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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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|  |  |  |  |  |  |  |
| 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** |
| **Class: 2** | |  | | | | |
| **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 |  |  |  |  |  |  |  |
| 2 | X |  |  |  |  |  |  |  |
| 3 | X |  |  |  |  |  |  |  |
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| 5 | X |  |  |  |  |  |  |  |
| 6 | X |  |  |  |  |  |  |  |
| 7 | X |  |  |  |  |  |  |  |
| 8 | X |  |  |  |  |  |  |  |
| 9 | X |  |  |  |  |  |  |  |
| 10 | X |  |  |  |  |  |  |  |
| 11 | X |  |  |  |  |  |  |  |
| 12 | X |  |  |  |  |  |  |  |
| 13 | X |  |  |  |  |  |  |  |
| 14 | X |  |  |  |  |  |  |  |
| 15 | X |  |  |  |  |  |  |  |
| 16 | X |  |  |  |  |  |  |  |
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| 18 | X |  |  |  |  |  |  |  |
| 19 | X |  |  |  |  |  |  |  |
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| 22 | X |  |  |  |  |  |  |  |
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| 25 | X |  |  |  |  |  |  |  |
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| 29 | X |  |  |  |  |  |  |  |
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| 33 | X |  |  |  |  |  |  |  |
| 34 | X |  |  |  |  |  |  |  |
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| 36 | X |  |  |  |  |  |  |  |
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| 39 | X |  |  |  |  |  |  |  |
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| 42 | X |  |  |  |  |  |  |  |
| 43 | X |  |  |  |  |  |  |  |
| 44 | X |  |  |  |  |  |  |  |
| 45 | X |  |  |  |  |  |  |  |
| 46 | X |  |  |  |  |  |  |  |
| 47 | X |  |  |  |  |  |  |  |
| 48 | X |  |  |  |  |  |  |  |
| 49 | X |  |  |  |  |  |  |  |
| 50 | X |  |  |  |  |  |  |  |

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

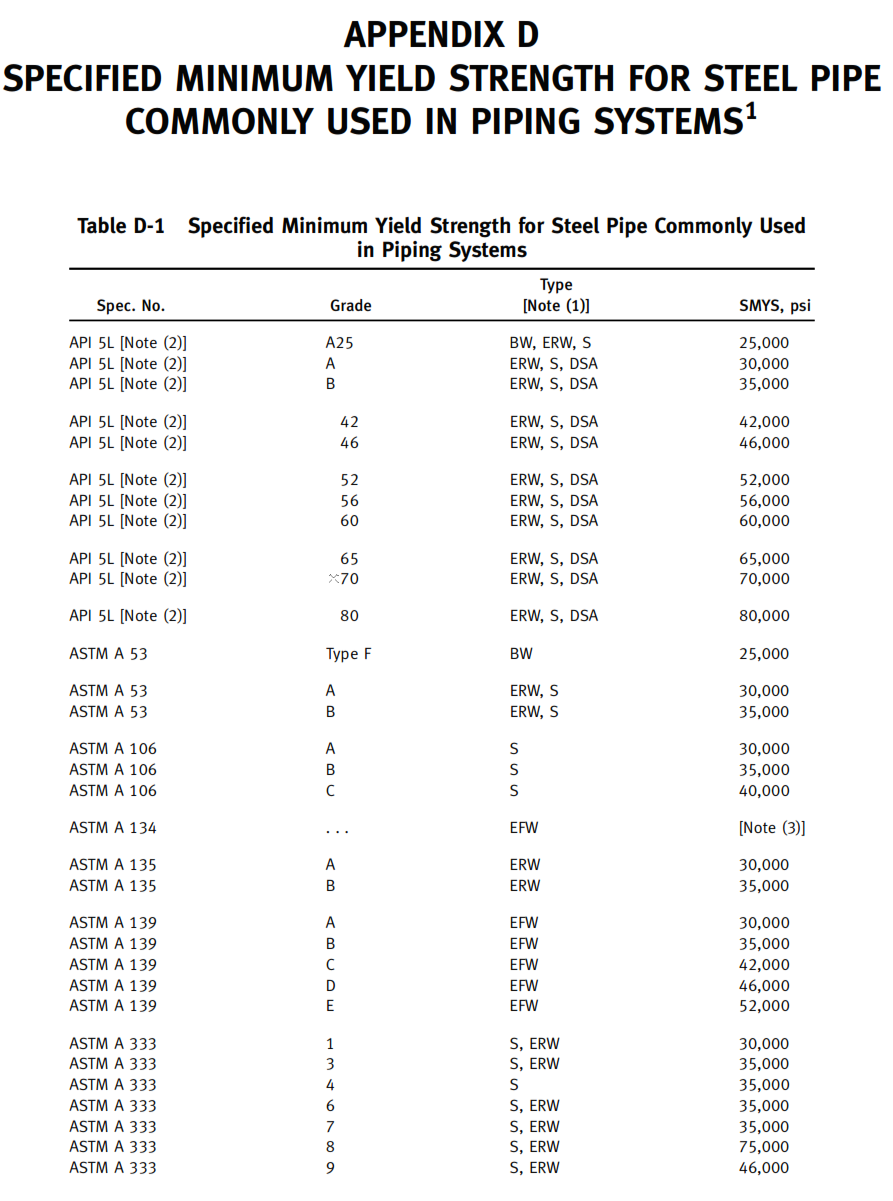
***F =*** Design factor obtained from Table 841.114A. In setting the values of the design factor, F, due consideration has been given and allowance has been made for the various under thickness toler­ances provided for in the pipe specifications listed and approved for usage in this Code.

***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): | 0.72 |
| 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 = 3.28 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 =2.64 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 =2.64 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 =1.04 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 =0.6 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 | 8.93254 |

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

Total | 374 | 260536.75 | 261 | 275080.16 | 18 |

**Weight of Details:**

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

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

| | kg. | mm. | mm. |

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

20|Sadl| 27.0234 | 1000 | 288.095 | Left Saddle

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

40|Sadl| 26.8849 | 2000 | 278.005 | RIGHT SADDLE

40|Nozl| 6.49327 | 300 | 157.443 | V1

40|Nozl| 6.49327 | 600 | 157.443 | A

40|Nozl| 6.15909 | 2400 | 157.443 | PSV

40|Nozl| 6.15908 | 2700 | 157.443 | P

40|Nozl| 6.15908 | 2400 | 157.443 | D1

40|Wght| 400 | 3000 | ... | QOC

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

**Total Weight of Each Detail Type:**

Saddles 53.9

Nozzles 61.7

Weights 400.0

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

Sum of the Detail Weights 515.6 kg.

**Weight Summation Results: (kg.)**

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

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

Main Elements | 393.3 | 393.3 | 393.3 | 393.3 | 393.3 | 393.3 |

Saddles | 53.9 | 53.9 | 53.9 | 53.9 | 53.9 | 53.9 |

Nozzles | 61.7 | 61.7 | 61.7 | 61.7 | 61.7 | 61.7 |

Ope Weights | ... | ... | ... | ... | ... | 400.0 |

Test Liquid | ... | 260.4 | ... | ... | ... | ... |

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

Totals | 508.9 | 769.3 | 508.9 | 508.9 | 508.9 | 908.9 |

**Miscellaneous Weight Percent: 5.0 %**

*Note that the above value for the miscellaneous weight percent has*

*been applied to the shells/heads/flange/tubesheets/tubes etc. in the*

*weight calculations for metallic components.*

**Weight Summary:**

Fabricated Wt. - Bare Weight without Removable Internals 508.9 kg.

Shop Test Wt. - Fabricated Weight + Water ( Full ) 769.3 kg.

Shipping Wt. - Fab. Weight + removable Intls.+ Shipping App. 508.9 kg.

Erected Wt. - Fab. Wt + or - loose items (trays,platforms etc.) 508.9 kg.

Ope. Wt. no Liq - Fab. Weight + Internals. + Details + Weights 508.9 kg.

Operating Wt. - Empty Weight + Operating Liq. Uncorroded 908.9 kg.

Oper. Wt. + CA - Corr Wt. + Operating Liquid 789.7 kg.

Field Test Wt. - Empty Weight + Water (Full) 769.3 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] 110 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]:

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

= max( 16, 0.00256 \* 0.849 \* 1.0 \* 0.95 \* 68.353² )

= 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 0.00 493.00 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 1.400

Short Period Acceleration value Ss 1.000

Long Period Acceleration Value Sl 0.400

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

User Value of Sd1 (used if > 0 ) 0.000

**Seismic Analysis Results:**

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

Sm1 = Fv \* S1 = 1.4 \* 0.4 = 0.56

Sds = 2/3 \* Sms = 2/3 \* 1.0 = 0.667

Sd1 = 2/3 \* Sm1 = 2/3 \* 0.56 = 0.373

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 \* 0.667 \* 790 \* 1.25

= 197.415 Kgf

Final Base Shear, V = 138.19 Kgf

**Earthquake Load Calculation:**

| | Earthquake | Earthquake | Element |

From| To | Height | Weight | Ope Load |

| | mm. | Kgf | Kgf |

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

10| 20| 101.346 | 131.61 | 21.4465 |

20| 30| 101.37 | 131.61 | 21.4515 |

20| 30| 101.37 | 131.61 | 21.4515 |

30| 40| 94.3784 | 131.61 | 19.972 |

40| 0| 127.28 | 131.61 | 26.9345 |

40| 50| 127.28 | 131.61 | 26.9345 |

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

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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# Saddle

## Operating Case

**ASME Horizontal Vessel Analysis: Stresses for the Left Saddle**

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

Horizontal Vessel Stress Calculations : Operating Case

**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 591.04 Kgf

Horizontal Vessel Analysis Results: Actual | Allowable |

N./mm² | N./mm² |

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

Long. Stress at Top of Midspan 47.37 | 151.70 |

Long. Stress at Bottom of Midspan 85.92 | 151.70 |

Long. Stress at Top of Saddles 69.92 | 151.70 |

Long. Stress at Bottom of Saddles 64.84 | 151.70 |

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

Tangential Shear in Shell 11.13 | 121.36 |

Circ. Stress at Horn of Saddle 3.77 | 189.62 |

Circ. Stress at Tip of Wear Plate 16.79 | 189.62 |

Circ. Compressive Stress in Shell 0.48 | 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 ) \* 493.0/207.0667

= 184.9 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( 138.19, 0.0, 0 ) \* 493.0/4327.5

= 15.7 Kgf

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

= 3.0 \* ( 138/2 + 0 ) \* 493.0/207.0667

= 493.5 Kgf

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

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

= 98 + Max( 0.2, 185, 16, 494 )

= 591.0 Kgf

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

Vertical Load (including saddle weight) 618.06 Kgf

Transverse Shear Load Saddle Ft 69.10 Kgf

Longitudinal Shear Load Saddle 138.19 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)]

= -591\*200.0[1-(1-200.0/3178.0+(107.06²-0.0²)/

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

= -6.4 Kg-m.

Moment per Equation 4.15.4 [M2]:

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

= 591\*3178/4(1+2(107²-0²)/(3178²))/(1+(4\*0)/

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

= 352.4 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) - 352.4/(pi\*107.1²\*4.98)

= 47.37 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) + 352.4/(pi \* 107.1² \* 4.98 )

= 85.92 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)--6.4/(0.1066\*pi\*107.1²\*4.98)

= 69.92 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)+-6.4/(0.1923\*pi\*107.1²\*4.98)

= 64.84 N./mm²

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

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

= 591( 3178.0 - 2 \* 200.0)/(3178.0 + ( 4 \* 0.0/3))

= 516.6 Kgf

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

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

= 1.1707 \* 516.65/( 107.06 \* 4.98 )

= 11.13 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 \* 591 \* 0.1/( 4.98 \* ( 150.0 + 18.01 + 18.01 ) )

= -0.48 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 Saddle Base with Wear Plate (4.15.26) [sigma6,r]:

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

= - 0.7603 \* 591 \* 0.1/( 186.021( 4.98 + 0.714 \* 10.0 ) )

= -0.20 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)

= -591/(4(4.98 + 0.714 \* 10.0)186.021) -

3 \* 0.053 \* 591/(2(4.98 + 0.714 \* 10.0)²)

= -3.77 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)

= -591/(4 \* 4.98\*(150.0 + 18.01 + 18.01)) -

3 \* 0.0434 \* 591/(2 \* 4.98²)

= -16.79 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 15.0000 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

Saddle Yield Stress Sy 206.9 N./

Height of Web at Center Hw,c 309.5 mm.

Friction Coefficient mu 0.000

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

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

B | D | Y | A | AY | Io |

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

Shell 235.6 | 5.0 | 2.5 | 11.7 | 2921.5 | 0.390E+04 |

Wearplate 200.0 | 10.0 | 10.0 | 20.0 | 19960.0 | 0.611E+04 |

Web 10.0 | 358.4 | 194.2 | 35.8 | 696127.8 | 0.387E+04 |

BasePlate 180.0 | 15.0 | 380.9 | 27.0 | 1028510.9 | 0.104E+05 |

Totals ... | ... | ... | 94.6 | 1747520.1 | 0.243E+05 |

Distance to Centroid [C1]:

= AY / A

= 688.0/94.578

= 184.771 mm.

Angle [beta]:

= 180 - Saddle Angle/2

= 180 - 120.0/2

= 120.0

Saddle Splitting Coefficient [K1]:

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

= ( 1 + cos(120.0) - 0.5\*sin(120.0)² )/(pi - 2.094 + sin(120.0)cos(120.0) )

= 0.2035

Saddle Splitting Force [Fh]:

= K1 \* Q

= 0.204 \* 591.036

= 120.2887 Kgf

Tension Stress, St = ( Fh/As ) = 0.1424 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 = 48.9009 Kg-m.

Bending Stress, Sb = ( M \* C1 / I ) = 0.3650 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(591 + 27)180.0/( 2 \* 250.0 \* 137.9 ))½

= 6.890 mm.

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

Web Length Dimension [ Web Length ]:

= 2 \* cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )

= 2 \* cos( 90 - 120.0/2 )( 101.37 + 8.18 + 10.0 )

= 207.067 mm.

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 \* 1.31

= 244.768 Kgf

Area of the Rib and Web [Ar]:

= Rib Area + Web Area

= 14.0 + 10.353

= 24.353 cm²

Compressive Stress [Sc]:

= P/Ar

= 244.8/24.3533

= 0.986 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 | 371. |

Web 103.5 | 10.0 | 5.0 | 10.4 | 5176.7 | 193. |

Totals ... | ... | ... | 24.4 | 117176.6 | 564. |

Rib dimension [D]:

= Saddle Width - Web Thickness

= 150.0 - 10.0

= 140.000 mm.

Distance to Centroid from Datum [ytot]:

= AY / A

= 117176.648/24.353

= 48.115 mm.

Distance to Centroid [C1]:

= max( ytot, Saddle Width - ytot )

= max( 48.115, 150.0 - 48.115 )

= 101.885 mm.

Radius of Gyration [r]:

= sqrt( Total Inertia / Total Area )

= sqrt( 564.3/24.353 )

= 48.137 mm.

Length of Outer Rib [L]:

= Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk

= 493.0 - cos( 120.0/2 )( 101.37 + 8.18 + 10.0 ) - 15.0

= 418.225 mm.

Intermediate Term [Cc]:

= sqrt( 2 \* pi² \* Elastic Modulus / Yield Stress )

= sqrt( 2 \* pi² \* 0.19994E+09/206.9 )

= 138.135

Slenderness ratio [KL/r]:

= KL/r

= 1 \* 418.225/48.137

= 8.688

Bending Moment [Rm]:

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

= 138.2/( 2 \* 250.0 ) \* 207.067 \* 418.23/2

= 11.968 Kg-m.

Compressive Allowable, KL/r < Cc ( 8.6881 < 138.1347 ) per AISC E2-1 [Sca]:

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

= ( 1-( 8.69 )²/(2 \* 138.13² ))207/

( 5/3+3\*(8.69)/(8\* 138.13)-( 8.69³)/(8\*138.13³)

= 122.1 N./mm²

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

= Sc/Sca + ( Rm \* C1 / I )/Sba

= 0.99/122.14 + ( 11.97 \* 101.885/5643193 )/137.9

= 0.023

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

Total Number of Bolts per BasePlate Nbolts 2

Total Number of Bolts in Tension/Baseplate Nbt 1

Bolt Material Specification SA-193 B7

Bolt Allowable Stress Stba 172.38 N./mm²

Bolt Corrosion Allowance Bca 0.0 mm.

Distance from Bolts to Edge Edgedis 80.0 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 124.5 Kgf

Saddle Load QL (Wind/Seismic contribution) QL 15.7 Kgf

Maximum Transverse Force Ft 69.1 Kgf

Maximum Longitudinal Force Fl 138.2 Kgf

Saddle Bolted to Steel Foundation No

Shear Stress in a Single Bolt [taub]:

= Shear Force / ( 2 \* Bolt Area \* Number of Bolts )

= 138/( 2 \* 0.81 \* 2 )

= 4.2 N./mm². Must be less than 103.4 N./mm².

**Bolt Area Calculation per Dennis R. Moss**

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

= Fl / (Stba \* Nbolts)

= 138.19/(172.38 \* 2.0)

= 0.0393 cm²

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

= B \* Ft + Sum of X Moments

= 493.0 \* 69.1 + 0.0

= 34.06 Kg-m.

Eccentricity (e):

= Rmom / QO

= 34.06/124.54

= 273.52 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 (273.52 - 0.5\*250.0)

= 445.57 mm.

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

= 6 \* 9.45 \* 0.81/180.0 \* (44.99 + 273.52)

= 8155.13 mm.²

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

= -8155.13 \* (0.5 \* 250.0 + 44.99)

= -1386289.83 mm.³

Iteratively Solving for the Effective Bearing Length:

Y³ + K1 \* Y² + K2 \* Y + K3 = 0

Y³ + 445.57 \* Y² + 8155.13 \* Y + -0.1E+07 = 0

Y = 45.47 mm.

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

= (250.0/2 - 45.47/3 - 273.52)

= -163.68

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

= (250.0/2 - 45.47/3 + 44.99)

= 154.83

Total Bolt Tension Force [Tforce]:

= - QO \* Num / Denom

= - 124.54 \* -163.68/154.83

= 131.66 Kgf

Bolt Area Required due to Transverse Load [Bltareart]:

= Tforce / (Stba \* Nbt)

= 131.66/( 172.38 \* 1.0 )

= 0.0749 cm²

Required Area of a Single Bolt [Bltarear]:

= max[Bltarearl, Bltarears, Bltareart]

= max[0.0, 0.0393, 0.0749]

= 0.0749 cm²

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

Bearing Pressure (fc)

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

= 2(124.54 + 131.66)/(45.47 \* 180.0)

= 6.14 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

= 131.66 \* 25.4

= 3.34 Kg-m.

Equivalent Bearing Pressure (f1):

= fc \* (Y - Adist) / Y

= 6.14 \* (45.47 - 25.4)/45.47

= 2.71 bars

Overturning Moment due to Bearing Pressure [Mc]:

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

= (25.4² \* 180.0/6) \* (2.71 + 2 \* 6.14)

= 2.96 Kg-m.

Baseplate Required Thickness [Treq]:

= (6 \* max(Mt,Mc) / (Bpwid \* Sba))½

= (6 \*max(3.34,2.96/(180.0 \* 162.38))½

= 2.5946 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 1004.09 Kgf

Horizontal Vessel Analysis Results: Actual | Allowable |

N./mm² | N./mm² |

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

Long. Stress at Top of Midspan 62.03 | 151.70 |

Long. Stress at Bottom of Midspan 104.21 | 151.70 |

Long. Stress at Top of Saddles 70.85 | 151.70 |

Long. Stress at Bottom of Saddles 66.72 | 151.70 |

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

Tangential Shear in Shell 12.43 | 121.36 |

Circ. Stress at Horn of Saddle 6.15 | 189.62 |

Circ. Compressive Stress in Shell 0.63 | 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 ) \* 448.0/253.8321

= 137.1 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( 138.19, 0.0, 0 ) \* 448.0/4327.5

= 14.3 Kgf

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

= 3.0 \* ( 138/2 + 0 ) \* 448.0/253.8321

= 365.8 Kgf

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

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

= 638 + Max( 0.3, 137, 14, 366 )

= 1004.1 Kgf

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

Vertical Load (including saddle weight) 1030.97 Kgf

Transverse Shear Load Saddle Ft 69.10 Kgf

Longitudinal Shear Load Saddle 138.19 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)]

= -1004\*200.0[1-(1-200.0/3178.0+(133.515²-0.0²)/

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

= -9.8 Kg-m.

Moment per Equation 4.15.4 [M2]:

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

= 1004\*3178/4(1+2(134²-0²)/(3178²))/(1+(4\*0)/

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

= 599.8 Kg-m.

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

= P \* Rm/(2t) - M2/(pi\*Rm²t)

= 62.0 \* 133.515/(2\*4.98) - 599.8/(pi\*133.5²\*4.98)

= 62.03 N./mm²

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

= P \* Rm/(2t) + M2/(pi \* Rm² \* t)

= 62.0 \* 133.515/(2 \* 4.98) + 599.8/(pi \* 133.5² \* 4.98 )

= 104.21 N./mm²

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

= P \* Rm/(2t) - M1/(K1\*pi\*Rm²t)

= 62.0\*133.515/(2\*6.07)--9.8/(0.1066\*pi\*133.5²\*6.07)

= 70.85 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\*133.515/(2\*6.07)+-9.8/(0.1923\*pi\*133.5²\*6.07)

= 66.72 N./mm²

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

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

= 1004( 3178.0 - 2 \* 200.0)/(3178.0 + ( 4 \* 0.0/3))

= 877.7 Kgf

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

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

= 1.1707 \* 877.71/( 133.515 \* 6.07 )

= 12.43 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 \* 1004 \* 0.1/( 6.07 \* ( 150.0 + 22.21 + 22.21 ) )

= -0.63 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 Saddle Base with Wear Plate (4.15.26) [sigma6,r]:

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

= - 0.7603 \* 1004 \* 0.1/( 194.41( 6.07 + 0.627 \* 10.0 ) )

= -0.31 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)

= -1004/(4(6.07 + 0.627 \* 10.0)194.41) -

3 \* 0.053 \* 1004/(2(6.07 + 0.627 \* 10.0)²)

= -6.15 N./mm²

**Results for Vessel Ribs, Web and Base:**

Baseplate Length Bplen 250.0000 mm.

Baseplate Thickness Bpthk 15.0000 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

Saddle Yield Stress Sy 239.9 N./

Height of Web at Center Hw,c 309.5 mm.

Friction Coefficient mu 0.000

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

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

B | D | Y | A | AY | Io |

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

Shell 243.9 | 6.1 | 3.0 | 14.8 | 4493.3 | 0.302E+04 |

Wearplate 200.0 | 10.0 | 11.1 | 20.0 | 22140.0 | 0.364E+04 |

Web 10.0 | 286.5 | 159.3 | 28.6 | 456300.5 | 0.201E+04 |

BasePlate 180.0 | 15.0 | 310.0 | 27.0 | 837054.0 | 0.727E+04 |

Totals ... | ... | ... | 90.4 | 1319987.8 | 0.159E+05 |

Distance to Centroid [C1]:

= AY / A

= 519.68/90.45

= 145.936 mm.

Angle [beta]:

= 180 - Saddle Angle/2

= 180 - 120.0/2

= 120.0

Saddle Splitting Coefficient [K1]:

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

= ( 1 + cos(120.0) - 0.5\*sin(120.0)² )/(pi - 2.094 + sin(120.0)cos(120.0) )

= 0.2035

Saddle Splitting Force [Fh]:

= K1 \* Q

= 0.204 \* 1004.087

= 204.3534 Kgf

Tension Stress, St = ( Fh/As ) = 0.2649 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 = 69.5007 Kg-m.

Bending Stress, Sb = ( M \* C1 / I ) = 0.6237 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(1004 + 27)180.0/( 2 \* 250.0 \* 159.964 ))½

= 8.262 mm.

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

Web Length Dimension [ Web Length ]:

= 2 \* cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )

= 2 \* cos( 90 - 120.0/2 )( 127.28 + 9.27 + 10.0 )

= 253.832 mm.

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 \* 2.23

= 509.739 Kgf

Area of the Rib and Web [Ar]:

= Rib Area + Web Area

= 14.0 + 12.692

= 26.692 cm²

Compressive Stress [Sc]:

= P/Ar

= 509.7/26.6916

= 1.873 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 | 407. |

Web 126.9 | 10.0 | 5.0 | 12.7 | 6345.8 | 197. |

Totals ... | ... | ... | 26.7 | 118345.8 | 604. |

Rib dimension [D]:

= Saddle Width - Web Thickness

= 150.0 - 10.0

= 140.000 mm.

Distance to Centroid from Datum [ytot]:

= AY / A

= 118345.789/26.692

= 44.338 mm.

Distance to Centroid [C1]:

= max( ytot, Saddle Width - ytot )

= max( 44.338, 150.0 - 44.338 )

= 105.662 mm.

Radius of Gyration [r]:

= sqrt( Total Inertia / Total Area )

= sqrt( 604.2/26.692 )

= 47.577 mm.

Intermediate Term [Cc]:

= sqrt( 2 \* pi² \* Elastic Modulus / Yield Stress )

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

= 128.255

Slenderness ratio [KL/r]:

= KL/r

= 1 \* 419.306/47.577

= 8.813

Bending Moment [Rm]:

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

= 138.2/( 2 \* 250.0 ) \* 253.832 \* 419.31/2

= 14.708 Kg-m.

Compressive Allowable, KL/r < Cc ( 8.8133 < 128.2549 ) per AISC E2-1 [Sca]:

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

= ( 1-( 8.81 )²/(2 \* 128.25² ))240/

( 5/3+3\*(8.81)/(8\* 128.25)-( 8.81³)/(8\*128.25³)

= 141.4 N./mm²

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

= Sc/Sca + ( Rm \* C1 / I )/Sba

= 1.87/141.44 + ( 14.71 \* 105.662/6041731 )/159.96

= 0.029

**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 0.0 mm.

Distance from Bolts to Edge Edgedis 80.0 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 665.1 Kgf

Saddle Load QL (Wind/Seismic contribution) QL 14.3 Kgf

Maximum Transverse Force Ft 69.1 Kgf

Maximum Longitudinal Force Fl 138.2 Kgf

Saddle Bolted to Steel Foundation No

Shear Stress in a Single Bolt [taub]:

= Shear Force / ( 2 \* Bolt Area \* Number of Bolts )

= 138/( 2 \* 0.81 \* 2 )

= 4.2 N./mm². Must be less than 103.4 N./mm².

**Bolt Area Calculation per Dennis R. Moss**

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

= Fl / (Stba \* Nbolts)

= 138.19/(172.38 \* 2.0)

= 0.0393 cm²

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

= B \* Ft + Sum of X Moments

= 448.0 \* 69.1 + 0.0

= 30.96 Kg-m.

Eccentricity (e):

= Rmom / QO

= 30.96/665.12

= 46.54 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 (46.54 - 0.5\*250.0)

= -235.38 mm.

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

= 6 \* 9.45 \* 0.81/180.0 \* (44.99 + 46.54)

= 2343.50 mm.²

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

= -2343.5 \* (0.5 \* 250.0 + 44.99)

= -398372.31 mm.³

Iteratively Solving for the Effective Bearing Length:

Y³ + K1 \* Y² + K2 \* Y + K3 = 0

Y³ + -235.38 \* Y² + 2343.5 \* Y + -398372.28 = 0

Y = 232.67 mm.

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

= (250.0/2 - 232.67/3 - 46.54)

= 0.90

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

= (250.0/2 - 232.67/3 + 44.99)

= 92.43

Total Bolt Tension Force [Tforce]:

= - QO \* Num / Denom

= - 665.12 \* 0.9/92.43

= -6.51 Kgf

Bolt Area Required due to Transverse Load [Bltareart]:

= Tforce / (Stba \* Nbt)

= -6.51/( 172.38 \* 1.0 )

= -0.0037 cm²

Required Area of a Single Bolt [Bltarear]:

= max[Bltarearl, Bltarears, Bltareart]

= max[0.0, 0.0393, -0.0037]

= 0.0393 cm²

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

Bearing Pressure (fc)

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

= 2(665.12 + -6.51)/(232.67 \* 180.0)

= 3.08 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

= -6.51 \* 25.4

= -0.17 Kg-m.

Equivalent Bearing Pressure (f1):

= fc \* (Y - Adist) / Y

= 3.08 \* (232.67 - 25.4)/232.67

= 2.75 bars

Overturning Moment due to Bearing Pressure [Mc]:

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

= (25.4² \* 180.0/6) \* (2.75 + 2 \* 3.08)

= 1.76 Kg-m.

Baseplate Required Thickness [Treq]:

= (6 \* max(Mt,Mc) / (Bpwid \* Sba))½

= (6 \*max(-0.17,1.76/(180.0 \* 142.73))½

= 2.0076 mm.

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## Test Case

**ASME Horizontal Vessel Analysis: Stresses for the Left Saddle**

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

Horizontal Vessel Stress Calculations : 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 413.98 Kgf

Horizontal Vessel Analysis Results: Actual | Allowable |

N./mm² | N./mm² |

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

Long. Stress at Top of Midspan 51.49 | 1326.66 |

Long. Stress at Bottom of Midspan 68.43 | 1326.66 |

Long. Stress at Top of Saddles 61.40 | 1326.66 |

Long. Stress at Bottom of Saddles 59.16 | 1326.66 |

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

Tangential Shear in Shell 4.82 | 1061.33 |

Circ. Stress at Horn of Saddle 4.55 | 1990.00 |

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 ) \* 493.0/207.0667

= 61.0 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 )

= 353 + Max( 0.1, 61, 0, 0 )

= 414.0 Kgf

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

Vertical Load (including saddle weight) 441.00 Kgf

Transverse Shear Load Saddle Ft 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)]

= -414\*200.0[1-(1-200.0/3178.0+(105.46²-0.0²)/

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

= -4.5 Kg-m.

Moment per Equation 4.15.4 [M2]:

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

= 414\*3178/4(1+2(105²-0²)/(3178²))/(1+(4\*0)/

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

= 246.8 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) - 246.8/(pi\*105.5²\*8.18)

= 51.49 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) + 246.8/(pi \* 105.5² \* 8.18 )

= 68.43 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)--4.5/(0.1066\*pi\*105.5²\*8.18)

= 61.40 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)+-4.5/(0.1923\*pi\*105.5²\*8.18)

= 59.16 N./mm²

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

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

= 414( 3178.0 - 2 \* 200.0)/(3178.0 + ( 4 \* 0.0/3))

= 361.9 Kgf

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

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

= 1.1707 \* 361.87/( 105.46 \* 8.18 )

= 4.82 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 \* 414 \* 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( 108.252/1326.664, 1 )

= 0.0816

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:

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

= - 0.7603 \* 414 \* 0.1/( 195.819( 8.18 + 0.082 \* 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)

= -414/(4(8.18 + 0.082 \* 10.0)195.819) -

3 \* 0.053 \* 414/(2(8.18 + 0.082 \* 10.0)²)

= -4.55 N./mm²

**Results for Vessel Ribs, Web and Base:**

Baseplate Length Bplen 250.0000 mm.

Baseplate Thickness Bpthk 15.0000 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

Saddle Yield Stress Sy 206.9 N./

Height of Web at Center Hw,c 309.5 mm.

Friction Coefficient mu 0.000

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

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

B | D | Y | A | AY | Io |

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

Shell 244.9 | 8.2 | 4.1 | 20.0 | 8194.1 | 0.571E+04 |

Wearplate 200.0 | 10.0 | 13.2 | 20.0 | 26360.0 | 0.511E+04 |

Web 10.0 | 358.4 | 197.4 | 35.8 | 707597.9 | 0.405E+04 |

BasePlate 180.0 | 15.0 | 384.1 | 27.0 | 1037150.8 | 0.120E+05 |

Totals ... | ... | ... | 102.9 | 1779302.8 | 0.269E+05 |

Distance to Centroid [C1]:

= AY / A

= 700.513/102.88

= 172.950 mm.

Angle [beta]:

= 180 - Saddle Angle/2

= 180 - 120.0/2

= 120.0

Saddle Splitting Coefficient [K1]:

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

= ( 1 + cos(120.0) - 0.5\*sin(120.0)² )/(pi - 2.094 + sin(120.0)cos(120.0) )

= 0.2035

Saddle Splitting Force [Fh]:

= K1 \* Q

= 0.204 \* 413.979

= 84.2537 Kgf

Tension Stress, St = ( Fh/As ) = 0.0997 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 = 34.4746 Kg-m.

Bending Stress, Sb = ( M \* C1 / I ) = 0.2172 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(414 + 27)180.0/( 2 \* 250.0 \* 137.9 ))½

= 5.820 mm.

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

Web Length Dimension [ Web Length ]:

= 2 \* cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )

= 2 \* cos( 90 - 120.0/2 )( 101.37 + 8.18 + 10.0 )

= 207.067 mm.

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 \* 0.92

= 171.443 Kgf

Area of the Rib and Web [Ar]:

= Rib Area + Web Area

= 14.0 + 10.353

= 24.353 cm²

Compressive Stress [Sc]:

= P/Ar

= 171.4/24.3533

= 0.690 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 | 371. |

Web 103.5 | 10.0 | 5.0 | 10.4 | 5176.7 | 193. |

Totals ... | ... | ... | 24.4 | 117176.6 | 564. |

Rib dimension [D]:

= Saddle Width - Web Thickness

= 150.0 - 10.0

= 140.000 mm.

Distance to Centroid from Datum [ytot]:

= AY / A

= 117176.648/24.353

= 48.115 mm.

Distance to Centroid [C1]:

= max( ytot, Saddle Width - ytot )

= max( 48.115, 150.0 - 48.115 )

= 101.885 mm.

Radius of Gyration [r]:

= sqrt( Total Inertia / Total Area )

= sqrt( 564.3/24.353 )

= 48.137 mm.

Length of Outer Rib [L]:

= Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk

= 493.0 - cos( 120.0/2 )( 101.37 + 8.18 + 10.0 ) - 15.0

= 418.225 mm.

Intermediate Term [Cc]:

= sqrt( 2 \* pi² \* Elastic Modulus / Yield Stress )

= sqrt( 2 \* pi² \* 0.19994E+09/206.9 )

= 138.135

Slenderness ratio [KL/r]:

= KL/r

= 1 \* 418.225/48.137

= 8.688

Bending Moment [Rm]:

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

= 0.7/( 2 \* 250.0 ) \* 207.067 \* 418.23/2

= 0.061 Kg-m.

Compressive Allowable, KL/r < Cc ( 8.6881 < 138.1347 ) per AISC E2-1 [Sca]:

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

= ( 1-( 8.69 )²/(2 \* 138.13² ))207/

( 5/3+3\*(8.69)/(8\* 138.13)-( 8.69³)/(8\*138.13³)

= 122.1 N./mm²

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

= Sc/Sca + ( Rm \* C1 / I )/Sba

= 0.69/122.14 + ( 0.06 \* 101.885/5643193 )/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 0.0 mm.

Distance from Bolts to Edge Edgedis 80.0 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 380.0 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

Shear Stress in a Single Bolt [taub]:

= Shear Force / ( 2 \* Bolt Area \* Number of Bolts )

= 9/( 2 \* 0.81 \* 2 )

= 0.3 N./mm². Must be less than 103.4 N./mm².

**Bolt Area Calculation per Dennis R. Moss**

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

= Fl / (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

= 4.21/379.97

= 11.09 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 1201.93 N./mm²

Head Allowable Stress used in Calculation 1201.93 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 407.69 Kgf

Horizontal Vessel Analysis Results: Actual | Allowable |

N./mm² | N./mm² |

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

Long. Stress at Top of Midspan 69.66 | 1201.93 |

Long. Stress at Bottom of Midspan 80.34 | 1201.93 |

Long. Stress at Top of Saddles 66.91 | 1201.93 |

Long. Stress at Bottom of Saddles 65.78 | 1201.93 |

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

Tangential Shear in Shell 3.35 | 961.55 |

Circ. Stress at Horn of Saddle 4.22 | 1802.90 |

Circ. Compressive Stress in Shell 0.16 | 1201.93 |

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

**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 ) \* 448.0/253.8321

= 45.2 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 )

= 362 + Max( 0.1, 45, 0, 0 )

= 407.7 Kgf

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

Vertical Load (including saddle weight) 434.57 Kgf

Transverse Shear Load Saddle Ft 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)]

= -408\*200.0[1-(1-200.0/3178.0+(131.915²-0.0²)/

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

= -4.0 Kg-m.

Moment per Equation 4.15.4 [M2]:

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

= 408\*3178/4(1+2(132²-0²)/(3178²))/(1+(4\*0)/

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

= 243.5 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) - 243.5/(pi\*131.9²\*8.18)

= 69.66 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) + 243.5/(pi \* 131.9² \* 8.18 )

= 80.34 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)--4.0/(0.1066\*pi\*131.9²\*9.27)

= 66.91 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)+-4.0/(0.1923\*pi\*131.9²\*9.27)

= 65.78 N./mm²

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

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

= 408( 3178.0 - 2 \* 200.0)/(3178.0 + ( 4 \* 0.0/3))

= 356.4 Kgf

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

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

= 1.1707 \* 356.37/( 131.915 \* 9.27 )

= 3.35 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 \* 408 \* 0.1/( 9.27 \* ( 150.0 + 27.28 + 27.28 ) )

= -0.16 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)

= -408/(4\*9.27\*(150.0+27.276+27.276)) -

3\* 0.0529\*408/(2\*9.27²)

= -4.22 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 15.0000 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

Saddle Yield Stress Sy 239.9 N./

Height of Web at Center Hw,c 309.5 mm.

Friction Coefficient mu 0.000

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

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

B | D | Y | A | AY | Io |

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

Shell 253.6 | 9.3 | 4.6 | 23.5 | 10895.7 | 0.407E+04 |

Wearplate 200.0 | 10.0 | 14.3 | 20.0 | 28540.0 | 0.298E+04 |

Web 10.0 | 286.5 | 162.5 | 28.6 | 465466.9 | 0.216E+04 |

BasePlate 180.0 | 15.0 | 313.2 | 27.0 | 845694.0 | 0.846E+04 |

Totals ... | ... | ... | 99.2 | 1350596.5 | 0.177E+05 |

Distance to Centroid [C1]:

= AY / A

= 531.731/99.152

= 136.214 mm.

Angle [beta]:

= 180 - Saddle Angle/2

= 180 - 120.0/2

= 120.0

Saddle Splitting Coefficient [K1]:

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

= ( 1 + cos(120.0) - 0.5\*sin(120.0)² )/(pi - 2.094 + sin(120.0)cos(120.0) )

= 0.2035

Saddle Splitting Force [Fh]:

= K1 \* Q

= 0.204 \* 407.687

= 82.9732 Kgf

Tension Stress, St = ( Fh/As ) = 0.1076 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 = 28.4388 Kg-m.

Bending Stress, Sb = ( M \* C1 / I ) = 0.2150 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(408 + 27)180.0/( 2 \* 250.0 \* 159.964 ))½

= 5.364 mm.

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

Web Length Dimension [ Web Length ]:

= 2 \* cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )

= 2 \* cos( 90 - 120.0/2 )( 127.28 + 9.27 + 10.0 )

= 253.832 mm.

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 \* 0.91

= 206.968 Kgf

Area of the Rib and Web [Ar]:

= Rib Area + Web Area

= 14.0 + 12.692

= 26.692 cm²

Compressive Stress [Sc]:

= P/Ar

= 207.0/26.6916

= 0.760 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 | 407. |

Web 126.9 | 10.0 | 5.0 | 12.7 | 6345.8 | 197. |

Totals ... | ... | ... | 26.7 | 118345.8 | 604. |

Rib dimension [D]:

= Saddle Width - Web Thickness

= 150.0 - 10.0

= 140.000 mm.

Distance to Centroid from Datum [ytot]:

= AY / A

= 118345.789/26.692

= 44.338 mm.

Distance to Centroid [C1]:

= max( ytot, Saddle Width - ytot )

= max( 44.338, 150.0 - 44.338 )

= 105.662 mm.

Radius of Gyration [r]:

= sqrt( Total Inertia / Total Area )

= sqrt( 604.2/26.692 )

= 47.577 mm.

Intermediate Term [Cc]:

= sqrt( 2 \* pi² \* Elastic Modulus / Yield Stress )

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

= 128.255

Slenderness ratio [KL/r]:

= KL/r

= 1 \* 419.116/47.577

= 8.809

Bending Moment [Rm]:

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

= 1.1/( 2 \* 250.0 ) \* 253.832 \* 419.12/2

= 0.116 Kg-m.

Compressive Allowable, KL/r < Cc ( 8.8093 < 128.2549 ) per AISC E2-1 [Sca]:

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

= ( 1-( 8.81 )²/(2 \* 128.25² ))240/

( 5/3+3\*(8.81)/(8\* 128.25)-( 8.81³)/(8\*128.25³)

= 141.4 N./mm²

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

= Sc/Sca + ( Rm \* C1 / I )/Sba

= 0.76/141.45 + ( 0.12 \* 105.662/6041731 )/159.96

= 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 0.0 mm.

Distance from Bolts to Edge Edgedis 80.0 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 389.3 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

Shear Stress in a Single Bolt [taub]:

= Shear Force / ( 2 \* Bolt Area \* Number of Bolts )

= 9/( 2 \* 0.81 \* 2 )

= 0.3 N./mm². Must be less than 103.4 N./mm².

**Bolt Area Calculation per Dennis R. Moss**

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

= Fl / (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

= 3.83/389.33

= 9.83 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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