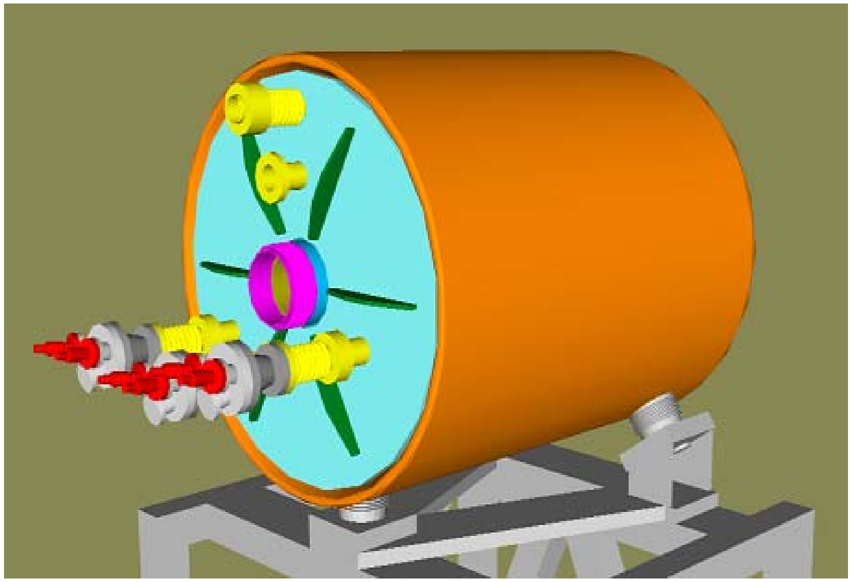
MC Collaboration Meeting Riverside California January 29 2004
Targetry Group Report FY04 R&D Plan – Pulsed Magnet Status
E951 15T Pulsed Magnet for Mercury Target Development

Peter H. Titus
MIT Plasma Science and Fusion Center, Cambridge MA
(617) 253 1344, titus@psfc.mit.edu, http://www.psfc.mit.edu/people/titus



BNL Pulsed Magnet –Inertially Cooled , 72K He Gas Cooled Between Shots

MC Collaboration Meeting January 27 - 31, 2004
Mission Inn Riverside, California

Engineering Status

Calculations and Drawings are "complete" – but small revisions are expected based on final manufacturing details. Drawings bid documents, and calculations may be found at: http://www.psfc.mit.edu/people/titus/

Manufacturing Contract Status – We have a Contract but no Magnet Vendor.

CVIP was chosen, Bid price was lower than, but consistent with MIT/PSFC Cost estimate

CVIP recently successfully built the HCX prototype Cryostat for MIT-PSFC.

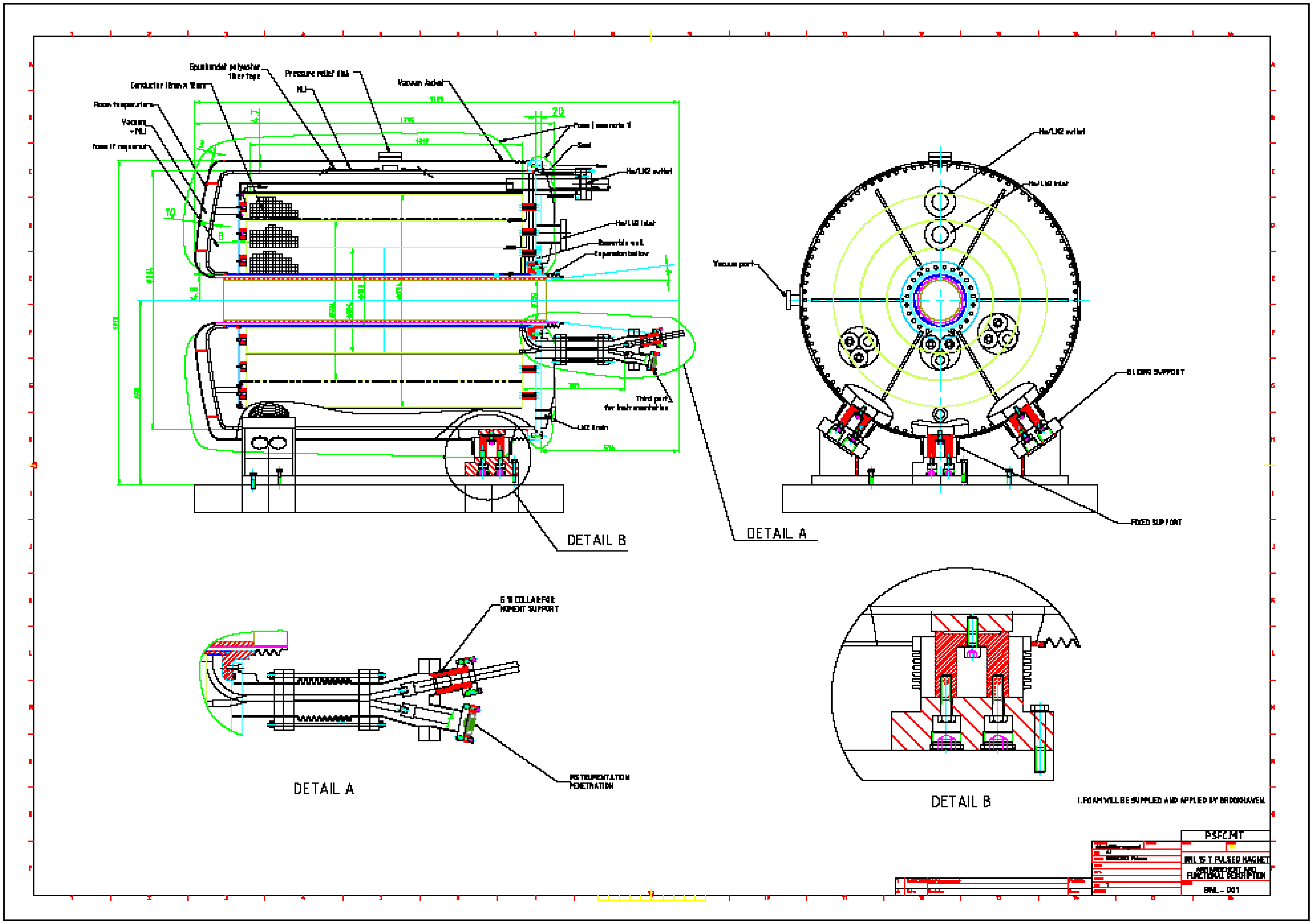
CVIP had a good track record with BNL

BNL/MIT obtained a special letter from CVIP stating that CVIP and their sub vendor (ACE/Peter Hwang) were both committed to the project and were well integrated as a project team. CVIP was awarded the contract with the provision that they would maintain their ties with acceptable magnet manufacturing expertise.

CVIP's Magnet Sub-Vendor, ACE, backed out after their shop consultant passed on, and financial disagreements between ACE and CVIP reached an impasse.

We are not exploring a re-bid at this time.
We are assisting CVIP in finding an acceptable sub-vendor.

- ✓ **Design Drawings Complete – Including some minor updates - weld details, material call-outs, resulting from the bid process. Drawing issue is controlled on the Titus MIT-PSFC web page with a A revision status table.**



✓ Engineering Calculations are “Complete” –Reviews and small refinements continue
- An example, from a BNL review: - Cryostat bolting thread shear.

Design Pressure= 15 atm

```
Allowable Bolt Stress= 57000
Bolt Ultimate Strength= 110000
Bolt Yield Strength= 95000
Number of Inner Bolts: 24
Number of Outer Bolts: 96
Bolt Tensile Area= .1416   Bolt Thread
Shear Area= .53014376
Tensile Load on inner Cyl: 110378.99
lbs
Tensile Load on inner Cyl: 491009.75 N
Inner Bolt Tensile Stress 32479.694
Inner Bolt Pull Out Shear Stress
8675.2406
Inner Bolt Tensile Factor Of Safety
1.1289105
Inner Bolt Shear Factor Of Safety
1.8443293
Inner Cylinder Stress Based on Bolt
Loading 178.33716 MPa
Tensile Load on outer Cyl: 138553.87
lbs
Tensile Load on outer Cyl: 616342.83 N
Outer Bolt Tensile Stress 10192.581
Outer Bolt Pull Out Stress 1837.6278
Outer Bolt Factor Of Safety 3.5973878
Outer Bolt Shear Factor of Safety=
8.7068776
Outer Cylinder Stress Based on Bolt
Loading 20.309319 MPa
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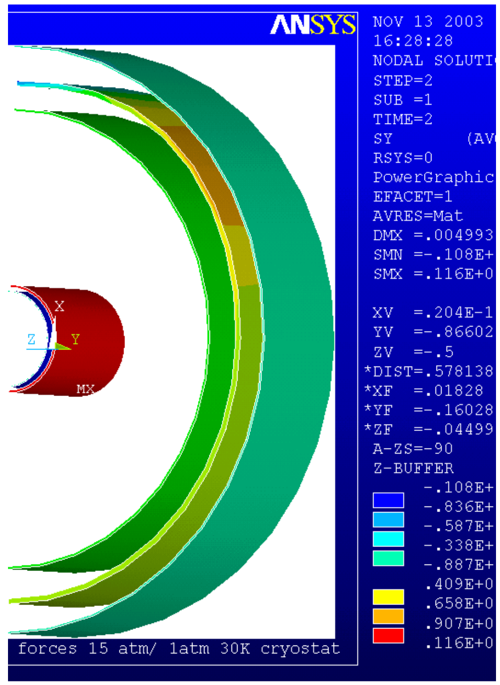


The axial tension in the bore tube is 116 MPa, which is lower than the bolt Basic program calculations predict (178 MPa). The reported inner bolt tension

FED-STD-H28
31 March 1978

coefficient of friction, other combined stresses will be directly proportional to the wrench torque.

Thread Shear Area.—The diameter corresponding to the effective thread shear area will vary with the relative unit tensile strengths of the materials of the internal and external threads. When the external and internal threads are manufactured from materials of equal unit tensile strength, failure will usually take place simultaneously in both threads at or near a diameter equal to the basic pitch diameter. The shear area (AS) for external and internal threads made of such materials can be computed from the following formula:

$$AS = 3.1416E\frac{L_e}{2}$$

where

E = basic pitch diameter
L_e = length of engagement at basic pitch diameter.

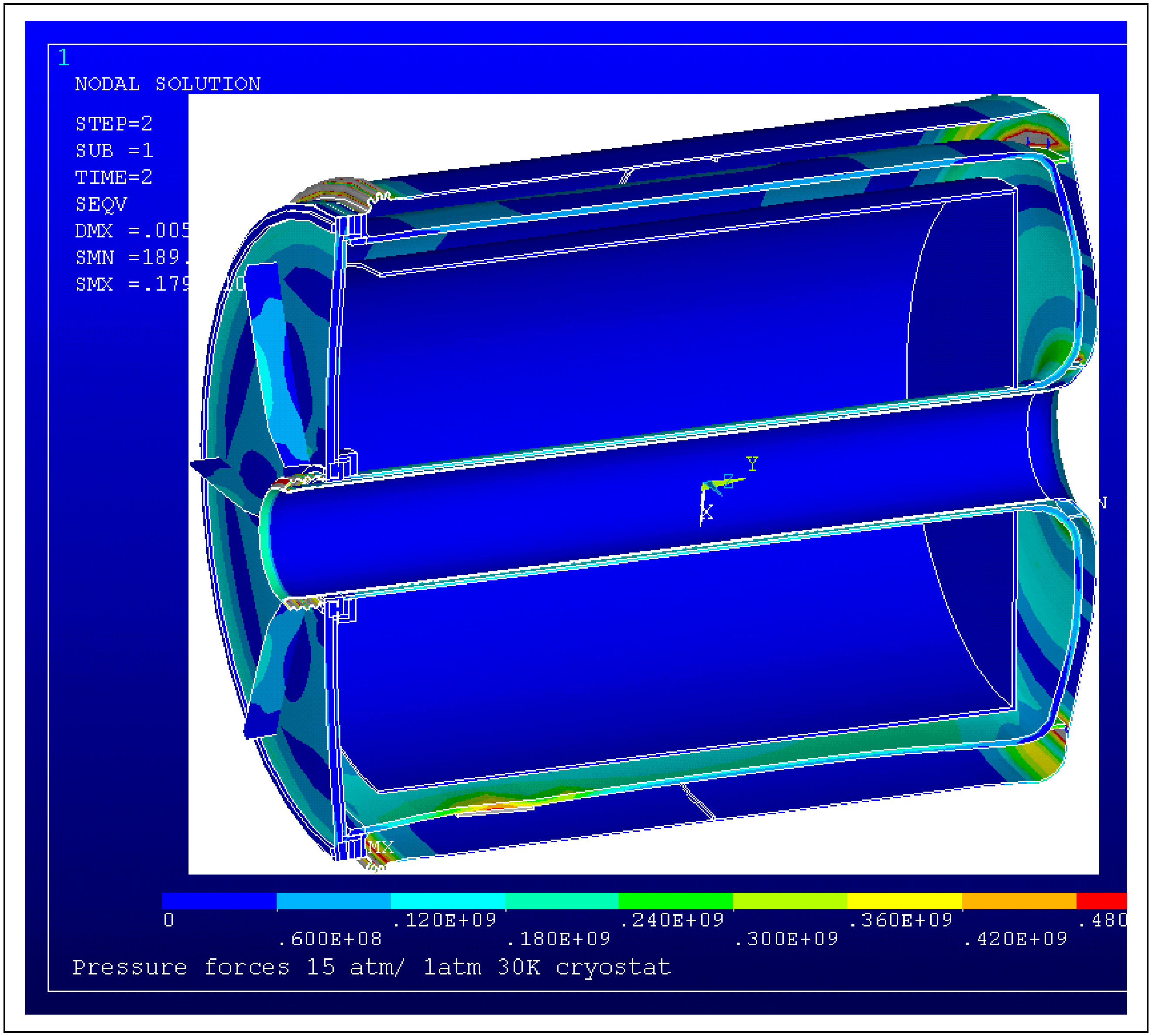
When the unit tensile strength of the external thread material greatly exceeds that of the internal thread material, as in the case of a threaded hole in a cast aluminum block mated with a 100,000 psi ultimate strength material bolt, the shear area of the internal thread (AS_n) can be computed from the following formulas:

(1) For simplified calculations that will provide shear areas within about 5 percent of those given by the precise formula shown below, the shear area of the internal thread may be computed as follows:

$$AS_n = 3.1416E\frac{3L_e}{4}$$

Excerpt from ref 15, the Federal Standards for Screw Threads, showing the recommended thread shear area for strong bolts in a weak threaded hole.

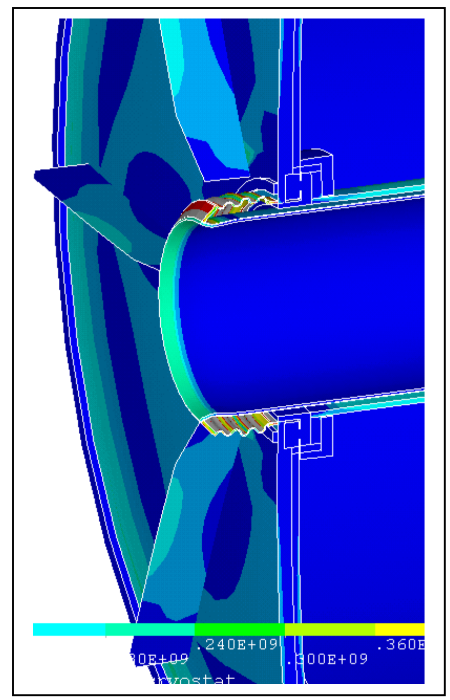
Latest Cryostat Model (not yet in web page)



Cover Stiffeners are 1cm thick.

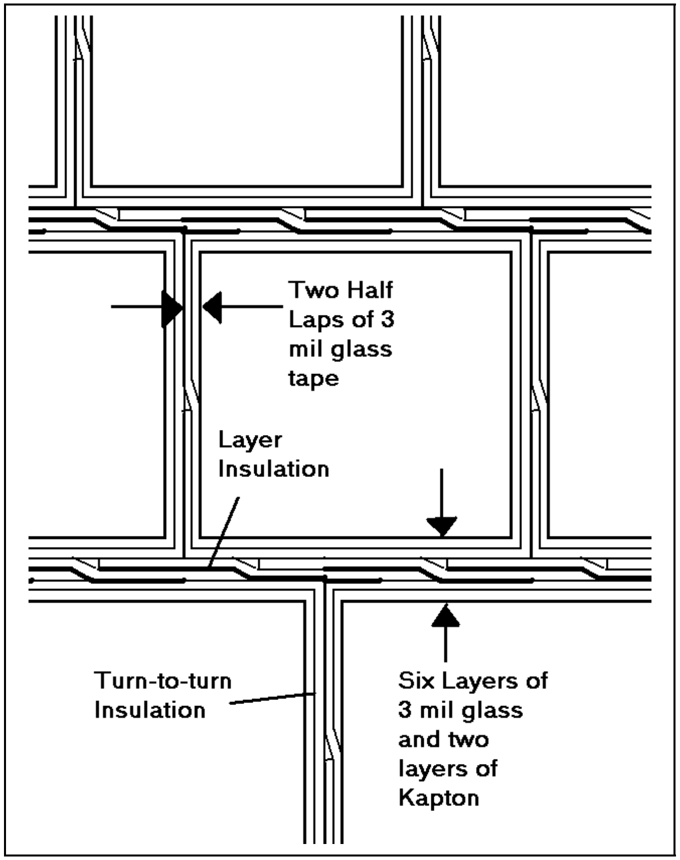
Updated bellows models are "representative" They are purchased based on a performance spec.

Discontinuity stress(<400 MPa) at Cryostat flare to dished head meets 3Sm allowable at the weld of 480, Membrane stress meets 160 MPa allowable



Coil Description:

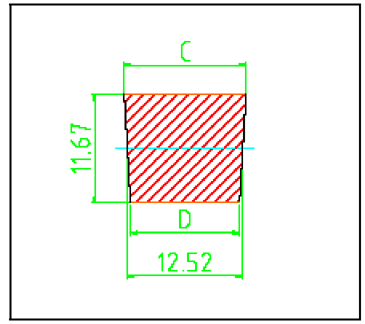
	Mode 1	Mode 2	Mode3
Number of Segments operating:	2	2	3
Number of turns per segment	624	624	624
Total number of turns active	1248	1248	1872
Layers in each coil segment	8	8	8
Turns per layer	78	78	78
Conductor radial thickness	.0116698 m .45944 in	.0116698 m .45944 in	.0116698 m .45944 in
Conductor Axial thickness	.012516m .49274359 in	.012516m .49274359 in	.012516m .49274359 in
Max Operating Field Bore CL	5T	10T	15.0T
Max Field at Magnet			
Max Terminal Current	3600A	7200A	7200A
Coolant Working Fluid	77K LN2	65K LN2	30 K Helium Gas
Terminal Voltage	150V	300V	300V
Layer to Layer Volts	18	36	24
Turn-to-Turn Volts	0.12	0.24	.16
Design Life			1000 full power pulses
Cryostat Pressure -Initial Operating			12 atm
Cryostat Pressure – During Cooldown			15atm max
Number of .54 MVA power supplies	1	4	4
Mode of Ganging Supplies	None	2 X 2	2 X 2
Charge Time	7.2 sec	6.3 sec	15.3 sec
Initial Temperature	84K	74K	30K
Temp Rise	5.8K	21.7K	48.3K
Final temperature			78.3
Cumulative heating at end of pulse	2.7MJ	9.1MJ	15.2MJ



Coil Builds used in the Finite Element Models:

#	r	z	dr	dz
1	.15	0	.098	1.0
3	.25	0	.098	1.0
5	.35	0	.098	1.0

Technical Issues the Vendor needs to Resolve

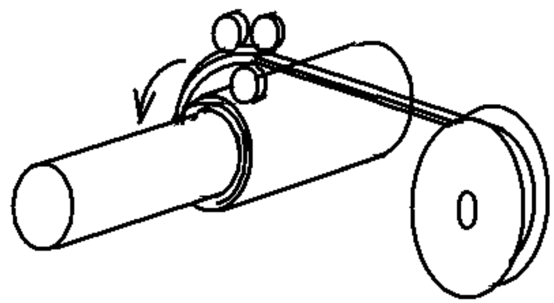


Winding ½ hard 12mm square copper on a .1m radius without crushing or cutting the Kapton and/or glass tape.

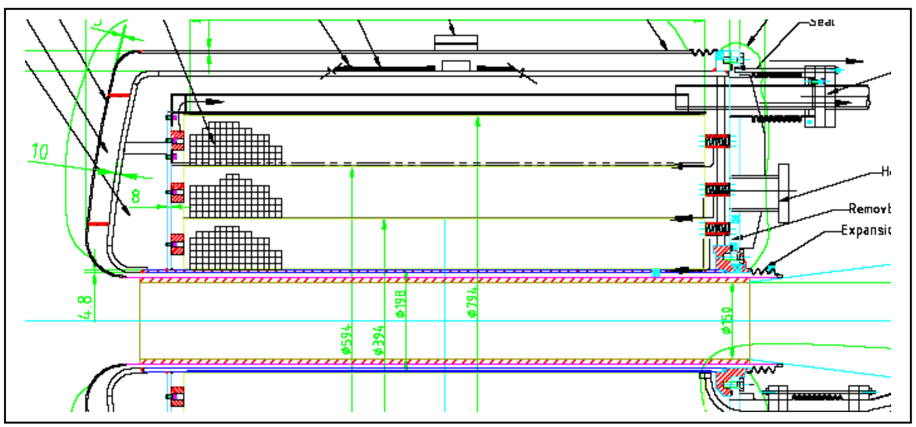
- **Qualify Annealed Copper Yielding, and "leaning" on next coil (Insulation strains are a problem)**
- **Accept lesser degree of cold work, and qualify by bending strains and hardness measurements**
- **Pre-roll to an intermediate radius with a roll set then apply Insulation, then wind down**

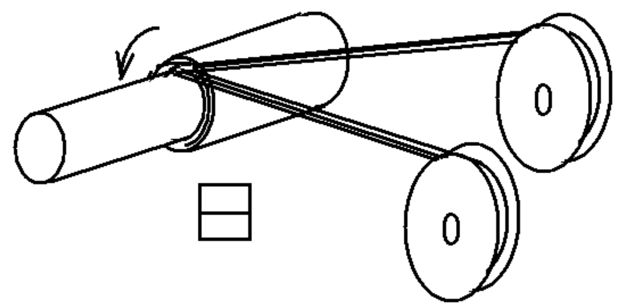
Integration Issues if there is a Magnet Sub-Vendor

- **Insertion of inner solenoid segment prior to ID flange welding**
- **Proof pressure test after inner solenoid is inserted**
- **Flow test**



Roll Set with Intermediate Radius (Tape head not shown)





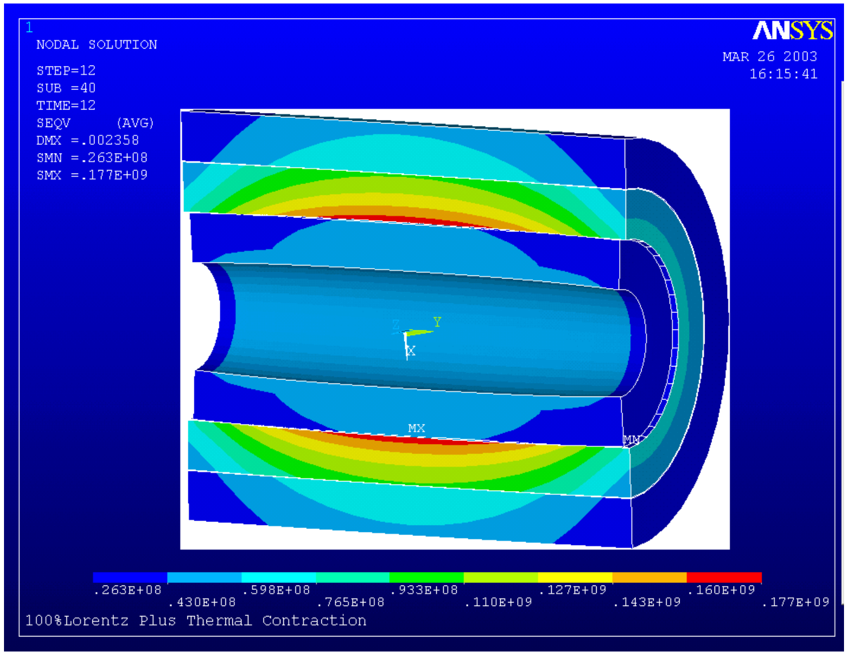
Split Conductor Option (Tape head not shown)

Use of Annealed Copper in Inner Coil Bears too hard on Second Coil

If the inner segment is annealed copper, and the middle segment of the coil supports most of the Lorentz Forces. The Von Mises stress at the ID of segment number two is 177 MPa, which would be acceptable, but there is a multiplier on the radial compressive stress that will increase the local Von Mises under the ribs significantly.
Insulation Strains would depend on segment 1 to 2 clearance, and would probably be too big.

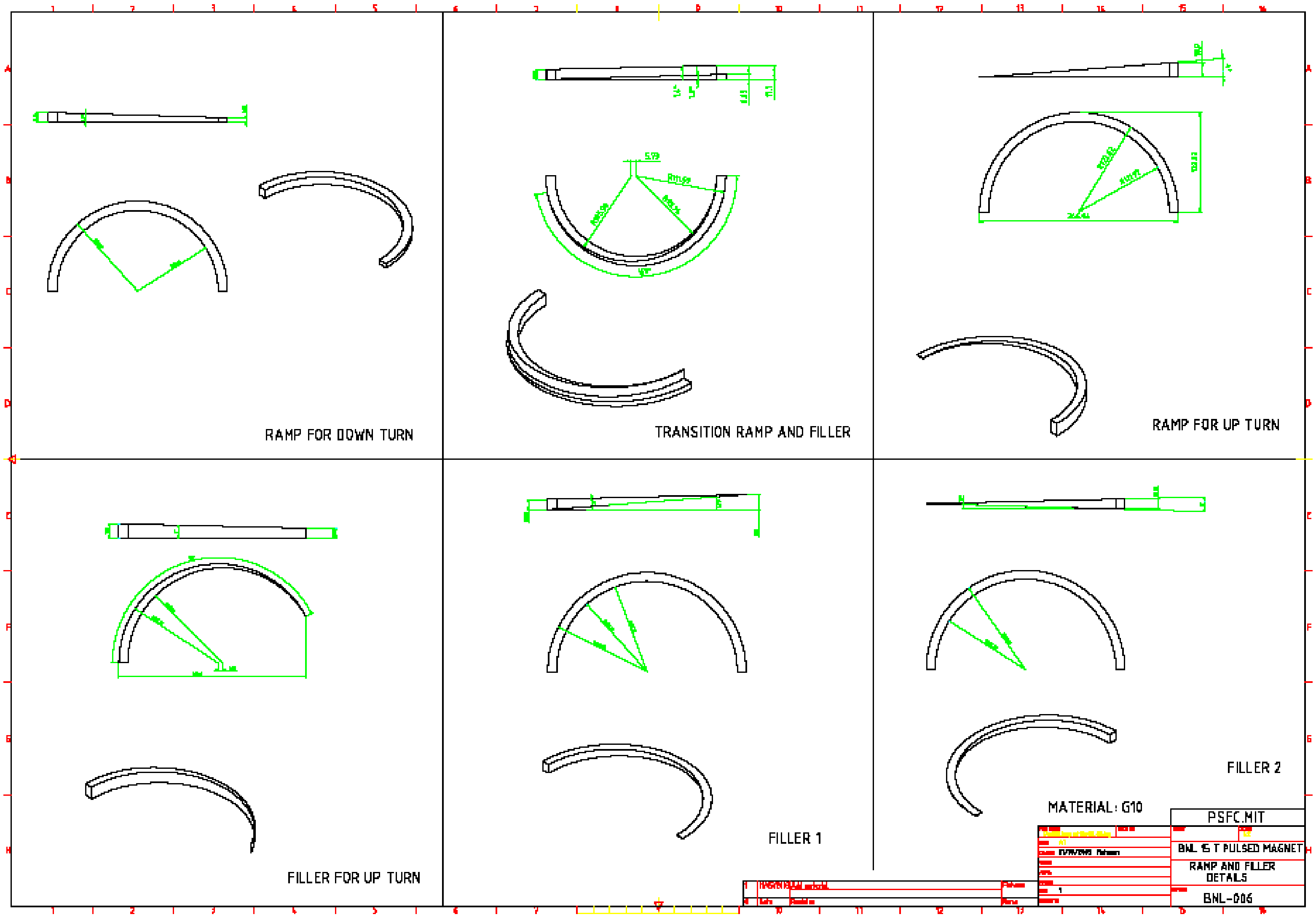
Taking Credit for Bending Strains

Elastic-Plastic behavior of the tight radius bending operation may introduce sufficient cold work to satisfy the stress allowables. H/2/R is 6% at the ID turn of the inner magnet section.
-Verify by hardness measurements

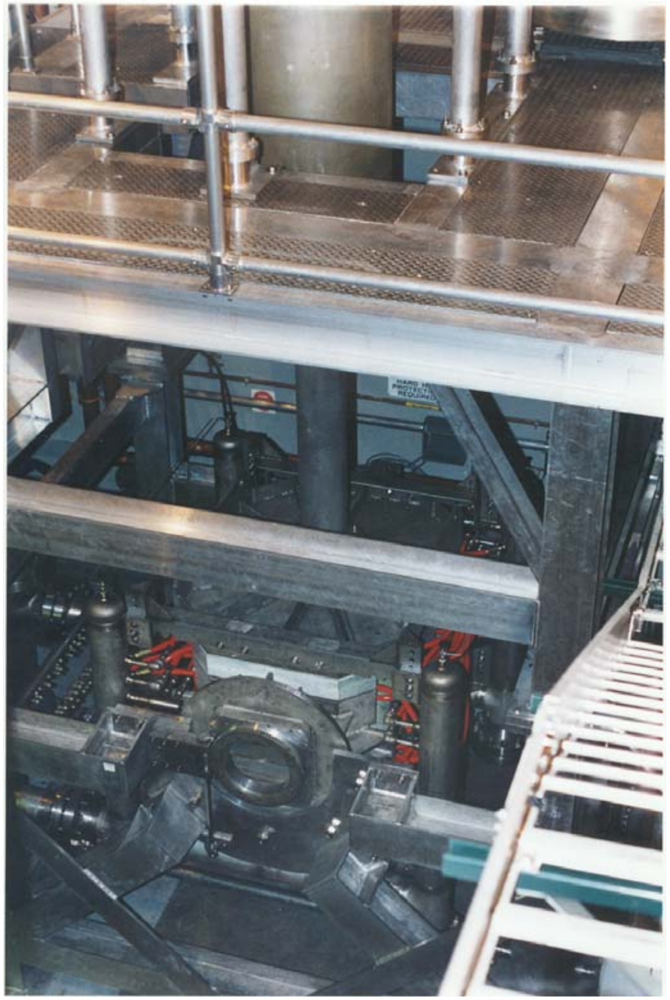


Von Mises Stress. – Elastic-plastic analysis of the inner segment made from annealed copper. .

Ramps and Fillers needed for each end of each layer require detailed thought, and either a tabular representation, or many manufacturing drawings. – A VRML file has been used to aid visualization



Pre-Operational Testing – Proposed to be Performed at MIT-PSFC Pulsed Test Facility

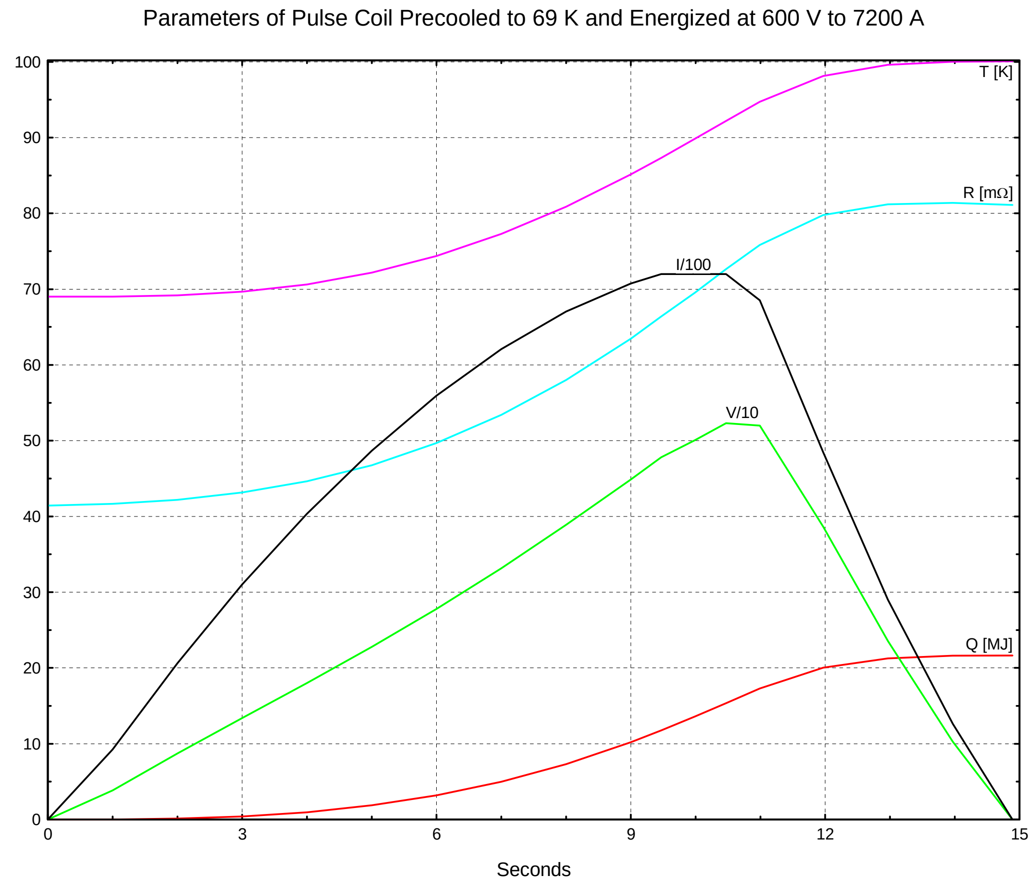


Lower Water Cooled Split Pair Copper Magnet - The BNL Pulsed Magnet would be in front of this Where the HXC Prototype cryostat is now positioned

PTF Upper Cryostat

Preliminary Review of the current /voltage profiles indicates that the PTF power supplies will meet the test requirements.

PTF Power Supplies



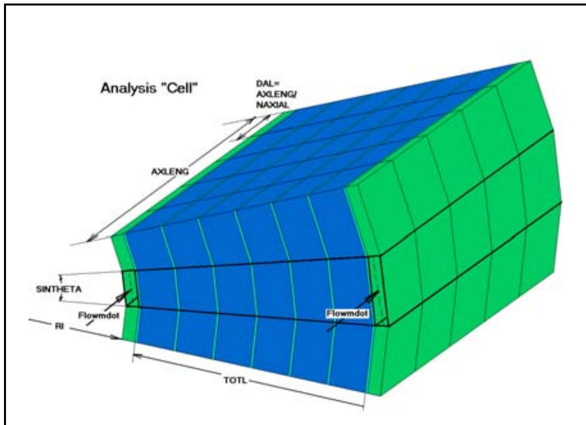
Bob Weggel's 10-14 analysis of the LN2 magnet operation

Only Liquid Nitrogen Cooling Will Be Employed During Pre-Operational Testing
C-Mod Main LN2 Supply Tank will be used with the LDX VTF supply line

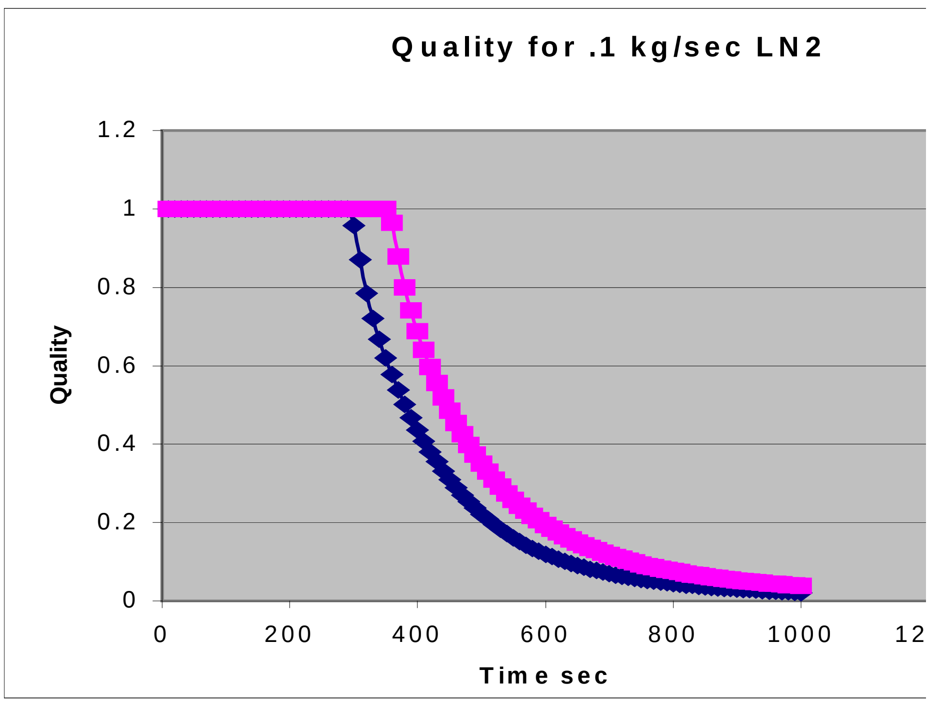
Two Approaches are possible:

Flood and Wait - Then Drain and Pulse.

Develop and implement a "skid mounted" , deliverable Controlled LN2 Cooling System



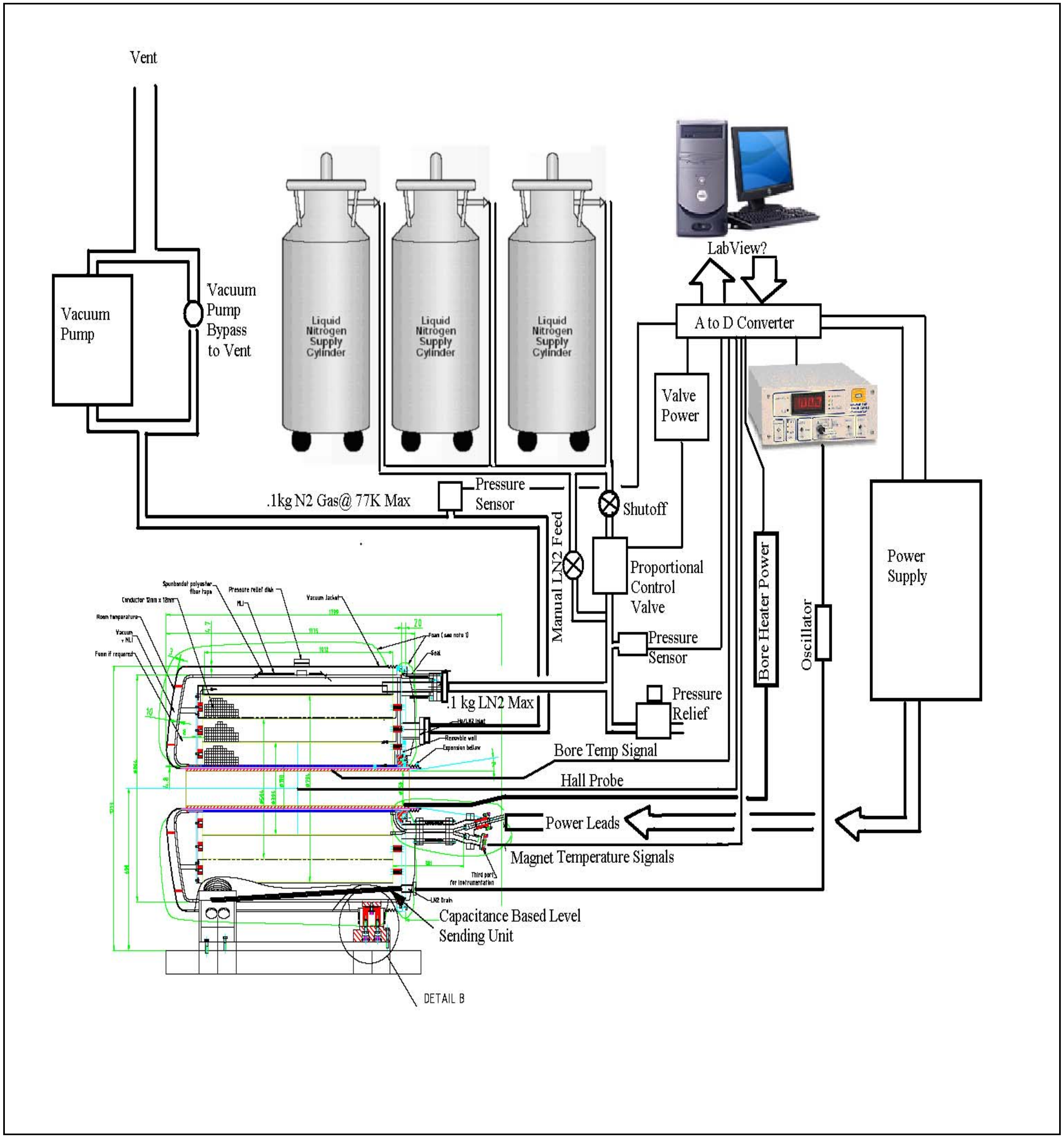
Finite Difference Cooling Model.

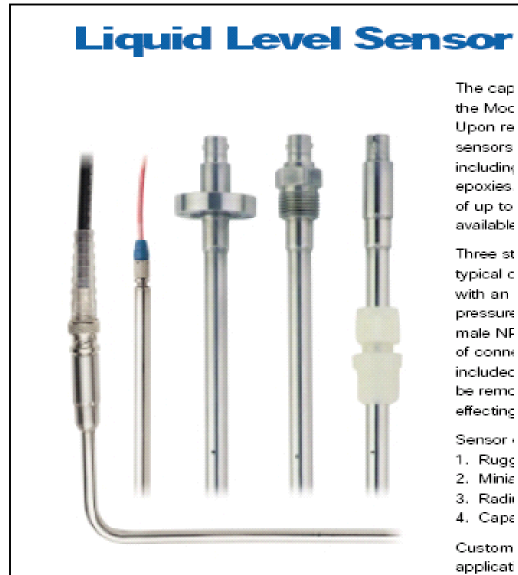


The intention is to control the LN2 flow with a proportional valve to provide only as much LN2 as is fully vaporized by the surface heat flux. After 700 sec, this would be only .1 * .1 = .01 kg/sec

C-Mod's LN2 Supply Tank

Proposed “Elaborate” LN2 System with flow metering capability.





Capacitance based level sensor