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Lifting Lug Design In Detail

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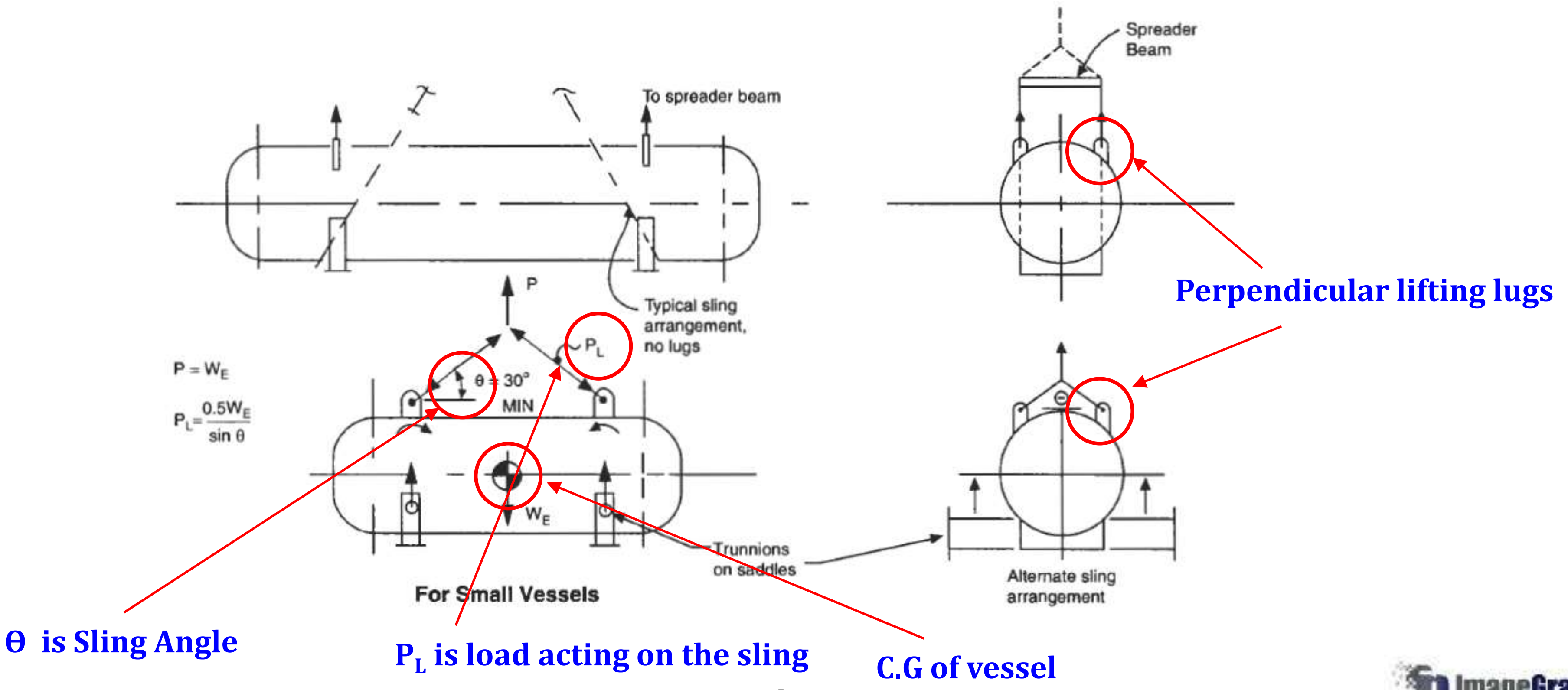
Typical Lifting Arrangements for Vessel

Different types of Lifting Arrangements

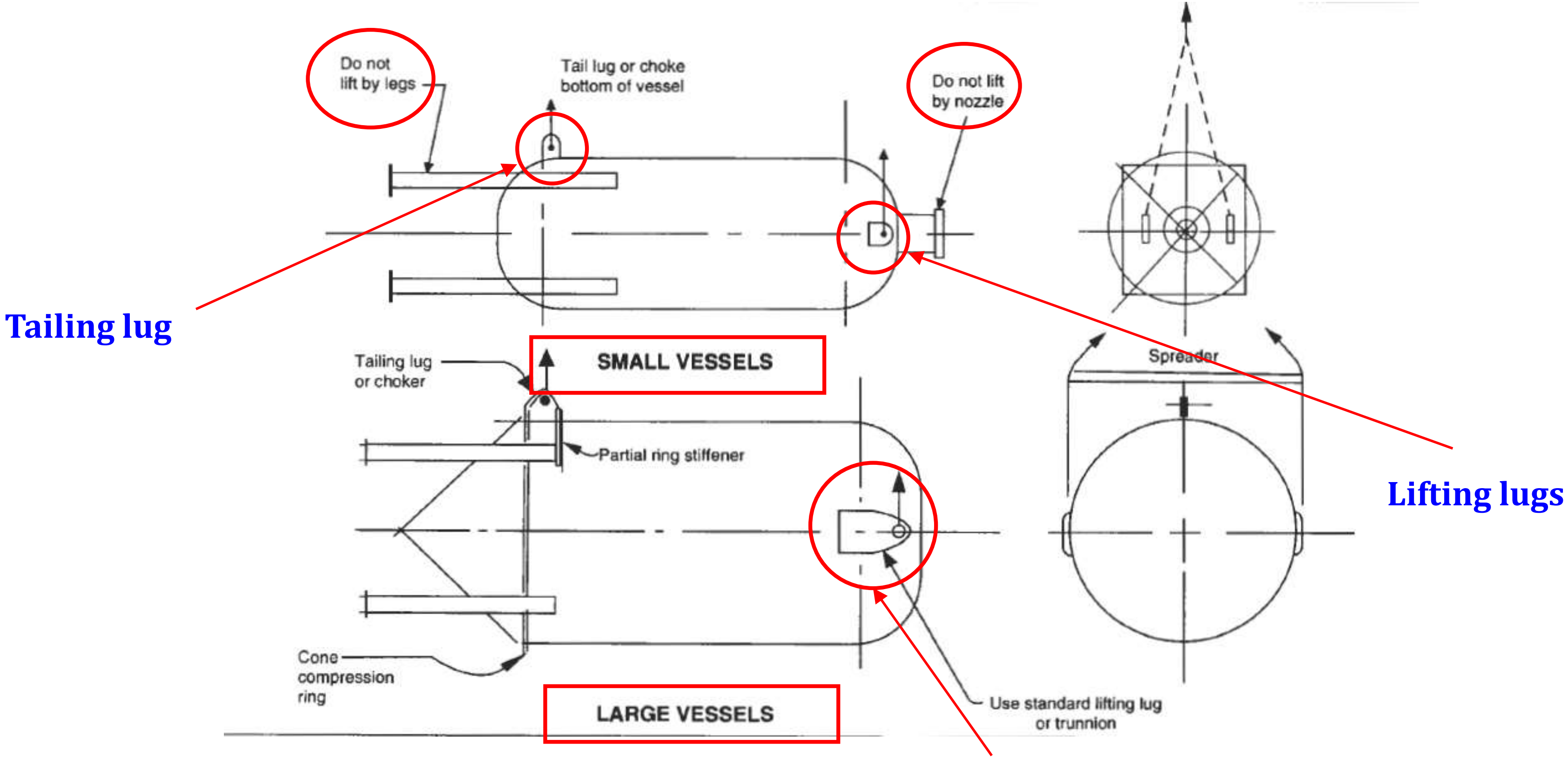





Typical Lifting Arrangements for Horizontal Vessels

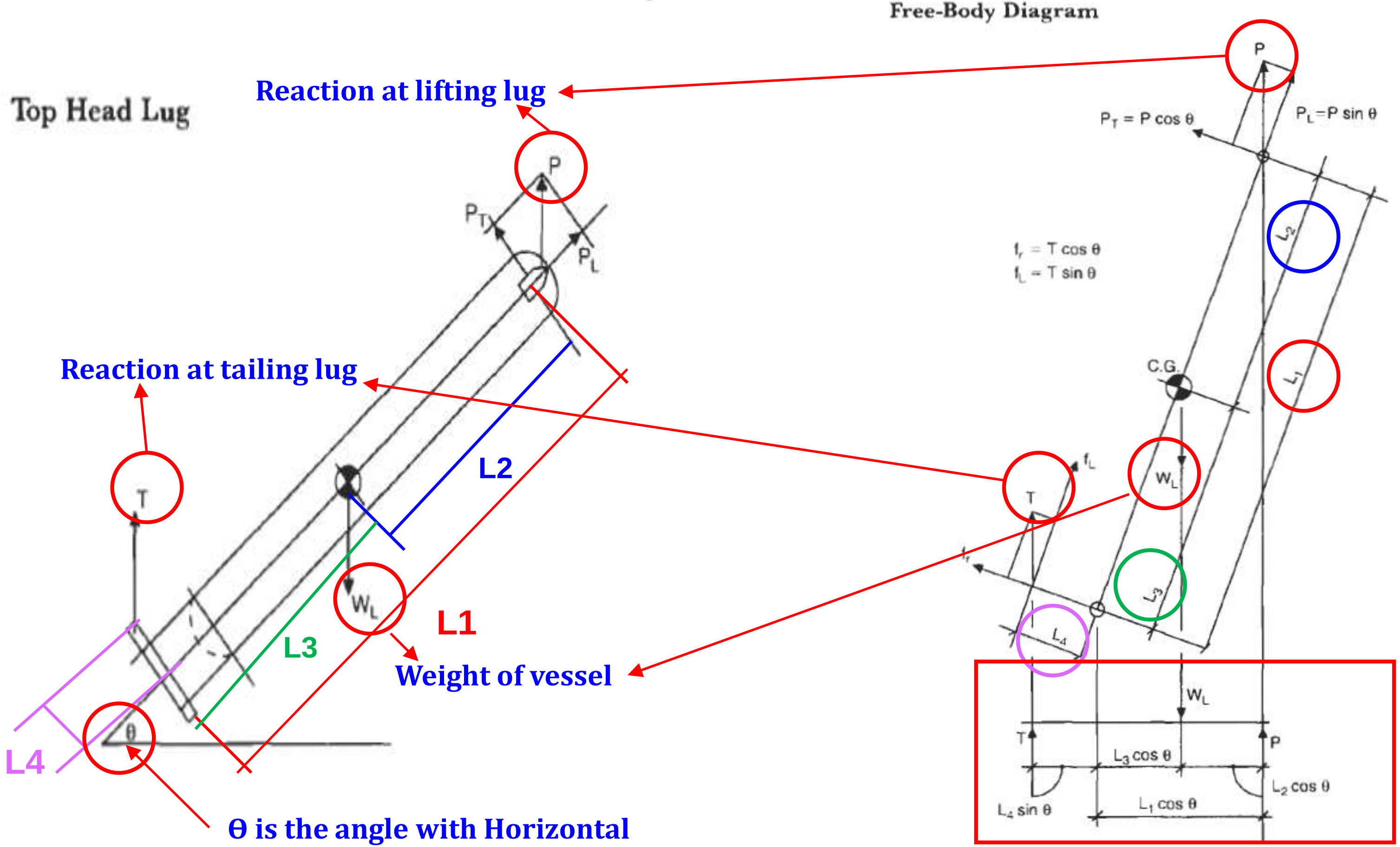


Typical Lifting Arrangements for Leg Supported Vessels

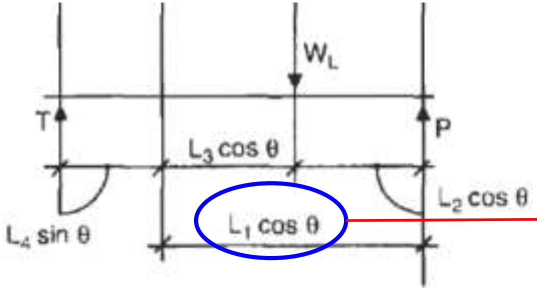


For large vessels Trunnion or Standard Heavy lifting lugs are used

Horizontal to vertical lifting Forces



Horizontal to vertical lifting Forces Calculations



Resolving the forces in vertical direction

$W_L = T + P$

Hence ,

$P = W_L - T$

Taking moment at T for equilibrium of the forces,

$W_L * (L_3 \cos\theta + L_4 \sin\theta) = P * (L_1 \cos\theta + L_4 \sin\theta)$

$W_L * (L_3 \cos\theta + L_4 \sin\theta) = (W_L - T) * (L_1 \cos\theta + L_4 \sin\theta)$

$W_L * L_3 \cos\theta + W_L * L_4 \sin\theta = W_L * L_1 \cos\theta + W_L * L_4 \sin\theta - T * L_1 \cos\theta - T * L_4 \sin\theta$

$W_L * L_3 \cos\theta = W_L * L_1 \cos\theta - T * L_1 \cos\theta - T * L_4 \sin\theta$

$L_1 \cos\theta = L_2 \cos\theta + L_3 \cos\theta$

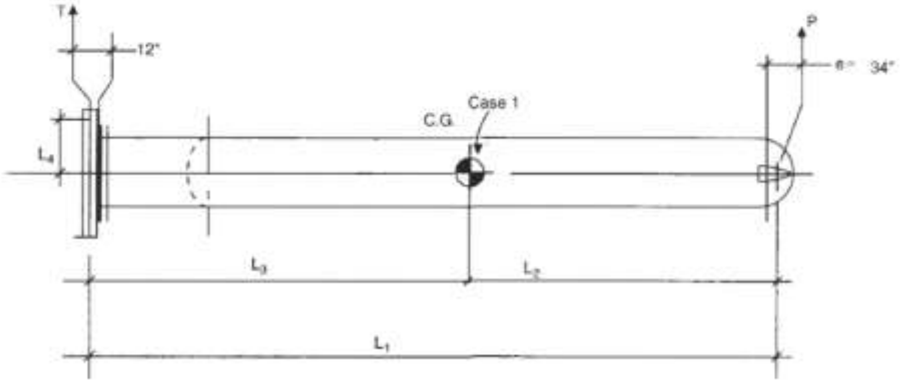
$W_L * L_3 \cos\theta = W_L * L_2 \cos\theta + W_L * L_3 \cos\theta - T * L_1 \cos\theta - T * L_4 \sin\theta$

$T * L_1 \cos\theta + T * L_4 \sin\theta = W_L * L_2 \cos\theta$

$$T = \frac{W_L * L_2 \cos\theta}{L_1 \cos\theta + L_4 \sin\theta}$$

Horizontal to vertical lifting Forces Calculations

Sample Problem



Where, $L_3 > L_2$

By Using Following Equations loads are calculated,

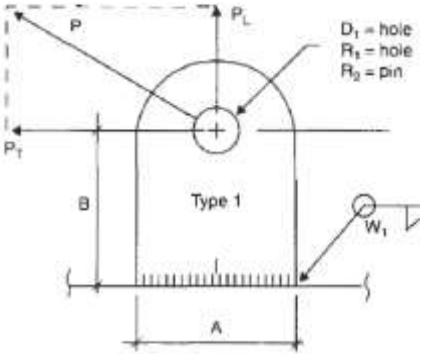
$$T = \frac{W_L * L_2 \cos\theta}{L_1 \cos\theta + L_4 \sin\theta}$$

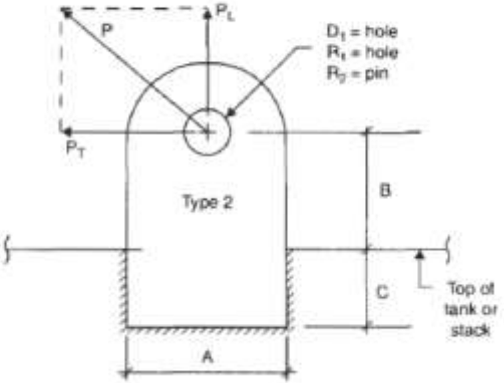
$$P = W_L - T$$

Loads T and P		
θ	T	P
0	171.7	228.3
10	170.6	229.4
20	169.6	230.4
30	168.3	231.7
40	166.8	233.2
50	164.8	235.2
60	161.9	238.1
70	156.6	243.4
80	143.2	256.8
90	0	400

Lifting Lug Design

Thickness calculations





Thickness Due to bending = t_L

$$t_L = \frac{6 P_T B}{A^2 F_b}$$

Now,

$$Fb = \frac{M}{Z}$$

$M = P_T \times B$

$Z = I / Y$

Here, $\frac{t_L \times A^3}{12} / (A/2)$ → $\frac{t_L \times A^2}{6}$

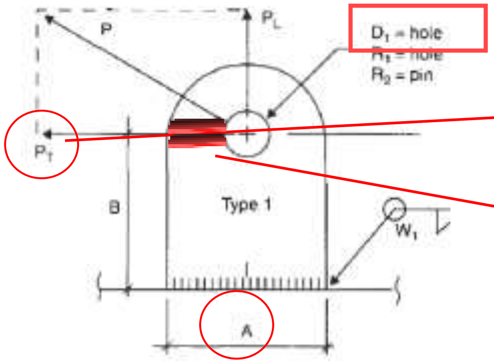
$$Z = \frac{t_L \times A^2}{6}$$

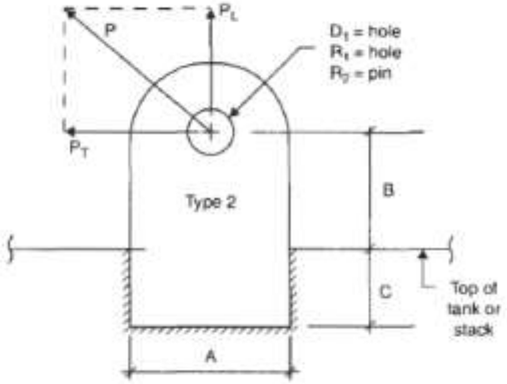
$$\text{Hence, } Fb = \frac{P_T \times B}{\frac{t_L \times A^2}{6}} = \frac{6 P_T B}{t_L \times A^2}$$

$$\text{Now, } t_L = \frac{6 P_T \times B}{F_b \times A^2}$$

Lifting Lug Design

Thickness calculations





Thickness Due to Shear= t_L

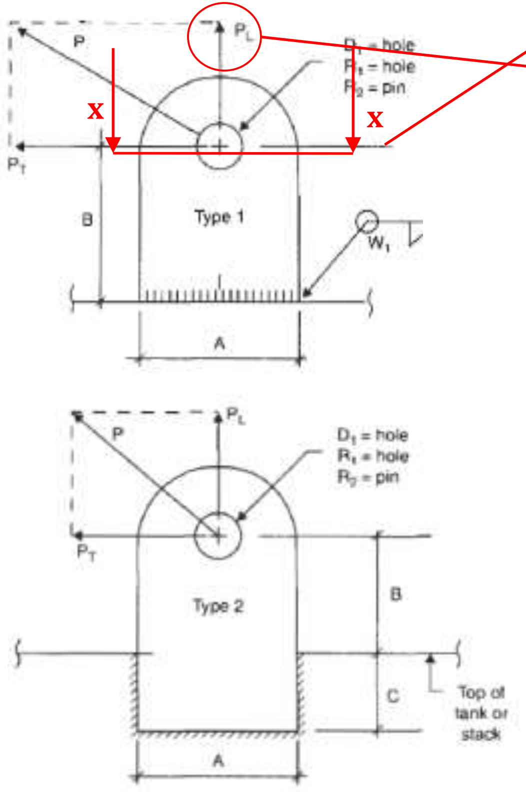
$$t_L = \frac{P_T}{(A - D_1)F_s}$$

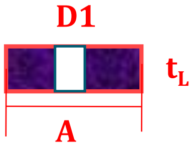
Shear Stress Fs $= \dfrac{\text{Shear Force}}{\text{Shear Area}} = \dfrac{P_T}{\frac{A - D1}{\cancel{2}} \times \cancel{2} \times t_L}$

Hence, $t_L = \dfrac{P_T}{(A - D1) \times Fs}$

Lifting Lug Design

Thickness calculations





Thickness Due to Tension= t_L

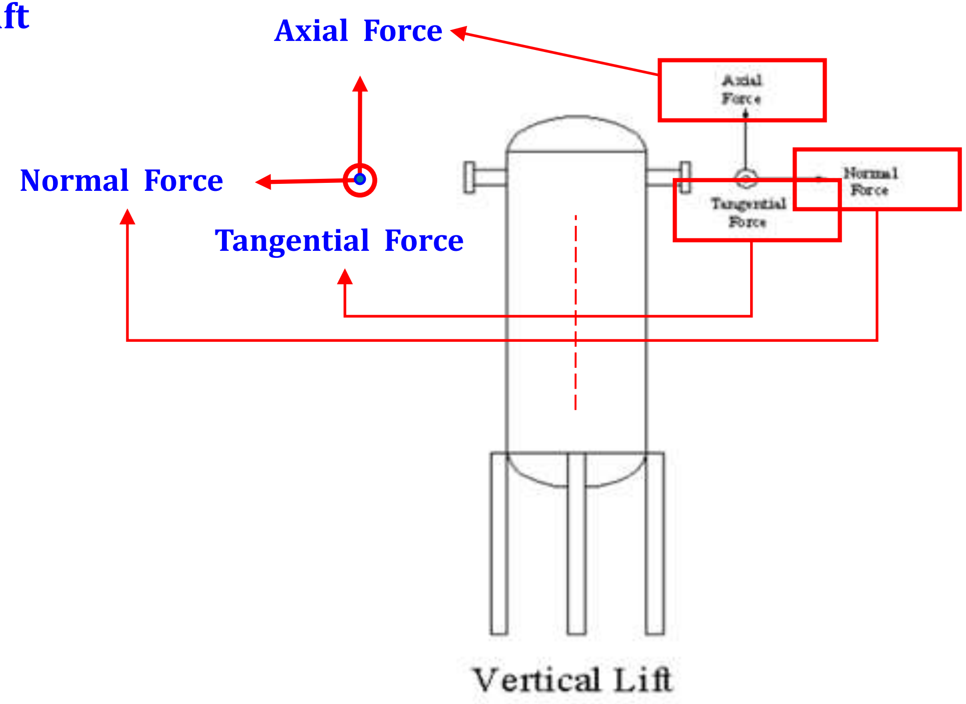
$$t_L = \frac{P_L}{(A - D_1)F_t}$$

Tensile Stress Ft = $\frac{\text{Tensile Force}}{\text{Area in tension}} = \frac{P_L}{(A - D1) \times t_L}$

Hence, $t_L = \frac{P_L}{(A - D1) \times Ft}$

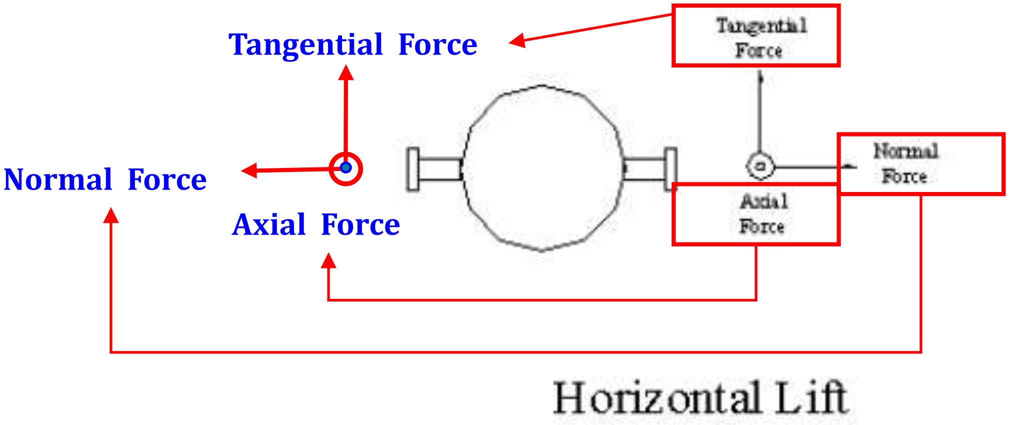
PV Elite Forces and sign Conventions

For Vertical Lift

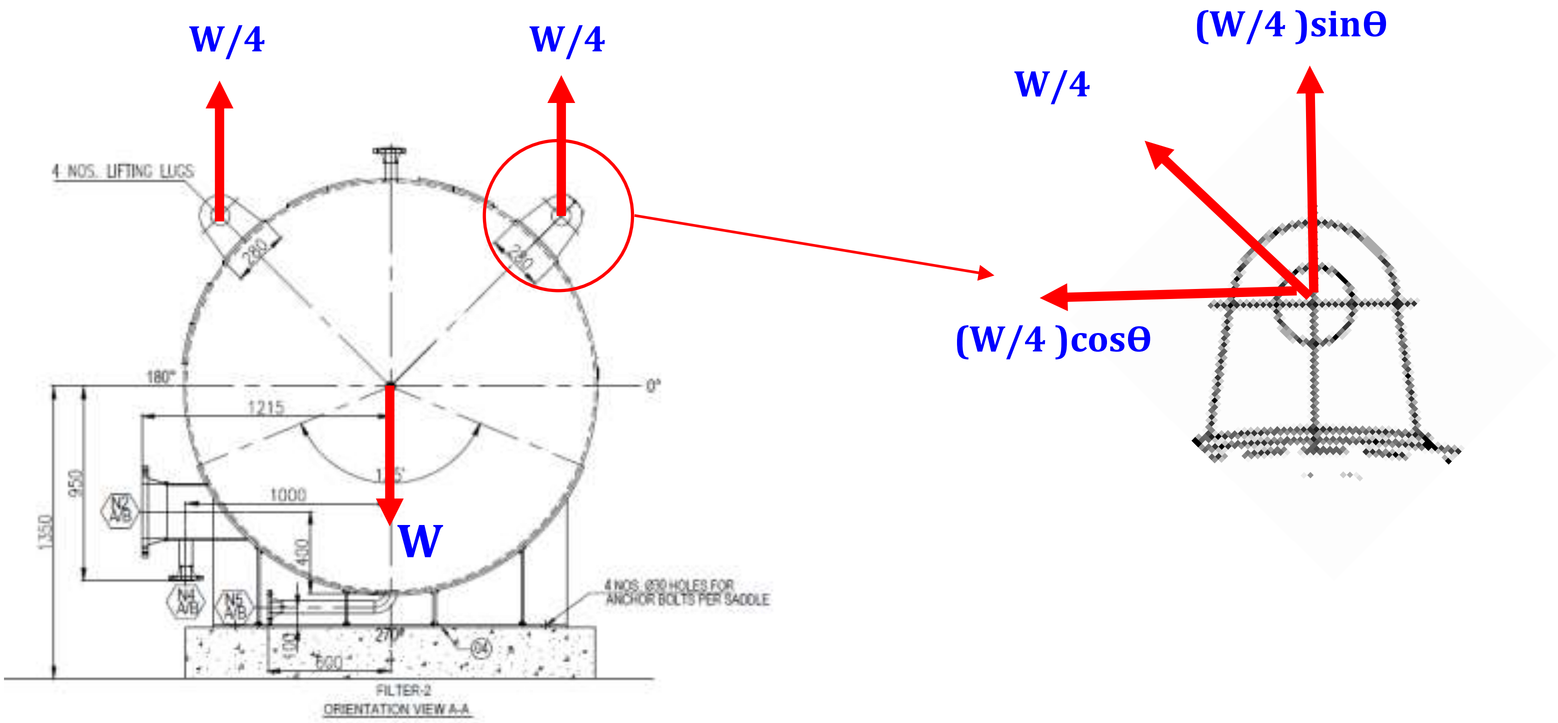


PV Elite Forces and sign Conventions

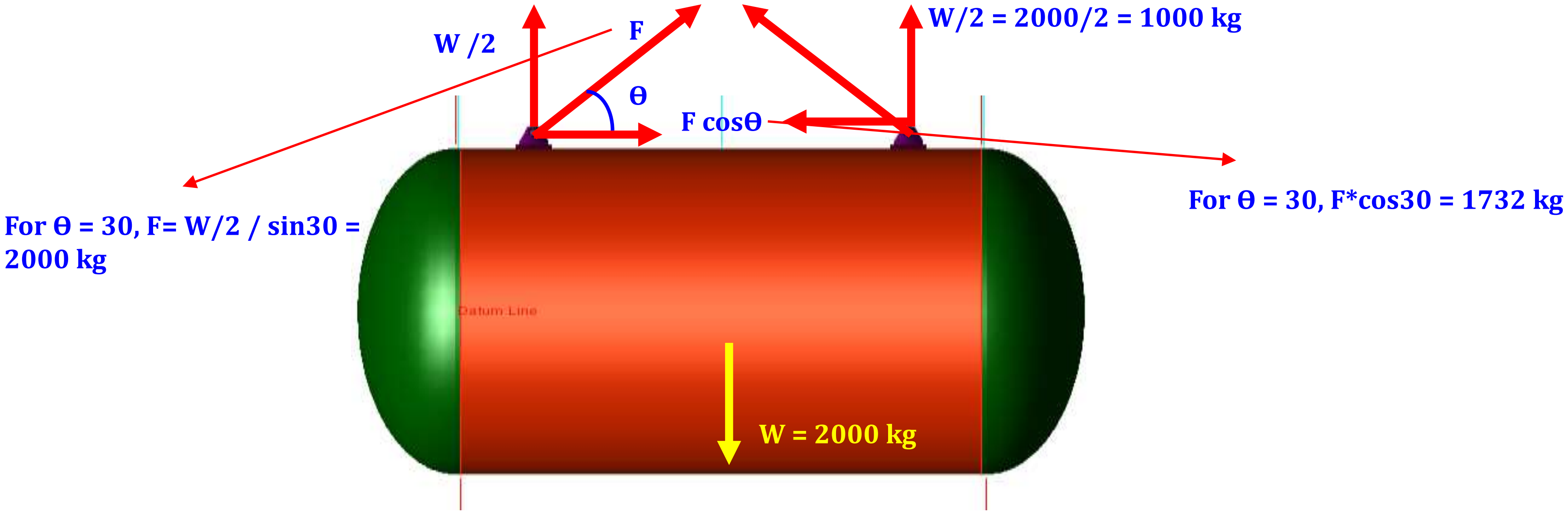
For Horizontal Lift



PV Elite Forces and sign Conventions



PV Elite Lifting Lug Sample Example



Vessel I.D = 1000 mm , Shell Thickness = 6mm , Weight = 2000 kg ,

2 Nos of perpendicular lifting lugs provided

PV Elite Lifting Lug Sample Example

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Identification	
Item Number	1
Description	Lifting Lug
Legs and Lugs	
Design Pressure, kgf/cm^2	3.5
Design Temperature for Internal Pressure, C	85
Outside Diameter of Vessel, mm	1012
Shell Thickness, mm	6
Shell Corrosion Allowance, mm	0
Tangent to Tangent Length of Vessel, cm	420
Shell Material	SA-516 70
Type of Analysis	Lifting Lug
Analyze Baseplate ?	☐

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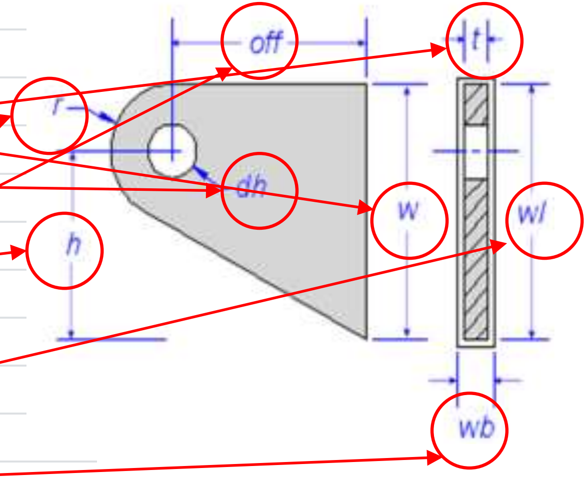
Additional Horizontal Force on Vessel, kgf	0
Location of Horizontal Force above Base Point, cm	0
Empty Weight of Vessel, kgf	2000
Operating Weight of Vessel (total vertical load), kg	0
Height of Bottom Tangent above Base Point, cm	0
Occasional Load Factor (AISC A5.2)	1
Apply Wind Loads to Vessel ?	☐
Apply Seismic Loads to Vessel ?	☐

PV Elite Lifting Lug Sample Example

Lifting Lug	
Lifting Lug Material	SA-516 70
Lug Orientation to Vessel	Perpendicular
Contact Width or Height (Perp. Lug) of Lifting Lug [w], mm	150
Thickness of Lifting Lug [t], mm	16
Diameter of Hole in Lifting Lug [dh], mm	50
Radius of Semi-circular Arc of Lifting Lug [r], mm	60
Height of the Lug from Bottom to Center of Hole [h], mm	75
Offset from Vessel OD to Center of Hole [off], mm	100
Minimum thickness of Fillet Weld around Lug, mm	6
Length of weld along side of Lifting Lug [wl], mm	150
Length of weld along bottom of Lifting Lug [wb], mm	28
Lift Information and Loads on one Lug	
Lift Orientation (optional)	Horizontal
Axial Force, kgf	**1732**
Normal Force, kgf	1000
Tangential Force, kgf	0
Impact Factor	1.5



PV Elite Lifting Lug Sample Example

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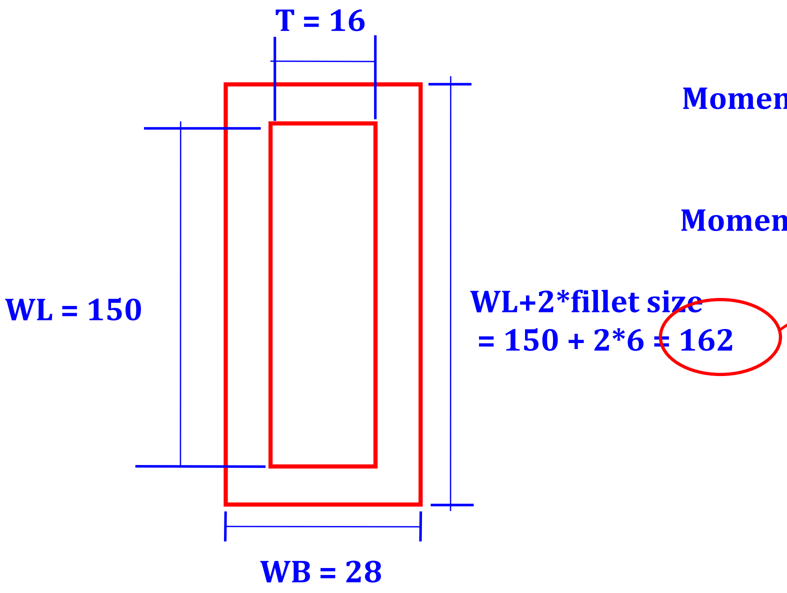
Results for lifting lugs, Description : Lifting Lug

Weld Group Inertia about the Circumferential Axis	ILC	542.023	cm**4
Weld Group Centroid distance in the Long. Direction	YLL	81.000	mm
Dist. of Weld Group Centroid from Lug bottom	YLL_B	75.000	mm
Weld Group Inertia about the Longitudinal Axis	ILL	24.515	cm**4
Weld Group Centroid Distance in the Circ. Direction	YLC	14.000	mm

$$\frac{162}{2}$$



$$\text{Moment of Inertia ILc} = \frac{2.8 \times 16.2^3 - 1.6 \times 15^3}{12} = 542.023$$

$$\text{Moment of Inertia ILL} = \frac{2.8^3 \times 16.2 - 1.6^3 \times 15}{12} = 24.515$$

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PV Elite Lifting Lug Sample Example

Results for lifting lugs, Description : Lifting Lug

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Weld Group Centroid distance in the Long. Direction	YLL	81.000	mm
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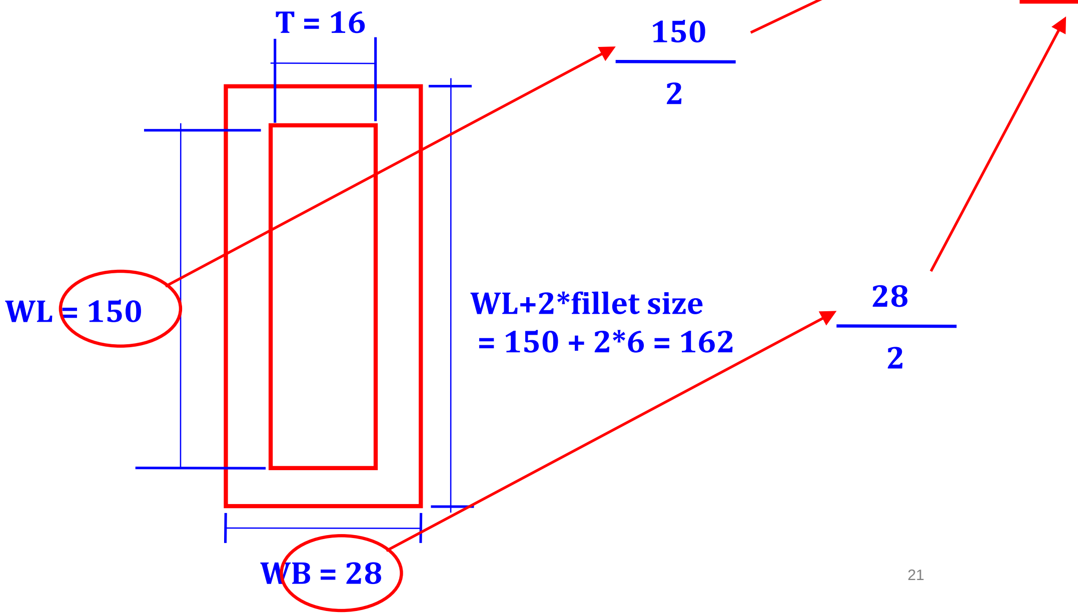


PV Elite Lifting Lug Sample Example

Applying the Impact factor to the loads:

```
 Fax = 1732.00 * 1.50 = 2598.00 kgf
 Fn  = 1000.00 * 1.50 = 1500.00 kgf
```

Primary Shear Stress in the Welds due to Shear Loads [Ssll]:

```
 = Sqrt( Fax^2+Ft^2+Fn^2 ) / ( (2*wl+wb) * tw )
 = Sqrt(2598^2+0^2+1500^2) / ( (2*150.0 +28.0 ) * 6.0000 )
 = 152.44 kgf/cm^2
```

Total Resultant force

$$\sqrt{Fax^2 + Ft^2 + Fn^2}$$

Total resisting area of weld

2 x (Wl + Wb)* Weld size

PV Elite Lifting Lug Sample Example

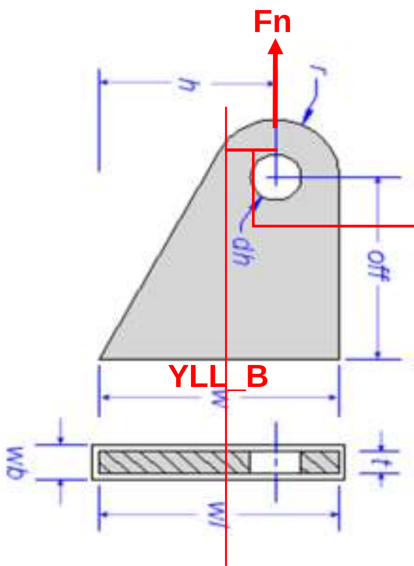
Shear Stress in the Welds due to Bending Loads [Sblf]:

```
 = (Fn*(h-YLL_B)) *YLL/ILC + (Fax*off *YLL/ILC) + (Ft*off *YLC/ILL)
 = (1500 *(75.000 -75.000 )) * 81.000 /542.023 +
   (1299 *100.000 * 81.000 /542.023 ) +
   (0 *100.000 * 14.000 /24.515 )
 = 194.13 kgf/cm^2
```

Stress = M / Z = Fn x (h-YLL_B) / ILC/YLL = Fn x (h-YLL_B) *YLL/ILC

M = Force * Moment arm = Fn x (h-YLL_B)

Z = Section modulus = I / Y = ILC / YLL



h – YLL_B

Moment will come only when there is offset distance

PV Elite Lifting Lug Sample Example

```
Pin Hole Bearing Stress [Pbs]:
 = Sqrt( Fax^2 + Fn^2 ) / ( t * dh )
 = Sqrt( 1299^2 + 1500^2 ) / ( 16.000 * 50.000 )
 = 248.04 kgf/cm^2
```

Bearing Area = diameter of hole x thickness of lug
= t x dh

Resultant Force in the sling

PV Elite Lifting Lug Sample Example

Bending stress at the base of the lug [Fbs]:

```
 = Ft*off / (w*t^(2) / 6) + Fax*off / (w^(2)*t / 6)
 = 0 * 100.000 / (150.000 * 16.000^(2) / 6) +
   1299 * 100.000 / (150.000^(2) * 16.000 / 6)
 = 216.51  kgf/cm^2
```

Tensile stress at the base of the lug [Fa]:

```
 = Fn / (w * t) = 1500 / (150.000 * 16.000 )
 = 62.50  kgf/cm^2
```

Total Combined Stress at the base of the lug:

```
 = Fbs + Fa = 279.0 kgf/cm^2
```

Section modulus in strong axis

Bending moment because of Fax

Section modulus in weak axis

Bending moment because of Ft

Tensile force acting on lug

Cross section area at the base = w x t

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Thank You!

Have a great conversation!

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