Argon/Titanium Target

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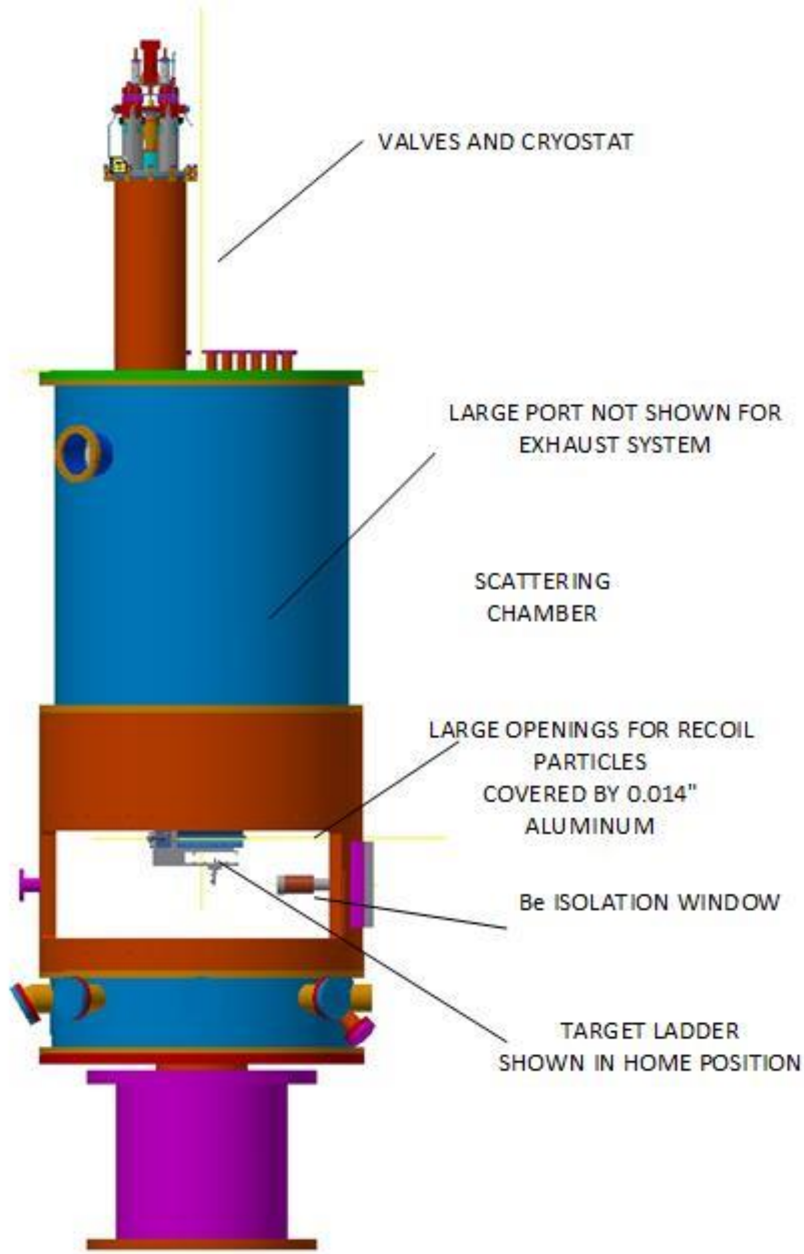
Concept

- Use T2 target cell design for Argon
  - Sealed cell design
  - Cooled by conduction
  - Stored energy is ~100 ft-lbf
- Installation on the standard Cyotarget
  - Possible but modifications will be required
  - Longer time to install than on T2 target
  - Controls will need to be altered (in process)
- Solid Targets
  - Ti foil
  - Support targets not an issue if reasonable

Concept-Cryotarget

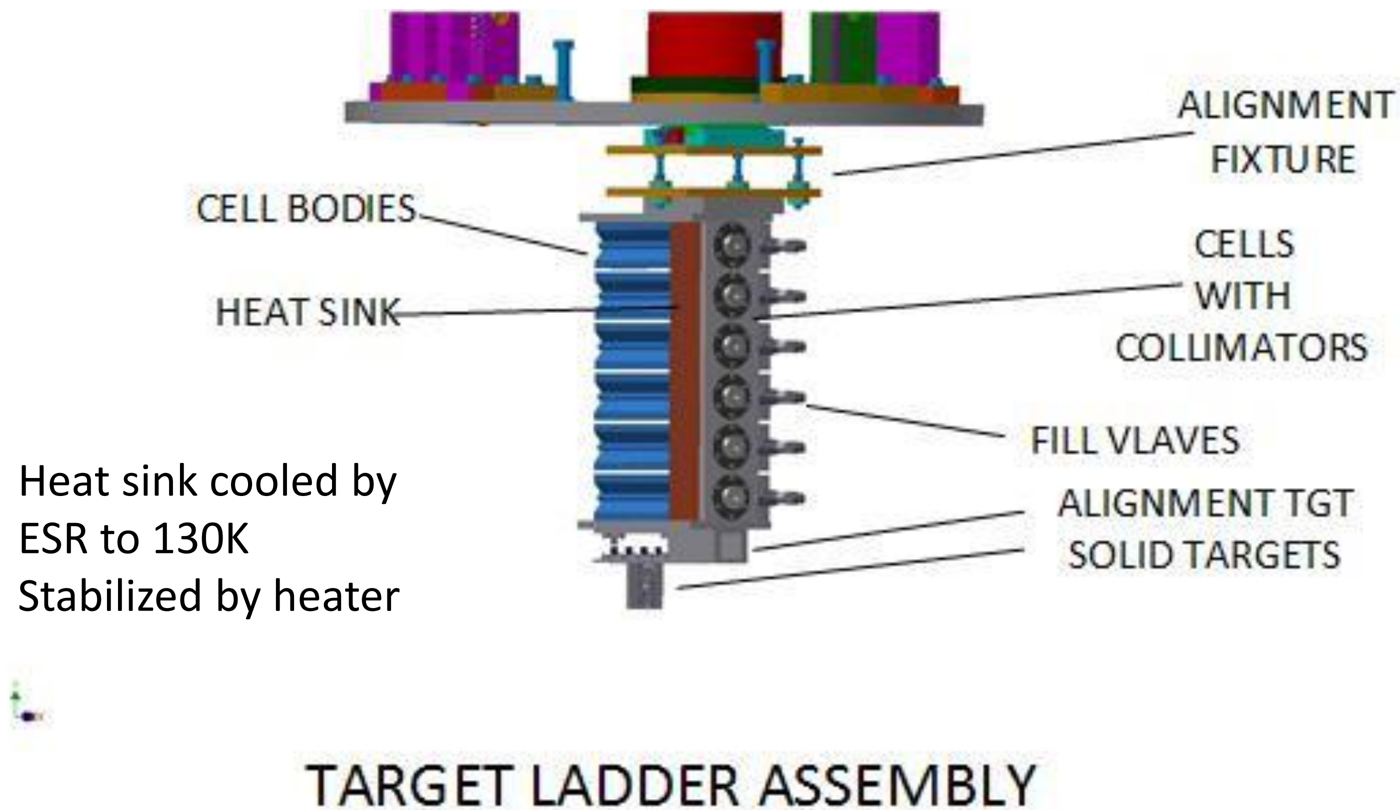
- Replace Loop 3 with argon cell
- Machine adapter/thermal brake
- Heat adapter to 130K (PID) controlled
  - Use heater supply and cable from loop 3
  - Use platinum RTDs for thermometry
  - Maintain block temp at 130K
- Stability is not known yet
  - Expect thermal lag
- Loop 3 PID controlled to 20 K



Target System

- Repurposed Qweak H2 Target
- Alter existing Cryostat
  - Alter internal piping
  - Add two valves
- H2 Loop piping and cell removed
- Alter cryo piping and instruments
- 15 K He from ESR
- Motion in “X” and “Y” directions
- Control system is similar to Hall A cryotarget
- “New Construction” pressure system

Target Ladder



Heat sink cooled by
ESR to 130K
Stabilized by heater

Argon Target Parameters

- Target length is 25 cm
- Fill pressure at room temp is 500 psi
  - Sealed cell design
- Maximum current is 20 microA
- Raster of 2x2 mm is required
- Expect at least a 20% density reduction along beam at max current
- A detailed run plan with characterization for the target will be required

Status

- Design proof testing complete
- Fabricated cell for T2 targets
- Mounting in T2 target system is trivial
- Mounting in Cryotarget can be done with some alterations
  - These alterations are now under development
- Solid targets are available with Ti (foil should be here tomorrow)
- Scheduling leak testing for early next week

Supporting Documentation

- Calculations:
  - TGT-CALC-16-001 Beam DE/Dx for Ar and Ti
  - TGT-CALC-16-002 Stored Energy of cell
  - TGT-CALC-16-003 General Hand Calc
  - TGT-CALC-16-004 Thermal/Mech model of cell
  - TGT-CALC-16-005 Elastic-Plastic model
  - TGT-CALC-16-006 Ti foil thermal model
- Drawings
  - TGT-103-1000-0010 to 0116
  - T2 target P&ID
- T2 target design report

Titanium Target

- 1.5 mm thick Ti foil
- 100 μA current
- 2x2 mm^2 raster
- 11 GeV Beam energy
- Edges of foil are assumed to be fixed at 150K

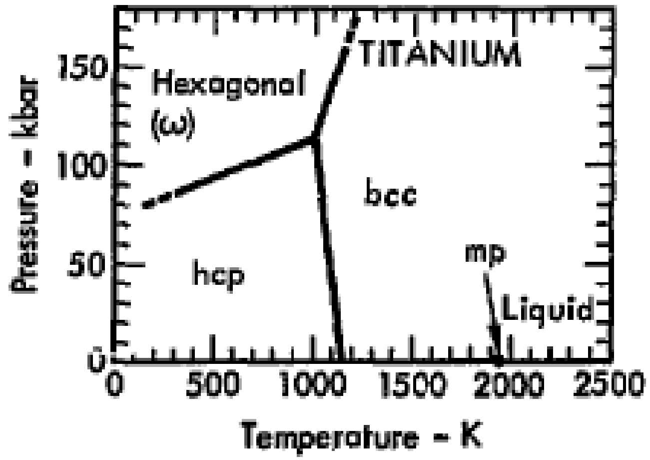
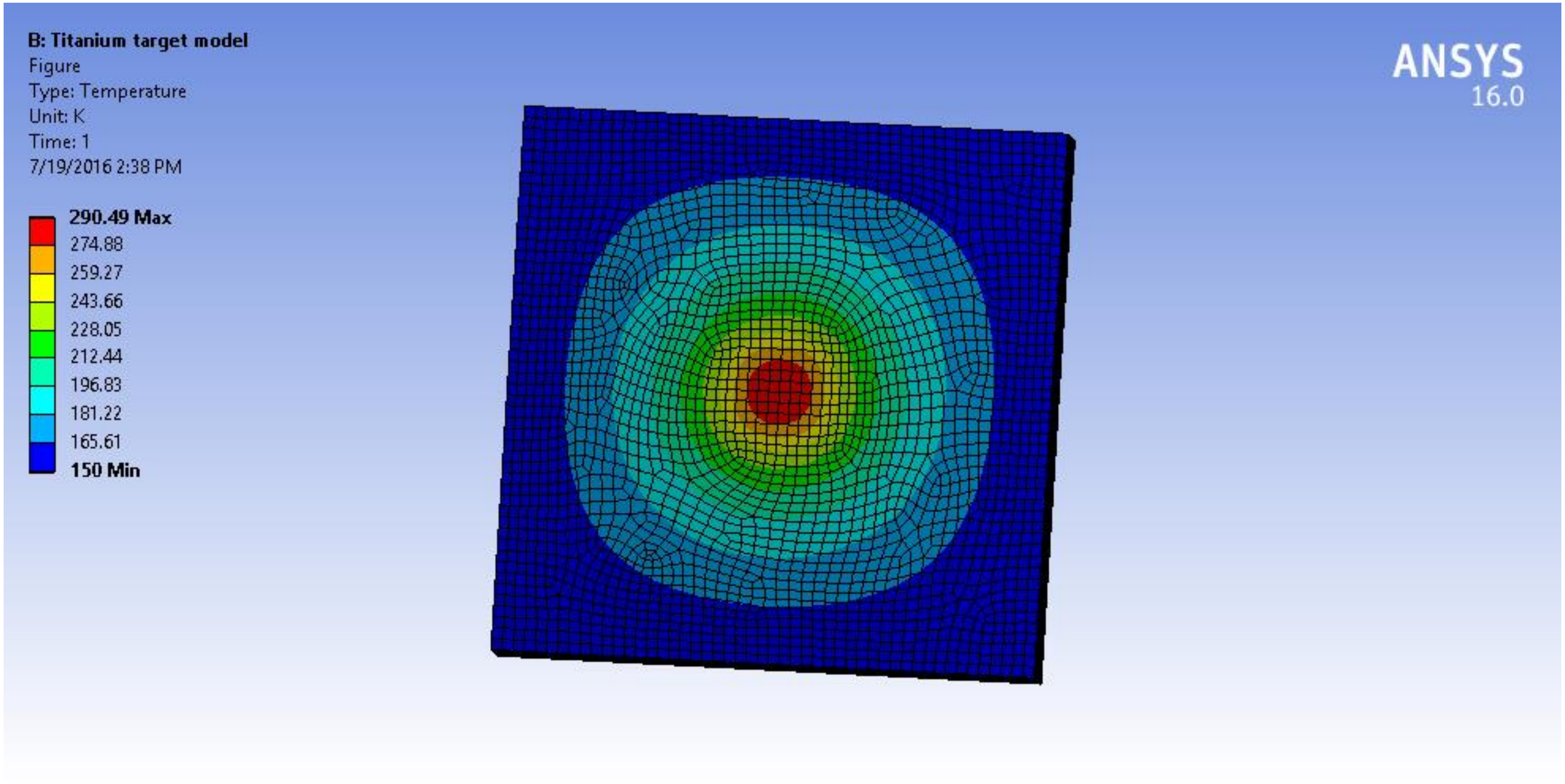


Fig. 25. The phase diagram of titanium.

Phase diagram for pure Ti

Titanium Thermal Profile

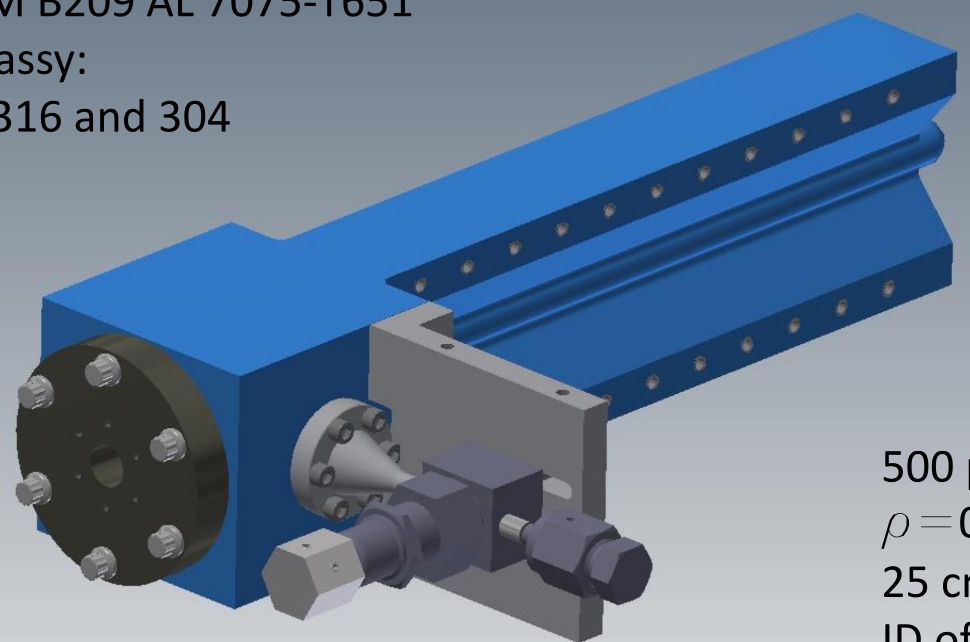


ESH&Q Requirements

- Pressure Safety
  - Cell is contained system with stored energy of ~100 ft-lbf.
  - Excepted from Pressure Safety Requirements per JLAB policy.
- Design to ASME B31.3
  - Not required but good practice
- Fabrication/testing/examination etc. shall comply with ASME B31.3
  - Not required but good practice
- Other hazards are equivalent to operating systems which cell can be installed

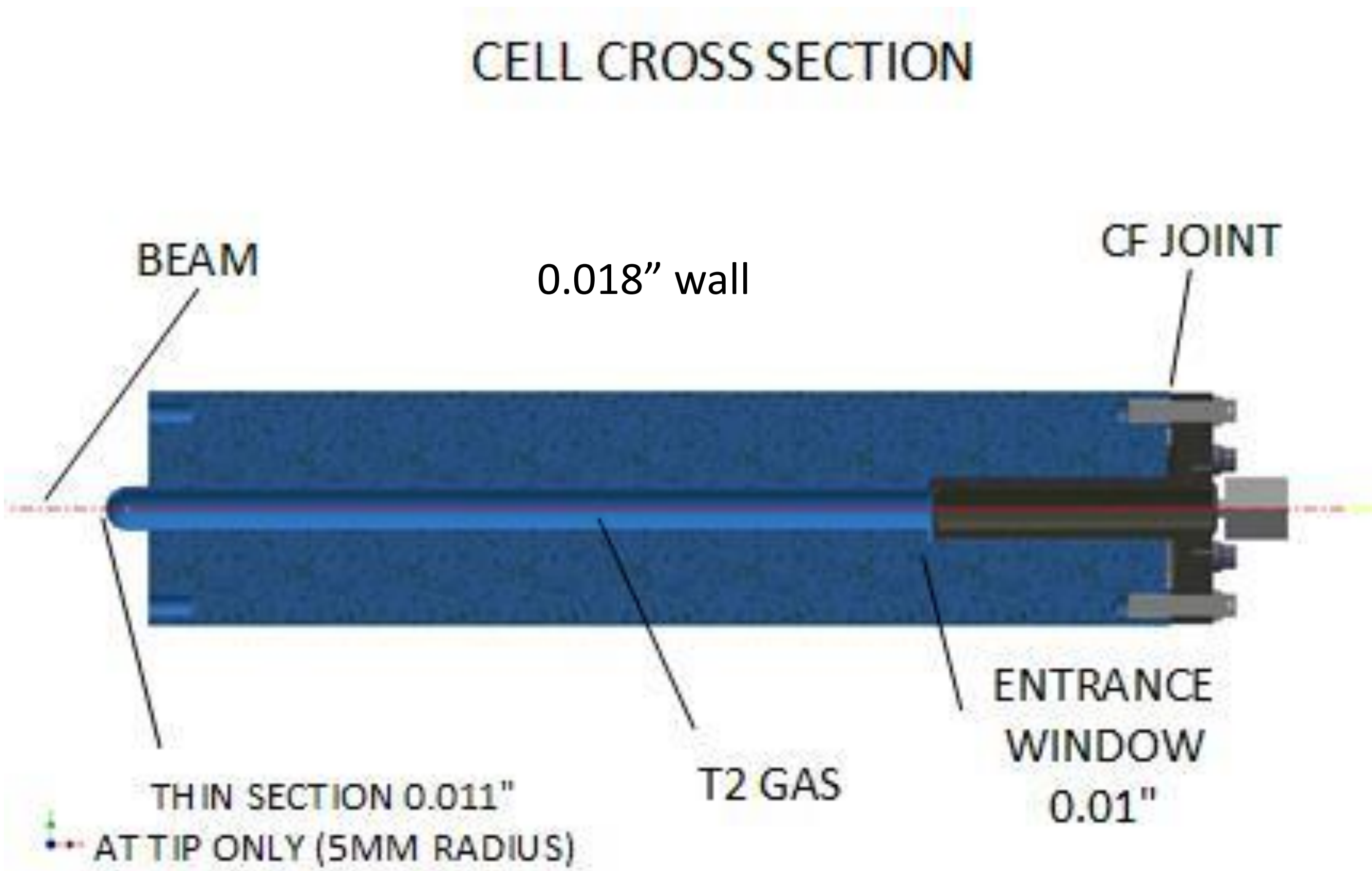
Target Cell

Main Body and Entrance Window
ASTM B209 AL 7075-T651
Valve assy:
SST 316 and 304



500 psi Ar gas at 300K
$\rho =$ 0.06 g/cc
25 cm long
ID of 12.7mm
Volume = 34 cc
Aluminum CF seals

Cell Cross Section



Features

- Cell is “sealed”
  - No recirculation
- Make Al-SST transition with CF flanges
  - Many years of successful experience at JLAB
  - Work well with H2, He, etc. at low temp < 1K
- Modular design
  - Can be installed as the final component of the system in place of T2 cell

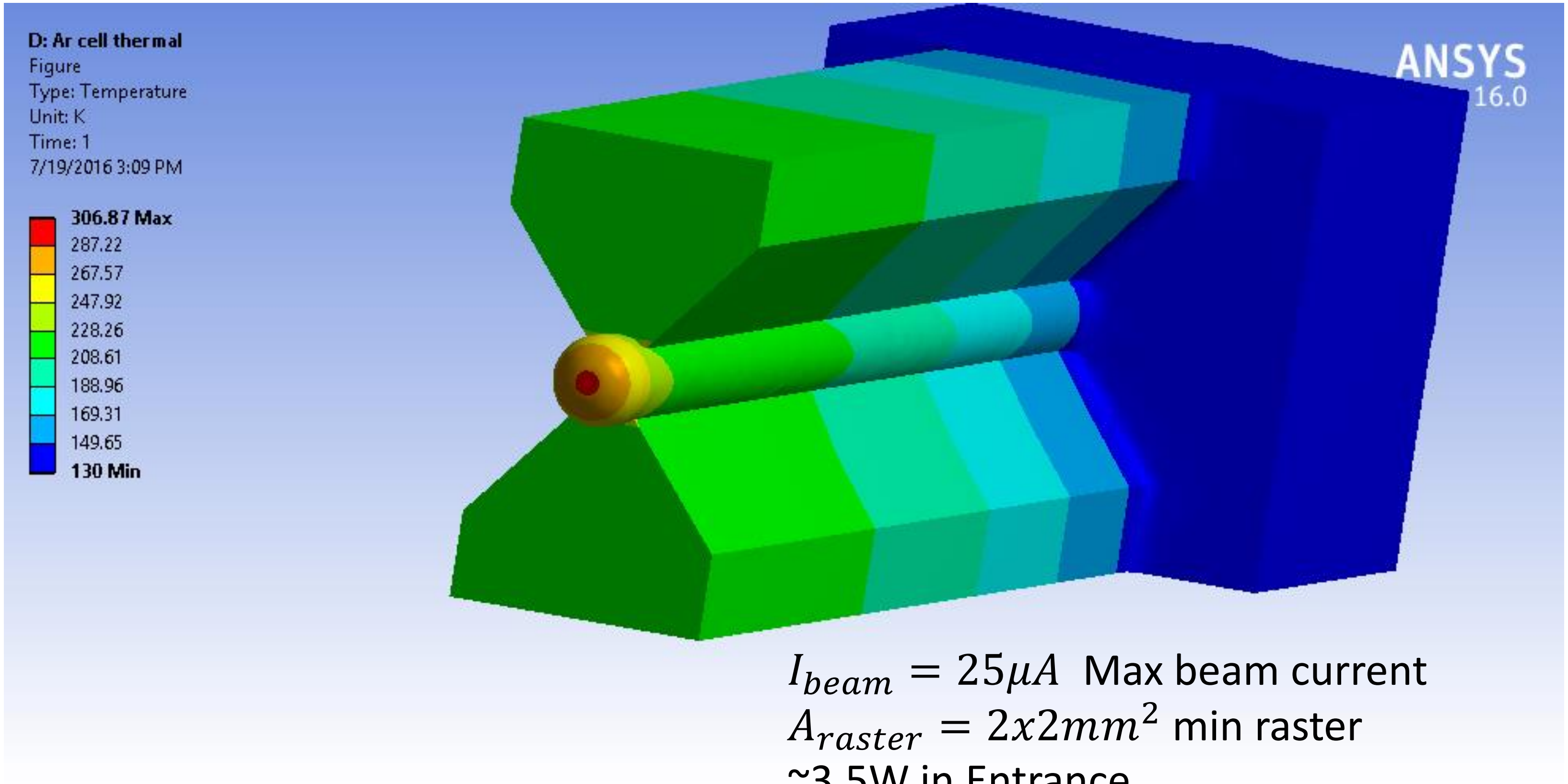
Materials

- Main Body and Entrance
  - Aluminum 7075-T651 ASTM B209
  - Extensive use of this alloy for 15 years
  - Strong, ductile, hard, non weldable
- Seals are Al 1100
- Valve assembly
  - SST 304/304L Fitting
  - Swagelok valve all metal bellows sealed (316L)
  - Butt welded ER316L (100% VT in process and RT)

Materials-2

- Al 7075 is unlisted
  - Design basis
    - $\mathrm{S_{ut}} = 72\ ksi$
    - $S_y = 61\ ksi$
    - $S_a = \min\left(\frac{1}{3}S_{ut}, \frac{2}{3}S_y\right) = 24\ ksi$ for tension
    - = 80% of 24 ksi for shear
    - = 150% OF 24 ksi bending
- Other wetted materials are SST
  - 304/304L
  - 316/316L
  - ER316L Filler for welds

Beam Heating



$I_{beam} = 25\mu A$ Max beam current

$A_{raster} = 2x2mm^2$ min raster

~3.5W in Entrance

~4 W in Exit

~80 W in Ar gas (absorbed by all walls)

$T_{max} = 307K$ on exit

$T_{max} = 190K$ on entrance

Load Conditions

- At room temp
  - P = 500 psi
- At 130K Beam Off
  - Pressure = ~175 psi
  - Temperature = 130 K
- Beam On
  - Pressure = 300 psi (avg temp of T = 200 K)
    - 500 psi is assumed for analysis
  - Max Temperature = ~280 K
- Cyclic loads
  - Cool down/warm up operating cycles = 3
  - 4320 beam trips (cycles between Beam On and Off)
    - 9 days, 100% duty factor, 20 trips/hr

Analysis

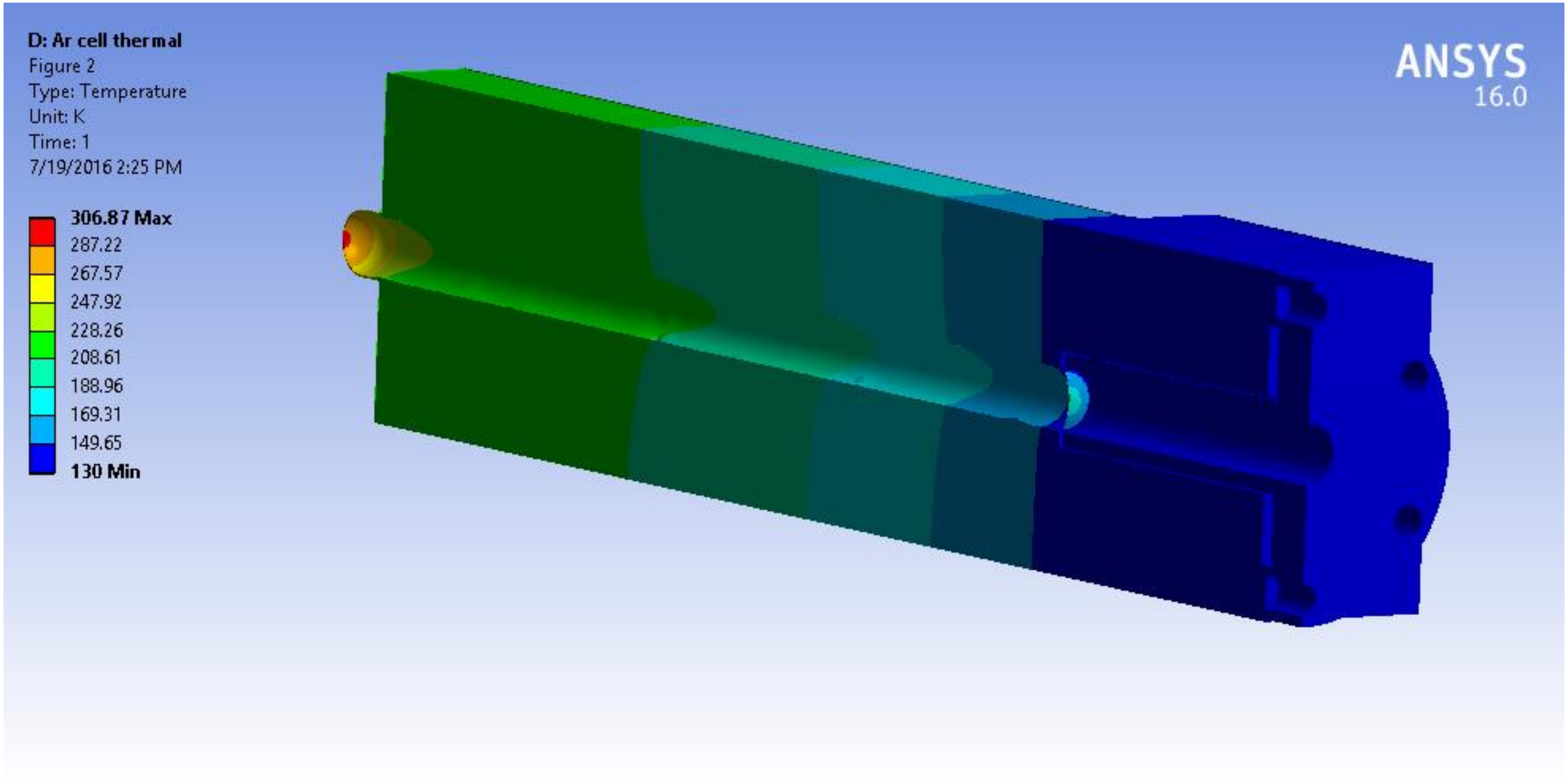
- Applicable Code ASME B31.3 (2014)
  - Section 304.7.2 because of odd geometry
    - Qualification of pressure design by: Experience, Testing, Detailed calculations.
  - Used both Hand Calculations and FEA
  - Analysis conforming to ASME BPVC VIII D2 with load factors from B31.3 (i.e. 3 instead of 2.4 on P)
- Used cyclic screening analysis from D2
  - Depth of loads do not require a fatigue analysis
    - 175 psi pressure cycle
    - Considers temperature cycle from
- Design pressure 618 psi
- No source of overpressure beyond excess beam current

Models

- Full temperature/pressure load (T/M)
  - Beam on at 25 µA 2x2 mm raster
  - Pressure load 600 psi internal Cooling using 130K heat sink
- Elastic-plastic (EP) model (TGT-CALC-16-005)
  - Model solves P=1800 psi (3x fill)
  - Local plastic failure requirements met
  - Cyclic analysis not required because of screening analysis (TGT-CALC-16-003)

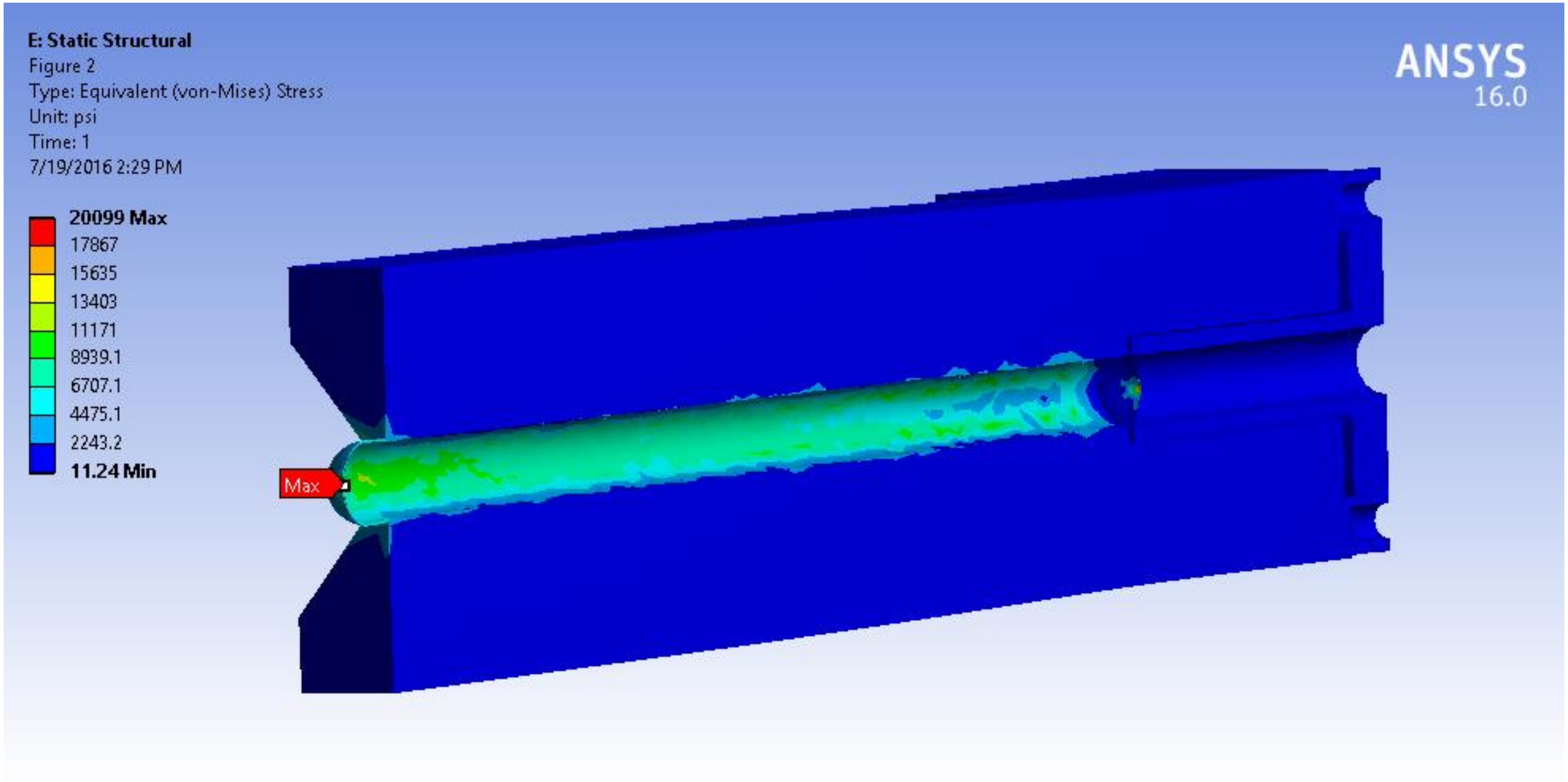
Temperature Profile T/M Model

25 μA 2x2 Raster



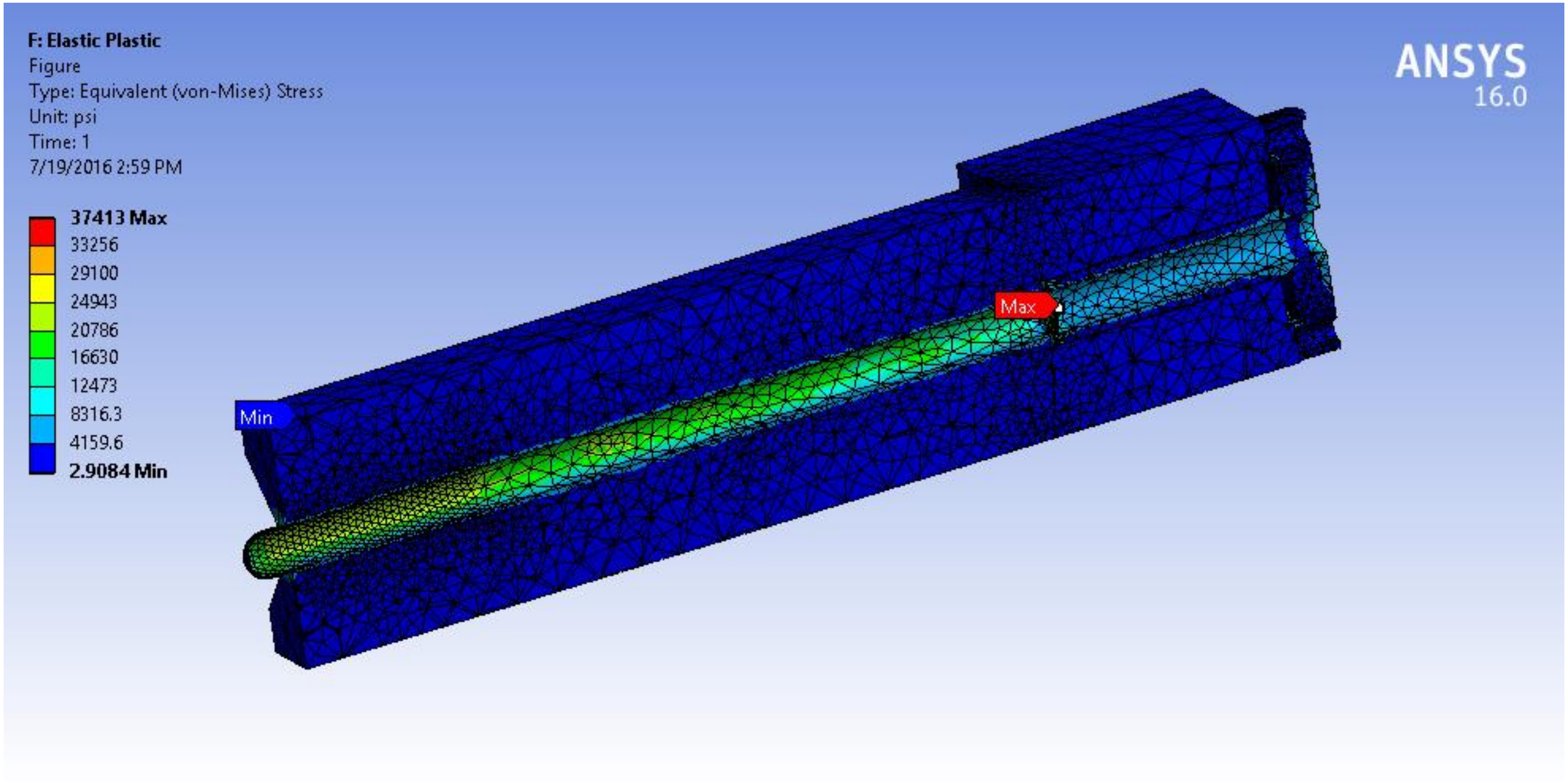
TGT-CALC-16-004

Equivalent stress T/M Model



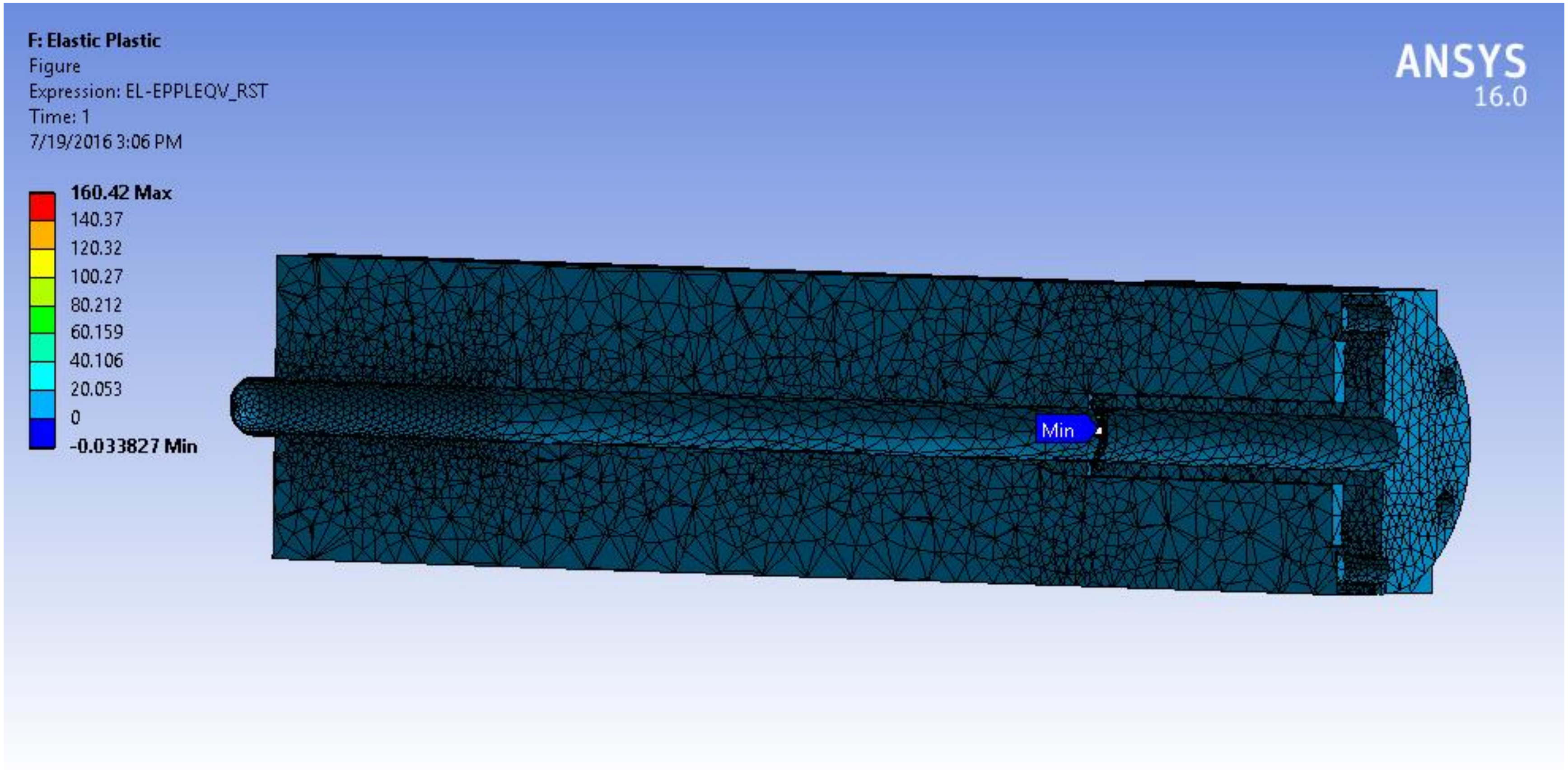
TGT-CALC-16-004

EP Equivalent Stress



TGT-CALC-16-005

EP Strain Limit



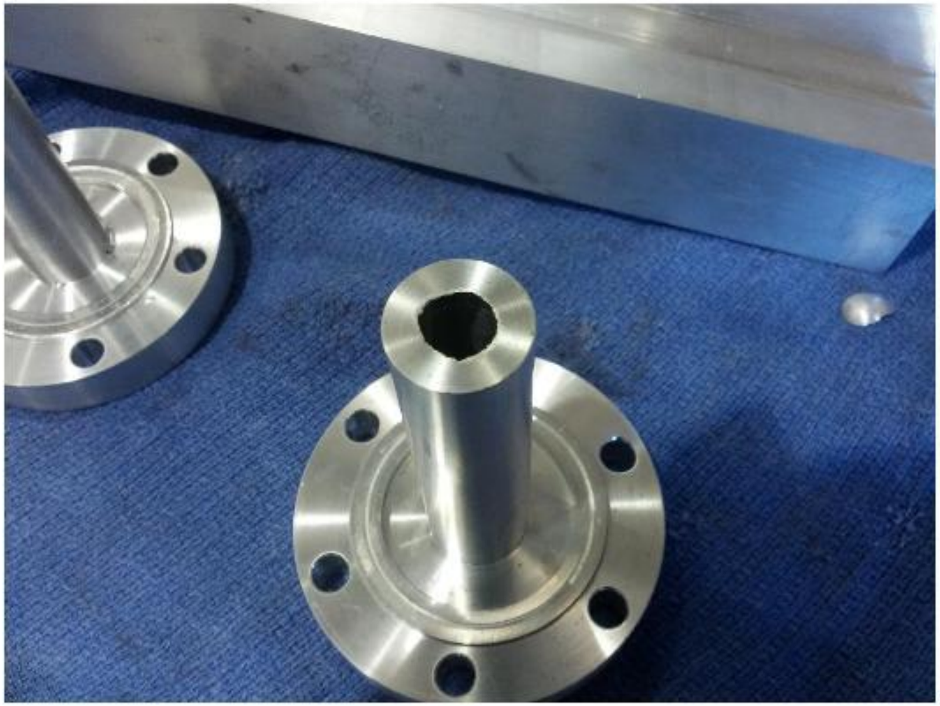
TGT-CALC-16-005

Summary of Test Results

- Multiple hydrotests on components
- Entrance: Minimum burst above 2900 psi
- Main body: Minimum burst above 3400 psi (0.014” section)
- This meets requirements for proof testing with design pressure greater than 600 psi. (UG-101)

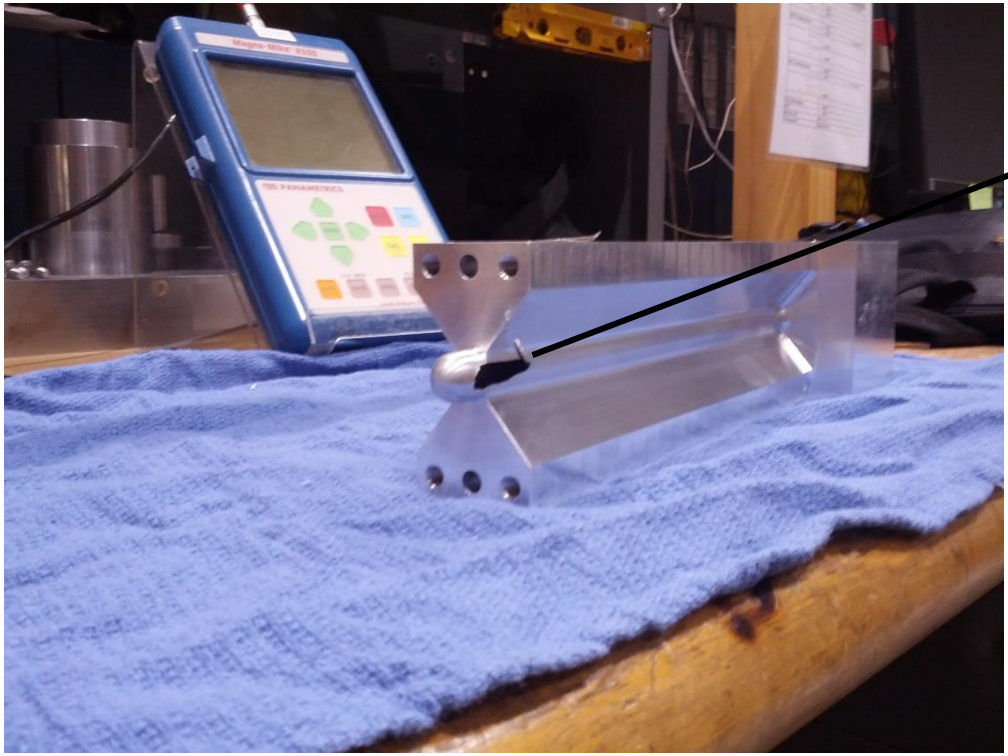
Entrance window hydro

Cell Entrance Window



Cell Entrance Window
Burst ~2900 psi

Exit window hydro



0.014” section
Failed above
3400 psi

Design Summary

- Hand calculations have been substantiated by detailed analysis
  - Div 2 Part 5.2.4 and 5.3.3 Elastic Plastic model solves with 3x pressure load
  - Thermal Mechanical model indicates acceptable stress levels for full current/pressure load
- Div 2 Part 5.5.4 Screening analysis indicates cyclic loads need not be analyzed.
- Hand calculations have also been substantiated by testing
  - Proof testing (UG-101) allows design pressure of more than 600 psi.

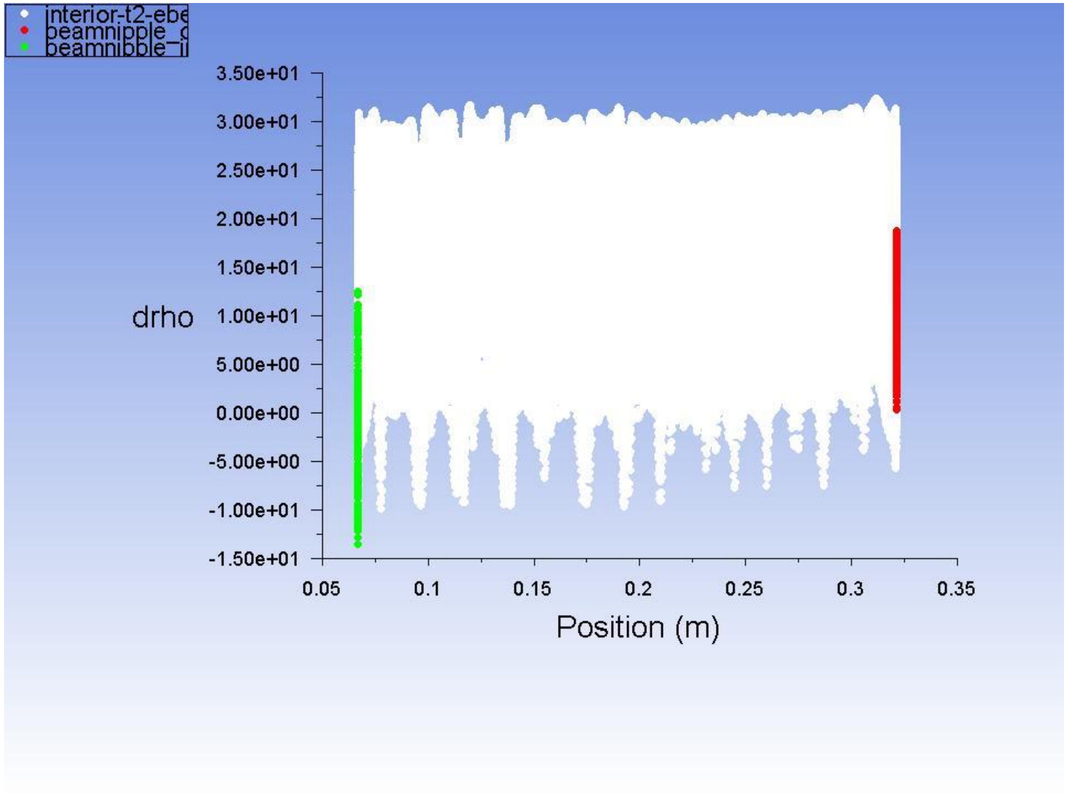
Control System

- Alter the Cryotarget Controls
- Use EPICS (distributed I/O)
  - Temperature/motion/valve control
  - User Interface (UI) through EDM
- FSD on high temperature
  - Uses interlocks from redundant 718s
- UI has integrated alarm handler
- EPICS data logger runs continuously
- Communications failures Alarm as well

Performance of Target

- A 20% reduction in the density along the beam should be assumed. Based on steady state ANSYS CFX simulation (D. Meekins)
- Target density must be studied in situ
- Detailed run plan should be developed

Silviu Covrig Analysis



- 25 microA 2x2
- Argon 47.44 kg/m3
- After 7 min density reduced by 17%

Commissioning Plan For Target Thickness

- Ensure beam profile is correct and BCM/Optics calibrated
- Step current 0-25 μA
- Collect data on Argon cell
- Collect data on Carbon
- Develop function for $L_{target} = L_{target}(I)$
- Optimize current/target length with max current of 25 μA

Installation in the Cryotarget System