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| **طرح نگهداشت و افزایش تولید 27 مخزن** | | | | | | |
| **Mechanical Calculation Book for Pig Receiver Trap (PR-3201)**  **نگهداشت و افزایش تولید میدان نفتی بینک** | | | | | | |
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|  |  |  |  |  |  |  |
| 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** | | | | | | |

**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 |  |  |  |  |  |  |
| 11 | X | X |  |  |  |  |  |  |
| 12 | X | X |  |  |  |  |  |  |
| 13 | X | X |  |  |  |  |  |  |
| 14 | X | X |  |  |  |  |  |  |
| 15 | X | X |  |  |  |  |  |  |
| 16 | X | X |  |  |  |  |  |  |
| 17 | X | X |  |  |  |  |  |  |
| 18 | X | X |  |  |  |  |  |  |
| 19 | X | X |  |  |  |  |  |  |
| 20 | X | X |  |  |  |  |  |  |
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| 22 | X | X |  |  |  |  |  |  |
| 23 | X | X |  |  |  |  |  |  |
| 24 | X | X |  |  |  |  |  |  |
| 25 | X | X |  |  |  |  |  |  |
| 26 | X | X |  |  |  |  |  |  |
| 27 | X | X |  |  |  |  |  |  |
| 28 | X | X |  |  |  |  |  |  |
| 29 | X | X |  |  |  |  |  |  |
| 30 | X | X |  |  |  |  |  |  |
| 31 | X | X |  |  |  |  |  |  |
| 32 | X | X |  |  |  |  |  |  |
| 33 | X | X |  |  |  |  |  |  |
| 34 | X | X |  |  |  |  |  |  |
| 35 | X | X |  |  |  |  |  |  |
| 36 | X | X |  |  |  |  |  |  |
| 37 | X | X |  |  |  |  |  |  |
| 38 | X | X |  |  |  |  |  |  |
| 39 | X | X |  |  |  |  |  |  |
| 40 | X | X |  |  |  |  |  |  |
| 41 | X | X |  |  |  |  |  |  |
| 42 | X | X |  |  |  |  |  |  |
| 43 | X | X |  |  |  |  |  |  |
| 44 | X | X |  |  |  |  |  |  |
| 45 | X | X |  |  |  |  |  |  |
| 46 | X | X |  |  |  |  |  |  |
| 47 | X | X |  |  |  |  |  |  |
| 48 | X | X |  |  |  |  |  |  |
| 49 | X | X |  |  |  |  |  |  |
| 50 | X | X |  |  |  |  |  |  |

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| **SHEET** | **V00** | **V01** | **V02** | **V03** | **V04** | **V05** | **V06** | **V07** |
| 51 | X | X |  |  |  |  |  |  |
| 52 | X | X |  |  |  |  |  |  |
| 53 | X | X |  |  |  |  |  |  |
| 54 | X | X |  |  |  |  |  |  |
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# 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**

1. 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:
2. The notations described below are used in the equations for the pressure design for Steel Pipe Design Formula.

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

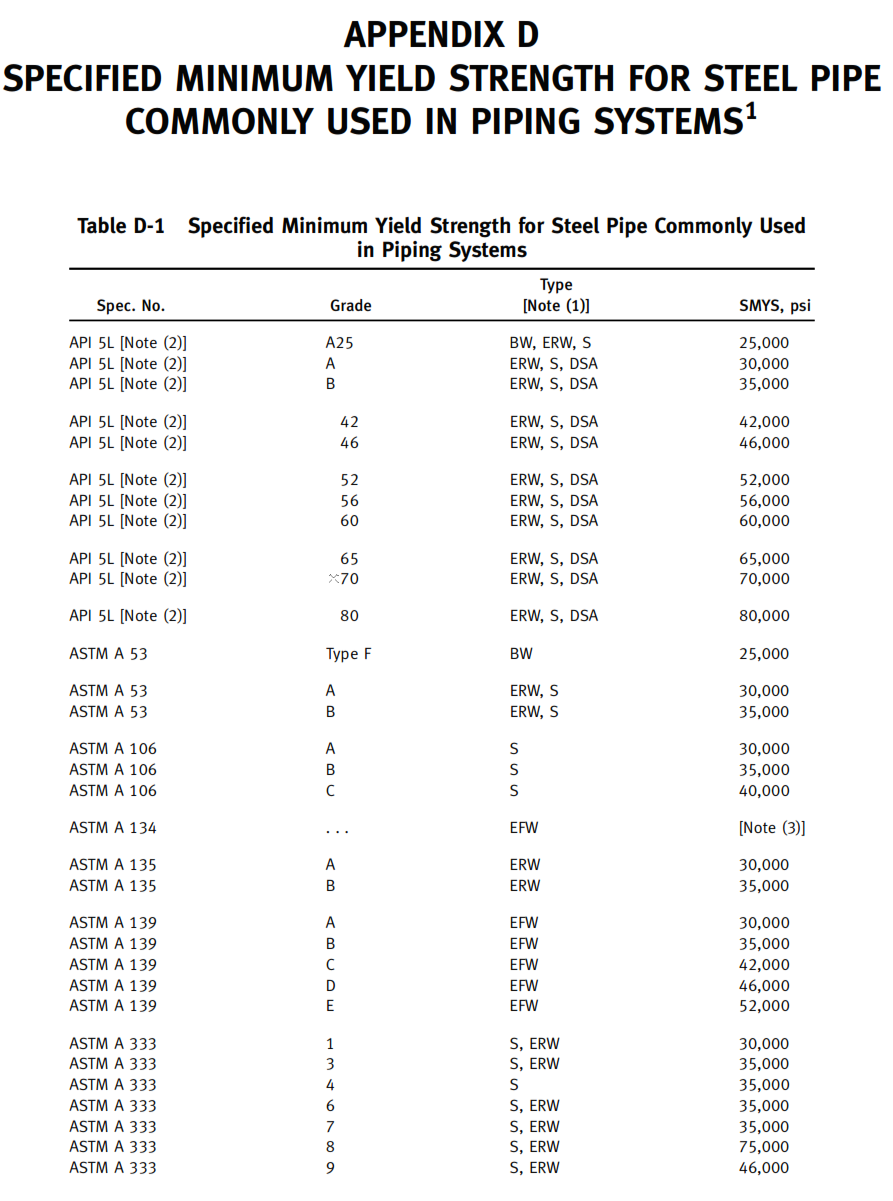
***F =*** Design factor obtained from Table 841.114A. In setting the values of the design factor, F, due consideration has been given and allowance has been made for the various under thickness toler­ances provided for in the pipe specifications listed and approved for usage in this Code.

***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.

****



# Design Data

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

# 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 = 4.73 mm**

***The required wall thicknesses***

**3.2**

# 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 =3.79 mm**

***The required wall thicknesses***

**3.2**

# Nozzle Neck

## 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 =3.79 mm**

***The required wall thicknesses***

**3.2**

## 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 =1.51 mm**

***The required wall thicknesses***

**3.2**

## 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 =0.83 mm**

***The required wall thicknesses***

**3.2**

# Element and Detail Weights:

| | Element | Element | Corroded | Corroded | Extra due |

From| To | Metal Wgt. | ID Volume |Metal Wgt. | ID Volume | Misc % |

| | kg. | Cm. | kg. | Cm. | kg. |

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

10| 20| 54.7515 | 4417.86 | 52.6293 | 4577.49 | 2.73758 |

20| 30| 126.029 | 96865.2 | 77.8911 | 103077 | 6.30147 |

30| 40| 15.1848 | 6543.02 | 12.1128 | 6939.45 | 0.75924 |

40| 50| 178.651 | 152711 | 118.4 | 160486 | 8.93256 |

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

**Total | 374 | 260536.70 | 261 | 275080.12 | 18 |**

**Weight of Details:**

| | Weight of | X Offset, | Y Offset, |

From|Type| Detail | Dtl. Cent. |Dtl. Cent. | Description

| | kg. | mm. | mm. |

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

20|Sadl| 25.3987 | 852.5 | 288.095 | Left Saddle

20|Liqd| 4.01746 | 1500 | ... | LIQUID

20|Nozl| 4.31941 | 308.475 | 131.533 | N3

20|Nozl| 6.40512 | 2713.47 | 131.533 | K

20|Nozl| 6.49327 | 600 | 131.533 | V2

20|Nozl| 6.49327 | 300 | 131.533 | B

20|Nozl| 6.49327 | 300 | 131.533 | D2

30|Liqd| 0.27137 | 89 | -13.6715 | LIQUID

40|Sadl| 25.2792 | 2002 | 278.005 | RIGHT SADDLE

40|Liqd| 6.33363 | 1500 | ... | LIQUID

40|Nozl| 6.49327 | 300 | 157.442 | V1

40|Nozl| 6.49327 | 600 | 157.442 | A

40|Nozl| 6.15909 | 2400 | 157.442 | PSV

40|Nozl| 6.15908 | 2700 | 157.442 | P

40|Nozl| 6.15908 | 2400 | 157.442 | D1

40|Wght| 80 | 3000 | ... | QOC

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

**Total Weight of Each Detail Type**

Total Weight of Saddles 50.7

Total Weight of Liquid 10.6

Total Weight of Nozzles 61.7

Total Weight of Weights 80.0

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

Sum of the Detail Weights 203.0 kg.

**Weight Summation: kg.**

Fabricated | Shop Test | Shipping | Erected | Empty | Operating |

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

393.3 | 505.7 | 393.3 | 505.7 | 393.3 | 585.7 |

50.7 | 260.4 | 50.7 | ... | 50.7 | 10.6 |

61.7 | 80.0 | 61.7 | ... | ... | ... |

... | ... | ... | ... | ... | 80.0 |

... | ... | ... | ... | ... | -80.0 |

... | ... | ... | ... | 61.7 | ... |

... | ... | ... | 80.0 | 80.0 | ... |

505.7 | 846.1 | 505.7 | 585.7 | 585.7 | 596.3 |

**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 505.7 kg.

Shop Test Wt. - Fabricated Weight + Water ( Full ) 846.1 kg.

Shipping Wt. - Fab. Wt + Rem. Intls.+ Shipping App. 505.7 kg.

Erected Wt. - Fab. Wt + Rem. Intls.+ Insul. (etc) 585.7 kg.

Ope. Wt. no Liq - Fab. Wt + Intls. + Details + Wghts. 585.7 kg.

Operating Wt. - Empty Wt + Operating Liq. Uncorroded 596.3 kg.

Oper. Wt. + CA - Corr Wt. + Operating Liquid 477.1 kg.

Field Test Wt. - Empty Weight + Water (Full) 846.1 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:**

| | Surface |

From| To | Area |

| | cm² |

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

10| 20| 2455.59 |

20| 30| 20649.7 |

30| 40| 1391.94 |

40| 50| 25739.1 |

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

Total 50236.293 cm²

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# Wind Load Calculation:

**Input Values:**

Wind Design Code ASCE-7 2010

Wind Load Reduction Scale Factor 0.600

Basic Wind Speed [V] 120 Km/hr

Surface Roughness Category C: Open Terrain

Importance Factor 1.0

Type of Surface Moderately Smooth

Base Elevation 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]:

= 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

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] 0.700

Structure Height to Diameter ratio 25.794

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

**Sample Calculation for the First Element**

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

Value of [Alpha] and [Zg]:

Exposure Category: C from Table 26.9.1

Alpha = 9.5: Zg = 274320. mm.

Effective Height [z]:

= Centroid Height + Vessel Base Elevation

= 493.0 + 0.0 = 493.0 mm.

= 1.617 ft. Imperial Units

Velocity Pressure coefficient evaluated at height z [Kz]:

Because z (1.617 ft.) < 15 ft.

= 2.01 \* ( 15 / Zg ) ^(2 / Alpha)

= 2.01 \* ( 15/900.0 )^(2/9.5)

= 0.849

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

= 0.95 per Table 26.6-1

As there is No Hill Present: [Kzt]:

K1 = 0, K2 = 0, K3 = 0

Topographical Factor [Kzt]:

= ( 1 + K1 \* K2 \* K3 )²

= ( 1 + 0.0\* 0.0\* 0.0 )²

= 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:

= min( 16, 0.00256 \* Kz \* Kzt \* Kd \* V(mph)² )

= min( 16, 0.00256 \* 0.849 \* 1.0 \* 0.95 \* 74.567² )

= 16.0 psf [78.12] Kgs/m²

Force on the first element [F]:

= qz \* G \* Cf \* WindArea

= 16.0 \* 0.85 \* 0.7 \* 0.349

= 3.3 lbs. [1.5] Kgf

Element Hgt (z) K1 K2 K3 Kz Kzt qz

mm. Kgs/m²

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

end flange 493.0 0.000 0.000 0.000 0.849 1.000 78.120

spool 493.0 0.000 0.000 0.000 0.849 1.000 78.120

ECCENTRIC REDUC 493.0 0.000 0.000 0.000 0.849 1.000 78.120

BARREL 493.0 0.000 0.000 0.000 0.849 1.000 78.120

**Platform Load Calculations**

ID Wind Area Elevation Pressure Force Cf

cm² mm. Kgs/m² Kgf

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

**Wind Loads on Masses/Equipment/Piping**

ID Wind Area Elevation Pressure Force

cm² mm. Kgs/m² Kgf

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

QOC 0.00 3000.00 78.12 0.00

**Wind Load Calculation:**

| | Wind | Wind | Wind | Wind | Element |

From| To | Height | Diameter | Area | Pressure | Wind Load |

| | mm. | mm. | cm² | Kgs/m² | Kgf |

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

10| 20| 493 | 243.23 | 324.348 | 78.12 | 0.90457 |

20| 30| 493 | 262.92 | 7887.6 | 78.12 | 21.9976 |

30| 40| 493 | 294.908 | 524.937 | 78.12 | 1.46399 |

40| 50| 493 | 327.72 | 9831.6 | 78.12 | 27.4193 |

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

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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# Earthquake Load Calculation:

**Input Values:**

Seismic Design Code ASCE 7-2010

Seismic Load Reduction Scale Factor 0.700

Importance Factor 1.250

Table Value Fa 1.000

Table Value Fv 1.330

Short Period Acceleration value Ss 1.125

Long Period Acceleration Value Sl 0.460

Moment Reduction Factor Tau 1.000

Force Modification Factor R 3.000

Site Class C

Component Elevation Ratio z/h 0.000

Amplification Factor Ap 0.000

Force Factor 0.000

Consider Vertical Acceleration No

Minimum Acceleration Multiplier 0.000

User Value of Sds (used if > 0 ) 0.000

**Seismic Analysis Results:**

Sms = Fa \* Ss = 1.0 \* 1.125 = 1.125

Sm1 = Fv \* S1 = 1.33 \* 0.46 = 0.612

Sds = 2/3 \* Sms = 2/3 \* 1.125 = 0.75

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

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

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

= 0.020 \* ( 1.8874^(0.75))

= 0.032 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

= ( 1/Natural Frequency ) = ( 1/33.0 )

= 0.030

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

= Minimum Value of (1.4 \* 0.032, 0.03 ) per 12.8.2

= 0.030

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

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

= 0.3 \* Sds \* W \* I

= 0.3 \* 0.75 \* 477 \* 1.25

= 134.171 Kgf

Final Base Shear, V = 93.92 Kgf

**Earthquake Load Calculation:**

| | Earthquake | Earthquake | Element |

From| To | Height | Weight | Ope Load |

| | mm. | Kgf | Kgf |

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

10| 20| 101.346 | 79.5089 | 14.5759 |

20| 30| 101.37 | 79.5089 | 14.5793 |

20| 30| 101.37 | 79.5089 | 14.5793 |

30| 40| 94.3784 | 79.5089 | 13.5738 |

40| 0| 127.28 | 79.5089 | 18.3058 |

40| 50| 127.28 | 79.5089 | 18.3058 |

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

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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# 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./mm²

Total Height of Lifting Lug w 100.0000 mm.

Thickness of Lifting Lug t 10.0000 mm.

Diameter of Hole in Lifting Lug dh 20.0000 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 30.0000 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) 585.69 Kgf

Design Reaction force at the tailing lug 420.71 Kgf

Design Reaction force at the lifting lug 457.83 Kgf

Force Along Vessel Axis Fax 0.00 Kgf

Force Normal to Vessel Fn 420.71 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)+421^(2))/((2\*(120.0+10.0))\*7.07)

= 2.24 N./mm²

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

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

= (421\*(50.0-60.0)) \* 67.07/260.754 +

(0\*30.0 \* 67.07/260.754) +

(0\*30.0 \* 5.0/1.189)

= -1.06 N./mm²

Total Shear Stress for Combined Loads [St]:

= Ssll + Sblf

= 2.244 + -1.061

= 1.18 N./mm²

Allowable Shear Stress for Combined Loads [Sta]:

= 0.4 \* Yield \* Occfac (AISC Shear Allowable)

= 0.4 \* 207 \* 1.0

= 82.74 N./mm²

Shear Stress in Lug above Hole [Shs]:

= sqrt( Pl^(2) + Fax^(2) ) / Sha

= sqrt( 421^(2) + 0^(2) )/6.0

= 6.88 N./mm²

Allowable Shear Stress in Lug above Hole [Sas]:

= 0.4 \* Yield \* Occfac

= 0.4 \* 207 \* 1.0

= 82.74 N./mm²

Pin Hole Bearing Stress [Pbs]:

= sqrt( Fax^(2) + Fn^(2) ) / ( t \* dh )

= sqrt( 0^(2) + 421^(2) )/( 10.0 \* 20.0 )

= 20.63 N./mm²

Allowable Bearing Stress [Pba]:

= min( 0.75 \* Yield \* Occfac, 0.9 \* Yield ) AISC Bearing All.

= min( 0.75 \* 207 \* 1.0, 186.2 )

= 155.14 N./mm²

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

= Ft \* off/(w \* t^(2)/6) + Fax \* off/(w^(2) \* t/6)

= 0 \* 30.0/(100.0 \* 10.0^(2)/6) +

0 \* 30.0/(100.0^(2) \* 10.0/6)

= 0.00 N./mm²

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

= Fn / (w \* t)

= 0/(100.0 \* 10.0)

= 4.13 N./mm²

Total Combined Stress at the Base of the Lug:

= Fbs + Fa

= 0.0 + 4.1

= 4.13 N./mm²

Lug Allowable Stress for Bending and Tension:

= min( 0.66 \* Yield \* Occfac, 0.75 \* Yield )

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

= 136.52 N./mm²

Required Shackle Pin Diameter [Spd]:

= sqrt[(2 \* sqrt(Fn^(2) + Fax^(2))/( Pi \* Sta))]

= sqrt[2 \* sqrt(421^(2) + 0^(2))/( Pi \* 83)]

= 5.6343 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 -420.7 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.

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 -420.7 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 = 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)**

| Stress Intensity Values at |

Type of | |Stress Load | Au Al Bu Bl Cu Cl Du Dl|

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

Circ. Memb. P | 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4|

Circ. Bend. P | 15.5| -15.5| 15.5| -15.5| 17.4| -17.4| 17.4| -17.4|

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.| 18.0| -13.1| 18.0| -13.1| 19.8| -15.1| 19.8| -15.1|

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

Long. Memb. P | 2.4| 2.4| 2.4| 2.4| 2.5| 2.5| 2.5| 2.5|

Long. Bend. P | 14.9| -14.9| 14.9| -14.9| 12.5| -12.5| 12.5| -12.5|

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.| 17.4| -12.5| 17.4| -12.5| 15.0| -10.0| 15.0| -10.0|

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

Shear VC | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Shear VL | 0.0| 0.0| 0.0| 0.0| 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. | 18.0| 13.1| 18.0| 13.1| 19.8| 15.1| 19.8| 15.1|

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)**

| Stress Intensity Values at |

Type of | |Stress Load | Au Al Bu Bl Cu Cl Du Dl|

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

Circ. Memb. P | 7.0| 7.0| 7.0| 7.0| 4.0| 4.0| 4.0| 4.0|

Circ. Bend. P | 6.4| -6.4| 6.4| -6.4| 20.4| -20.4| 20.4| -20.4|

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.| 13.3| 0.6| 13.3| 0.6| 24.4| -16.4| 24.4| -16.4|

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

Long. Memb. P | 4.0| 4.0| 4.0| 4.0| 7.0| 7.0| 7.0| 7.0|

Long. Bend. P | 12.4| -12.4| 12.4| -12.4| 11.8| -11.8| 11.8| -11.8|

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.| 16.4| -8.5| 16.4| -8.5| 18.7| -4.8| 18.7| -4.8|

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

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. | 16.4| 9.0| 16.4| 9.0| 24.4| 16.4| 24.4| 16.4|

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

**WRC 107/537 Stress Summations:**

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

| Stress Intensity Values at |

Type of | |Stress Load | 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) | 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4|

Circ. Q (SUS) | 15.5| -15.5| 15.5| -15.5| 17.4| -17.4| 17.4| -17.4|

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

Long. Pm (SUS) | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Long. Pl (SUS) | 2.4| 2.4| 2.4| 2.4| 2.5| 2.5| 2.5| 2.5|

Long. Q (SUS) | 14.9| -14.9| 14.9| -14.9| 12.5| -12.5| 12.5| -12.5|

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

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) | 2.4| 2.4| 2.4| 2.4| 2.5| 2.5| 2.5| 2.5|

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

Pm+Pl+Q (Total)| 18.0| 13.1| 18.0| 13.1| 19.8| 15.1| 19.8| 15.1|

**Stress Summation Comparison (N./mm²):**

Type of | Max. S.I. S.I. Allowable | Result |

Stress Int. | | |

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

Pm (SUS) | 0.00 151.70 | Passed |

Pm+Pl (SUS) | 2.49 227.55 | Passed |

Pm+Pl+Q (TOTAL)| 19.78 455.10 | Passed |

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

**WRC 107/537 Stress Summations:**

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

| Stress Intensity Values at |

Type of | |Stress Load | Au Al Bu Bl Cu Cl Du Dl|

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

Circ. Pm (SUS) | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Circ. Pl (SUS) | 7.0| 7.0| 7.0| 7.0| 4.0| 4.0| 4.0| 4.0|

Circ. Q (SUS) | 6.4| -6.4| 6.4| -6.4| 20.4| -20.4| 20.4| -20.4|

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

Long. Pm (SUS) | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Long. Pl (SUS) | 4.0| 4.0| 4.0| 4.0| 7.0| 7.0| 7.0| 7.0|

Long. Q (SUS) | 12.4| -12.4| 12.4| -12.4| 11.8| -11.8| 11.8| -11.8|

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

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) | 7.0| 7.0| 7.0| 7.0| 7.0| 7.0| 7.0| 7.0|

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

Pm+Pl+Q (Total)| 16.4| 9.0| 16.4| 9.0| 24.4| 16.4| 24.4| 16.4|

**Stress Summation Comparison (N./mm²):**

Type of | Max. S.I. S.I. Allowable | Result |

Stress Int. | | |

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

Pm (SUS) | 0.00 151.70 | Passed |

Pm+Pl (SUS) | 6.96 227.55 | Passed |

Pm+Pl+Q (TOTAL)| 24.35 455.10 | 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./mm²

Total Height of Lifting Lug w 100.0000 mm.

Thickness of Lifting Lug t 10.0000 mm.

Diameter of Hole in Lifting Lug dh 20.0000 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 30.0000 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) 585.69 Kgf

Design Reaction force at the tailing lug 420.71 Kgf

Design Reaction force at the lifting lug 457.83 Kgf

Force Along Vessel Axis Fax 0.00 Kgf

Force Normal to Vessel Fn 457.83 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)+458^(2))/((2\*(120.0+10.0))\*7.07)

= 2.44 N./mm²

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

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

= (458\*(50.0-60.0)) \* 67.07/260.754 +

(0\*30.0 \* 67.07/260.754) +

(0\*30.0 \* 5.0/1.189)

= -1.15 N./mm²

Total Shear Stress for Combined Loads [St]:

= Ssll + Sblf

= 2.443 + -1.155

= 1.29 N./mm²

Allowable Shear Stress for Combined Loads [Sta]:

= 0.4 \* Yield \* Occfac (AISC Shear Allowable)

= 0.4 \* 207 \* 1.0

= 82.74 N./mm²

Shear Stress in Lug above Hole [Shs]:

= sqrt( Pl^(2) + Fax^(2) ) / Sha

= sqrt( 458^(2) + 0^(2) )/6.0

= 7.48 N./mm²

Allowable Shear Stress in Lug above Hole [Sas]:

= 0.4 \* Yield \* Occfac

= 0.4 \* 207 \* 1.0

= 82.74 N./mm²

Pin Hole Bearing Stress [Pbs]:

= sqrt( Fax^(2) + Fn^(2) ) / ( t \* dh )

= sqrt( 0^(2) + 458^(2) )/( 10.0 \* 20.0 )

= 22.45 N./mm²

Allowable Bearing Stress [Pba]:

= min( 0.75 \* Yield \* Occfac, 0.9 \* Yield ) AISC Bearing All.

= min( 0.75 \* 207 \* 1.0, 186.2 )

= 155.14 N./mm²

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

= Ft \* off/(w \* t^(2)/6) + Fax \* off/(w^(2) \* t/6)

= 0 \* 30.0/(100.0 \* 10.0^(2)/6) +

0 \* 30.0/(100.0^(2) \* 10.0/6)

= 0.00 N./mm²

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

= Fn / (w \* t)

= 0/(100.0 \* 10.0)

= 4.49 N./mm²

Total Combined Stress at the Base of the Lug:

= Fbs + Fa

= 0.0 + 4.5

= 4.49 N./mm²

Lug Allowable Stress for Bending and Tension:

= min( 0.66 \* Yield \* Occfac, 0.75 \* Yield )

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

= 136.52 N./mm²

Required Shackle Pin Diameter [Spd]:

= sqrt[(2 \* sqrt(Fn^(2) + Fax^(2))/( Pi \* Sta))]

= sqrt[2 \* sqrt(458^(2) + 0^(2))/( Pi \* 83)]

= 5.8776 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 -457.8 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.

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 -457.8 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 | 2.4| 2.4| 2.4| 2.4| 2.3| 2.3| 2.3| 2.3|

Circ. Bend. P | 16.0| -16.0| 16.0| -16.0| 18.0| -18.0| 18.0| -18.0|

Circ. Memb. MC | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Circ. Memb. MC | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Circ. Memb. ML | 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.| 18.4| -13.6| 18.4| -13.6| 20.4| -15.7| 20.4| -15.7|

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

Long. Memb. P | 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4|

Long. Bend. P | 15.8| -15.8| 15.8| -15.8| 13.1| -13.1| 13.1| -13.1|

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.| 18.2| -13.4| 18.2| -13.4| 15.5| -10.7| 15.5| -10.7|

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

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. | 18.4| 13.6| 18.4| 13.6| 20.4| 15.7| 20.4| 15.7|

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)**

| Stress Intensity Values at |

Type of | |Stress Load | Au Al Bu Bl Cu Cl Du Dl|

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

Circ. Memb. P | 5.7| 5.7| 5.7| 5.7| 3.2| 3.2| 3.2| 3.2|

Circ. Bend. P | 4.8| -4.8| 4.8| -4.8| 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. 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.| 10.5| 0.8| 10.5| 0.8| 20.5| -14.1| 20.5| -14.1|

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

Long. Memb. P | 3.2| 3.2| 3.2| 3.2| 5.7| 5.7| 5.7| 5.7|

Long. Bend. P | 9.7| -9.7| 9.7| -9.7| 9.7| -9.7| 9.7| -9.7|

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.| 12.9| -6.5| 12.9| -6.5| 15.3| -4.0| 15.3| -4.0|

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

Shear VC | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Shear VL | 0.0| 0.0| 0.0| 0.0| 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. | 12.9| 7.4| 12.9| 7.4| 20.5| 14.1| 20.5| 14.1|

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

**WRC 107/537 Stress Summations:**

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

| Stress Intensity Values at |

Type of | |Stress Load | 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) | 2.4| 2.4| 2.4| 2.4| 2.3| 2.3| 2.3| 2.3|

Circ. Q (SUS) | 16.0| -16.0| 16.0| -16.0| 18.0| -18.0| 18.0| -18.0|

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

Long. Pm (SUS) | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Long. Pl (SUS) | 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4|

Long. Q (SUS) | 15.8| -15.8| 15.8| -15.8| 13.1| -13.1| 13.1| -13.1|

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

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) | 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4| 2.4|

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

Pm+Pl+Q (Total)| 18.4| 13.6| 18.4| 13.6| 20.4| 15.7| 20.4| 15.7|

**Stress Summation Comparison (N./mm²):**

Type of | Max. S.I. S.I. Allowable | Result |

Stress Int. | | |

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

Pm (SUS) | 0.00 151.70 | Passed |

Pm+Pl (SUS) | 2.42 227.55 | Passed |

Pm+Pl+Q (TOTAL)| 20.36 455.10 | Passed |

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

**WRC 107/537 Stress Summations:**

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

| Stress Intensity Values at |

Type of | |Stress Load | 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) | 5.7| 5.7| 5.7| 5.7| 3.2| 3.2| 3.2| 3.2|

Circ. Q (SUS) | 4.8| -4.8| 4.8| -4.8| 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) | 3.2| 3.2| 3.2| 3.2| 5.7| 5.7| 5.7| 5.7|

Long. Q (SUS) | 9.7| -9.7| 9.7| -9.7| 9.7| -9.7| 9.7| -9.7|

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

Shear Pm (SUS) | 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0| 0.0|

Shear Pl (SUS) | 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) | 5.7| 5.7| 5.7| 5.7| 5.7| 5.7| 5.7| 5.7|

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

Pm+Pl+Q (Total)| 12.9| 7.4| 12.9| 7.4| 20.5| 14.1| 20.5| 14.1|

**Stress Summation Comparison (N./mm²):**

Type of | Max. S.I. S.I. Allowable | Result |

Stress Int. | | |

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

Pm (SUS) | 0.00 151.70 | Passed |

Pm+Pl (SUS) | 5.69 227.55 | Passed |

Pm+Pl+Q (TOTAL)| 20.52 455.10 | Passed |

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# 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 3178.00 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./mm²

Shell Allowable Stress used in Calculation 151.70 N./mm²

Head Allowable Stress used in Calculation 137.90 N./mm²

Circumferential Efficiency in Plane of Saddle 1.00

Circumferential Efficiency at Mid-Span 1.00

Saddle Force Q, Operating Case 550.14 Kgf

Horizontal Vessel Analysis Results: Actual | Allowable |

N./mm² | N./mm² |

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

Long. Stress at Top of Midspan 48.71 | 151.70 |

Long. Stress at Bottom of Midspan 84.59 | 151.70 |

Long. Stress at Top of Saddles 69.69 | 151.70 |

Long. Stress at Bottom of Saddles 64.96 | 151.70 |

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

Tangential Shear in Shell 10.36 | 121.36 |

Circ. Stress at Horn of Saddle 3.51 | 189.62 |

Circ. Stress at Tip of Wear Plate 15.63 | 189.62 |

Circ. Compressive Stress in Shell 0.44 | 151.70 |

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

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

Saddle Reaction Force due to Wind Ft [Fwt]:

= Ftr \* ( Ft/Num of Saddles + Z Force Load ) \* B / E

= 3.0 \* ( 51.8/2 + 0 ) \* 493.0/185.4334

= 206.5 Kgf

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

= max( Fl, Friction Load, Sum of X Forces) \* B / Ls

= max( 2.12, 0.0, 0 ) \* 493.0/4327.5

= 0.2 Kgf

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

= max( Fl, Friction Force, Sum of X Forces ) \* B / Ls

= max( 93.92, 0.0, 0 ) \* 493.0/4327.5

= 10.7 Kgf

Saddle Reaction Force due to Earthquake Ft [Fst]:

= Ftr \* ( Ft/Num of Saddles + Z Force Load ) \* B / E

= 3.0 \* ( 94/2 + 0 ) \* 493.0/185.4334

= 374.5 Kgf

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

= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )

= 176 + Max( 0.2, 207, 11, 375 )

= 550.1 Kgf

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight) 575.54 Kgf

Transverse Shear Load Saddle 46.96 Kgf

Longitudinal Shear Load Saddle 93.92 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 Rm / 2.

Moment per Equation 4.15.3 [M1]:

= -Q\*a [1 - (1- a/L + (R²-h2²)/(2a\*L))/(1+(4h2)/3L)]

= -550\*200.0[1-(1-200.0/3178.0+(107.06²-0.0²)/

(2\*200.0\*3178.0))/(1+(4\*0.0)/(3\*3178.0))]

= -5.9 Kg-m.

Moment per Equation 4.15.4 [M2]:

= Q\*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L

= 550\*3178/4(1+2(107²-0²)/(3178²))/(1+(4\*0)/

(3\*3178))-4\*200/3178

= 328.1 Kg-m.

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

= P \* Rm/(2t) - M2/(pi\*Rm²t)

= 62.0 \* 107.06/(2\*4.98) - 328.1/(pi\*107.1²\*4.98)

= 48.71 N./mm²

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

= P \* Rm/(2t) + M2/(pi \* Rm² \* t)

= 62.0 \* 107.06/(2 \* 4.98) + 328.1/(pi \* 107.1² \* 4.98 )

= 84.59 N./mm²

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

= P \* Rm/(2t) - M1/(K1\*pi\*Rm²t)

= 62.0\*107.06/(2\*4.98)--5.9/(0.1066\*pi\*107.1²\*4.98)

= 69.69 N./mm²

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

= P \* Rm/(2t) + M1/(K1\* \* pi \* Rm² \* t)

= 62.0\*107.06/(2\*4.98)+-5.9/(0.1923\*pi\*107.1²\*4.98)

= 64.96 N./mm²

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

= Q(L-2a)/(L+(4\*h2/3))

= 550( 3178.0 - 2 \* 200.0)/(3178.0 + ( 4 \* 0.0/3))

= 480.9 Kgf

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

= K2 \* T / ( Rm \* t )

= 1.1707 \* 480.9/( 107.06 \* 4.98 )

= 10.36 N./mm²

Decay Length (4.15.22) [x1,x2]:

= 0.78 \* sqrt( Rm \* t )

= 0.78 \* sqrt( 107.06 \* 4.98 )

= 18.010 mm.

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

= -K5 \* Q \* k / ( t \* ( b + X1 + X2 ) )

= - 0.7603 \* 550 \* 0.1/( 4.98 \* ( 150.0 + 18.01 + 18.01 ) )

= -0.44 N./mm²

Effective reinforcing plate width (4.15.1) [B1]:

= min( b + 1.56 \* sqrt( Rm \* t ), 2a )

= min( 150.0 + 1.56 \* sqrt( 107.06 \* 4.98 ), 2 \* 200.0 )

= 186.02 mm.

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

= min( Sr/S, 1 )

= min( 108.252/151.7, 1 )

= 0.7136

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

= -K5 \* Q \* k / ( B1( t + eta \* tr ) )

= - 0.7603 \* 550 \* 0.1/( 186.021( 4.98 + 0.714 \* 10.0 ) )

= -0.18 N./mm²

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

= -Q/(4(t+eta\*tr)b1) - 3\*K7\*Q/(2(t+eta\*tr)²)

= -550/(4(4.98 + 0.714 \* 10.0)186.021) -

3 \* 0.053 \* 550/(2(4.98 + 0.714 \* 10.0)²)

= -3.51 N./mm²

Circ. Comp. Stress at Tip of Wearplate, w/Pad L>=8Rm (4.15.30) [sigma7,1]:

= -Q/(4\*t\*(b+X1+X2)) - 3\*K7,1\*Q/(2\*t²)

= -550/(4 \* 4.98\*(150.0 + 18.01 + 18.01)) -

3 \* 0.0434 \* 550/(2 \* 4.98²)

= -15.63 N./mm²

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

= Alpha \* Ls \* ( Design Temperature - Ambient Temperature )

= 0.000012 \* 4327.5 \* ( 85.0 - 21.1 )

= 3.319 mm.

**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. | 363. | 197. | 36. | 714925. | 0.181E+05 |

BasePlate 180. | 10. | 383. | 18. | 690174. | 0.265E+05 |

Totals ... | ... | ... | 86. | 1427980. | 0.446E+05 |

Value C1 = Sumof(Ay)/Sumof(A) = 166. mm.

Value I = Sumof(Io) - C1\*Sumof(Ay) = 0.209E+05 cm\*\*4

Value As = Sumof(A) - Ashell = 74.3 cm²

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

Fh = K1 \* Q = 0.2035 \* 550.142 = 111.9659 Kgf

Tension Stress, St = ( Fh/As ) = 0.1477 N./mm²

Allowed Stress, Sa = 0.6 \* Yield Str = 124.1100 N./mm²

Saddle Splitting Dimension [d]:

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

= 493.0 - 104.57 \* sin( 1.0472 )/1.0472

= 406.521 mm.

Bending Moment, M = Fh \* d = 45.5174 Kg-m.

Bending Stress, Sb = ( M \* C1 / I ) = 0.3550 N./mm²

Allowed Stress, Sa = 2/3 \* Yield Str = 137.9000 N./mm²

**Minimum Thickness of Baseplate per Moss:**

= ( 3( Q + Saddle\_Wt )BasePlateWidth / ( 2 \* BasePlateLength \* AllStress ))½

= ( 3(550 + 25)180.0/( 2 \* 250.0 \* 137.9 ))½

= 6.649 mm.

**Calculation of Axial Load, Intermediate Values and Compressive Stress:**

Distance between Ribs [e]:

= Web Length / ( Nribs - 1 )

= 212.6092/( 2 - 1 )

= 212.609 mm.

Baseplate Pressure Area [Ap]:

= e \* Bpwid / 2

= 212.6092 \* 180.0/2

= 191.348 cm²

Axial Load [P]:

= Ap \* Bp

= 191.3 \* 1.22

= 233.931 Kgf

Area of the Rib and Web [Ar]:

= Rib Area + Web Area

= 14.0 + 10.63

= 24.630 cm²

Compressive Stress [Sc]:

= P/Ar

= 233.9/24.6305

= 0.931 N./mm²

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]:

= Fl /( 2 \* Bplen ) \* e \* rl / 2

= 93.9/( 2 \* 250.0 ) \* 212.609 \* 421.62/2

= 8.419 Kg-m.

Compressive Allowable, KL/R < Cc ( 8.7688 < 138.1347 ) per AISC E2-1 [Sca]:

= (1-(Klr)²/(2\*Cc²))\*Fy/(5/3+3\*(Klr)/(8\*Cc)-(Klr³)/(8\*Cc³)

= ( 1-( 8.77 )²/(2 \* 138.13² )) \* 207/

( 5/3+3\*(8.77)/(8\* 138.13)-( 8.77³)/(8\*138.13³)

= 122.118 N./mm²

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

= Sc/Sca + ( Rm \* Distance Side/I )/Sba

= 0.93/122.12 + ( 8.42 \* 102.37/5694364 )/137.9

= 0.018

**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./mm²

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./mm²

Area Available in a Single Bolt BltArea 0.8129 cm²

Saddle Load QO (Weight) QO 201.0 Kgf

Saddle Load QL (Wind/Seismic contribution) QL 10.7 Kgf

Maximum Transverse Force Ft 47.0 Kgf

Maximum Longitudinal Force Fl 93.9 Kgf

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]:

= Fl / (Stba \* Nbolts)

= 93.92/(172.38 \* 2.0)

= 0.0267 cm²

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

= B \* Ft + Sum of X Moments

= 493.0 \* 46.96 + 0.0

= 23.15 Kg-m.

Eccentricity (e):

= Rmom / QO

= 23.15/200.99

= 115.18 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis

= 250.0/2 - 80.01

= 44.99 mm.

Modular Ratio Of Steel/Concrete (n1):

= ES / EC

= 203402.5/21526.32

= 9.45

K1 = 3 (e - 0.5 \* Bplen)

= 3 (115.18 - 0.5\*250.0)

= -29.45 mm.

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

= 6 \* 9.45 \* 0.81/180.0 \* (44.99 + 115.18)

= 4101.06 mm.²

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

= -4101.06 \* (0.5 \* 250.0 + 44.99)

= -697138.69 mm.³

Iteratively Solving for the Effective Bearing Length:

Y³ + K1 \* Y² + K2 \* Y + K3 = 0

Y³ + -29.45 \* Y² + 4101.06 \* Y + -697138.75 = 0

Y = 82.38 mm.

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

= (250.0/2 - 82.38/3 - 115.18)

= -17.65

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

= (250.0/2 - 82.38/3 + 44.99)

= 142.53

Total Bolt Tension Force [Tforce]:

= - QO \* Num / Denom

= - 200.99 \* -17.65/142.53

= 24.88 Kgf

Bolt Area Required due to Transverse Load [Bltareart]:

= Tforce / (Stba \* Nbt)

= 24.88/( 172.38 \* 1.0 )

= 0.0142 cm²

Required Area of a Single Bolt [Bltarear]:

= max[Bltarearl, Bltarears, Bltareart]

= max[0.0, 0.0267, 0.0142]

= 0.0267 cm²

**Baseplate Thickness Calculation per D. Moss:**

Bearing Pressure (fc)

= 2(QO + Tforce) / (Y \* Bpwid)

= 2(200.99 + 24.88)/(82.38 \* 180.0)

= 2.99 bars

Distance from Baseplate Edge to the Web [ADIST]:

= (Bplen - Weblngth) / 2

= (250.0 - 199.2)/2

= 25.4000 mm.

Overturning Moment due To Bolt Tension [Mt]:

= Tforce \* Adist

= 24.88 \* 25.4

= 0.63 Kg-m.

Equivalent Bearing Pressure (f1):

= fc \* (Y - Adist) / Y

= 2.99 \* (82.38 - 25.4)/82.38

= 2.07 bars

Overturning Moment due to Bearing Pressure [Mc]:

= (Adist² \* Bpwid / 6) \* (f1 + 2 \* fc)

= (25.4² \* 180.0/6) \* (2.07 + 2 \* 2.99)

= 1.59 Kg-m.

Baseplate Required Thickness [Treq]:

= (6 \* max(Mt,Mc) / (Bpwid \* Sba))½

= (6 \*max( 0.63,1.59/(180.0 \* 162.38))½

= 1.7875 mm.

**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 3178.00 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 95.15 N./mm²

Shell Allowable Stress used in Calculation 151.70 N./mm²

Head Allowable Stress used in Calculation 0.00 N./mm²

Circumferential Efficiency in Plane of Saddle 1.00

Circumferential Efficiency at Mid-Span 1.00

Saddle Force Q, Operating Case 523.70 Kgf

Horizontal Vessel Analysis Results: Actual | Allowable |

N./mm² | N./mm² |

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

Long. Stress at Top of Midspan 72.12 | 151.70 |

Long. Stress at Bottom of Midspan 94.12 | 151.70 |

Long. Stress at Top of Saddles 69.58 | 151.70 |

Long. Stress at Bottom of Saddles 67.42 | 151.70 |

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

Tangential Shear in Shell 6.49 | 121.36 |

Circ. Stress at Horn of Saddle 3.21 | 189.62 |

Circ. Compressive Stress in Shell 0.33 | 151.70 |

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

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

Saddle Reaction Force due to Wind Ft [Fwt]:

= Ftr \* ( Ft/Num of Saddles + Z Force Load ) \* B / E

= 3.0 \* ( 51.8/2 + 0 ) \* 448.0/231.2548

= 150.5 Kgf

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

= max( Fl, Friction Load, Sum of X Forces) \* B / Ls

= max( 3.29, 0.0, 0 ) \* 448.0/4327.5

= 0.3 Kgf

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

= max( Fl, Friction Force, Sum of X Forces ) \* B / Ls

= max( 93.92, 0.0, 0 ) \* 448.0/4327.5

= 9.7 Kgf

Saddle Reaction Force due to Earthquake Ft [Fst]:

= Ftr \* ( Ft/Num of Saddles + Z Force Load ) \* B / E

= 3.0 \* ( 94/2 + 0 ) \* 448.0/231.2548

= 272.9 Kgf

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

= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )

= 251 + Max( 0.3, 150, 10, 273 )

= 523.7 Kgf

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight) 548.98 Kgf

Transverse Shear Load Saddle 46.96 Kgf

Longitudinal Shear Load Saddle 93.92 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 Rm / 2.

Moment per Equation 4.15.3 [M1]:

= -Q\*a [1 - (1- a/L + (R²-h2²)/(2a\*L))/(1+(4h2)/3L)]

= -524\*200.0[1-(1-200.0/3178.0+(133.515²-0.0²)/

(2\*200.0\*3178.0))/(1+(4\*0.0)/(3\*3178.0))]

= -5.1 Kg-m.

Moment per Equation 4.15.4 [M2]:

= Q\*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L

= 524\*3178/4(1+2(134²-0²)/(3178²))/(1+(4\*0)/

(3\*3178))-4\*200/3178

= 312.8 Kg-m.

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

= P \* Rm/(2t) - M2/(pi\*Rm²t)

= 62.001 \* 133.515/(2\*4.98) - 312.8/(pi\*133.5²\*4.98)

= 72.12 N./mm²

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

= P \* Rm/(2t) + M2/(pi \* Rm² \* t)

= 62.001 \* 133.515/(2 \* 4.98) + 312.8/(pi \* 133.5² \* 4.98 )

= 94.12 N./mm²

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

= P \* Rm/(2t) - M1/(K1\*pi\*Rm²t)

= 62.001\*133.515/(2\*6.07)--5.1/(0.1066\*pi\*133.5²\*6.07)

= 69.58 N./mm²

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

= P \* Rm/(2t) + M1/(K1\* \* pi \* Rm² \* t)

= 62.001\*133.515/(2\*6.07)+-5.1/(0.1923\*pi\*133.5²\*6.07)

= 67.42 N./mm²

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

= Q(L-2a)/(L+(4\*h2/3))

= 524( 3178.0 - 2 \* 200.0)/(3178.0 + ( 4 \* 0.0/3))

= 457.8 Kgf

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

= K2 \* T / ( Rm \* t )

= 1.1707 \* 457.79/( 133.515 \* 6.07 )

= 6.49 N./mm²

Decay Length (4.15.22) [x1,x2]:

= 0.78 \* sqrt( Rm \* t )

= 0.78 \* sqrt( 133.515 \* 6.07 )

= 22.205 mm.

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

= -K5 \* Q \* k / ( t \* ( b + X1 + X2 ) )

= - 0.7603 \* 524 \* 0.1/( 6.07 \* ( 150.0 + 22.21 + 22.21 ) )

= -0.33 N./mm²

Effective reinforcing plate width (4.15.1) [B1]:

= min( b + 1.56 \* sqrt( Rm \* t ), 2a )

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

= 194.41 mm.

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

= min( Sr/S, 1 )

= min( 95.151/151.7, 1 )

= 0.6272

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

= -K5 \* Q \* k / ( B1( t + eta \* tr ) )

= - 0.7603 \* 524 \* 0.1/( 194.41( 6.07 + 0.627 \* 10.0 ) )

= -0.16 N./mm²

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

= -Q/(4(t+eta\*tr)b1) - 3\*K7\*Q/(2(t+eta\*tr)²)

= -524/(4(6.07 + 0.627 \* 10.0)194.41) -

3 \* 0.053 \* 524/(2(6.07 + 0.627 \* 10.0)²)

= -3.21 N./mm²

**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. | 291. | 162. | 29. | 471552. | 0.969E+04 |

BasePlate 180. | 10. | 313. | 18. | 562536. | 0.176E+05 |

Totals ... | ... | ... | 82. | 1060721. | 0.273E+05 |

Value C1 = Sumof(Ay)/Sumof(A) = 129. mm.

Value I = Sumof(Io) - C1\*Sumof(Ay) = 0.136E+05 cm\*\*4

Value As = Sumof(A) - Ashell = 67.1 cm²

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

Fh = K1 \* Q = 0.2035 \* 523.701 = 106.5845 Kgf

Tension Stress, St = ( Fh/As ) = 0.1557 N./mm²

Allowed Stress, Sa = 0.6 \* Yield Str = 143.9676 N./mm²

Saddle Splitting Dimension [d]:

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

= 448.0 - 130.48 \* sin( 1.0472 )/1.0472

= 340.094 mm.

Bending Moment, M = Fh \* d = 36.2495 Kg-m.

Bending Stress, Sb = ( M \* C1 / I ) = 0.3390 N./mm²

Allowed Stress, Sa = 2/3 \* Yield Str = 159.9640 N./mm²

**Minimum Thickness of Baseplate per Moss:**

= ( 3( Q + Saddle\_Wt )BasePlateWidth / ( 2 \* BasePlateLength \* AllStress ))½

= ( 3(524 + 25)180.0/( 2 \* 250.0 \* 159.964 ))½

= 6.029 mm.

**Calculation of Axial Load, Intermediate Values and Compressive Stress:**

Distance between Ribs [e]:

= Web Length / ( Nribs - 1 )

= 259.3746/( 2 - 1 )

= 259.375 mm.

Baseplate Pressure Area [Ap]:

= e \* Bpwid / 2

= 259.3746 \* 180.0/2

= 233.437 cm²

Axial Load [P]:

= Ap \* Bp

= 233.4 \* 1.16

= 271.670 Kgf

Area of the Rib and Web [Ar]:

= Rib Area + Web Area

= 14.0 + 12.969

= 26.969 cm²

Compressive Stress [Sc]:

= P/Ar

= 271.7/26.9687

= 0.988 N./mm²

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]:

= Fl /( 2 \* Bplen ) \* e \* rl / 2

= 93.9/( 2 \* 250.0 ) \* 259.375 \* 363.13/2

= 8.846 Kg-m.

Compressive Allowable, KL/R < Cc ( 7.645 < 128.2549 ) per AISC E2-1 [Sca]:

= (1-(Klr)²/(2\*Cc²))\*Fy/(5/3+3\*(Klr)/(8\*Cc)-(Klr³)/(8\*Cc³)

= ( 1-( 7.64 )²/(2 \* 128.25² )) \* 240/

( 5/3+3\*(7.64)/(8\* 128.25)-( 7.64³)/(8\*128.25³)

= 141.812 N./mm²

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

= Sc/Sca + ( Rm \* Distance Side/I )/Sba

= 0.99/141.81 + ( 8.85 \* 106.066/6084409 )/159.96

= 0.016

**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./mm²

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./mm²

Area Available in a Single Bolt BltArea 0.8129 cm²

Saddle Load QO (Weight) QO 276.1 Kgf

Saddle Load QL (Wind/Seismic contribution) QL 9.7 Kgf

Maximum Transverse Force Ft 47.0 Kgf

Maximum Longitudinal Force Fl 93.9 Kgf

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]:

= Fl / (Stba \* Nbolts)

= 93.92/(172.38 \* 2.0)

= 0.0267 cm²

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

= B \* Ft + Sum of X Moments

= 448.0 \* 46.96 + 0.0

= 21.04 Kg-m.

Eccentricity (e):

= Rmom / QO

= 21.04/276.06

= 76.21 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis

= 250.0/2 - 80.01

= 44.99 mm.

Modular Ratio Of Steel/Concrete (n1):

= ES / EC

= 203402.5/21526.32

= 9.45

K1 = 3 (e - 0.5 \* Bplen)

= 3 (76.21 - 0.5\*250.0)

= -146.38 mm.

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

= 6 \* 9.45 \* 0.81/180.0 \* (44.99 + 76.21)

= 3103.13 mm.²

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

= -3103.13 \* (0.5 \* 250.0 + 44.99)

= -527500.40 mm.³

Iteratively Solving for the Effective Bearing Length:

Y³ + K1 \* Y² + K2 \* Y + K3 = 0

Y³ + -146.38 \* Y² + 3103.13 \* Y + -527500.38 = 0

Y = 149.26 mm.

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

= (250.0/2 - 149.26/3 - 76.21)

= -0.96

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

= (250.0/2 - 149.26/3 + 44.99)

= 120.24

Total Bolt Tension Force [Tforce]:

= - QO \* Num / Denom

= - 276.06 \* -0.96/120.24

= 2.21 Kgf

Bolt Area Required due to Transverse Load [Bltareart]:

= Tforce / (Stba \* Nbt)

= 2.21/( 172.38 \* 1.0 )

= 0.0013 cm²

Required Area of a Single Bolt [Bltarear]:

= max[Bltarearl, Bltarears, Bltareart]

= max[0.0, 0.0267, 0.0013]

= 0.0267 cm²

**Baseplate Thickness Calculation per D. Moss:**

Bearing Pressure (fc)

= 2(QO + Tforce) / (Y \* Bpwid)

= 2(276.06 + 2.21)/(149.26 \* 180.0)

= 2.03 bars

Distance from Baseplate Edge to the Web [ADIST]:

= (Bplen - Weblngth) / 2

= (250.0 - 199.2)/2

= 25.4000 mm.

Overturning Moment due To Bolt Tension [Mt]:

= Tforce \* Adist

= 2.21 \* 25.4

= 0.06 Kg-m.

Equivalent Bearing Pressure (f1):

= fc \* (Y - Adist) / Y

= 2.03 \* (149.26 - 25.4)/149.26

= 1.69 bars

Overturning Moment due to Bearing Pressure [Mc]:

= (Adist² \* Bpwid / 6) \* (f1 + 2 \* fc)

= (25.4² \* 180.0/6) \* (1.69 + 2 \* 2.03)

= 1.13 Kg-m.

Baseplate Required Thickness [Treq]:

= (6 \* max(Mt,Mc) / (Bpwid \* Sba))½

= (6 \*max( 0.06,1.13/(180.0 \* 142.73))½

= 1.6120 mm.

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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 3178.00 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./mm²

Shell Allowable Stress used in Calculation 1326.66 N./mm²

Head Allowable Stress used in Calculation 1326.66 N./mm²

Circumferential Efficiency in Plane of Saddle 1.00

Circumferential Efficiency at Mid-Span 1.00

Saddle Force Q, Test Case, no Ext. Forces 403.68 Kgf

Horizontal Vessel Analysis Results: Actual | Allowable |

N./mm² | N./mm² |

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

Long. Stress at Top of Midspan 51.70 | 1326.66 |

Long. Stress at Bottom of Midspan 68.22 | 1326.66 |

Long. Stress at Top of Saddles 61.37 | 1326.66 |

Long. Stress at Bottom of Saddles 59.18 | 1326.66 |

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

Tangential Shear in Shell 4.70 | 1061.33 |

Circ. Stress at Horn of Saddle 4.44 | 1989.99 |

Circ. Compressive Stress in Shell 0.19 | 1326.66 |

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

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

Saddle Reaction Force due to Wind Ft [Fwt]:

= Ftr \* ( Ft/Num of Saddles + Z Force Load ) \* B / E

= 3.0 \* ( 17.1/2 + 0 ) \* 493.0/182.6621

= 69.2 Kgf

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

= max( Fl, Friction Load, Sum of X Forces) \* B / Ls

= max( 0.7, 0.0, 0 ) \* 493.0/4327.5

= 0.1 Kgf

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

= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )

= 334 + Max( 0.1, 69, 0, 0 )

= 403.7 Kgf

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight) 429.08 Kgf

Transverse Shear Load Saddle 8.54 Kgf

Longitudinal Shear Load Saddle 0.70 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 Rm / 2.

Moment per Equation 4.15.3 [M1]:

= -Q\*a [1 - (1- a/L + (R²-h2²)/(2a\*L))/(1+(4h2)/3L)]

= -404\*200.0[1-(1-200.0/3178.0+(105.46²-0.0²)/

(2\*200.0\*3178.0))/(1+(4\*0.0)/(3\*3178.0))]

= -4.4 Kg-m.

Moment per Equation 4.15.4 [M2]:

= Q\*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L

= 404\*3178/4(1+2(105²-0²)/(3178²))/(1+(4\*0)/

(3\*3178))-4\*200/3178

= 240.7 Kg-m.

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

= P \* Rm/(2t) - M2/(pi\*Rm²t)

= 93.01 \* 105.46/(2\*8.18) - 240.7/(pi\*105.5²\*8.18)

= 51.70 N./mm²

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

= P \* Rm/(2t) + M2/(pi \* Rm² \* t)

= 93.01 \* 105.46/(2 \* 8.18) + 240.7/(pi \* 105.5² \* 8.18 )

= 68.22 N./mm²

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

= P \* Rm/(2t) - M1/(K1\*pi\*Rm²t)

= 93.01\*105.46/(2\*8.18)--4.4/(0.1066\*pi\*105.5²\*8.18)

= 61.37 N./mm²

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

= P \* Rm/(2t) + M1/(K1\* \* pi \* Rm² \* t)

= 93.01\*105.46/(2\*8.18)+-4.4/(0.1923\*pi\*105.5²\*8.18)

= 59.18 N./mm²

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

= Q(L-2a)/(L+(4\*h2/3))

= 404( 3178.0 - 2 \* 200.0)/(3178.0 + ( 4 \* 0.0/3))

= 352.9 Kgf

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

= K2 \* T / ( Rm \* t )

= 1.1707 \* 352.87/( 105.46 \* 8.18 )

= 4.70 N./mm²

Decay Length (4.15.22) [x1,x2]:

= 0.78 \* sqrt( Rm \* t )

= 0.78 \* sqrt( 105.46 \* 8.18 )

= 22.909 mm.

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

= -K5 \* Q \* k / ( t \* ( b + X1 + X2 ) )

= - 0.7603 \* 404 \* 0.1/( 8.18 \* ( 150.0 + 22.91 + 22.91 ) )

= -0.19 N./mm²

Effective reinforcing plate width (4.15.1) [B1]:

= min( b + 1.56 \* sqrt( Rm \* t ), 2a )

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

= 195.82 mm.

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

= min( Sr/S, 1 )

= min( 108.252/1326.663, 1 )

= 0.0816

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

= -K5 \* Q \* k / ( B1( t + eta \* tr ) )

= - 0.7603 \* 404 \* 0.1/( 195.819( 8.18 + 0.082 \* 10.0 ) )

= -0.17 N./mm²

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

= -Q/(4(t+eta\*tr)b1) - 3\*K7\*Q/(2(t+eta\*tr)²)

= -404/(4(8.18 + 0.082 \* 10.0)195.819) -

3 \* 0.053 \* 404/(2(8.18 + 0.082 \* 10.0)²)

= -4.44 N./mm²

**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. | 363. | 200. | 36. | 726555. | 0.185E+05 |

BasePlate 180. | 10. | 387. | 18. | 695934. | 0.269E+05 |

Totals ... | ... | ... | 94. | 1457043. | 0.455E+05 |

Value C1 = Sumof(Ay)/Sumof(A) = 154. mm.

Value I = Sumof(Io) - C1\*Sumof(Ay) = 0.230E+05 cm\*\*4

Value As = Sumof(A) - Ashell = 74.3 cm²

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

Fh = K1 \* Q = 0.2035 \* 403.684 = 82.1584 Kgf

Tension Stress, St = ( Fh/As ) = 0.1084 N./mm²

Allowed Stress, Sa = 0.6 \* Yield Str = 124.1100 N./mm²

Saddle Splitting Dimension [d]:

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

= 493.0 - 101.37 \* sin( 1.0472 )/1.0472

= 409.168 mm.

Bending Moment, M = Fh \* d = 33.6172 Kg-m.

Bending Stress, Sb = ( M \* C1 / I ) = 0.2215 N./mm²

Allowed Stress, Sa = 2/3 \* Yield Str = 137.9000 N./mm²

**Minimum Thickness of Baseplate per Moss:**

= ( 3( Q + Saddle\_Wt )BasePlateWidth / ( 2 \* BasePlateLength \* AllStress ))½

= ( 3(404 + 25)180.0/( 2 \* 250.0 \* 137.9 ))½

= 5.741 mm.

**Calculation of Axial Load, Intermediate Values and Compressive Stress:**

Distance between Ribs [e]:

= Web Length / ( Nribs - 1 )

= 207.0667/( 2 - 1 )

= 207.067 mm.

Baseplate Pressure Area [Ap]:

= e \* Bpwid / 2

= 207.0667 \* 180.0/2

= 186.360 cm²

Axial Load [P]:

= Ap \* Bp

= 186.4 \* 0.9

= 167.179 Kgf

Area of the Rib and Web [Ar]:

= Rib Area + Web Area

= 14.0 + 10.353

= 24.353 cm²

Compressive Stress [Sc]:

= P/Ar

= 167.2/24.3533

= 0.673 N./mm²

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]:

= Fl /( 2 \* Bplen ) \* e \* rl / 2

= 0.7/( 2 \* 250.0 ) \* 207.067 \* 423.22/2

= 0.061 Kg-m.

Compressive Allowable, KL/R < Cc ( 8.792 < 138.1347 ) per AISC E2-1 [Sca]:

= (1-(Klr)²/(2\*Cc²))\*Fy/(5/3+3\*(Klr)/(8\*Cc)-(Klr³)/(8\*Cc³)

= ( 1-( 8.79 )²/(2 \* 138.13² )) \* 207/

( 5/3+3\*(8.79)/(8\* 138.13)-( 8.79³)/(8\*138.13³)

= 122.112 N./mm²

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

= Sc/Sca + ( Rm \* Distance Side/I )/Sba

= 0.67/122.11 + ( 0.06 \* 101.885/5643196 )/137.9

= 0.006

**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./mm²

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./mm²

Area Available in a Single Bolt BltArea 0.8129 cm²

Saddle Load QO (Weight) QO 359.9 Kgf

Saddle Load QL (Wind/Seismic contribution) QL 0.1 Kgf

Maximum Transverse Force Ft 8.5 Kgf

Maximum Longitudinal Force Fl 1.1 Kgf

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]:

= Fl / (Stba \* Nbolts)

= 1.09/(172.38 \* 2.0)

= 0.0003 cm²

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

= B \* Ft + Sum of X Moments

= 493.0 \* 8.54 + 0.0

= 4.21 Kg-m.

Eccentricity (e):

= Rmom / QO

= 4.21/359.9

= 11.70 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, 0.0003, 0.0]

= 0.0003 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 3178.00 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./mm²

Head Allowable Stress used in Calculation 1201.94 N./mm²

Circumferential Efficiency in Plane of Saddle 1.00

Circumferential Efficiency at Mid-Span 1.00

Saddle Force Q, Test Case, no Ext. Forces 511.16 Kgf

Horizontal Vessel Analysis Results: Actual | Allowable |

N./mm² | N./mm² |

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

Long. Stress at Top of Midspan 68.31 | 1201.94 |

Long. Stress at Bottom of Midspan 81.70 | 1201.94 |

Long. Stress at Top of Saddles 67.10 | 1201.94 |

Long. Stress at Bottom of Saddles 65.68 | 1201.94 |

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

Tangential Shear in Shell 4.19 | 961.55 |

Circ. Stress at Horn of Saddle 5.29 | 1802.90 |

Circ. Compressive Stress in Shell 0.20 | 1201.94 |

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

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

Saddle Reaction Force due to Wind Ft [Fwt]:

= Ftr \* ( Ft/Num of Saddles + Z Force Load ) \* B / E

= 3.0 \* ( 17.1/2 + 0 ) \* 448.0/228.4835

= 50.3 Kgf

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

= max( Fl, Friction Load, Sum of X Forces) \* B / Ls

= max( 1.09, 0.0, 0 ) \* 448.0/4327.5

= 0.1 Kgf

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

= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )

= 461 + Max( 0.1, 50, 0, 0 )

= 511.2 Kgf

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight) 536.44 Kgf

Transverse Shear Load Saddle 8.54 Kgf

Longitudinal Shear Load Saddle 1.09 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 + (R²-h2²)/(2a\*L))/(1+(4h2)/3L)]

= -511\*200.0[1-(1-200.0/3178.0+(131.915²-0.0²)/

(2\*200.0\*3178.0))/(1+(4\*0.0)/(3\*3178.0))]

= -5.0 Kg-m.

Moment per Equation 4.15.4 [M2]:

= Q\*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L

= 511\*3178/4(1+2(132²-0²)/(3178²))/(1+(4\*0)/

(3\*3178))-4\*200/3178

= 305.3 Kg-m.

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

= P \* Rm/(2t) - M2/(pi\*Rm²t)

= 93.013 \* 131.915/(2\*8.18) - 305.3/(pi\*131.9²\*8.18)

= 68.31 N./mm²

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

= P \* Rm/(2t) + M2/(pi \* Rm² \* t)

= 93.013 \* 131.915/(2 \* 8.18) + 305.3/(pi \* 131.9² \* 8.18 )

= 81.70 N./mm²

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

= P \* Rm/(2t) - M1/(K1\*pi\*Rm²t)

= 93.013\*131.915/(2\*9.27)--5.0/(0.1066\*pi\*131.9²\*9.27)

= 67.10 N./mm²

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

= P \* Rm/(2t) + M1/(K1\* \* pi \* Rm² \* t)

= 93.013\*131.915/(2\*9.27)+-5.0/(0.1923\*pi\*131.9²\*9.27)

= 65.68 N./mm²

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

= Q(L-2a)/(L+(4\*h2/3))

= 511( 3178.0 - 2 \* 200.0)/(3178.0 + ( 4 \* 0.0/3))

= 446.8 Kgf

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

= K2 \* T / ( Rm \* t )

= 1.1707 \* 446.82/( 131.915 \* 9.27 )

= 4.19 N./mm²

Decay Length (4.15.22) [x1,x2]:

= 0.78 \* sqrt( Rm \* t )

= 0.78 \* sqrt( 131.915 \* 9.27 )

= 27.276 mm.

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

= -K5 \* Q \* k / ( t \* ( b + X1 + X2 ) )

= - 0.7603 \* 511 \* 0.1/( 9.27 \* ( 150.0 + 27.28 + 27.28 ) )

= -0.20 N./mm²

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

= -Q/(4\*t\*(b+X1+X2)) - 3\*K7\*Q/(2\*t²)

= -511/(4\*9.27\*(150.0+27.276+27.276)) -

3\* 0.0529\*511/(2\*9.27²)

= -5.29 N./mm²

Effective reinforcing plate width (4.15.1) [B1]:

= min( b + 1.56 \* sqrt( Rm \* t ), 2a )

= min( 150.0 + 1.56 \* sqrt( 131.915 \* 9.27 ), 2 \* 200.0 )

= 204.55 mm.

**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. | 291. | 165. | 29. | 480878. | 0.100E+05 |

BasePlate 180. | 10. | 316. | 18. | 568296. | 0.179E+05 |

Totals ... | ... | ... | 91. | 1088610. | 0.280E+05 |

Value C1 = Sumof(Ay)/Sumof(A) = 120. mm.

Value I = Sumof(Io) - C1\*Sumof(Ay) = 0.149E+05 cm\*\*4

Value As = Sumof(A) - Ashell = 67.1 cm²

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

Fh = K1 \* Q = 0.2035 \* 511.156 = 104.0314 Kgf

Tension Stress, St = ( Fh/As ) = 0.1519 N./mm²

Allowed Stress, Sa = 0.6 \* Yield Str = 143.9676 N./mm²

Saddle Splitting Dimension [d]:

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

= 448.0 - 127.28 \* sin( 1.0472 )/1.0472

= 342.740 mm.

Bending Moment, M = Fh \* d = 35.6565 Kg-m.

Bending Stress, Sb = ( M \* C1 / I ) = 0.2815 N./mm²

Allowed Stress, Sa = 2/3 \* Yield Str = 159.9640 N./mm²

**Minimum Thickness of Baseplate per Moss:**

= ( 3( Q + Saddle\_Wt )BasePlateWidth / ( 2 \* BasePlateLength \* AllStress ))½

= ( 3(511 + 25)180.0/( 2 \* 250.0 \* 159.964 ))½

= 5.960 mm.

**Calculation of Axial Load, Intermediate Values and Compressive Stress:**

Distance between Ribs [e]:

= Web Length / ( Nribs - 1 )

= 253.8321/( 2 - 1 )

= 253.832 mm.

Baseplate Pressure Area [Ap]:

= e \* Bpwid / 2

= 253.8321 \* 180.0/2

= 228.449 cm²

Axial Load [P]:

= Ap \* Bp

= 228.4 \* 1.14

= 259.496 Kgf

Area of the Rib and Web [Ar]:

= Rib Area + Web Area

= 14.0 + 12.692

= 26.692 cm²

Compressive Stress [Sc]:

= P/Ar

= 259.5/26.6916

= 0.953 N./mm²

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]:

= Fl /( 2 \* Bplen ) \* e \* rl / 2

= 1.1/( 2 \* 250.0 ) \* 253.832 \* 364.73/2

= 0.101 Kg-m.

Compressive Allowable, KL/R < Cc ( 7.6661 < 128.2549 ) per AISC E2-1 [Sca]:

= (1-(Klr)²/(2\*Cc²))\*Fy/(5/3+3\*(Klr)/(8\*Cc)-(Klr³)/(8\*Cc³)

= ( 1-( 7.67 )²/(2 \* 128.25² )) \* 240/

( 5/3+3\*(7.67)/(8\* 128.25)-( 7.67³)/(8\*128.25³)

= 141.806 N./mm²

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

= Sc/Sca + ( Rm \* Distance Side/I )/Sba

= 0.95/141.81 + ( 0.1 \* 105.662/6041733 )/159.96

= 0.007

**Input Data for Base Plate Bolting Calculations:**

Total Number of Bolts per BasePlate Nbolts 2

Total Number of Bolts in Tension/Baseplate Nbt 1

Bolt Material Specification SA-193 B7

Bolt Allowable Stress Stba 172.38 N./mm²

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./mm²

Area Available in a Single Bolt BltArea 0.8129 cm²

Saddle Load QO (Weight) QO 486.2 Kgf

Saddle Load QL (Wind/Seismic contribution) QL 0.1 Kgf

Maximum Transverse Force Ft 8.5 Kgf

Maximum Longitudinal Force Fl 1.1 Kgf

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]:

= Fl / (Stba \* Nbolts)

= 1.09/(172.38 \* 2.0)

= 0.0003 cm²

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

= B \* Ft + Sum of X Moments

= 448.0 \* 8.54 + 0.0

= 3.83 Kg-m.

Eccentricity (e):

= Rmom / QO

= 3.83/486.17

= 7.87 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, 0.0003, 0.0]

= 0.0003 cm²

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