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

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BNL Pulsed Magnet –Inertially Cooled , 72K He Gas Cooled Between Shots
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 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 = 0.1416
Bolt Thread Shear Area = 0.53014376
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

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

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:

<table>
<thead>
<tr>
<th></th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Segments operating:</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Number of turns per segment</td>
<td>624</td>
<td>624</td>
<td>624</td>
</tr>
<tr>
<td>Total number of turns active</td>
<td>1248</td>
<td>1248</td>
<td>1872</td>
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<tr>
<td>Layers in each coil segment</td>
<td>8</td>
<td>8</td>
<td>8</td>
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<tr>
<td>Turns per layer</td>
<td>78</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Conductor radial thickness</td>
<td>0.0116698 m, 0.45944 in</td>
<td>0.0116698 m, 0.45944 in</td>
<td>0.0116698 m, 0.45944 in</td>
</tr>
<tr>
<td>Conductor Axial thickness</td>
<td>0.012516 m, 0.49274359 in</td>
<td>0.012516 m, 0.49274359 in</td>
<td>0.012516 m, 0.49274359 in</td>
</tr>
<tr>
<td>Max Operating Field Bore CL</td>
<td>5T</td>
<td>10T</td>
<td>15.0T</td>
</tr>
<tr>
<td>Max Field at Magnet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Terminal Current</td>
<td>3600A</td>
<td>7200A</td>
<td>7200A</td>
</tr>
<tr>
<td>Coolant Working Fluid</td>
<td>77K LN2</td>
<td>65K LN2</td>
<td>30 K Helium Gas</td>
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<tr>
<td>Terminal Voltage</td>
<td>150V</td>
<td>300V</td>
<td>300V</td>
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<tr>
<td>Layer to Layer Volts</td>
<td>18</td>
<td>36</td>
<td>24</td>
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<tr>
<td>Turn-to-Turn Volts</td>
<td>0.12</td>
<td>0.24</td>
<td>0.16</td>
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<tr>
<td>Design Life</td>
<td>1000 full power pulses</td>
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<tr>
<td>Cryostat Pressure - Initial Operating</td>
<td>12 atm</td>
<td></td>
<td></td>
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<tr>
<td>Cryostat Pressure – During Cooldown</td>
<td>15 atm max</td>
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<tr>
<td>Number of .54 MVA power supplies</td>
<td>1</td>
<td>4</td>
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<tr>
<td>Mode of Ganging Supplies</td>
<td>None</td>
<td>2 X 2</td>
<td>2 X 2</td>
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<tr>
<td>Charge Time</td>
<td>7.2 sec</td>
<td>6.3 sec</td>
<td>15.3 sec</td>
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<tr>
<td>Initial Temperature</td>
<td>84K</td>
<td>74K</td>
<td>30K</td>
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<td>Temp Rise</td>
<td>5.8K</td>
<td>21.7K</td>
<td>48.3K</td>
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<td>Final temperature</td>
<td></td>
<td>78.3</td>
<td></td>
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<tr>
<td>Cumulative heating at end of pulse</td>
<td>2.7MJ</td>
<td>9.1MJ</td>
<td>15.2MJ</td>
</tr>
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### Coil Builds used in the Finite Element Models:

<table>
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<tr>
<th>#</th>
<th>r</th>
<th>z</th>
<th>dr</th>
<th>dz</th>
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<tbody>
<tr>
<td>1</td>
<td>.15</td>
<td>0</td>
<td>.098</td>
<td>1.0</td>
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<tr>
<td>3</td>
<td>.25</td>
<td>0</td>
<td>.098</td>
<td>1.0</td>
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<td>5</td>
<td>.35</td>
<td>0</td>
<td>.098</td>
<td>1.0</td>
</tr>
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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
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
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

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
Proposed “Elaborate” LN2 System with flow metering capability.

Capacitance based level sensor