_m * t}$$

$$= 0.78 * \sqrt{133.515 * 6.07}$$

$$= 22.205 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [σ_6]:

$$= -K_5 * Q * k / (t * (b + X_1 + X_2))$$

$$= -0.7603 * 496 * 0.1 / (6.07 * (150.0 + 22.21 + 22.21))$$

$$= -0.31 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

$$= \min(b + 1.56 * \sqrt{R_m * t}, 2a)$$

$$= \min(150.0 + 1.56 * \sqrt{133.515 * 6.07}, 2 * 200.0)$$

$$= 194.41 \text{ mm.}$$

Wear Plate/Shell Stress ratio (4.15.29) [η]:

$$= \min(S_r/S, 1)$$

$$= \min(95.151/151.7, 1)$$

$$= 0.6272$$

Circumferential Stress at wear plate (4.15.26) [σ_6, r]:

$$= -K_5 * Q * k / (B_1(t + \eta * t_r))$$

$$= -0.7603 * 496 * 0.1 / (194.41(6.07 + 0.627 * 10.0))$$

$$= -0.15 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, $L \geq 8R_m$ (4.15.27) [σ_7, r]:

$$= -Q / (4(t + \eta * t_r)b_1) - 3 * K_7 * Q / (2(t + \eta * t_r)^2)$$

$$= -496 / (4(6.07 + 0.627 * 10.0)194.41) -$$

$$3 * 0.053 * 496 / (2(6.07 + 0.627 * 10.0)^2)$$

$$= -3.04 \text{ N./mm}^2$$

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	250.0000	mm.
Baseplate Thickness	Bpthk	10.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	244.	6.	3.	15.	4493.	1.82
Wearplate	200.	10.	11.	20.	22140.	26.2
Web	10.	314.	173.	31.	544926.	0.120E+05
BasePlate	180.	10.	336.	18.	603936.	0.203E+05
Totals	...	...	...	84.	1175496.	0.323E+05

$$\text{Value } C_1 = \text{Sumof}(AY) / \text{Sumof}(A) = 140. \text{ mm.}$$

$$\text{Value } I = \text{Sumof}(Io) - C_1 * \text{Sumof}(AY) = 0.159E+05 \text{ cm}^4$$

$$\text{Value } A_s = \text{Sumof}(A) - A_{\text{shell}} = 69.4 \text{ cm}^2$$

$$K_1 = (1 + \cos(\beta) - 0.5 * \sin(\beta)^2) / (\pi - \beta + \sin(\beta) * \cos(\beta)) = 0.2035$$

$$F_h = K_1 * Q = 0.2035 * 495.837 = 100.9136 \text{ Kg}$$

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$$\begin{aligned} \text{Tension Stress, } St &= (Fh/As) = 0.1425 \text{ N./mm}^2 \\ \text{Allowed Stress, } Sa &= 0.6 * \text{Yield Str} = 143.9676 \text{ N./mm}^2 \end{aligned}$$

Saddle Splitting Dimension [d]:

$$\begin{aligned} &= B - R * \sin(\theta) / \theta \\ &= 471.0 - 130.48 * \sin(1.0472) / 1.0472 \\ &= 363.094 \text{ mm.} \end{aligned}$$

$$\text{Bending Moment, } M = Fh * d = 36.6418 \text{ Kg-m.}$$

$$\begin{aligned} \text{Bending Stress, } Sb &= (M * C1 / I) = 0.3148 \text{ N./mm}^2 \\ \text{Allowed Stress, } Sa &= 2/3 * \text{Yield Str} = 159.9640 \text{ N./mm}^2 \end{aligned}$$

Minimum Thickness of Baseplate per Moss:

$$\begin{aligned} &= (3(Q + \text{Saddle_Wt})\text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress}))^{1/2} \\ &= (3(496 + 26)180.0 / (2 * 250.0 * 159.964))^{1/2} \\ &= 5.880 \text{ mm.} \end{aligned}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

$$\begin{aligned} &= \text{Web Length} / (\text{Nr ribs} - 1) \\ &= 259.3746 / (2 - 1) \\ &= 259.375 \text{ mm.} \end{aligned}$$

Baseplate Pressure Area [Ap]:

$$\begin{aligned} &= e * \text{Bpwid} / 2 \\ &= 259.3746 * 180.0 / 2 \\ &= 233.437 \text{ cm}^2 \end{aligned}$$

Axial Load [P]:

$$\begin{aligned} &= Ap * Bp \\ &= 233.4 * 1.1 \\ &= 257.215 \text{ Kg} \end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 14.0 + 12.969 \\ &= 26.969 \text{ cm}^2 \end{aligned}$$

Compressive Stress [Sc]:

$$\begin{aligned} &= P/Ar \\ &= 257.2 / 26.9687 \\ &= 0.935 \text{ N./mm}^2 \end{aligned}$$

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	229.
Web	129.7	10.0	5.0	13.0	6484.4	1.08
Values	...	...	...	27.0	118484.4	230.

Bending Moment [Rm]:

$$\begin{aligned} &= Fl / (2 * \text{Bplen}) * e * r1 / 2 \\ &= 78.4 / (2 * 250.0) * 259.375 * 386.13 / 2 \end{aligned}$$

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$$= 7.853 \text{ Kg-m.}$$

Compressive Allowable, $KL/R < C_c$ ($8.1292 < 128.2549$) per AISC E2-1 [Sca]:

$$= (1 - (Kl_r)^2 / (2 * C_c^2)) * F_y / (5/3 + 3 * (Kl_r) / (8 * C_c) - (Kl_r^3) / (8 * C_c^3))$$

$$= (1 - (8.13)^2 / (2 * 128.25^2)) * 240 /$$

$$(5/3 + 3 * (8.13) / (8 * 128.25) - (8.13^3) / (8 * 128.25^3))$$

$$= 141.661 \text{ N./mm}^2$$

AISC Unity Check of Outside Ribs (must be ≤ 1)

$$= S_c / S_{ca} + (R_m * \text{Distance Side} / I) / S_{ba}$$

$$= 0.94 / 141.66 + (7.85 * 106.066 / 6084409) / 159.96$$

$$= 0.015$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2
Total Number of Bolts in Tension/Baseplate	Nbt	1
Bolt Material Specification		SA-193 B7
Bolt Allowable Stress	Stba	172.38 N./mm ²
Bolt Corrosion Allowance	Bca	0.0000 mm.
Distance from Bolts to Edge	Edgedis	80.0100 mm.
Nominal Bolt Diameter	Bnd	12.7000 mm.
Thread Series	Series	TEMA
BasePlate Allowable Stress	S	95.15 N./mm ²
Area Available in a Single Bolt	BlArea	0.8129 cm ²
Saddle Load QO (Weight)	QO	237.8 Kgf
Saddle Load QL (Wind/Seismic contribution)	QL	14.6 Kgf
Maximum Transverse Force	Ft	46.5 Kgf
Maximum Longitudinal Force	Fl	78.4 Kgf
Saddle Bolted to Steel Foundation	No	

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ (} QO > QL \text{ --> No Uplift in Longitudinal direction)}$$

Bolt Area due to Shear Load [Bltarears]:

$$= Fl / (Stba * Nbolts)$$

$$= 78.41 / (172.38 * 2.0)$$

$$= 0.0223 \text{ cm}^2$$

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$= B * Ft + \text{Sum of X Moments}$$

$$= 471.0 * 46.53 + 0.0$$

$$= 21.92 \text{ Kg-m.}$$

Eccentricity (e):

$$= Rmom / QO$$

$$= 21.92 / 237.84$$

$$= 92.15 \text{ mm.} > B_{plen} / 6 \text{ --> Uplift in Transverse direction}$$

$$f = B_{plen} / 2 - Edgedis$$

$$= 250.0 / 2 - 80.01$$

$$= 44.99 \text{ mm.}$$

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Modular Ratio Of Steel/Concrete (n1):

$$\begin{aligned}
 &= E_S / E_C \\
 &= 203402.5 / 21526.32 \\
 &= 9.45
 \end{aligned}$$

$$\begin{aligned}
 K1 &= 3 (e - 0.5 * B_{plen}) \\
 &= 3 (92.15 - 0.5 * 250.0) \\
 &= -98.55 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 K2 &= 6 * n1 * A_t / B_{pwid} * (f + e) \\
 &= 6 * 9.45 * 0.81 / 180.0 * (44.99 + 92.15) \\
 &= 3511.27 \text{ mm.}^2
 \end{aligned}$$

$$\begin{aligned}
 K3 &= -K2 * (0.5 * B_{plen} + f) \\
 &= -3511.27 * (0.5 * 250.0 + 44.99) \\
 &= -596881.12 \text{ mm.}^3
 \end{aligned}$$

Iteratively Solving for the Effective Bearing Length:

$$\begin{aligned}
 Y^3 + K1 * Y^2 + K2 * Y + K3 &= 0 \\
 Y^3 + -98.55 * Y^2 + 3511.27 * Y + -596881.12 &= 0 \\
 Y &= 113.79 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 \text{Num} &= (B_{plen} / 2 - Y / 3 - e) \\
 &= (250.0 / 2 - 113.79 / 3 - 92.15) \\
 &= -5.08
 \end{aligned}$$

$$\begin{aligned}
 \text{Denom} &= (B_{plen} / 2 - Y / 3 + f) \\
 &= (250.0 / 2 - 113.79 / 3 + 44.99) \\
 &= 132.06
 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned}
 &= -QO * \text{Num} / \text{Denom} \\
 &= -237.84 * -5.08 / 132.06 \\
 &= 9.15 \text{ Kgf}
 \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned}
 &= T_{force} / (Stba * N_{bt}) \\
 &= 9.15 / (172.38 * 1.0) \\
 &= 0.0052 \text{ cm}^2
 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned}
 &= \max[Bltarearl, Bltarears, Bltareart] \\
 &= \max[0.0, 0.0223, 0.0052] \\
 &= 0.0223 \text{ cm}^2
 \end{aligned}$$

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

$$\begin{aligned}
 &= 2(QO + T_{force}) / (Y * B_{pwid}) \\
 &= 2(237.84 + 9.15) / (113.79 * 180.0) \\
 &= 2.36 \text{ bars}
 \end{aligned}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$\begin{aligned}
 &= (B_{plen} - W_{blength}) / 2 \\
 &= (250.0 - 199.2) / 2 \\
 &= 25.4000 \text{ mm.}
 \end{aligned}$$

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	BK	PPL	BV	320	ME	CN	0001	V02	

Overturning Moment due To Bolt Tension [Mt]:

$$\begin{aligned}
&= T_{force} * A_{dist} \\
&= 9.15 * 25.4 \\
&= 0.23 \text{ Kg-m.}
\end{aligned}$$

Equivalent Bearing Pressure (f1):

$$\begin{aligned}
&= f_c * (Y - A_{dist}) / Y \\
&= 2.36 * (113.79 - 25.4) / 113.79 \\
&= 1.84 \text{ bars}
\end{aligned}$$

Overturning Moment due to Bearing Pressure [Mc]:

$$\begin{aligned}
&= (A_{dist}^2 * B_{pwid} / 6) * (f_1 + 2 * f_c) \\
&= (25.4^2 * 180.0 / 6) * (1.84 + 2 * 2.36) \\
&= 1.30 \text{ Kg-m.}
\end{aligned}$$

Baseplate Required Thickness [Treq]:

$$\begin{aligned}
&= (6 * \max(M_t, M_c) / (B_{pwid} * S_{ba}))^{1/2} \\
&= (6 * \max(0.23, 1.3 / (180.0 * 142.73)))^{1/2} \\
&= 1.7230 \text{ mm.}
\end{aligned}$$

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ASME Horizontal Vessel Analysis: Stresses for the Left Saddle

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

Horizontal Vessel Stress Calculations : Test Case

Input and Calculated Values:

Vessel Mean Radius	Rm	105.46	mm.
Stiffened Vessel Length per 4.15.6	L	1178.00	mm.
Distance from Saddle to Vessel tangent	a	200.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	200.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm.
Wear Plate Allowable Stress	Sr	108.25	N./mm ²
Shell Allowable Stress used in Calculation		1326.66	N./mm ²
Head Allowable Stress used in Calculation		1326.66	N./mm ²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		371.86	Kgf
Horizontal Vessel Analysis Results:			
	Actual	Allowable	
	N./mm ²	N./mm ²	
Long. Stress at Top of Midspan	58.69	1326.66	
Long. Stress at Bottom of Midspan	61.23	1326.66	
Long. Stress at Top of Saddles	63.46	1326.66	
Long. Stress at Bottom of Saddles	58.02	1326.66	

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	BK	PPL	BV	320	ME	CN	0001	V02	

Tangential Shear in Shell	3.27	1061.33
Circ. Stress at Horn of Saddle	4.09	1989.99
Circ. Compressive Stress in Shell	0.17	1326.66

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

$$= F_{tr} * (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E$$

$$= 3.0 * (30.7/2 + 0) * 455.0/182.6621$$

$$= 114.7 \text{ Kgf}$$

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

$$= \max(F_l, \text{Friction Load, Sum of X Forces}) * B / L_s$$

$$= \max(1.88, 0.0, 0) * 455.0/2521.0002$$

$$= 0.3 \text{ Kgf}$$

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

$$= \text{Saddle Load} + \max(F_{wl}, F_{wt}, F_{sl}, F_{st})$$

$$= 257 + \max(0.3, 115, 0, 0)$$

$$= 371.9 \text{ Kgf}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	395.69	Kgf
Transverse Shear Load Saddle	15.36	Kgf
Longitudinal Shear Load Saddle	1.88	Kgf

Hydrostatic Test Pressure at center of Vessel: 93.010 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0434			

The suffix 'p' denotes the values for a wear plate if it exists.

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

Moment per Equation 4.15.3 [M1]:

$$= -Q * a [1 - (1 - a/L + (R^2 - h^2) / (2a * L)) / (1 + (4h^2) / (3L))]$$

$$= -372 * 200.0 [1 - (1 - 200.0/1178.0 + (105.46^2 - 0.0^2) / (2 * 200.0 * 1178.0)) / (1 + (4 * 0.0) / (3 * 1178.0))]$$

$$= -10.9 \text{ Kg-m.}$$

Moment per Equation 4.15.4 [M2]:

$$= Q * L / 4 (1 + 2(R^2 - h^2) / (L^2)) / (1 + (4h^2) / (3L)) - 4a/L$$

$$= 372 * 1178 / 4 (1 + 2(105^2 - 0^2) / (1178^2)) / (1 + (4 * 0) / (3 * 1178)) - 4 * 200 / 1178$$

$$= 36.9 \text{ Kg-m.}$$

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

$$= P * R_m / (2t) - M2 / (\pi * R_m^2 t)$$

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$$= 93.01 * 105.46 / (2 * 8.18) - 36.9 / (\pi * 105.5^2 * 8.18)$$

$$= 58.69 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) + M_2 / (\pi * R_m^2 * t)$$

$$= 93.01 * 105.46 / (2 * 8.18) + 36.9 / (\pi * 105.5^2 * 8.18)$$

$$= 61.23 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) - M_1 / (K_1 * \pi * R_m^2 * t)$$

$$= 93.01 * 105.46 / (2 * 8.18) - 10.9 / (0.1066 * \pi * 105.5^2 * 8.18)$$

$$= 63.46 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) + M_1 / (K_1 * \pi * R_m^2 * t)$$

$$= 93.01 * 105.46 / (2 * 8.18) + 10.9 / (0.1923 * \pi * 105.5^2 * 8.18)$$

$$= 58.02 \text{ N./mm}^2$$

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

$$= Q(L-2a) / (L + (4 * h^2 / 3))$$

$$= 372(1178.0 - 2 * 200.0) / (1178.0 + (4 * 0.0 / 3))$$

$$= 245.6 \text{ Kg}$$

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

$$= K_2 * T / (R_m * t)$$

$$= 1.1707 * 245.59 / (105.46 * 8.18)$$

$$= 3.27 \text{ N./mm}^2$$

Decay Length (4.15.22) [x1,x2]:

$$= 0.78 * \sqrt{R_m * t}$$

$$= 0.78 * \sqrt{105.46 * 8.18}$$

$$= 22.909 \text{ mm.}$$

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

$$= -K_5 * Q * k / (t * (b + X_1 + X_2))$$

$$= -0.7603 * 372 * 0.1 / (8.18 * (150.0 + 22.91 + 22.91))$$

$$= -0.17 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

$$= \min(b + 1.56 * \sqrt{R_m * t}, 2a)$$

$$= \min(150.0 + 1.56 * \sqrt{105.46 * 8.18}, 2 * 200.0)$$

$$= 195.82 \text{ mm.}$$

Wear Plate/Shell Stress ratio (4.15.29) [eta]:

$$= \min(S_r / S, 1)$$

$$= \min(108.252 / 1326.663, 1)$$

$$= 0.0816$$

Circumferential Stress at wear plate (4.15.26) [sigma6,r]:

$$= -K_5 * Q * k / (B_1(t + \eta * t_r))$$

$$= -0.7603 * 372 * 0.1 / (195.819(8.18 + 0.082 * 10.0))$$

$$= -0.16 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:

$$= -Q / (4(t + \eta * t_r) b_1) - 3 * K_7 * Q / (2(t + \eta * t_r)^2)$$

$$= -372 / (4(8.18 + 0.082 * 10.0) 195.819) -$$

$$3 * 0.053 * 372 / (2(8.18 + 0.082 * 10.0)^2)$$

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$$= -4.09 \text{ N./mm}^2$$

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	250.0000	mm.
Baseplate Thickness	Bpthk	10.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	245.	8.	4.	20.	8194.	4.47
Wearplate	200.	10.	13.	20.	26360.	36.4
Web	10.	325.	181.	33.	588756.	0.135E+05
BasePlate	180.	10.	349.	18.	627534.	0.219E+05
Totals	...	...	...	91.	1250844.	0.354E+05

Value	C1 = Sumof (Ay) / Sumof (A)	=	138.	mm.
Value	I = Sumof (Io) - C1*Sumof (Ay)	=	0.182E+05	cm**4
Value	As = Sumof (A) - Ashell	=	70.5	cm ²

$$K1 = (1 + \cos(\beta) - 0.5 \sin(\beta)^2) / (\pi - \beta + \sin(\beta) \cos(\beta)) = 0.2035$$

$$Fh = K1 * Q = 0.2035 * 371.861 = 75.6817 \text{ Kgf}$$

Tension Stress, St	=	0.1052	N./mm ²
Allowed Stress, Sa	=	124.1100	N./mm ²

Saddle Splitting Dimension [d]:

$$= B - R * \sin(\theta) / \theta$$

$$= 455.0 - 101.37 * \sin(1.0472) / 1.0472$$

$$= 371.168 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 28.0911 \text{ Kg-m.}$$

Bending Stress, Sb	=	0.2094	N./mm ²
Allowed Stress, Sa	=	137.9000	N./mm ²

Minimum Thickness of Baseplate per Moss:

$$= (3(Q + \text{Saddle_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress}))^{1/2}$$

$$= (3(372 + 24)180.0 / (2 * 250.0 * 137.9))^{1/2}$$

$$= 5.513 \text{ mm.}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

$$= \text{Web Length} / (\text{Nribs} - 1)$$

$$= 207.0667 / (2 - 1)$$

$$= 207.067 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

$$= e * \text{Bpwid} / 2$$

$$= 207.0667 * 180.0 / 2$$

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$$= 186.360 \text{ cm}^2$$

Axial Load [P]:

$$= A_p * B_p$$

$$= 186.4 * 0.83$$

$$= 154.000 \text{ Kg}$$

Area of the Rib and Web [Ar]:

$$= \text{Rib Area} + \text{Web Area}$$

$$= 14.0 + 10.353$$

$$= 24.353 \text{ cm}^2$$

Compressive Stress [Sc]:

$$= P/Ar$$

$$= 154.0/24.3533$$

$$= 0.620 \text{ N./mm}^2$$

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io	
Rib	10.0	140.0	80.0	14.0	112000.0	229.	
Web	103.5	10.0	5.0	10.4	5176.7	0.863	
Values	...	...	...	24.4	117176.7	230.	

Bending Moment [Rm]:

$$= F_l / (2 * B_{plen}) * e * r_l / 2$$

$$= 1.9 / (2 * 250.0) * 207.067 * 385.22/2$$

$$= 0.150 \text{ Kg-m.}$$

Compressive Allowable, $KL/R < C_c$ ($8.0026 < 138.1347$) per AISC E2-1 [Sca]:

$$= (1 - (Kl/r)^2 / (2 * C_c^2)) * F_y / (5/3 + 3 * (Kl/r) / (8 * C_c) - (Kl/r^3) / (8 * C_c^3))$$

$$= (1 - (8.0)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (8.0) / (8 * 138.13) - (8.0^3) / (8 * 138.13^3))$$

$$= 122.309 \text{ N./mm}^2$$

AISC Unity Check of Outside Ribs (must be ≤ 1)

$$= S_c/S_{ca} + (R_m * \text{Distance Side}/I) / S_{ba}$$

$$= 0.62/122.31 + (0.15 * 101.885/5643196) / 137.9$$

$$= 0.005$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm ²
Bolt Corrosion Allowance	Bca	0.0000	mm.
Distance from Bolts to Edge	Edgedis	80.0100	mm.
Nominal Bolt Diameter	Bnd	12.7000	mm.
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	108.25	N./mm ²
Area Available in a Single Bolt	BlArea	0.8129	cm ²
Saddle Load QO (Weight)	QO	280.9	Kgf
Saddle Load QL (Wind/Seismic contribution)	QL	0.3	Kgf
Maximum Transverse Force	Ft	15.4	Kgf
Maximum Longitudinal Force	Fl	2.9	Kgf

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Saddle Bolted to Steel Foundation

No

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

= $F_l / (Stba * Nbolts)$
= $2.92 / (172.38 * 2.0)$
= 0.0008 cm²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

= $B * Ft + \text{Sum of X Moments}$
= $455.0 * 15.36 + 0.0$
= 6.99 Kg-m.

Eccentricity (e):

= $Rmom / QO$
= $6.99 / 280.94$
= 24.87 mm. < $Bplen/6$ --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:

= 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:

= $\max[Bltarearl, Bltarears, Bltareart]$
= $\max[0.0, 0.0008, 0.0]$
= 0.0008 cm²

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle

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

Note:

Wear Pad Width (200.00) is less than $1.56 * \sqrt{rm * t}$ and less than 2a. The wear plate will be ignored.

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

= $\min(b + 1.56 * \sqrt{Rm * t}, 2a)$
= $\min(150.0 + 1.56 * \sqrt{131.915 * 9.27}, 2 * 200.0)$
= 204.5521 mm.

Input and Calculated Values:

Vessel Mean Radius	Rm	131.92	mm.
Stiffened Vessel Length per 4.15.6	L	1178.00	mm.
Distance from Saddle to Vessel tangent	a	200.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		1201.94	N./mm ²
Head Allowable Stress used in Calculation		1201.94	N./mm ²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	

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V02	0001	CN	ME	320	BV	PPL	BK																			

Saddle Force Q, Test Case, no Ext. Forces 460.36 Kgf

Horizontal Vessel Analysis Results:		Actual N./mm ²	Allowable N./mm ²
Long. Stress at Top of Midspan		73.97	1201.94
Long. Stress at Bottom of Midspan		76.03	1201.94
Long. Stress at Top of Saddles		68.40	1201.94
Long. Stress at Bottom of Saddles		64.95	1201.94
Tangential Shear in Shell		2.85	961.55
Circ. Stress at Horn of Saddle		4.76	1802.90
Circ. Compressive Stress in Shell		0.18	1201.94

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

$$= F_{tr} * (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E$$

$$= 3.0 * (30.7/2 + 0) * 471.0/228.4835$$

$$= 95.0 \text{ Kgf}$$

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

$$= \max(F_l, \text{Friction Load, Sum of X Forces}) * B / L_s$$

$$= \max(2.92, 0.0, 0) * 471.0/2521.0002$$

$$= 0.5 \text{ Kgf}$$

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

$$= \text{Saddle Load} + \max(F_{wl}, F_{wt}, F_{sl}, F_{st})$$

$$= 365 + \max(0.5, 95, 0, 0)$$

$$= 460.4 \text{ Kgf}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	486.68	Kgf
Transverse Shear Load Saddle	15.36	Kgf
Longitudinal Shear Load Saddle	2.92	Kgf

Hydrostatic Test Pressure at center of Vessel: 93.013 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:

$$= -Q * a [1 - (1 - a/L + (R^2 - h^2) / (2a * L)) / (1 + (4h^2) / (3L))]$$

$$= -460 * 200.0 [1 - (1 - 200.0/1178.0 + (131.915^2 - 0.0^2) / (2 * 200.0 * 1178.0)) / (1 + (4 * 0.0) / (3 * 1178.0))]$$

$$= -12.2 \text{ Kg-m.}$$

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پروژه	بسته کاری	صادر کننده	تسهیلات	رشته	نوع مدرک	سریال	نسخه											
BK	PPL	BV	320	ME	CN	0001	V02											

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= Q \cdot L / 4 (1 + 2 (R^2 - h^2) / (L^2)) / (1 + (4h^2) / (3L)) - 4a/L \\
 &= 460 \cdot 1178 / 4 (1 + 2 (132^2 - 0^2) / (1178^2)) / (1 + (4 \cdot 0) / (3 \cdot 1178)) - 4 \cdot 200 / 1178 \\
 &= 46.9 \text{ Kg-m.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 93.013 \cdot 131.915 / (2 \cdot 8.18) - 46.9 / (\pi \cdot 131.9^2 \cdot 8.18) \\
 &= 73.97 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 93.013 \cdot 131.915 / (2 \cdot 8.18) + 46.9 / (\pi \cdot 131.9^2 \cdot 8.18) \\
 &= 76.03 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 93.013 \cdot 131.915 / (2 \cdot 9.27) - 12.2 / (0.1066 \cdot \pi \cdot 131.9^2 \cdot 9.27) \\
 &= 68.40 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 93.013 \cdot 131.915 / (2 \cdot 9.27) + 12.2 / (0.1923 \cdot \pi \cdot 131.9^2 \cdot 9.27) \\
 &= 64.95 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Q (L - 2a) / (L + (4 \cdot h^2 / 3)) \\
 &= 460 (1178.0 - 2 \cdot 200.0) / (1178.0 + (4 \cdot 0.0 / 3)) \\
 &= 304.0 \text{ Kg}
 \end{aligned}$$

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

$$\begin{aligned}
 &= K2 \cdot T / (R_m \cdot t) \\
 &= 1.1707 \cdot 304.04 / (131.915 \cdot 9.27) \\
 &= 2.85 \text{ N./mm}^2
 \end{aligned}$$

Decay Length (4.15.22) [x1,x2]:

$$\begin{aligned}
 &= 0.78 \cdot \sqrt{R_m \cdot t} \\
 &= 0.78 \cdot \sqrt{131.915 \cdot 9.27} \\
 &= 27.276 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= -K5 \cdot Q \cdot k / (t \cdot (b + X1 + X2)) \\
 &= -0.7603 \cdot 460 \cdot 0.1 / (9.27 \cdot (150.0 + 27.28 + 27.28)) \\
 &= -0.18 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= -Q / (4 \cdot t \cdot (b + X1 + X2)) - 3 \cdot K7 \cdot Q / (2 \cdot t^2) \\
 &= -460 / (4 \cdot 9.27 \cdot (150.0 + 27.276 + 27.276)) - 3 \cdot 0.0529 \cdot 460 / (2 \cdot 9.27^2) \\
 &= -4.76 \text{ N./mm}^2
 \end{aligned}$$

Effective reinforcing plate width (4.15.1) [B1]:

$$\begin{aligned}
 &= \min(b + 1.56 \cdot \sqrt{R_m \cdot t}, 2a) \\
 &= \min(150.0 + 1.56 \cdot \sqrt{131.915 \cdot 9.27}, 2 \cdot 200.0) \\
 &= 204.55 \text{ mm.}
 \end{aligned}$$

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Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	250.0000	mm.
Baseplate Thickness	Bpthk	10.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	254.	9.	5.	24.	10896.	6.73
Wearplate	200.	10.	14.	20.	28540.	42.4
Web	10.	314.	176.	31.	554989.	0.124E+05
BasePlate	180.	10.	339.	18.	609696.	0.207E+05
Totals	...	...	...	93.	1204121.	0.331E+05

Value	C1 = Sumof(Ay) / Sumof(A)	=	130.	mm.
Value	I = Sumof(Io) - C1*Sumof(Ay)	=	0.175E+05	cm**4
Value	As = Sumof(A) - Ashell	=	69.4	cm ²

$$K1 = (1 + \cos(\beta) - 0.5 \sin(\beta)^2) / (\pi - \beta + \sin(\beta) \cos(\beta)) = 0.2035$$

$$Fh = K1 * Q = 0.2035 * 460.361 = 93.6935 \text{ Kg}$$

Tension Stress, St = (Fh/As)	=	0.1323	N./mm ²
Allowed Stress, Sa = 0.6 * Yield Str	=	143.9676	N./mm ²

Saddle Splitting Dimension [d]:

$$= B - R * \sin(\theta) / \theta$$

$$= 471.0 - 127.28 * \sin(1.0472) / 1.0472$$

$$= 365.740 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 34.2682 \text{ Kg-m.}$$

Bending Stress, Sb = (M * C1 / I)	=	0.2489	N./mm ²
Allowed Stress, Sa = 2/3 * Yield Str	=	159.9640	N./mm ²

Minimum Thickness of Baseplate per Moss:

$$= (3 (Q + \text{Saddle_Wt}) \text{BasePlateWidth} / (2 * \text{BasePlateLength} * \text{AllStress}))^{1/2}$$

$$= (3 (460 + 26) 180.0 / (2 * 250.0 * 159.964))^{1/2}$$

$$= 5.677 \text{ mm.}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

$$= \text{Web Length} / (\text{Nribs} - 1)$$

$$= 253.8321 / (2 - 1)$$

$$= 253.832 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

$$= e * \text{Bpwid} / 2$$

$$= 253.8321 * 180.0 / 2$$

$$= 228.449 \text{ cm}^2$$

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Axial Load [P]:

$$\begin{aligned}
&= A_p * B_p \\
&= 228.4 * 1.02 \\
&= 233.709 \text{ Kg}
\end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned}
&= \text{Rib Area} + \text{Web Area} \\
&= 14.0 + 12.692 \\
&= 26.692 \text{ cm}^2
\end{aligned}$$

Compressive Stress [Sc]:

$$\begin{aligned}
&= P/Ar \\
&= 233.7/26.6916 \\
&= 0.859 \text{ N./mm}^2
\end{aligned}$$

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	229.
Web	126.9	10.0	5.0	12.7	6345.8	1.06
Values	...	...	...	26.7	118345.9	230.

Bending Moment [Rm]:

$$\begin{aligned}
&= F_l / (2 * B_{plen}) * e * r_l / 2 \\
&= 2.9 / (2 * 250.0) * 253.832 * 387.73 / 2 \\
&= 0.287 \text{ Kg-m.}
\end{aligned}$$

Compressive Allowable, $KL/R < C_c$ (8.1495 < 128.2549) per AISC E2-1 [Sca]:

$$\begin{aligned}
&= (1 - (Kl/r)^2 / (2 * C_c^2)) * F_y / (5/3 + 3 * (Kl/r) / (8 * C_c) - (Kl/r^3) / (8 * C_c^3)) \\
&= (1 - (8.15)^2 / (2 * 128.25^2)) * 240 / \\
&\quad (5/3 + 3 * (8.15) / (8 * 128.25) - (8.15^3) / (8 * 128.25^3)) \\
&= 141.654 \text{ N./mm}^2
\end{aligned}$$

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

$$\begin{aligned}
&= S_c / S_{ca} + (R_m * \text{Distance Side} / I) / S_{ba} \\
&= 0.86 / 141.65 + (0.29 * 105.662 / 6041733) / 159.96 \\
&= 0.006
\end{aligned}$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2
Total Number of Bolts in Tension/Baseplate	Nbt	1
Bolt Material Specification		SA-193 B7
Bolt Allowable Stress	Stba	172.38 N./mm ²
Bolt Corrosion Allowance	Bca	0.0000 mm.
Distance from Bolts to Edge	Edgedis	80.0100 mm.
Nominal Bolt Diameter	Bnd	12.7000 mm.
Thread Series	Series	TEMA
BasePlate Allowable Stress	S	95.15 N./mm ²
Area Available in a Single Bolt	BlArea	0.8129 cm ²
Saddle Load QO (Weight)	QO	391.7 Kg
Saddle Load QL (Wind/Seismic contribution)	QL	0.5 Kg
Maximum Transverse Force	Ft	15.4 Kg
Maximum Longitudinal Force	Fl	2.9 Kg
Saddle Bolted to Steel Foundation	No	

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Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ (} QO > QL \text{ --> No Uplift in Longitudinal direction)}$$

Bolt Area due to Shear Load [Bltarears]:

$$= F_l / (Stba * Nbolts)$$

$$= 2.92 / (172.38 * 2.0)$$

$$= 0.0008 \text{ cm}^2$$

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$= B * Ft + \text{Sum of X Moments}$$

$$= 471.0 * 15.36 + 0.0$$

$$= 7.23 \text{ Kg-m.}$$

Eccentricity (e):

$$= Rmom / QO$$

$$= 7.23 / 391.72$$

$$= 18.46 \text{ mm.} < Bplen / 6 \text{ --> No Uplift in Transverse direction}$$

Bolt Area due to Transverse Load [Bltareart]:

$$= 0 \text{ (No Uplift)}$$

Required Area of a Single Bolt [Bltarear]:

$$= \max[Bltarearl, Bltarears, Bltareart]$$

$$= \max[0.0, 0.0008, 0.0]$$

$$= 0.0008 \text{ cm}^2$$

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