Transportation Calculation of D-350

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Ocean Transport

Note:
Wear Pad Width (300.00) 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( 200 + 1.56*sqrt( 918.4 * 8 ), 2 * 508 )
  = 333.7166 mm
```

Input and Calculated Values:

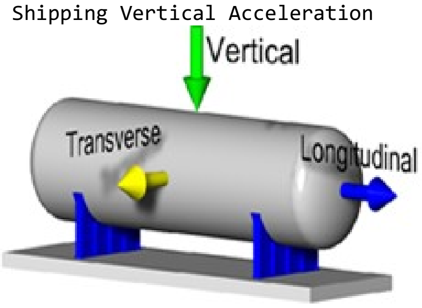
```
 Vessel Mean Radius                               Rm      918.40  mm
 Shell Thickness used in this Case                 t       8.000  mm
 Stiffened Vessel Length per 4.15.6                L     5028.40  mm
 Distance from Saddle to Vessel tangent    a1 or a       508.00  mm

 Saddle Width                              b1 or b       200.00  mm
 Saddle Bearing Angle               delta or theta       120.00  degrees

 Shell Allowable Stress used in Calculation              115.15  MPa
 Head Allowable Stress used in Calculation                 0.00  MPa
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline           B     1300.00  mm
 Coefficient of Friction                          mu        0.00

 Saddle Force Q for this Transportation Case           76992.21  N
 Shipping Longitudinal Acceleration               gx        0.40  g
 Shipping Transverse Acceleration                 gz        0.75  g
 Shipping Vertical Acceleration                   gy        2.00  g
```




```
 Vertical Acceleration Acting with Transverse  gw         2.00  g
 Internal Pressure during Transport                       0.00  MPa
 Transportation Wind Load Scalar Factor      wlsf         1.00
 Transportation Wind Velocity                  wv          0.0  km/hr
```

```
 Horizontal Vessel Analysis Results:       Actual |     Allowable |
                                              MPa |           MPa |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan          -3.03 |       -155.14 |
 Long. Stress at Top    of Midspan           3.03 |        115.15 |
 Long. Stress at Bottom of Midspan           3.03 |        115.15 |
 Long. Stress at Top    of Saddles          -1.11 |       -155.14 |
 Long. Stress at Top    of Saddles           1.11 |        115.15 |
 Long. Stress at Bottom of Saddles           0.61 |        115.15 |
```

```
---------------------------------------------------------------
Tangential Shear in Shell                 9.79 |         69.83 |
Circ. Stress at Horn of Saddle           53.16 |        172.72 |
Circ. Compressive Stress in Shell        21.93 |        115.15 |
---------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Ocean Transport Load:

Transverse Force due to Wind during Transport [Ft_w]:

```
= Transverse Area * 0.00256 * wv^2 * wlsf
= 235.96 * 0.00256 * 0^2 * 1
= 0.0 lbf
= 0.000 N
```

Longitudinal Force due to Wind during Transport [Fl_w]:

```
= pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
= pi * 6.0525^2/4 * 0.00256 * 0^2 * 1 * 1.2
= 0.0 lbf
= 0.0 N
```

Transverse Force due to Axial Acceleration [Ft]:

```
= gx * saddle Load * gw + Ft_w
= 0.75 * 25664 * 2 + 0
= 38496.1 N
```

Longitudinal Force due to Axial Acceleration [Fl]:

```
= gz * saddle Load * gw + Fl_w
= 0.4 * 25664 * 2 + 0
= 20531.3 N
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:

```
= Ft/Num of Saddles * B / E
= 38496/2 * 1300/1635
= 15304.3 N
```

Saddle Reaction Force due to Transport Load [Fwl]:

```
= Fl * B / Ls
= 20531 * 1300/6025
= 4430.0 N
```

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:

```
= Saddle Load * gy
= 25664 * 2
= 51328.145 N
```

Load Combination Results due to Transport Loading [Q]:

```
= Saddle Load + max( Fwl, Fwt, Fsl )
= 25664 + max( 4430, 15304, 51328 )
= 76992.2 N
```

Summary of Loads at the base of this Saddle:

```
Vertical Load (including saddle weight)           78948.56   N
Transverse Shear Load Saddle                      15304.26   N
Longitudinal Shear Load Saddle                    20531.26   N
```

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is not Welded to the Shell, k = 1.0

Saddle Dimension [E]:

```
= Specified by Analyst
= 1635.000 mm
```

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  = 0.0174     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 4.15.1 [M1]:

```
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -76992*508[1-(1-508/5028.4+(918.4²-0²)/
  (2*508*5028.4))/(1+(4*0)/(3*5028.4))]
= 2506970.8 N-mm
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 76992*5028.4/4(1+2(918.4²-0²)/(5028.4²))/(1+(4*0)/
  (3*5028.4))-4*508/5028.4
= 64158184.0 N-mm
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 0 * 918.4/(2*8 ) - 64158184/(pi*918.4²*8 )
= -3.03 MPa
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 0 * 918.4/(2 * 8 ) + 64158184/(pi * 918.4² * 8 )
= 3.03 MPa
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma∗3]:

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 0*918.4/(2*8)-2506970/(0.1066*pi*918.4²*8)
= -1.11 MPa
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma∗4]:

```
= P * Rm/(2t) + M1/(K1∗ * pi * Rm² * t)
= 0*918.4/(2*8)+2506970/(0.1923*pi*918.4²*8)
= 0.61 MPa
```

Maximum Shear Force in the Saddle (4.15.3) [T]:

```
= Q(L-2a)/(L+(4*h2/3))
= 76992( 5028.4 - 2 * 508 )/(5028.4 +( 4 * 0/3))
= 61435.8 N
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:

```
= K2 * T / ( Rm * t )
= 1.1707 * 61436/( 918.4 * 8 )
= 9.79 MPa
```

Decay Length (4.15.20) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 918.4 * 8 )
= 66.858 mm
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:

```
= -K5 * Q * k / ( t( b + X1 + X2 ) )
= -0.7603 * 76992 * 1.0/( 8( 200 + 66.858 + 66.858 ) )
= -21.93 MPa
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.23) [sigma7∗]:

```
= -Q/(4*t(b+X1+X2)) - 12*K7*Q*Rm/(L*t²)
= -76992/(4*8(200 +66.858 +66.858 )) -
   12 * 0.01743 * 76992 * 918.4/(5028.4 * 8²)
= -53.16 MPa
```

Effective reinforcing plate width (4.15.24) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(200 + 1.56 * sqrt(918.4 * 8), 2 * 508)
= 333.72 mm

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1660.0000	mm
Baseplate Thickness	Bpthk	10.0000	mm
Baseplate Width	Bpwid	220.0000	mm
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	8.0000	mm
Web Thickness	Webtk	8.0000	mm
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	245.2	MPa
Height of Web at Center	Hw,c	352.0	mm
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12
= ((1.56 * sqrt(914.4 * 8) + 300)8^3)/12
= 18492.787 mm^4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y $)^2$
= 18493 + 3467.4(131.88 - 4 $)^2$
= 56717476.000 mm^4

	B	D	Y	A	AY	I + AD^2
	mm	mm	mm	mm^2	mm^3	mm^4
Shell	433.4	8.0	4.0	3467.4	13869.6	0.567E+08
Wearplate	300.0	8.0	12.0	2400.0	28800.0	0.345E+08
Web	8.0	359.6	195.8	2876.8	563277.4	0.428E+08
BasePlate	220.0	10.0	380.6	2200.0	837319.9	0.136E+09
Totals	...	...	...	10944.2	1443267.0	0.270E+09

Distance to Centroid [C1]:
= AY / A
= 56822/10944
= 131.875 mm

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta$)^2$)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120) - 0.5*sin(120 $)^2$)/(pi - 2.0944 + sin(120)cos(120))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.2035 * 76992
= 15669.5850 N

Tension Stress, St = (Fh/As) = 2.0959 MPa
Allowed Stress, Sa = 0.6 * Yield Str = 147.0961 MPa

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 1300 - 914.4 * sin(120/2)/1.0472

```
  = 543.797 mm

 Bending Moment, M  = Fh * d          =    8524532.0000  N-mm

 Bending Stress, Sb = ( M * C1 / I  ) =          4.1608  MPa
 Allowed Stress, Sa = 2/3 * Yield Str =        163.4401  MPa
```

Minimum Thickness of Baseplate per Moss:

```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))
  = sqrt( 3(76992 + 1956.4 )220/( 4 * 1660 * 163.44 ))
  = 6.929 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 - 120/2 )( 914.4 + 8 + 8 )
  = 1611.500 mm
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1611.5/( 4 - 1 )
  = 537.167 mm
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 537.17 * 220/2
  = 59088.328 mm^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 76992/( 1660 * 220 )
  = 0.211 N/mm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 59088 * 0.2108
  = 12457.123 N
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 1536 + 2148.7
  = 3684.667 mm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 12457/3684.7
  = 3.381 MPa
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	8.0	200.0	...	1600.0	...	0.533E+07

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 200 - 8
  = 192.000 mm
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0/3684.7
```

= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 200/2
= 100.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(5333328/3684.7)
= 38.045 mm

Length of Outer Rib [L]:
= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 1300 - cos(120/2)(914.4 + 8 + 8) - 10
= 824.800 mm

Intermediate Term [Cc]:
= sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)
= sqrt(2 * pi^2 * 199955/245.16)
= 126.884

Slenderness ratio [KL/r]:
= KL/r
= 1 * 824.8/38.045
= 21.679

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 20531/(2 * 1660) * 537.17 * 824.8/2
= 1370506.875 N-mm

Compressive Allowable, KL/r < Cc(21.679 < 126.88) per AISC E2-1 [Sca]:
= (1-$(Klr)^2$/($2*Cc^2$))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/($8*Cc^3$)
= (1-(21.679 $)^2$/(2 * 126.88^2))245.16/
(5/3+3*(21.679)/(8* 126.88)-(21.679^3)/($8*126.88^3$)
= 139.6 MPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 3.3811/139.63 +(1370506 * 100/5333333)/163.44
= 0.181

AISC Unity Check of Outside Ribs, due to Transverse Force Ft (must be <= 1)

This analysis assumes the entire saddle weight load and load due to transverse forces are concentrated on the outer rib + some portion of the web. This generally would not be the case and as such this analysis is very conservative.

Inertia of Saddle, Outer Ribs - Transverse Direction:

	B	D	Y	A	AY	Io
Rib	192.0	8.0	4.0	1536.0	6144.0	0.893E+06
Web	8.0	128.0	64.0	1024.0	65536.0	0.273E+07
Totals	...	...	...	2560.0	71680.0	0.362E+07

Web dimension [D]:
= 16 * Web Thickness
= 16 * 8
= 128.000 mm

Moment at base of outer Rib [Mbase]:
= Ft(Centerline dimension B - Baseplate thickness)

= 3831.1(1300 - 10)
= 4944118.500 N-mm

Bending Stress due to Transverse Force [SigmaB,base]:
= Bending Moment / Section Modulus
= 4944118/129219
= 38.249 MPa

Vertical Load on the Rib due to the Bending Moment [Fv,mom]:
= Bending Moment / Web Length
= 4944118/1611.5
= 3066.779 N

Total Vertical Load on the Rib [Fv,total]:
= Fv,mom + Vertical Load
= 3066.8 + 192848
= 195914.969 N

Compressive Stress on Outer Rib [Sigma,cr]:
= Fv,total / Area
= 195915/2560
= 76.536 MPa

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(3618129/2560)
= 37.594 mm

Slenderness ratio [KL/r]:
= KL/r
= 1 * 824.8/37.594
= 21.939

Compressive Allowable, KL/r < Cc(21.939 < 126.88) per AISC E2-1 [Sca]:
= $(1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3))$
= $(1-(21.939)^2/(2 * 126.88^2))245.16/$
$(5/3+3*(21.939)/(8* 126.88)-(21.939^3)/(8*126.88^3))$
= 139.5 MPa

Unity Check on Outer Rib [UCheck,outer]:
= Sigma,cr / Sca + SigmaB,base / Sba
= 76.536/139.52 + 38.249/163.44
= 0.783

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	8.0	192.0	0.0	1536.0	0.0	0.533E+07
Web	537.2	8.0	0.0	4297.3	0.0	0.229E+05
Totals	...	...	...	5833.3	...	0.536E+07

Distance to Centroid from Datum [ytot]:
= AY / A
= 0/5833.3
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 200/2
= 100.000 mm

Length of Inner Rib [L]:

```
= Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
= 1300 - sqrt((930.4 + 8 )^2 -(537.17/2)^2 ) - 10
= 399.210 mm
```

Radius of Gyration [r]:

```
= sqrt( Total Inertia / Total Area )
= sqrt( 5355905/5833.3 )
= 30.301 mm
```

Slenderness ratio [KL/r]:

```
= KL/r
= 1 * 399.21/30.301
= 13.175
```

Unit Force [Force,u]:

```
= Fl / ( 2 * Baseplate Length )
= 20531/( 2 * 1660 )
= 6.184 N/mm
```

Moment at base of inner Rib [Mbase,c]:

```
= Unit Force * e * L
= 6.1841 * 537.17 * 399.21
= 1326672.625 N-mm
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

```
= Bending Moment / Section Modulus
= 1326672/53559
= 24.762 MPa
```

Compressive Allowable, KL/r < Cc(13.175 < 126.88) per AISC E2-1 [Sca]:

$$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3))$$
$$= (1-(13.175)^2/(2 * 126.88^2))245.16/$$
$$(5/3+3*(13.175)/(8* 126.88)-(13.175^3)/(8*126.88^3))$$
$$= 143 \text{ MPa}$$

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

```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 4.3032/142.97 +( 1326672 * 100/5355905 )/163.44
= 0.182
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Note:
Wear Pad Width (300.00) 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( 200 + 1.56*sqrt( 918.4 * 8 ), 2 * 508 )
= 333.7166 mm
```

Input and Calculated Values:

Vessel Mean Radius	Rm	918.40	mm
Shell Thickness used in this Case	t	8.000	mm
Stiffened Vessel Length per 4.15.6	L	5028.40	mm
Distance from Saddle to Vessel tangent	a1 or a	508.00	mm
Saddle Width	b1 or b	200.00	mm
Saddle Bearing Angle	delta or theta	120.00	degrees
Inside Depth of Head	Hi or h2	458.00	mm
Shell Allowable Stress used in Calculation		115.15	MPa

```
Head Allowable Stress used in Calculation           115.15  MPa
Circumferential Efficiency in Plane of Saddle         1.00
Circumferential Efficiency at Mid-Span                1.00

Distance from Saddle Base to Centerline       B     1300.00  mm
Coefficient of Friction                      mu        0.00

Saddle Force Q for this Transportation Case        65712.59  N
Shipping Longitudinal Acceleration           gx        0.40  g
Shipping Transverse Acceleration             gz        0.75  g
Shipping Vertical Acceleration               gy        2.00  g
Vertical Acceleration Acting with Transverse  gw       2.00  g
Internal Pressure during Transport                     0.00  MPa
Transportation Wind Load Scalar Factor      wlsf       1.00
Transportation Wind Velocity                 wv         0.0  km/hr

Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                            MPa |          MPa |
----------------------------------------------------------------
Long. Stress at Top    of Midspan        -2.07 |      -155.14 |
Long. Stress at Top    of Midspan         2.07 |       115.15 |
Long. Stress at Bottom of Midspan         2.07 |       115.15 |
Long. Stress at Top    of Saddles         1.30 |       115.15 |
Long. Stress at Bottom of Saddles        -0.72 |      -155.14 |
Long. Stress at Bottom of Saddles         0.72 |       115.15 |
----------------------------------------------------------------
Tangential Shear in Shell                 7.45 |        69.83 |
Circ. Stress at Horn of Saddle           45.37 |       172.72 |
Circ. Compressive Stress in Shell        18.71 |       115.15 |
----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Ocean Transport Load:

Transverse Force due to Wind during Transport [Ft_w]:

```
  = Transverse Area * 0.00256 * wv^2 * wlsf
  = 235.96 * 0.00256 * 0^2 * 1
  = 0.0 lbf
  = 0.000 N
```

Longitudinal Force due to Wind during Transport [Fl_w]:

```
  = pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
  = pi * 6.0525^2/4 * 0.00256 * 0^2 * 1 * 1.2
  = 0.0 lbf
  = 0.0 N
```

Transverse Force due to Axial Acceleration [Ft]:

```
  = gx * saddle Load * gw + Ft_w
  = 0.75 * 21904 * 2 + 0
  = 32856.3 N
```

Longitudinal Force due to Axial Acceleration [Fl]:

```
  = gz * saddle Load * gw + Fl_w
  = 0.4 * 21904 * 2 + 0
  = 17523.4 N
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:

```
  = Ft/Num of Saddles * B / E
  = 32856/2 * 1300/1611.5
  = 13252.6 N
```

Saddle Reaction Force due to Transport Load [Fwl]:

```
  = Fl * B / Ls
  = 17523 * 1300/6025
  = 3781.0 N
```

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:
= Saddle Load * gy
= 21904 * 2
= 43808.398 N

Load Combination Results due to Transport Loading [Q]:
= Saddle Load + max(Fwl, Fwt, Fsl)
= 21904 + max(3781, 13253, 43808)
= 65712.6 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	67668.95	N
Transverse Shear Load Saddle	13252.62	N
Longitudinal Shear Load Saddle	17523.36	N

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is not Welded to the Shell, k = 1.0

Saddle Dimension [E]:
= min(2(ShellID/2 + t + WearPadThickness)sin(θ /2), 2*Rm)
= min(2(1828.8/2 + 8 + 8)sin(120/2), 2*918.4)
= 1611.500 mm

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 = 0.0174	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 4.15.1 [M1]:
= -Q*a [1 - (1- a/L + (Rm^2 -h2^2)/(2a*L))/(1+(4h2)/3L)]
= -65713*508[1-(1-508/5028.4+(918.4^2 -458^2)/
(2*508*5028.4))/(1+(4*458)/(3*5028.4))]
= -2931189.2 N-mm

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm^2 -h2^2)/(L^2))/(1+(4h2)/(3L))-4a/L
= 65713*5028.4/4(1+2(918.4^2 -458^2)/(5028.4^2))/(1+(4*458)/
(3*5028.4))-4*508/5028.4
= 43989672.0 N-mm

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
= P * Rm/(2t) - M2/(pi*Rm^2 t)
= 0 * 918.4/(2*8) - 43989672/(pi*918.4^2 *8)
= -2.07 MPa

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
= P * Rm/(2t) + M2/(pi * Rm^2 * t)
= 0 * 918.4/(2 * 8) + 43989672/(pi * 918.4^2 * 8)
= 2.07 MPa

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm^2 t)
= 0*918.4/(2*8)--2931189/(0.1066*pi*918.4^2 *8)
= 1.30 MPa

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm^2 * t)
= 0*918.4/(2*8)+-2931189/(0.1923*pi*918.4^2 *8)
= -0.72 MPa

Maximum Shear Force in the Saddle (4.15.3) [T]:

```
= Q(L-2a)/(L+(4*h2/3))
= 65713( 5028.4 - 2 * 508 )/(5028.4 +( 4 * 458/3))
= 46756.9 N
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:

```
= K2 * T / ( Rm * t )
= 1.1707 * 46757/( 918.4 * 8 )
= 7.45 MPa
```

Decay Length (4.15.20) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 918.4 * 8 )
= 66.858 mm
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:

```
= -K5 * Q * k / ( t( b + X1 + X2 ) )
= -0.7603 * 65713 * 1.0/( 8( 200 + 66.858 + 66.858 ) )
= -18.71 MPa
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.23) [sigma7*]:

$= -Q/(4*t(b+X1+X2)) - 12*K7*Q*Rm/(L*t^2)$

$= -65713/(4*8(200 +66.858 +66.858)) -$
$\quad 12 * 0.01743 * 65713 * 918.4/(5028.4 * 8^2)$

$= -45.37$ MPa

Effective reinforcing plate width (4.15.24) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 200 + 1.56 * sqrt( 918.4 * 8 ), 2 * 508 )
= 333.72 mm
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1660.0000	mm
Baseplate Thickness	Bpthk	10.0000	mm
Baseplate Width	Bpwid	220.0000	mm
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	8.0000	mm
Web Thickness	Webtk	8.0000	mm
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	245.2	MPa
Height of Web at Center	Hw,c	352.0	mm
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:

$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$

$= ((1.56 * sqrt(914.4 * 8) + 300)8^3)/12$

$= 18492.787$ mm^4

Resolved Inertia for the Shell [I,shell]:

$= ShellInertia + AShell(C1 - Y)^2$

$= 18493 + 3467.4(131.88 - 4)^2$

$= 56717476.000$ mm^4

	B mm	D mm	Y mm	A mm^2	AY mm^3	I + AD^2 mm^4
Shell	433.4	8.0	4.0	3467.4	13869.6	0.567E+08
Wearplate	300.0	8.0	12.0	2400.0	28800.0	0.345E+08
Web	8.0	359.6	195.8	2876.8	563277.4	0.428E+08
BasePlate	220.0	10.0	380.6	2200.0	837319.9	0.136E+09

```
 Totals            ... |         ... |         ... |     10944.2 |   1443267.0 |   0.270E+09 |
```

Distance to Centroid [C1]:
```
  = AY / A
  = 56822/10944
  = 131.875 mm
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2035 * 65713
  = 13373.9385 N

 Tension Stress, St = ( Fh/As )       =          1.7889  MPa
 Allowed Stress, Sa = 0.6 * Yield Str =        147.0961  MPa
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 1300 - 914.4 * sin(120/2)/1.0472
  = 543.797 mm

 Bending Moment, M  = Fh * d          =    7275659.5000  N-mm

 Bending Stress, Sb = ( M * C1 / I  ) =          3.5512  MPa
 Allowed Stress, Sa = 2/3 * Yield Str =        163.4401  MPa
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))
  = sqrt( 3(65713 + 1956.4 )220/( 4 * 1660 * 163.44 ))
  = 6.415 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 - 120/2 )( 914.4 + 8 + 8 )
  = 1611.500 mm
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1611.5/( 4 - 1 )
  = 537.167 mm
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 537.17 * 220/2
  = 59088.328 mm^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 65713/( 1660 * 220 )
  = 0.180 N/mm^2
```

Axial Load [P]:
```
  = Ap * Bp
```

```
  = 59088 * 0.1799
  = 10632.114 N
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 1536 + 2148.7
  = 3684.667 mm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 10632/3684.7
  = 2.886 MPa
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	8.0	200.0	...	1600.0	...	0.533E+07

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 200 - 8
  = 192.000 mm
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0/3684.7
  = 0.000 mm
```

Distance to Centroid [C1]:

```
  = Saddle Width / 2
  = 200/2
  = 100.000 mm
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 5333328/3684.7 )
  = 38.045 mm
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 1300 - cos( 120/2 )( 914.4 + 8 + 8 ) - 10
  = 824.800 mm
```

Intermediate Term [Cc]:

  = sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)
  = sqrt(2 * pi^2 * 199955/245.16)
  = 126.884

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 824.8/38.045
  = 21.679
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 17523/( 2 * 1660 ) * 537.17 * 824.8/2
  = 1169723.000 N-mm
```

Compressive Allowable, KL/r < Cc(21.679 < 126.88) per AISC E2-1 [Sca]:

  = (1-$(Klr)^2$/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)
  = (1-(21.679 $)^2$/(2 * 126.88^2))245.16/

(5/3+3*(21.679)/(8* 126.88)-(21.679^3)/(8*126.88^3))
= 139.6 MPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 2.8857/139.63 +(1169723 * 100/5333333)/163.44
= 0.155

AISC Unity Check of Outside Ribs, due to Transverse Force Ft (must be <= 1)

This analysis assumes the entire saddle weight load and load due to transverse forces are concentrated on the outer rib + some portion of the web. This generally would not be the case and as such this analysis is very conservative.

Inertia of Saddle, Outer Ribs - Transverse Direction:

	B	D	Y	A	AY	Io
Rib	192.0	8.0	4.0	1536.0	6144.0	0.893E+06
Web	8.0	128.0	64.0	1024.0	65536.0	0.273E+07
Totals	...	...	...	2560.0	71680.0	0.362E+07

Web dimension [D]:
= 16 * Web Thickness
= 16 * 8
= 128.000 mm

Moment at base of outer Rib [Mbase]:
= Ft(Centerline dimension B - Baseplate thickness)
= 3831.1(1300 - 10)
= 4944118.500 N-mm

Bending Stress due to Transverse Force [SigmaB,base]:
= Bending Moment / Section Modulus
= 4944118/129219
= 38.249 MPa

Vertical Load on the Rib due to the Bending Moment [Fv,mom]:
= Bending Moment / Web Length
= 4944118/1611.5
= 3066.779 N

Total Vertical Load on the Rib [Fv,total]:
= Fv,mom + Vertical Load
= 3066.8 + 132072
= 135138.828 N

Compressive Stress on Outer Rib [Sigma,cr]:
= Fv,total / Area
= 135139/2560
= 52.793 MPa

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(3618129/2560)
= 37.594 mm

Slenderness ratio [KL/r]:
= KL/r
= 1 * 824.8/37.594
= 21.939

Compressive Allowable, KL/r < Cc(21.939 < 126.88) per AISC E2-1 [Sca]:
= (1-$(Klr)^2$/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)

$= (1-(21.939)^2/(2 * 126.88^2))245.16/$
$(5/3+3*(21.939)/(8* 126.88)-(21.939^3)/(8*126.88^3))$
= 139.5 MPa

Unity Check on Outer Rib [UCheck,outer]:
= Sigma,cr / Sca + SigmaB,base / Sba
= 52.793/139.52 + 38.249/163.44
= 0.612

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	8.0	192.0	0.0	1536.0	0.0	0.533E+07
Web	537.2	8.0	0.0	4297.3	0.0	0.229E+05
Totals	...	...	...	5833.3	...	0.536E+07

Distance to Centroid from Datum [ytot]:
= AY / A
= 0/5833.3
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 200/2
= 100.000 mm

Length of Inner Rib [L]:
= Saddle Height - sqrt((Ro + Wpdthk)^2 - (Pitch/2)^2) - Bpthk
= 1300 - sqrt((930.4 + 8)^2 -(537.17/2)^2) - 10
= 399.210 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(5355905/5833.3)
= 30.301 mm

Slenderness ratio [KL/r]:
= KL/r
= 1 * 399.21/30.301
= 13.175

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 17523/(2 * 1660)
= 5.278 N/mm

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 5.2781 * 537.17 * 399.21
= 1132310.625 N-mm

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 1132310/53559
= 21.135 MPa

Compressive Allowable, KL/r < Cc(13.175 < 126.88) per AISC E2-1 [Sca]:
$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3))$
$= (1-(13.175)^2/(2 * 126.88^2))245.16/$
$(5/3+3*(13.175)/(8* 126.88)-(13.175^3)/(8*126.88^3))$
= 143 MPa

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 3.6728/142.97 +( 1132310 * 100/5355905 )/163.44
  = 0.155
```