TRANSPORT CALCULATION REPORT

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WUXI CHEMICAL EQUIPMENT CO., LTD.

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ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Ocean Transport

Note:
Wear Pad Width (9.00) 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( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

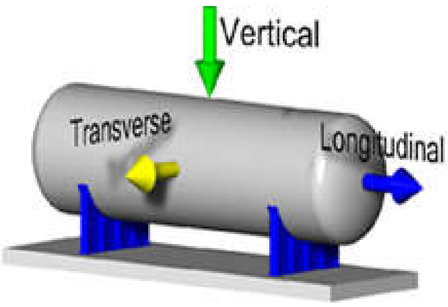
```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent     a1 or a       20.35  in

 Saddle Width                               b1 or b        7.43  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Shell Allowable Stress used in Calculation        20000.00  psi
 Head Allowable Stress used in Calculation         20000.00  psi
 Circumferential Efficiency in Plane of Saddle         1.00
 Circumferential Efficiency at Mid-Span                1.00

 Distance from Saddle Base to Centerline          B       51.81  in
 Coefficient of Friction                         mu        0.40

 Saddle Force Q for this Transportation Case       80745.06  lbf
 Shipping Longitudinal Acceleration              gx        1.50  g
 Shipping Transverse Acceleration                gz        1.50  g
 Shipping Vertical Acceleration                  gy        2.00  g
 Vertical Acceleration Acting with Transverse    gw        1.00  g
 Internal Pressure during Transport                        5.08  psig
 Transportation Wind Load Scalar Factor        wlsf        1.00
 Transportation Wind Velocity                    wv        89.5  mile/hr
```



Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	-2764.36	-34200.00
Long. Stress at Top of Midspan	2764.36	20000.00
Long. Stress at Bottom of Midspan	2945.18	20000.00
Long. Stress at Top of Saddles	657.44	20000.00
Long. Stress at Bottom of Saddles	-223.87	-34200.00
Long. Stress at Bottom of Saddles	223.87	20000.00

```
 Tangential Shear in Shell             5436.19 |     16000.00 |
 Circ. Stress at Horn of Saddle       16289.16 |     30000.00 |
 Circ. Compressive Stress in Shell      733.13 |     20000.00 |
 ----------------------------------------------------------------
```

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
  = 128.14 * 0.00256 * 89.479^2 * 1
  = 2626.5 lbf
```

Longitudinal Force due to Wind during Transport [Fl_w]:
```
  = pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
  = pi * 4.0427^2/4 * 0.00256 * 89.479^2 * 1 * 1.37
  = 360.4 lbf
```

Transverse Force due to Axial Acceleration [Ft]:
```
  = gx * saddle Load * gw + Ft_w
  = 1.5 * 26915 * 1 + 2626.5
  = 42999.0 lbf
```

Longitudinal Force due to Axial Acceleration [Fl]:
```
  = gz * saddle Load * gw + Fl_w
  = 1.5 * 26915 * 1 + 360.44
  = 40733.0 lbf
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:
```
  = Ft/Num of Saddles * B / E
  = 42999/2 * 51.811/40.506
  = 27500.1 lbf
```

Saddle Reaction Force due to Transport Load [Fwl]:
```
  = Fl * B / Ls
  = 40733 * 51.811/139
  = 15182.8 lbf
```

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:
```
  = Saddle Load * gy
  = 26915 * 2
  = 53830.043 lbf
```

Load Combination Results due to Transport Loading [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl )
  = 26915 + max( 15183, 27500, 53830 )
  = 80745.1 lbf
```

Summary of Loads at the base of this Saddle:
```
 Vertical Load (including saddle weight)          81819.61  lbf
 Transverse Shear Load Saddle                     27500.11  lbf
 Longitudinal Shear Load Saddle                   40732.97  lbf
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = min( 2( ShellID/2 + t + WearPadThickness )sin(θ/2 ), 2*Rm )
  = min( 2( 44.252/2 + 0.63 + 0.63 )sin( 120/2 ), 2*22.441 )
  = 40.506 in
```

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  = 0.0455     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)]
= -80745*20.354[1-(1-20.354/217.75+(22.441²-0²)/
  (2*20.354*217.75))/(1+(4*0)/(3*217.75))]
= -5021.1 ft-lb
```

Moment per Equation 4.15.4 [M2]:
```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 80745*217.75/4(1+2(22.441²-0²)/(217.75²))/(1+(4*0)/
  (3*217.75))-4*20.354/217.75
= 237117.7 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 5.0764 * 22.441/(2*0.63 ) - 2845412/(pi*22.441²*0.63 )
= -2764.36 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 5.0764 * 22.441/(2 * 0.63 ) + 2845412/(pi * 22.441² * 0.63 )
= 2945.18 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 5.0764*22.441/(2*0.63)--60253/(0.1066*pi*22.441²*0.63)
= 657.44 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
= P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
= 5.0764*22.441/(2*0.63)+-60253/(0.1923*pi*22.441²*0.63)
= -223.87 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
= Q(L-2a)/(L+(4*h2/3))
= 80745( 217.75 - 2 * 20.354 )/(217.75 +( 4 * 0/3))
= 65649.8 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
= K2 * T / ( Rm * t )
= 1.1707 * 65650/( 22.441 * 0.63 )
= 5436.19 psi
```

Decay Length (4.15.20) [x1,x2]:
```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 22.441 * 0.63 )
= 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
= -K5 * Q * k / ( t( b + X1 + X2 ) )
= -0.7603 * 80745 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
= -733.13 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
= -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
= -80745/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
   3 * 0.04548 * 80745/(2*0.63²)
= -16289.16 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	59.0551	in
Baseplate Thickness	Bpthk	1.4173	in
Baseplate Width	Bpwid	19.6850	in
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	0.6299	in
Web Thickness	Webtk	0.6299	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:
$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$
$= ((1.56 * sqrt(22.126 * 0.63) + 9)0.63^3)/12$
= 0.309 in**4

Resolved Inertia for the Shell [I,shell]:
$= ShellInertia + AShell(C1 - Y)^2$
$= 0.3089 + 9.3393(17.822 - 0.315)^2$
= 2862.681 in**4

	B in	D in	Y in	A in^2	AY in^3	$I + AD^2$ in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	2862.6809
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	1615.1414
Web	0.6299	27.0077	14.7639	17.0127	251.1736	1193.1941
BasePlate	19.6850	1.4173	28.9764	27.9001	808.4426	3476.1628
Totals	...	...	...	59.9221	1067.9163	9147.1758

Distance to Centroid [C1]:
= AY / A
= 1067.9/59.922
= 17.822 in

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 * 80745
= 16433.3711 lbf

```
 Tension Stress, St = ( Fh/As )       =       324.8807  psi
 Allowed Stress, Sa = 0.6 * Yield Str =     19962.0000  psi
```

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 51.811 - 22.126 * sin(120/2)/1.0472
= 33.513 in

```
 Bending Moment, M  = Fh * d          =      45894.2695  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =       1073.0074  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      22180.0000  psi
```

Minimum Thickness of Baseplate per Moss:

```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(80745 + 1074.5 )19.685/( 2 * 59.055 * 22180 ))
  = 1.358 in
```

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 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 4 - 1 )
  = 13.502 in
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 13.502 * 19.685/2
  = 132.893 in^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 80745/( 59.055 * 19.685 )
  = 69.458 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 132.89 * 69.458
  = 9230.461 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 4.2805 + 4.2526
  = 8.533 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 9230.5/8.5331
  = 1081.730 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.6299	6.7953	4.0276	4.2805	17.2399	31.1248
Web	6.7510	0.6299	0.3150	4.2526	1.3394	14.8904
Totals	...	...	...	8.5331	18.5793	46.0152

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.6299
  = 6.795 in
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.579/8.5331
  = 2.177 in
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 2.1773, 7.4252 - 2.1773 )
  = 5.248 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.015/8.5331 )
  = 2.322 in
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 51.811 - cos( 120/2 )( 22.126 + 0.63 + 0.63 ) - 1.4173
  = 38.701 in
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 29000000/33270 )
  = 131.171
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 38.701/2.3222
  = 16.666
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 40733/( 2 * 59.055 ) * 13.502 * 38.701/2
  = 7508.639 ft-lb
```

Compressive Allowable, KL/r < Cc(16.666 < 131.17) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 16.666 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(16.666 )/(8* 131.17 )-( 16.666³)/(8*131.17³)
  = 19253 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1081.7/19253 +( 90104 * 5.2479/46.015 )/22180
  = 0.519
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.6299	6.7953	4.0276	4.2805	17.2399	42.5789
Web	13.5019	0.6299	0.3150	8.5051	2.6788	13.4208
Totals	...	...	...	12.7856	19.9187	55.9997

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 19.919/12.786
  = 1.558 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.5579, abs( 7.4252 - 1.5579 ) )
  = 5.867 in
```

Length of Inner Rib [L]:
= Saddle Height - sqrt((Ro + Wpdthk)^2 - (Pitch/2)^2) - Bpthk
= 51.811 - sqrt((23.386 + 0.63)^2 -(13.502/2)^2) - 1.4173
= 28.003 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(56/12.786)
= 2.093 in

Slenderness ratio [KL/r]:
= KL/r
= 1 * 28.003/2.0928
= 13.381

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 40733/(2 * 59.055)
= 344.872 lbf/in

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 344.87 * 13.502 * 28.003
= 130395.680 in.lbs

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 130396/9.5444
= 13662.051 psi

Compressive Allowable, KL/r < Cc(13.381 < 131.17) per AISC E2-1 [Sca]:
= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)
= (1-(13.381)^2/(2 * 131.17^2))33270/
(5/3+3*(13.381)/(8* 131.17)-(13.381^3)/(8*131.17^3)
= 19414 psi

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 928.69/19414 +(130396 * 5.8673/56)/22180
= 0.664

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

*Warning - Distance to Saddle (a) > 0.25 * Tangent Distance (L) - 4.15.3.2*

Note:
Wear Pad Width (9.00) 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(7.4252 + 1.56*sqrt(22.441 * 0.63), 2 * 58.638)
= 13.2908 in

Input and Calculated Values:

Vessel Mean Radius	Rm	22.44	in
Shell Thickness used in this Case	t	0.630	in
Stiffened Vessel Length per 4.15.6	L	217.75	in
Distance from Saddle to Vessel tangent	a1 or a	58.64	in
Saddle Width	b1 or b	7.43	in
Saddle Bearing Angle	delta or theta	120.00	degrees

```
 Inside Depth of Head                    Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline        B       51.81  in
 Coefficient of Friction                       mu        0.00

 Saddle Force Q for this Transportation Case        28319.31  lbf
 Shipping Longitudinal Acceleration            gx        1.50  g
 Shipping Transverse Acceleration              gz        1.50  g
 Shipping Vertical Acceleration                gy        2.00  g
 Vertical Acceleration Acting with Transverse  gw        1.00  g
 Internal Pressure during Transport                      5.08  psig
 Transportation Wind Load Scalar Factor      wlsf        1.00
 Transportation Wind Velocity                  wv        89.5  mile/hr

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan        284.61 |     20000.00 |
 Long. Stress at Bottom of Midspan       -103.79 |    -34200.00 |
 Long. Stress at Bottom of Midspan        103.79 |     20000.00 |
 Long. Stress at Top    of Saddles       4804.75 |     20000.00 |
 Long. Stress at Bottom of Saddles      -2522.56 |    -34200.00 |
 Long. Stress at Bottom of Saddles       2522.56 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               1013.37 |     16000.00 |
 Circ. Stress at Horn of Saddle          6502.09 |     30000.00 |
 Circ. Compressive Stress in Shell        257.13 |     20000.00 |
 ----------------------------------------------------------------
```

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
  = 128.14 * 0.00256 * 89.479^2 * 1
  = 2626.5 lbf
```

Longitudinal Force due to Wind during Transport [Fl_w]:
```
  = pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
  = pi * 4.0427^2/4 * 0.00256 * 89.479^2 * 1 * 1.37
  = 360.4 lbf
```

Transverse Force due to Axial Acceleration [Ft]:
```
  = gx * saddle Load * gw + Ft_w
  = 1.5 * 9439.8 * 1 + 2626.5
  = 16786.1 lbf
```

Longitudinal Force due to Axial Acceleration [Fl]:
```
  = gz * saddle Load * gw + Fl_w
  = 1.5 * 9439.8 * 1 + 360.44
  = 14520.1 lbf
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:
```
  = Ft/Num of Saddles * B / E
  = 16786/2 * 51.811/40.506
  = 10735.6 lbf
```

Saddle Reaction Force due to Transport Load [Fwl]:
```
  = Fl * B / Ls
  = 14520 * 51.811/139
```

```
  = 5412.2 lbf
```

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

```
  = Saddle Load * gy
  = 9439.8 * 2
  = 18879.543 lbf
```

Load Combination Results due to Transport Loading [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl )
  = 9439.8 + max( 5412.2, 10736, 18880 )
  = 28319.3 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	29119.46	lbf
Transverse Shear Load Saddle	10735.61	lbf
Longitudinal Shear Load Saddle	14520.10	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = min( 2( ShellID/2 + t + WearPadThickness )sin(θ/2 ), 2*Rm )
  = min( 2( 44.252/2 + 0.63 + 0.63 )sin( 120/2 ), 2*22.441 )
  = 40.506 in
```

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 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm^2-h2^2)/(2a*L))/(1+(4h2)/3L)]
  = -28319*58.638[1-(1-58.638/217.75+(22.441^2-11.063^2)/
    (2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
  = -41746.1 ft-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm^2-h2^2)/(L^2))/(1+(4h2)/( 3L))-4a/L
  = 28319*217.75/4(1+2(22.441^2-11.063^2)/(217.75^2))/(1+(4*11.063)/
    (3*217.75))-4*58.638/217.75
  = -16130.2 ft-lb
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm^2t)
  = 5.0764 * 22.441/(2*0.63 ) - -193562/(pi*22.441^2*0.63 )
  = 284.61 psi
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm^2 * t)
  = 5.0764 * 22.441/(2 * 0.63 ) + -193562/(pi * 22.441^2 * 0.63 )
  = -103.79 psi
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm^2t)
  = 5.0764*22.441/(2*0.63)--500954/(0.1066*pi*22.441^2*0.63)
  = 4804.75 psi
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm^2 * t)
  = 5.0764*22.441/(2*0.63)+-500954/(0.1923*pi*22.441^2*0.63)
```

```
  = -2522.56 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 28319( 217.75 - 2 * 58.638 )/(217.75 +( 4 * 11.063/3))
  = 12237.9 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 12238/( 22.441 * 0.63 )
  = 1013.37 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 28319 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -257.13 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -28319/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.05285 * 28319/(2*0.63²)
  = -6502.09 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	59.0551	in
Baseplate Thickness	Bpthk	1.4173	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	0.6299	in
Web Thickness	Webtk	0.6299	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
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 )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:
```
  = ShellInertia + AShell( C1 - Y )²
  = 0.3089 + 9.3393( 14.049 - 0.315 )²
  = 1761.964 in**4
```

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	1761.9644
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	973.8370
Web	0.6299	27.0077	14.7639	17.0127	251.1736	1042.8040

BasePlate	9.0000	1.4173	28.9764	12.7559	369.6200	2844.4229
Totals	...	...	...	44.7780	629.0936	6623.0273

Distance to Centroid [C1]:
```
  = AY / A
  = 629.09/44.778
  = 14.049 in
```

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 * 28319
  = 5763.5947 lbf

 Tension Stress, St = ( Fh/As )       =        162.6359  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 51.811 - 22.126 * sin(120/2)/1.0472
  = 33.513 in

 Bending Moment, M  = Fh * d          =      16096.2705  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        409.7329  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(28319 + 800.14 )9/( 2 * 59.055 * 25333 ))
  = 0.513 in
```

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 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 4 - 1 )
  = 13.502 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 13.502 * 9/2
  = 60.759 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 28319/( 59.055 * 9 )
  = 53.282 lbf/in^2
```

Axial Load [P]:

= Ap * Bp
= 60.759 * 53.282
= 3237.354 lbf

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 4.2805 + 4.2526
= 8.533 in^2

Compressive Stress [Sc]:
= P/Ar
= 3237.4/8.5331
= 379.390 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.6299	6.7953	4.0276	4.2805	17.2399	31.1248
Web	6.7510	0.6299	0.3150	4.2526	1.3394	14.8904
Totals	...	...	...	8.5331	18.5793	46.0152

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.4252 - 0.6299
= 6.795 in

Distance to Centroid from Datum [ytot]:
= AY / A
= 18.579/8.5331
= 2.177 in

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(2.1773, 7.4252 - 2.1773)
= 5.248 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(46.015/8.5331)
= 2.322 in

Length of Outer Rib [L]:
= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 51.811 - cos(120/2)(22.126 + 0.63 + 0.63) - 1.4173
= 38.701 in

Intermediate Term [Cc]:
= sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)
= sqrt(2 * pi^2 * 29000000/38000)
= 122.736

Slenderness ratio [KL/r]:
= KL/r
= 1 * 38.701/2.3222
= 16.666

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 14520/(2 * 59.055) * 13.502 * 38.701/2
= 2676.607 ft-lb

Compressive Allowable, KL/r < Cc(16.666 < 122.74) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 16.666 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(16.666 )/(8* 122.74 )-( 16.666³)/(8*122.74³)
  = 21924 psi
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 379.39/21924 +( 32119 * 5.2479/46.015 )/25333
  = 0.162
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.6299	6.7953	4.0276	4.2805	17.2399	42.5789
Web	13.5019	0.6299	0.3150	8.5051	2.6788	13.4208
Totals	...	...	...	12.7856	19.9187	55.9997

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 19.919/12.786
  = 1.558 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.5579, abs( 7.4252 - 1.5579 ) )
  = 5.867 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 51.811 - sqrt((23.386 + 0.63 )^2 -(13.502/2)^2 ) - 1.4173
  = 28.003 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 56/12.786 )
  = 2.093 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 28.003/2.0928
  = 13.381
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 14520/( 2 * 59.055 )
  = 122.937 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 122.94 * 13.502 * 28.003
  = 46482.195 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 46482/9.5444
  = 4870.116 psi
```

Compressive Allowable, KL/r < Cc(13.381 < 122.74) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 13.381 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(13.381 )/(8* 122.74 )-( 13.381³)/(8*122.74³)
```

= 22124 psi

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

```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 492.46/22124 +( 46482 * 5.8673/56 )/25333
= 0.215
```

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Road Transport

Note:
Wear Pad Width (9.00) 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( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

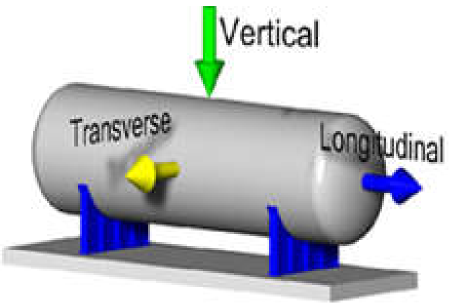
```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent      a1 or a      20.35  in

 Saddle Width                                b1 or b       7.43  in
 Saddle Bearing Angle                 delta or theta     120.00  degrees

 Shell Allowable Stress used in Calculation            20000.00  psi
 Head Allowable Stress used in Calculation             20000.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B       51.81  in
 Coefficient of Friction                         mu        0.40

 Saddle Force Q for this Transportation Case           80745.06  lbf
 Shipping Longitudinal Acceleration              gx        1.50  g
 Shipping Transverse Acceleration                gz        1.50  g
 Shipping Vertical Acceleration                  gy        2.00  g
 Vertical Acceleration Acting with Transverse    gw        1.00  g
 Internal Pressure during Transport                        5.08  psig
 Transportation Wind Load Scalar Factor        wlsf        1.00
 Transportation Wind Velocity                    wv         0.0  mile/hr
```



Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	-2764.36	-34200.00
Long. Stress at Top of Midspan	2764.36	20000.00
Long. Stress at Bottom of Midspan	2945.18	20000.00
Long. Stress at Top of Saddles	657.44	20000.00
Long. Stress at Bottom of Saddles	-223.87	-34200.00
Long. Stress at Bottom of Saddles	223.87	20000.00

```
 Tangential Shear in Shell              5436.19 |     16000.00 |
 Circ. Stress at Horn of Saddle        16289.16 |     30000.00 |
 Circ. Compressive Stress in Shell       733.13 |     20000.00 |
 ---------------------------------------------------------------
```

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

Transverse Force due to Wind during Transport [Ft_w]:
```
  = Transverse Area * 0.00256 * wv^2 * wlsf
  = 128.14 * 0.00256 * 0^2 * 1
  = 0.0 lbf
```

Longitudinal Force due to Wind during Transport [Fl_w]:
```
  = pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
  = pi * 4.0427^2/4 * 0.00256 * 0^2 * 1 * 1.37
  = 0.0 lbf
```

Transverse Force due to Lateral Acceleration [Ft]:
```
  = gz * saddle Load * gw + Ft_w
  = 1.5 * 26915 * 1 + 0
  = 40372.5 lbf
```

Longitudinal Force due to Axial Acceleration [Fl]:
```
  = gx * saddle Load * gw + Fl_w
  = 1.5 * 26915 * 1 + 0
  = 40372.5 lbf
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:
```
  = Ft/Num of Saddles * B / E
  = 40373/2 * 51.811/40.506
  = 25820.3 lbf
```

Saddle Reaction Force due to Transport Load [Fwl]:
```
  = Fl * B / Ls
  = 40373 * 51.811/139
  = 15048.5 lbf
```

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:
```
  = Saddle Load * gy
  = 26915 * 2
  = 53830.043 lbf
```

Load Combination Results due to Transport Loading [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl )
  = 26915 + max( 15048, 25820, 53830 )
  = 80745.1 lbf
```

Summary of Loads at the base of this Saddle:
```
 Vertical Load (including saddle weight)           81819.61  lbf
 Transverse Shear Load Saddle                      25820.34  lbf
 Longitudinal Shear Load Saddle                    40372.53  lbf
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = min( 2( ShellID/2 + t + WearPadThickness )sin(θ/2 ), 2*Rm )
  = min( 2( 44.252/2 + 0.63 + 0.63 )sin( 120/2 ), 2*22.441 )
  = 40.506 in
```

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  = 0.0455     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)]
  = -80745*20.354[1-(1-20.354/217.75+(22.441²-0²)/
    (2*20.354*217.75))/(1+(4*0)/(3*217.75))]
  = -5021.1 ft-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 80745*217.75/4(1+2(22.441²-0²)/(217.75²))/(1+(4*0)/
    (3*217.75))-4*20.354/217.75
  = 237117.7 ft-lb
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 5.0764 * 22.441/(2*0.63 ) - 2845412/(pi*22.441²*0.63 )
  = -2764.36 psi
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 5.0764 * 22.441/(2 * 0.63 ) + 2845412/(pi * 22.441² * 0.63 )
  = 2945.18 psi
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 5.0764*22.441/(2*0.63)--60253/(0.1066*pi*22.441²*0.63)
  = 657.44 psi
```

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

```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 5.0764*22.441/(2*0.63)+-60253/(0.1923*pi*22.441²*0.63)
  = -223.87 psi
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 80745( 217.75 - 2 * 20.354 )/(217.75 +( 4 * 0/3))
  = 65649.8 lbf
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 65650/( 22.441 * 0.63 )
  = 5436.19 psi
```

Decay Length (4.15.20) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

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

```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 80745 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -733.13 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:

```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -80745/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.04548 * 80745/(2*0.63²)
  = -16289.16 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	59.0551	in
Baseplate Thickness	Bpthk	1.4173	in
Baseplate Width	Bpwid	19.6850	in
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	0.6299	in
Web Thickness	Webtk	0.6299	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:

$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$
$= ((1.56 * sqrt(22.126 * 0.63) + 9)0.63^3)/12$
$= 0.309$ in**4

Resolved Inertia for the Shell [I,shell]:

$= ShellInertia + AShell(C1 - Y)^2$
$= 0.3089 + 9.3393(17.822 - 0.315)^2$
$= 2862.681$ in**4

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	2862.6809
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	1615.1414
Web	0.6299	27.0077	14.7639	17.0127	251.1736	1193.1941
BasePlate	19.6850	1.4173	28.9764	27.9001	808.4426	3476.1628
Totals	...	...	...	59.9221	1067.9163	9147.1758

Distance to Centroid [C1]:

```
  = AY / A
  = 1067.9/59.922
  = 17.822 in
```

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 * 80745
  = 16433.3711 lbf
```

```
 Tension Stress, St = ( Fh/As )       =        324.8807  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      19962.0000  psi
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 51.811 - 22.126 * sin(120/2)/1.0472
  = 33.513 in
```

```
Bending Moment, M  = Fh * d         =      45894.2695  ft-lb

Bending Stress, Sb = ( M * C1 / I  ) =       1073.0074  psi
Allowed Stress, Sa = 2/3 * Yield Str =      22180.0000  psi
```

Minimum Thickness of Baseplate per Moss:

```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(80745 + 1074.5 )19.685/( 2 * 59.055 * 22180 ))
  = 1.358 in
```

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 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 4 - 1 )
  = 13.502 in
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 13.502 * 19.685/2
  = 132.893 in^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 80745/( 59.055 * 19.685 )
  = 69.458 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 132.89 * 69.458
  = 9230.461 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 4.2805 + 4.2526
  = 8.533 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 9230.5/8.5331
  = 1081.730 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.6299	6.7953	4.0276	4.2805	17.2399	31.1248
Web	6.7510	0.6299	0.3150	4.2526	1.3394	14.8904
Totals	...	...	...	8.5331	18.5793	46.0152

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.6299
  = 6.795 in
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.579/8.5331
  = 2.177 in
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 2.1773, 7.4252 - 2.1773 )
  = 5.248 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.015/8.5331 )
  = 2.322 in
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 51.811 - cos( 120/2 )( 22.126 + 0.63 + 0.63 ) - 1.4173
  = 38.701 in
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 29000000/33270 )
  = 131.171
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 38.701/2.3222
  = 16.666
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 40373/( 2 * 59.055 ) * 13.502 * 38.701/2
  = 7442.197 ft-lb
```

Compressive Allowable, KL/r < Cc(16.666 < 131.17) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 16.666 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(16.666 )/(8* 131.17 )-( 16.666³)/(8*131.17³)
  = 19253 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1081.7/19253 +( 89306 * 5.2479/46.015 )/22180
  = 0.515
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.6299	6.7953	4.0276	4.2805	17.2399	42.5789
Web	13.5019	0.6299	0.3150	8.5051	2.6788	13.4208
Totals	...	...	...	12.7856	19.9187	55.9997

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 19.919/12.786
  = 1.558 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.5579, abs( 7.4252 - 1.5579 ) )
  = 5.867 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 51.811 - sqrt((23.386 + 0.63 )^2 -(13.502/2)^2 ) - 1.4173
  = 28.003 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 56/12.786 )
  = 2.093 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 28.003/2.0928
  = 13.381
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 40373/( 2 * 59.055 )
  = 341.821 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 341.82 * 13.502 * 28.003
  = 129241.828 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 129242/9.5444
  = 13541.157 psi
```

Compressive Allowable, KL/r < Cc(13.381 < 131.17) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 13.381 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(13.381 )/(8* 131.17 )-( 13.381³)/(8*131.17³)
  = 19414 psi
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 928.69/19414 +( 129242 * 5.8673/56 )/22180
  = 0.658
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

*Warning - Distance to Saddle (a) > 0.25 * Tangent Distance (L) - 4.15.3.2*

Note:
Wear Pad Width (9.00) 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( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

Vessel Mean Radius	Rm	22.44	in
Shell Thickness used in this Case	t	0.630	in
Stiffened Vessel Length per 4.15.6	L	217.75	in
Distance from Saddle to Vessel tangent	a1 or a	58.64	in
Saddle Width	b1 or b	7.43	in
Saddle Bearing Angle	delta or theta	120.00	degrees

```
 Inside Depth of Head                   Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline        B       51.81  in
 Coefficient of Friction                       mu        0.00

 Saddle Force Q for this Transportation Case        28319.31  lbf
 Shipping Longitudinal Acceleration            gx        1.50  g
 Shipping Transverse Acceleration              gz        1.50  g
 Shipping Vertical Acceleration                gy        2.00  g
 Vertical Acceleration Acting with Transverse  gw        1.00  g
 Internal Pressure during Transport                      5.08  psig
 Transportation Wind Load Scalar Factor      wlsf        1.00
 Transportation Wind Velocity                  wv         0.0  mile/hr

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ---------------------------------------------------------------
 Long. Stress at Top    of Midspan        284.61 |     20000.00 |
 Long. Stress at Bottom of Midspan       -103.79 |    -34200.00 |
 Long. Stress at Bottom of Midspan        103.79 |     20000.00 |
 Long. Stress at Top    of Saddles       4804.75 |     20000.00 |
 Long. Stress at Bottom of Saddles      -2522.56 |    -34200.00 |
 Long. Stress at Bottom of Saddles       2522.56 |     20000.00 |
 ---------------------------------------------------------------
 Tangential Shear in Shell               1013.37 |     16000.00 |
 Circ. Stress at Horn of Saddle          6502.09 |     30000.00 |
 Circ. Compressive Stress in Shell        257.13 |     20000.00 |
 ---------------------------------------------------------------
```

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

Transverse Force due to Wind during Transport [Ft_w]:
```
  = Transverse Area * 0.00256 * wv^2 * wlsf
  = 128.14 * 0.00256 * 0^2 * 1
  = 0.0 lbf
```

Longitudinal Force due to Wind during Transport [Fl_w]:
```
  = pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
  = pi * 4.0427^2/4 * 0.00256 * 0^2 * 1 * 1.37
  = 0.0 lbf
```

Transverse Force due to Lateral Acceleration [Ft]:
```
  = gz * saddle Load * gw + Ft_w
  = 1.5 * 9439.8 * 1 + 0
  = 14159.7 lbf
```

Longitudinal Force due to Axial Acceleration [Fl]:
```
  = gx * saddle Load * gw + Fl_w
  = 1.5 * 9439.8 * 1 + 0
  = 14159.7 lbf
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:
```
  = Ft/Num of Saddles * B / E
  = 14160/2 * 51.811/40.506
  = 9055.8 lbf
```

Saddle Reaction Force due to Transport Load [Fwl]:
```
  = Fl * B / Ls
  = 14160 * 51.811/139
```

```
  = 5277.9 lbf
```

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

```
  = Saddle Load * gy
  = 9439.8 * 2
  = 18879.543 lbf
```

Load Combination Results due to Transport Loading [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl )
  = 9439.8 + max( 5277.9, 9055.8, 18880 )
  = 28319.3 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	29119.46	lbf
Transverse Shear Load Saddle	9055.84	lbf
Longitudinal Shear Load Saddle	14159.66	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = min( 2( ShellID/2 + t + WearPadThickness )sin(θ/2 ), 2*Rm )
  = min( 2( 44.252/2 + 0.63 + 0.63 )sin( 120/2 ), 2*22.441 )
  = 40.506 in
```

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 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -28319*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
    (2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
  = -41746.1 ft-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 28319*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
    (3*217.75))-4*58.638/217.75
  = -16130.2 ft-lb
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 5.0764 * 22.441/(2*0.63 ) - -193562/(pi*22.441²*0.63 )
  = 284.61 psi
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 5.0764 * 22.441/(2 * 0.63 ) + -193562/(pi * 22.441² * 0.63 )
  = -103.79 psi
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 5.0764*22.441/(2*0.63)--500954/(0.1066*pi*22.441²*0.63)
  = 4804.75 psi
```

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

```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 5.0764*22.441/(2*0.63)+-500954/(0.1923*pi*22.441²*0.63)
```

```
  = -2522.56 psi
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 28319( 217.75 - 2 * 58.638 )/(217.75 +( 4 * 11.063/3))
  = 12237.9 lbf
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 12238/( 22.441 * 0.63 )
  = 1013.37 psi
```

Decay Length (4.15.20) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

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

```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 28319 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -257.13 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:

```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -28319/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.05285 * 28319/(2*0.63²)
  = -6502.09 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	59.0551	in
Baseplate Thickness	Bpthk	1.4173	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	0.6299	in
Web Thickness	Webtk	0.6299	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
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 )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:

```
  = ShellInertia + AShell( C1 - Y )²
  = 0.3089 + 9.3393( 14.049 - 0.315 )²
  = 1761.964 in**4
```

	B in	D in	Y in	A in^2	AY in^3	$I + AD^2$ in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	1761.9644
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	973.8370
Web	0.6299	27.0077	14.7639	17.0127	251.1736	1042.8040

BasePlate	9.0000	1.4173	28.9764	12.7559	369.6200	2844.4229
Totals	...	...	...	44.7780	629.0936	6623.0273

Distance to Centroid [C1]:
```
  = AY / A
  = 629.09/44.778
  = 14.049 in
```

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 * 28319
  = 5763.5947 lbf

 Tension Stress, St = ( Fh/As )       =       162.6359  psi
 Allowed Stress, Sa = 0.6 * Yield Str =     22800.0000  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 51.811 - 22.126 * sin(120/2)/1.0472
  = 33.513 in

 Bending Moment, M  = Fh * d          =     16096.2705  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =       409.7329  psi
 Allowed Stress, Sa = 2/3 * Yield Str =     25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(28319 + 800.14 )9/( 2 * 59.055 * 25333 ))
  = 0.513 in
```

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 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 4 - 1 )
  = 13.502 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 13.502 * 9/2
  = 60.759 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 28319/( 59.055 * 9 )
  = 53.282 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 60.759 * 53.282
  = 3237.354 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 4.2805 + 4.2526
  = 8.533 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 3237.4/8.5331
  = 379.390 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.6299	6.7953	4.0276	4.2805	17.2399	31.1248
Web	6.7510	0.6299	0.3150	4.2526	1.3394	14.8904
Totals	...	...	...	8.5331	18.5793	46.0152

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.6299
  = 6.795 in
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.579/8.5331
  = 2.177 in
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 2.1773, 7.4252 - 2.1773 )
  = 5.248 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.015/8.5331 )
  = 2.322 in
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 51.811 - cos( 120/2 )( 22.126 + 0.63 + 0.63 ) - 1.4173
  = 38.701 in
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 29000000/38000 )
  = 122.736
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 38.701/2.3222
  = 16.666
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 14160/( 2 * 59.055 ) * 13.502 * 38.701/2
  = 2610.165 ft-lb
```

Compressive Allowable, KL/r < Cc(16.666 < 122.74) per AISC E2-1 [Sca]:
```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 16.666 )²/(2 * 122.74² ))38000/
  ( 5/3+3*(16.666 )/(8* 122.74 )-( 16.666³)/(8*122.74³)
= 21924 psi
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
= Sc/Sca + ( Rm * C1 / I )/Sba
= 379.39/21924 +( 31322 * 5.2479/46.015 )/25333
= 0.158
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.6299	6.7953	4.0276	4.2805	17.2399	42.5789
Web	13.5019	0.6299	0.3150	8.5051	2.6788	13.4208
Totals	...	...	...	12.7856	19.9187	55.9997

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 19.919/12.786
= 1.558 in
```

Distance to Centroid [C1]:
```
= max( ytot, abs( Saddle Width - ytot ) )
= max( 1.5579, abs( 7.4252 - 1.5579 ) )
= 5.867 in
```

Length of Inner Rib [L]:
```
= Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
= 51.811 - sqrt((23.386 + 0.63 )^2 -(13.502/2)^2 ) - 1.4173
= 28.003 in
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 56/12.786 )
= 2.093 in
```

Slenderness ratio [KL/r]:
```
= KL/r
= 1 * 28.003/2.0928
= 13.381
```

Unit Force [Force,u]:
```
= Fl / ( 2 * Baseplate Length )
= 14160/( 2 * 59.055 )
= 119.885 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
= Unit Force * e * L
= 119.89 * 13.502 * 28.003
= 45328.344 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
= Bending Moment / Section Modulus
= 45328/9.5444
= 4749.223 psi
```

Compressive Allowable, KL/r < Cc(13.381 < 122.74) per AISC E2-1 [Sca]:
```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 13.381 )²/(2 * 122.74² ))38000/
  ( 5/3+3*(13.381 )/(8* 122.74 )-( 13.381³)/(8*122.74³)
```

= 22124 psi

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

= Sc/Sca + (Mbase,c * C1/I)/Sba
= 492.46/22124 +(45328 * 5.8673/56)/25333
= 0.210

Appendix 1 Transport load Calculation

The IMO rules Annex 13 section 7 “Advanced Calculation Method” to be used to calculate transport load. For Ocean shipment, the IMO wind load (Load = 1.0 kN / m2, 21 lbf/ ft2) is additive to the transverse dynamic loading. The IMO (deck) sea sloshing load shall be ignored according to 4WEQ‐1014.

The shipping weight is 16.685 tonnes, the distance of Center of gravity to base is 1.316m. The transverse wind load is 11.683 kN. (Refer to page6)

Longitudinal load:
Fx=m*ax=16.685*1.5*9.8=245.27 kN

Transverse load:
Fy=m*ay+Fw=16.685*1.5*9.8+11.683=256.95 kN

Tipping moment:
Fy*a=256.95*1.316=338.15 kN.m

Appendix 2 IMO Rules Annex 13 section 7 - Advanced Calculation Method.

Calculation of Lashing Capacity (LC)(For the most severe working points)

Longitudinal acceleration		=	a_x	=	1.5	
Transverse acceleration		=	a_y	=	1.5	
Vertical acceleration		=	a_z	=	2	
Coefficient of friction		=	μ	=	0.3	
Vertical lashing angle		=	α	=	52.4	deg
			cos α	=	0.610	
Horizontal lashing angle		=	β	=	41.4	deg
			cosβ	=	0.750	
Shipping mass	G	=	m	=	16685	kg
				=	16.685	Ton
Number of effective lashing belt		=	n	=	8	nos.
Lashing capacity	LC	=	G*Cx / (cos α*cos β*n)	=	6839	kg
				=	6.839	Ton

The provided lashing belts are 8 nos. of lashing rope 6 x 19 diameter 12mm having total capacity of 100.8 Ton
(i.e. single belt having capacity 8.4 Ton.)

Advanced calculation method

1. Transverse Sliding:

In order to calculate the required lashing on each side a balance of forces calculations has to meet the following ineequality:

No. of soft lashing		=	n	=	8	Nos.	
Transverse acceleration		=	ay	=	1.5	m/s^2	
Coefficient of friction		=	μ	=	0.3		
Mass of cargo [ton]		=	m	=	16.69	Ton	
Gravity acceleration of earth		=	g	=	9.81	m/s^2	
Lashing Diameter		=	d	=	12	mm	wire rope 6 x 19
Breaking Load				=	84	kN	securing load
MSL		=	Breaking Load / 2	=	42	kN	
Calculated strength of transverse securing device (MSL)	CS	=	MSL / 1.5	=	28.0	kN	...MSL-Maximum
Function of friction coefficient & the vertical securing angle	f	=	μ * sin α + cos α	=	0.848		
			sin α	=	0.792		
			cos α	=	0.610		
	f1	=	μ * sin α + cos α	=	0.848		
	f2	=	μ * sin α + cos α	=	0.848		
Overall Length of vessel		=	L	=	7.410	m	
Overall Width of vessel		=	w	=	1.71	m	
Overall Height of vessel		=	h	=	2.57	m	
Wind force acting on each m2 area				=	1.0	kN	
Area Exposed to wind in Longitudinal direction		=	L * w	=	12.67	m^2	
Longitudinal wind force = 1 kN * Longitudinal exposed area		=	Fwy	=	12.67	kN	
Area Exposed to wind in Transverse direction		=	h * w	=	4.39	m^2	
Transverse wind force = 1 kN * Transverse exposed area		=	Fsy	=	4.39	kN	
Transverse sliding force	Fy	=	m*ay + Fwy + Fsy	=	**42.09**	kN	

Since the below equation is satisfied i.e.

Fy	<	μ * m * g + CS1 * f1 + CS2 * f2
42.09	<	**96.58**

So the provided lashing is suitable for Transverse Sliding.

2. Transverse Tipping:

In order to calculate the required lashing on each side a balance of forces calculations has to meet the following inequality:

No. of soft lashing		=	n	=	8	Nos.	
Transverse acceleration		=	ay	=	1.500	m/s^2	
Lever arm of tipping		=	a	=	1.316	m	
Lever arm of stableness		=	b	=	0.750	m	
mass of cargo		=	m	=	16.685	Ton	
Gravity acceleration of earth		=	g	=	9.81	m/s^2	
Lashing Diameter		=	d	=	12	mm	wire rope 6 x 19
Breaking Load				=	84	kN	
MSL		=	Breaking Load / 2	=	42.0	kN	
Calculated strength of transverse securing device (MSL)	CS	=	MSL / 1.5	=	28.0	kN	
Lever arm of securing force		=	c				
Lever arm of securing force (Shell Lashing)			c1	=	1.9		
Lever arm of securing force (Stool Lashing)			c2	=	1.9		
Longitudinal wind force = 1 kN x Longitudinal exposed area			Fwy	=	12.67	kN	
Transverse wind force = 1 kN x Transverse exposed area			Fsy	=	4.39	kN	
Transverse sliding force	Fy	=	m * ay+ Fwy + Fsy	=	42.1	kN	
			Fy * a	=	**55.39**	kN	
			b * m * g + CS1 * c1 + CS2 * c2	=	**231.68**	kN	

Since the below equation is satisfied i.e.

Fy * a	<	b * m * g+ CS1 * c1 + CS2 * c2
55.39	<	**231.68**

So the provided lashing is suitable for Transverse Tipping.

3. Longitudinal Sliding

Generally, the transverse securing devices provide sufficient longitudinal components to prevent longitudinal sliding.

In order to ensure the above the balance of forces calculations has to meet the following inequality:

No. of soft lashing		=	n	=	8	Nos.	
Longitudinal acceleration		=	a_x	=	1.5	m/s^2	
Coefficient of friction		=	μ	=	0.3		
mass of cargo		=	m	=	16.7	Ton	
Gravity acceleration of earth		=	g	=	9.81	m/s^2	
Vertical acceleration		=	a_z	=	2	m/s^2	
Vertical force	Fz	=	$m*a_z$	=	33.37	kN	
Lashing Diameter		=	d	=	12	mm	wire rope 6 x 19
Breaking Load				=	84	kN	
MSL		=	Breaking Load / 2	=	42	kN	
Calculated strength of transverse securing device (MSL)	CS	=	MSL / 1.5	=	28.0	kN	

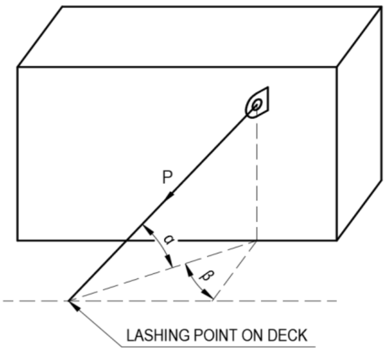
Longitudinal wind force = Longitudinal exposed area * 1 kN		=	Fsx	=	12.67	kN
Area Exposed to wind in Transverse direction		=	h * w	=	4.39	m^2
Transverse wind force = 1 kN * Transverse exposed area		=	Fw_x		4.39	kN
Vertical lashing angle in longitudinal direction		=	α	=	52	deg
Function of friction coefficient & the vertical securing angle	f	=	μ * sin a + cos a	=	0.848	
		=	sin α	=	0.792	
		=	cos α	=	0.610	
	f1	=	μ * sin 45 + cos 45	=	0.848	
	f2	=	μ * sin 45 + cos 45	=	0.848	
	Fx	=	m * ay + Fwx + Fsx	=	**42.09**	kN
			μ * (m * g - Fz) + CS1 * fl + CS2 * f2	=	**86.6**	kN

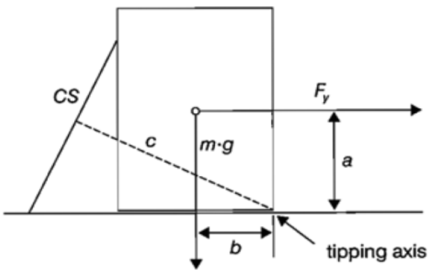
Since the below equation is satisfied i.e.

Fx	<	μ * (m * g - Fz) + CS1 * fl + CS2 * f2
42.09	<	**86.6**

So the provided lashing is suitable for Longitudinal Sliding.

Figure





6 X 19 + FIBRE CORE

Winch / lashing wire rope 6 x 19 + fibre core

Lashing rope 6 x 19 + fibre core has minimum breaking load of 1770 N/mm² 180Kg/mm²

DRAWINGS

DIAMETER (mm)	WIRE DIAMETER (mm)	SECTION (mm²)	WEIGHT/m (kg)	BREAKING LOAD 1770 N/mm² (kN)	BREAKING LOAD 1960 N/mm² (kN)
3	0,2	-	0,03	4,9	5,4
4	0,25	-	0,06	8,7	9,6
5	0,33	-	0,09	13,6	15,1
6	0,39	14	0,12	21	23
7	0,45	18	0,16	28	31
8	0,52	24	0,22	37	41
9	0,58	30	0,27	46	51
10	0,64	37	0,33	56	63
11	0,72	47	0,41	71	79
12	0,78	55	0,49	84	93
13	0,84	64	0,57	97	108
14	0,9	73	0,65	111	124
15	0,96	83	0,74	127	141
16	1,04	98	0,87	149	165
17	1,1	109	0,97	166	185
18	1,16	122	1,08	185	206
19	1,22	135	1,19	205	227
20	1,28	148	1,32	225	251
21	1,36	167	1,48	254	282
22	1,42	183	1,62	277	308