EMP ENGINEERING SERVICES INC.

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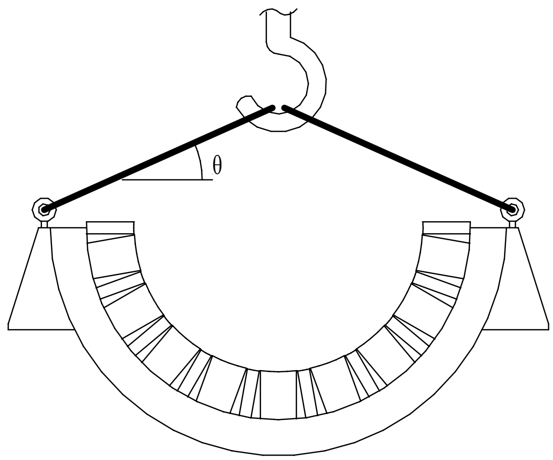
APPENDIX A

FRAME BENDING STRESS FROM SINGLE POINT LIFTING

The top frame halves are lifted using factory installed lifting eyes. However, the bottom frame halves are often lifted on a single point suspension using threaded eye bolts in the four corners with a sling to each corner. The field frame weighs 80,500 pounds of which about 60% is in the bottom half. This gives a unit weight of about 48,000 pounds.



If the slings are at 45^o to the horizontal, then the sides of the ring are being pulled together by the same amount (half in each of the symmetrical slings), i.e.:

$$Force_{Horiz} = \frac{Force_{Vert}}{\tan\theta} = \frac{48{,}000}{\tan(45)} = 48{,}000 lb$$

However if the vertical distance from the eyes to the hook becomes less than half of the distance between the eyes and θ goes down, then the force compressing the frame becomes greater than its weight. Some example lifts and resulting compressive loads are shown here.

Height (inches)	80	56	37	21
θ (deg)	45	35	25	15
Compression (lb)	48,000	68,550	102,935	179,140

Is this compression enough to bend the shell? That will happen if the maximum stress in the shell exceeds the yield stress for steel, about 50,000 psi (assume medium carbon steel and minimal heat treatment).

The bottom frame half may be modeled as a semi-circular shell. The maximum stress will be in the outside edge of the shell. The stress due to bending in a curved member is: $\sigma_o = \frac{Mc_o}{Aer_o}$

Where:
- M=applied bending moment
- c_o=distance from neutral axis to outer fibers
- A=area
- e=distance from center to neutral axis
- r_o=radius of outer fibers

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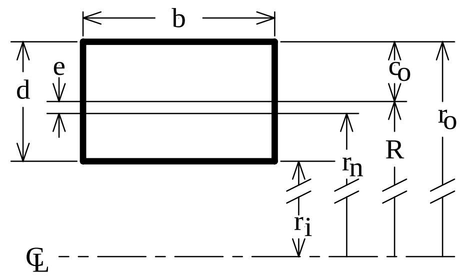
This cross section shows relative dimensions:



Outside radius	r_o	= <u>76.875”</u>
Inside radius	r_i	= <u>71”</u>
Radius	R	=(76.875+71)/2
		=<u>73.938”</u>
Width	b	=<u>41”</u>
Depth	d	=76.875-71=<u>5.875”</u>
Neutral radius	r_n	=5.875/ln(76.875/71) =<u>73.899”</u>
Neutral offset	e	=73.938-73.899=<u>0.0385”</u>
Area	A	=5.875 x 41=<u>240.9 sq. in.</u>
	c_o	=76.875-73.899=<u>2.976”</u>
	c_i	=73.899-71=<u>2.899”</u>

The moment can be determined with these dimensions in terms of applied load.

M = FR = 73.938F

Using substitution, the applied force may be determined as a function of stress.

$$\sigma_o = \frac{73.938F \bullet 2.976}{240.9 \bullet 0.0385 \bullet 76.875} = 0.309F$$

Rearranging:

$$F = 3.24\sigma_o$$

F, the horizontal load applied to the frame, may be stated in terms of θ, the angle of the slings.

$$\tan\theta = \frac{48{,}000}{3.24\sigma_o}$$

To find what angle will push the stress past yield and bend the shell, substitute a yield strength of 50,000 psi for the stress. Using the earlier force equation, rearranging and substituting produces:

$$Force_{Horiz} = \frac{Force_{Vert}}{\tan\theta}$$

$$\tan\theta = \frac{Force_{Vert}}{Force_{Horiz}} = \frac{48{,}000}{3.24\sigma_{yield}} = \frac{48{,}000}{3.24 \bullet 50{,}000} = 0.296$$

$$\boxed{\therefore \theta = 16.5\deg}$$

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Because the base is 80”, this corresponds to a hook height of:

$$h = \tan(16.5) \bullet 80 = 23.7 \approx 24 inches$$

Conclusion: If the hook is 24 inches or less above the lifting eyes then the frame will bend.