Horizontal Vessel Analysis: Stresses for the Left Saddle

Horizontal Vessel Stress Calculations : Operating Case

Shell Allowable Stress used in Calculation	137.90	N./mm^2
Shell Comp. Yield Stress used in Calculation	242.93	N./mm^2
Head Allowable Stress used in Calculation	137.90	N./mm^2
Saddle Force Q, Operating Case	230076.16	N

Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Saddles	51.48	137.90	N./mm^2
Long. Stress at Bottom of Saddles	49.93	137.90	N./mm^2
Long. Stress at Top of Midspan	47.00	137.90	N./mm^2
Long. Stress at Bottom of Midspan	54.40	137.90	N./mm^2
Tangential Shear in Shell	7.47	110.32	N./mm^2
Tangential Shear in Head	9.84	110.32	N./mm^2
Circ. Stress at Horn of Saddle	-6.30	-206.85	N./mm^2
Circ. Stress at Tip of Wear Plate	-12.49	-206.85	N./mm^2
Addl. Stress in Head as Stiffener	5.13	34.48	N./mm^2
Circ. Compressive Stress in Shell	-9.82	-121.46	N./mm^2

Note: The Longitudinal Stress from the Zick Analysis is combined with
the Longitudinal Pressure Stress to get the total stress.

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
  = 3.00 * ( 85421.9 /2 + 5079 ) * 2200.0000 / 1735.8881
  = 181703.4 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = Max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = Max( 42675.63 , 0.00 , 12900 ) * 2200.0000 / 5086.0000
  = 18459.8 N
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = Max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = Max( 9645.62 , 0.00 , 12900 ) * 2200.0000 / 5086.0000
  = 5580.0 N
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.00 * ( 9645 /2 + 5079 ) * 2200.0000 / 1735.8881
  = 37649.4 N
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
```

= 48372 + Max(18459 , 181703 , 5580 , 37649)
= 230076.2 N

Summary of Loads at the base of this Saddle:

Vertical Load (including sadddle weight)	236597.45	N
Transverse Shear Load Saddle	47790.41	N
Longitudinal Shear Load Saddle	42675.63	N

Formulas and Substitutions for Horizontal Analysis:

Intermediate Term [MFract1]:

= 1 - (1- a/L + (R^2-$H2^2$)/(2a*L))/(1+(4H)/3L)

= 1-(1-457.00/6000.00+(917.500^2-457.250^2)/(2*457.00*6000.00))/
(1+(4*38.10)/(2*6000.00))
= 0.0566

Bending Moment over the Saddle (+-) [M1]:
= Q * a(MFract1)
= 230076 * 457.000 (0.0566)
= 5958.32 N-m

Intermediate Term [MFract2]:

= (1+2(R^2-H^2)/(L^2))/(1+(4H)/(3L))-4a/L

= (1+2(917^2-457^2)/(6000^2))/(1+(4*457)/(3*6000))-
4*457.00/6000.00
= 0.6350

Moment at Mid-Span [M2]:
= QL/4 * MFract2
= 230076 * 6000.000 /4 * 0.6350
= 219237.73 N-m

Longitudinal Bending (+-) at Midspan:

= (0.25 * Q * L * K.2 / (pi * R^2*(Ts - Ca)))
= (0.25 * 230076 * 6000.00 * 0.6350) /
(3.141 * 917.5000 * 917.5000 * (25.4000 - 3.0000)))
= 3.70 N./mm^2

Compute the area ratio [K]:
= pi * (sin(delta)/Delta - cos(delta)) / (delta + sin(delta) * cos(delta) -
(delta + sin(delta) * cos(delta) - 2 * sin(delta) * sin(delta)/delta)
= Pi * (sin(1.498) / 1.498 - cos(1.498)) / (1.498 + sin(1.498) *
cos(1.498) - 2 * sin(1.498) * sin(1.498)/ 1.498)
= 7.6823

Intermediate Product [K.1]:
= K * MFract1 * 4 * A / L
= 7.682 * 0.057 * 4 * 457.000 / 6000.000
= 0.1326

Longitudinal Bending (+-) at Saddle:

= (0.25 * Q * L * K.1 / (pi * R^2*(Ts - Ca)))
= (0.25 * 230076 * 6000.00 * 0.1326) /
(3.141 * 917.5000 * 917.5000 * (25.4000 - 3.0000)))
= 0.77 N./mm^2

Tangential Shear in Shell near Saddle:
```
  = K3 * Q / ( R * t )
  = 0.6668 * 230076 / ( 917.5000 * 22.4000 )
  = 7.47 N./mm^2
```

Tangential Shear in Head used as Stiffener:
```
  = K4 * Q / ( R * Th )
  = 0 * 0.2E+06 / ( 917.50 * ( 17.0000 - 0.0000 )
  = 9.84 N./mm^2
```

Circumferential Stress at Tip of the Wear Plate:
```
  = -Q/(4t(b+x1+x2)) - 12*Q*R*K7,1/(L*t^2)
  = -230076 /( 4 * 22.4000 (250.00 + 111.8205 + 111.8205 ))
    -12 * 230076 * 76.46 * 0.0084 /( 6000.0000 * 22.4000 ^2 )
  = -12.49 N./mm^2
```

Note: Wear Plate is considered as A < R/2 and WearPlate extension > R/10)

Equivalent Membrane Thickness [Tem]:
```
  = Corroded Thickness + Wearplate Thickness
  = 22.400 + 25.400
  = 47.800 mm.
```

Equivalent Bending Thickness squared [Teb]:
```
  = Corroded Thickness^2 + Wearplate Thickness^2
  = 22.400 ^2 + 25.400 ^2
  = 1146.920 mm.^2
```

Circumferential Stress at Horn of Saddle:
```
  = -Q/(4t(b+x1+x2)) - 12*Q*R*K7/(L*t^2)
  = -230076 /( 4 * 47.8000 (250.00 + 111.8205 + 111.8205 ))
    -12 * 230076 * 76.46 * 0.0102 / ( 6000.0000 * 1146.9199 )
  = -6.30 N./mm^2
```

```
 Parameter [K4]:
  = (3/8)*(sin(alpha)^2/(pi-alpha+sin(alpha*cos(alpha)))
  = (3/8)*(sin(107.3 )^2/(pi-107.3 +sin(107.3 *cos(107.3 )))
  = 0.3474
```

Additional Tension in Head used as Stiffener:
```
  = K4 * Q/( R * th )
  = 0.3474 * 230076 /( 917.5000 * 17.0000 )
  = 5.13 N./mm^2
```

Circumferential Compression at Bottom of Shell:
```
  = (Q*( K.9/( TEM9 * WPDWTH ) ) )
  = ( 230076 *( 0.7137 /( 47.8000 * 350.000 ) ) )
  = -9.82 N./mm^2
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls * ( Design Temperature - Ambient Temperature )
  = 0.120E-04 * 5086.000 * ( 80.0 - 21.1 )
  = 3.586 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1842.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.

Baseplate Width	Bpwid	330.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	Y	A	AY	Ay^2	Io
Shell	11.	128.	143915.	161.	54.
Wearplate	35.	89.	312039.	1095.	48.
Web	629.	139.	8770890.	551601.	156979.
BasePlate	1222.	83.	10085625.	1232966.	43.
Totals	1898.	439.	19312470.	1785824.	157124.

Value C1 = Sumof(Ay)/Sumof(A) = 440. mm.

Value I = Sumof(Ay^2) + Sumof(Io) - C1*Sumof(Ay) = 1094050. cm**4

Value As = Sumof(A) - Ashell = 311. cm^2

K1 = (1+Cos(beta)-.5*Sin(beta)^2)/(pi-beta+Sin(beta)*Cos(beta)) = 0.2292

Fh = K1 * Q = 0.2292 * 230076.156 = 52739.3750 N

Tension Stress, St = (Fh/As) = 1.6967 N./mm^2

Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

d = B - R*Sin(theta) / theta = 1430.2626 mm.
Bending Moment, M = Fh * d = 75461.7344 N-m

Bending Stress, Sb = (M * C1 / I) = 3.0309 N./mm^2

Allowed Stress, Sa = 2/3 * Yield Str = 137.9000 N./mm^2

Minimum Thickness of Baseplate per Moss :

= (3 * (Q + Saddle_Wt) * BasePlateWidth / (4 * BasePlateLength * AllStress))$^{0.5}$

= (3 * (230076 + 6521) * 330.00 / (4 * 1842.000 * 137.900))$^{0.5}$

= 15.184 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress

Effective Baseplate Length [e]:
= (Bplen - Clearance) / (Nribs - 1)
= (1842.0000 - 25.4) / (4 - 1) = 605.5333 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2

= 605.5333 * 330.0000 / 2 = 999.1300 cm^2

Axial Load [P]:
= Ap * Bp
= 999.1 * 37.85 = 37817.3 N

Area of the Rib and Web [Ar]:

```
  = ( Bpwid - Clearance - Webtk ) * Ribtk + e/2 * Webtk
  = ( 330.000 - 25.4 - 12.000 ) * 10.000 + 605.5333 /2 * 12.000
```
$= 65.592\ cm^2$

Compressive Stress [Sc]:

```
  = P/Ar
```
$= 37817.3 / 65.5920 = 5.7660\ N./mm^2$

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	Y	A	AY	Ay^2	Io
Rib	125.0	26.5	331625.0	0.0	1776.9
Web	125.0	36.3	454150.0	0.0	8.7
Values	125.0	62.9	785775.0	0.0	1785.6

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 42675.6 /( 2 * 1842.00 ) * 605.533 * 1785.25 / 2
  = 6263.887 N-m
```

KL/R < Cc (34.2159 < 138.1347) per AISC E2-1

$Sca = (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$

$Sca = (1-(34.22)^2/(2 * 138.13^2)) * 206 /$

$(5/3+3*(34.22)/(8* 138.13)-(34.22^3)/(8*138.13^3)$

$Sca = 114.07\ N./mm^2$

AISC Unity Check on Outside Ribs (must be <= 1.0)

```
 Check = Sc/Sca + (Rm/Z)/Sba
 Check = 5.77 / 114.07 + (6263.89 /9.942 ) / 137.90
 Check = 0.51
```

Check of Inside Ribs

Inertia of Saddle, Inner Ribs - Axial Direction

	Y	A	AY	Ay^2	Io
Rib	152.3	29.3	445629.8	0.0	2355.1
Web	152.3	72.7	1106672.8	0.0	8.7
Values	152.3	101.9	1552302.5	0.0	2363.8

KL/R < Cc (25.6637 < 138.1347) per AISC E2-1

$Sca = (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$

$Sca = (1-(25.66)^2/(2 * 138.13^2)) * 206 /$

$(5/3+3*(25.66)/(8* 138.13)-(25.66^3)/(8*138.13^3)$

$Sca = 117.13\ N./mm^2$

AISC Unity Check on Inside Ribs (must be <= 1.0)

```
 Check = Sc/Sca + (Rm/Z)/Sba
 Check = 7.42 / 117.13 + ( 8672.84 /15.521 ) / 137.90
 Check = 0.47
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		AS 1252-Gr.8.8	
Bolt Allowable Stress	Stba	199.96	$N./mm^2$
Bolt Corrosion Allowance	Bca	0.0000	mm.
Distance from Bolts to Edge	Edgedis	259.9944	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	$N./mm^2$
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	54894.1	N
Saddle Load QL (Wind/Seismic contribution)	QL	18459.8	N
Maximum Transverse Force	Ft	50531.4	N
Maximum Longitudinal Force	Fl	42675.6	N
Saddle Bolted to Steel Foundation		Yes	

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)
= 42675.63 / (199.96 * 4.00)
= 0.5336 cm^2

Bolt Area due to Transverse Load

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 2200.00 * 50531.45 + 4800.00
= 116014.24 N-m

Eccentricity (e):
= Rmom / QO
= 116014.24 / 54894.09
= 2112.56 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis
= 1842.00 / 2 - 259.99
= 661.01 mm.

K1 = 3 (e - 0.5 * Bplen)
= 3 (2112.56 - 0.5*1842.00)
= 3574.69 mm.

K2 = 6 * n1 * At / Bpwid * (f + e)
= 6 * 1.00 * 4.34 / 330.00 * (661.01 + 2112.56)
= 21891.12 $mm.^2$

K3 = -K2 * (0.5 * Bplen + f)
= -33.93 * (0.5 * 1842.00 + 661.01)
= -2113.37 $mm.^2$

Iteratively Solving for the Effective Bearing Length:

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

$Y^3 + 140.74 * Y^2 + 33.93 * Y + -2113.37 = 0$

Y = 94.22 mm.

Num = (Bplen / 2 - Y / 3 - e)
= (1842.00 / 2 - 94.22 / 3 - 2112.56)
= -48.15

Denom = (Bplen / 2 - Y / 3 + f)
= (1842.00 / 2 - 94.22 / 3 + 661.01)
= 61.05

Total Bolt Tension Force [Tforce]:
= - QO * Rnum / Denom
= - 54894.09 * -1222.97 / 1550.60
= 43295.38 N

Bolt Area Required due to Transverse Load [Bltareart]
= Tforce / (Stba * Nbt)
= 43295.38 / (199.96 * 2.00)

= 1.0827 cm^2

Required of a Single Bolt [Bltarear]
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0000 , 0.5336 , 1.0827]

= 1.0827 cm^2

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
= 2 * (QO + Tforce) / (Y * Bplen)
= 2 * (54894.09 + 43295.38) / (3.71 * 1842.00)
= 1131.57 KPa.

Distance from Baseplate Edge to the Web [ADIST]:
= (Bplen - Weblngth) / 2
= (1842.00 - 1791.20) / 2.0
= 25.4000 mm.

Overturning Moment due To Bolt Tension [Mt]:
= Tforce * (0.5 * Bplen + f - Y)
= 43295.38 * (0.5 * 1842.00 + 661.01 - 94.22)
= 64440.42 N-m

Equivalent Bearing Pressure (f1):
= fc * (Y - Adist) / Y
= 1131.57 * (94.22 - 25.40) / 94.22
= 826.51 KPa.

Overturning Moment due to Bearing Pressure [Mc]:

= $(Adist^2 * Bpwid / 6) * (f1 + 2 * fc)$

= $(25.40^2 * 330.00 / 6) * (826.51 + 2 * 1131.57)$

= 109.67 N-m

Baseplate Required Thickness [Treq]:

= $(6 * max(Mt,Mc) / (Bpwid * Sba))^{0.5}$

= $(6 * 64440.42 / (330.00 * 162.38))^{0.5}$

= 84.9306 mm.

Zick Analysis: Stresses for the Right Saddle

Shell Allowable Stress used in Calculation		137.90	$N./mm^2$
Shell Comp. Yield Stress used in Calculation		242.93	$N./mm^2$
Head Allowable Stress used in Calculation		137.90	$N./mm^2$
Saddle Force Q, Operating Case		238134.86	N
Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Saddles	51.50	137.90	$N./mm^2$
Long. Stress at Bottom of Saddles	49.90	137.90	$N./mm^2$
Long. Stress at Top of Midspan	46.87	137.90	$N./mm^2$
Long. Stress at Bottom of Midspan	54.53	137.90	$N./mm^2$
Tangential Shear in Shell	7.73	110.32	$N./mm^2$
Tangential Shear in Head	10.18	110.32	$N./mm^2$
Circ. Stress at Horn of Saddle	-6.52	-206.85	$N./mm^2$
Circ. Stress at Tip of Wear Plate	-12.93	-206.85	$N./mm^2$
Addl. Stress in Head as Stiffener	5.30	34.48	$N./mm^2$
Circ. Compressive Stress in Shell	-10.16	-121.46	$N./mm^2$

Note: The Longitudinal Stress from the Zick Analysis is combined with
the Longitudinal Pressure Stress to get the total stress.

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
  = 3.00 * ( 85421.9 /2 + 7820 ) * 2200.0000 / 1735.8881
  = 192125.0 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = Max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = Max( 42675.63 , 0.00 , 12900 ) * 2200.0000 / 5086.0000
  = 18459.8 N
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = Max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = Max( 9645.62 , 0.00 , 12900 ) * 2200.0000 / 5086.0000
  = 5580.0 N
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.00 * ( 9645 /2 + 7820 ) * 2200.0000 / 1735.8881
  = 48071.1 N
```

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

= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 46009 + Max(18459 , 192125 , 5580 , 48071)
= 238134.9 N

Summary of Loads at the base of this Saddle:

Vertical Load (including sadddle weight)	244656.17	N
Transverse Shear Load Saddle	50531.45	N
Longitudinal Shear Load Saddle	42675.63	N

Formulas and Substitutions for Horizontal Analysis:

Intermediate Term [MFract1]:

= 1 - (1- a/L + (R^2-H2^2)/(2a*L))/(1+(4H)/3L)

= 1-(1-457.00/6000.00+(917.500^2-457.250^2)/(2*457.00*6000.00))/
(1+(4*38.10)/(2*6000.00))
= 0.0566

Bending Moment over the Saddle (+-) [M1]:
= Q * a(MFract1)
= 238134 * 457.000 (0.0566)
= 6167.02 N-m

Intermediate Term [MFract2]:

= (1+2(R^2-H^2)/(L^2))/(1+(4H)/(3L))-4a/L

= (1+2(917^2-457^2)/(6000^2))/(1+(4*457)/(3*6000))-
4*457.00/6000.00
= 0.6350

Moment at Mid-Span [M2]:
= QL/4 * MFract2
= 238134 * 6000.000 /4 * 0.6350
= 226916.81 N-m

Longitudinal Bending (+-) at Midspan:

= (0.25 * Q * L * K.2 / (pi * R^2*(Ts - Ca)))
= (0.25 * 238134 * 6000.00 * 0.6350) /
(3.141 * 917.5000 * 917.5000 * (25.4000 - 3.0000)))
= 3.83 N./mm^2

Compute the area ratio [K]:
= pi * (sin(delta)/Delta - cos(delta)) / (delta + sin(delta) * cos(delta) -
(delta + sin(delta) * cos(delta) - 2 * sin(delta) * sin(delta)/delta)
= Pi * (sin(1.498) / 1.498 - cos(1.498)) / (1.498 + sin(1.498) *
cos(1.498) - 2 * sin(1.498) * sin(1.498)/ 1.498)
= 7.6823

Intermediate Product [K.1]:
= K * MFract1 * 4 * A / L
= 7.682 * 0.057 * 4 * 457.000 / 6000.000
= 0.1326

Longitudinal Bending (+-) at Saddle:

= (0.25 * Q * L * K.1 / (pi * R^2*(Ts - Ca)))
= (0.25 * 238134 * 6000.00 * 0.1326) /
(3.141 * 917.5000 * 917.5000 * (25.4000 - 3.0000)))
= 0.80 N./mm^2

Tangential Shear in Shell near Saddle:

```
  = K3 * Q / ( R * t )
  = 0.6668 * 238134 / ( 917.5000 * 22.4000 )
  = 7.73 N./mm^2
```

Tangential Shear in Head used as Stiffener:

```
  = K4 * Q / ( R * Th )
  = 0 * 0.2E+06 / ( 917.50 * ( 17.0000 - 0.0000 )
  = 10.18 N./mm^2
```

Circumferential Stress at Tip of the Wear Plate:

```
  = -Q/(4t(b+x1+x2)) - 12*Q*R*K7,1/(L*t^2)
  = -238134 /( 4 * 22.4000 (250.00 + 111.8205 + 111.8205 ))
    -12 * 238134 * 76.46 * 0.0084 /( 6000.0000 * 22.4000 ^2 )
  = -12.93 N./mm^2
```

Note: Wear Plate is considered as A < R/2 and WearPlate extension > R/10)

Equivalent Membrane Thickness [Tem]:

```
  = Corroded Thickness + Wearplate Thickness
  = 22.400 + 25.400
  = 47.800 mm.
```

Equivalent Bending Thickness squared [Teb]:

```
  = Corroded Thickness^2 + Wearplate Thickness^2
  = 22.400 ^2 + 25.400 ^2
  = 1146.920 mm.^2
```

Circumferential Stress at Horn of Saddle:

```
  = -Q/(4t(b+x1+x2)) - 12*Q*R*K7/(L*t^2)
  = -238134 /( 4 * 47.8000 (250.00 + 111.8205 + 111.8205 ))
    -12 * 238134 * 76.46 * 0.0102 / ( 6000.0000 * 1146.9199 )
  = -6.52 N./mm^2
```

```
 Parameter [K4]:
  = (3/8)*(sin(alpha)^2/(pi-alpha+sin(alpha*cos(alpha)))
  = (3/8)*(sin(107.3 )^2/(pi-107.3 +sin(107.3 *cos(107.3 )))
  = 0.3474
```

Additional Tension in Head used as Stiffener:

```
  = K4 * Q/( R * th )
  = 0.3474 * 238134 /( 917.5000 * 17.0000 )
  = 5.30 N./mm^2
```

Circumferential Compression at Bottom of Shell:

```
  = (Q*( K.9/( TEM9 * WPDWTH ) ) )
  = ( 238134 *( 0.7137 /( 47.8000 * 350.000 ) ) )
  = -10.16 N./mm^2
```

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1842.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	330.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.

Web Thickness	Webtk	12.0000 mm.
Web Location	Webloc	Center

Moment of Inertia of Saddle - Lateral Direction

	Y	A	AY	Ay^2	Io
Shell	11.	128.	143915.	161.	54.
Wearplate	35.	89.	312039.	1095.	48.
Web	629.	139.	8770890.	551601.	156979.
BasePlate	1222.	83.	10085625.	1232966.	43.
Totals	1898.	439.	19312470.	1785824.	157124.

Value C1 = Sumof(Ay)/Sumof(A) = 440. mm.

Value I = Sumof(Ay^2) + Sumof(Io) - C1*Sumof(Ay) = 1094050. cm**4

Value As = Sumof(A) - Ashell = 311. cm^2

K1 = (1+Cos(beta)-.5*Sin(beta)^2)/(pi-beta+Sin(beta)*Cos(beta)) = 0.2292

Fh = K1 * Q = 0.2292 * 238134.859 = 54586.6406 N

Tension Stress, St = (Fh/As) = 1.7561 N./mm^2

Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

d = B - R*Sin(theta) / theta = 1430.2626 mm.
Bending Moment, M = Fh * d = 78104.8828 N-m

Bending Stress, Sb = (M * C1 / I) = 3.1370 N./mm^2

Allowed Stress, Sa = 2/3 * Yield Str = 137.9000 N./mm^2

Minimum Thickness of Baseplate per Moss :

= (3 * (Q + Saddle_Wt) * BasePlateWidth / (4 * BasePlateLength * AllStress))$^{0.5}$

= (3 * (238134 + 6521) * 330.00 / (4 * 1842.000 * 137.900))$^{0.5}$

= 15.440 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress

Effective Baseplate Length [e]:
= (Bplen - Clearance) / (Nribs - 1)
= (1842.0000 - 25.4) / (4 - 1) = 605.5333 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2

= 605.5333 * 330.0000 / 2 = 999.1300 cm^2

Axial Load [P]:
= Ap * Bp
= 999.1 * 39.18 = 39141.9 N

Area of the Rib and Web [Ar]:
= (Bpwid - Clearance - Webtk) * Ribtk + e/2 * Webtk
= (330.000 - 25.4 - 12.000) * 10.000 + 605.5333 /2 * 12.000

= 65.592 cm^2

Compressive Stress [Sc]:
= P/Ar

= 39141.9 / 65.5920 = 5.9680 $N./mm^2$

Check of Outside Ribs:
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	Y	A	AY	Ay^2	Io
Rib	125.0	26.5	331625.0	0.0	1776.9
Web	125.0	36.3	454150.0	0.0	8.7
Values	125.0	62.9	785775.0	0.0	1785.6

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * rl / 2
= 42675.6 /(2 * 1842.00) * 605.533 * 1785.25 / 2
= 6263.887 N-m

KL/R < Cc (34.2159 < 138.1347) per AISC E2-1

$Sca = (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$

$Sca = (1-(34.22)^2/(2 * 138.13^2)) * 206 /$

$(5/3+3*(34.22)/(8* 138.13)-(34.22^3)/(8*138.13^3)$

Sca = 114.07 $N./mm^2$

AISC Unity Check on Outside Ribs (must be <= 1.0)
Check = Sc/Sca + (Rm/Z)/Sba
Check = 5.97 / 114.07 + (6263.89 /9.942) / 137.90
Check = 0.51

Check of Inside Ribs
Inertia of Saddle, Inner Ribs - Axial Direction

	Y	A	AY	Ay^2	Io
Rib	152.3	29.3	445629.8	0.0	2355.1
Web	152.3	72.7	1106672.8	0.0	8.7
Values	152.3	101.9	1552302.5	0.0	2363.8

KL/R < Cc (25.6637 < 138.1347) per AISC E2-1

$Sca = (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$

$Sca = (1-(25.66)^2/(2 * 138.13^2)) * 206 /$

$(5/3+3*(25.66)/(8* 138.13)-(25.66^3)/(8*138.13^3)$

Sca = 117.13 $N./mm^2$

AISC Unity Check on Inside Ribs (must be <= 1.0)
Check = Sc/Sca + (Rm/Z)/Sba
Check = 7.68 / 117.13 + (8672.84 /15.521) / 137.90
Check = 0.47

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate Nbolts 4

Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		AS 1252-Gr.8.8	
Bolt Allowable Stress	Stba	199.96	N./mm^2
Bolt Corrosion Allowance	Bca	0.0000	mm.
Distance from Bolts to Edge	Edgedis	259.9944	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	52531.1	N
Saddle Load QL (Wind/Seismic contribution)	QL	18459.8	N
Maximum Transverse Force	Ft	50531.4	N
Maximum Longitudinal Force	Fl	42675.6	N
Saddle Bolted to Steel Foundation		Yes	

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)
= 42675.63 / (199.96 * 4.00)
= 0.5336 cm^2

Bolt Area due to Transverse Load

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 2200.00 * 50531.45 + 4800.00
= 116014.24 N-m

Eccentricity (e):
= Rmom / QO
= 116014.24 / 52531.14
= 2207.59 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis
= 1842.00 / 2 - 259.99
= 661.01 mm.

K1 = 3 (e - 0.5 * Bplen)
= 3 (2207.59 - 0.5*1842.00)
= 3859.77 mm.

K2 = 6 * n1 * At / Bpwid * (f + e)
= 6 * 1.00 * 4.34 / 330.00 * (661.01 + 2207.59)
= 22641.15 mm.^{2}

K3 = -K2 * (0.5 * Bplen + f)
= -35.09 * (0.5 * 1842.00 + 661.01)
= -2185.77 mm.^{2}

Iteratively Solving for the Effective Bearing Length:

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

$Y^3 + 151.96 * Y^2 + 35.09 * Y + -2185.77 = 0$

```
 Y  = 92.38 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1842.00 / 2 - 92.38 / 3 - 2207.59 )
     = -51.87

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1842.00 / 2 - 92.38 / 3 + 661.01 )
       = 61.07
```

Total Bolt Tension Force [Tforce]:
= - QO * Rnum / Denom
= - 52531.14 * -1317.38 / 1551.21
= 44612.61 N

Bolt Area Required due to Transverse Load [Bltareart]
= Tforce / (Stba * Nbt)
= 44612.61 / (199.96 * 2.00)
= 1.1157 cm^2

Required of a Single Bolt [Bltarear]
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0000 , 0.5336 , 1.1157]
= 1.1157 cm^2

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
= 2 * (QO + Tforce) / (Y * Bplen)
= 2 * (52531.14 + 44612.61) / (3.64 * 1842.00)
= 1141.81 KPa.

Distance from Baseplate Edge to the Web [ADIST]:
= (Bplen - Weblngth) / 2
= (1842.00 - 1791.20) / 2.0
= 25.4000 mm.

Overturning Moment due To Bolt Tension [Mt]:
= Tforce * (0.5 * Bplen + f - Y)
= 44612.61 * (0.5 * 1842.00 + 661.01 - 92.38)
= 66483.08 N-m

Equivalent Bearing Pressure (f1):
= fc * (Y - Adist) / Y
= 1141.81 * (92.38 - 25.40) / 92.38
= 827.87 KPa.

Overturning Moment due to Bearing Pressure [Mc]:
= $(Adist^2 * Bpwid / 6) * (f1 + 2 * fc)$
= $(25.40^2 * 330.00 / 6) * (827.87 + 2 * 1141.81)$
= 110.45 N-m

Baseplate Required Thickness [Treq]:
= $(6 * max(Mt,Mc) / (Bpwid * Sba))^{0.5}$
= $(6 * 66483.08 / (330.00 * 162.38))^{0.5}$
= 86.2662 mm.

Horizontal Vessel Analysis: Stresses for the Left Saddle

Horizontal Vessel Stress Calculations : Test Case

Shell Allowable Stress used in Calculation		137.90	$N./mm^2$
Shell Comp. Yield Stress used in Calculation		262.01	$N./mm^2$
Head Allowable Stress used in Calculation		137.90	$N./mm^2$
Saddle Force Q, Test Case, no Ext. Forces		192160.20	N
Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Saddles	58.44	137.90	$N./mm^2$
Long. Stress at Bottom of Saddles	57.28	137.90	$N./mm^2$
Long. Stress at Top of Midspan	55.12	137.90	$N./mm^2$
Long. Stress at Bottom of Midspan	60.60	137.90	$N./mm^2$
Tangential Shear in Shell	5.52	110.32	$N./mm^2$
Tangential Shear in Head	7.01	110.32	$N./mm^2$
Circ. Stress at Horn of Saddle	-4.72	-206.85	$N./mm^2$
Circ. Stress at Tip of Wear Plate	-8.45	-206.85	$N./mm^2$
Addl. Stress in Head as Stiffener	3.65	34.48	$N./mm^2$
Circ. Compressive Stress in Shell	-7.71	-131.01	$N./mm^2$
Hydrostatic Test Pressure at top of Vessel		3250.000	KPa.

Note: The Longitudinal Stress from the Zick Analysis is combined with
the Longitudinal Pressure Stress to get the total stress.

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
= 3.00 * ( 28189.2 /2 + 0 ) * 2200.0000 / 1730.3651
= 53760.0 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= Max( Fl, Friction Load, Sum of X Forces) * B / Ls
= Max( 14082.96 , 0.00 , 0 ) * 2200.0000 / 5086.0000
= 6091.7 N
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
= 138400 + Max( 6091 , 53759 , 0 , 0 )
= 192160.2 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including sadddle weight)	198681.52	N
Transverse Shear Load Saddle	14094.61	N
Longitudinal Shear Load Saddle	14082.96	N

Formulas and Substitutions for Horizontal Analysis:

Intermediate Term [MFract1]:

$= 1 - (1- a/L + (R^2-H2^2)/(2a*L))/(1+(4H)/3L)$

$= 1-(1-457.00/6000.00+(914.500^2-457.250^2)/(2*457.00*6000.00))/$
$(1+(4*38.10)/(2*6000.00))$
= 0.0576

Bending Moment over the Saddle (+-) [M1]:
= Q * a(MFract1)
= 192160 * 457.000 (0.0576)
= 5056.33 N-m

Intermediate Term [MFract2]:

$= (1+2(R^2-H^2)/(L^2))/(1+(4H)/(3L))-4a/L$

$= (1+2(914^2-457^2)/(6000^2))/(1+(4*457)/(3*6000))-$
4*457.00/6000.00
= 0.6347

Moment at Mid-Span [M2]:
= QL/4 * MFract2
= 192160 * 6000.000 /4 * 0.6347
= 183028.00 N-m

Longitudinal Bending (+-) at Midspan:

$= (0.25 * Q * L * K.2 / (pi * R^2*(Ts - Ca)))$
= (0.25 * 192160 * 6000.00 * 0.6347) /
(3.141 * 914.5000 * 914.5000 * (25.4000 - 0.0000)))

$= 2.74\ N./mm^2$

Compute the area ratio [K]:
= pi * (sin(delta)/Delta - cos(delta)) / (delta + sin(delta) * cos(delta) -
(delta + sin(delta) * cos(delta) - 2 * sin(delta) * sin(delta)/delta)
= Pi * (sin(1.498) / 1.498 - cos(1.498)) / (1.498 + sin(1.498) *
cos(1.498) - 2 * sin(1.498) * sin(1.498)/ 1.498)
= 7.6823

Intermediate Product [K.1]:
= K * MFract1 * 4 * A / L
= 7.682 * 0.058 * 4 * 457.000 / 6000.000
= 0.1347

Longitudinal Bending (+-) at Saddle:

$= (0.25 * Q * L * K.1 / (pi * R^2*(Ts - Ca)))$
= (0.25 * 192160 * 6000.00 * 0.1347) /
(3.141 * 914.5000 * 914.5000 * (25.4000 - 0.0000)))

$= 0.58\ N./mm^2$

Tangential Shear in Shell near Saddle:
= K3 * Q / (R * t)
= 0.6668 * 192160 / (914.5000 * 25.4000)

$= 5.52\ N./mm^2$

Tangential Shear in Head used as Stiffener:
= K4 * Q / (R * Th)

= 0 * 0.2E+06 / (914.50 * (20.0000 - 0.0000)

= 7.01 $N./mm^2$

Circumferential Stress at Tip of the Wear Plate:
= $-Q/(4t(b+x1+x2)) - 12*Q*R*K7,1/(L*t^2)$
= -192160 /(4 * 25.4000 (250.00 + 118.8785 + 118.8785))
-12 * 192160 * 76.21 * 0.0084 /(6000.0000 * 25.4000 ^{2})

= -8.45 $N./mm^2$

Note: Wear Plate is considered as A < R/2 and WearPlate extension > R/10)

Equivalent Membrane Thickness [Tem]:
= Corroded Thickness + Wearplate Thickness
= 25.400 + 25.400
= 50.800 mm.

Equivalent Bending Thickness squared [Teb]:
= Corroded Thickness^2 + Wearplate Thickness^2
= 25.400 ^2 + 25.400 ^2
= 1290.320 mm.^2

Circumferential Stress at Horn of Saddle:
= $-Q/(4t(b+x1+x2)) - 12*Q*R*K7/(L*t^2)$
= -192160 /(4 * 50.8000 (250.00 + 118.8785 + 118.8785))
-12 * 192160 * 76.21 * 0.0102 / (6000.0000 * 1290.3199)

= -4.72 $N./mm^2$

Parameter [K4]:

= $(3/8)*(\sin(alpha)^2/(pi-alpha+\sin(alpha*\cos(alpha)))$

= $(3/8)*(\sin(107.3)^2/(pi-107.3+\sin(107.3*\cos(107.3)))$

= 0.3474

Additional Tension in Head used as Stiffener:
= K4 * Q/(R * th)
= 0.3474 * 192160 /(914.5000 * 20.0000)

= 3.65 $N./mm^2$

Circumferential Compression at Bottom of Shell:
= (Q*(K.9/(TEM9 * WPDWTH)))
= (192160 *(0.7137 /(50.8000 * 350.000)))

= -7.71 $N./mm^2$

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1842.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	330.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	Y	A	AY	Ay^2	Io
Shell	13.	149.	189599.	241.	80.
Wearplate	38.	89.	338709.	1290.	48.
Web	630.	139.	8769115.	552804.	155767.

BasePlate	1222.	83.	10085625.	1232966.	43.
Totals	1904.	460.	19383046.	1787302.	155938.

Value C1 = Sumof(Ay)/Sumof(A) = 422. mm.

Value I = Sumof(Ay^2) + Sumof(Io) - C1*Sumof(Ay) = 1126131. cm**4

Value As = Sumof(A) - Ashell = 311. cm^2

K1 = (1+Cos(beta)-.5*Sin(beta)^2)/(pi-beta+Sin(beta)*Cos(beta)) = 0.2292

Fh = K1 * Q = 0.2292 * 192160.203 = 44048.0664 N

Tension Stress, St = (Fh/As) = 1.4187 N./mm^2

Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

d = B - R*Sin(theta) / theta = 1429.6241 mm.
Bending Moment, M = Fh * d = 62997.7031 N-m

Bending Stress, Sb = (M * C1 / I) = 2.3575 N./mm^2

Allowed Stress, Sa = 2/3 * Yield Str = 137.9000 N./mm^2

Minimum Thickness of Baseplate per Moss :

= (3 * (Q + Saddle_Wt) * BasePlateWidth / (4 * BasePlateLength * AllStress))$^{0.5}$

= (3 * (192160 + 6521) * 330.00 / (4 * 1842.000 * 137.900))$^{0.5}$

= 13.914 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress

Effective Baseplate Length [e]:
= (Bplen - Clearance) / (Nribs - 1)
= (1842.0000 - 25.4) / (4 - 1) = 605.5333 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 605.5333 * 330.0000 / 2 = 999.1300 cm^2

Axial Load [P]:
= Ap * Bp
= 999.1 * 31.61 = 31585.1 N

Area of the Rib and Web [Ar]:
= (Bpwid - Clearance - Webtk) * Ribtk + e/2 * Webtk
= (330.000 - 25.4 - 12.000) * 10.000 + 605.5333 /2 * 12.000
= 65.592 cm^2

Compressive Stress [Sc]:
= P/Ar
= 31585.1 / 65.5920 = 4.8158 N./mm^2

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	Y	A	AY	Ay^2	Io
Rib	125.0	26.5	331625.0	0.0	1776.9
Web	125.0	36.3	454150.0	0.0	8.7
Values	125.0	62.9	785775.0	0.0	1785.6

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * rl / 2
= 14083.0 /(2 * 1842.00) * 605.533 * 1782.25 / 2
= 2063.609 N-m

KL/R < Cc (34.1584 < 138.1347) per AISC E2-1

$Sca = (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3))$

$Sca = (1-(34.16)^2/(2 * 138.13^2))*206 /$

$(5/3+3*(34.16)/(8* 138.13)-(34.16^3)/(8*138.13^3))$

$Sca = 114.10$ N./mm^2

AISC Unity Check on Outside Ribs (must be <= 1.0)
Check = Sc/Sca + (Rm/Z)/Sba
Check = 4.82 / 114.10 + (2063.61 /9.942) / 137.90
Check = 0.19

Check of Inside Ribs
Inertia of Saddle, Inner Ribs - Axial Direction

	Y	A	AY	Ay^2	Io
Rib	152.3	29.3	445629.8	0.0	2355.1
Web	152.3	72.7	1106672.8	0.0	8.7
Values	152.3	101.9	1552302.5	0.0	2363.8

KL/R < Cc (25.6014 < 138.1347) per AISC E2-1

$Sca = (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3))$

$Sca = (1-(25.60)^2/(2 * 138.13^2))*206 /$

$(5/3+3*(25.60)/(8* 138.13)-(25.60^3)/(8*138.13^3))$

$Sca = 117.15$ N./mm^2

AISC Unity Check on Inside Ribs (must be <= 1.0)
Check = Sc/Sca + (Rm/Z)/Sba
Check = 6.20 / 117.15 + (2855.09 /15.521) / 137.90
Check = 0.19

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification	AS	1252-Gr.8.8	
Bolt Allowable Stress	Stba	199.96	N./mm^2
Bolt Corrosion Allowance	Bca	0.0000	mm.
Distance from Bolts to Edge	Edgedis	259.9944	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2

Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	144921.5	N
Saddle Load QL (Wind/Seismic contribution)	QL	6091.7	N
Maximum Transverse Force	Ft	14094.6	N
Maximum Longitudinal Force	Fl	14083.0	N
Saddle Bolted to Steel Foundation		Yes	

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)
= 14082.96 / (199.96 * 4.00)
= 0.1761 cm^2

Bolt Area due to Transverse Load

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 2200.00 * 14094.61 + 4800.00
= 35820.71 N-m

Eccentricity (e):
= Rmom / QO
= 35820.71 / 144921.52
= 247.07 mm. < Bplen/6 --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:
= 0 (No Uplift)

Required of a Single Bolt [Bltarear]
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0000 , 0.1761 , 0.0000]
= 0.1761 cm^2

Zick Analysis: Stresses for the Right Saddle

Shell Allowable Stress used in Calculation	137.90	$N./mm^2$
Shell Comp. Yield Stress used in Calculation	262.01	$N./mm^2$
Head Allowable Stress used in Calculation	137.90	$N./mm^2$
Saddle Force Q, Test Case, no Ext. Forces	189904.52	N

Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Saddles	58.43	137.90	$N./mm^2$
Long. Stress at Bottom of Saddles	57.28	137.90	$N./mm^2$
Long. Stress at Top of Midspan	55.15	137.90	$N./mm^2$
Long. Stress at Bottom of Midspan	60.57	137.90	$N./mm^2$

Tangential Shear in Shell	5.45	110.32	N./mm^2
Tangential Shear in Head	6.92	110.32	N./mm^2
Circ. Stress at Horn of Saddle	-4.66	-206.85	N./mm^2
Circ. Stress at Tip of Wear Plate	-8.36	-206.85	N./mm^2
Addl. Stress in Head as Stiffener	3.61	34.48	N./mm^2
Circ. Compressive Stress in Shell	-7.62	-131.01	N./mm^2
Hydrostatic Test Pressure at top of Vessel		3250.000	KPa.

Note: The Longitudinal Stress from the Zick Analysis is combined with
the Longitudinal Pressure Stress to get the total stress.

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
= 3.00 * (28189.2 /2 + 0) * 2200.0000 / 1730.3651
= 53760.0 N

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= Max(Fl, Friction Load, Sum of X Forces) * B / Ls
= Max(14082.96 , 0.00 , 0) * 2200.0000 / 5086.0000
= 6091.7 N

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 136144 + Max(6091 , 53759 , 0 , 0)
= 189904.5 N

Summary of Loads at the base of this Saddle:

Vertical Load (including sadddle weight)	196425.81	N
Transverse Shear Load Saddle	14094.61	N
Longitudinal Shear Load Saddle	14082.96	N

Formulas and Substitutions for Horizontal Analysis:

Intermediate Term [MFract1]:

= $1 - (1- a/L + (R^2-H2^2)/(2a*L))/(1+(4H)/3L)$

= $1-(1-457.00/6000.00+(914.500^2-457.250^2)/(2*457.00*6000.00))/$
$(1+(4*38.10)/(2*6000.00))$
= 0.0576

Bending Moment over the Saddle (+-) [M1]:
= Q * a(MFract1)
= 189904 * 457.000 (0.0576)
= 4996.98 N-m

Intermediate Term [MFract2]:

= $(1+2(R^2-H^2)/(L^2))/(1+(4H)/(3L))-4a/L$

= $(1+2(914^2-457^2)/(6000^2))/(1+(4*457)/(3*6000))-$
$4*457.00/6000.00$
= 0.6347

Moment at Mid-Span [M2]:

```
= QL/4 * MFract2
= 189904 * 6000.000 /4 * 0.6347
= 180879.52 N-m
```

Longitudinal Bending (+-) at Midspan:

$$= (0.25 * Q * L * K.2 / (pi * R^2 *(Ts - Ca)))$$

```
= ( 0.25 * 189904 * 6000.00 * 0.6347 ) /
  ( 3.141 * 914.5000 * 914.5000 * ( 25.4000 - 0.0000 )))
```

$= 2.71\ N./mm^2$

Compute the area ratio [K]:

```
= pi * (sin(delta)/Delta - cos(delta) ) / (delta + sin(delta) * cos(delta) -
  (delta + sin(delta) * cos(delta) - 2 * sin(delta) * sin(delta)/delta)
= Pi * (sin(1.498 ) / 1.498 - cos(1.498 )) / ( 1.498 + sin(1.498 ) *
  cos(1.498 ) - 2 * sin(1.498 ) * sin(1.498 )/ 1.498 )
= 7.6823
```

Intermediate Product [K.1]:

```
= K * MFract1 * 4 * A / L
= 7.682 * 0.058 * 4 * 457.000 / 6000.000
= 0.1347
```

Longitudinal Bending (+-) at Saddle:

$$= (0.25 * Q * L * K.1 / (pi * R^2 *(Ts - Ca)))$$

```
= ( 0.25 * 189904 * 6000.00 * 0.1347 ) /
  ( 3.141 * 914.5000 * 914.5000 * ( 25.4000 - 0.0000 )))
```

$= 0.58\ N./mm^2$

Tangential Shear in Shell near Saddle:

```
= K3 * Q / ( R * t )
= 0.6668 * 189904 / ( 914.5000 * 25.4000 )
```

$= 5.45\ N./mm^2$

Tangential Shear in Head used as Stiffener:

```
= K4 * Q / ( R * Th )
= 0 * 0.2E+06 / ( 914.50 * ( 20.0000 - 0.0000 )
```

$= 6.92\ N./mm^2$

Circumferential Stress at Tip of the Wear Plate:

$$= -Q/(4t(b+x1+x2)) - 12*Q*R*K7,1/(L*t^2)$$

$$= -189904 /(4 * 25.4000 (250.00 + 118.8785 + 118.8785)) -12 * 189904 * 76.21 * 0.0084 /(6000.0000 * 25.4000^2)$$

$= -8.36\ N./mm^2$

Note: Wear Plate is considered as A < R/2 and WearPlate extension > R/10)

Equivalent Membrane Thickness [Tem]:

```
= Corroded Thickness + Wearplate Thickness
= 25.400 + 25.400
= 50.800 mm.
```

Equivalent Bending Thickness squared [Teb]:

```
= Corroded Thickness^2 + Wearplate Thickness^2
= 25.400 ^2 + 25.400 ^2
= 1290.320 mm.^2
```

Circumferential Stress at Horn of Saddle:

= -Q/(4t(b+x1+x2)) - 12*Q*R*K7/(L*t^2)
= -189904 /(4 * 50.8000 (250.00 + 118.8785 + 118.8785))
-12 * 189904 * 76.21 * 0.0102 / (6000.0000 * 1290.3199)
= -4.66 N./mm^2

Parameter [K4]:
= (3/8)*(sin(alpha)^2/(pi-alpha+sin(alpha*cos(alpha)))
= (3/8)*(sin(107.3)^2/(pi-107.3 +sin(107.3 *cos(107.3)))
= 0.3474

Additional Tension in Head used as Stiffener:
= K4 * Q/(R * th)
= 0.3474 * 189904 /(914.5000 * 20.0000)
= 3.61 N./mm^2

Circumferential Compression at Bottom of Shell:
= (Q*(K.9/(TEM9 * WPDWTH)))
= (189904 *(0.7137 /(50.8000 * 350.000)))
= -7.62 N./mm^2

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1842.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	330.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	Y	A	AY	Ay^2	Io
Shell	13.	149.	189599.	241.	80.
Wearplate	38.	89.	338709.	1290.	48.
Web	630.	139.	8769115.	552804.	155767.
BasePlate	1222.	83.	10085625.	1232966.	43.
Totals	1904.	460.	19383046.	1787302.	155938.

Value C1 = Sumof(Ay)/Sumof(A) = 422. mm.

Value I = Sumof(Ay^2)+Sumof(Io) - C1*Sumof(Ay) = 1126131. cm**4

Value As = Sumof(A) - Ashell = 311. cm^2

K1 = (1+Cos(beta)-.5*Sin(beta)^2)/(pi-beta+Sin(beta)*Cos(beta)) = 0.2292

Fh = K1 * Q = 0.2292 * 189904.516 = 43531.0039 N

Tension Stress, St = (Fh/As) = 1.4021 N./mm^2

Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

d = B - R*Sin(theta) / theta = 1429.6241 mm.
Bending Moment, M = Fh * d = 62258.2031 N-m

Bending Stress, Sb = (M * C1 / I) = 2.3298 $N./mm^2$

Allowed Stress, Sa = 2/3 * Yield Str = 137.9000 $N./mm^2$

Minimum Thickness of Baseplate per Moss :

$= (3 * (Q + Saddle\_Wt) * BasePlateWidth / (4 * BasePlateLength * AllStress))^{0.5}$

$= (3 * (189904 + 6521) * 330.00 / (4 * 1842.000 * 137.900))^{0.5}$

= 13.835 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress

Effective Baseplate Length [e]:
= (Bplen - Clearance) / (Nribs - 1)
= (1842.0000 - 25.4) / (4 - 1) = 605.5333 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2

= 605.5333 * 330.0000 / 2 = 999.1300 cm^2

Axial Load [P]:
= Ap * Bp
= 999.1 * 31.24 = 31214.3 N

Area of the Rib and Web [Ar]:
= (Bpwid - Clearance - Webtk) * Ribtk + e/2 * Webtk
= (330.000 - 25.4 - 12.000) * 10.000 + 605.5333 /2 * 12.000

= 65.592 cm^2

Compressive Stress [Sc]:
= P/Ar

= 31214.3 / 65.5920 = 4.7593 $N./mm^2$

<u>Check of Outside Ribs:</u>
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	Y	A	AY	Ay^2	Io
Rib	125.0	26.5	331625.0	0.0	1776.9
Web	125.0	36.3	454150.0	0.0	8.7
Values	125.0	62.9	785775.0	0.0	1785.6

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * rl / 2
= 14083.0 /(2 * 1842.00) * 605.533 * 1782.25 / 2
= 2063.609 N-m

KL/R < Cc (34.1584 < 138.1347) per AISC E2-1

$Sca = (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$

$Sca = (1-(34.16)^2/(2 * 138.13^2)) * 206 /$

$(5/3+3*(34.16)/(8* 138.13)-(34.16^3)/(8*138.13^3)$

Sca = 114.10 $N./mm^2$

AISC Unity Check on Outside Ribs (must be <= 1.0)

Check = Sc/Sca + (Rm/Z)/Sba
Check = 4.76 / 114.10 + (2063.61 /9.942) / 137.90
Check = 0.19

Check of Inside Ribs

Inertia of Saddle, Inner Ribs - Axial Direction

	Y	A	AY	Ay^2	Io
Rib	152.3	29.3	445629.8	0.0	2355.1
Web	152.3	72.7	1106672.8	0.0	8.7
Values	152.3	101.9	1552302.5	0.0	2363.8

KL/R < Cc (25.6014 < 138.1347) per AISC E2-1

$Sca = (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3))$

$Sca = (1-(25.60)^2/(2 * 138.13^2)) * 206 /$

$(5/3+3*(25.60)/(8* 138.13)-(25.60^3)/(8*138.13^3))$

Sca = 117.15 N./mm^2

AISC Unity Check on Inside Ribs (must be <= 1.0)

Check = Sc/Sca + (Rm/Z)/Sba
Check = 6.13 / 117.15 + (2855.09 /15.521) / 137.90
Check = 0.19

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		AS 1252-Gr.8.8	
Bolt Allowable Stress	Stba	199.96	N./mm^2
Bolt Corrosion Allowance	Bca	0.0000	mm.
Distance from Bolts to Edge	Edgedis	259.9944	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	142665.8	N
Saddle Load QL (Wind/Seismic contribution)	QL	6091.7	N
Maximum Transverse Force	Ft	14094.6	N
Maximum Longitudinal Force	Fl	14083.0	N
Saddle Bolted to Steel Foundation		Yes	

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)
= 14082.96 / (199.96 * 4.00)
= 0.1761 cm^2

Bolt Area due to Transverse Load

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments

= 2200.00 * 14094.61 + 4800.00
= 35820.71 N-m

Eccentricity (e):
= Rmom / QO
= 35820.71 / 142665.84
= 250.98 mm. < Bplen/6 --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:
= 0 (No Uplift)

Required of a Single Bolt [Bltarear]
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0000 , 0.1761 , 0.0000]
= 0.1761 cm^2