Integrated Modeling of APEX FW-Blanket Modules

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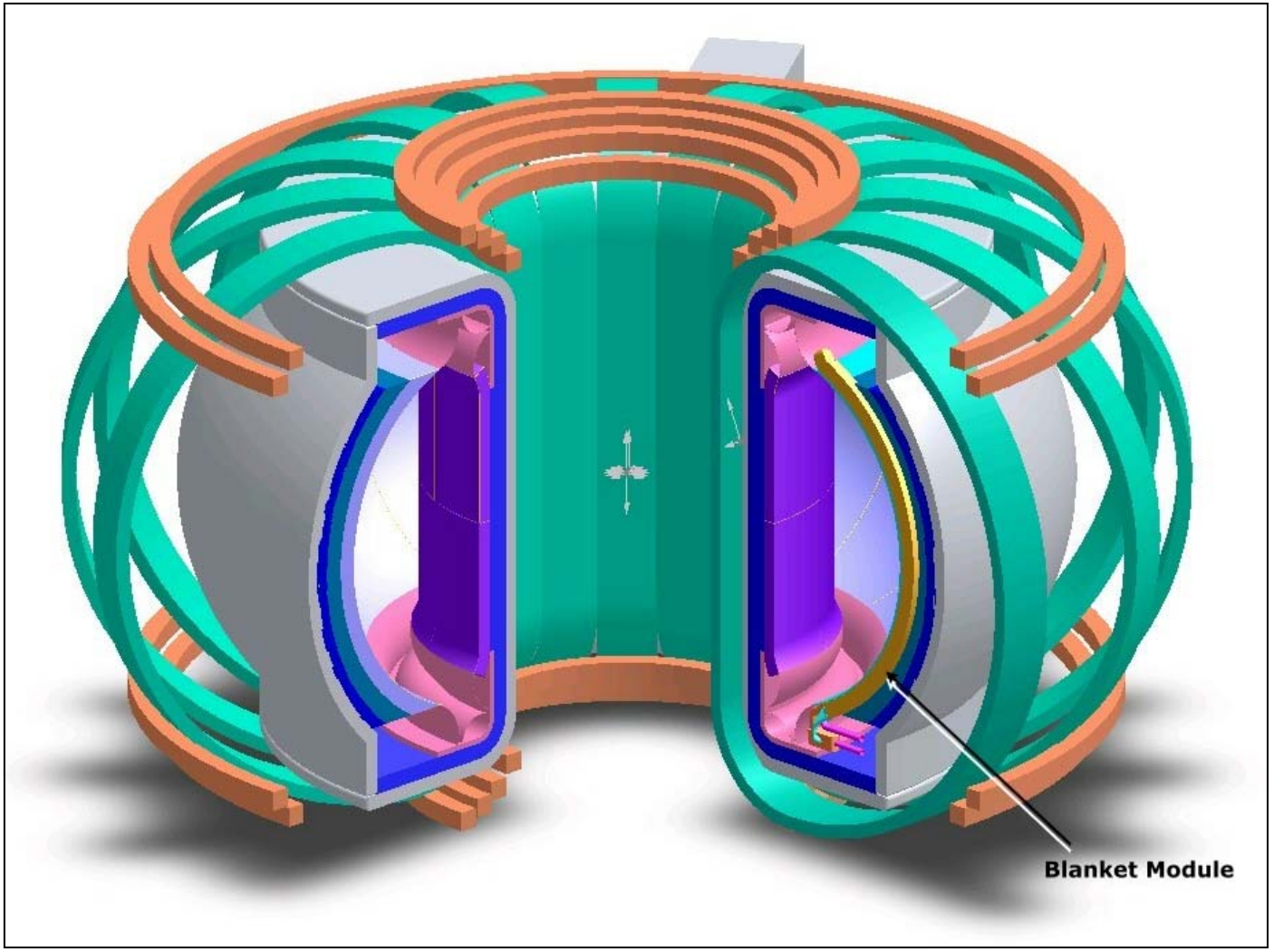
OUTLINE

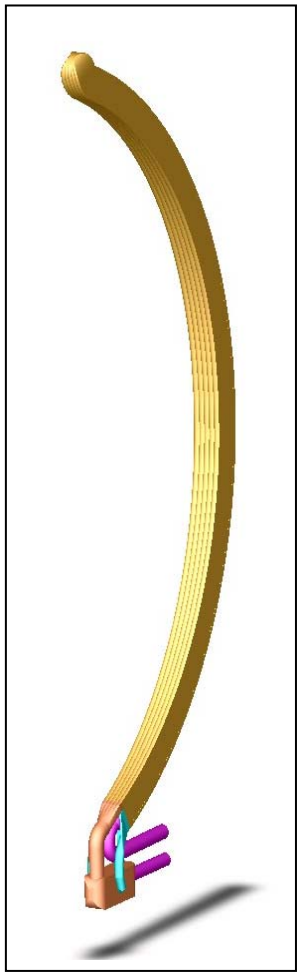
- Modeling structural loads due to Liquid Pb.
- Modeling of non-uniform heating on the entire FW-Panel
- Summary

APEX Solid Wall Reactor

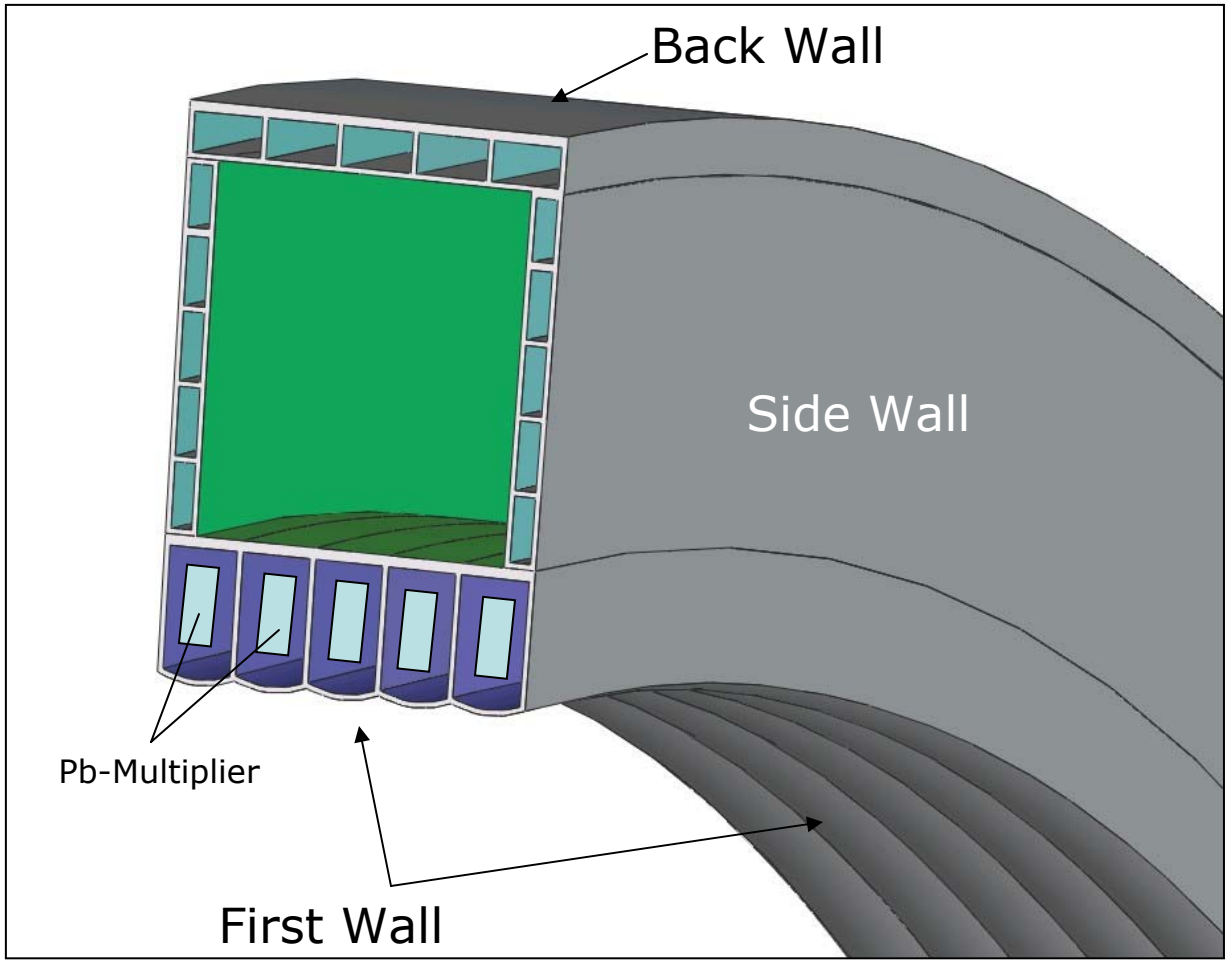


Major Radius	5.5 m	Aspect Ratio	3.44
Elongation	2.15	Blanket Height	8.09 m

Outboard Blanket Module



Entire Module
(8 m tall)



Details of the Blanket Internal Flow Channels

Modeling Structural Loads Due to Liquid Pb

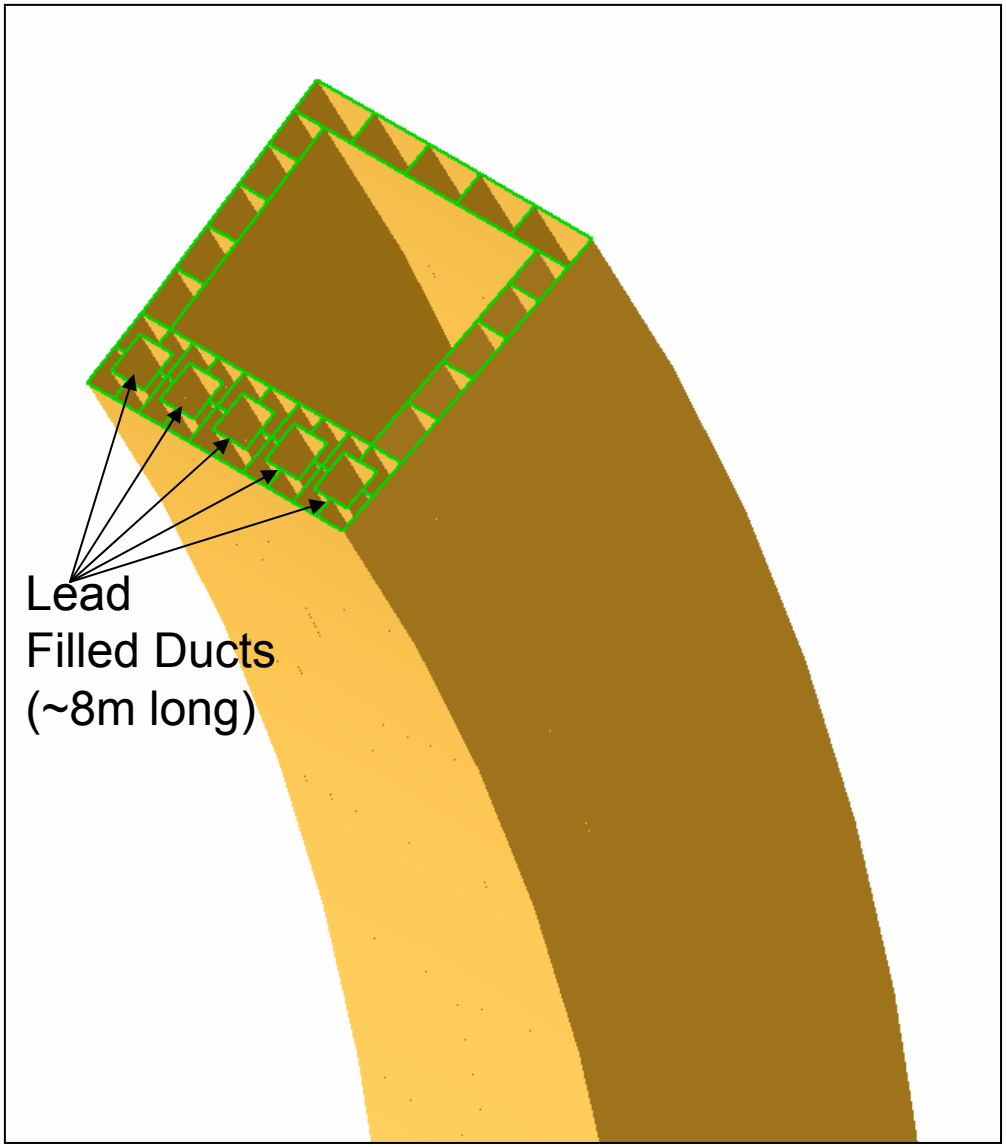
Weight of Pb per duct: 109 kg

Weight of Pb per module: 545 kg

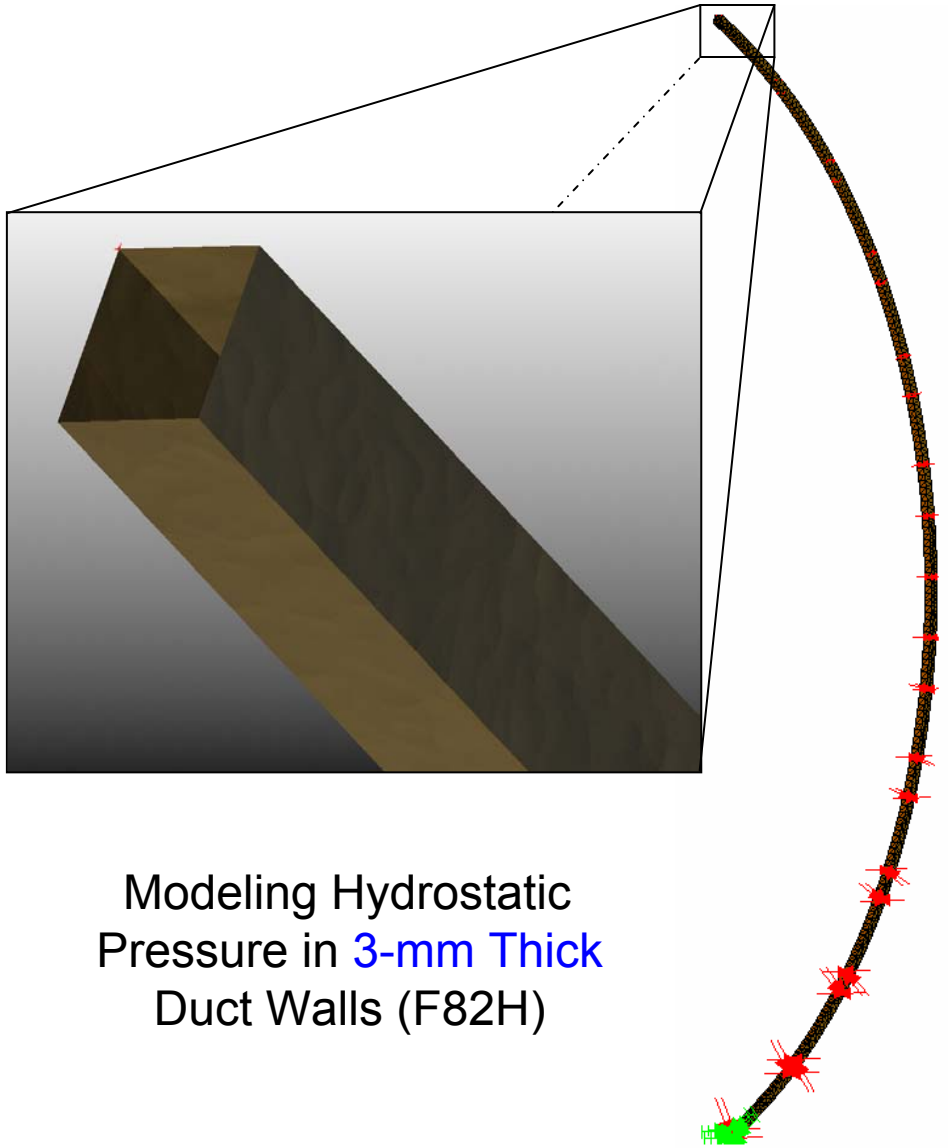
Total Pb in Outboard: ~15,470 kg

Liquid Pb will result in:

1. **Hydrostatic Pressure on Duct Walls.**
2. **Bending moments in Duct Walls due to curvature of the OB-module**



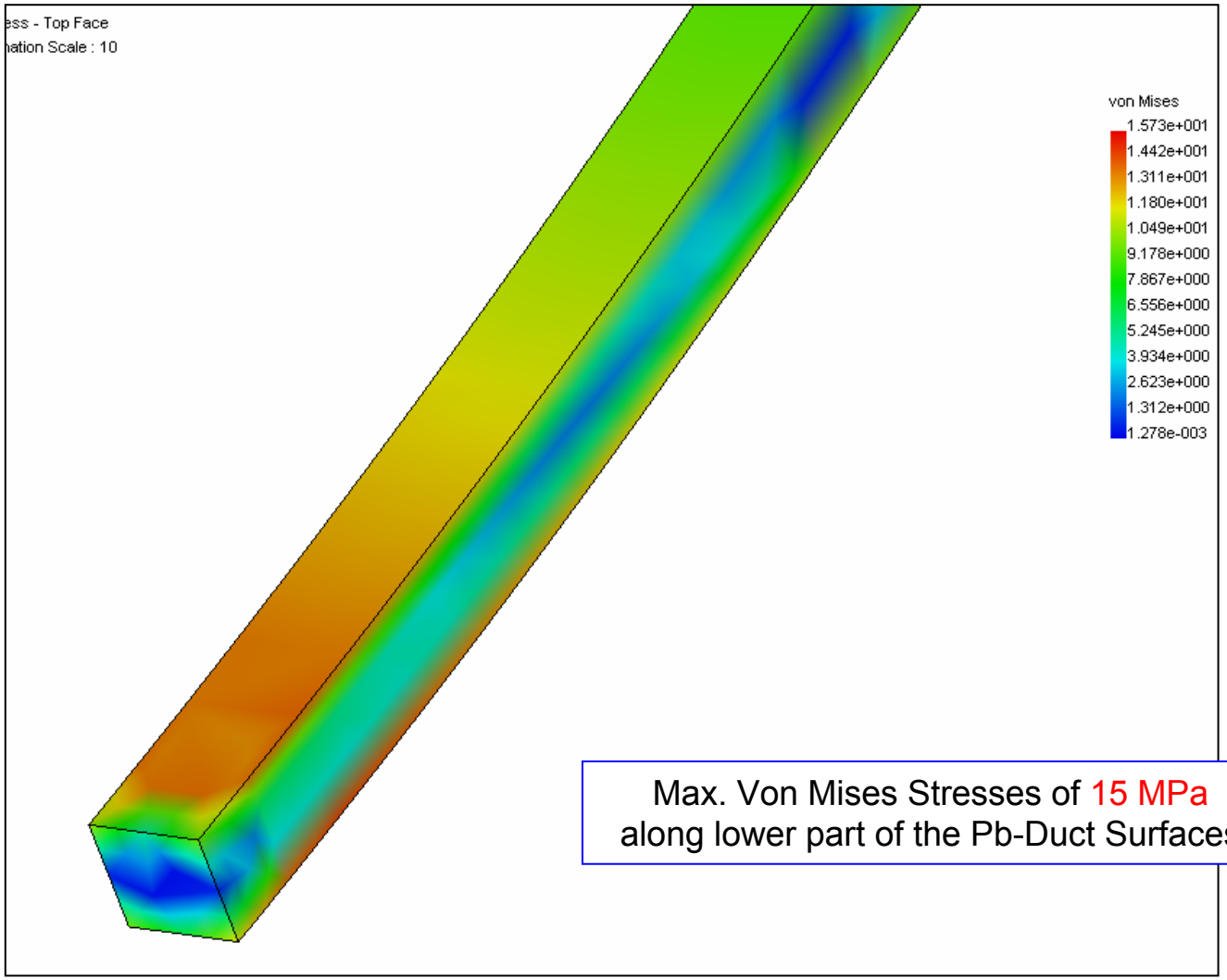
Stress in FW Pb D



Modeling Hydrostatic Pressure in 3-mm Thick Duct Walls (F82H)

Hydrostatic Pressure:

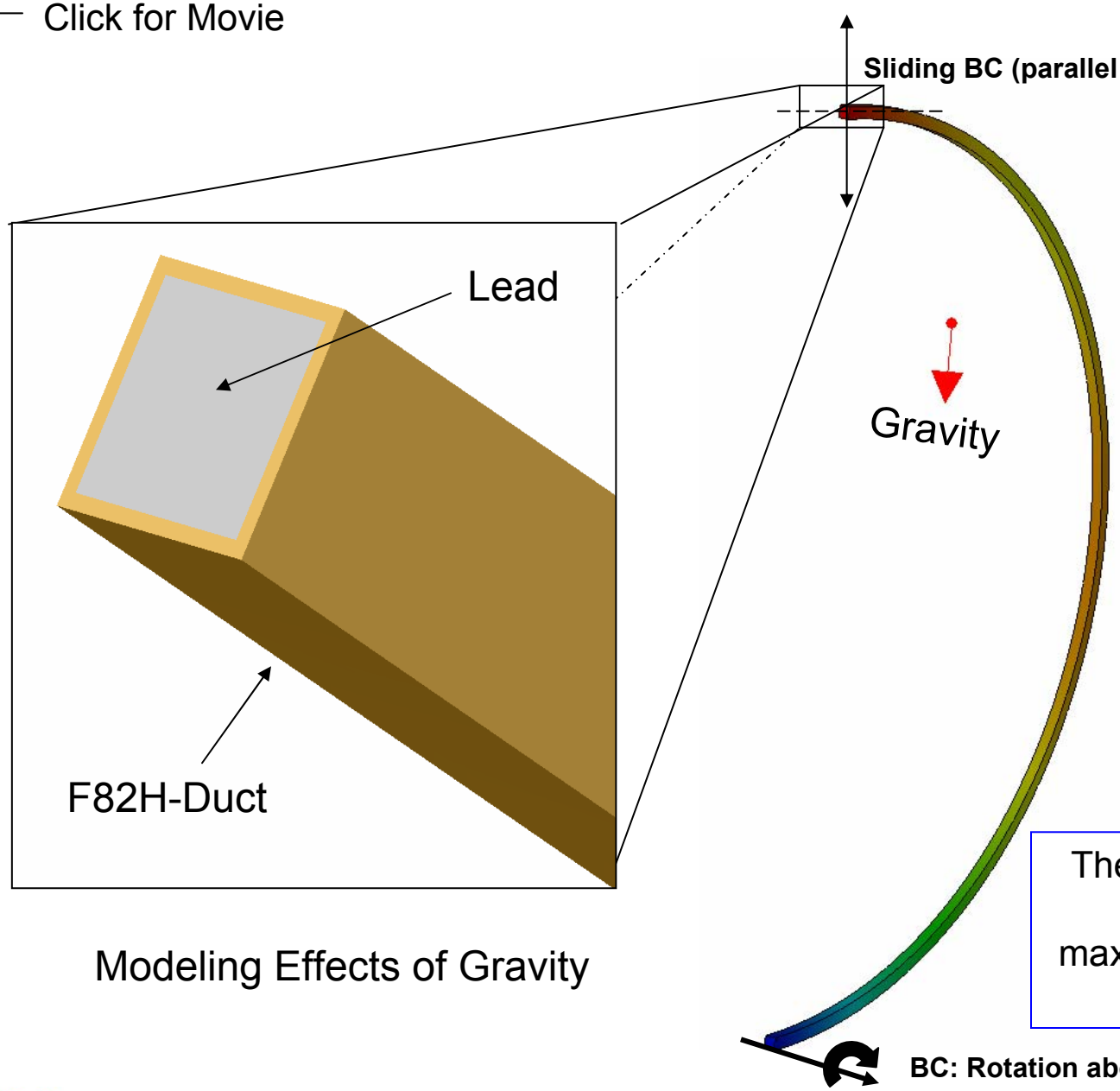
Equivalent Stresses In the Pb-Duct

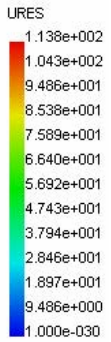


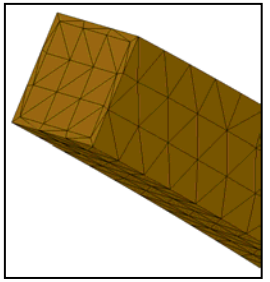
Max. Von Mises Stresses of 15 MPa
along lower part of the Pb-Duct Surfaces

Effect of Gravity on FW Pb-Filled Duct

Click for Movie







Modeling Effects of Gravity

The weight of the Lead could results in max. Displacement of 100 mm for a free-floating duct

Gravity Effect:

Equivalent Stresses In the Pb-Duct

Weight of Pb per duct: 109 kg

Total Pb in Outboard: 15,478 kg

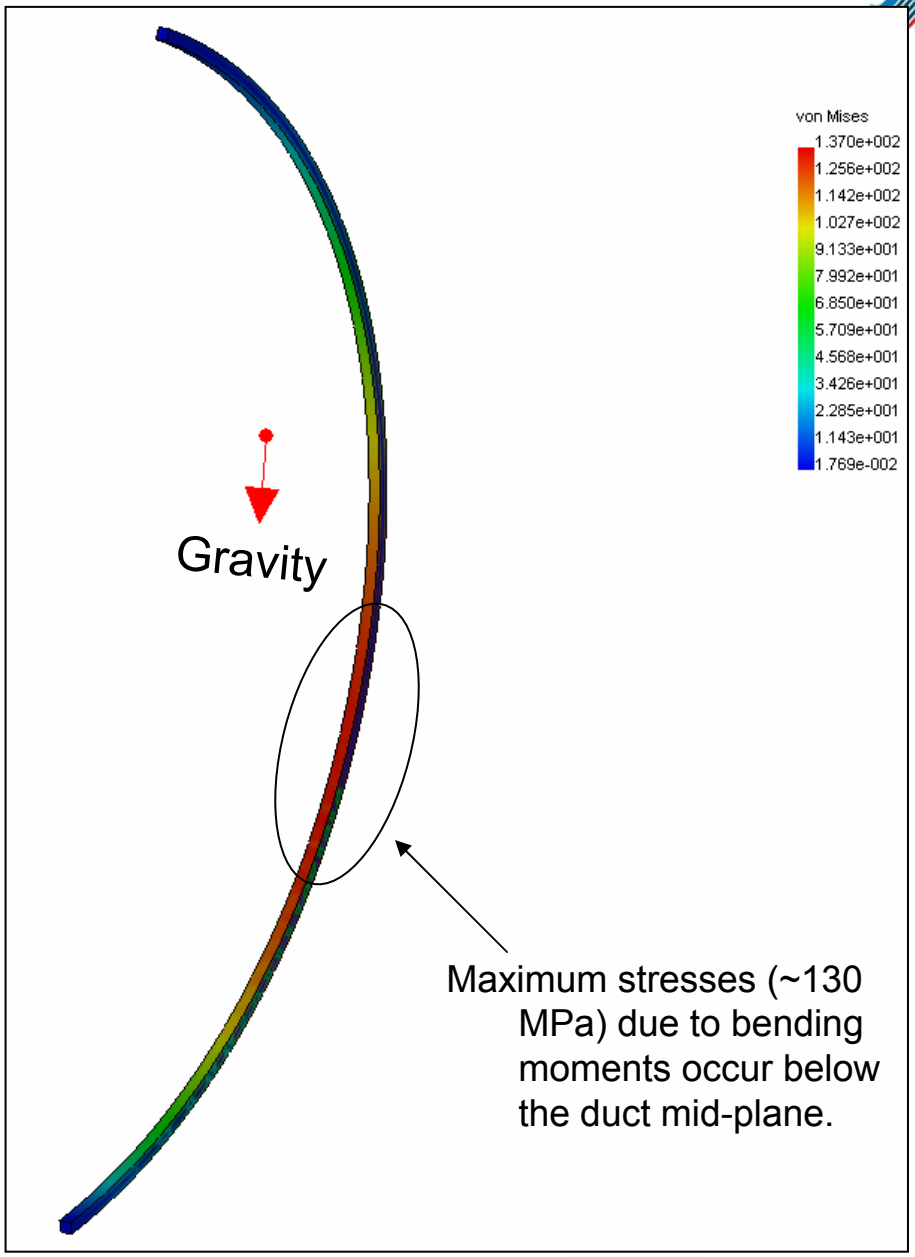
(There are 5 ducts per FW module; or a total of 142 OB-ducts)

Boundary Conditions:

(1) Top of the duct is free to slide up and down parallel to side-walls (no translation)

(2) Bottom of the duct is free to rotate about the outer edge (no translation).

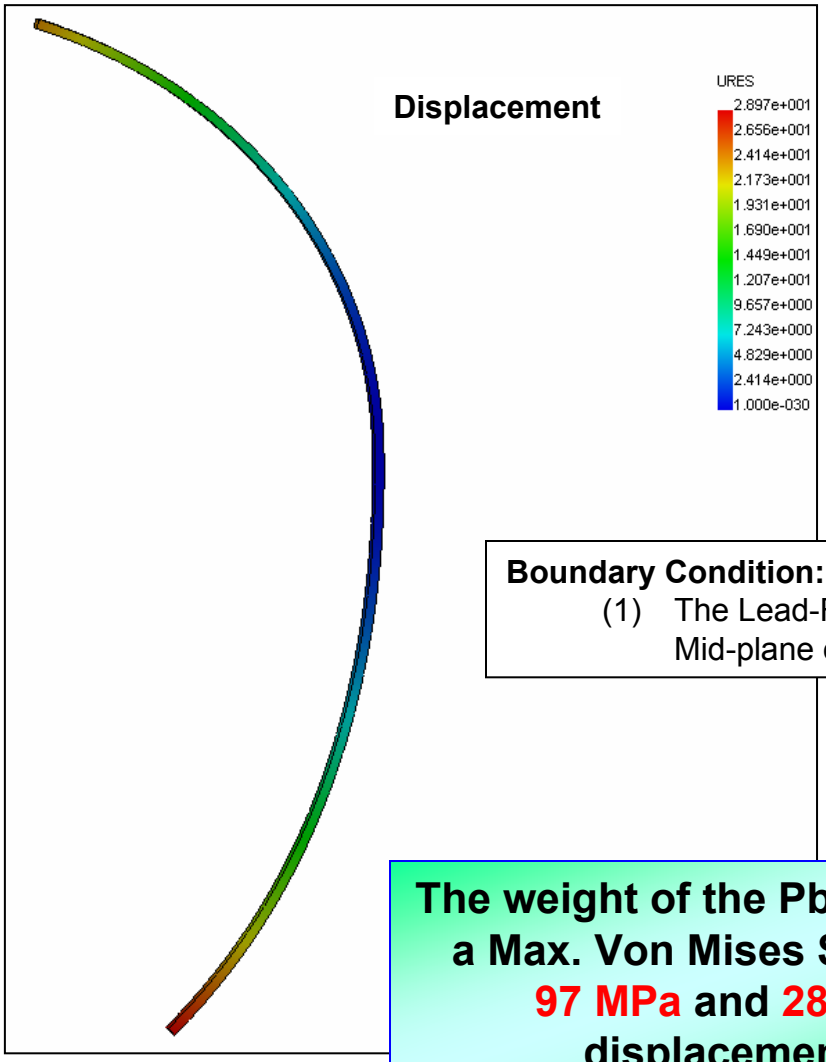
The weight of the Pb produces a Max. Von Mises Stress of 130 MPa in the Duct Structure

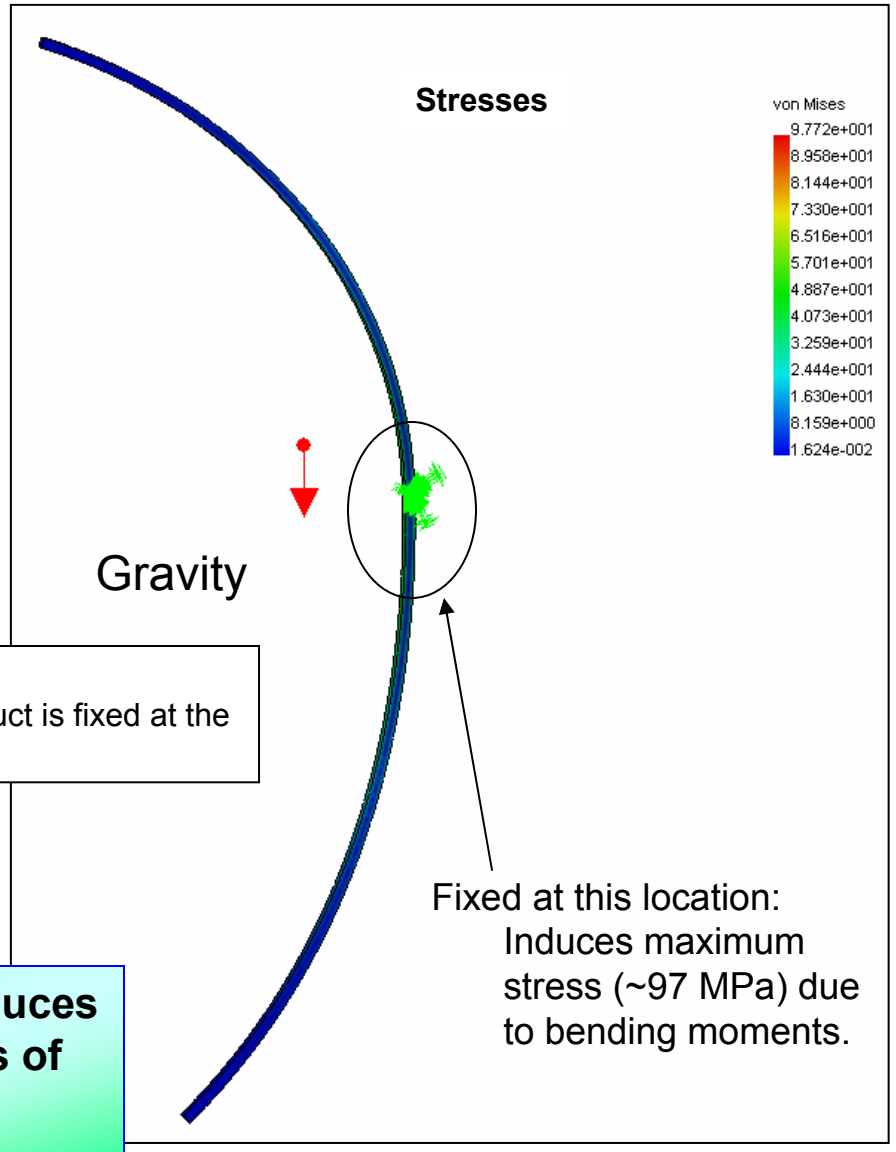


Click for Movie

Gravity Effect:

Equivalent Stresses In the Pb-Duct





Boundary Condition:

(1) The Lead-Filled Duct is fixed at the Mid-plane only.

Fixed at this location:
Induces maximum stress (~97 MPa) due to bending moments.

The weight of the Pb produces a Max. Von Mises Stress of 97 MPa and 28 mm displacement.

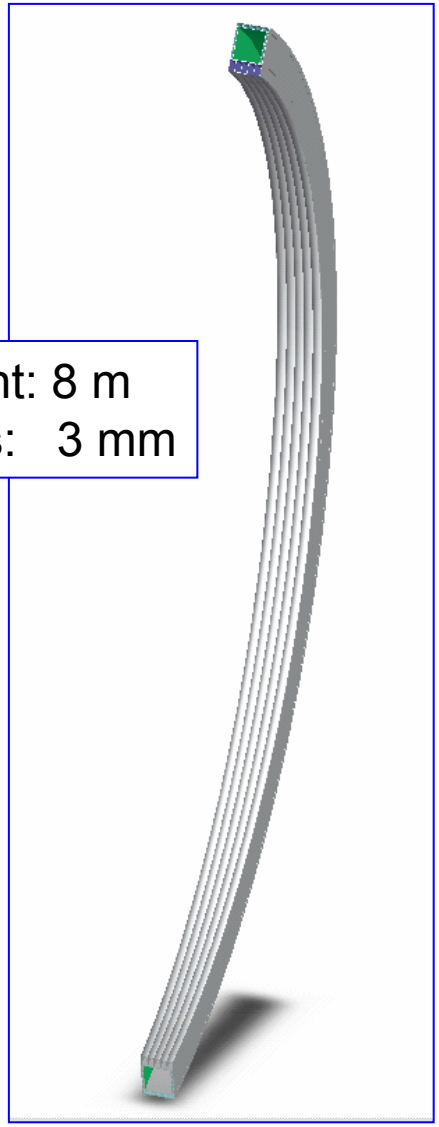
Summary: Liquid Pb

- Structural loads due to the hydrostatic pressure and the gravity bending moments of liquid Pb were analyzed.
- Hydrostatic pressure of liquid Pb results in 15 MPa stresses in the lower sections of the duct.
- Two Simple Boundary Conditions
  - Free to rotate along a bottom edge:
    - Bending moments result in equivalent stresses of over ~130 MPa along the duct walls.
  - Fixed at the Mid-plane only:
    - Bending moments result in von Mises stress of ~97 MP, concentrated at the point of support
- Each Module has 5 ducts:
  - Each module has to accommodated the load caused by 545 kg of Pb.
  - Internal support of the Lead-Ducts will distribute the bending moments to the rest of the module structure: →Lowering localized stresses in the ducts significantly.
- Recommendation:

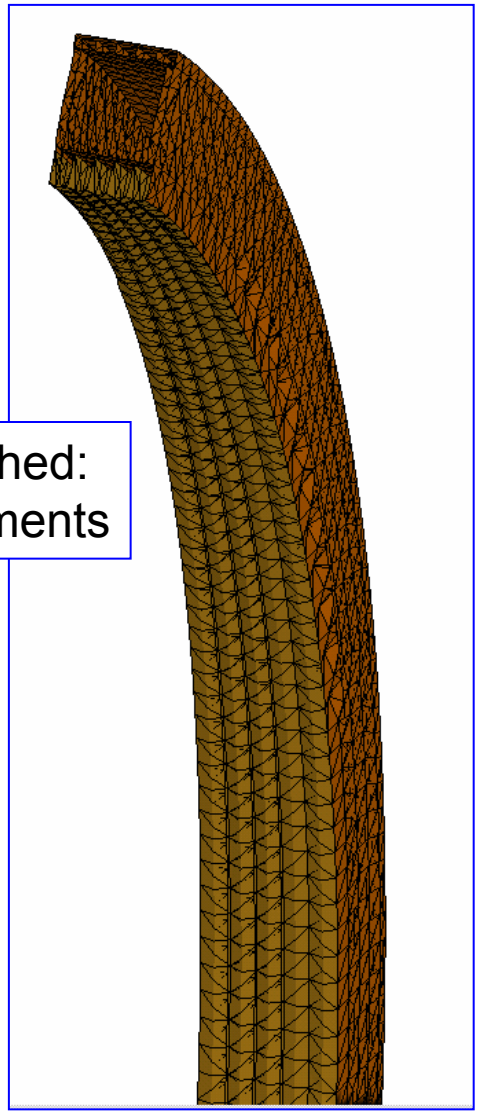
  Beryllium could be considered as an alternative to liquid Pb.

Full OB-Blanket Model

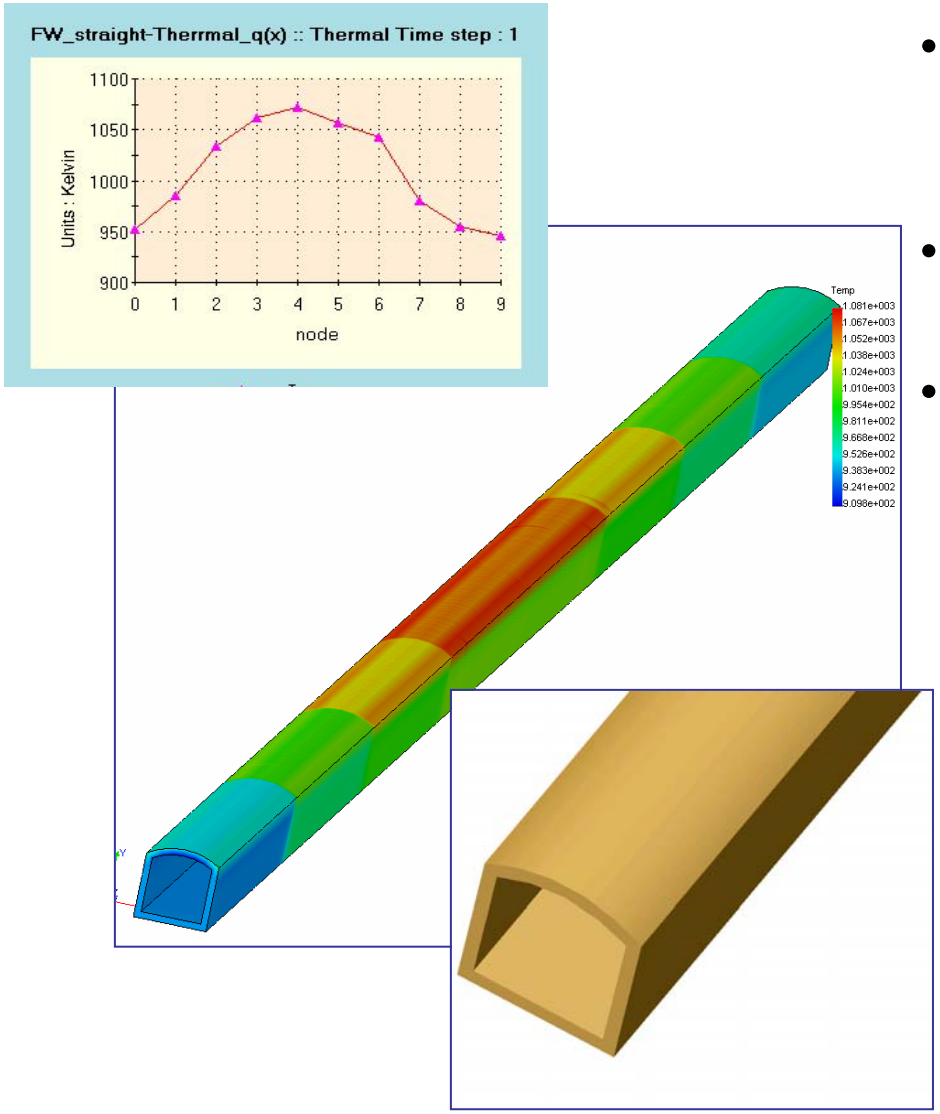
Height: 8 m
Walls: 3 mm



Fully Meshed:
Shell Elements

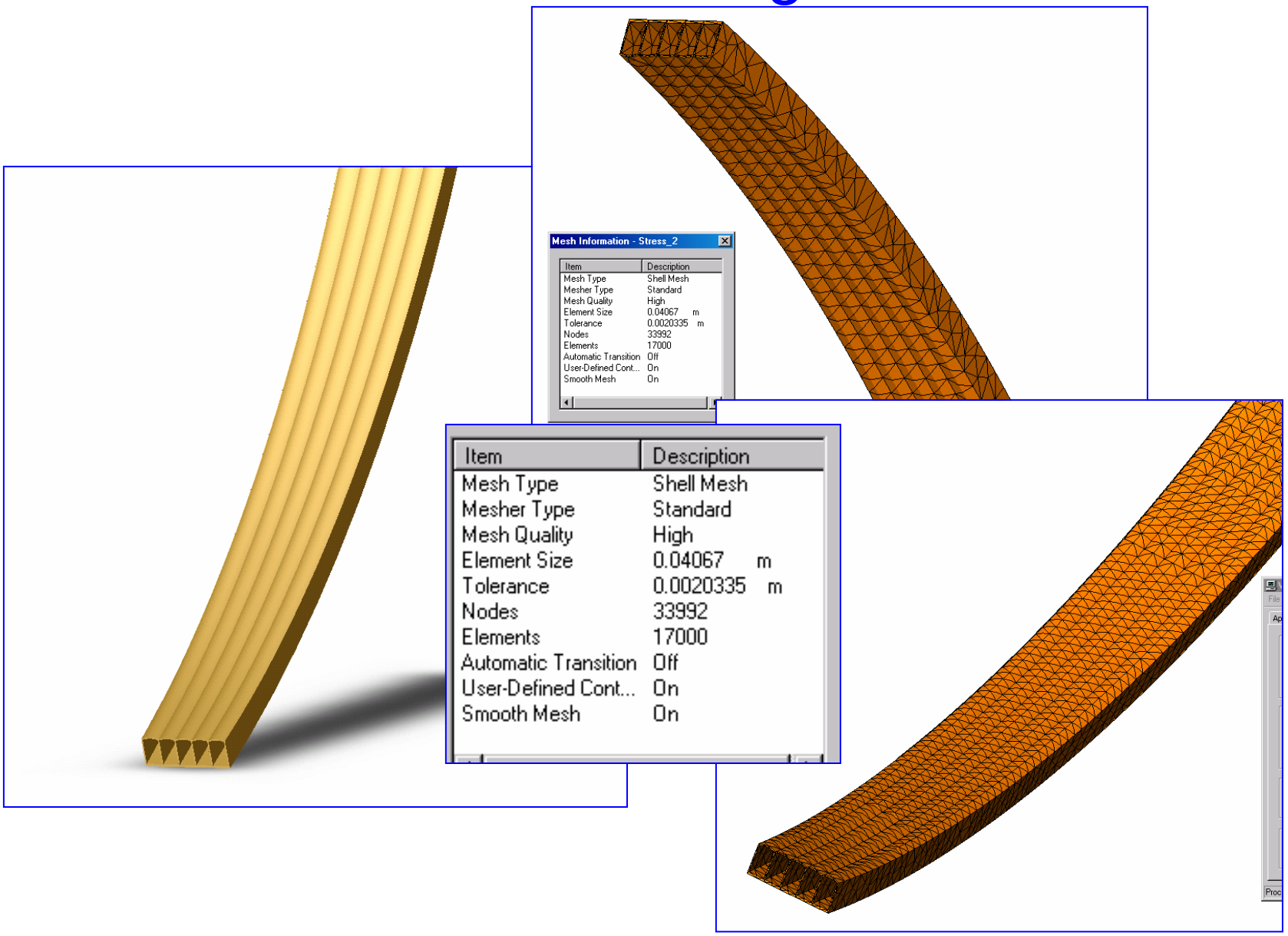


Temperature Distribution Along a Single FW-Channel



- Currently not enough computing power to model the entire module
- The UCLA Cluster has just come up on line.
- As an example look at the FW-module only:
  - 5 FW-Coolant channels
  - Secured at the bottom to a manifold
  - Top is free to slide along a plane
  - Temperature distribution taken from a single channel analysis

Finite Element Modeling of FW-Module



Finite Element Modeling of FW-Panel

3 Boundary Conditions Examined:

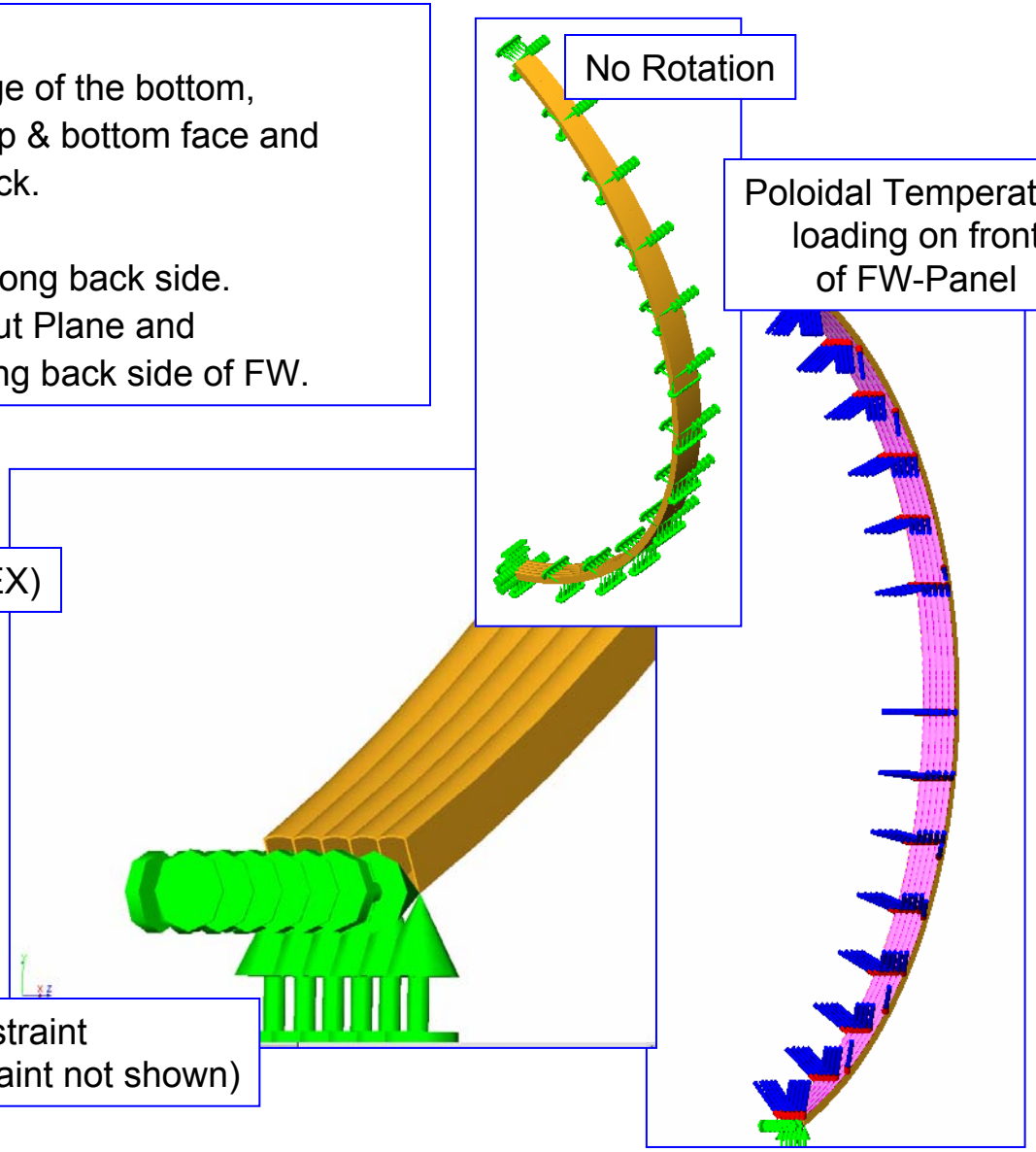
I) Fixed along the back edge of the bottom,
Free to slide along the top & bottom face and
No restraint along the back.

II) Floating top and
No Rotational freedom along back side.

III) Fixed Top and Bottom Cut Plane and
No Rotation freedom along back side of FW.

F82H Properties at 600C(Zinkle et al., APEX)

Property	Description	Value	Units
EX	Elasticity modulus (1st di	1.6e+011	N/m^2
NUXY	Poisson's ratio in XY dir	0.3	NA
GXY	Shear modulus in XY dir	6e+010	N/m^2
DENS	Mass Density	7800	kg/m^3
SIGXT	Tensile strength (X dir)	3e+008	N/m^2
SIGXC	Compressive strength (X		N/m^2
SIGYLD	Yield stress	5e+008	N/m^2
ALPX	Coeff. of thermal expans	1.24e-005	/Kelvin
KX	Thermal conductivity (X-	33	W/(m.K)



Boundary Conditions:

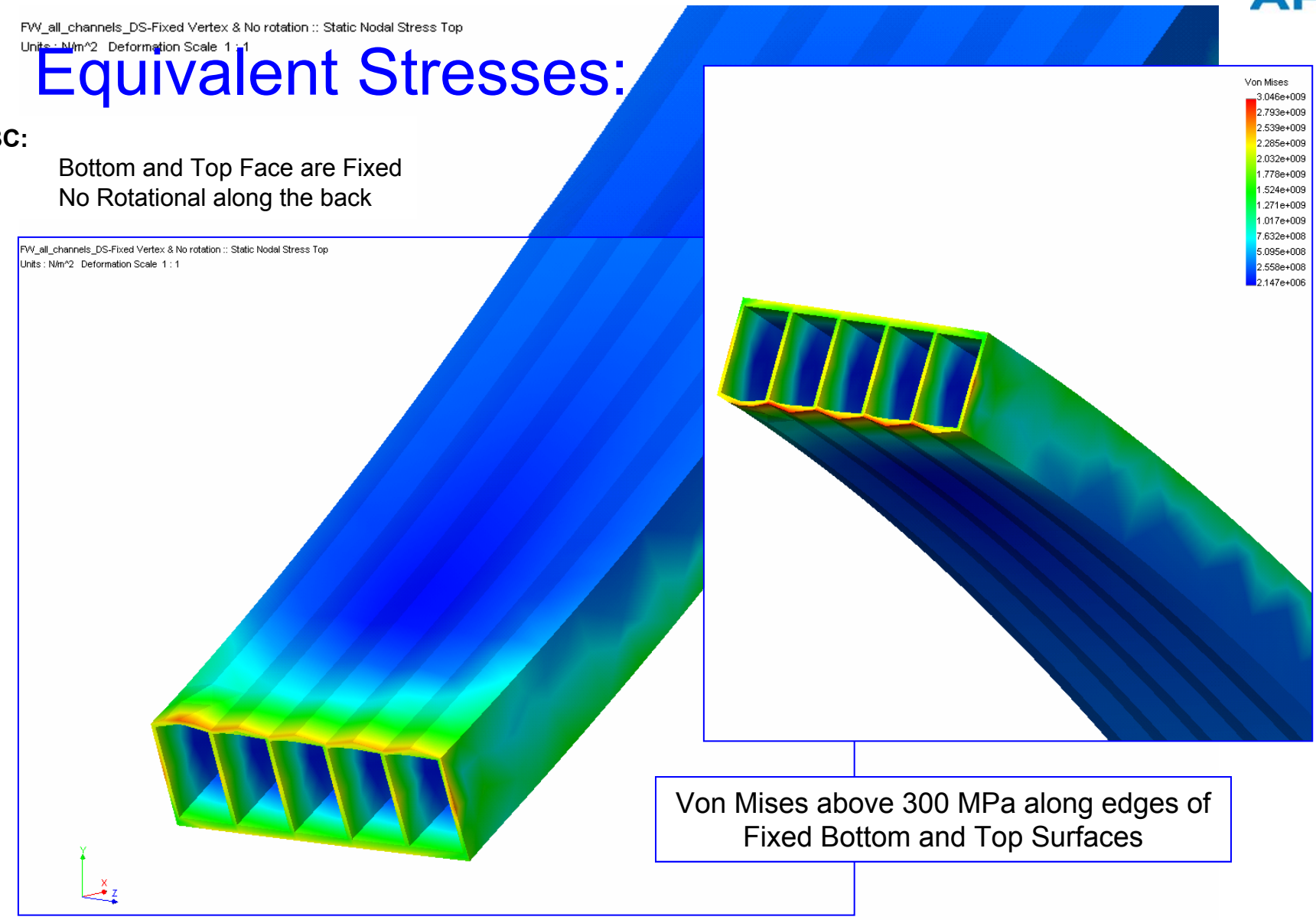
a) Bottom and Top face are Fixed

b) Back of FW-Panel has No Rotational Freedom

Equivalent Stresses:

BC:

Bottom and Top Face are Fixed
No Rotational along the back

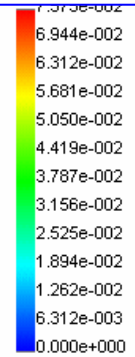


Von Mises above 300 MPa along edges of Fixed Bottom and Top Surfaces

Movie

FW-Panel Displacement:

The Movie shows the displacement at a 1:1 Scale



BC:

Bottom and Top Face are Fixed
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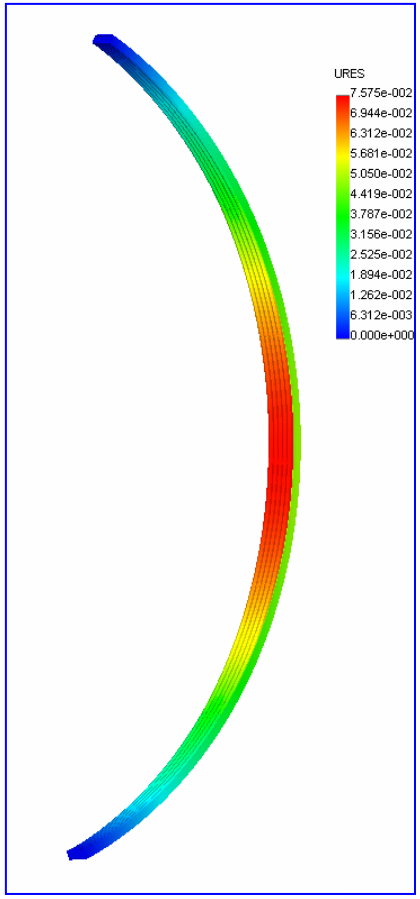

Max Displacement at Center ~ 7.3 cm

Summary: FW-Panel

- A 3-D Solid Model of the APEX OB-Blanket Module was developed
- A 3-D Fluid flow model was used to simulated temperature distribution of the FW
- A single FW-Channel was modeled to establish Temp-Distribution along the FW.
- One entire FW-Panel was modeled using shell elements.
- Oversimplified Boundary conditions were applied.
- Effects of non-uniform heating along the 8-m tall FW-Panel can result in LARGE STRESSES (above 200 MPa) and LARGE DEFORMATIONS (above 7 cm) in the FW-Panel, for a free standing unit.