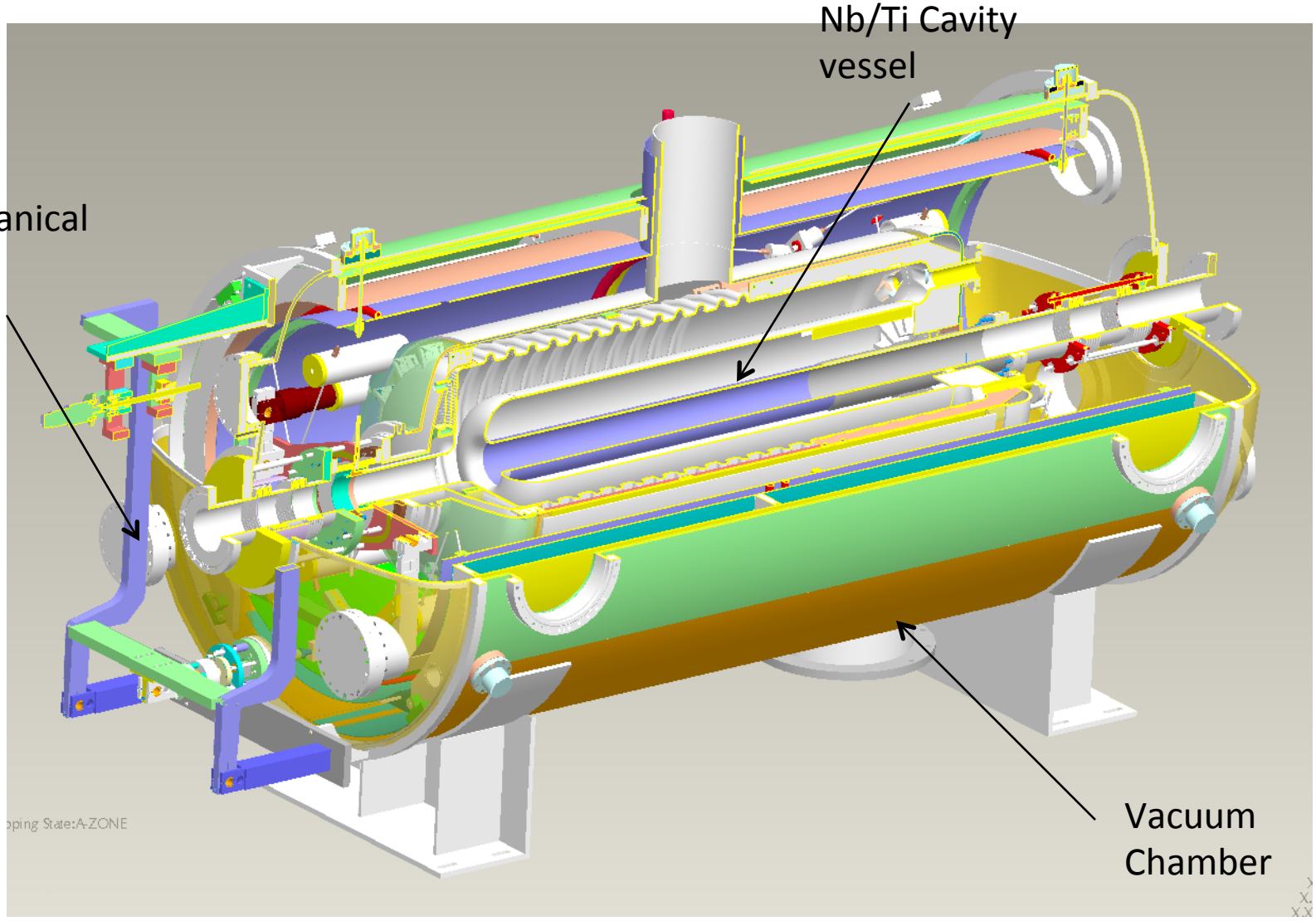
56 MHz SRF Cavity Cryostat support system, Shielding and Vacuum Vessel

C. Pai

3-8-2011

Cut Out Section View of 56 MHz Cryostat

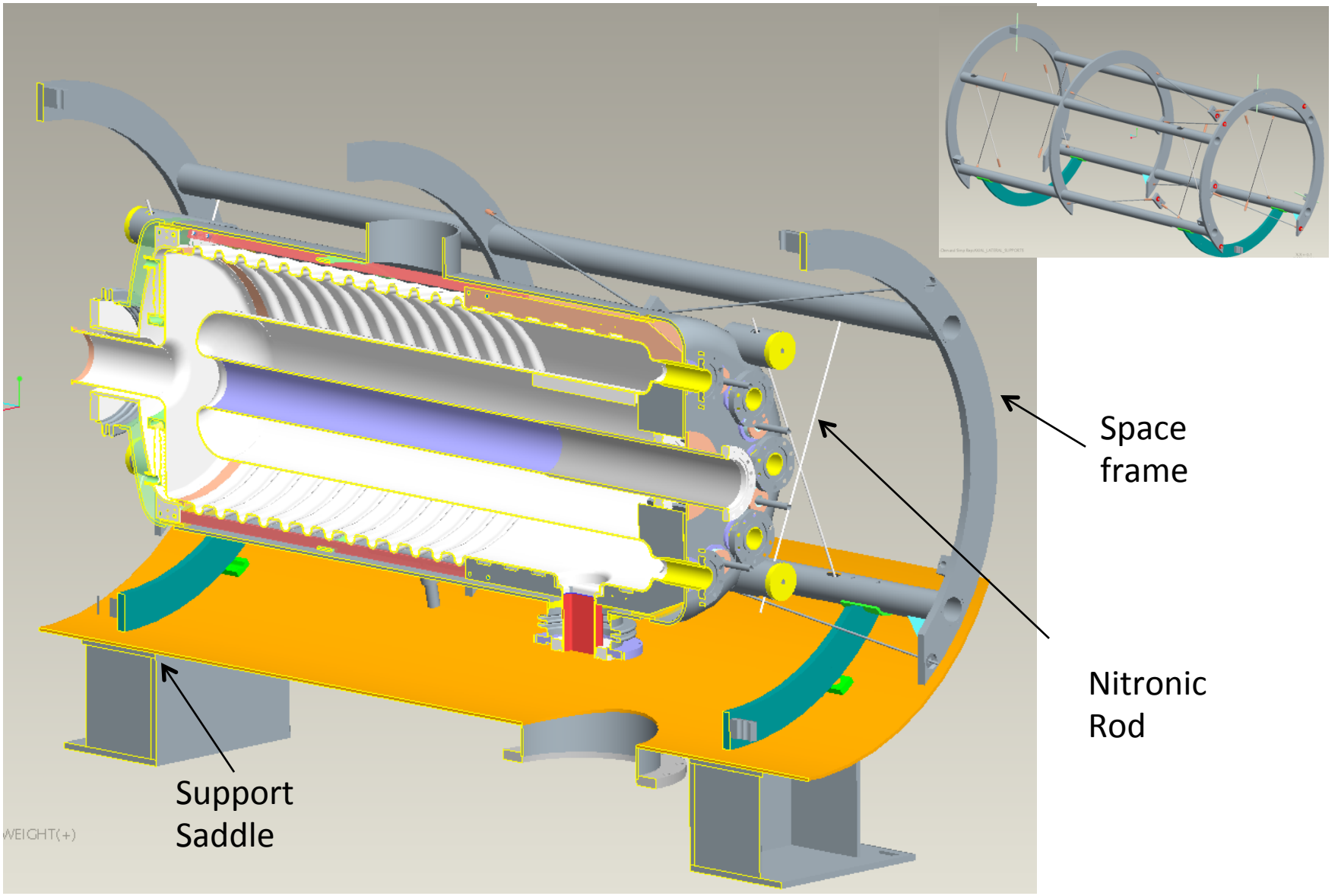


Total Weight estimate of 56 RF cavity cryostat

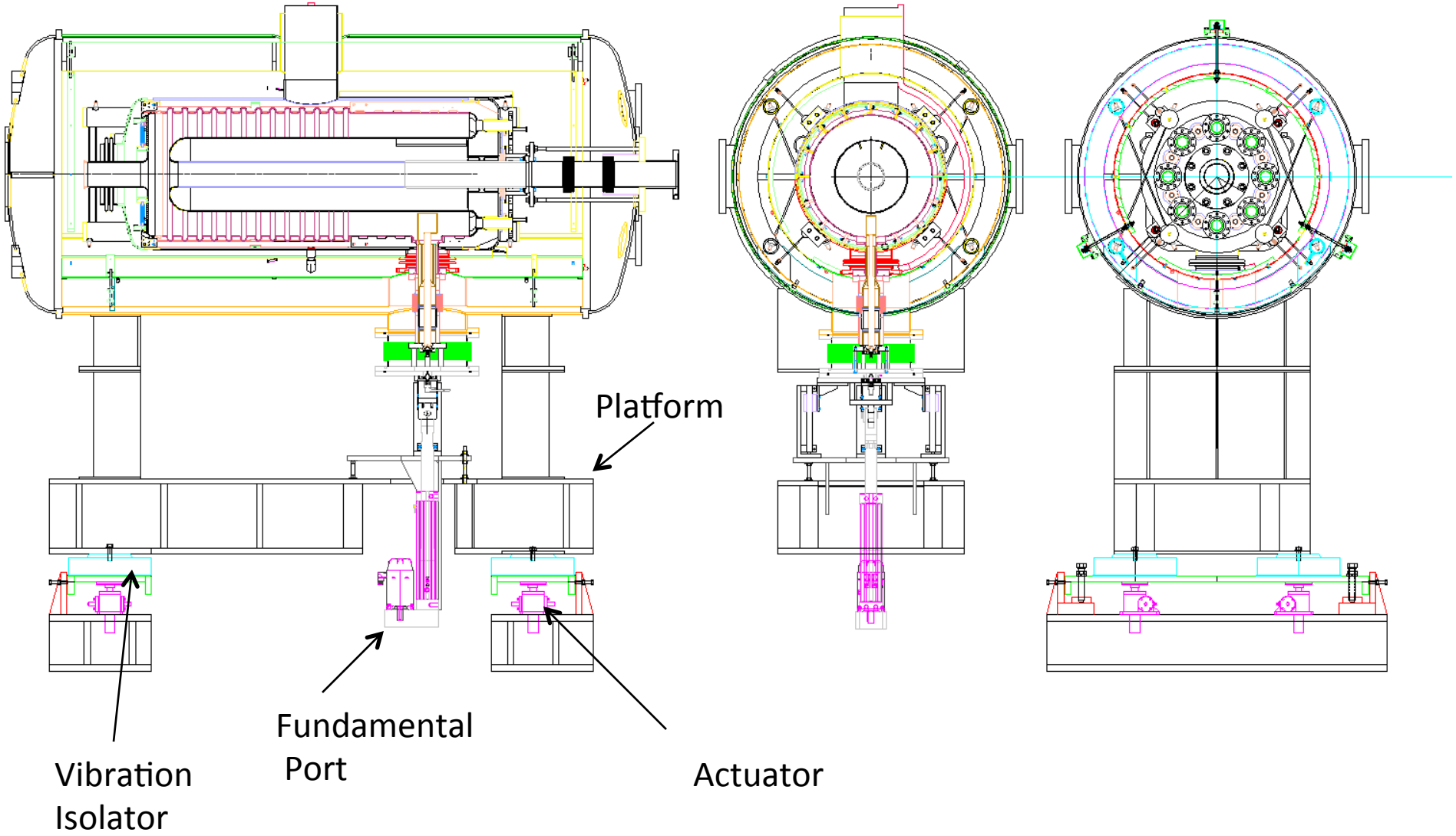
Niobium + Titanium Vessel:	760 lb	
Tuner Linkage:	100 lb	
Space Frame:	400 lb	
Heat Shield:	150 lb	
Inner Magnetic Shield:	200 lb	
Outer Magnetic Shield:	250 lb	
Mis. :	240 lb	
Total Inside cryostat:		2100 lb
Vacuum Chamber:	1500 lb	
Tuner, 2nd stage	200 lb	
Thermal transition	500 lb	
Piping and Mis.	200 lb	
Total in Cryomodule:		4500 lb

Load Path in the 56 MHz Cryostat

Cavity → Nitronic Rods → Space Frame → Vacuum Chamber → Saddle Support

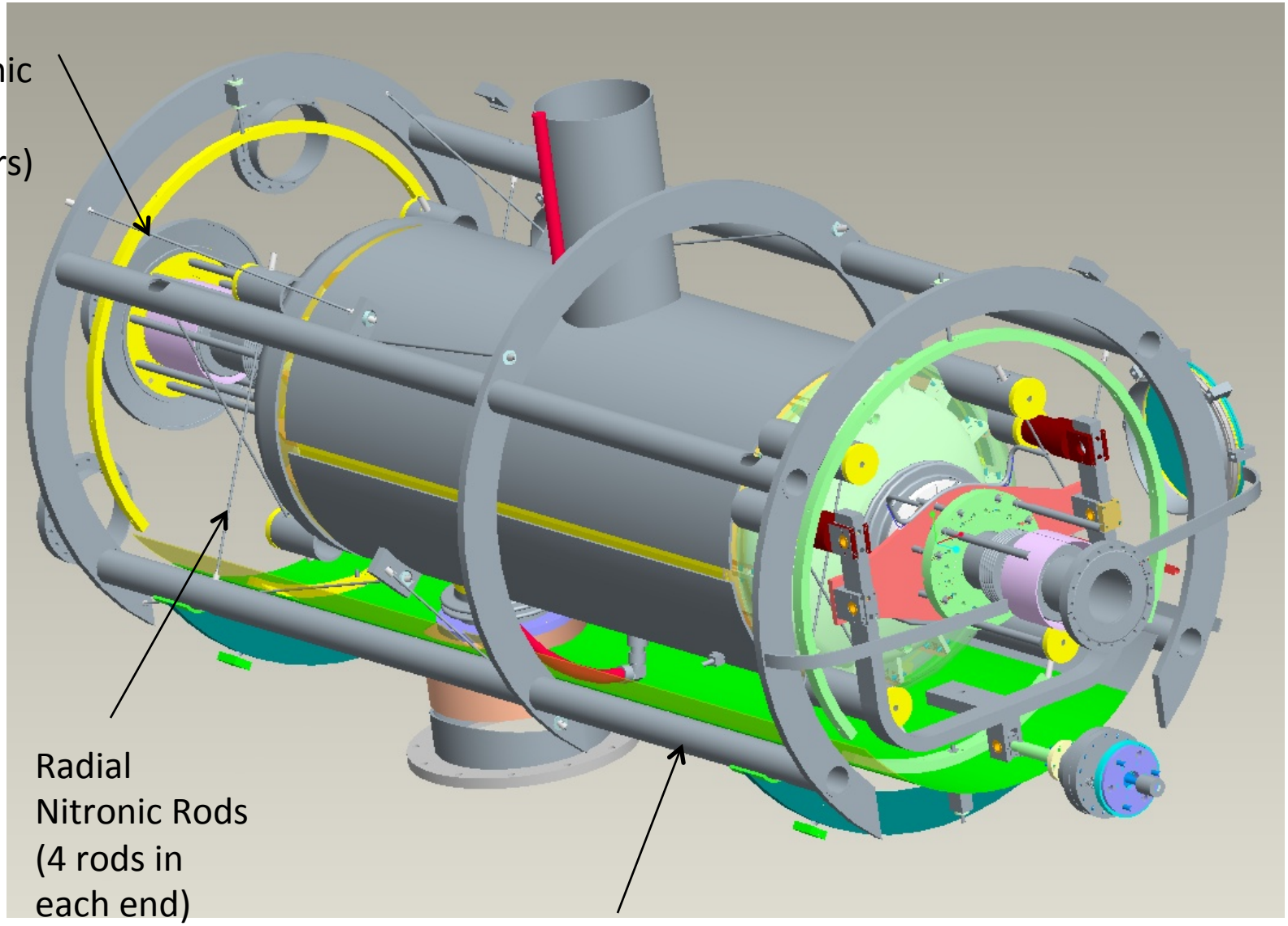


Cryostat Support Base



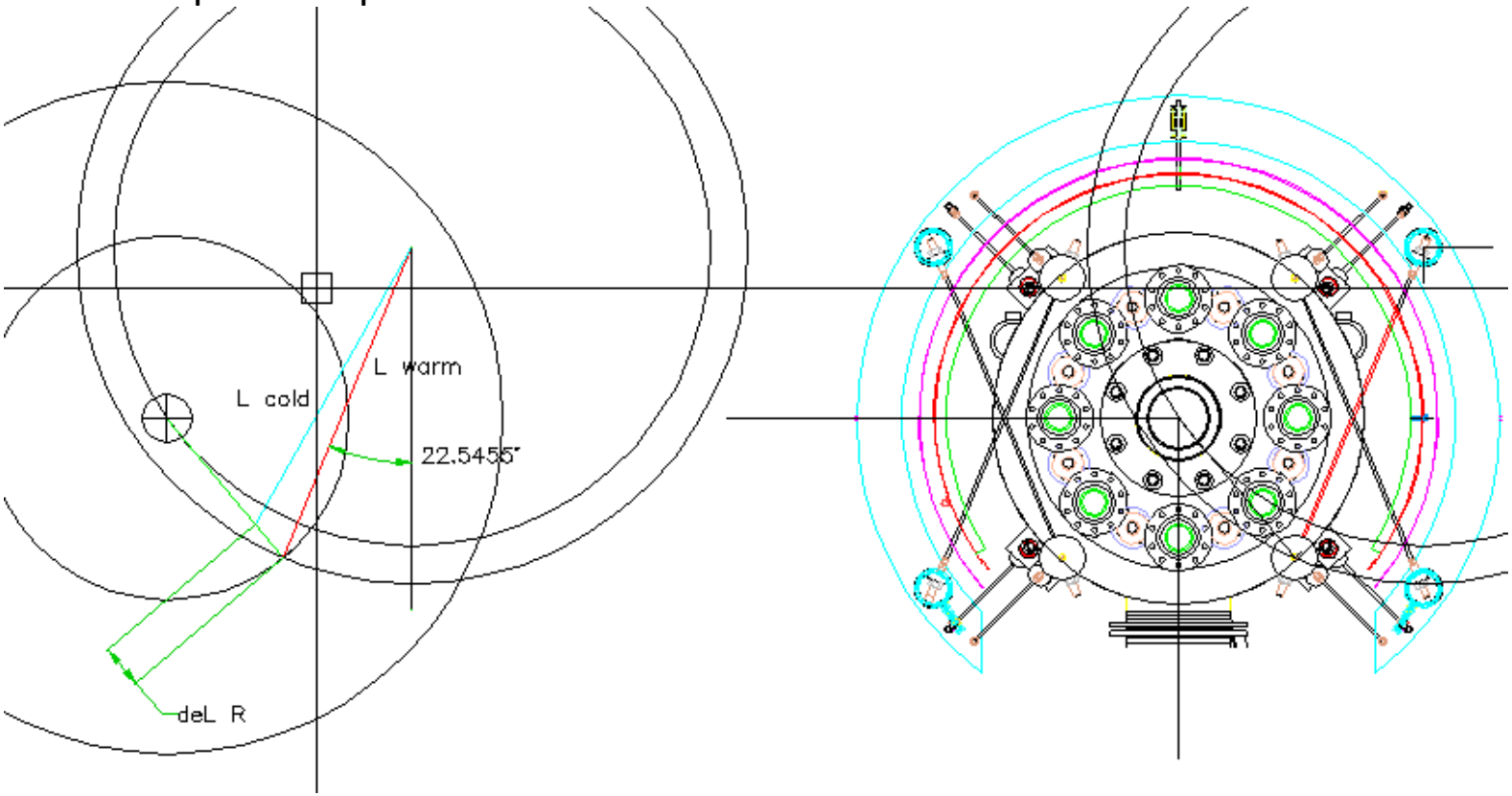
Nitronic Rod and Space Frame support system

SRF cavity Support, Space Frame with Nitronic Rods



Radial Nitronic rod shrinkage in cold temperature

1. Support Wight
2. Keep center position



1. Length of Rod:

   Warm: 22.158”

   Cold shrink: a. Due to Helium tank shrink: + .0085” too long (22.1498”)

   b. Due to Rod shrink: -.0339”

   Net shrink of rod: +.0085-.0339= -.0254” (D)

Stiffness and Force Induced in Radial Nitronic Rod

Stiffness of Rod: 37,909 lb/in (K)

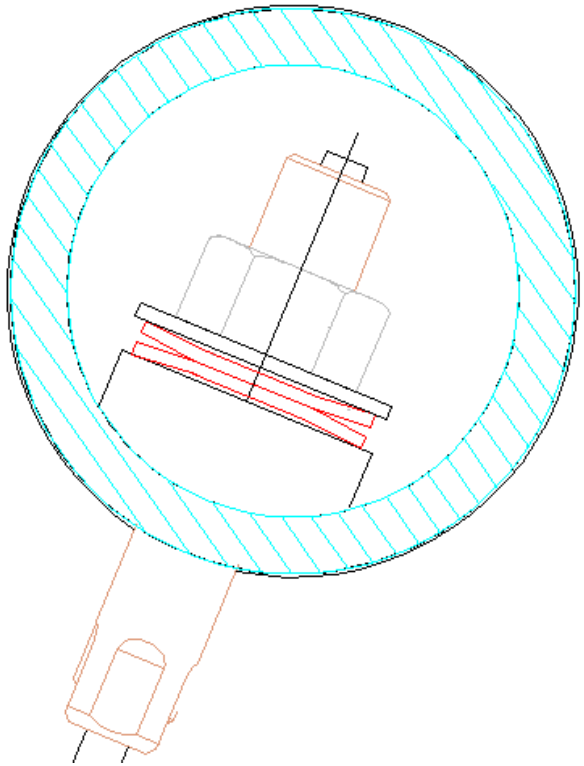
Stiffness of spring
Parts No. 9713K81
Quantity: 2
Load at 1/2 deflection =410 lb
K of spring =14642 lb/in

Combined stiffness of system:
K=10562 lb/in

Force induced in the rod:
F= 268 lb

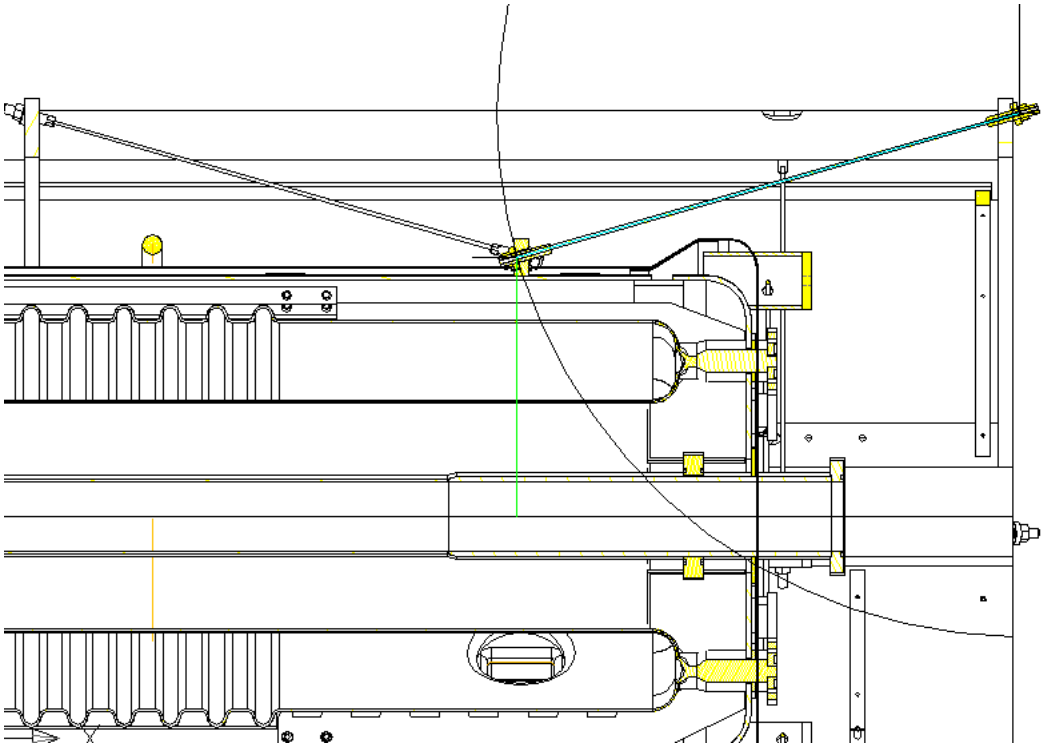
Weight in each rod: 225 lb

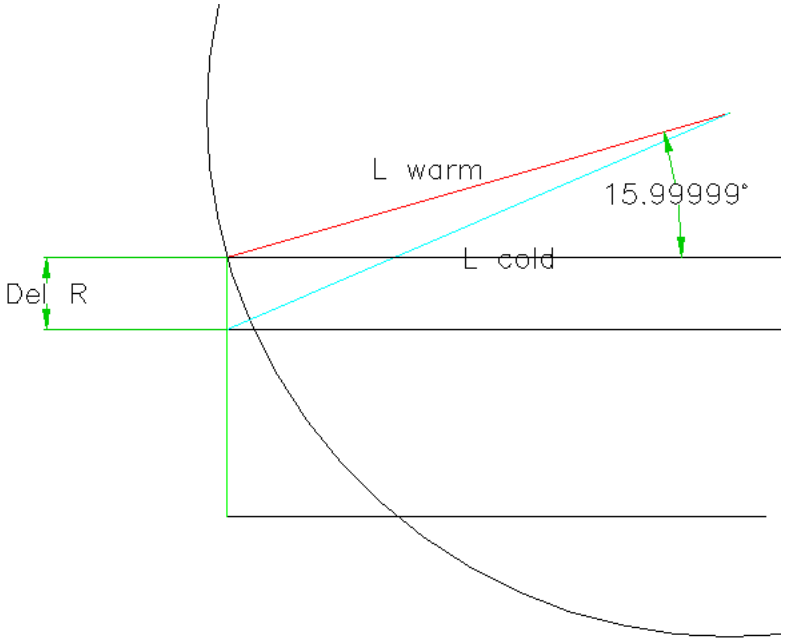
Total Force in each Rod: 500 lb



Axial Nitronic rod shrinkage in cold temperature

1. Resist Tuning Force
2. Keep Axial position (along beam line)





1. Length of Rod:
   Warm: 26.5875”
   Cold shrink: a. Due to Helium tank shrink: - .0054” (26.5929”)
   b. Due Rod shrink: -.03988”
   Net shrink of rod: -.0054-.03988= -.04528” (D)

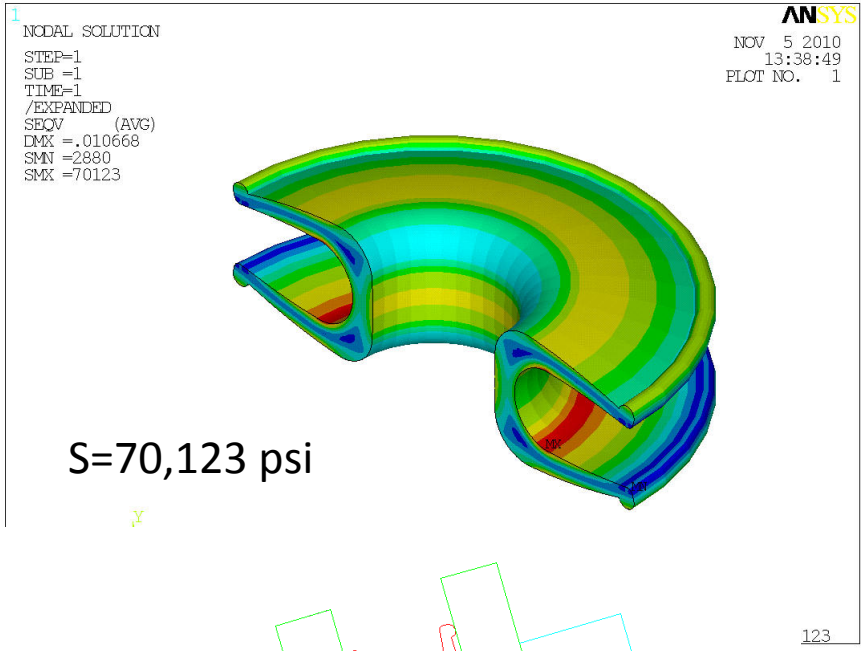
Stiffness and Force Induced in Axial Nitronic Rod

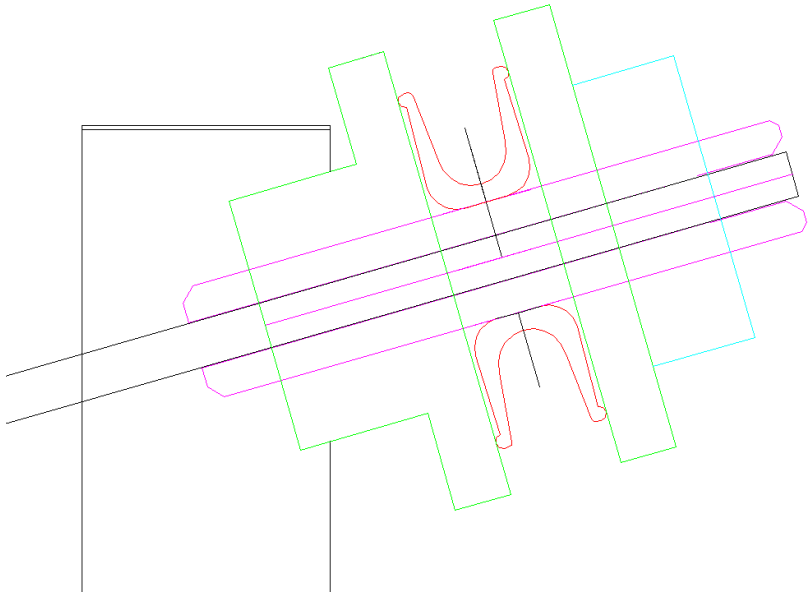
Stiffness of Rod: 31,593 lb/in (K)

Torsional Spring:
Material: Ti-6Al-4V
Yield strength: 128,000 psi
K=840/.02=42,000 lb/in

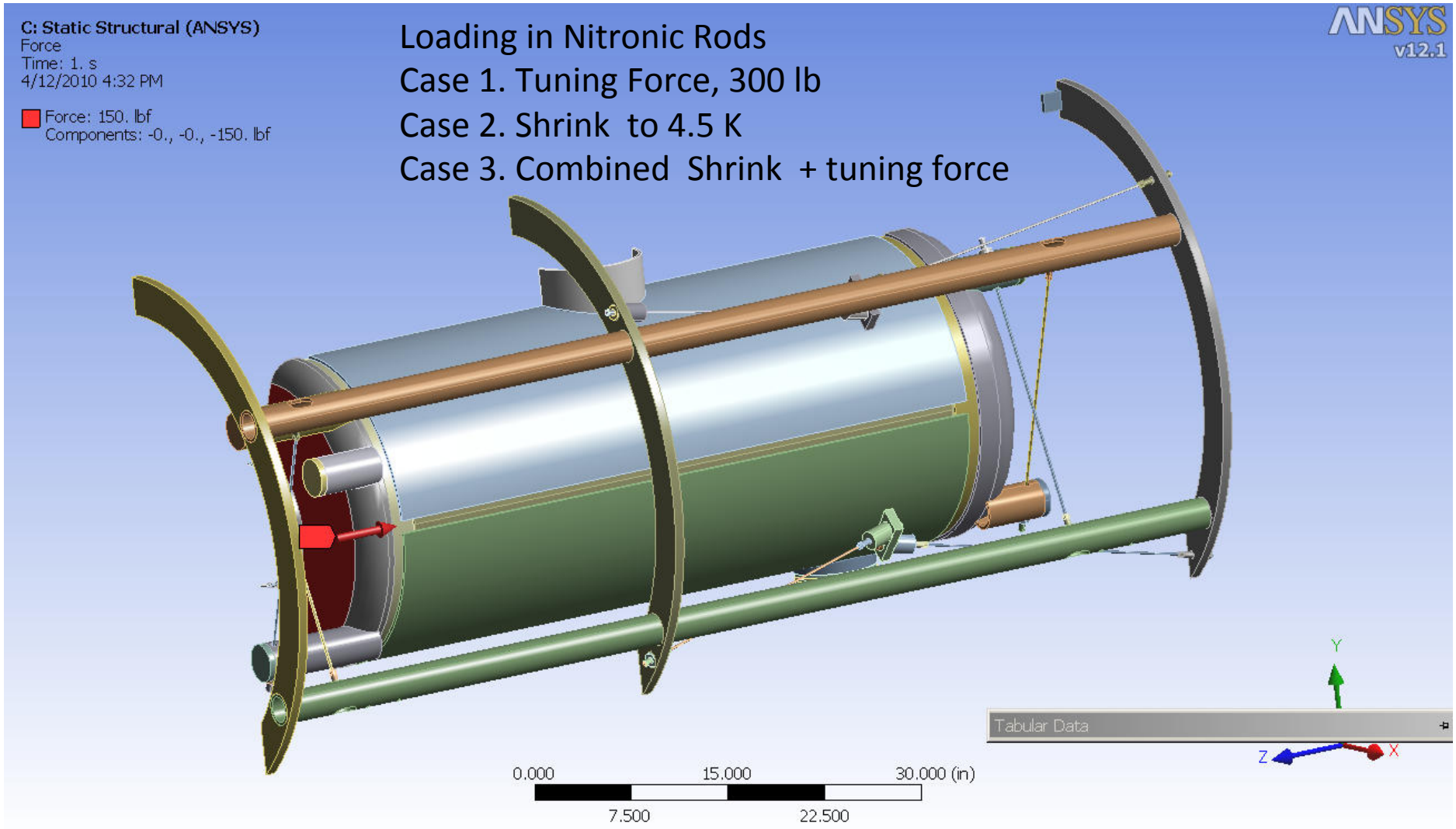
Combined stiffness of System:
K=18,117 lb/in

Force induced in the rod: F=K*D=
815 lb (@ 3/5 load)

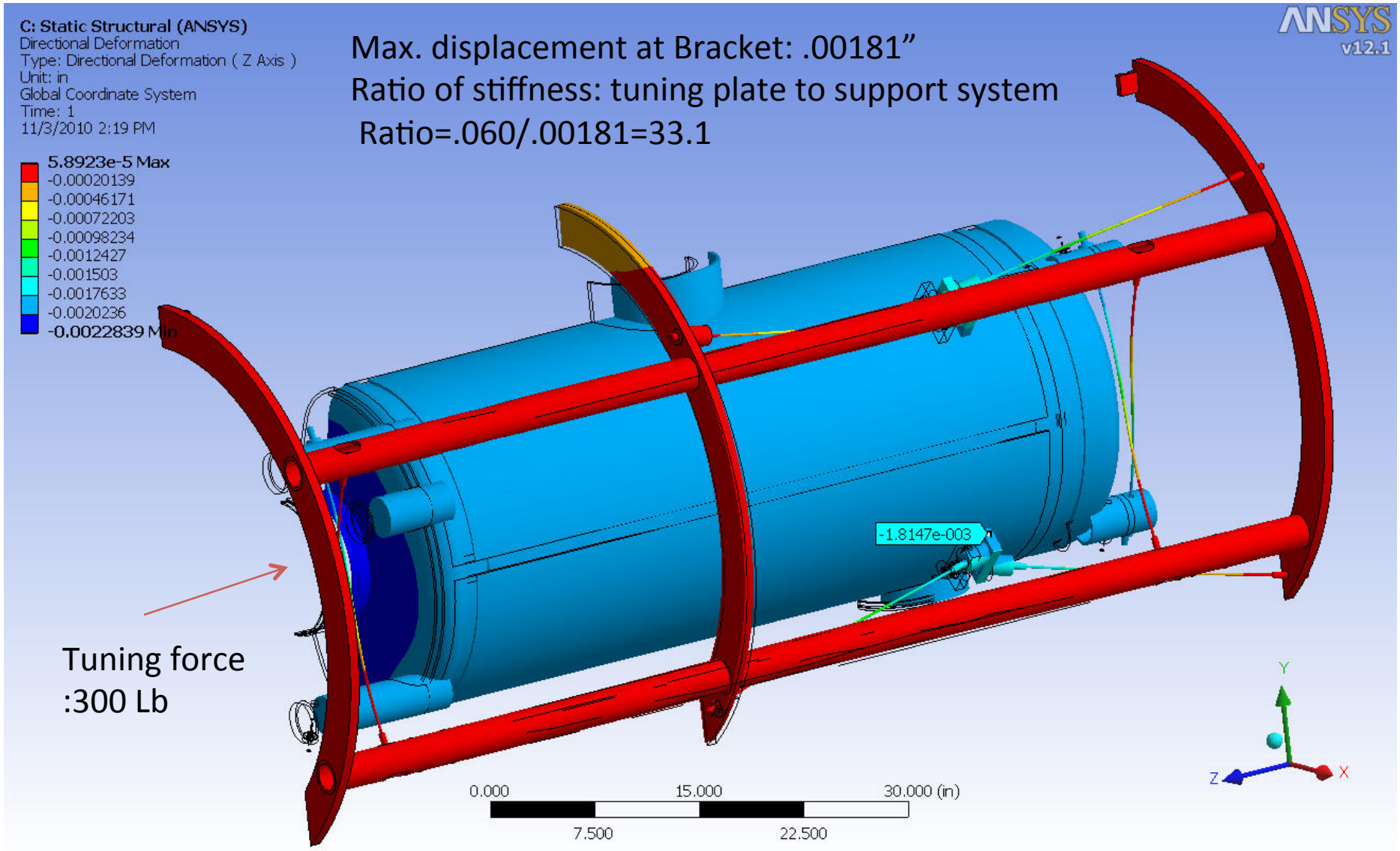




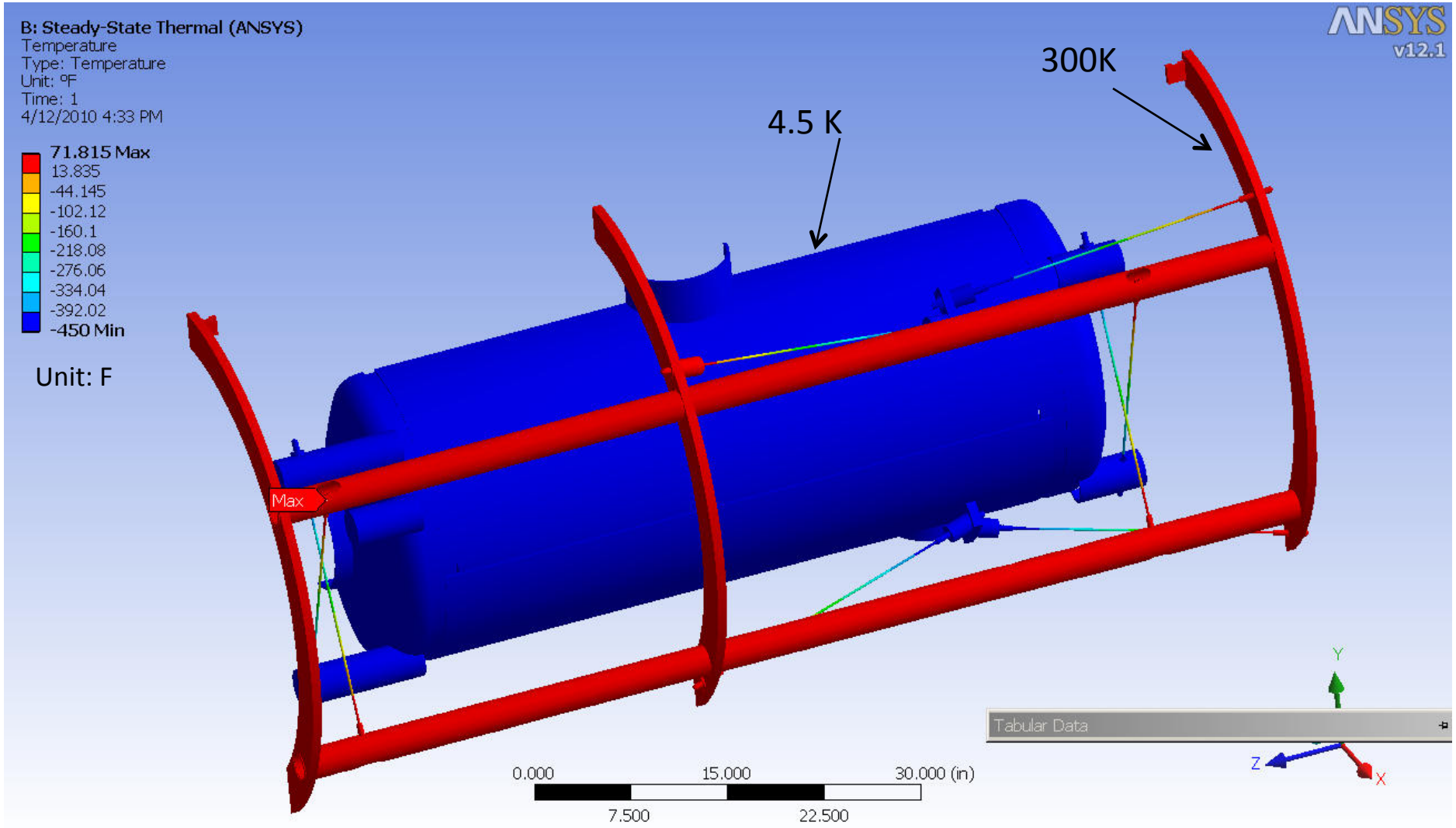
Simulation: Loading in the Nitronic rods



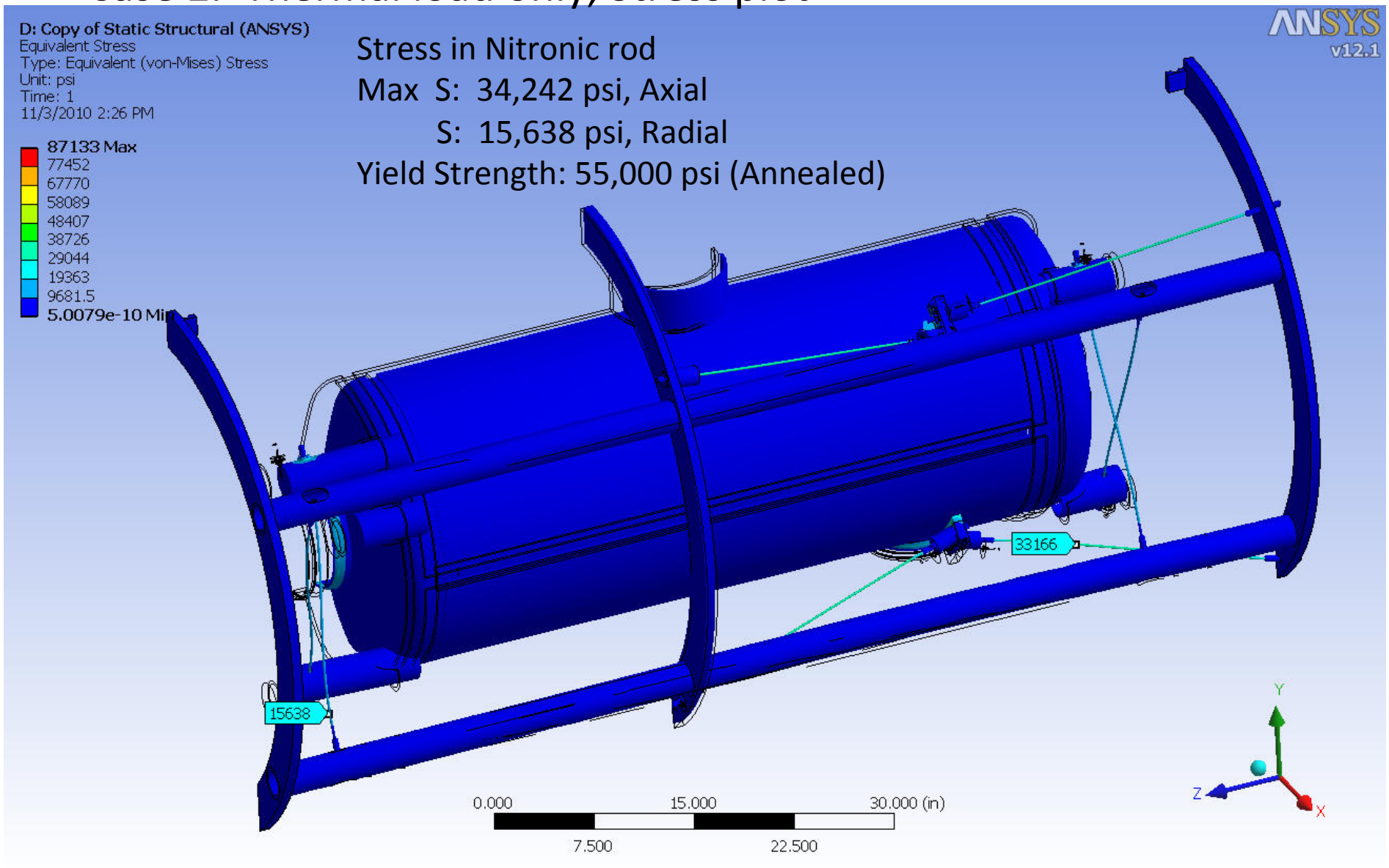
Case 1. Displacement Plot, Under tuning force only



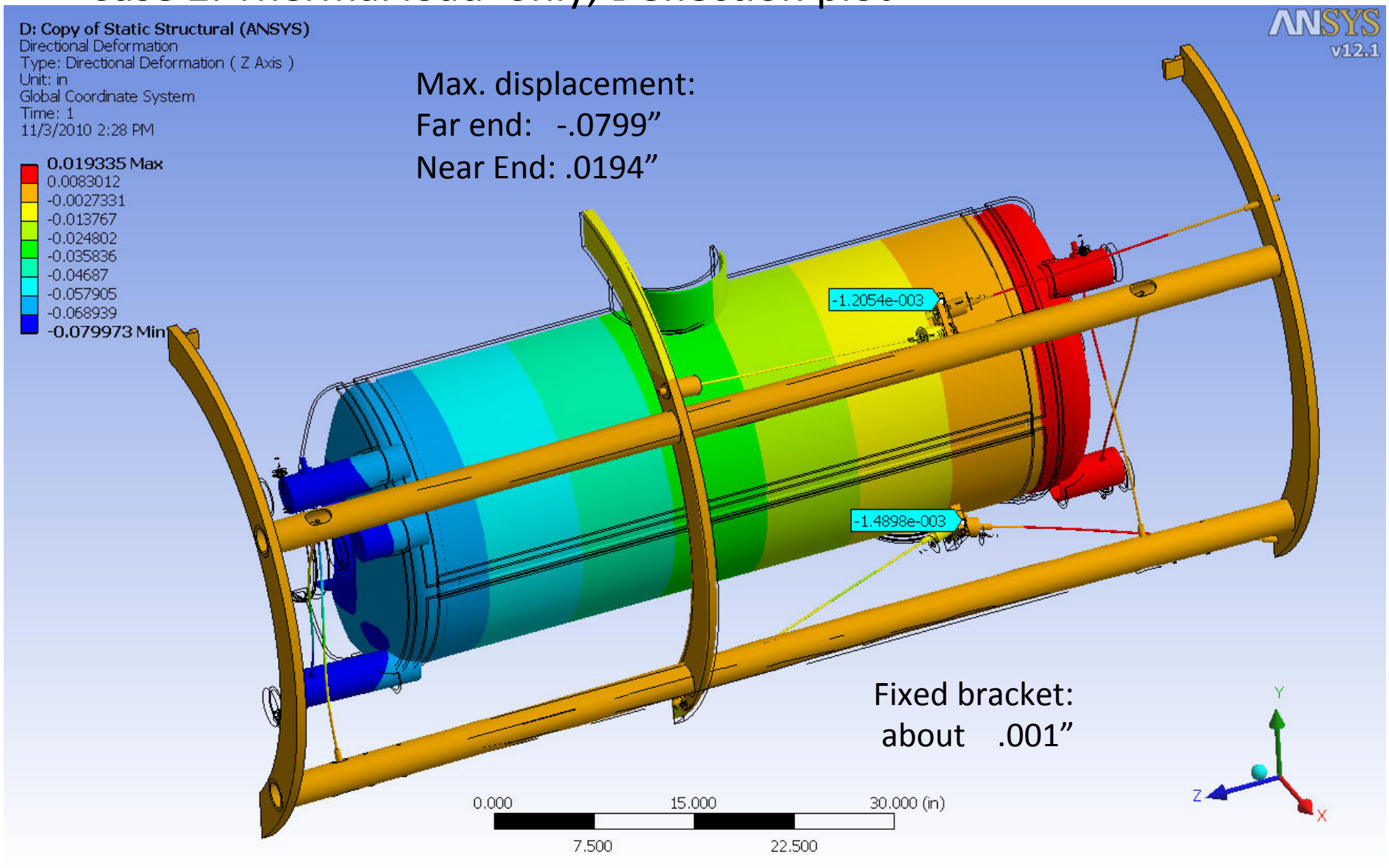
Case 2. Temperature distribution in the support system



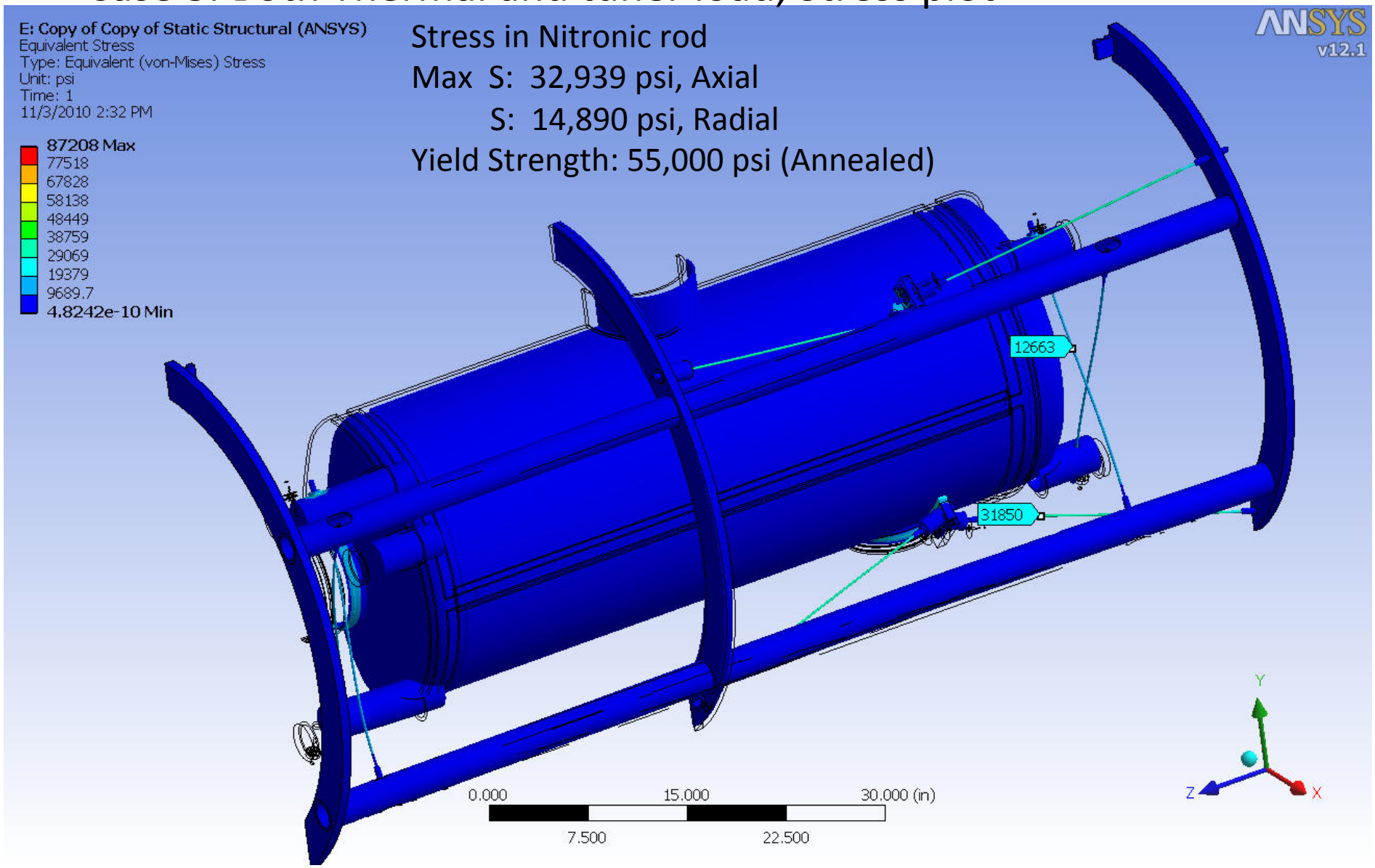
Case 2. Thermal load only, Stress plot



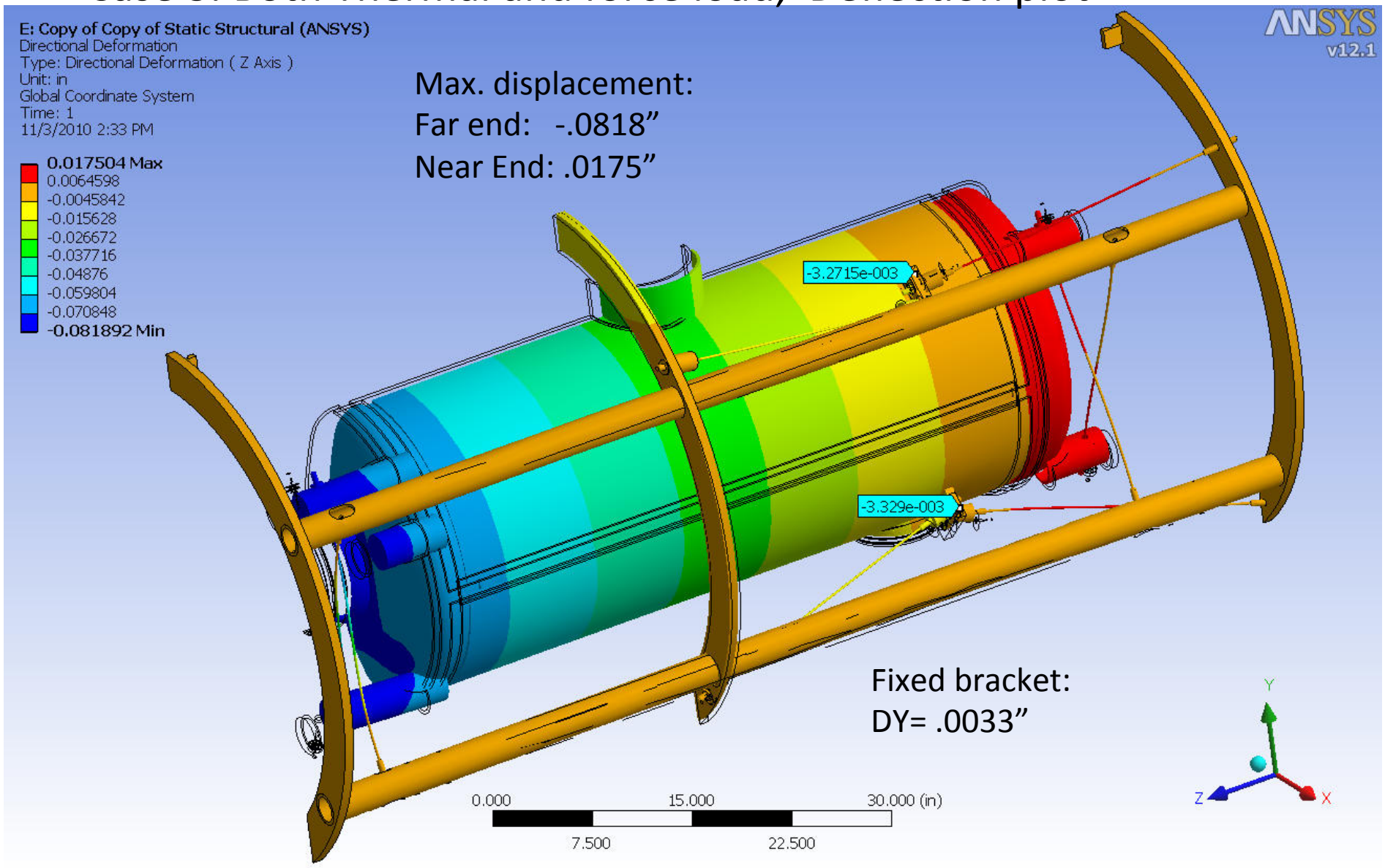
Case 2. Thermal load only, Deflection plot



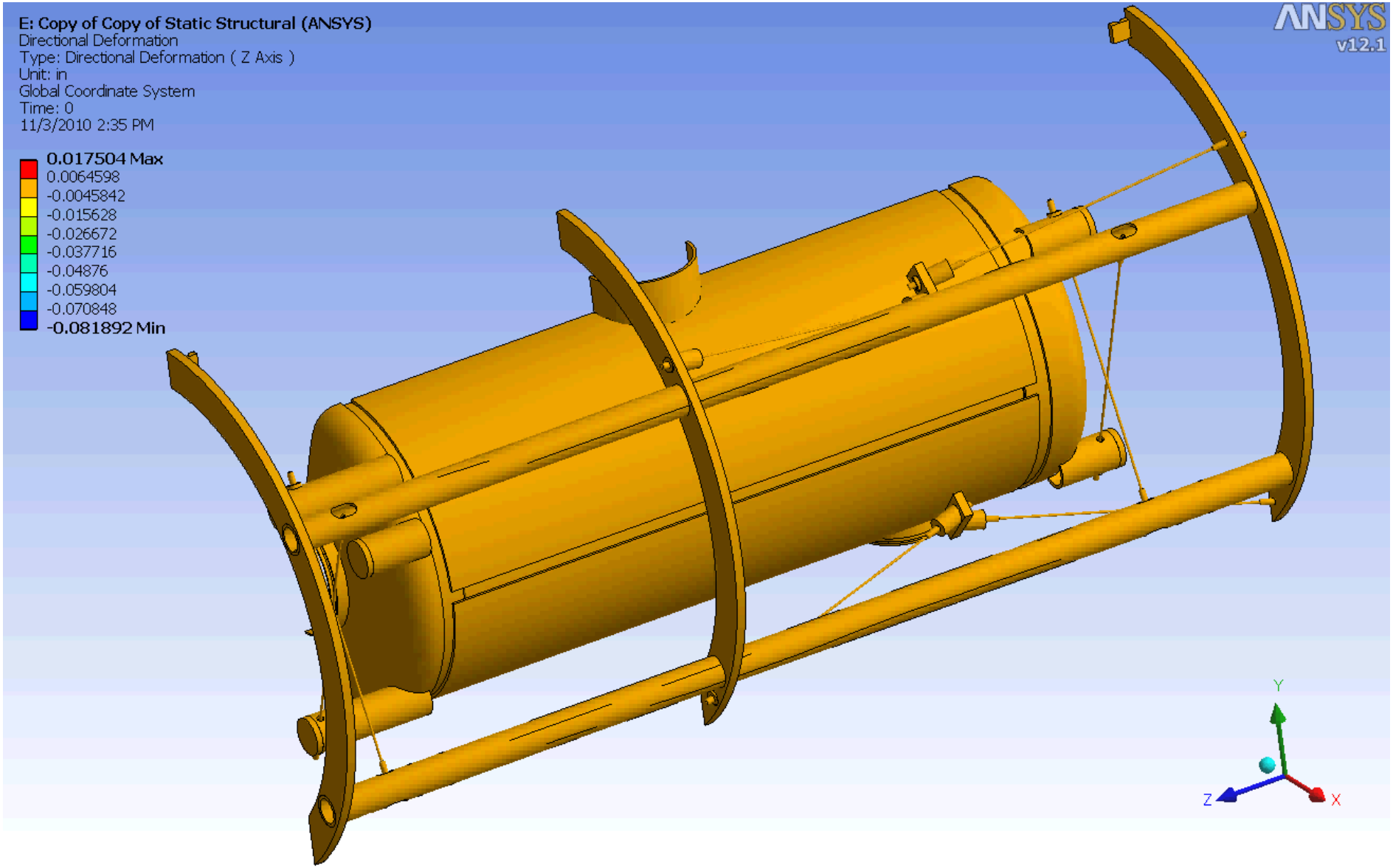
Case 3. Both Thermal and tuner load, Stress plot



Case 3. Both Thermal and force load, Deflection plot

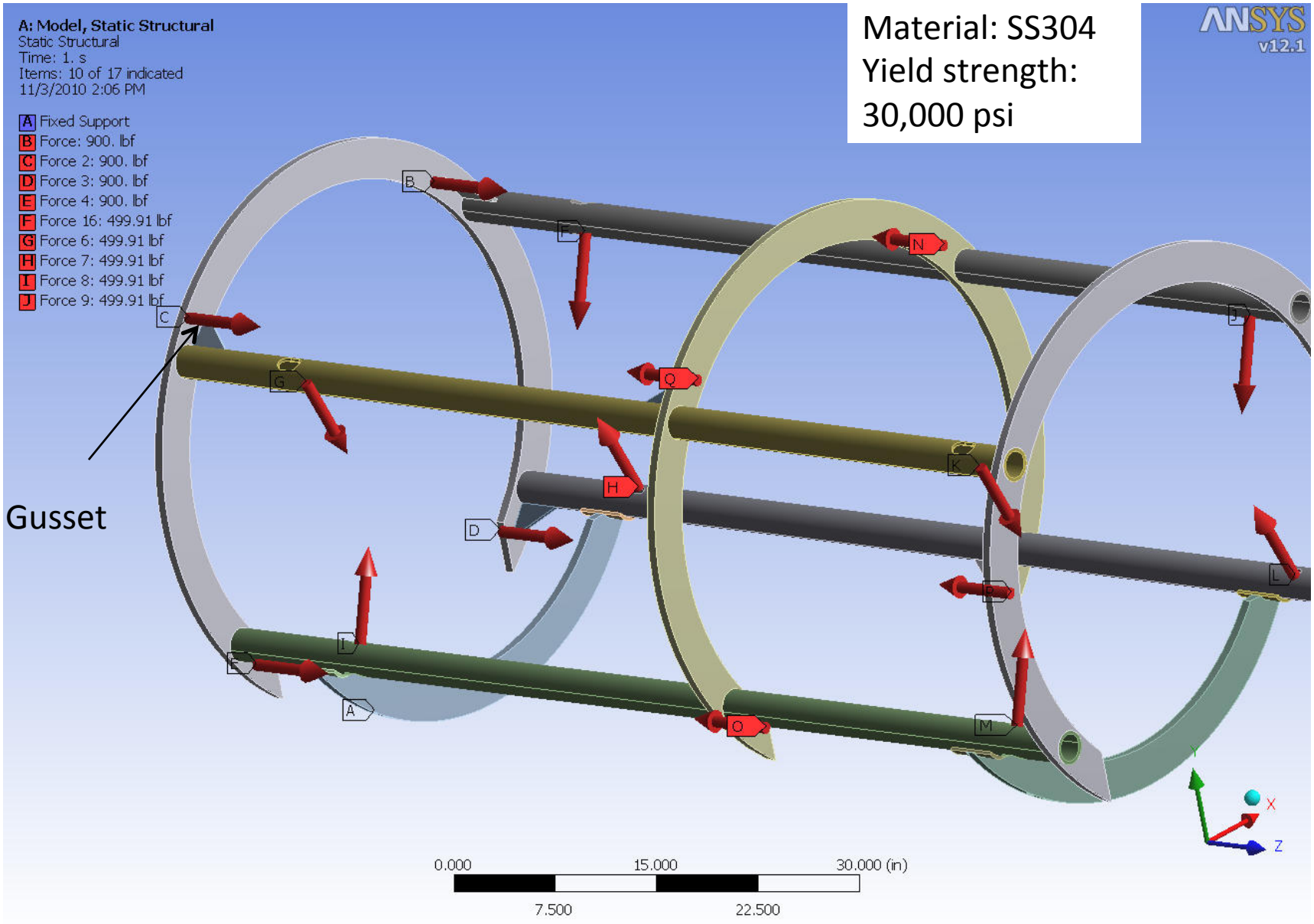


Animation

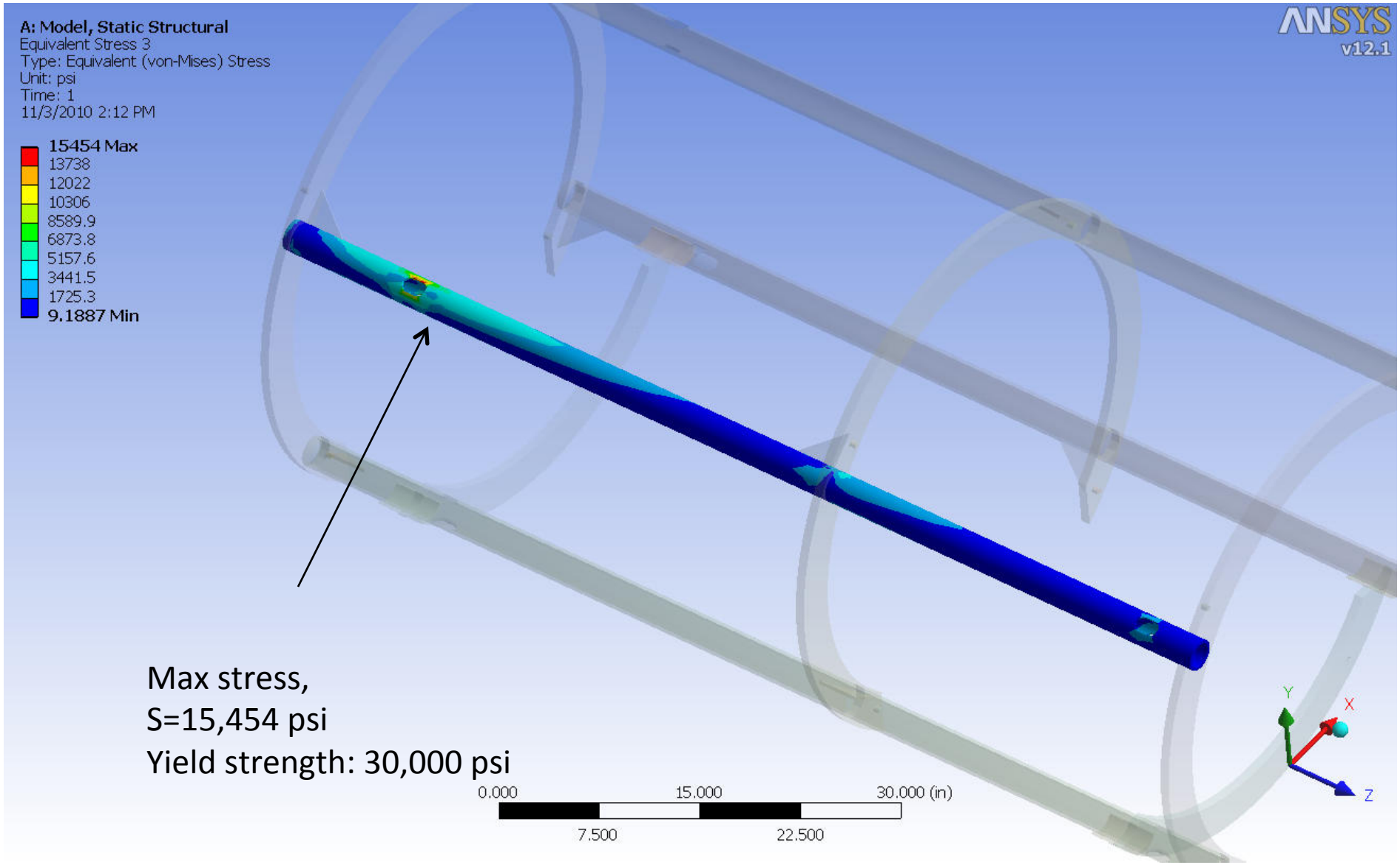

E: Copy of Copy of Static Structural (ANSYS)
Directional Deformation
Type: Directional Deformation (Z Axis)
Unit: in
Global Coordinate System
Time: 0
11/3/2010 2:35 PM
0.017504 Max
0.0064598
-0.0045842
-0.015628
-0.026672
-0.037716
-0.04876
-0.059804
-0.070848
-0.081892 Min
ANSYS
v12.1
Y
Z
X

Space Frame strength Calculation

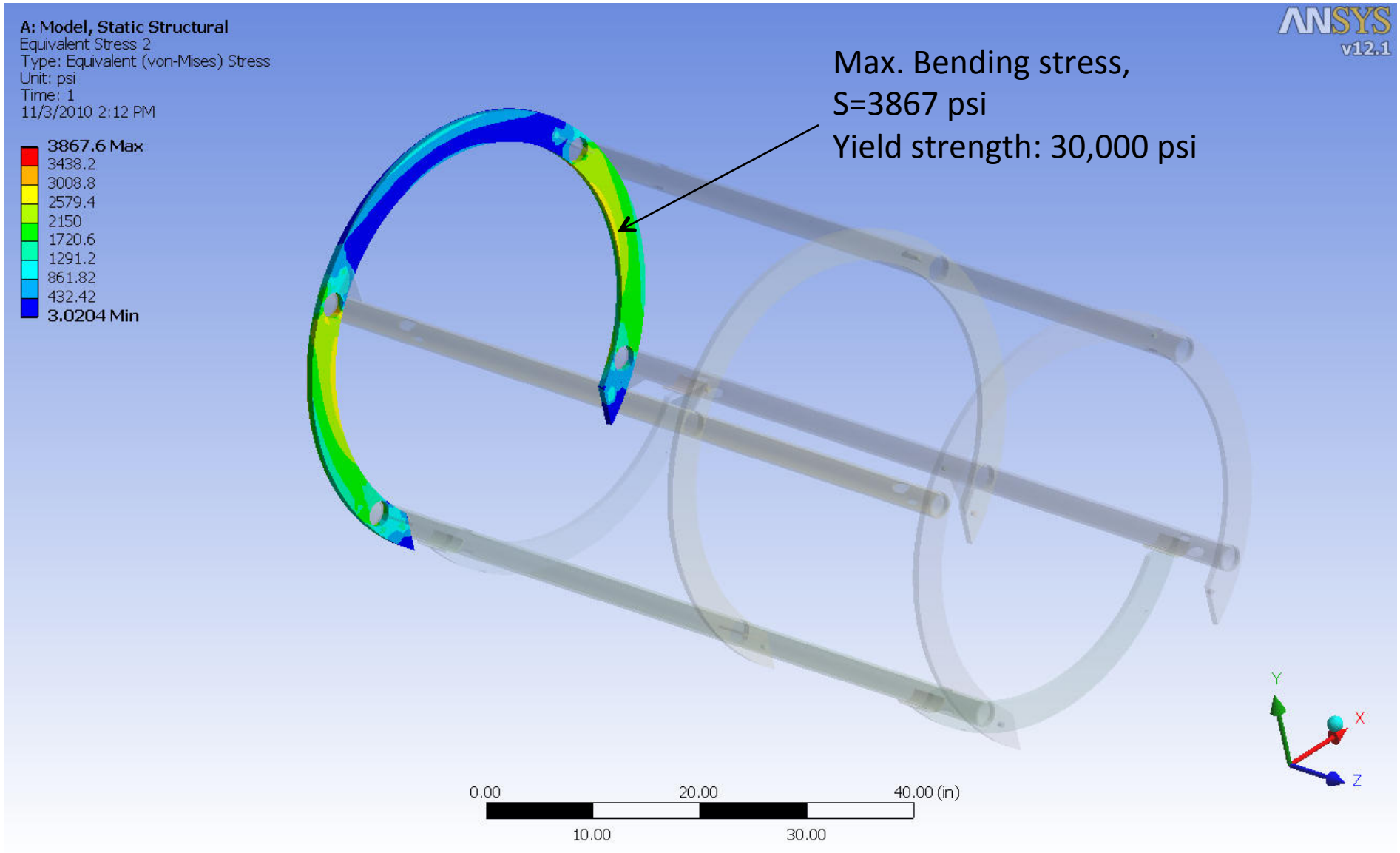
Space Frame strength Calculation
Model and Loading



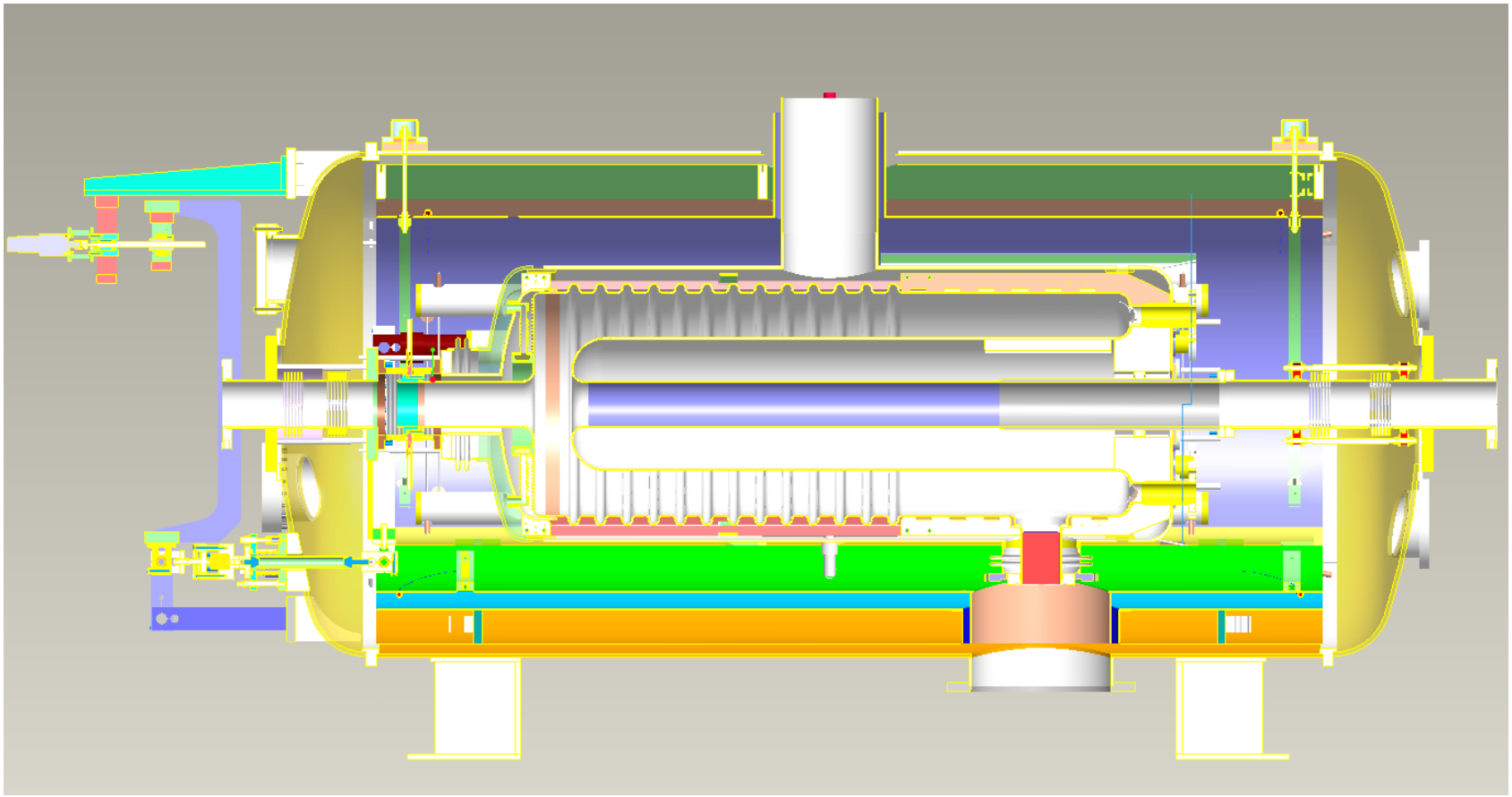
Von Mises Stress



Stress at end plate



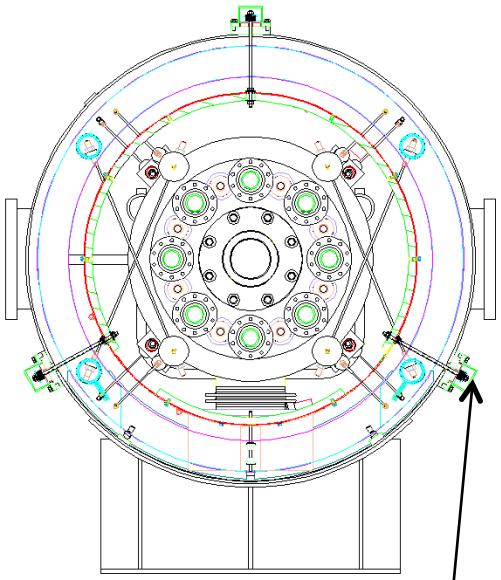
Heat shield, Inner and Outer Magnetic shields

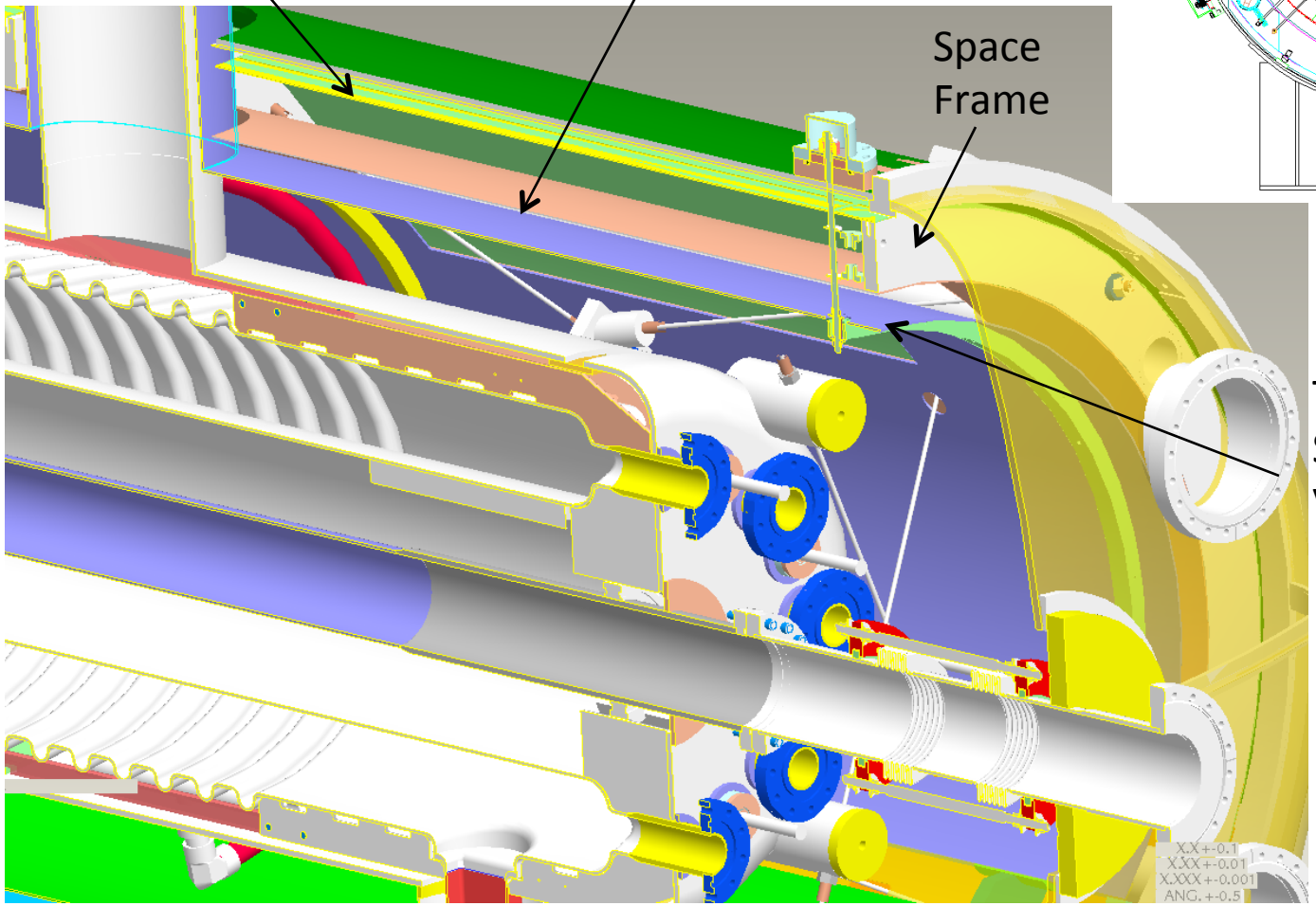


Cross section view of 3 shields

Outer magnetic shield
Outside of spaced frame

Inner magnetic shield
Inside of Space Frame





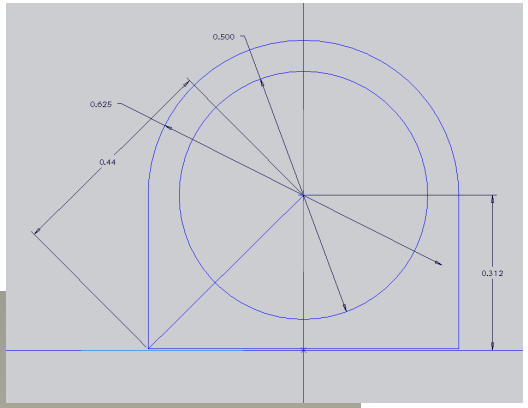
Thermal heat shield
Supported by
Vacuum chamber

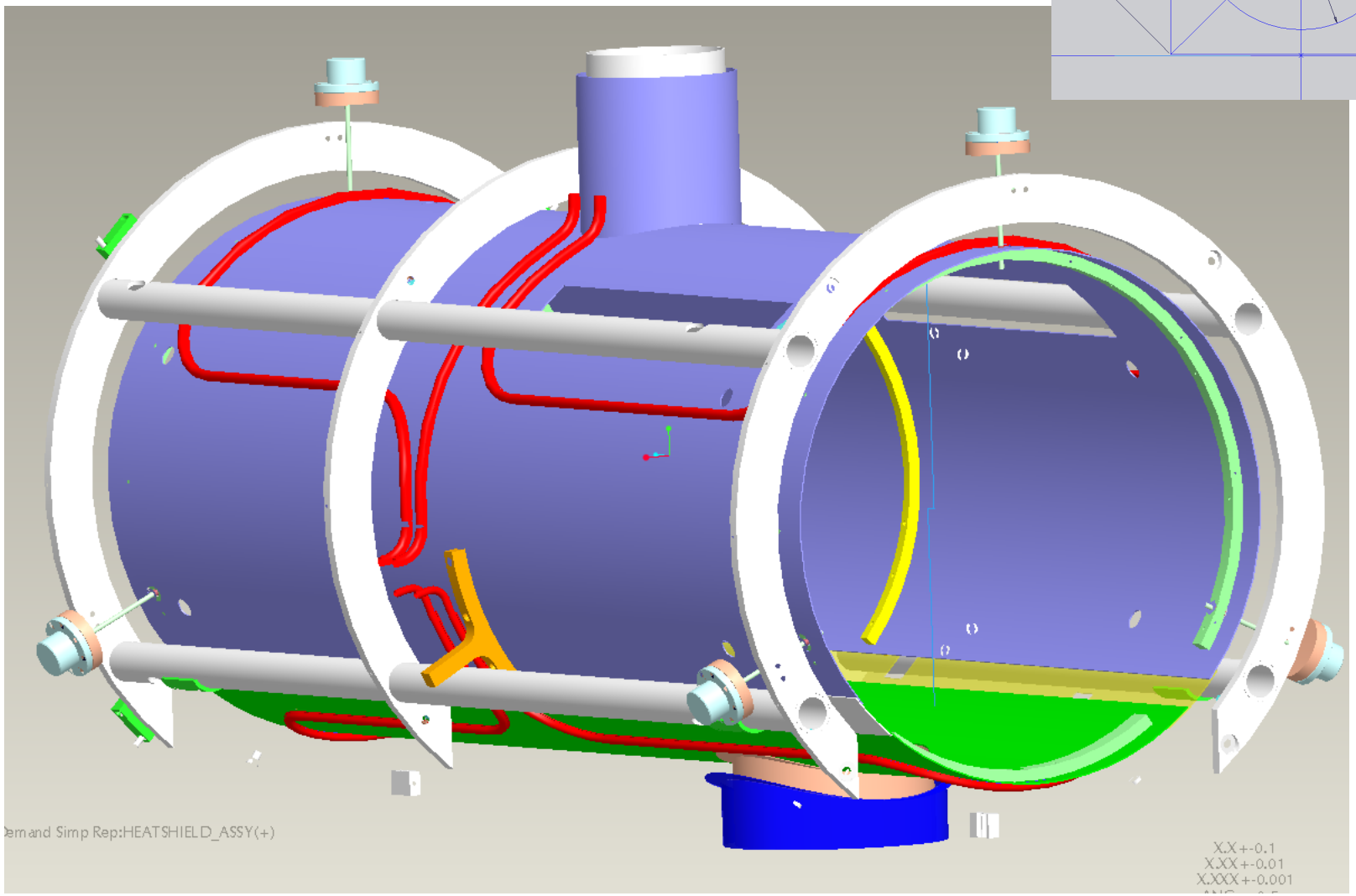
Thermal Heat Shield (aluminum, .080”)

Cooling Tube ID: 0.5” (aluminum extrusion)

Thickness for welding, t=.19”

Supported by Vacuum chamber

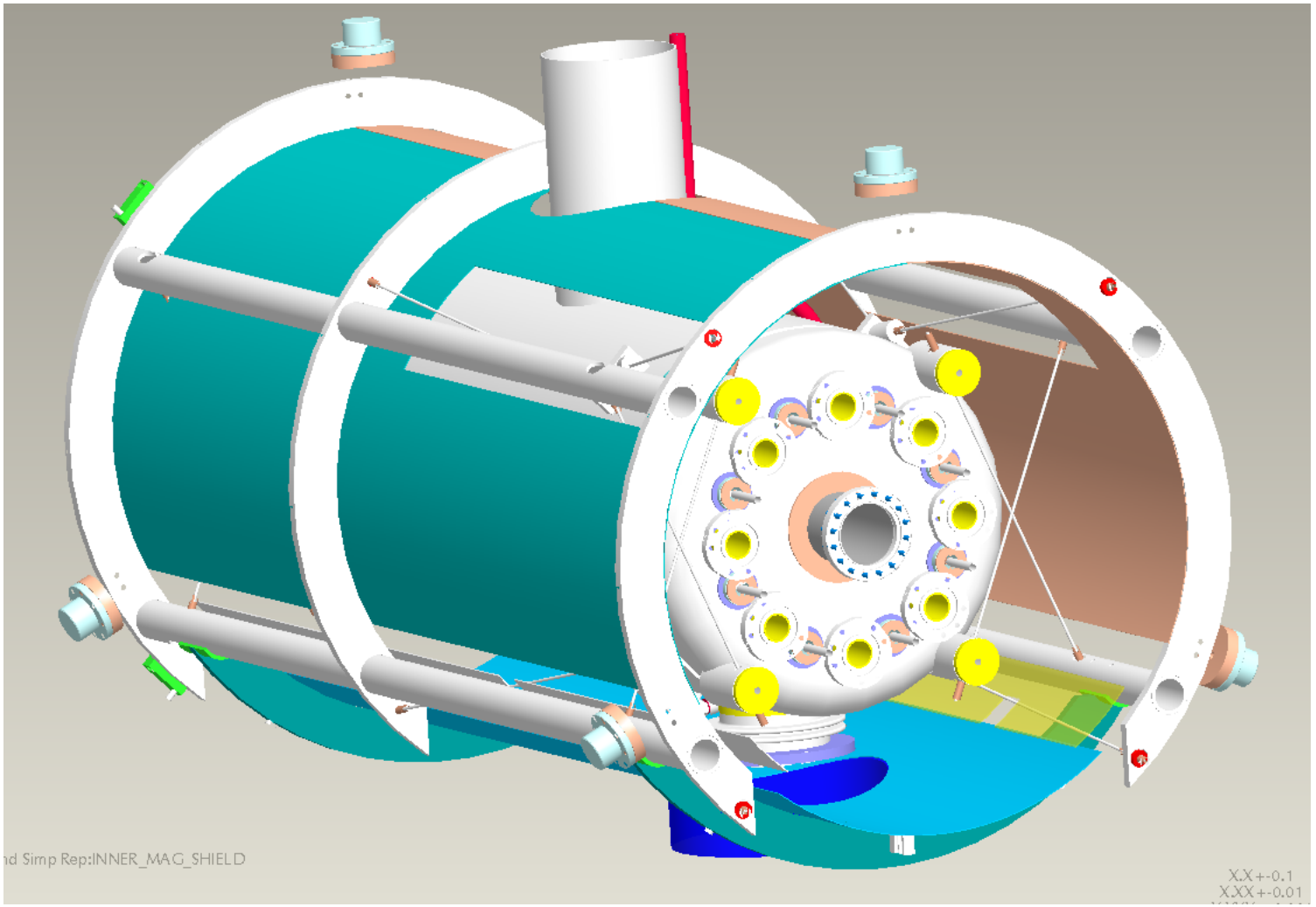




Inner Magnetic shield

Supported at inside of space frame

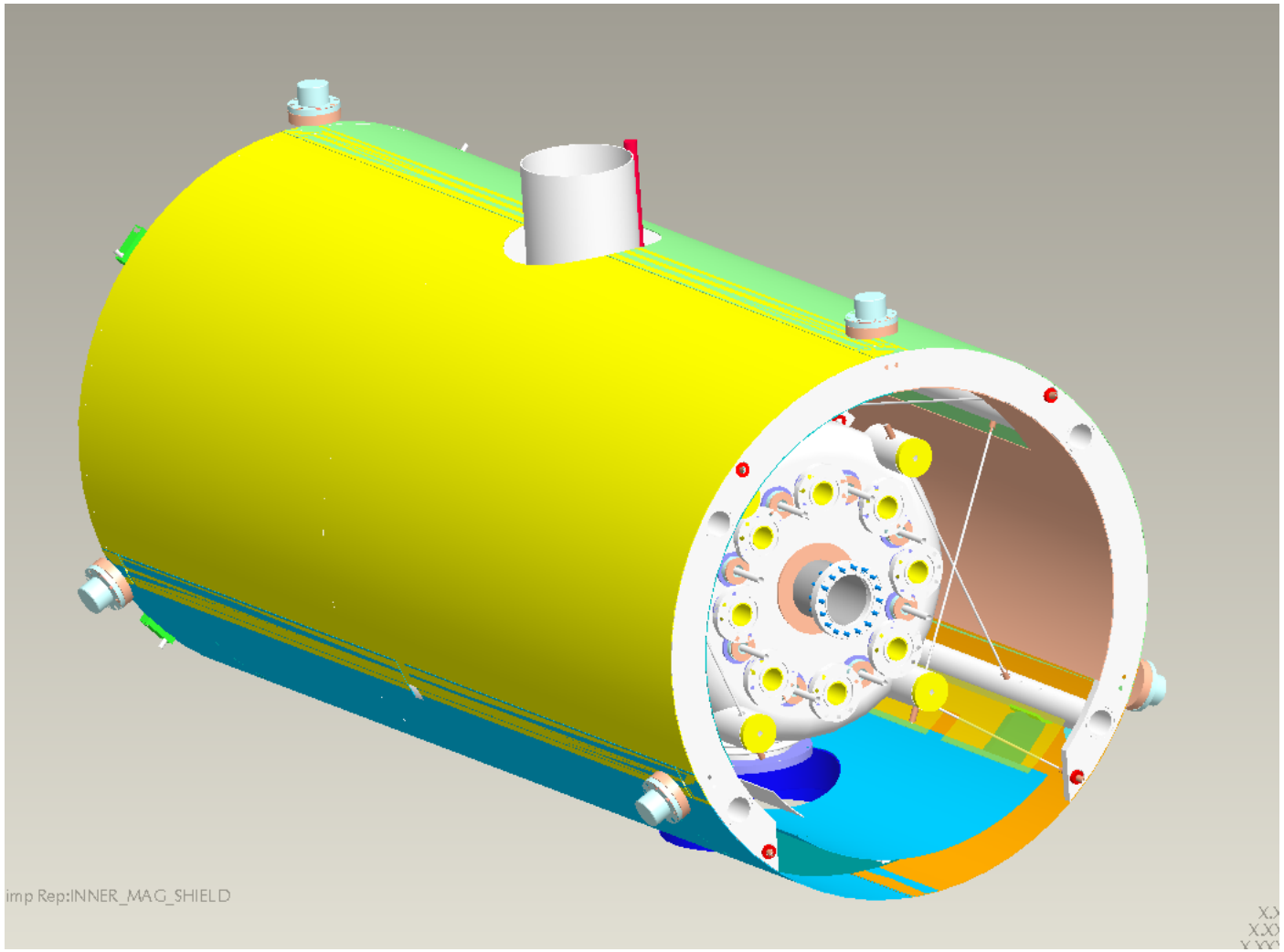
Amumetal, .062”, Room Temperature



Outer Magnetic Shield

Supported at outside of space frame

Amumetal, .062”, room temperature



Magnetic shielding effect: (Attenuation)

Magnetic shielding effect: (Attenuation)

Properties of Amumetal:

Mu=15,000, t= .0625”

Inner Radius: 18.148 in, Outer Radius: 21.25 in

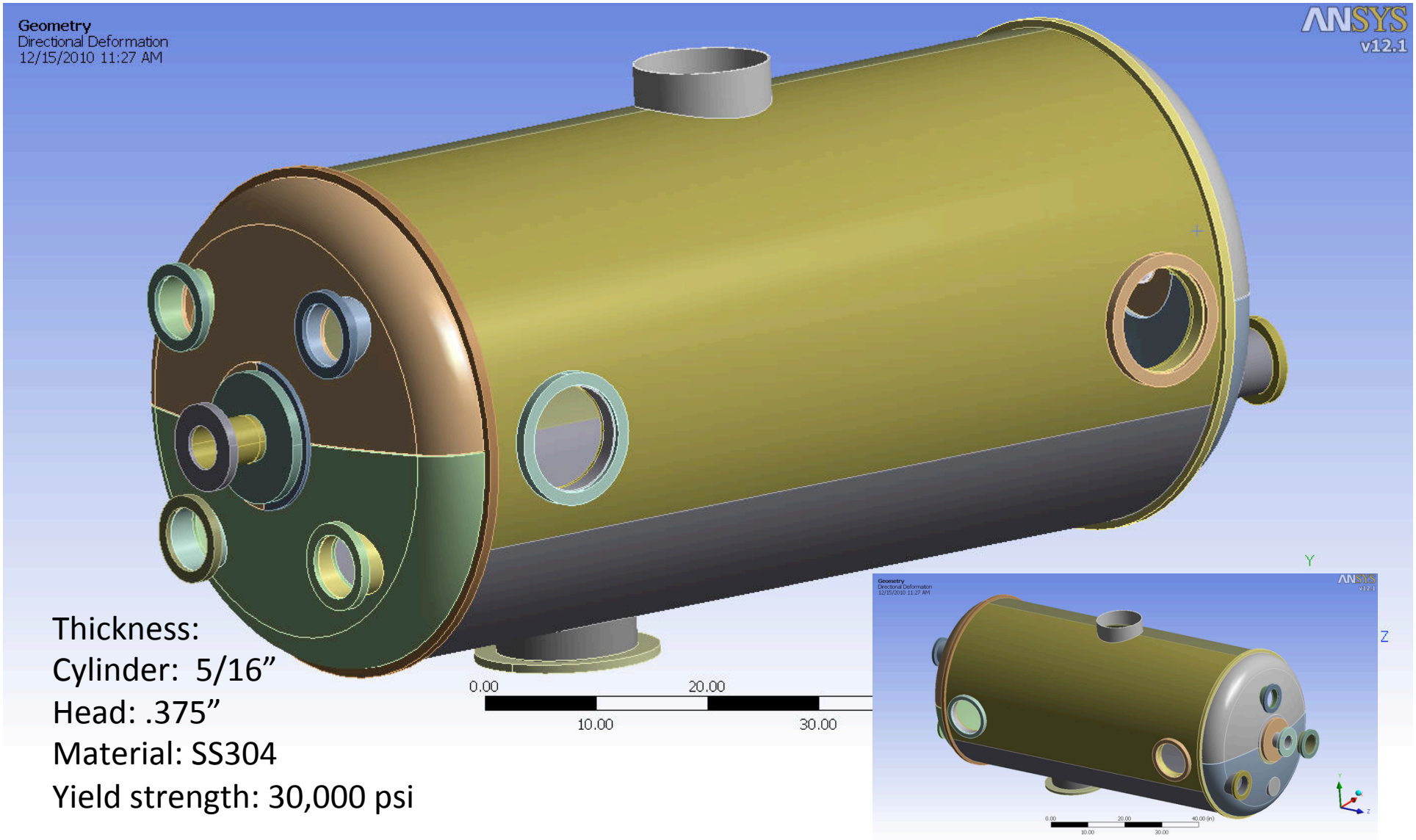
Attenuation of outer shield = 23

Attenuation of inner shield=26.7

Total combined Attenuation: 213

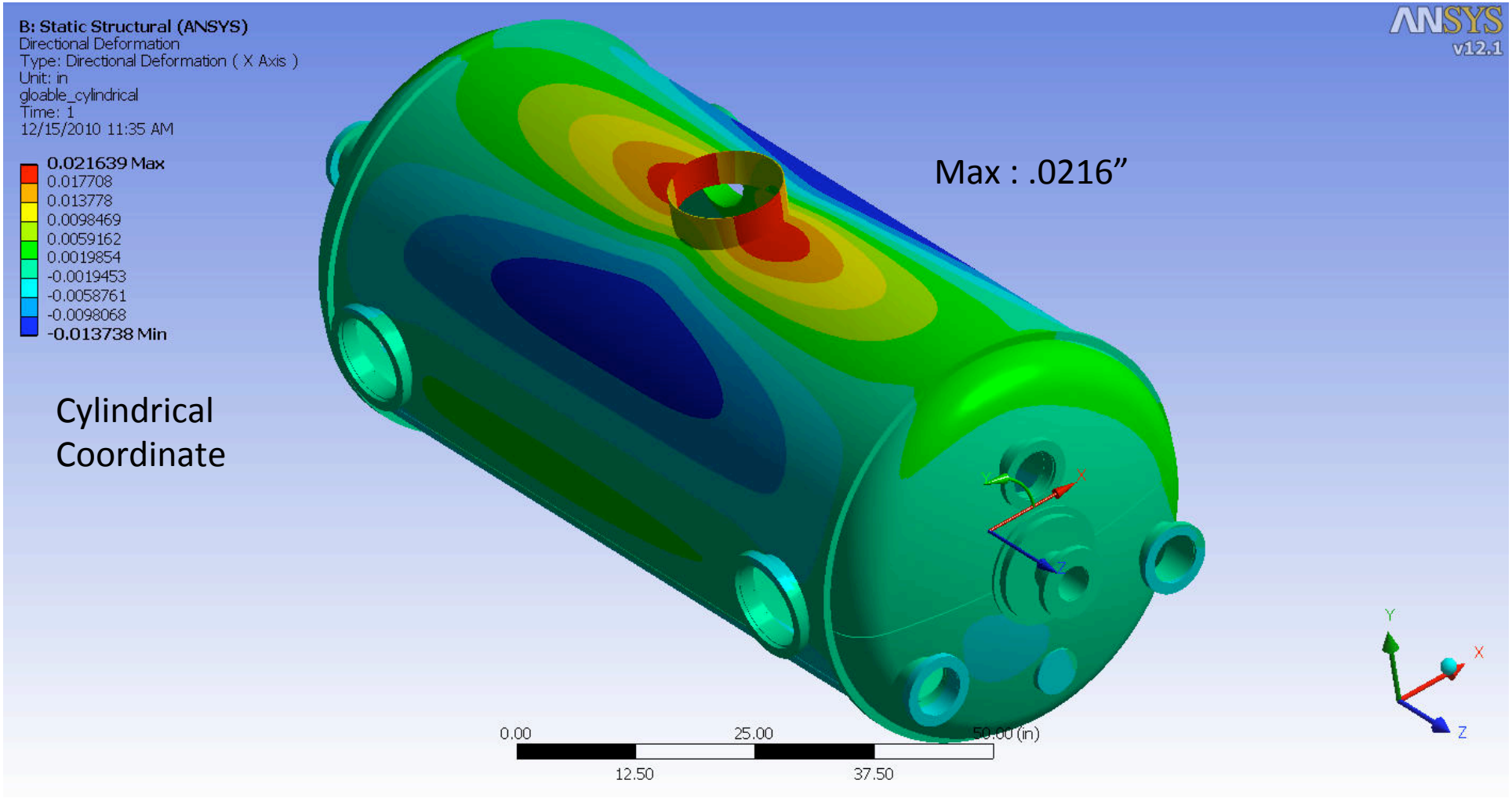
Effect: if stray magnetic field from DX magnet is 5 gauss,
the penetrated field to RF cavity is about .023 gauss.

Vacuum Chamber Strength

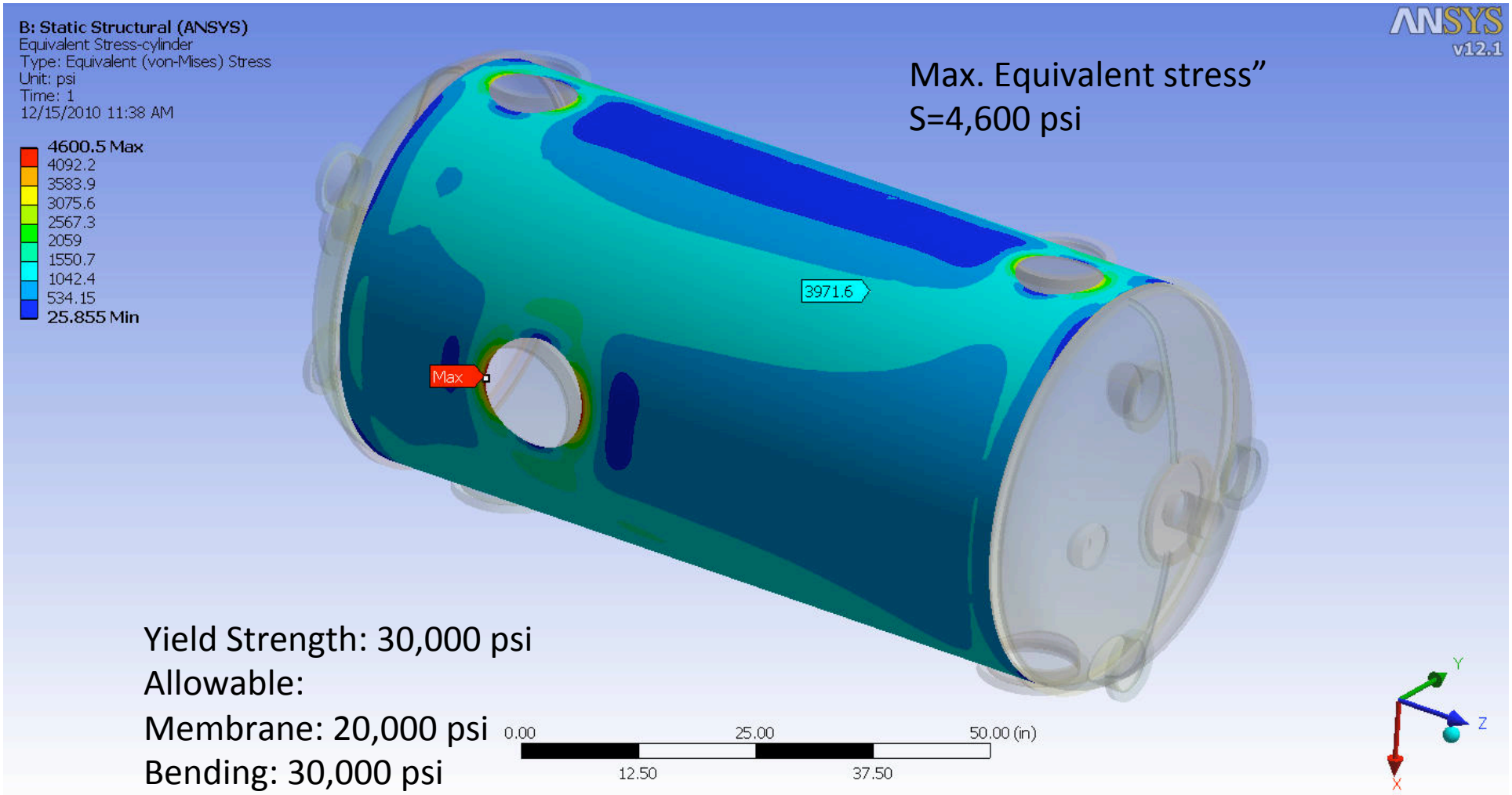


Thickness:
Cylinder: 5/16”
Head: .375”
Material: SS304
Yield strength: 30,000 psi

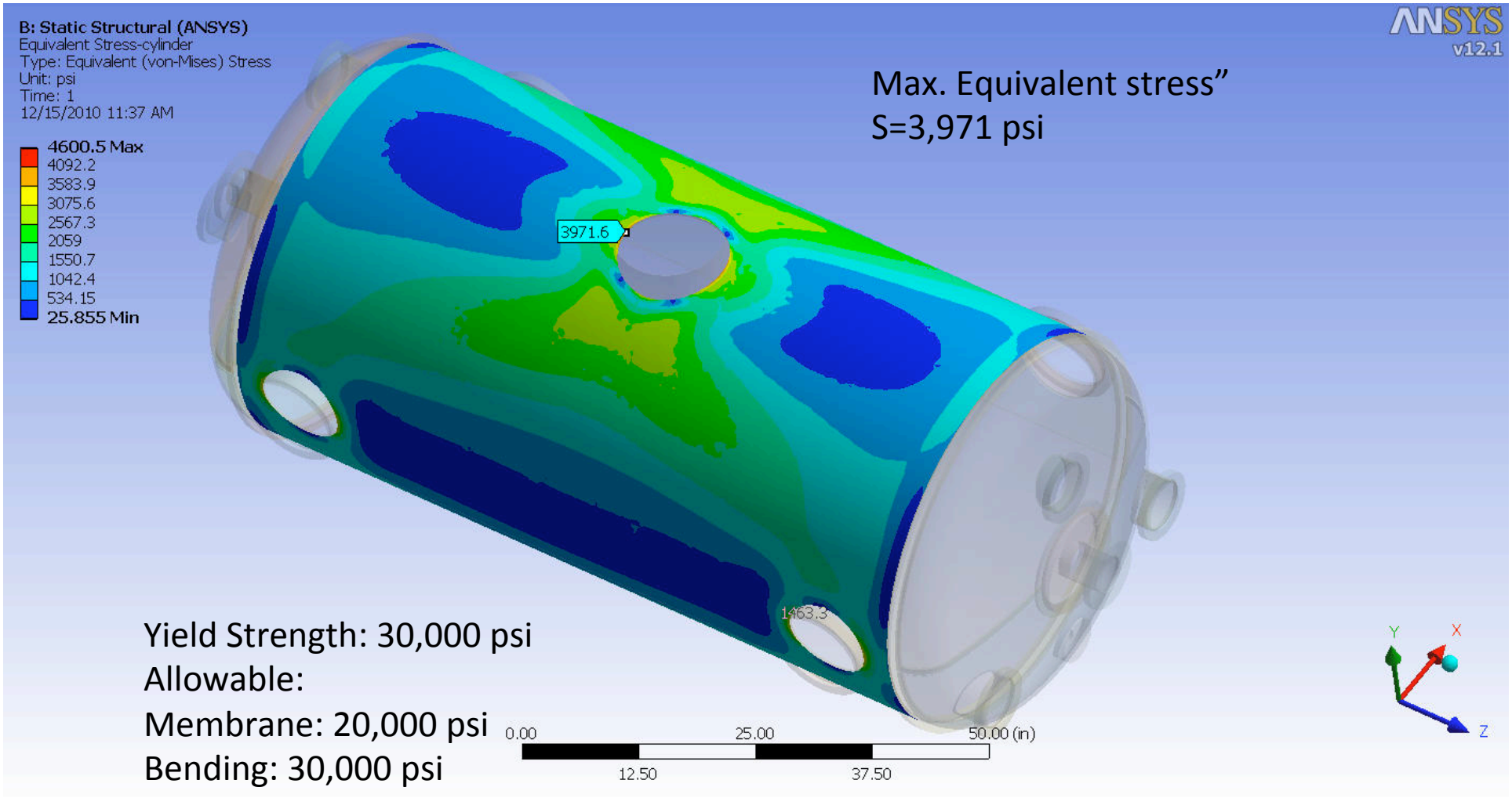
Displacement, in cylindrical coordinate, radial Under Vacuum P=14.7 psi



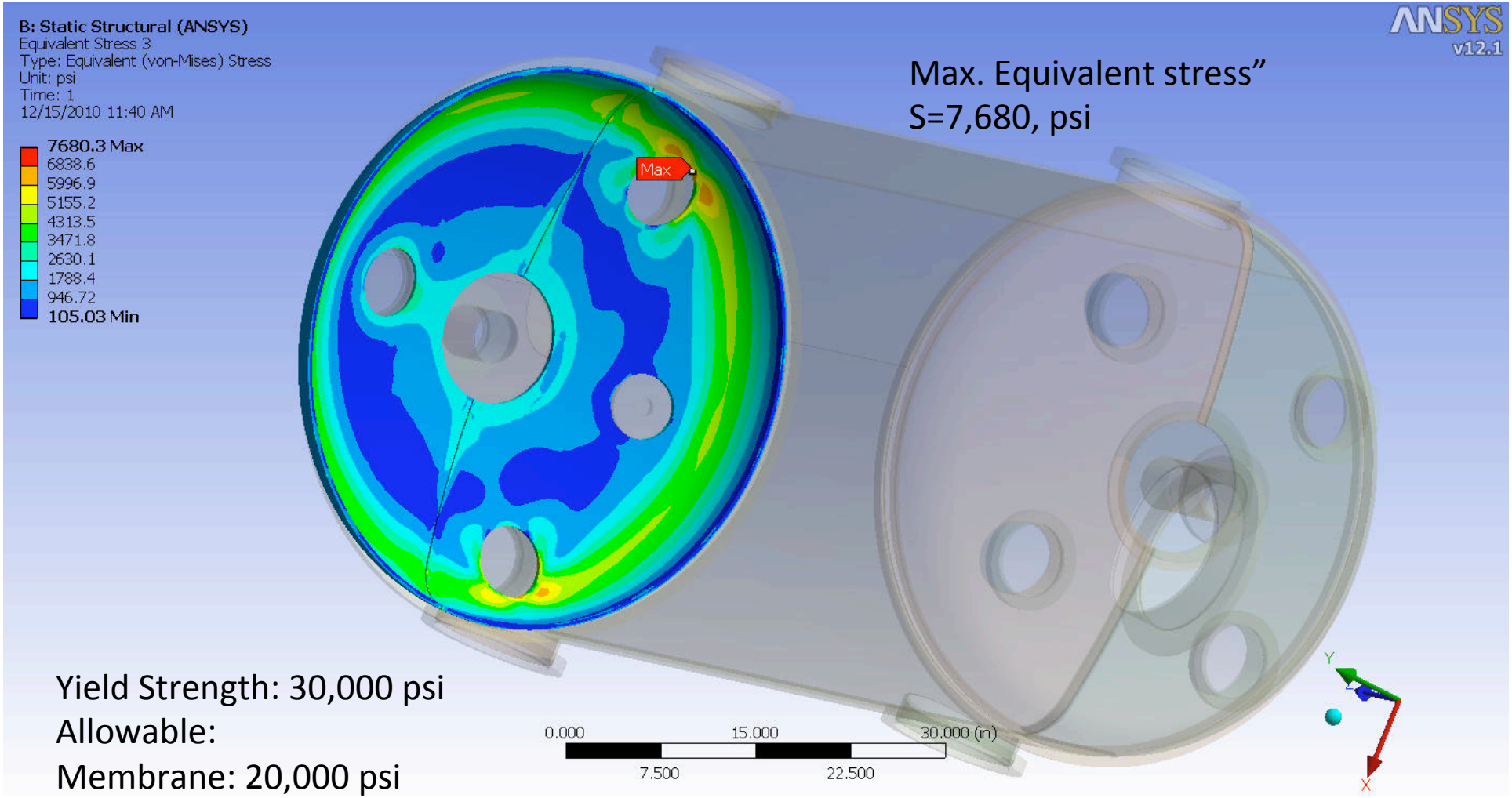
Equivalent Stress, cylinder shell



Equivalent Stress, cylinder shell



Equivalent Stress, 3 port Head

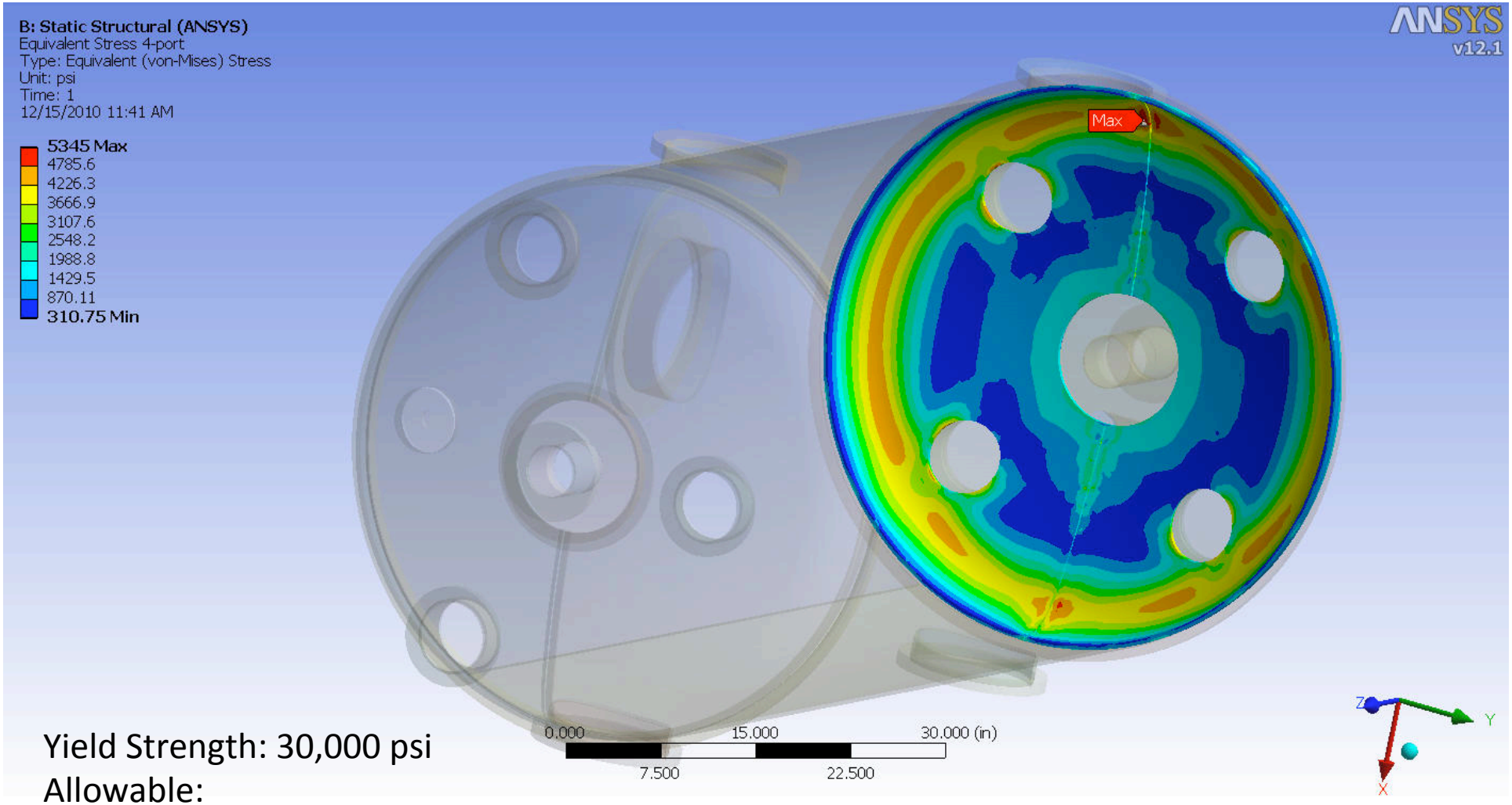


Max. Equivalent stress"
S=7,680, psi

Yield Strength: 30,000 psi
Allowable:
Membrane: 20,000 psi
Bending: 30,000 psi

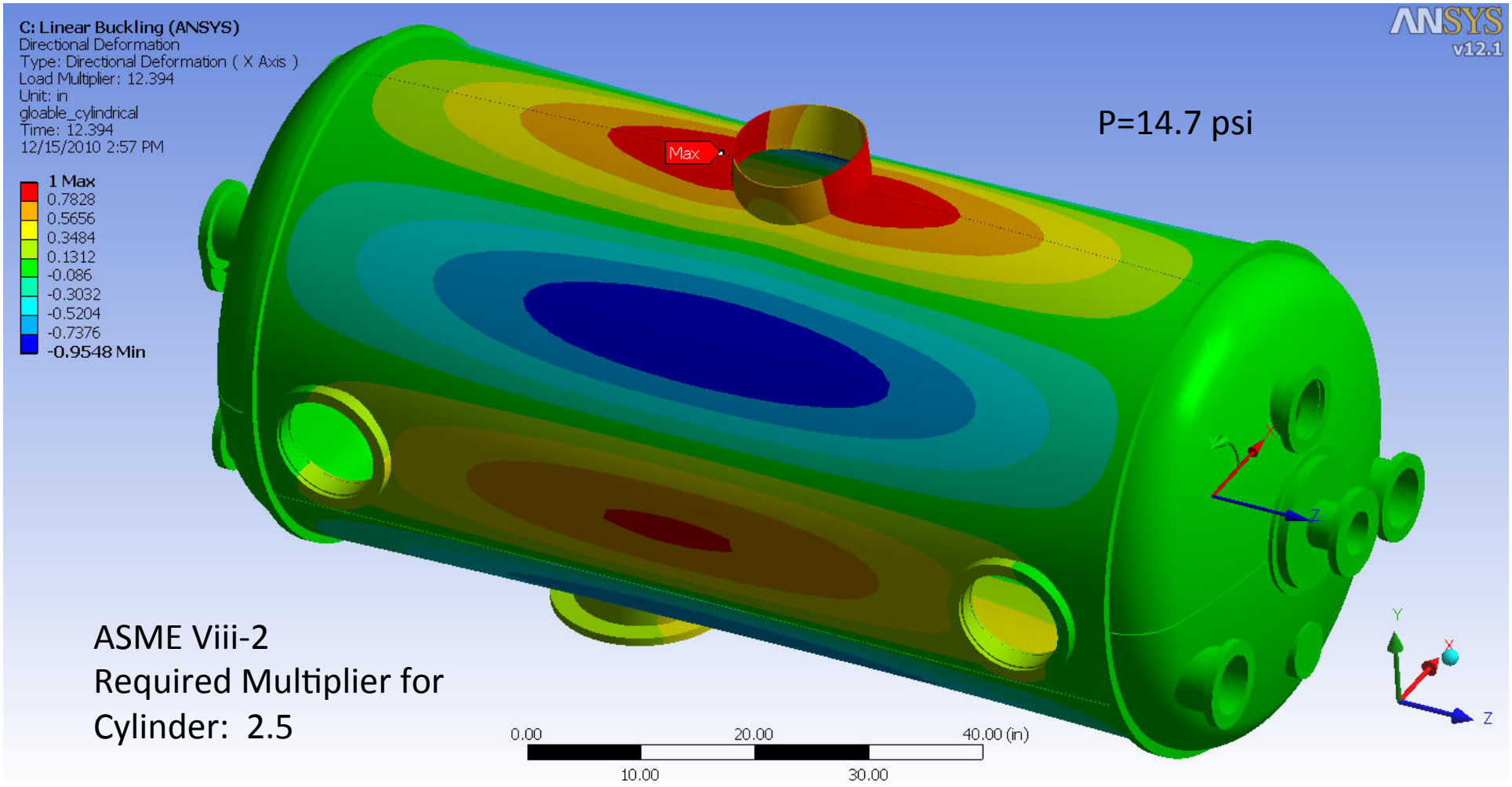
Equivalent Stress, 4 port Head

Max. Equivalent stress”
S=5,345 psi

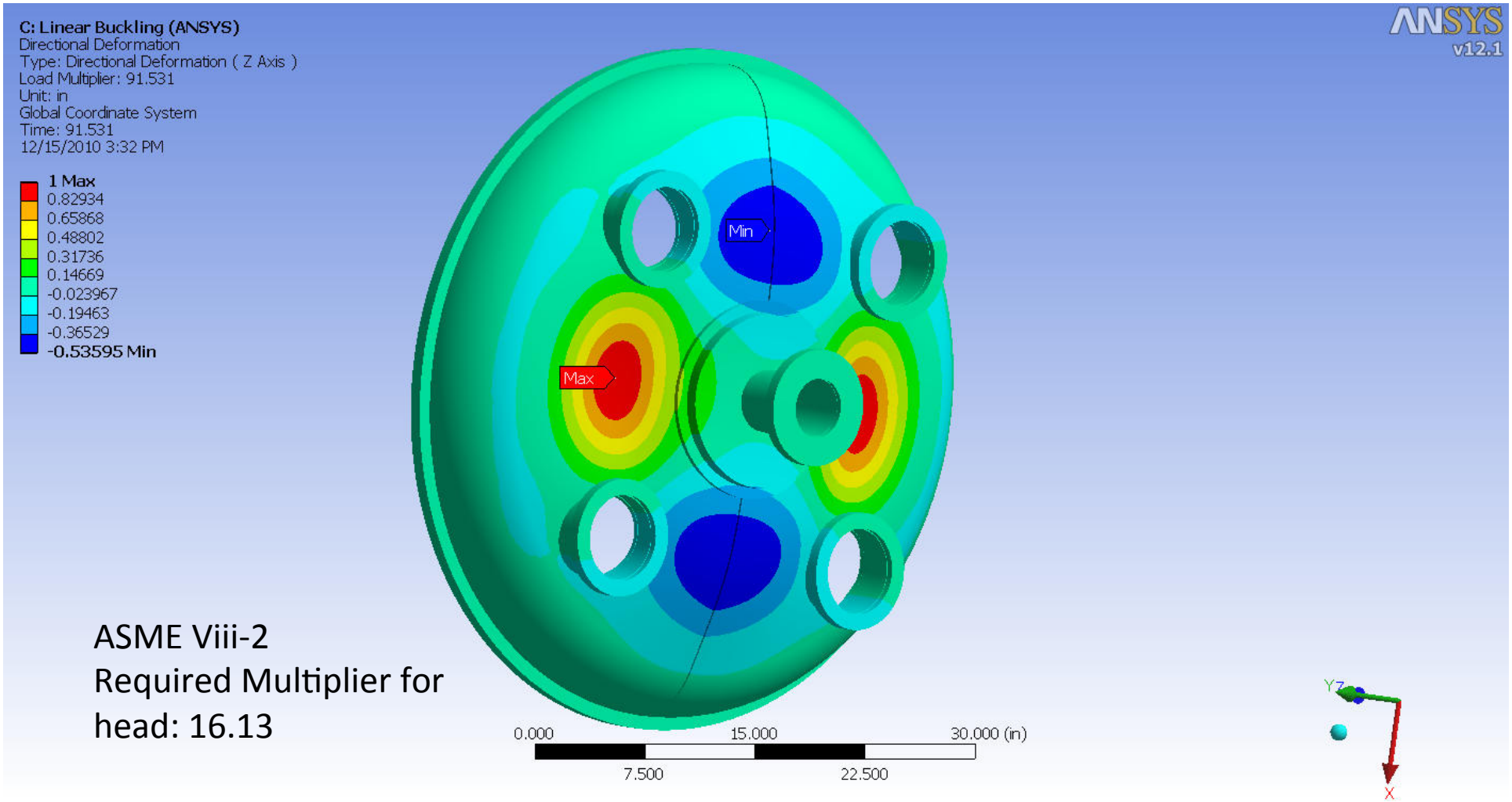


Yield Strength: 30,000 psi
Allowable:
Membrane: 20,000 psi
Bending: 30,000 psi

Buckling Multiplier in cylinder, M=12.39,> 2.5 (Cylinder)



Buckling Multiplier in Head, M=91.5,>16.13 (head)



ASME Viii-2
Required Multiplier for head: 16.13

RHIC 56 MHz Cryomodule

External Review 03/08/11

- Cryomodule Components

  (Vacuum Vessel, Shielding & Support System)

- Magnetic & Heat Shields Designs Complete 05/18/11
- Shields Procurement Complete 11/08/11

- Space Frame Design Complete 06/21/11
- Space Frame Procurement Complete 12/14/11

- Vacuum Vessel Design Complete 10/14/11
- Vacuum Vessel Procurement Complete 04/10/12