Company Logo

Internal Pontoon Floating Roof Design Per API 650, Appendix H

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Internal Pontoon Floating Design

A. Introduction

This program designs pontoon floating roofs to the requirements of API 650, Appendix H (internal roofs)

Design methodologies are as follows:

1. Pontoon ring is designed using section properties determined in accordance with the AISI Cold-Formed Steel Design Manual (accounts for local buckling of plates with large width to thickness ratios)
2. Floating roof legs are designed in accordance with AISC 360, Latest Edition for loads listed in API 650, Appendix H.
3. Deck stresses and deflections are determined in accordance with the paper: "Stresses in Ruptured Floating Roofs", H.I. Epstein and J.R. Buzek, *1978 ASME Journal of Pressure Vessel Technology*.
4. Pontoon ring is modeled as a ring on elastic foundation.
5. Ponton ring strength is evaluated in accordance with AISI Cold-Formed Steel Design Manual.

B. Pontoon Geometry

Diameter	Rim space	Pontoon width	Height of inner rim	Height of outer rim
$D := 220 \cdot ft$	$S_{rim} := 8 \cdot in$	$W_{pon} := 12 \cdot ft$	$H_{ir} := 30 \cdot in$	$H_{or} := 30 \cdot in$

Width of inner rim extension	Width of outer rim extension	Height of outer rim extension	Backslope	Cover slope
$W_{iExt} := 0 \cdot in$	$W_{oExt} := 0 \cdot in$	$H_{oExt} := 3 \cdot in$	$BS := 0 \cdot in$	$CS_{min} := -.1875 \cdot \frac{in}{ft}$

Deck thickness	Cover thickness	Bulkhead thickness	Inner rim thickness	Outer rim thickness
$t_d := .1875 \cdot in$	$t_c := .1875 \cdot in$	$t_{bh} := .1875 \cdot in$	$t_{ir} := .75 \cdot in$	$t_{or} := .75 \cdot in$

Suggested number of bulkheads

$$\frac{(D - 2 \cdot S_{rim}) \cdot \pi}{17.75 \cdot ft} = 38.70$$

Suggested number of posts per rafter

$$\text{floor}\left(\frac{W_{pon}}{6 \cdot ft}\right) = 2.00$$

Rafters per Pontoon	Number of bulkheads	Posts per Rafter	Spacing of weld to rafter	Length of weld per spacing	Weld size for cover to rafter connection
$N_{rp} := 2$	$N_{bh} := 40$	$N_{pp} := 2$	$S_{wr} := 12 \cdot in$	$L_{wr} := 2 \cdot in$	$t_{wr} := .1875 \cdot in$

○ Angle Rafters
◉ Channel Rafters

Angle Rafter

- L2X2X3/16 / L51X51X4.8
- L2-1/2X2X3/16 / L64X51X4.8
- L2-1/2X2-1/2X3/16 / L64X64X4.8
- L3X2X3/16 / L76X51X4.8

Channel Rafter

- C3X4.1 / C75X6.1
- C4X4.5 / C100X6.7
- C3X5 / C75X7.4
- C4X5.4 / C100X8

Internal Pontoon Floating Roof Design

C. Leg Geometry

- (●) Low Legs Stops
- ( ) Low Leg Sleeves

Leg diameter $d_{legs} := 2.875 \cdot in$

Leg thickness $t_{legs} := .276 \cdot in$

Sleeve diameter $d_{slv} := 3.5 \cdot in$

Sleeve thickness $t_{slv} := .216 \cdot in$

Maximum leg spacing $S_{legMax} := 24 \cdot ft$

Low leg setting $H_{low} := 3 \cdot ft$

High leg setting $H_{hi} := 7 \cdot ft$

Sleeve extension below deck $H_{dslv} := 3 \cdot in$

Radius to deck legs

$$R_{legs} := \begin{pmatrix} 12 \\ 32 \\ 52 \\ 72 \end{pmatrix} \cdot ft$$

Pin height for deck legs

$$H_{pin} := \begin{pmatrix} 24 \\ 24 \\ 24 \\ 24 \end{pmatrix} \cdot in$$

$$\frac{D}{2} - S_{rim} - W_{pon} = 97.33\,ft$$

$$n := 1 .. rows(R_{legs})$$

$$N_{legMin_n} := ceil\left(\frac{2 \cdot \pi \cdot R_{legs_n}}{S_{legMax}}\right)$$

$$N_{legMin} = \begin{pmatrix} 4.00 \\ 9.00 \\ 14.00 \\ 19.00 \end{pmatrix}$$

Number of deck legs at each radius

$$N_{legs} := \begin{pmatrix} 4 \\ 10 \\ 16 \\ 20 \end{pmatrix}$$

Number of inner rim legs $N_{irlegs} := 36$

Internal Pontoon Floating Roof Design

D. Appurtenance Geometry

☐ Center Weight Used?

Weight of pontoon manway

$w_{pmw} := 75 \cdot lbs$

Weight of center weight

$W_{cw} := 1 \cdot lbs$

Diameter of centerweight

$D_{cw} := 20 \cdot ft$

Length of ladder track

$L_{ltr} := 45 \cdot ft$

Number of deck manways

$N_{dmw} := 2$

Weight of deck manways

$w_{dmw} := 100 \cdot lbs$

Number of bleeder vents

$N_{bv} := 2$

Weight of bleeder vents

$w_{bv} := 250 \cdot lbs$

E. Corrosion Allowances

Outer rim corrosion allowance

$CA_{or} := 0 \cdot in$

Inner rim corrosion allowance

$CA_{ir} := 0 \cdot in$

Deck corrosion allowance

$CA_d := 0 \cdot in$

Cover plate corrosion allowance

$CA_c := 0 \cdot in$

Corrosion allowance on legs

$CA_{legs} := 0 \cdot in$

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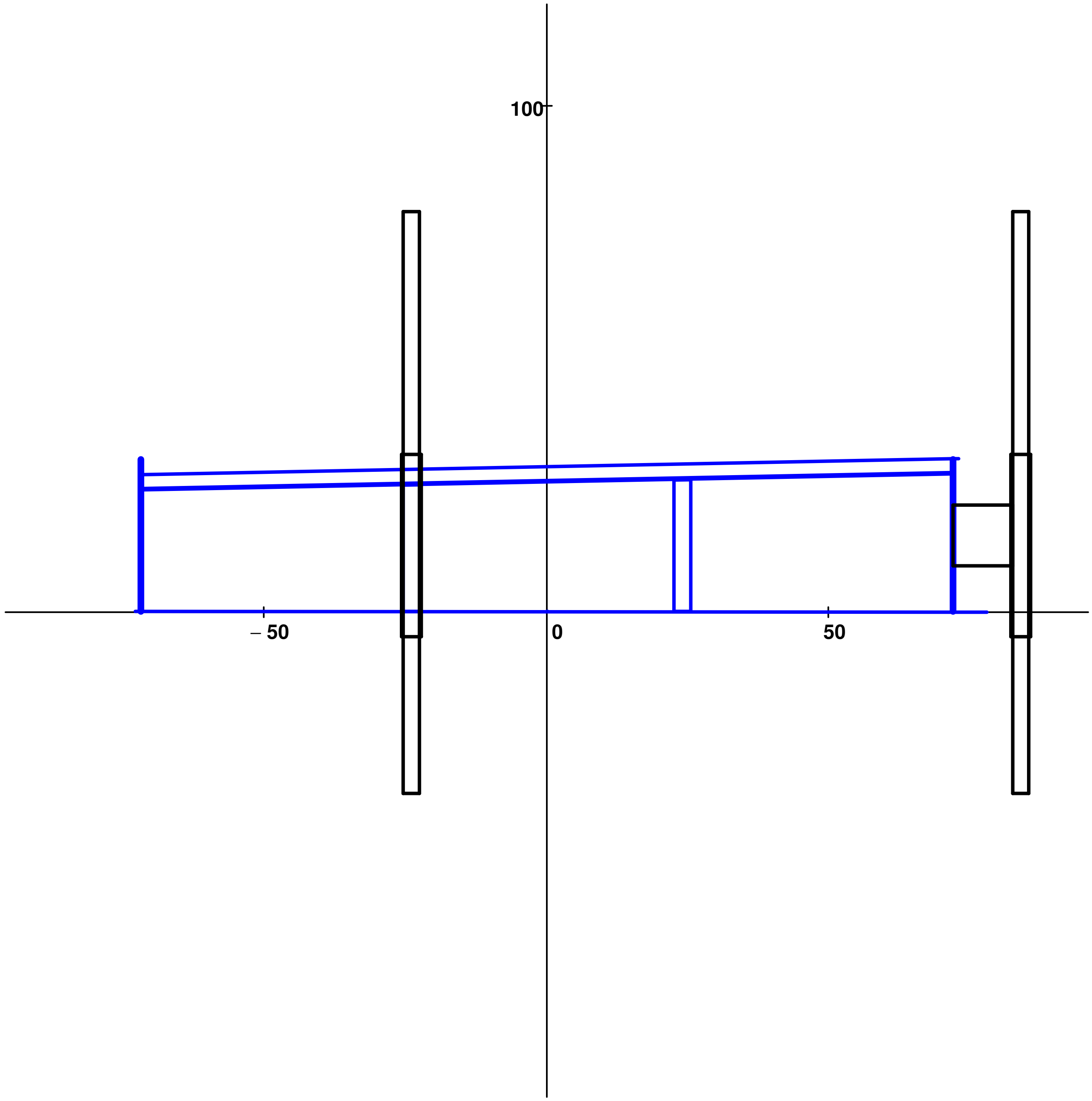
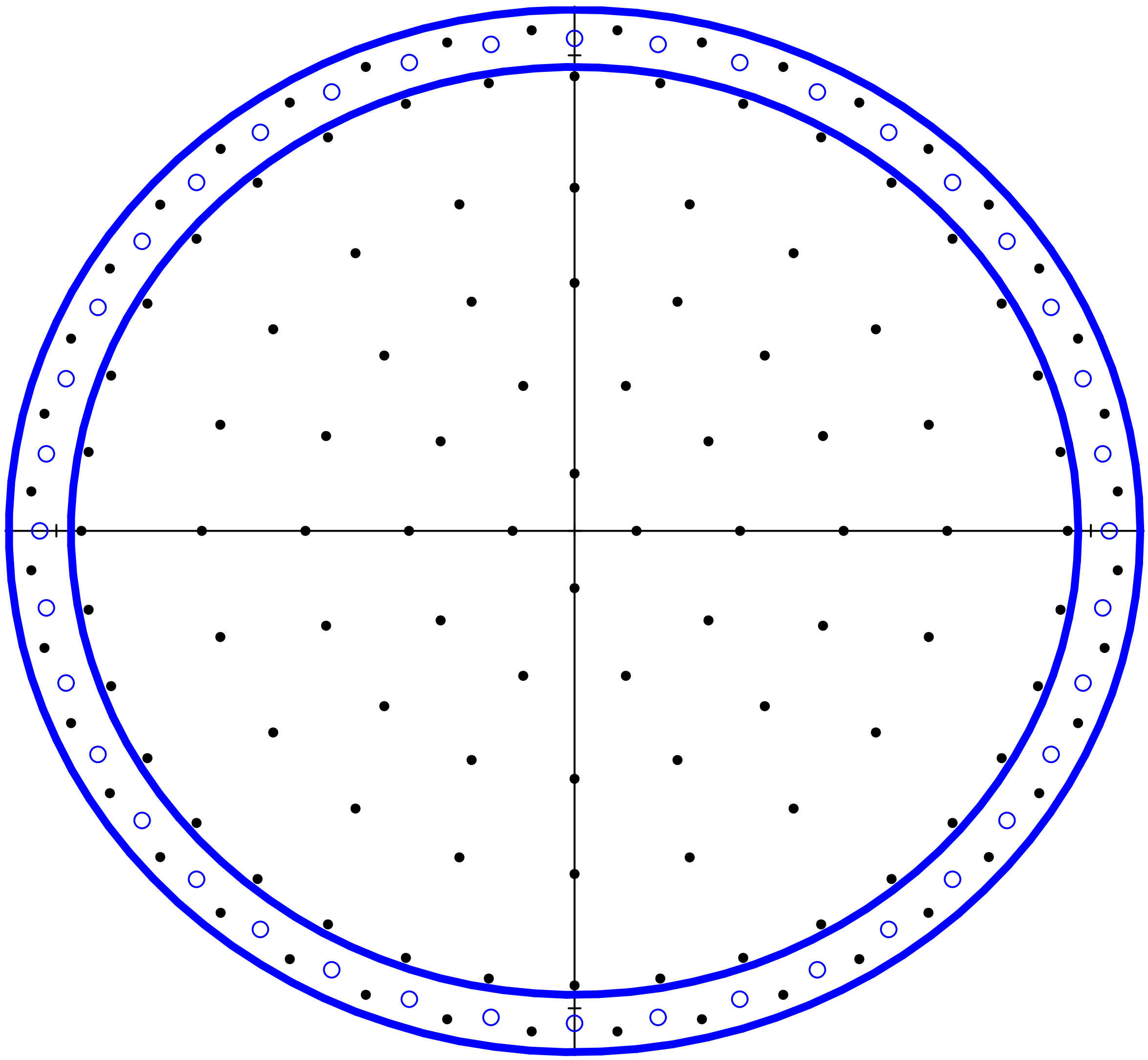
SK

Pontoon Section



Internal Pontoon Floating Roof Design

Plan View of Roof



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E. Material Properties

Yield strength of rim plate

$F_{yrim} := 36 \cdot ksi$

Yield strength of deck plate

$F_{yd} := 36 \cdot ksi$

Yield strength of plate

$F_{yp} := 36 \cdot ksi$

Yield strength of rafter

$F_{yr} := 36 \cdot ksi$

Weld tensile strength

$F_{uw} := 60 \cdot ksi$

Leg yield strength

$F_{ylegs} := 35 \cdot ksi$

F. Design Criteria

Live load

$LL := 12.5 \cdot psf$

Minimum specific gravity

$SG_{min} := 0.7$

Number of punctured pontoons

$N_p := 2$

Fricition from seal

$\mu_{seal} := 15 \cdot \frac{lbs}{ft}$

Unit weight of seal

$w_{seal} := 20 \cdot plf$

Radial force from seal

$k_{seal} := 45 \cdot \frac{lbs}{ft}$

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G. Roof Weight

$W_{or} := t_{or} \cdot (H_{or} + W_{oExt}) \cdot 2 \cdot \pi \cdot R_{or} \cdot \gamma_s$ — $W_{or} = 52595.50 \cdot lbs$ — Weight of outer rim

$W_{ir} := t_{ir} \cdot (H_{ir} + W_{iExt}) \cdot 2 \cdot \pi \cdot R_{ir} \cdot \gamma_s$ — $W_{ir} = 46822.82 \cdot lbs$ — Weight of inner rim

$W_{cover} := \frac{W_{pon}}{\cos(\alpha_c)} \cdot \left[2 \cdot \pi \cdot \left(\frac{R_{ir} + R_{or}}{2}\right)\right] \cdot t_c \cdot \gamma_s$ — $W_{cover} = 59663.93 \cdot lbs$ — Weight of cover plate

$W_{BS} := \frac{W_{pon}}{\cos(\alpha_{BS})} \cdot \left[2 \cdot \pi \cdot \left(\frac{R_{ir} + R_{or}}{2}\right)\right] \cdot t_d \cdot \gamma_s$ — $W_{BS} = 59650.99 \cdot lbs$ — Weight of backslope

$W_{bh} := N_{bh} \cdot W_{pon} \cdot \left[\frac{H_{ir} + (H_{or} - H_{oExt})}{2}\right] \cdot t_{bh} \cdot \gamma_s$ — $W_{bh} = 8728.13 \cdot lbs$ — Weight of bulkheads

$w_{raft} = 4.10 \cdot plf$

$W_{raft} := N_{rp} \cdot N_{bh} \cdot \frac{W_{pon}}{\cos(\alpha_c)} \cdot w_{raft}$ — $W_{raft} = 3936.85 \cdot lbs$ — Weight of rafters

$W_{post} := N_{rp} \cdot N_{pp} \cdot N_{bh} \cdot \left(\frac{H_{or} - H_{oExt} + H_{ir}}{2}\right) \cdot w_{raft}$ — $W_{post} = 1558.00 \cdot lbs$ — Weight of posts

$W_{seal} := w_{seal} \cdot \pi \cdot D$ — $W_{seal} = 13823.01 \cdot lbs$ — Weight of seal

$F_{fseal} := \mu_{seal} \cdot \pi \cdot D$ — $F_{fseal} = 10367.26 \cdot lbs$ — Total frictional force on seal

Internal Pontoon Floating Roof Design

G. Roof Weight

$W_{deck} := \pi \cdot R_{ir}^{2} \cdot t_d \cdot \gamma_s \cdot 1.05$ $W_{deck} = 239264.61 \cdot lbs$ Weight of deck

$$W_{slv} := \begin{cases} \left[\sum_{n=1}^{rows(H_{pin})} \left[\left(H_{pin_n} + H_{dslv} + 2 \cdot in\right) \cdot N_{legs_n}\right]\right] \cdot w_{slv} & \text{if SleeveType} = 1 \\ \left[\sum_{n=1}^{rows(H_{pin})} \left[\left(H_{pin_n} + H_{low} + 2 \cdot in\right) \cdot N_{legs_n}\right]\right] \cdot w_{slv} & \text{otherwise} \end{cases}$$

$W_{slv} = 916.28 \cdot lbs$ Weight of deck sleeves

$$W_{legs} := \sum_{n=1}^{rows(H_{pin})} \left[\left(H_{pin_n} + H_{dslv} + H_{hi} + 2 \cdot in\right) \cdot N_{legs_n}\right] \cdot w_{legs}$$ Weight of deck legs

$W_{legs} = 3610.49 \cdot lbs$

$W_{pslv} := \left(N_{bh} \cdot H_{pslv} + N_{irlegs} \cdot H_{irslv}\right) \cdot w_{slv}$ $W_{pslv} = 1728.92 \cdot lbs$ Weight of pontoon sleeves

$W_{plegs} := \left[N_{bh} \cdot \left(H_{pslv} + H_{hi}\right) + N_{irlegs} \cdot \left(H_{irslv} + H_{hi}\right)\right] \cdot w_{legs}$

$W_{plegs} = 5827.90 \cdot lbs$ Weight of pontoon legs

$W_{cw} = 1.00 \cdot lbs$ Weight of centerweight

$W_{pmw} := w_{pmw} \cdot N_{bh}$ $W_{pmw} = 3000.00 \cdot lbs$ Weight of pontoon manways

$W_{dmw} := N_{dmw} \cdot w_{dmw}$ $W_{dmw} = 200.00 \cdot lbs$ Weight of deck manways

$W_{bv} := N_{bv} \cdot w_{bv}$ $W_{bv} = 500.00 \cdot lbs$ Weight of bleeder vents

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G. Roof Weight

$$W_{PON} := W_{or} + W_{ir} + W_{cover} + W_{BS} + W_{bh} + W_{raft} + W_{seal} + W_{plegs} + W_{pslv} + W_{pmw} + W_{post}$$

$W_{PON} = 257336.05 \cdot lbs$ — Total pontoon weight

$W_{dTOT} := W_{deck} + W_{legs} + W_{slv} + W_{bv} + W_{dmw}$ — Total deck weight

$W_{dTOT} = 244491.38 \cdot lbs$

$W_{roof} := W_{PON} + W_{dTOT}$ — Total roof weight

$W_{roof} = 501827.43 \cdot lbs$

$\gamma_{deck} := \dfrac{W_{dTOT}}{\pi \cdot R_{ir}^{2}}$ $\quad \gamma_{deck} = 8.21 \cdot psf$ — Unit weight of deck considering appurtenances

H. Check Cover Slope

$$CS := \frac{H_{or} - H_{oExt} - BS - H_{ir}}{W_{pon}} = -0.25 \cdot \frac{in}{ft}$$

$\dfrac{CS_{min}}{CS} = 75.00 \cdot \%$ — Check minimum cover slope

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J. Check Rafters

RafterName = "C3X4.1"	Rafter size used
$w_{raft} = 4.10 \cdot plf$	Weight of rafter per foot
$S_{ro} := \dfrac{2 \cdot \pi \cdot R_{or}}{N_{bh} \cdot (N_{rp} + 1)}$ $\quad S_{ro} = 5.72\,ft$	Spacing at outer end of rafter
$\dfrac{S_{ro}}{7 \cdot ft} = 81.78 \cdot \%$	Check maximum spacing
$S_{ri} := \dfrac{2 \cdot \pi \cdot R_{ir}}{N_{bh} \cdot (N_{rp} + 1)}$	Spacing at inner end of rafter
$S_{ri} = 5.10\,ft$	
$DL := \gamma_s \cdot t_c$	
$DL = 7.66 \cdot psf$	Dead load on rafter
$LL = 12.50 \cdot psf$	Live load on rafter

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J. Check Rafters

$$q_1 := \begin{cases} S_{ro} \cdot DL + w_{raft} + S_{ro} \cdot LL & \text{if } W_{pon} > \frac{S_{ro}}{2} + \frac{S_{ri}}{2} \\ W_{pon} \cdot DL + w_{raft} + W_{pon} \cdot LL & \text{otherwise} \end{cases}$$

Uniform load toward outer end of rafter

$$q_2 := \begin{cases} S_{ri} \cdot DL + w_{raft} + S_{ri} \cdot LL & \text{if } W_{pon} > \frac{S_{ro}}{2} + \frac{S_{ri}}{2} \\ W_{pon} \cdot DL + w_{raft} + W_{pon} \cdot LL & \text{otherwise} \end{cases}$$

Uniform load toward inner end of rafter

$$x_1 := \begin{cases} \frac{S_{ro}}{2} & \text{if } W_{pon} > \frac{S_{ro}}{2} + \frac{S_{ri}}{2} \\ \frac{W_{pon}}{2} & \text{otherwise} \end{cases} \qquad x_1 = 2.86\,ft$$

Location of q1 loading form outer end

$$x_2 := \begin{cases} \frac{S_{ri}}{2} & \text{if } W_{pon} > \frac{S_{ro}}{2} + \frac{S_{ri}}{2} \\ \frac{W_{pon}}{2} & \text{otherwise} \end{cases} \qquad x_2 = 2.55\,ft$$

Location of q2 loading form inner end

$$x_3 := W_{pon} - x_1 - x_2$$

$$x_3 = 6.59\,ft$$

Width of transition loading

$$q_{ur}(x) := \begin{cases} \frac{x}{x_1} \cdot q_1 & \text{if } x < x_1 \\ q_1 - \frac{(x - x_1)}{x_3} \cdot (q_1 - q_2) & \text{if } (x \ge x_1) \cdot (x < x_1 + x_3) \\ q_2 - \frac{[x - (x_1 + x_3)]}{x_2} \cdot q_2 & \text{otherwise} \end{cases}$$

Uniform load as a function of x

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J. Check Rafters

$$R_1 := \frac{\int_{0\cdot ft}^{W_{pon}} q_{ur}(x)\cdot x\,dx}{W_{pon}}$$

Reaction at outer end of rafter

$R_1 = 0.52\cdot kip$

$$x_{max} := \left| \begin{array}{l} xx \leftarrow \frac{W_{pon}}{3} \\ \text{while } \int_{0\cdot ft}^{xx} q_{ur}(xx)\,dxx < R_1 \\ \quad xx \leftarrow xx + .5\cdot in \\ xx \end{array} \right.$$

Location of maximum moment

$x_{max} = 5.92\,ft$

$$M_{ur}(x) := R_1\cdot x - \int_{0\cdot ft}^{x} q_{ur}(x1)\cdot(x - x1)\,dx1$$

Ultimate moment in rafter

$M_{ur}(x_{max}) = 1.86\cdot ft\cdot kip$

$\Omega_B := 1.67$

Safety factor for bending

$M_{nr} := S_{xr}\cdot F_{yr}$

Nominal moment capacity of rafter per AISC 360-05

$$\frac{M_{ur}(x_{max})}{M_{nr}} = 45.00\cdot\%$$

Compare moment to nominal capacity

$$v_{fr} := \frac{R_1\cdot Q_r}{I_{xr}} \qquad v_{fr} = 0.15\cdot\frac{kip}{in}$$

Ultimate shear flow at rafter cover connection

$\Omega_w := 2$

Safety factor for weld

$$v_{fn} := 0.6\cdot .7071\cdot t_{wr}\cdot\frac{L_{wr}}{S_{wr}}\cdot\frac{F_{uw}}{\Omega_w} \qquad v_{fn} = 0.40\cdot\frac{kip}{in}$$

Nominal shear strength of weld at rafter to cover connection

$$\frac{v_{fr}}{v_{fn}} = 38.88\cdot\%$$

Compare shear flow to nominal capacity

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K. Check Legs

$$R_{legs} = \begin{pmatrix} 12.00 \\ 32.00 \\ 52.00 \\ 72.00 \end{pmatrix} ft \qquad N_{legs} = \begin{pmatrix} 4.00 \\ 10.00 \\ 16.00 \\ 20.00 \end{pmatrix} \qquad N_{irlegs} = 36.00 \qquad N_{bh} = 40.00$$

$$TL_{deck} := \gamma_{deck} + LL$$

$$TL_{deck} = 20.71 \cdot psf$$

Deck load

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K. Check Legs

$$P_{ulegs} := \left| \begin{array}{l} \text{for } i \in 1..\text{rows}(R_{legs}) \\ \quad p_i \leftarrow \dfrac{\pi \cdot \left(\dfrac{R_{legs_i} + R_{ir}}{2}\right)^2 \cdot TL_{deck}}{N_{legs_i}} \text{ if } (i = 1)\cdot(i = \text{rows}(R_{legs})) \\ \quad p_i \leftarrow \dfrac{\pi \cdot \left[\left(\dfrac{R_{legs_{i+1}} + R_{legs_i}}{2}\right)^2 - \left(\dfrac{R_{legs_i} + R_{legs_{i-1}}}{2}\right)^2\right] \cdot TL_{deck}}{N_{legs_i}} \text{ if } (i > 1)\cdot(i < \text{rows}(R_{legs})) \\ \quad p_i \leftarrow \dfrac{\pi \cdot \left[\left(\dfrac{R_{legs_{i+1}} + R_{legs_i}}{2}\right)^2\right] \cdot TL_{deck}}{N_{legs_i}} \text{ if } (i = 1)\cdot(i < \text{rows}(R_{legs}))\cdot(R_{legs_i} > 0 \cdot ft) \\ \quad p_i \leftarrow \dfrac{1}{2} \cdot \dfrac{\pi \cdot \left[\left(R_{legs_{i+1}}\right)^2\right] \cdot TL_{deck}}{N_{legs_i}} \text{ if } (i = 1)\cdot(i < \text{rows}(R_{legs}))\cdot(R_{legs_i} = 0 \cdot ft) \\ \quad p_i \leftarrow \dfrac{\pi \cdot \left[\left(\dfrac{R_{ir} + R_{legs_i}}{2}\right)^2 - \left(\dfrac{R_{legs_i} + R_{legs_{i-1}}}{2}\right)^2\right] \cdot TL_{deck}}{N_{legs_i}} \text{ if } (i > 1)\cdot(i = \text{rows}(R_{legs})) \\ \quad p_i \leftarrow \dfrac{\pi \cdot \left[\left(\dfrac{R_{legs_{i+1}} + R_{legs_i}}{2}\right)^2 - \left(\dfrac{R_{legs_i} + R_{legs_{i-1}}}{2}\right)^2\right] \cdot TL_{deck}}{N_{legs_i}} \text{ otherwise} \\ p \end{array} \right.$$

$$P_{ulegs} = \begin{pmatrix} 7.87 \\ 8.33 \\ 8.46 \\ 10.82 \end{pmatrix} \cdot kip$$

Load at deck legs

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K. Check Legs

$$P_{uirlegs} := \begin{cases} \dfrac{\pi \cdot \left[\left(R_{ir}\right)^2 - \left(\dfrac{R_{ir} + R_{legs_{rows(R_{legs})}}}{2} \right)^2 \right] \cdot TL_{deck}}{N_{irlegs}} + \dfrac{1}{4} \cdot \dfrac{1.2 \cdot W_{PON}}{N_{irlegs}} \; ... \\ \quad + \dfrac{1}{4} \cdot \dfrac{1.6 \cdot \left[\pi \cdot \left(R_{or}^2 - R_{ir}^2 \right) \right] \cdot LL}{N_{bh}} & \text{if } N_{irlegs} > 0 \\ 0 \cdot kip & \text{otherwise} \end{cases}$$

$P_{uirlegs} = 7.29 \cdot kip$ Load at inner rim legs

$$P_{uplegs} := \begin{cases} \dfrac{\pi \cdot \left[\left(R_{ir}\right)^2 - \left(\dfrac{R_{ir} + R_{legs_{rows(R_{legs})}}}{2} \right)^2 \right] \cdot TL_{deck}}{N_{bh}} + \dfrac{1.2 \cdot W_{PON}}{N_{bh}} \; ... \\ \quad + \dfrac{1.6 \cdot \left[\pi \cdot \left(R_{or}^2 - R_{ir}^2 \right) \right] \cdot LL}{N_{bh}} & \text{if } N_{irlegs} = 0 \\ \dfrac{3}{4} \cdot \dfrac{1.2 \cdot W_{PON}}{N_{bh}} + \dfrac{3}{4} \cdot \dfrac{1.6 \cdot \left[\pi \cdot \left(R_{or}^2 - R_{ir}^2 \right) \right] \cdot LL}{N_{bh}} & \text{otherwise} \end{cases}$$

$P_{uplegs} = 8.71 \cdot kip$ Load at pontoon legs

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K. Check Legs

$$PR_{TOT} := N_{bh} \cdot P_{uplegs} \cdot \left(R_{ir} + \frac{2}{3} \cdot W_{pon} \right) + N_{irlegs} \cdot P_{uirlegs} \cdot R_{ir}$$

$$PR_{TOT} = 62234.58\,ft \cdot kip$$

$$QR_{TOT} := \sum_{n=1}^{rows(R_{legs})} \left(P_{ulegs_n} \cdot N_{legs_n} \cdot R_{legs_n} \right)$$

$$QR_{TOT} = 25659.11 \cdot ft \cdot kip$$

$$K_{plegs} := 2.0 \cdot \sqrt{\frac{QR_{TOT} + PR_{TOT}}{PR_{TOT}}}$$

$$K_{plegs} = 2.38$$

$$K_{legs} := 1.0$$

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K. Check Legs

$d_{legs} = 2.88 \cdot in$ Leg diameter

$t_{legs} = 0.28 \cdot in$ Leg thickness

$d_{clegs} := d_{legs} - 2 \cdot CA_{legs}$ Leg diameter - corroded

$t_{clegs} := t_{legs} - CA_{legs}$ Leg thickness - corroded

$A_{clegs} := \frac{\pi}{4} \cdot \left[\left(d_{clegs}\right)^2 - \left(d_{clegs} - 2 \cdot t_{clegs}\right)^2 \right]$ Leg cross sectional area - corroded

$A_{clegs} = 2.25 \cdot in^2$

$I_{clegs} := \frac{\pi}{64} \cdot \left[\left(d_{clegs}\right)^4 - \left(d_{clegs} - 2 \cdot t_{clegs}\right)^4 \right]$ Moment of inertia - corroded

$I_{clegs} = 1.92 \cdot in^4$

$S_{clegs} := \frac{2 \cdot I_{clegs}}{d_{clegs}}$ $S_{clegs} = 1.34 \cdot in^3$ Section modulus

$r_{clegs} := \sqrt{\frac{I_{clegs}}{A_{clegs}}}$ $r_{clegs} = 0.92 \cdot in$ Radius of gyration

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K. Check Legs

$$\lambda_{plegs} := \frac{K_{plegs} \cdot \left[H_{hi} - \left(\frac{2}{3} \cdot BS\right) - H_{dslv}\right]}{r_{clegs}} \qquad \lambda_{plegs} = 208.34$$

$$F_{Eplegs} := \frac{\pi^2 \cdot E_s}{\left(\lambda_{plegs}\right)^2}$$

Euler buckling load for pontoon legs

$$F_{crplegs} := \begin{cases} .658^{\frac{F_{ylegs}}{F_{Eplegs}}} \cdot F_{ylegs} & \text{if } \lambda_{plegs} \le 4.71 \cdot \sqrt{\frac{E_s}{F_{ylegs}}} \\ 0.877 \cdot F_{Eplegs} & \text{otherwise} \end{cases}$$

$$F_{crplegs} = 5782.75\,psi$$

Critical buckling load for pontoon legs

$$\Omega_C := 1.67$$

Safety factor for compression

$$P_{nplegs} := \frac{F_{crplegs} \cdot A_{clegs}}{\Omega_C} = 7803.384 \cdot lbs$$

Allowable Strength fo pontoon legs

$$\frac{P_{uplegs}}{P_{nplegs}} = 111.64 \cdot \%$$

Check pontoon legs

$$F_{Eirlegs} := \frac{\pi^2 \cdot E_s}{\left(\lambda_{plegs}\right)^2}$$

Euler buckling load for inner rim legs

$$F_{crirlegs} := \begin{cases} .658^{\frac{F_{ylegs}}{F_{Eirlegs}}} \cdot F_{ylegs} & \text{if } \lambda_{plegs} \le 4.71 \cdot \sqrt{\frac{E_s}{F_{ylegs}}} \\ 0.877 \cdot F_{Eirlegs} & \text{otherwise} \end{cases}$$

Critical buckling load for inner rim legs

$$F_{crirlegs} = 5782.75\,psi$$

$$P_{nirlegs} := \frac{F_{crirlegs} \cdot A_{clegs}}{\Omega_C} = 7803.384 \cdot lbs$$

Allowable Strength fo inner rim legs

$$\frac{P_{uirlegs}}{P_{nirlegs}} = 93.37 \cdot \%$$

Check inner rim legs

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K. Check Legs

$$\lambda_{legs} := \frac{K_{legs} \cdot H_{hi}}{r_{clegs}} \qquad \lambda_{legs} = 90.90$$

$$F_{Elegs} := \frac{\pi^2 \cdot E_s}{(\lambda_{legs})^2}$$

Euler buckling load for deck legs

$$F_{crlegs} := \begin{cases} .658^{\frac{F_{ylegs}}{F_{Elegs}}} \cdot F_{ylegs} & \text{if } \lambda_{legs} \le 4.71 \cdot \sqrt{\frac{E_s}{F_{ylegs}}} \\ 0.877 \cdot F_{Elegs} & \text{otherwise} \end{cases}$$

Critical buckling load for deck rim legs

$$F_{crlegs} = 22929.02\,\text{psi}$$

$$P_{nlegs} := \frac{F_{crlegs} \cdot A_{clegs}}{\Omega_C} = 30940.989 \cdot \text{lbs}$$

Allowable Strength for deck legs

$$\frac{P_{ulegs}}{P_{nlegs}} = \begin{pmatrix} 25.45 \\ 26.92 \\ 27.34 \\ 34.96 \end{pmatrix} \cdot \%$$

Check deck legs

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L. Pontoon Ring Section Properties

$$H_{BScone} := R_{or} \cdot \tan\left(\operatorname{atan}\left(\frac{BS}{W_{pon}}\right)\right)$$

$$H_{BStrunc} := H_{BScone} - BS$$

$$V_{BS} := \pi \cdot R_{or}^{2} \cdot BS - \left(\frac{\pi}{3} \cdot R_{or}^{2} \cdot H_{BScone} - \frac{\pi}{3} \cdot R_{ir}^{2} \cdot H_{BStrunc}\right)$$

$$w_{dNET} := \frac{W_{dTOT}}{\pi R_{ir}^{2}} \cdot \left(\frac{\gamma_s - SG_{min} \cdot \gamma_w}{\gamma_s}\right)$$

$$\frac{W_{PON} + w_{dNET} \cdot \pi \cdot R_{ir}^{2} - V_{BS} \cdot SG_{min} \cdot \gamma_w}{\pi \cdot \left(R_{or}^{2} - R_{ir}^{2}\right) \cdot SG_{min} \cdot \gamma_w} = 1.41 \cdot ft$$

$$CRise := H_{or} - H_{oExt} - H_{ir} - BS$$

$$b_c := \sqrt{CRise^{2} + W_{pon}^{2}}$$

$$b_c = 144.03 \cdot in$$

$$b_{BS} := \sqrt{BS^{2} + W_{pon}^{2}} \qquad b_{BS} = 12.00\,ft$$

$$\theta_{BS} := \operatorname{atan}\left(\frac{BS}{W_{pon}}\right)$$

$$A_p := b_{BS} \cdot t_d + b_c \cdot t_c + \left(H_{ir} + W_{iExt}\right) \cdot t_{ir} + \left(H_{or} + W_{oExt}\right) \cdot t_{or}$$

$$A_p = 99.01 \cdot in^{2}$$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$c_{py} := \frac{1}{A_p} \cdot \left[H_{or} \cdot (t_{or} - CA_{or}) \cdot \frac{H_{or}}{2} + H_{ir} \cdot (t_{ir} - CA_{ir}) \cdot \left(BS + \frac{H_{ir}}{2} \right) + b_c \cdot (t_c - CA_c) \cdot \left(\frac{H_{or} - H_{oExt} + BS + H_{ir}}{2} \right) + b_{BS} \cdot (t_d - CA_d) \cdot \left(\frac{BS}{2} \right) + W_{oExt} \cdot (t_{or} - CA_{or}) \cdot H_{or} + W_{iExt} \cdot (t_{ir} - CA_{ir}) \cdot (BS + H_{ir}) \right]$$

$$c_{py} = 14.59 \cdot in$$

$$I_{zp} := \frac{(t_{or} - CA_{or}) \cdot H_{or}^3}{12} + \frac{(t_{ir} - CA_{ir}) \cdot H_{ir}^3}{12} + H_{or} \cdot (t_{or} - CA_{or}) \cdot \left(\frac{H_{or}}{2} - c_{py} \right)^2 + H_{ir} \cdot (t_{ir} - CA_{ir}) \cdot \left(BS + \frac{H_{ir}}{2} - c_{py} \right)^2 + b_c \cdot (t_c - CA_c) \cdot \left(\frac{H_{or} - H_{oExt} + BS + H_{ir}}{2} - c_{py} \right)^2 + W_{iExt} \cdot (t_{ir} - CA_{ir}) \cdot (BS + H_{ir} - c_{py})^2 + \int_{0 \cdot ft}^{W_{pon}} \frac{(t_d - CA_d) \cdot \left(\frac{x}{W_{pon}} \cdot BS - c_{py} \right)^2}{\cos(\theta_{BS})} \, dx + W_{oExt} \cdot (t_{or} - CA_{or}) \cdot (H_{or} - c_{py})^2$$

$$I_{zp} = 14355.32 \cdot in^4$$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$c_{px} := \frac{1}{A_p} \cdot \left[H_{or} \cdot \frac{(t_{or})^2}{2} + H_{ir} \cdot (t_{ir}) \cdot W_{pon} + \frac{W_{oExt}^2 \cdot (t_{or})}{2} \ldots + W_{iExt} \cdot (t_{ir}) \cdot \left(W_{pon} + \frac{W_{iExt}}{2} \right) \ldots + b_c \cdot (t_c) \cdot \left(\frac{W_{pon}}{2} \right) \ldots + b_{BS} \cdot (t_d) \cdot \left(\frac{W_{pon}}{2} \right) \right]$$

$$c_{px} = 6.01\,ft$$

$$I_{yp} := H_{or} \cdot (t_{or} - CA_{or}) \cdot \left(c_{px} - \frac{t_{or} - CA_{or}}{2} \right)^2 + H_{ir} \cdot (t_{ir} - CA_{ir}) \cdot (W_{pon} - c_{px})^2 \ldots + \frac{(t_c - CA_c) \cdot (b_c)^3}{12} + (t_c - CA_c) \cdot b_c \cdot \left(c_{px} - \frac{b_c}{2} \right)^2 \ldots + \frac{(t_d - CA_d) \cdot (b_{BS})^3}{12} + (t_d - CA_d) \cdot b_{BS} \cdot \left(c_{px} - \frac{b_{BS}}{2} \right)^2 \ldots + \frac{(t_{or} - CA_{or}) \cdot W_{oExt}^3}{12} + (t_{or} - CA_{or}) \cdot W_{oExt} \cdot \left(c_{px} - \frac{W_{oExt}}{2} \right)^2 \ldots + \frac{(t_{ir} - CA_{ir}) \cdot W_{iExt}^3}{12} + (t_{ir} - CA_{ir}) \cdot W_{iExt} \cdot \left(W_{pon} + \frac{W_{iExt}}{2} - c_{px} \right)^2$$

$$I_{yp} = 325409.76 \cdot in^4$$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$C_{wCH}(d, bf, tf, tw) := \frac{tf \cdot (d - tf)^2 \cdot \left(bf - \frac{tw}{2}\right)^3}{6} \cdot \left[\frac{\left(bf - \frac{tw}{2}\right) \cdot tf + 2 \cdot (d - tf) \cdot tw}{(d - tf) \cdot tw + 2 \cdot \left(bf - \frac{tw}{2}\right) \cdot tw}\right]$$

$$A_{pJ} := \left(\frac{H_{or} - H_{oExt} + H_{ir}}{2}\right)(W_{pon})$$

$$J_{BHP} := \frac{W_{pon} \cdot (t_d - CA_d)^3}{3} + \frac{H_{or} \cdot (t_{or} - CA_{or})^3}{3} + \frac{H_{ir} \cdot (t_{ir} - CA_{ir})^3}{3} \dots + \frac{W_{oExt} \cdot (t_{or} - CA_{or})^3}{3} + \frac{W_{iExt} \cdot (t_{ir} - CA_{ir})^3}{3}$$

$$J_{BHP} = 8.75 \cdot in^4$$

$$J_{RSF} := \frac{4 \cdot A_{pJ}^2}{\frac{H_{or} - H_{oExt}}{t_{or} - CA_{or}} + \frac{H_{ir}}{t_{ir} - CA_{ir}} + \frac{b_c}{t_c - CA_c} + \frac{b_{BS}}{t_d - CA_d}}$$

$$J := \begin{cases} J_{RSF} & \text{if } RoofType = 1 \\ J_{BHP} & \text{otherwise} \end{cases}$$

$J = 41789.27 \cdot in^4$ Torsional constant

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$t_{fCw} := \begin{cases} t_{ir} - CA_{ir} & \text{if } H_{or} > H_{ir} \\ t_{or} - CA_{or} & \text{if } H_{ir} > H_{or} \\ \min(t_{ir} - CA_{ir}, t_{or} - CA_{or}) & \text{otherwise} \end{cases}$$

$$t_{f2Cw} := \begin{cases} t_{or} - CA_{or} & \text{if } H_{or} > H_{ir} \\ t_{ir} - CA_{ir} & \text{if } H_{ir} > H_{or} \\ \max(t_{ir} - CA_{ir}, t_{or} - CA_{or}) & \text{otherwise} \end{cases}$$

$$\alpha_w := \frac{1}{1 + \left(\frac{\min(H_{or}, H_{ir})}{\max(H_{or}, H_{ir})}\right)^3 \cdot \frac{t_{fCw}}{t_{f2Cw}}}$$

$\alpha_w = 0.50$

$R_{eff} := \frac{D}{2} - S_{rim} - c_{px}$ $\quad R_{eff} = 103.33\,ft$ Effective radius of roof

$$C_w := \begin{cases} 0 \cdot in^6 & \text{if RoofType} = 1 \\ C_{wCH}(W_{pon}, \min(H_{or}, H_{ir}), t_{fCw}, t_d - CA_d) \cdot \alpha_w & \text{otherwise} \end{cases}$$ Warping constant

$C_w = 0.00 \cdot in^6$

$$C_T := \frac{\pi^2 \cdot E_s \cdot C_w}{(1.7725 \cdot R_{eff})^2} + G \cdot J$$ Torsional rigidity

$C_T = 4.66 \times 10^{11} \cdot lbs \cdot in^2$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$F_{crd} := \frac{4 \cdot \pi^2 \cdot E_s}{12 \cdot \left(1 - \nu^2\right)} \cdot \left(\frac{t_d - CA_d}{b_{BS}}\right)^2 = 177.75\,\text{psi}$$

$$F_{crc} := \frac{4 \cdot \pi^2 \cdot E_s}{12 \cdot \left(1 - \nu^2\right)} \cdot \left(\frac{t_c - CA_c}{b_c}\right)^2 = 177.67\,\text{psi}$$

$$F_{cror} := \frac{4 \cdot \pi^2 \cdot E_s}{12 \cdot \left(1 - \nu^2\right)} \cdot \left(\frac{t_{or} - CA_{or}}{H_{or} - H_{oExt}}\right)^2$$

$$F_{cror} = 80896.57\,\text{psi}$$

$$F_{crir} := \frac{4 \cdot \pi^2 \cdot E_s}{12 \cdot \left(1 - \nu^2\right)} \cdot \left(\frac{t_{ir} - CA_{ir}}{H_{ir}}\right)^2$$

$$F_{crir} = 65526.22\,\text{psi}$$

$$\lambda_{crd}(f) := \sqrt{\frac{f}{F_{crd}}}$$

$$\lambda_{crc}(f) := \sqrt{\frac{f}{F_{crc}}}$$

$$\lambda_{cror}(f) := \sqrt{\frac{f}{F_{cror}}}$$

$$\lambda_{crir}(f) := \sqrt{\frac{f}{F_{crir}}}$$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$\rho_{crd}(f) := \frac{1 - \frac{.22}{\lambda_{crd}(f)}}{\lambda_{crd}(f)}$$

$$\rho_{crc}(f) := \frac{1 - \frac{.22}{\lambda_{crc}(f)}}{\lambda_{crc}(f)}$$

$$\rho_{cror}(f) := \frac{1 - \frac{.22}{\lambda_{cror}(f)}}{\lambda_{cror}(f)}$$

$$\rho_{crir}(f) := \frac{1 - \frac{.22}{\lambda_{crir}(f)}}{\lambda_{crir}(f)}$$

$$b_{effd}(f) := \begin{cases} b_{BS} & \text{if } \lambda_{crd}(f) \le .673 \\ \rho_{crd}(f) \cdot b_{BS} & \text{otherwise} \end{cases}$$

$$b_{effc}(f) := \begin{cases} W_{pon} & \text{if } \lambda_{crc}(f) \le .673 \\ \rho_{crc}(f) \cdot b_{c} & \text{otherwise} \end{cases}$$

$$b_{effor}(f) := \begin{cases} H_{or} & \text{if } \lambda_{cror}(f) \le .673 \\ \rho_{cror}(f) \cdot \left(H_{or} - H_{oExt}\right) + H_{oExt} & \text{otherwise} \end{cases}$$

$$b_{effir}(f) := \begin{cases} H_{ir} & \text{if } \lambda_{crir}(f) \le .673 \\ \rho_{crir}(f) \cdot \left(H_{ir}\right) & \text{otherwise} \end{cases}$$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$A_{effC}(f) := b_{effor}(f)\cdot(t_{or} - CA_{or}) + b_{effir}(f)\cdot(t_{ir} - CA_{ir}) + b_{effc}(f)\cdot(t_c - CA_c) + b_{effd}(f)\cdot(t_d - CA_d)\ ...$$
$$+ W_{oExt}\cdot(t_{or} - CA_{or}) + W_{iExt}\cdot(t_{ir} - CA_{ir}) + H_{oExt}\cdot(t_{or} - CA_{or})$$

$$c_{effC}(f) := \frac{1}{A_{effC}(f)}\cdot\left[\begin{array}{l} b_{effor}(f)\cdot(t_{or} - CA_{or})\cdot\dfrac{(H_{or} - H_{oExt})}{2} + b_{effir}(f)\cdot(t_{ir} - CA_{ir})\cdot\left(BS + \dfrac{H_{ir}}{2}\right)\ ... \\ + b_{effc}(f)\cdot(t_c - CA_c)\cdot\left(\dfrac{H_{or} - H_{oExt} + BS + H_{ir}}{2}\right)\ ... \\ + b_{effd}(f)\cdot(t_d - CA_d)\cdot\left(\dfrac{BS}{2}\right) + H_{oExt}\cdot(t_{or} - CA_{or})\cdot\left(H_{or} - \dfrac{H_{oExt}}{2}\right)\ ... \\ + W_{oExt}\cdot(t_{or} - CA_{or})\cdot H_{or} + W_{iExt}\cdot(t_{ir} - CA_{ir})\cdot(BS + H_{ir}) \end{array}\right]$$

$$K_{rad} := \frac{R_{ir}\cdot R_{eff}}{A_p\cdot E_s} \qquad K_{rad} = 5.04\times 10^{-4}\cdot\frac{in^2}{lbs}$$

Radial flexibility of pontoon ring

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$I_{effC}(f) := \frac{(t_{or} - CA_{or}) \cdot \left(\frac{b_{effor}(f)}{2} + H_{oExt}\right)^3}{12} + \frac{(t_{or} - CA_{or}) \cdot \left(\frac{b_{effor}(f)}{2}\right)^3}{12} \ldots$$
$$+ \frac{b_{effor}(f)}{2} \cdot (t_{or} - CA_{or}) \cdot \left(\frac{b_{effor}(f)}{4} - c_{effC}(f)\right)^2 + \frac{2 \cdot (t_{ir} - CA_{ir}) \cdot \left(\frac{b_{effir}(f)}{2}\right)^3}{12} \ldots$$
$$+ \left(\frac{b_{effor}(f)}{2} + H_{oExt}\right) \cdot (t_{or} - CA_{or}) \cdot \left[\left(H_{or} - \frac{\frac{b_{effor}(f)}{2} + H_{oExt}}{2}\right) - c_{effC}(f)\right]^2 \ldots$$
$$+ \frac{b_{effir}(f)}{2} \cdot (t_{ir} - CA_{or}) \cdot \left(\frac{b_{effir}(f)}{4} + BS - c_{effC}(f)\right)^2 \ldots$$
$$+ \frac{b_{effir}(f)}{2} \cdot (t_{ir} - CA_{or}) \cdot \left[\left(H_{ir} + BS - \frac{b_{effir}(f)}{4}\right) - c_{effC}(f)\right]^2 \ldots$$
$$+ b_{effc}(f) \cdot (t_c - CA_c) \cdot \left(\frac{H_{or} - H_{oExt} + H_{ir}}{2} - c_{effC}(f)\right)^2 \ldots$$
$$+ W_{iExt} \cdot (t_{ir} - CA_{ir}) \cdot (BS + H_{ir} - c_{effC}(f))^2 + W_{oExt} \cdot (t_{or} - CA_{or}) \cdot (H_{or} - c_{effC}(f))^2 \ldots$$
$$+ \frac{b_{effd}(f)}{2} \cdot (t_d - CA_d) \cdot \left(c_{effC}(f) - \frac{b_{effd}(f)}{4} \cdot \frac{BS}{W_{pon}}\right)^2 \ldots$$
$$+ \frac{b_{effd}(f)}{2} \cdot (t_d - CA_d) \cdot \left[c_{effC}(f) - \left(BS - \frac{b_{effd}(f)}{4} \cdot \frac{BS}{W_{pon}}\right)\right]^2$$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$F_{crorB} := \frac{24 \cdot \pi^2 \cdot E_s}{12 \cdot \left(1 - \nu^2\right)} \cdot \left(\frac{t_{or}}{H_{or} - H_{oExt}}\right)^2$$

$$F_{crorB} = 485379.41\,\text{psi}$$

$$F_{crirB} := \frac{24 \cdot \pi^2 \cdot E_s}{12 \cdot \left(1 - \nu^2\right)} \cdot \left(\frac{t_{ir}}{H_{ir}}\right)^2$$

$$F_{crirB} = 393157.32\,\text{psi}$$

$$\lambda_{crorB}(f) := \sqrt{\frac{f}{F_{cror}}}$$

$$\lambda_{crirB}(f) := \sqrt{\frac{f}{F_{crir}}}$$

$$\rho_{crorB}(f) := \frac{1 - \frac{.22}{\lambda_{cror}(f)}}{\lambda_{cror}(f)}$$

$$\rho_{crirB}(f) := \frac{1 - \frac{.22}{\lambda_{crir}(f)}}{\lambda_{crir}(f)}$$

$$b_{efforB}(f) := \begin{cases} H_{or} - H_{oExt} & \text{if } \lambda_{crorB}(f) \le .673 \\ \rho_{crorB}(f) \cdot \left(H_{or} - H_{oExt}\right) & \text{otherwise} \end{cases}$$

$$b_{effirB}(f) := \begin{cases} H_{ir} & \text{if } \lambda_{crirB}(f) \le .673 \\ \rho_{crirB}(f) \cdot \left(H_{ir}\right) & \text{otherwise} \end{cases}$$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$A_{effB}(f) := b_{efforB}(f)\cdot\left(t_{or} - CA_{or}\right) + b_{effirB}(f)\cdot\left(t_{ir} - CA_{ir}\right) + b_{effc}(f)\cdot\left(t_c - CA_c\right) + b_{BS}\cdot\left(t_d - CA_d\right) \dots$$
$$+ W_{oExt}\cdot\left(t_{or} - CA_{or}\right) + W_{iExt}\cdot\left(t_{ir} - CA_{ir}\right) + H_{oExt}\cdot\left(t_{or} - CA_{or}\right)$$

$$c_{effB}(f) := \frac{1}{A_{effB}(f)}\cdot\left[\begin{array}{l} b_{efforB}(f)\cdot\left(t_{or} - CA_{or}\right)\cdot\frac{\left(H_{or} - H_{oExt}\right)}{2} + b_{effirB}(f)\cdot\left(t_{ir} - CA_{ir}\right)\cdot\left(BS + \frac{H_{ir}}{2}\right) \dots \\ + b_{effc}(f)\cdot\left(t_c - CA_c\right)\cdot\left(\frac{H_{or} - H_{oExt} + BS + H_{ir}}{2}\right) \dots \\ + b_{BS}\cdot\left(t_d - CA_d\right)\cdot\left(\frac{BS}{2}\right) + H_{oExt}\cdot\left(t_{or} - CA_{or}\right)\cdot\left(H_{or} - \frac{H_{oExt}}{2}\right) \dots \\ + W_{oExt}\cdot\left(t_{or} - CA_{or}\right)\cdot H_{or} + W_{iExt}\cdot\left(t_{ir} - CA_{ir}\right)\cdot\left(BS + H_{ir}\right) \end{array}\right]$$

Internal Pontoon Floating Roof Design

L. Pontoon Ring Section Properties

$$I_{effB}(f) := \frac{(t_{or} - CA_{or}) \cdot \left(\frac{b_{efforB}(f)}{2} + H_{oExt}\right)^3}{12} + \frac{(t_{or} - CA_{or}) \cdot \left(\frac{b_{efforB}(f)}{2}\right)^3}{12} \ldots$$

$$+ \frac{b_{efforB}(f)}{2} \cdot (t_{or} - CA_{or}) \cdot \left(\frac{b_{efforB}(f)}{4} - c_{effB}(f)\right)^2 + \frac{2 \cdot (t_{ir} - CA_{ir}) \cdot \left(\frac{b_{effirB}(f)}{2}\right)^3}{12} \ldots$$

$$+ \left(\frac{b_{efforB}(f)}{2} + H_{oExt}\right) \cdot (t_{or} - CA_{or}) \cdot \left[\left(H_{or} - \frac{\frac{b_{efforB}(f)}{2} + H_{oExt}}{2}\right) - c_{effB}(f)\right]^2 \ldots$$

$$+ \frac{b_{effirB}(f)}{2} \cdot (t_{ir} - CA_{or}) \cdot \left(\frac{b_{effirB}(f)}{4} + BS - c_{effB}(f)\right)^2 \ldots$$

$$+ \frac{b_{effirB}(f)}{2} \cdot (t_{ir} - CA_{or}) \cdot \left[\left(H_{ir} + BS - \frac{b_{effirB}(f)}{4}\right) - c_{effB}(f)\right]^2 \ldots$$

$$+ b_{effc}(f) \cdot (t_c - CA_c) \cdot \left(\frac{H_{or} - H_{oExt} + H_{ir}}{2} - c_{effB}(f)\right)^2 \ldots$$

$$+ W_{iExt} \cdot (t_{ir} - CA_{ir}) \cdot (BS + H_{ir} - c_{effB}(f))^2 + W_{oExt} \cdot (t_{or} - CA_{or}) \cdot (H_{or} - c_{effB}(f))^2 \ldots$$

$$+ \int_{0 \cdot ft}^{W_{pon}} \frac{(t_d - CA_d) \cdot \left(\frac{x}{W_{pon}} \cdot BS - c_{effB}(f)\right)^2}{\cos(\theta_{BS})} \, dx$$

$$S_{effB}(f) := \frac{I_{effB}(f)}{\max(c_{effB}(f), H_{or} - c_{effB}(f))}$$

$$S_{effB}(10 \cdot psi) = 6.47\,ft^{2.00} \cdot in$$

Internal Pontoon Floating Roof Design

M. Check Pontoon Ring Strength

$$n_{rpE} = 527.73 \cdot \frac{lbs}{in}$$

$$\Omega_c := 1.8$$

$$\Omega_b := 1.67$$

$$P_p := n_{rpE} \cdot R_{ir}$$

$$P_p = 616.39 \cdot kip$$

$$F'_{cr}(n) := \frac{E \cdot I_{effC}(36 \cdot ksi) \cdot \left(n^2 - 4\right)}{4 \cdot R_{ir} \cdot R_{eff}^{\,2} \cdot \left(1 + \frac{4 \cdot E \cdot I_{effC}(36 \cdot ksi)}{n^2 \cdot C_T}\right)}$$

$$K_f := \gamma_w \cdot SG_{min} \cdot W_{pon}$$

$$F''_{cr}(n) := 4 \cdot \frac{K_f \cdot R_{eff}^{\,2}}{R_{ir} \cdot n^2}$$

$$F''_{cr}(4) = 14378.14 \cdot \frac{lbs}{ft}$$

$$F_{crp} := \min\left(F'_{cr}(4) + F''_{cr}(4), F'_{cr}(8) + F''_{cr}(8)\right)$$

$$F_{crp} = 15442.92 \cdot \frac{lbs}{ft}$$

$$P_{crp} := \frac{1}{\Omega_c} \cdot F_{crp} \cdot R_{ir}$$

$$P_{crp} = 835.06 \cdot kip$$

$$P_{yp} := \frac{1}{\Omega_c} \cdot A_{effC}\left(F_{yp}\right) \cdot F_{yp}$$

$$P_{yp} = 996.63 \cdot kip$$

Internal Pontoon Floating Roof Design

M. Check Pontoon Ring Strength

$$P_n := \min(P_{crp}, P_{yp})$$

$$\frac{P_p}{P_n} = 73.81 \cdot \%$$

$$M_p = 401.74 \cdot ft \cdot kip$$

$$M_n := \frac{1}{\Omega_b} \cdot S_{effB}(F_{yp}) \cdot F_{yp}$$

$$M_n = 693.46 \cdot ft \cdot kip$$

$$\frac{M_p}{M_n} = 57.93 \cdot \%$$

$$INT_{PM} := \begin{cases} \frac{P_p}{P_n} + \frac{M_p}{M_n} & \text{if } \frac{P_p}{P_n} \le 0.15 \\ \max\left(\begin{pmatrix} \frac{P_p}{P_n} + \frac{M_p}{M_n} \\ \frac{P_p}{P_{yp}} + \frac{M_p}{M_n} \end{pmatrix}\right) & \text{otherwise} \end{cases}$$

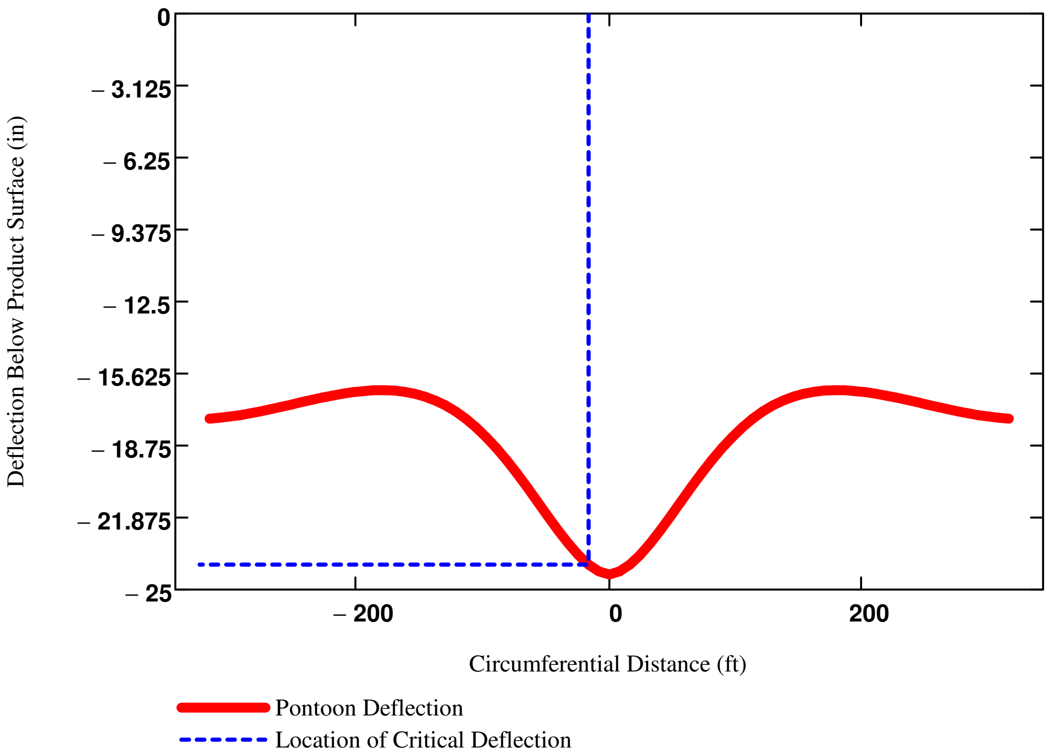
$$INT_{PM} = 131.75 \cdot \%$$

$$\frac{t_{or}}{t_{ir}} = 100.00 \cdot \%$$

Internal Pontoon Floating Roof Design

N. Check Pontoon Ring Floating Stability

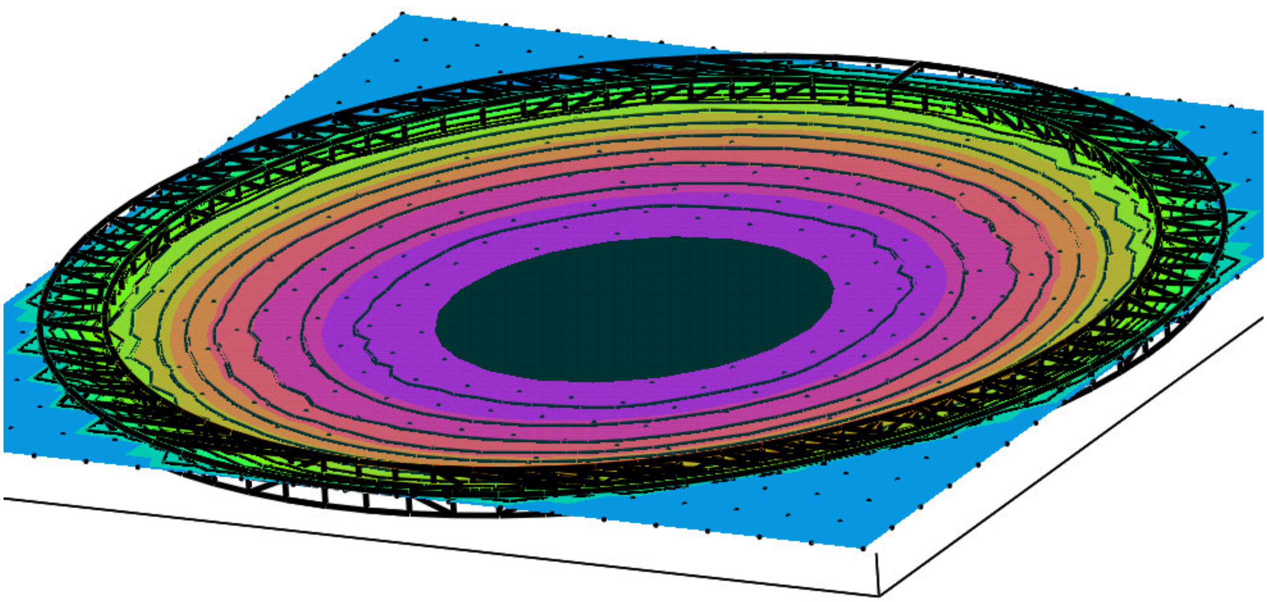
$$\frac{2 \cdot |\Delta_{TOT}|}{H_{ir} + (H_{or} - H_{oExt} - BS)} = 83.93 \cdot \%$$ $\Delta_{TOT} = -23.92 \cdot in$ Check pontoon floating stability



Internal Pontoon Floating Roof Design

O. Plot of Results

3D Plot of Deflected Pontoon



Internal Pontoon Floating Roof Design

O. Plot of Results

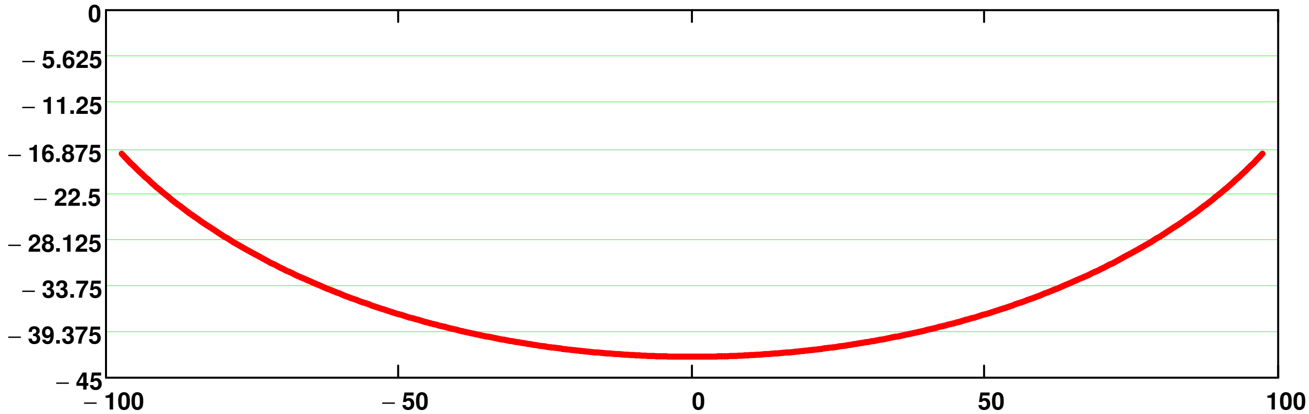
Deflection of deck relative to pontoon attachment

$$\delta_{deck_{rows(\delta_{deck})}} = -24.85 \cdot in$$

Deflection of deck relative to product surface

$$\delta_{deck_{rows(\delta_{deck})}} + \frac{\delta_{pon_{rows(\delta_{pon})}} + \delta_{pon_1}}{2} = -42.44 \cdot in$$

Deflection of Deck Below Product Surface (in)



Internal Pontoon Floating Roof Design

O. Plot of Results

$i := 1 .. rows(r_{deck})$

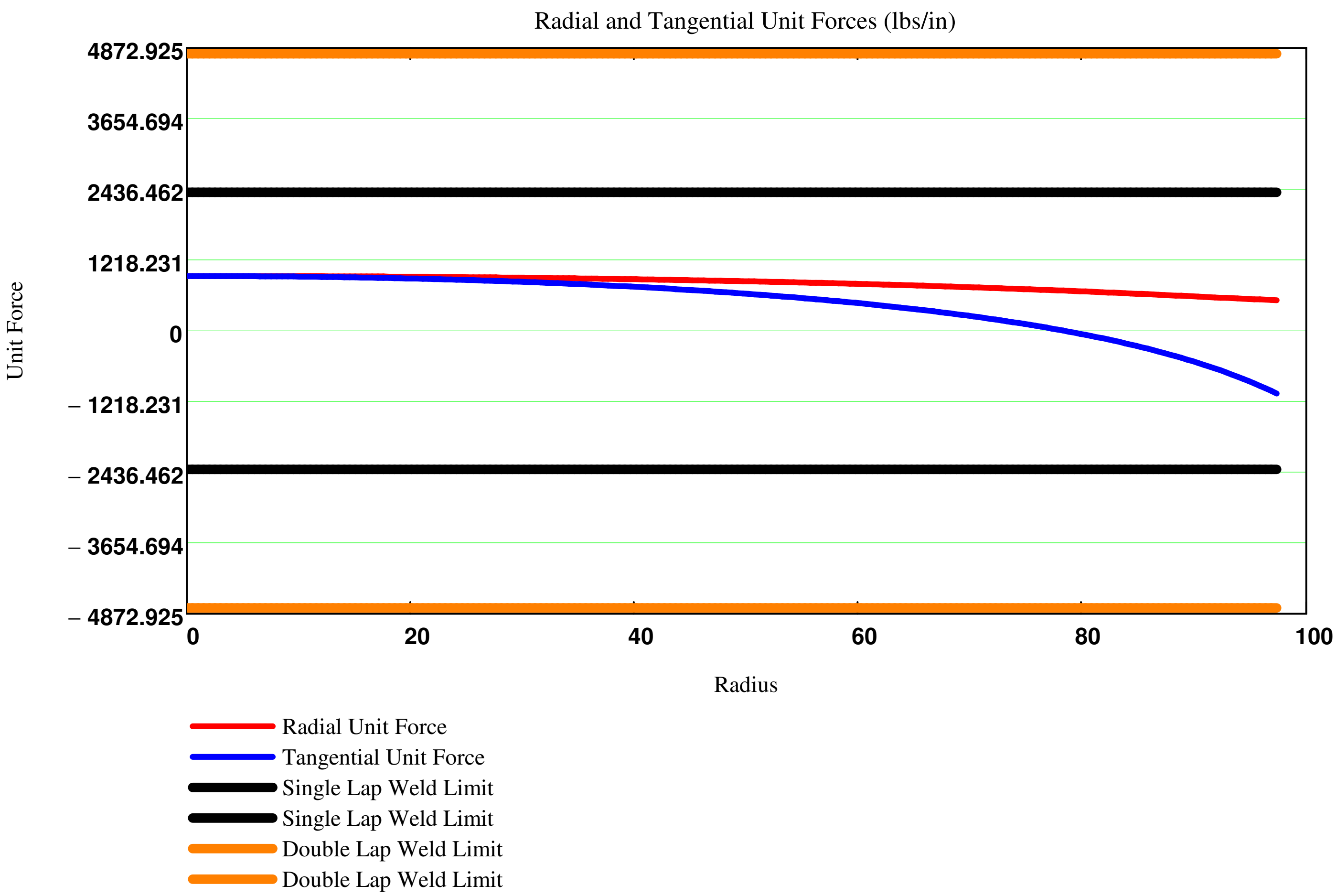
Safety factor for weld strength

Maximum unit for in weld per AISC 360

$\Omega_w := 2$

$$n_{dMax_i} := \frac{(t_d - CA_d) \cdot .7071 \cdot 0.6 \cdot F_{uw}}{\Omega_w}$$

$n_{dMax_1} = 2386.46 \cdot \frac{lbs}{in}$



Unit force curves must be within single lap weld limit, otherwise double lap weld is required. If double lap weld is limit is exceeded, geometry must be changed. Deck shall have a 2" in 12" underside weld at all supports, bulkheads, and appurtenances as a minimum.