

MIAMI SCIENCE MUSEUM - BONDED POST-TENSIONING OF GULF STREAM TANK



by

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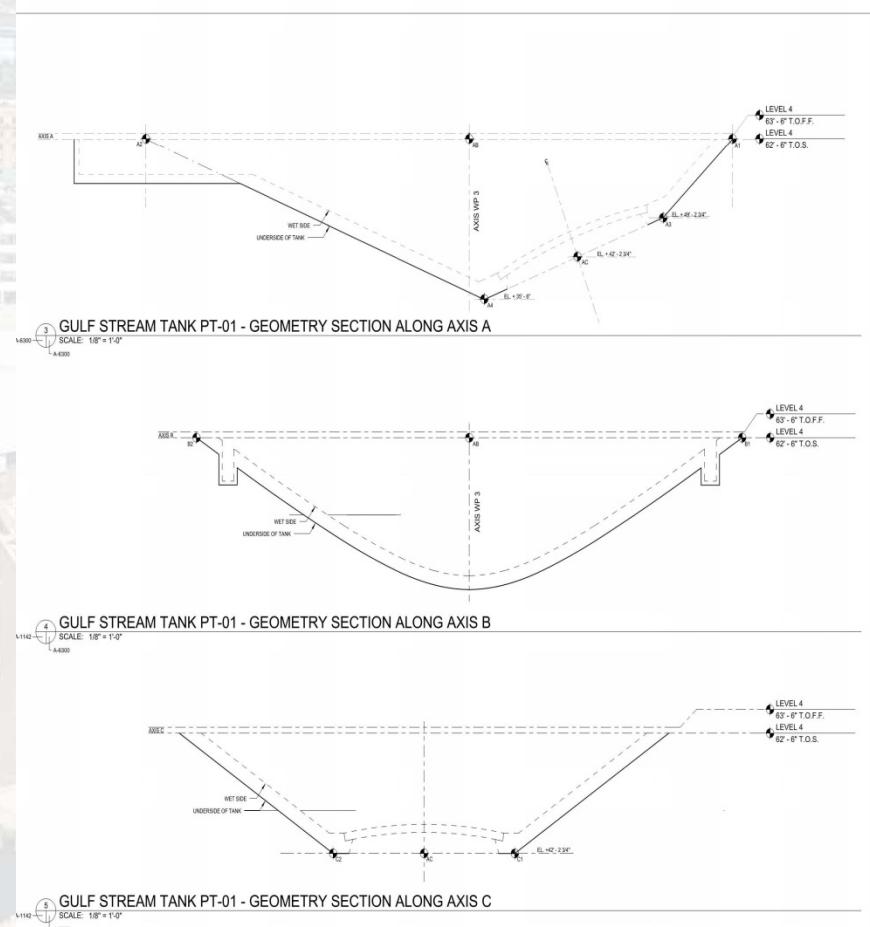
Outline of Presentation

- Overview of Tank
- Post-Tensioning and Constructability Details
- Design Criteria
- Loading Scheme
- Modeling
- Analysis & Results

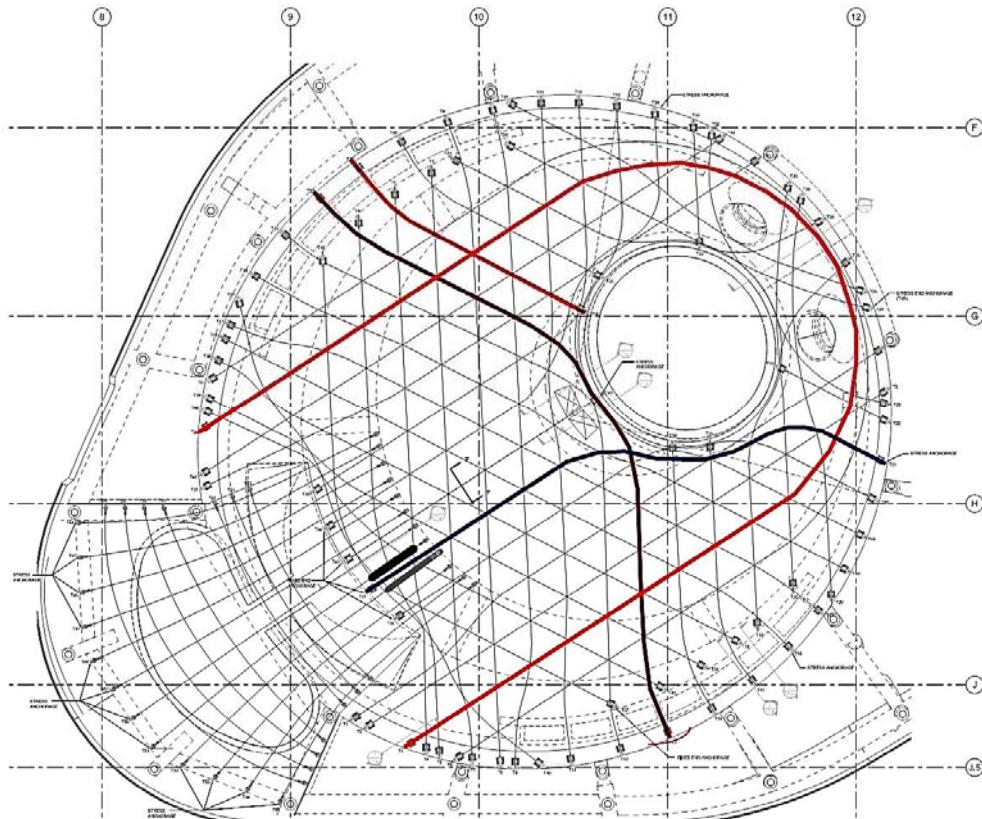


Overview

- 600,000 Gallons Capacity
- Tilted Conical Shape
- Approx. 120 ft. diameter at the top and 27 ft. in height
- 30 ft. Diameter Oculus at the bottom of the cone
- Concrete design as opposed to Structural Steel to dampen the interference with shark's sensory system



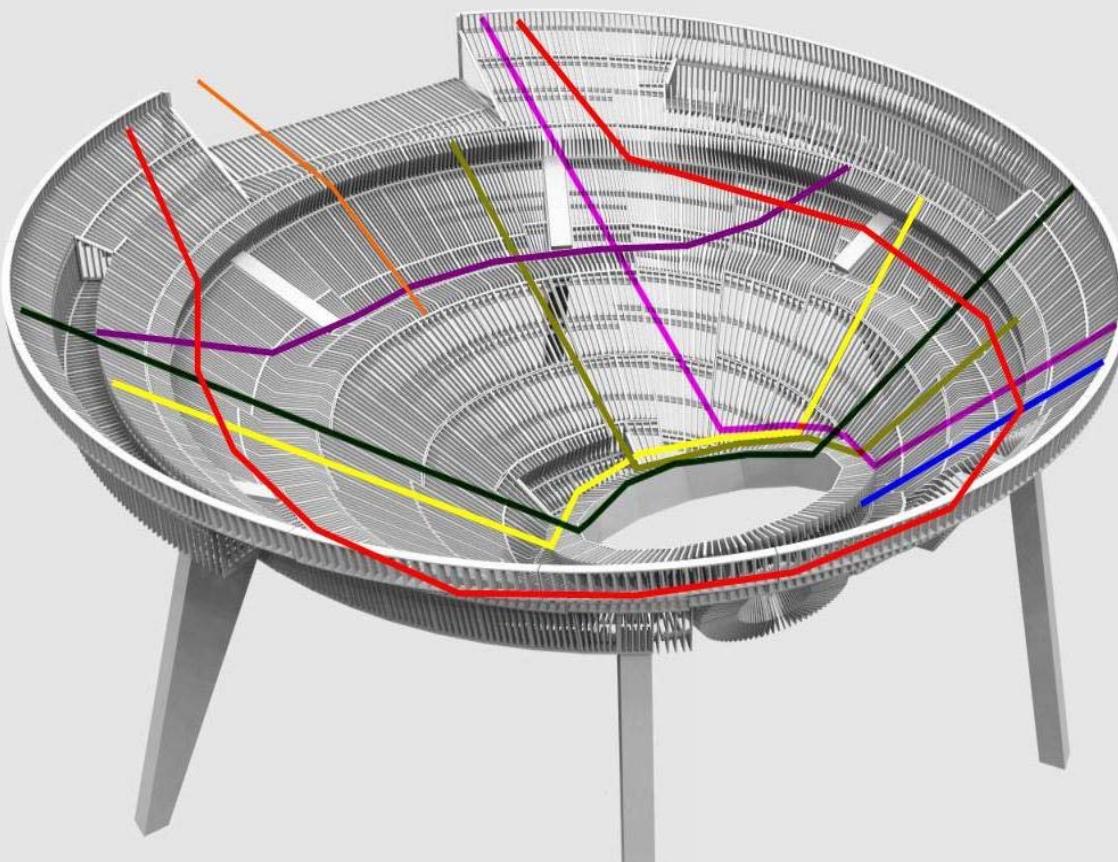
PT Considerations



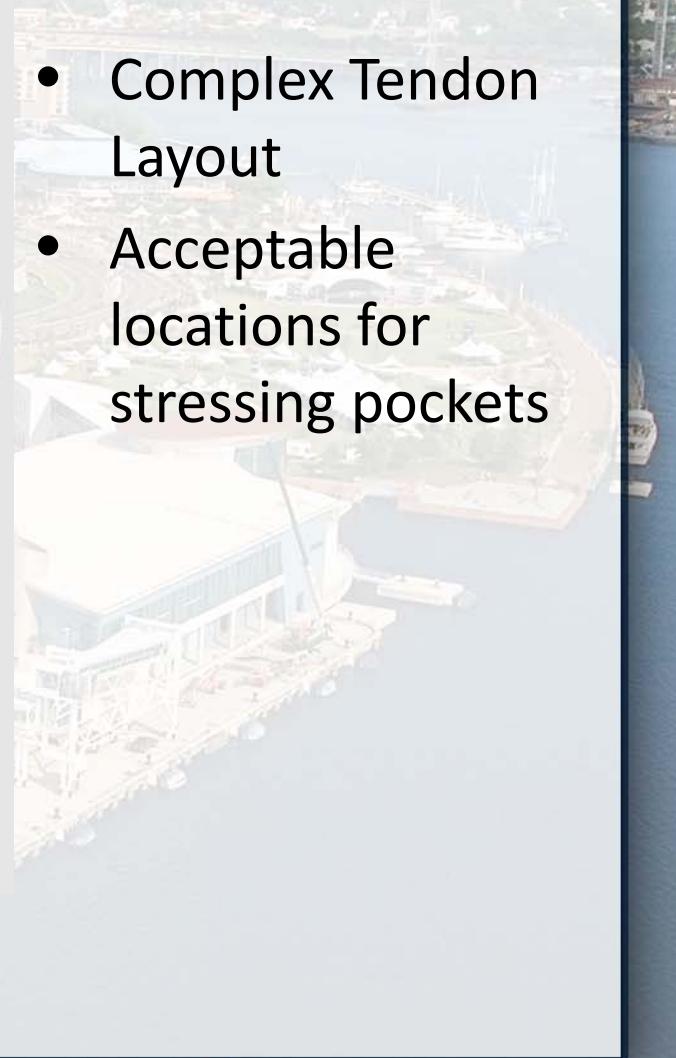
Considerations:

- P/A requirements.
- 28" thick Tank Wall (Main Tank) and 18" Thick slab (Acclimation Tank)
- VSL ECI 6-12 System with 12 ea. 0.6" dia. low-relaxation strands for main tank and VSlab 6-4 system for acclimation tank/main tank interface

Proposed Tendon layout



- Complex Tendon Layout
- Acceptable locations for stressing pockets



Design Criteria

- Stresses below $6\sqrt{f'_c}$ per ACI318.
- Minimum pre-compression of 200psi.
- Concrete strength:
 - At 28 days: 5,000psi
 - At stressing: 3,500psi
- Post-tensioning systems:
 - ECI6-12 with an effective force of 420 kips in the Gulf Stream tank.
 - Vslab6-4 with an effective force of 140 kips in the Acclimation tank.
- Mild steel reinforcement is added as needed to meet strength requirements.

Design Criteria

Load Combinations:

A. Service Load Combinations:

A.1 Sustained Loads: 1SW + 0.3LL + 1PT

A.2 Total Load: 1SW + 1LL + 1PT

B. Strength Load Combinations:

B.1 1.4SW

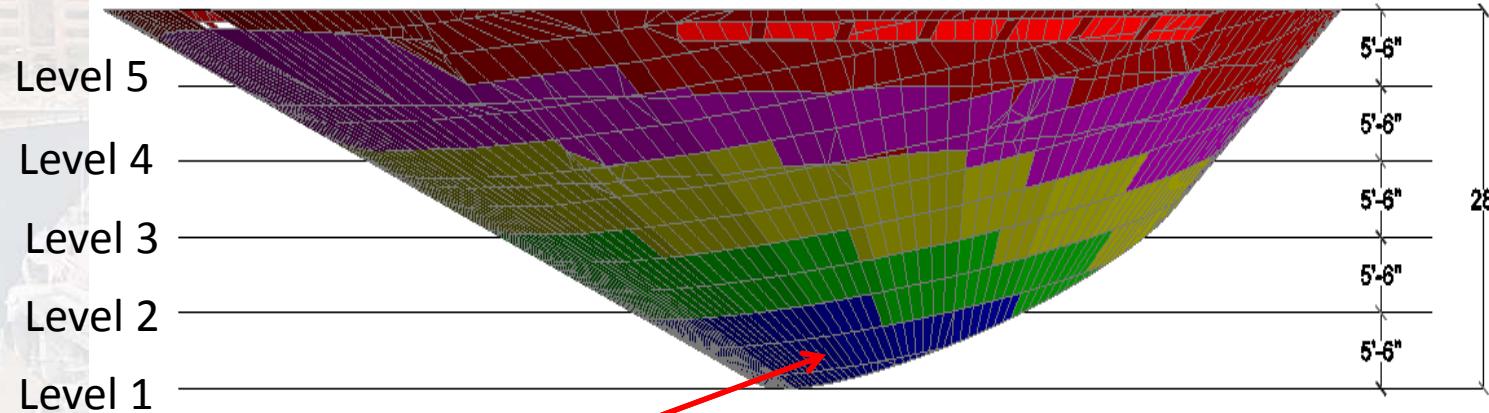
B.2 1.2SW + 1.6LL

Where:

- SW: Self-weight
- LL: Live load (water pressure)
- PT: Load due to pre-stress

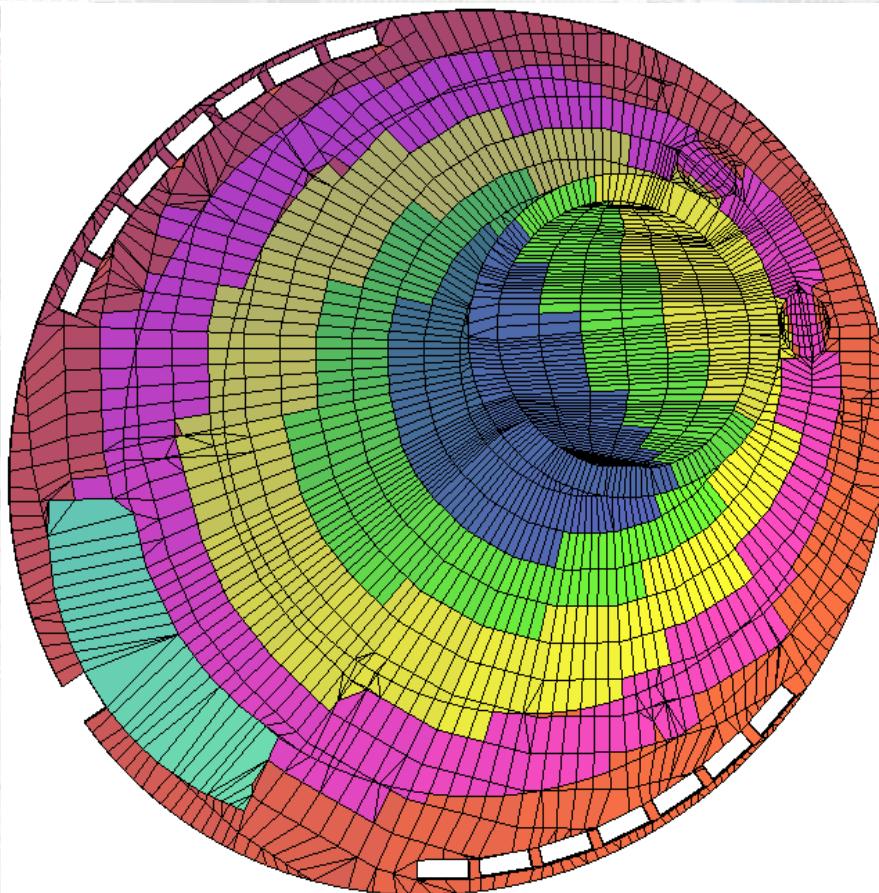
Loading Scheme

- Water pressure is determined at 5 different water levels:



$$WP_1 = 62.43 \text{ lb/ft}^3 \times 28\text{ft} = 1748.4\text{lb/ft}^2 = 12.13 \text{ psi}$$

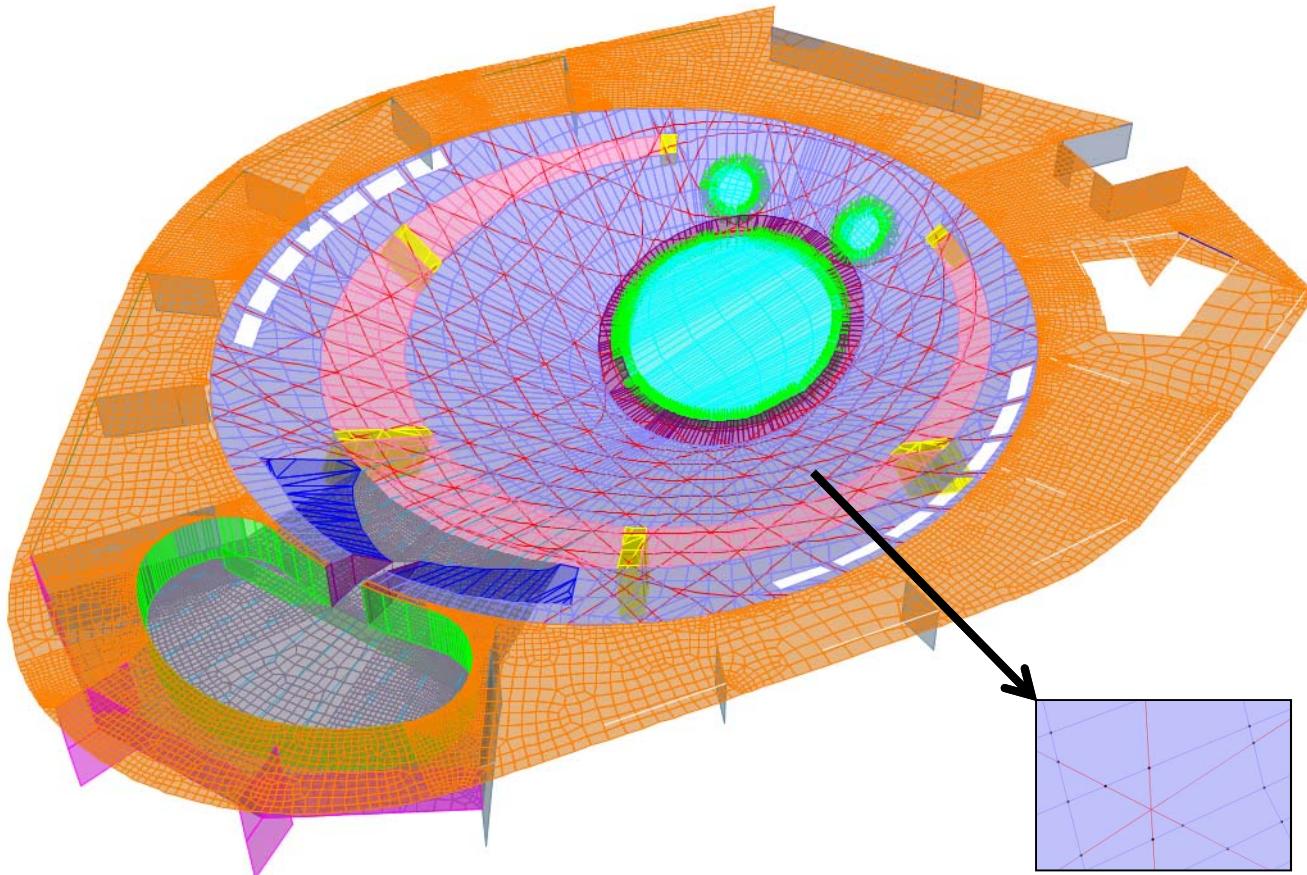
Loading Scheme



WP1 (12.13psi)	[Blue Box]
WP2 (9.71psi)	[Green Box]
WP3 (7.28psi)	[Yellow Box]
WP4 (4.853psi)	[Pink Box]
WP5 (2.13psi)	[Red Box]
WP6 (3.50psi)	[Cyan Box]

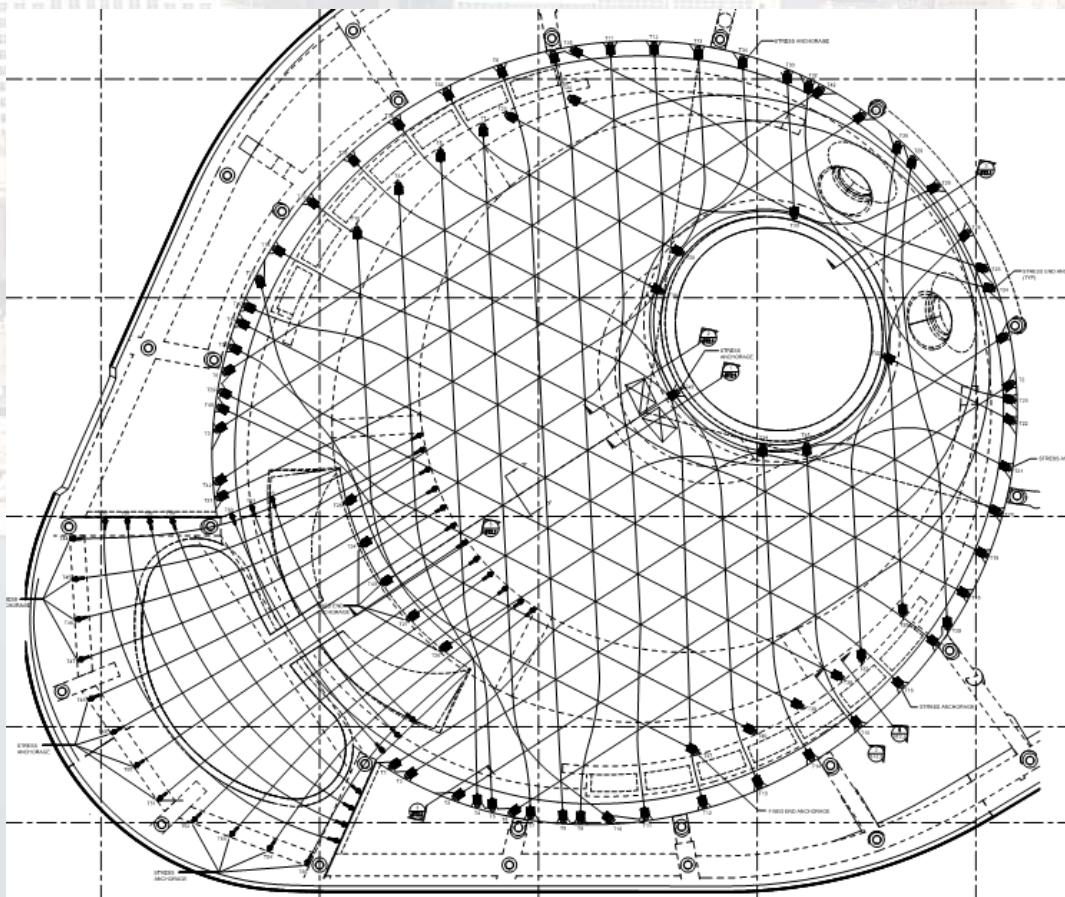
Modeling - Geometry

- The tank is modeled using SAP2000.



28" Tank Wall	[Purple square]
ECI6-12 PT Tendons	[Red square]
Columns	[Yellow square]
56" Deep Ring Beam	[Pink square]
40" Deep Beam	[Magenta square]
15" Acrylic Panel	[Cyan square]
18" Acclimation Tank	[Grey square]
Level 4 slab	[Orange square]
Vslab6-4 PT Tendons	[Light Blue square]

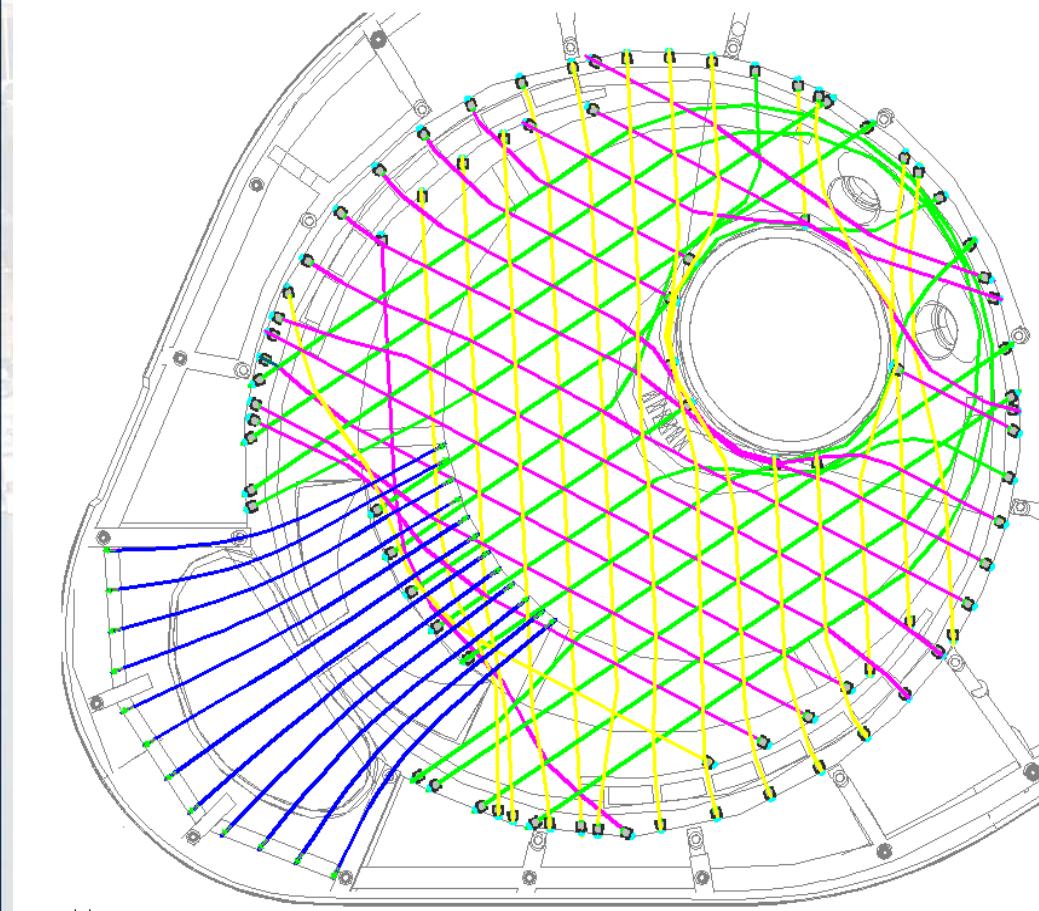
Modeling – Tendon layout



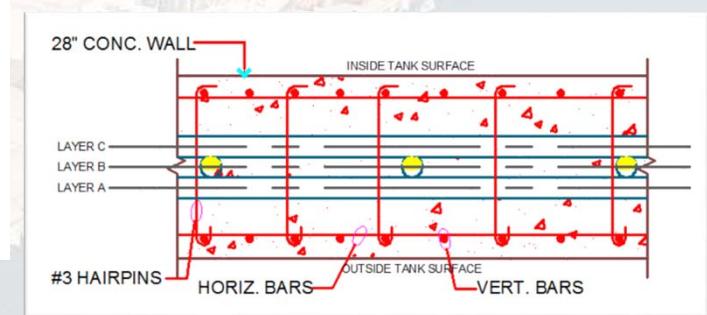
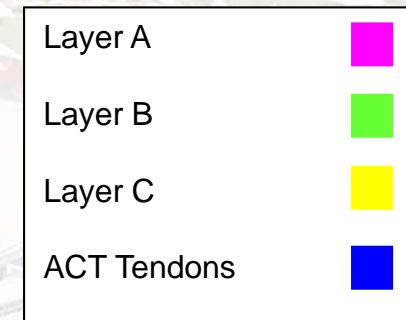
Considerations:

- Meet P/A requirements:
 - $420 \text{ kips}/(28'' \times S) = 0.200 \text{ ksi} \rightarrow 75''$
- Achieve even prestress distribution throughout the tank.

Modeling-Tendon Profile

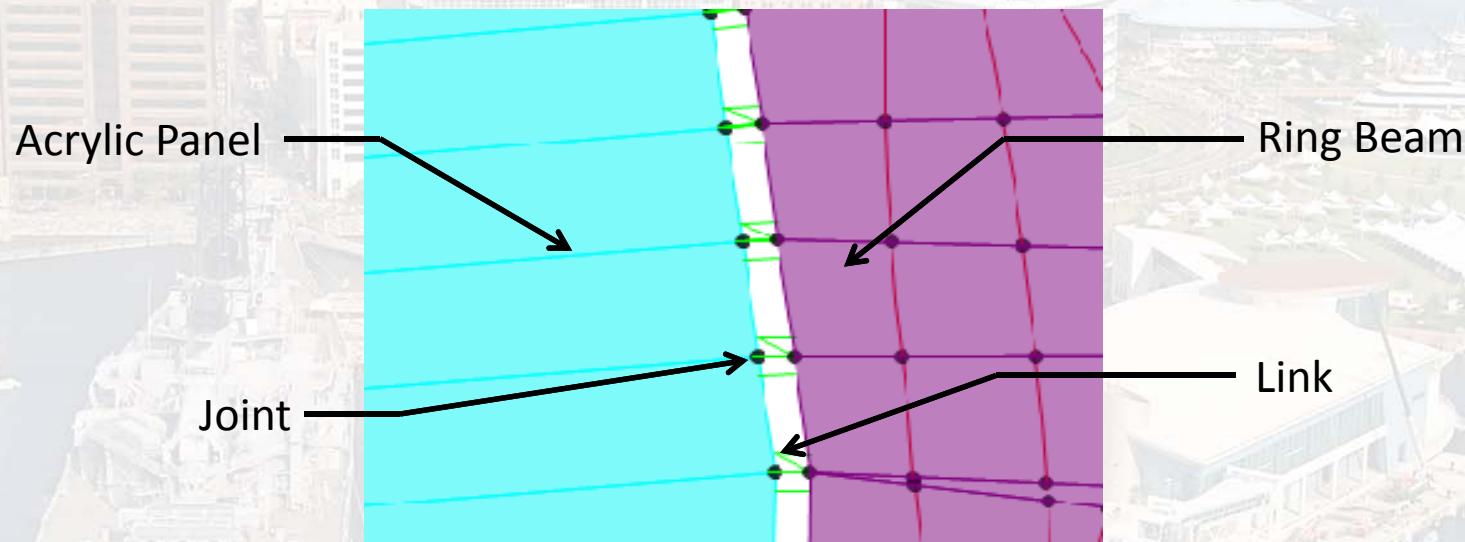


- The typical CGS of the tendons is at mid-depth of the tank wall.



Modeling - Connections

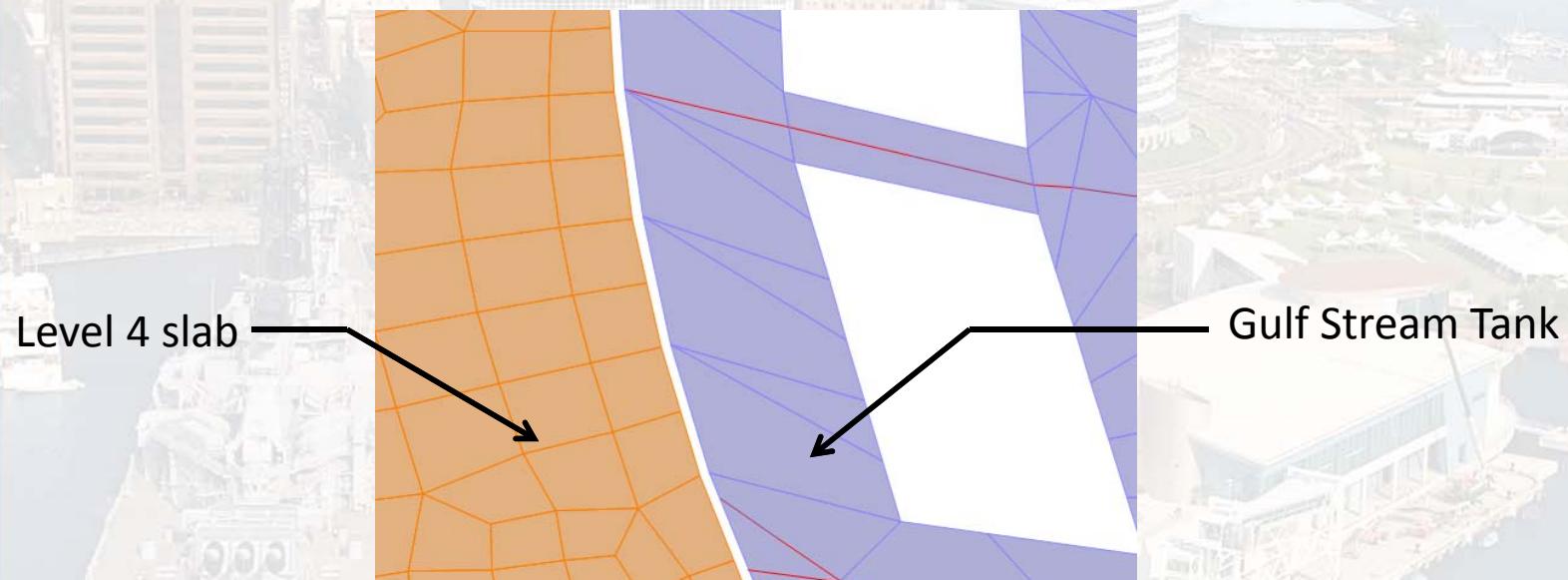
1. Acrylic Panel & Circular Beam:



Link: It is a zero length non-linear link that transfer only x, y and z translation reactions from panel to beam.

Modeling - Connections

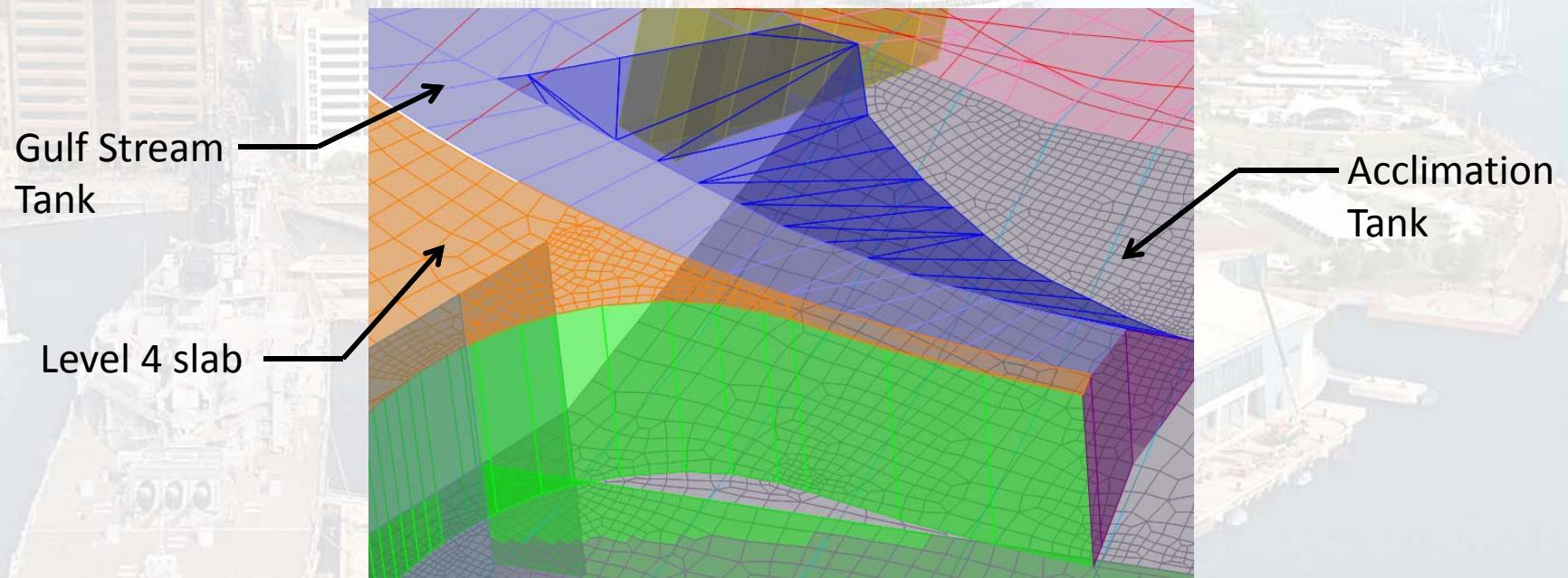
2. Gulf Stream Tank & Level 4 slab:



A 1" gap is assigned between both structural elements, thus there is no connection between them.

Modeling - Connections

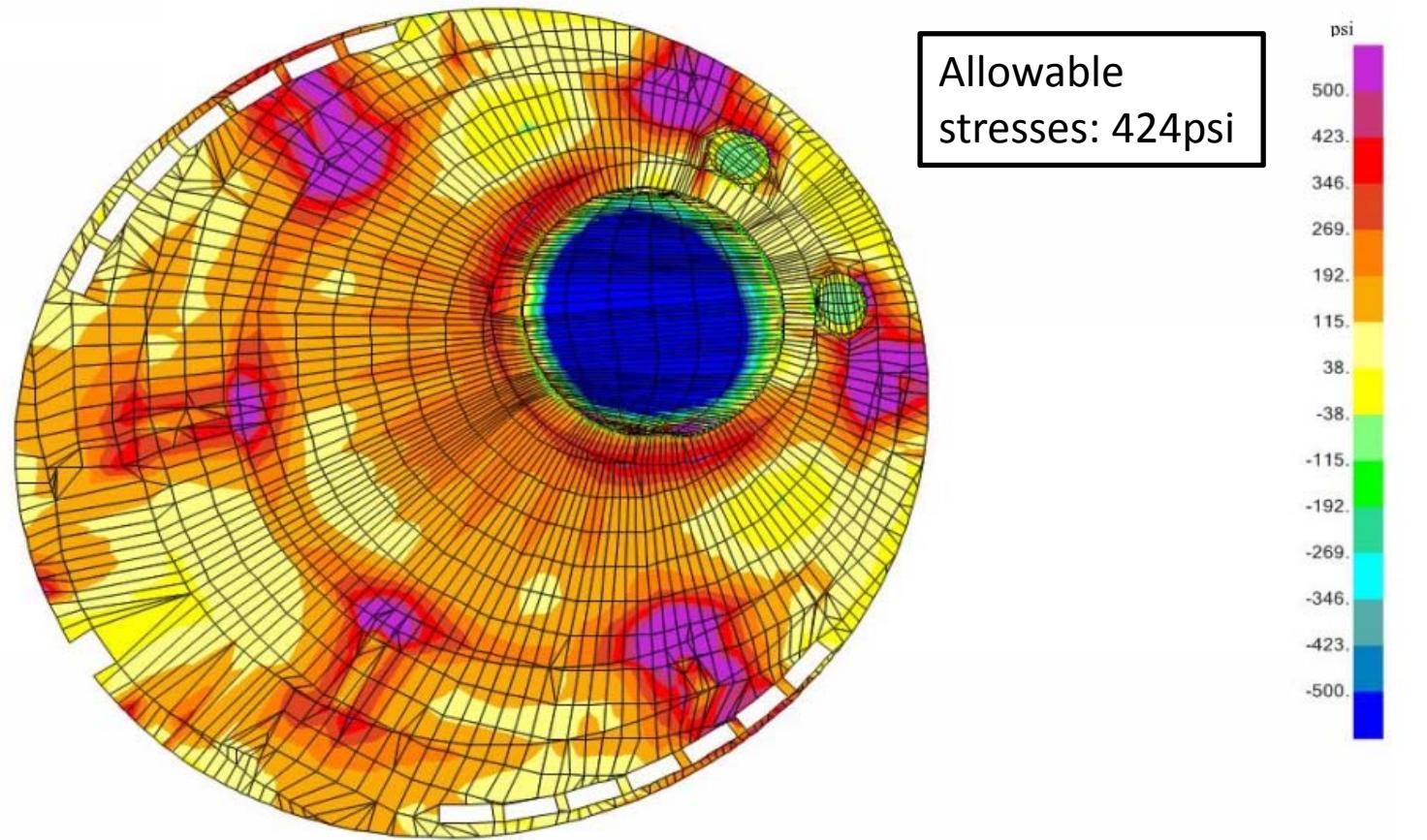
3. Gulf Stream Tank & Level 4 slab & Acclimation Tank:



There is continuity between all these elements at this side of the Gulf Stream tank only.

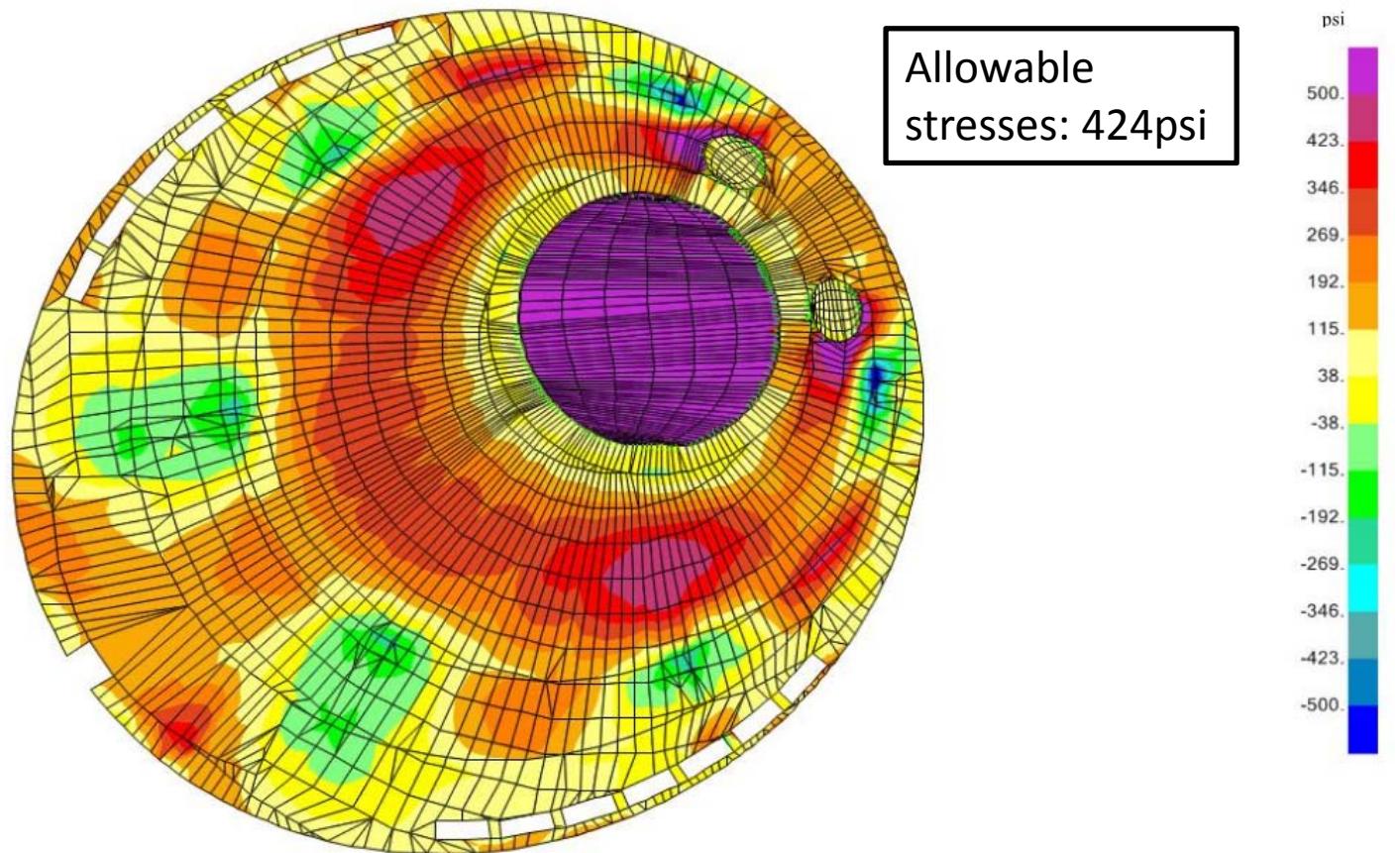
Analysis & Results

1. Top Stress Diagram – Load Combination: DL + LL



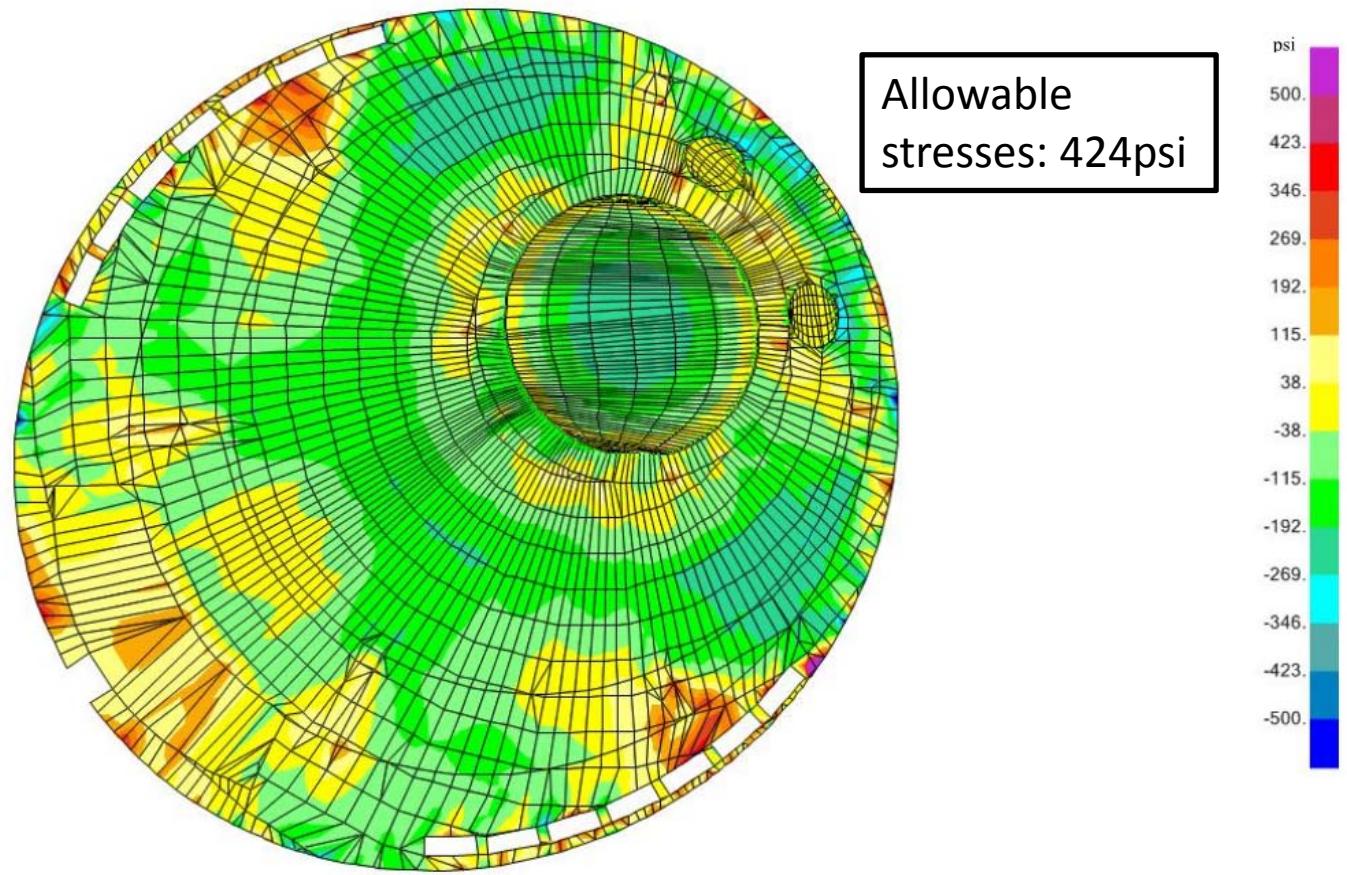
Analysis & Results

2. Bottom Stress Diagram – Load Combination: DL + LL



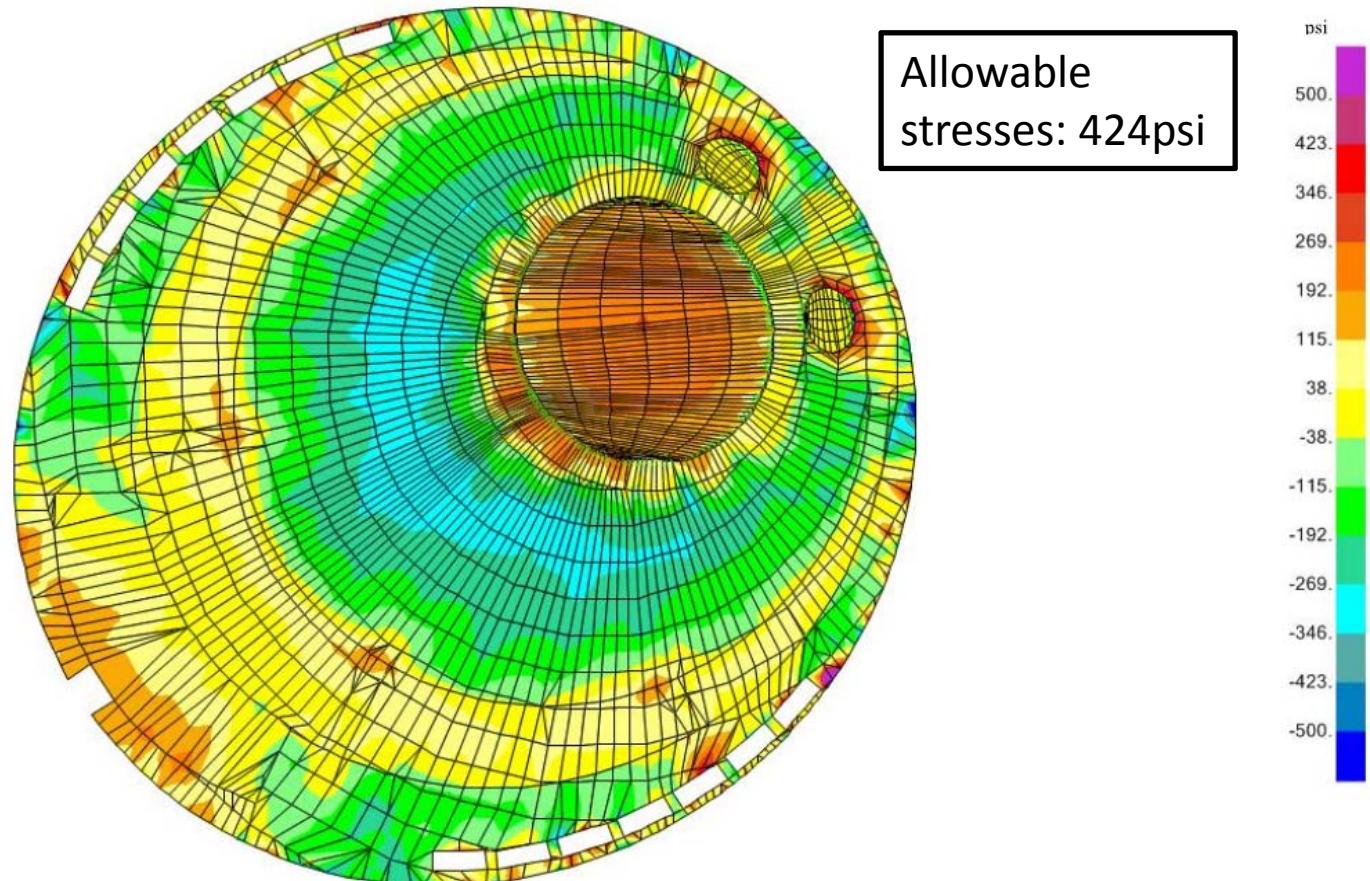
Analysis & Results

3. Top Stress Diagram – Load Combination: DL + PT



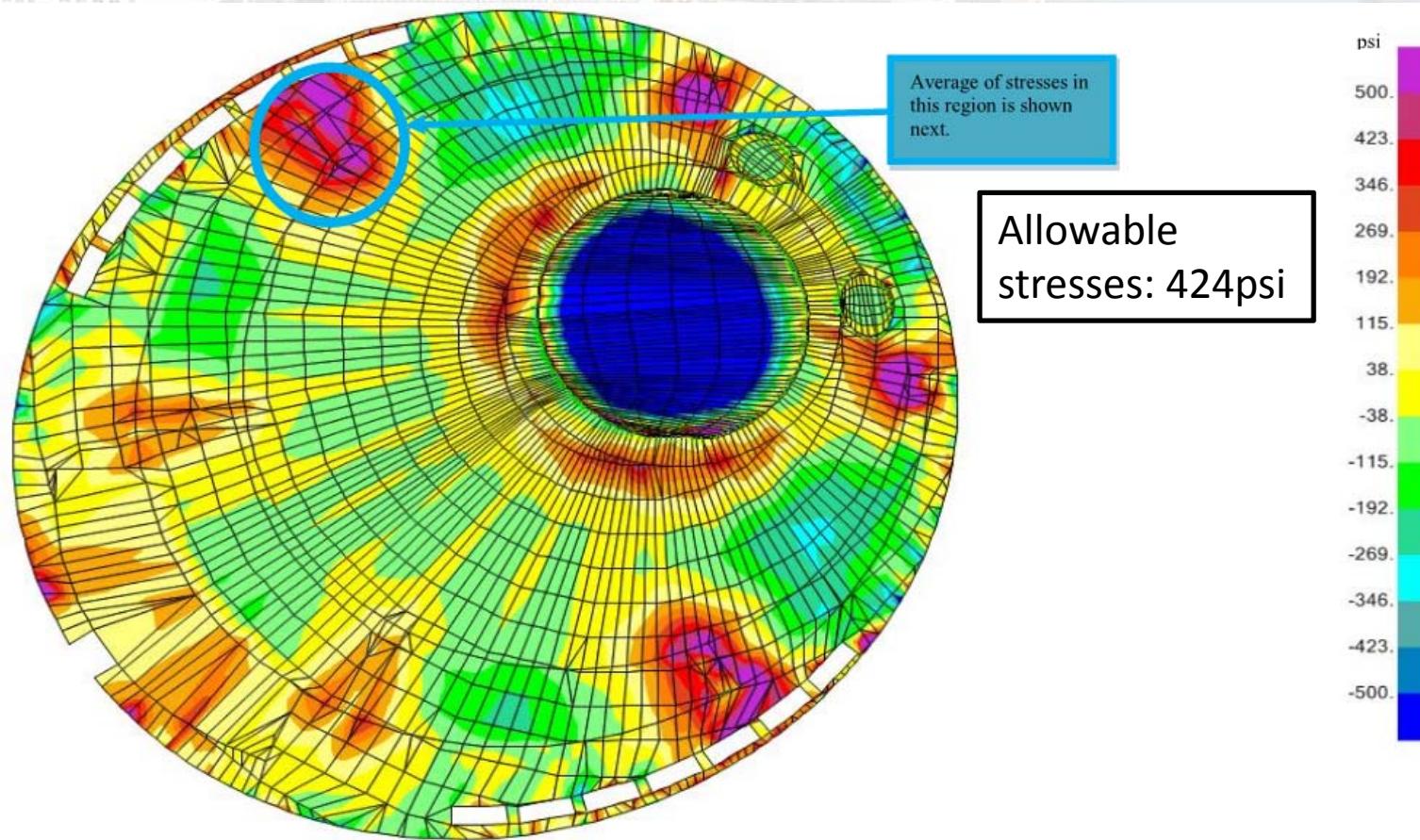
Analysis & Results

4. Bottom Stress Diagram – Load Combination: DL + PT



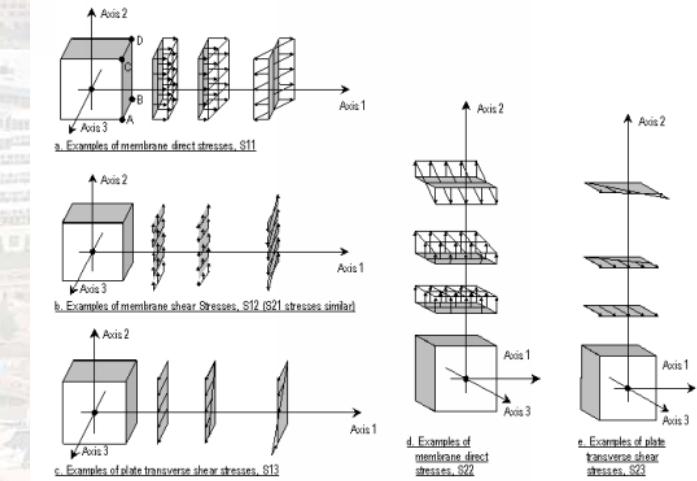
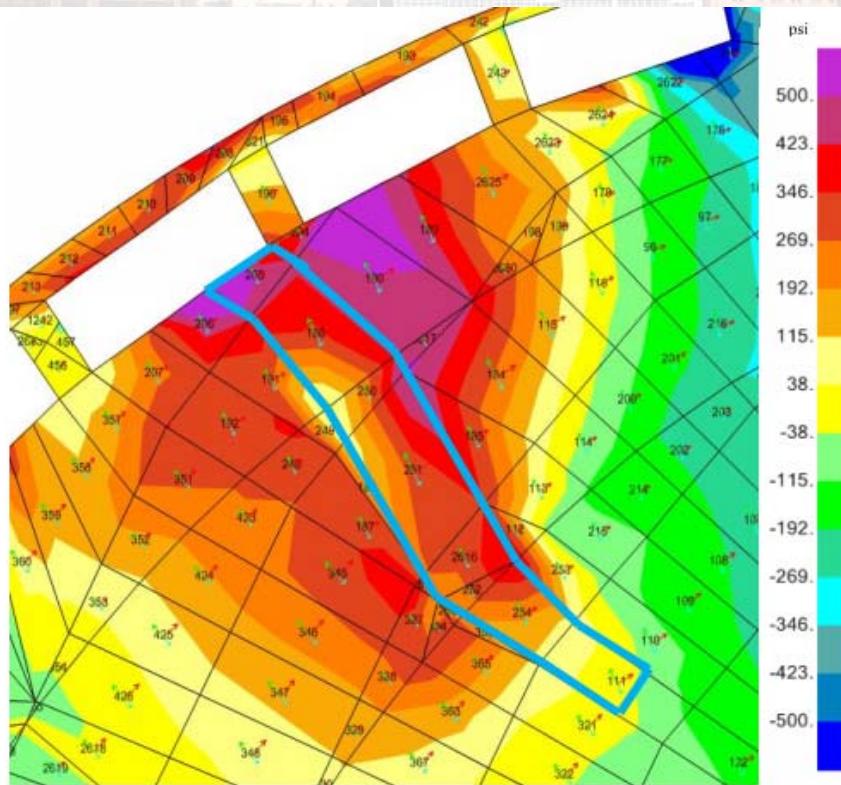
Analysis & Results

5. Top Stress Diagram – Load Combination: DL+ LL + PT



Analysis & Results

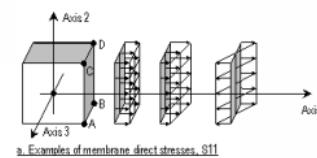
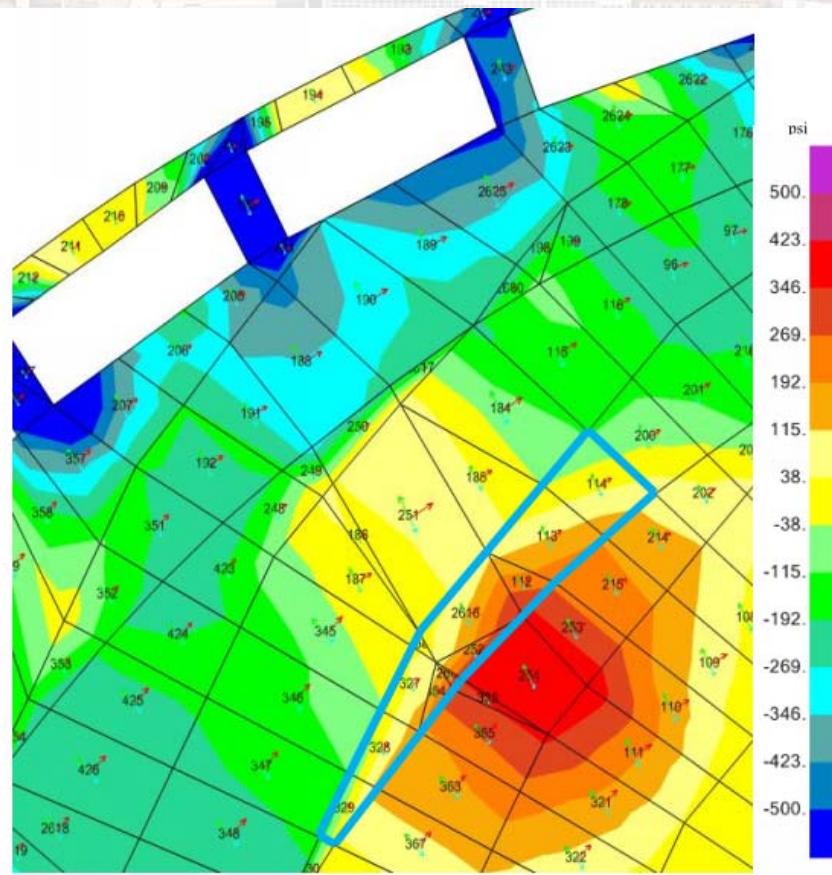
S11 SHELL LOCAL AXIS STRESSES:



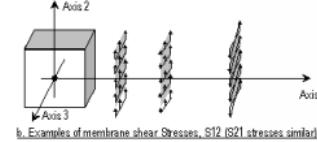
Shell	S11 (psi)	W (in)	S11 x W
205	811.5	11.19	9080.685
188	341.1	46.33	15800.85
250	397.9	6.03	2399.427
251	453.7	50.21	22780.78
2616	482.37	21.37	10308.14
254	419.36	27.99	11737.89
111	-64.345	28	-1801.66
TOTAL	191.12		70306.1
AVERAGE STRESS (psi)			367.86

Analysis & Results

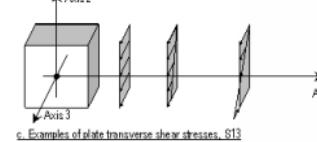
S22 SHELL LOCAL AXIS STRESSES:



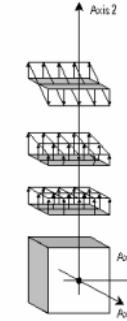
a. Examples of membrane direct stresses, S11



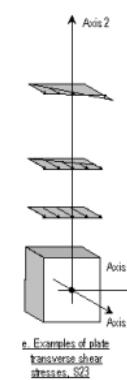
b. Examples of membrane shear stresses, S12 (S21 stresses similar)



c. Examples of plate transverse shear stresses, S13



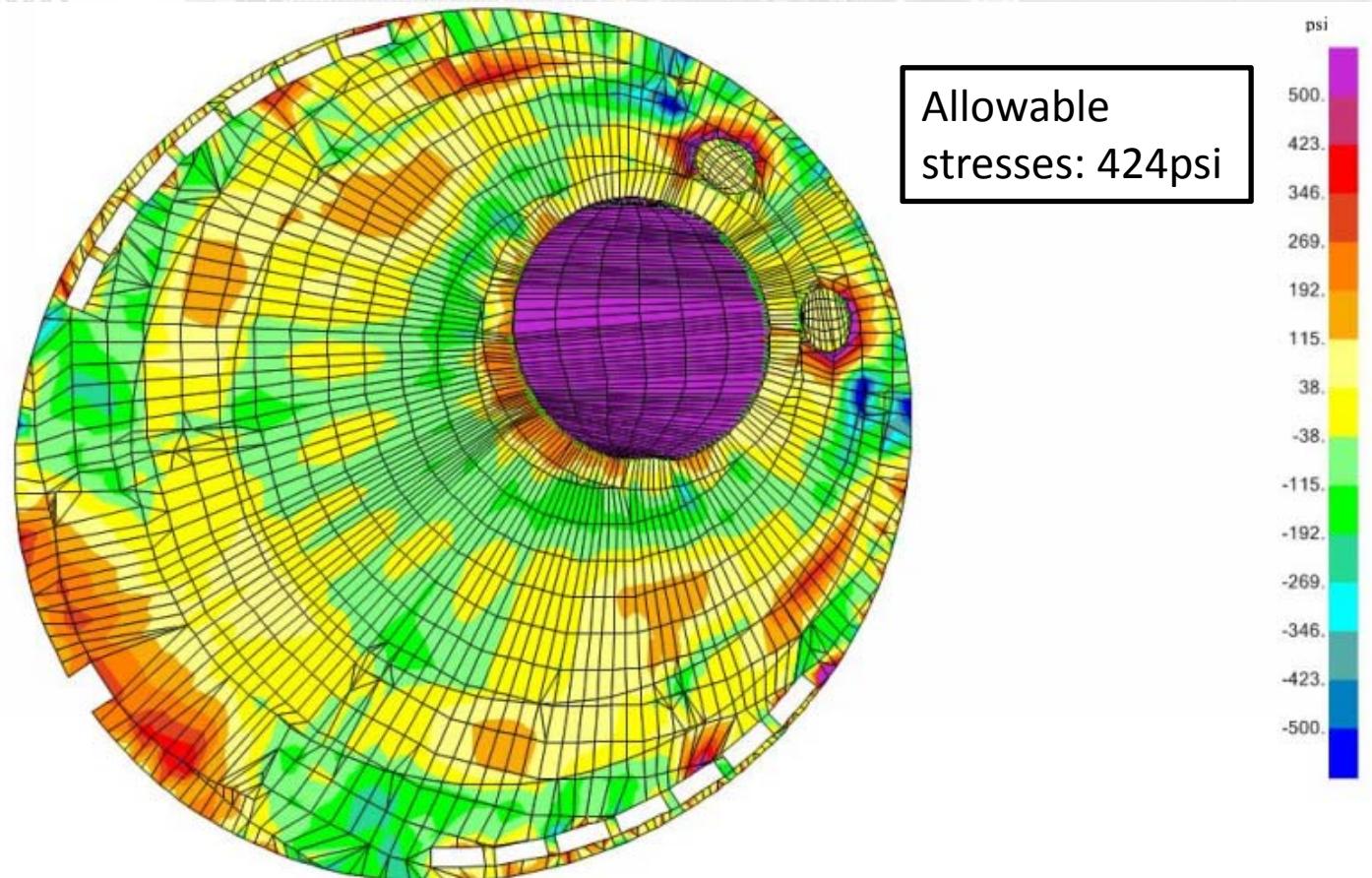
d. Examples of membrane direct stresses, S21



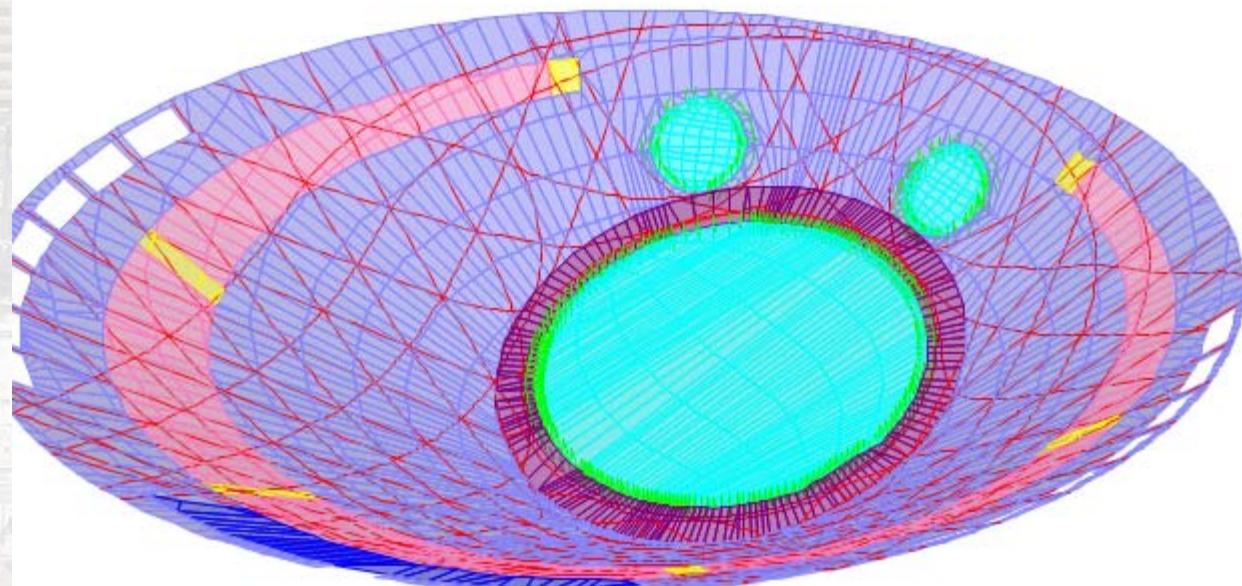
e. Examples of plate transverse shear stresses, S23

Analysis & Results

6. Bottom Stress Diagram – Load Combination: DL+ LL + PT

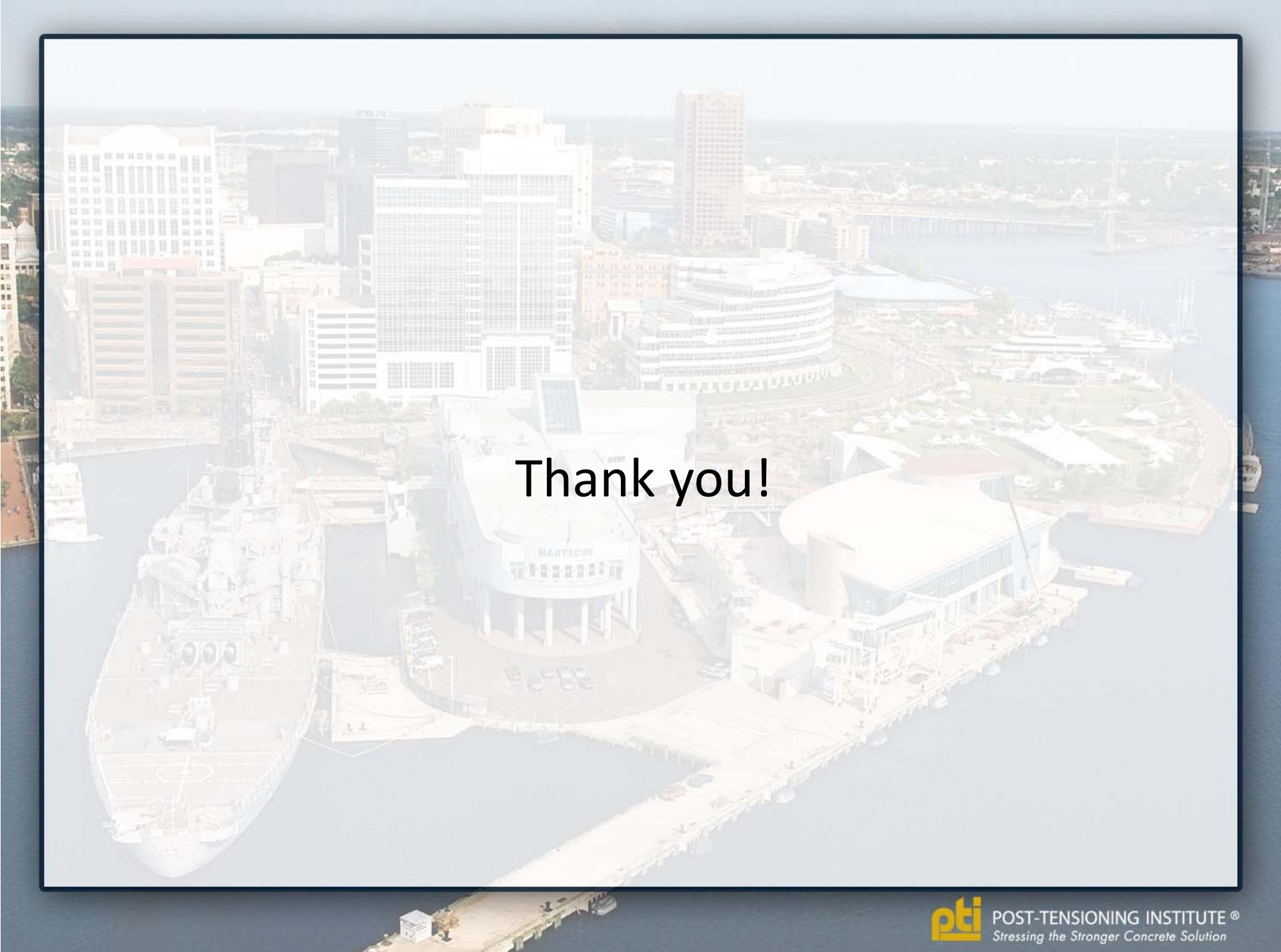


Deformation



Challenges

- Map post-tensioning tendons on tank wall.
- Assign the corresponding PT profile to each tendon element.
- Limited capability of the software to generate hyperstatic forces and moments.



Thank you!