PSFC/JA-06-17

Test Plan for:
Pre-Operational Testing of
MERIT BNL – E951/(n-ToF-11), 15T Pulsed Magnet for Mercury Target Development Neutrino Factory and Muon Collider Collaboration

P.H.Titus

February 2006

Plasma Science and Fusion Center
Massachusetts Institute of Technology
Cambridge MA 02139 USA

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MIT Plasma Science and Fusion Center
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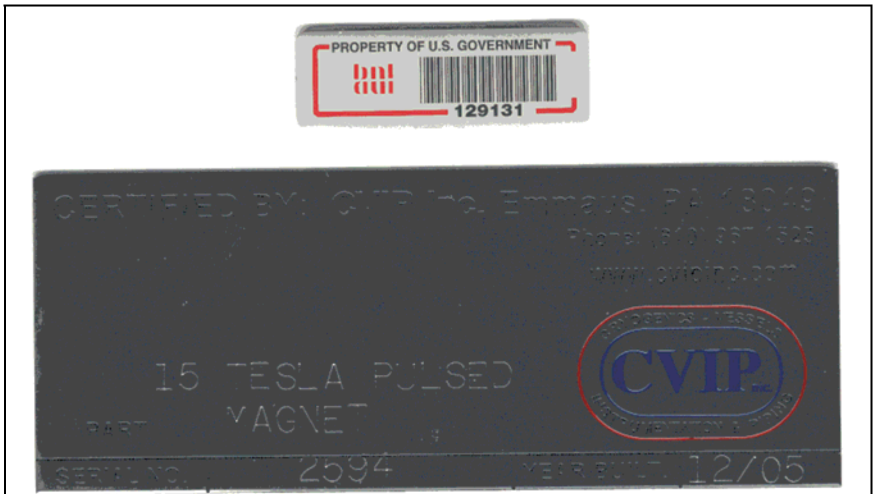
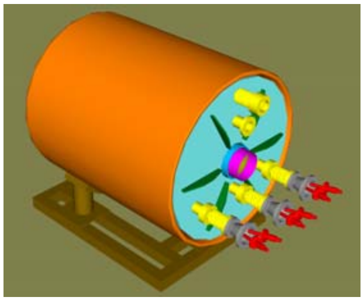
6896066

MERIT/BNL Pulsed Magnet –Inertially Cooled , LN2 or 30K He Gas Cooled Between Shots –MIT test will use only LN2





Conceptual Design

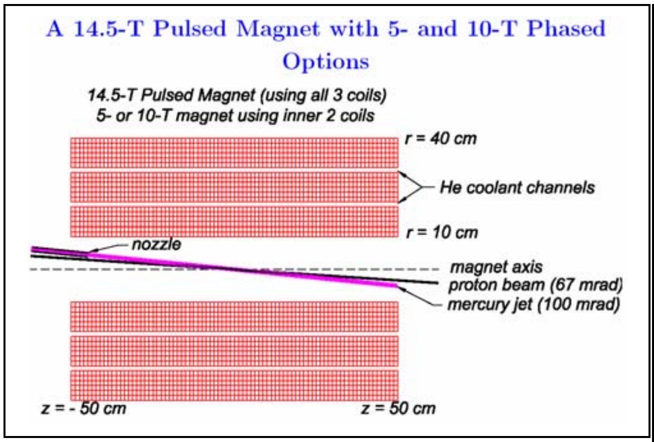
1.3 Table of Contents

1.4 Introduction

The Tests performed at MIT are documented in two reports, a test plan (this document), PSFC/JA-06-17, and a report of the results of the test, PSFC/JA-06-18. This test plan includes the original test plan that formed the basis of the test contract, in section 9.0. This was modified extensively to address changes in cooling concept, and difficulties with power supplies and temperature measurements.

The purpose of the experiment is to study mercury targets for neutrino beams and a muon collider source. In these experiments, a mercury jet intersects a proton beam in a high field. The particles that are produced are confined by the magnetic field. The beam energy deposited in the jet is large enough to violently disrupt the jet reducing its usefulness as a target. The magnetic field is expected to stabilize the mercury flow. The behavior of the mercury jet in this environment needs to be understood before resources are committed to the larger experiments. The tests performed at MIT are intended to first, exercise the magnet to it's design field of 15T, second verify that the cryogenic system can provide a 20 minute cooldown time between experimental pulses, and possibly, third to perform mercury jet tests in the magnetic field (exclusive of the proton beam)

Cost issues dictated a modest coil design. Power supply limitations dictate a compact, low inductance, high packing fraction design. three segment, layer wound solenoid is proposed for the pulsed magnet. The conductor is half inch square, cold worked OFHC copper. The coil is inertially cooled with options for liquid nitrogen or gaseous Helium cooling between shots. Coolant flows through axial channels in the coil. The coil has been epoxy impregnated, assembled into it's vessels and as of March 2006, is in the PTF test area.



Simulations of the Mercury Jet interactions with the magnetic field, and proton beam.

1.5 References

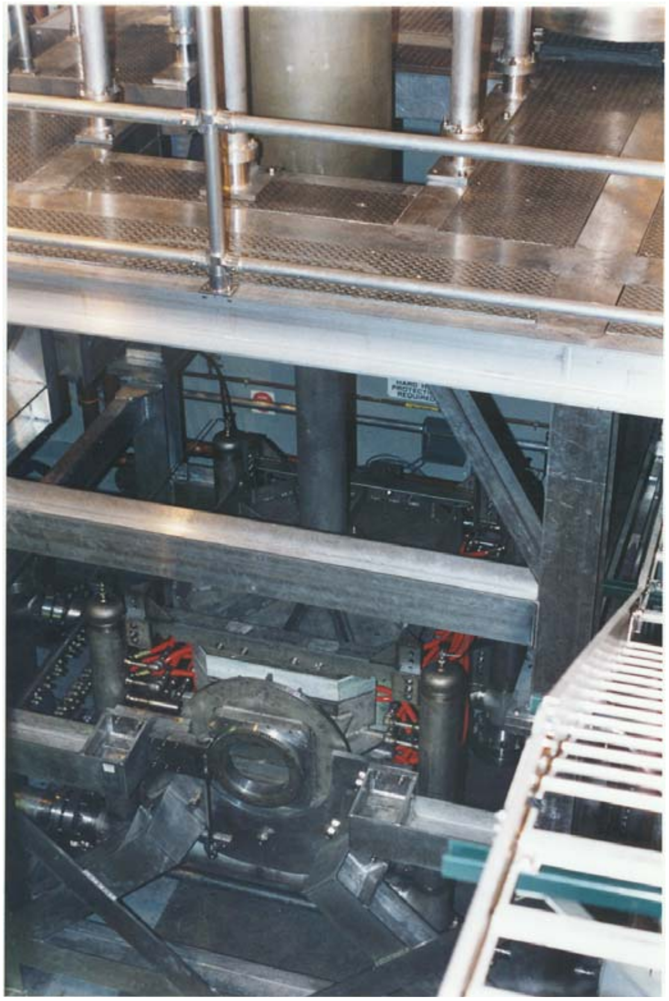
[1] Test Results For: Pre-Operational Testing of: MERIT BNL - E951(n-ToF-11) 15T Pulsed Magnet for Mercury Target Development

2.0 Objectives

- Demonstrate the capability of the magnet to operate successfully at 15 T
- Characterize the electrical performance of the magnet to verify simulations (measure inductance and resistance of the magnet and demonstrate applicability of the power supply specifications)
- Characterize the cooldown and operating displacements to verify analyses, and provide input to the mercury jet cassette design.
- Characterize the fields in the bore and in the ends of the magnet that might effect the mercury jet behavior

3.0 Test Location

The BNL pulsed magnet will be installed in the “pit” in front of the existing PSFC Pulsed Test Facility. The HCX prototype cryostat, recently in this location, (Jan 2004) has been removed(?).

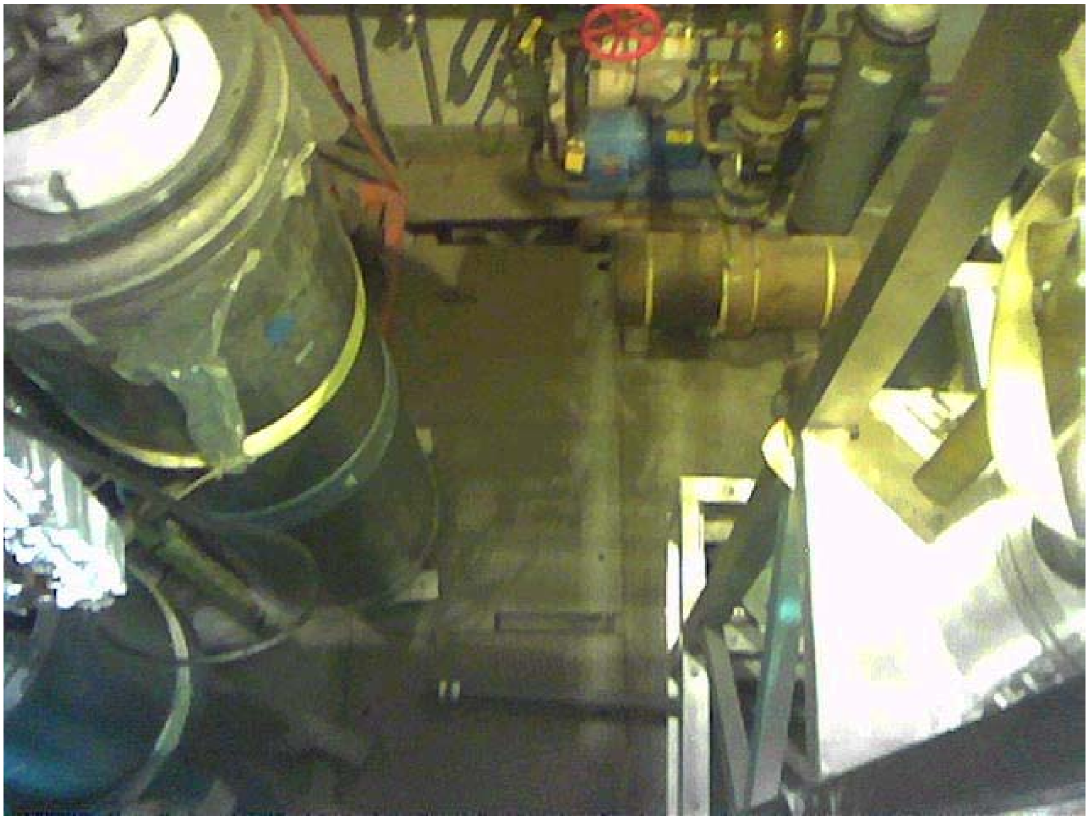


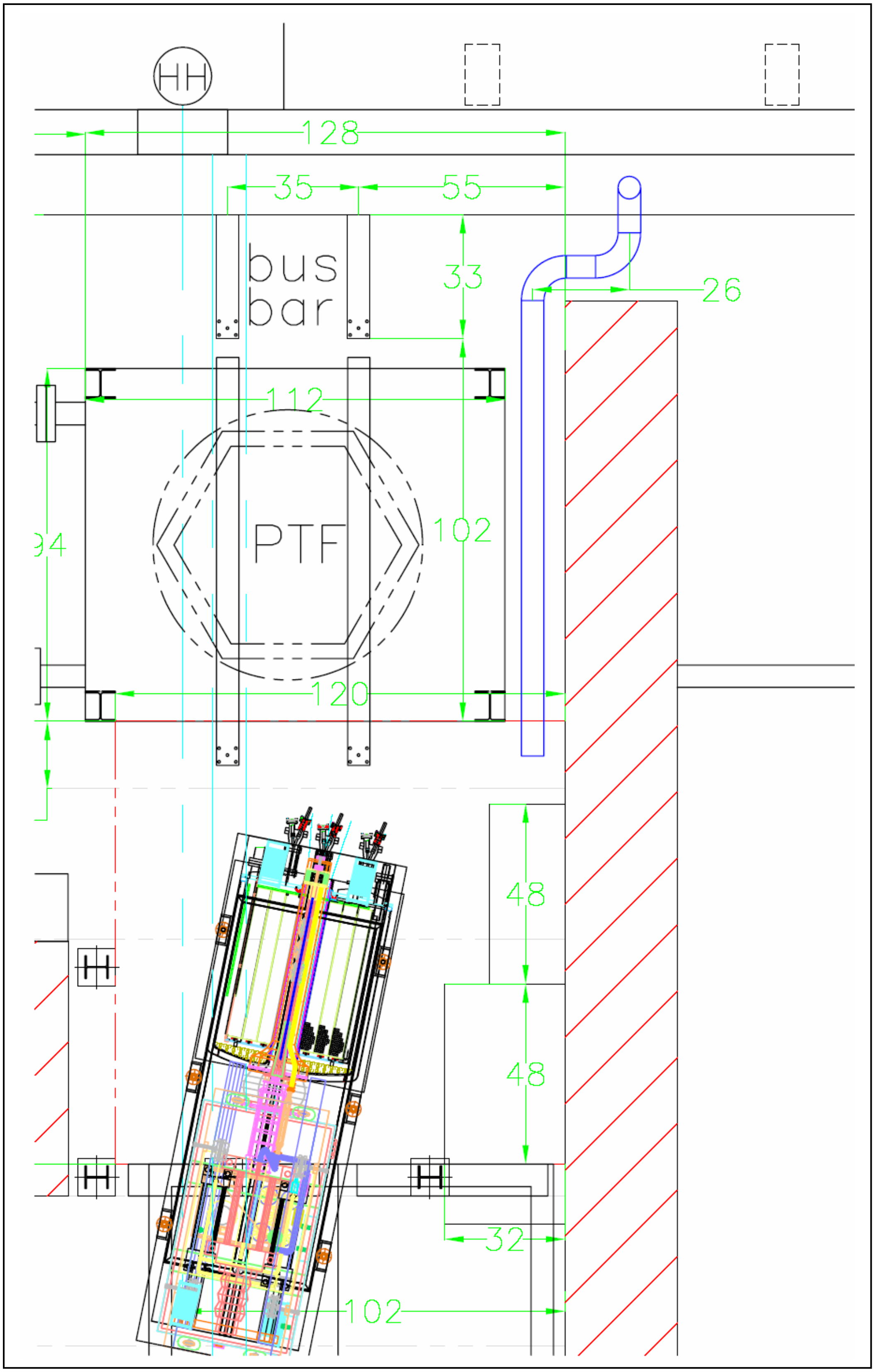
Lower Water Cooled Split Pair Copper Magnet - The BNL Pulsed Magnet will be in front of this
Where the HXC Prototype cryostat is now positioned

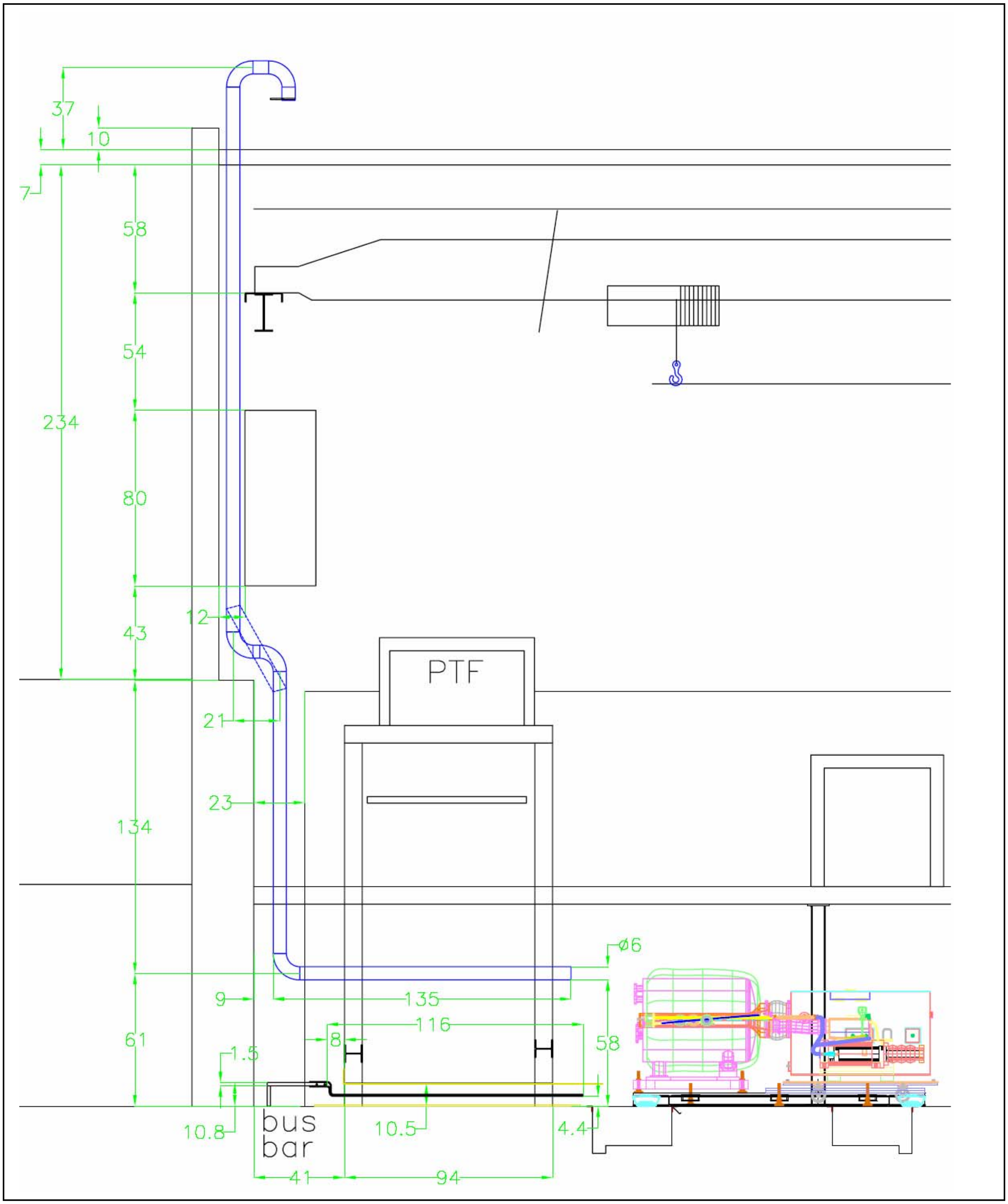
PTF Upper Cryostat

The test area will need to be cleared of extraneous equipment. Magnetic materials and tools will be removed.


View of test area at floor level


View of the test area floor prior to placement of the magnet on the floor. The dewars at left and HCX components at right have been removed. The iron core of the split pair magnet has been removed welll away from the magnetic field.


HH
128
35
55
bus
bar
33
26
112
PTF
102
120
48
48
32
102


37
10
7
58
54
234
80
12
43
21
23
134
PTF
ø6
9
135
116
8
58
61
1.5
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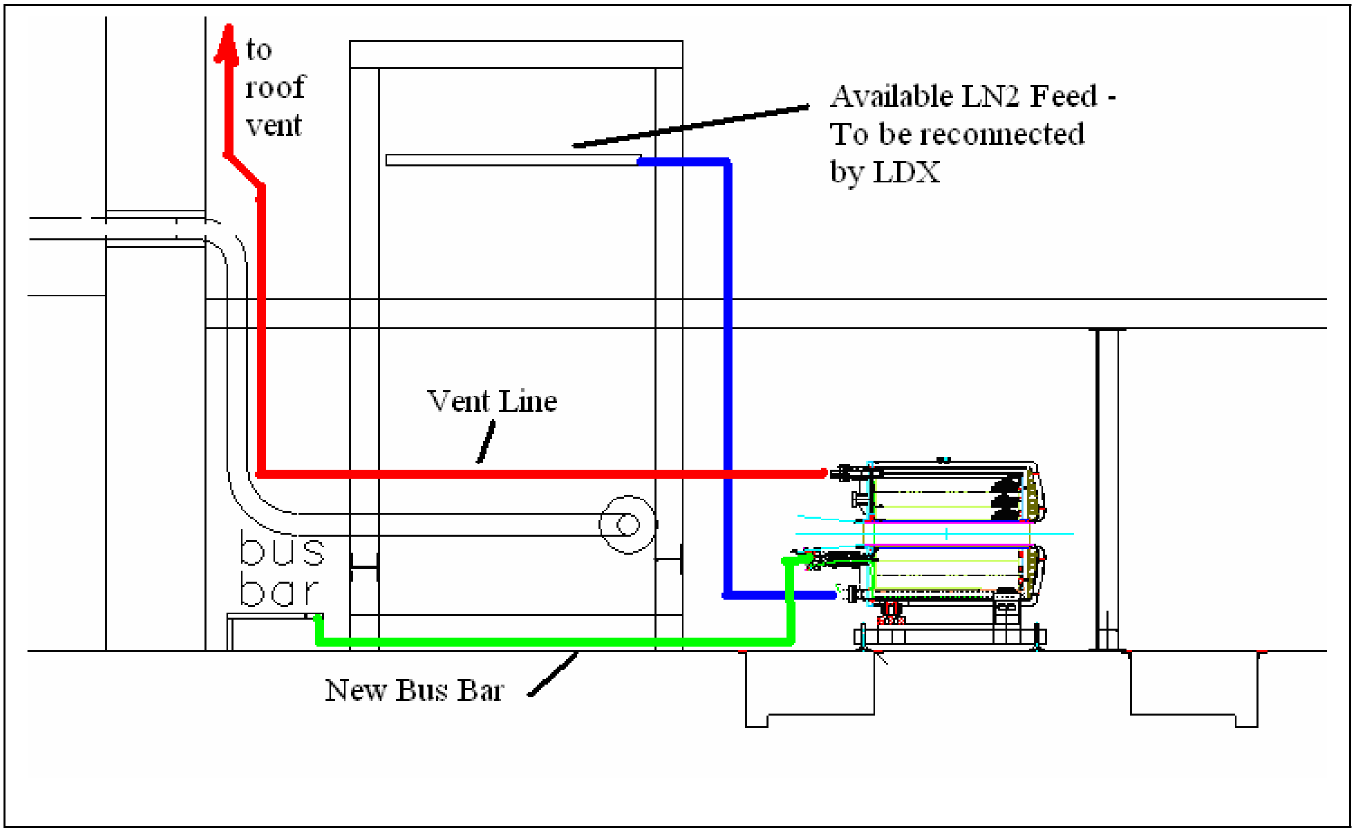
bus
bar
10.5
4.4
41
94


to
roof
vent
Available LN2 Feed -
To be reconnected
by LDX
Vent Line
bus
bar
New Bus Bar

4.0 Critical Lifts

The magnet can be lifted using slings under the mounting frame. The preferred method of lifting is using swivel lift lugs bolted to the lower frame. There is also a provision to attaché a single lift point through the vacuum pressure relieve valve on the top of the magnet, that, after removal exposes a lift lug welded to the inner cryostat.

Magnet Quantities

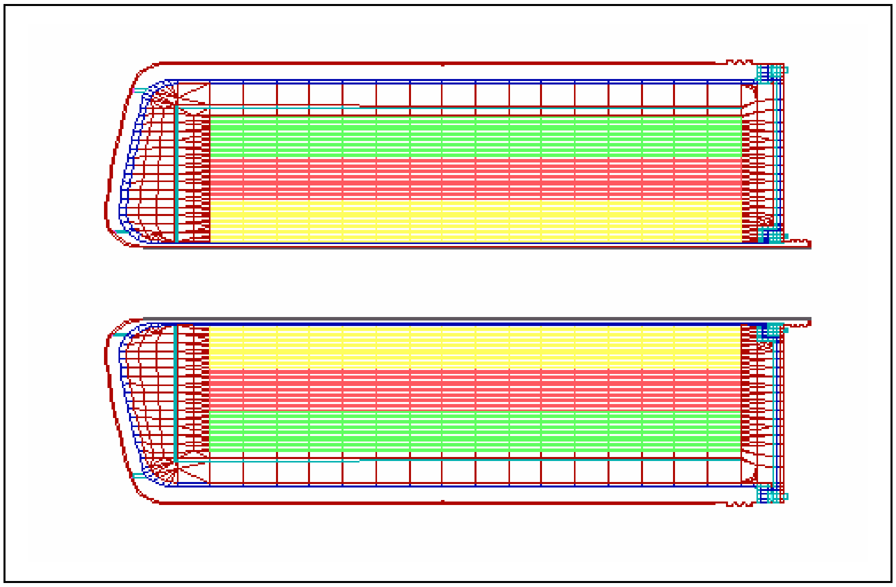
	Segment 1	Segment 2	Segment 3	Total
Volume (m^3)	9.2362824e-2	.15393804	.21551326	.4618
numturn	624	624	624	
weight (kg)	748.04651	1246.7442	1745.4419	3740.232

Magnet and Vessel and Filler Quantities from the Finite Element Model

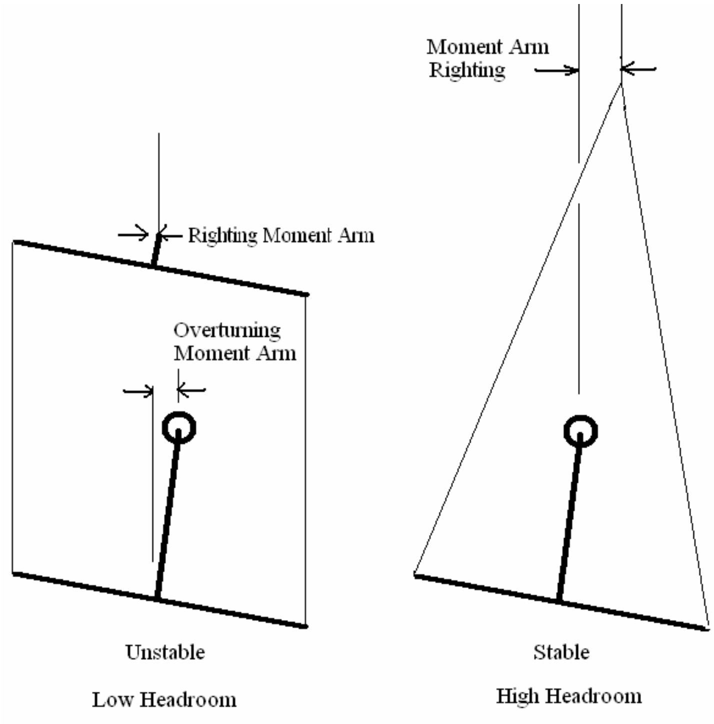
Component	FEM Mat#	Volume	Density Kg/m^3	Mass kg
Coil	1 3 5	.4618	8900	4110
Vessels		.1119	8700	973
G-10 Filler	91	.3119	1794	559
Total				5642

A 6 ton lift should be planned for .

The initial lifting rig was unstable. This can be seen in the diagram below. The triangular sling arrangement is planned for use. In order for the headroom to be acceptable, the spreaders supplied by CVIP had to be extended by about 7 inches. .



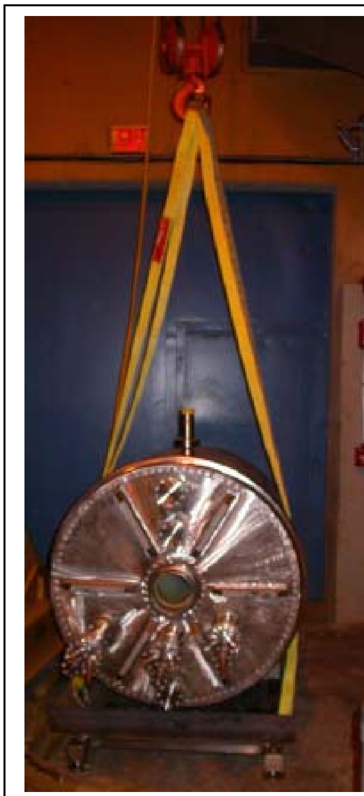
Lift Rig Design



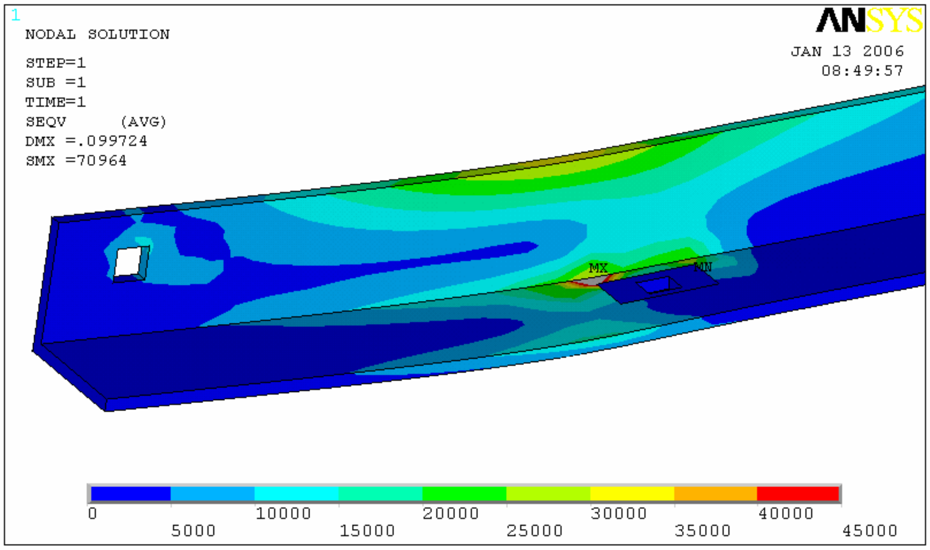
Instability of initial Spreader Beam and Stability of wider support beam with triangular slings

The CVIP angles bolt lower base plate using the threaded extensions of the leveling screws. The CVIP angles were not wide enough to avoid loading the vacuum jacket. The vacuum jacket is supported against the inner cryostat dished head via thin G-10 rings that must not be disturbed. – especially by lateral loading. The large PSFC spreader beam was first used to allow the slings to run vertical and not touch the vacuum shell. We hadn't lifted the coil by more than an inch and it was clear this was unstable. The reason is that the righting moment provided by the cross beam was lower than the overturning moment caused by the height of the coil CG. To fix this, wider angles were purchased in parallel with efforts to analyze the specified size. The purchased 4 inch by 3/8 inch angles did not come with any pedigree, but they were obtained from a framing steel contractor and are assumed to be A36 (36ksi yield, minimum ultimate of 58 ksi). At the increased width needed for the slings to clear the vacuum jacket, the new angle iron was overstressed. It was decided to reinforce the new angle with the CVIP angle by welding them together.

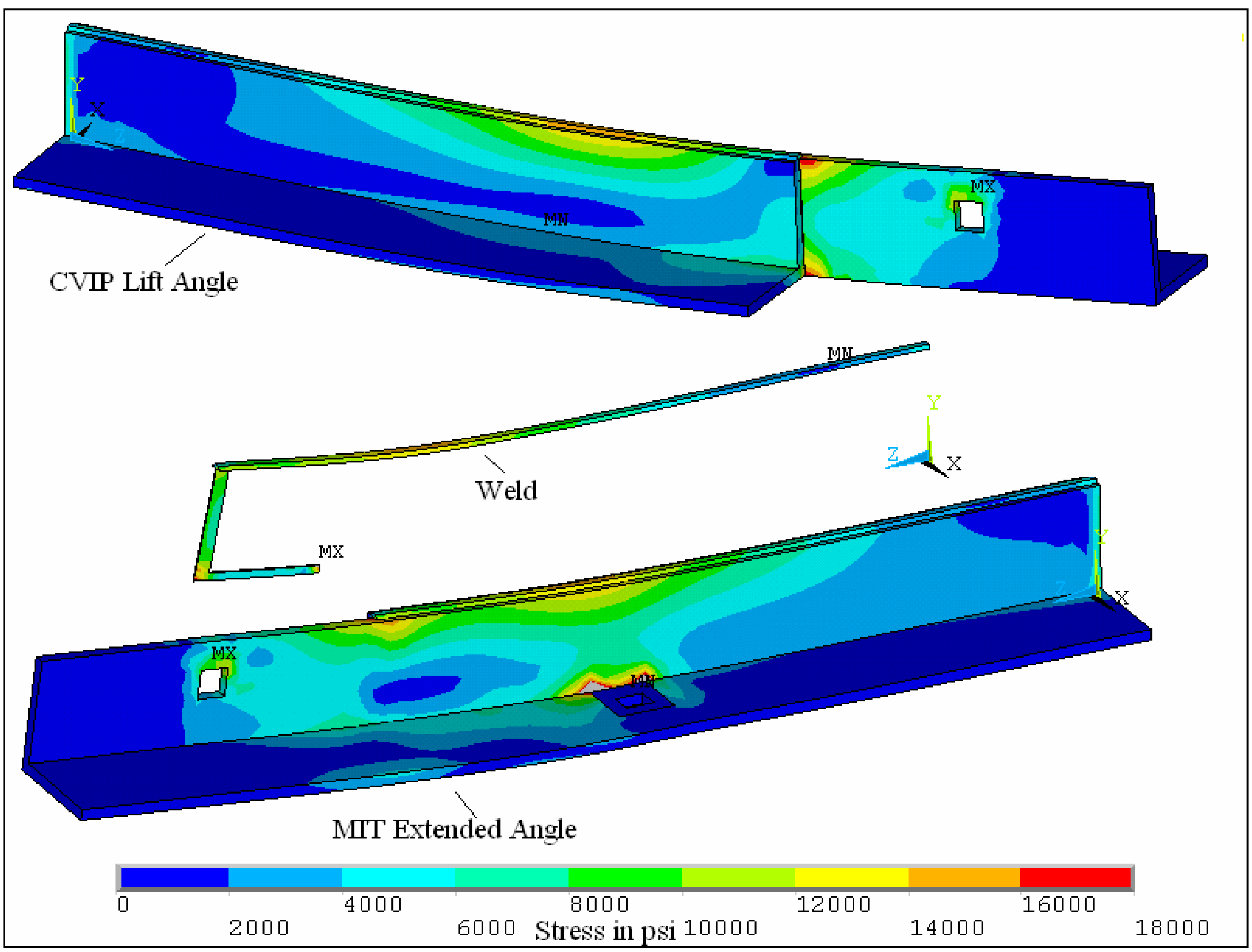
Unstable lift beam configuration



Without extensions the slings interfered with the vacuum Shell.



Wider angles, needed to allow a reasonable headroom, had excessive stress. Bending stress is about 30 ksi.



The weld is modeled as 1/8 inch thick in the finite element analysis. ¼ inch welds are used, which have a throat size of .25*.707= .176 in. Ignoring the local peaks near the bolts, and weld leading edge, the beam bending stress is about 14ksi, local weld details at leading edges are near 18ksi but 16 ksi is more representative. Von Mises Stresses are plotted. Weld stresses need to be corrected for the actual vs. modeled throat size.

Bending Stress levels in the MIT/CVIP spreader beams are about 14ksi. Peak stresses are 18ksi., The factor of safety, based on bending stress is 36/16= 2.25. Based on plastic collapse (plastic hinge formation), the factor of safety is 2.25*6/4=3.375.

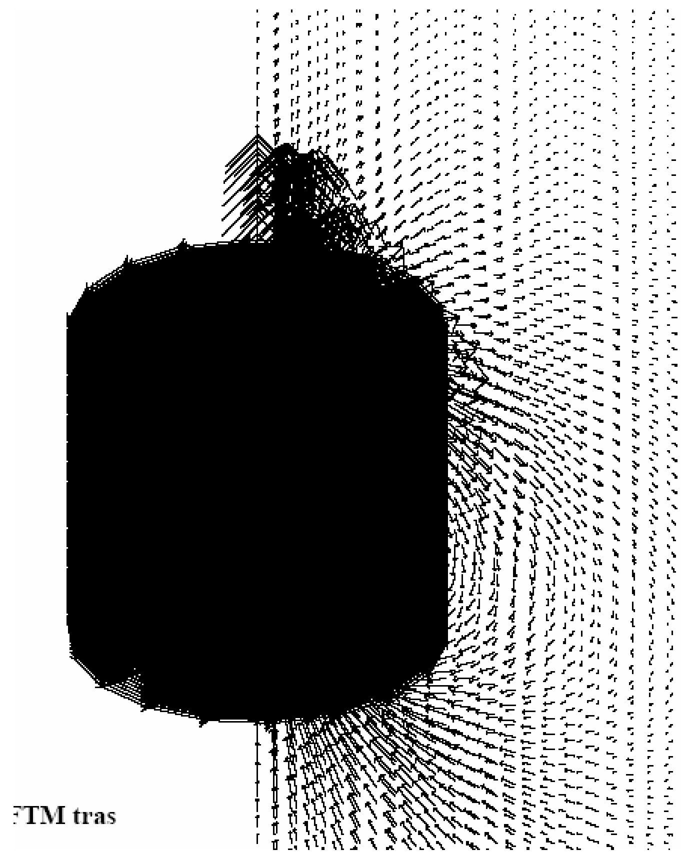
Correcting the weld stress for actual vs. modeled throat size the weld stress intensity is 16*.125/.176 =11.36ksi. Weld material properties will be better than base metal, but use AISC allowables. for A36 welded with E60 rod and submerged arc welding, the allowable is 13,600 psi shear on the throat of a fillet weld in any direction (Blogget, Design of Welded Structures, page 3.6-3) . Doubling this to compare with a stress intensity, the factor of safety in the weld is 13.6*2/11.36 = 2.39. If the lack of pedigree and welder qualification is a problem, CERN can provide a heavier angle.

Magnet lowered into place in front of PTF split pair magnet. This shows the MIT/CVIP lift rig in use.

5.0 Power Supplies

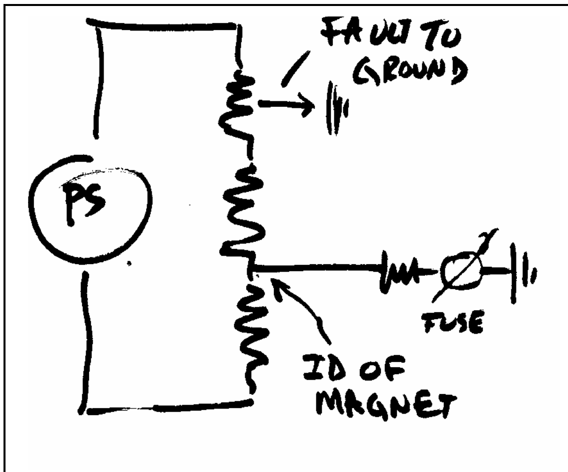
Preliminary Review of the current /voltage profiles indicates that the PTF power supplies will meet the test requirements. The existing PLC controllers and Kronos (VMS) operating environment are planned to be used for the BNL tests. The power supplies will be re-configured to produce the required current and voltage. There are a couple of amplifiers that need to be replaced. These have been included in the cost estimate,

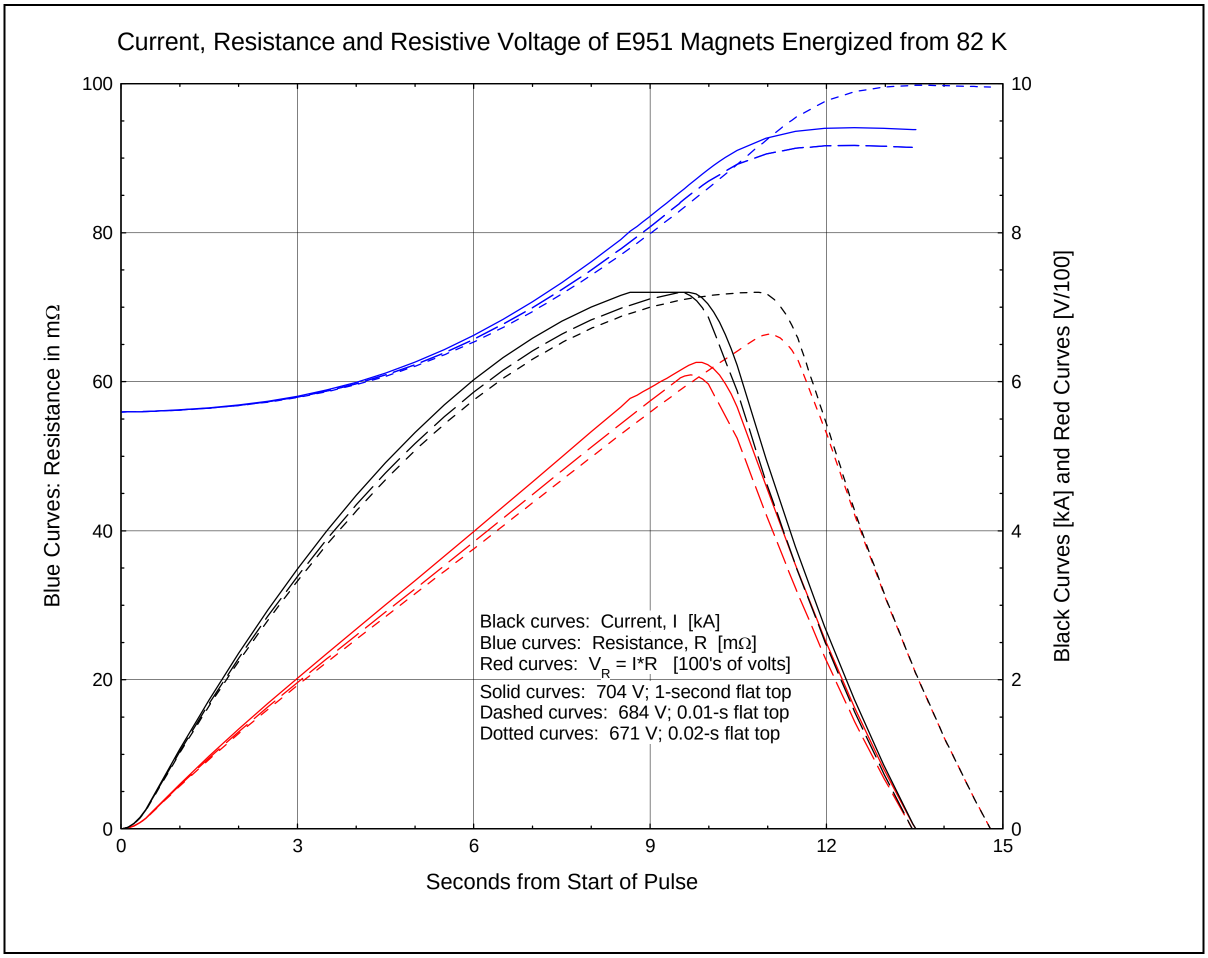
PTF Power Supplies



Inductance Calculation from Field-Volume Integral. Inductance=.484 Henries

We also are going to center tap the magnet - grounding the terminal connected to the inner layer of segment 1, and grounding the vessels. This minimizes the voltage across the ground plane where mechanical damage to the coil is most likely - where the magnet bears against the spline tube. This is possible because our power supply "floats" i.e. the negative lead does not have to be at ground potential. The center tap also is used for a ground fault detection. I think we will want this configuration at CERN. The center tap does not require a large cable.



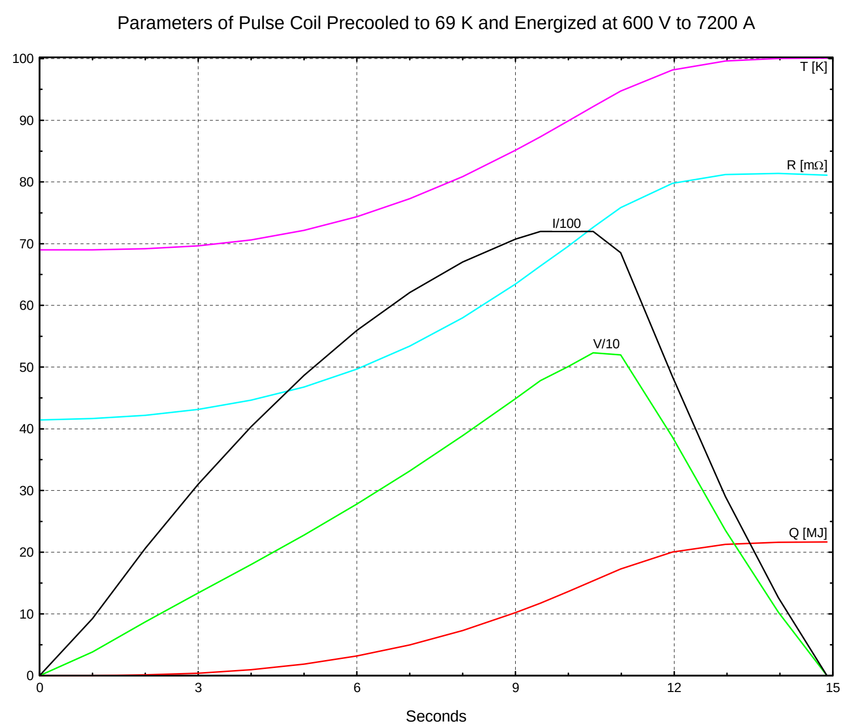

Current, Resistance and Resistive Voltage of E951 Magnets Energized from 82 K
Blue Curves: Resistance in mΩ
Black Curves [kA] and Red Curves [V/100]
Seconds from Start of Pulse
Black curves: Current, I [kA]
Blue curves: Resistance, R [mΩ]
Red curves: V_R = I*R [100's of volts]
Solid curves: 704 V; 1-second flat top
Dashed curves: 684 V; 0.01-s flat top
Dotted curves: 671 V; 0.02-s flat top
0
3
6
9
12
15
20
40
60
80
100
2
4
6
8
10


1 - MAIN INPUT SWITCH
CONVERTERS 7-8-9
#5 TRANSFORMER 3
CONVERTER

Phil Michaels talked with Gary Dekow and with Bill Parker about our plans to reactivate the PTF power system control circuitry.

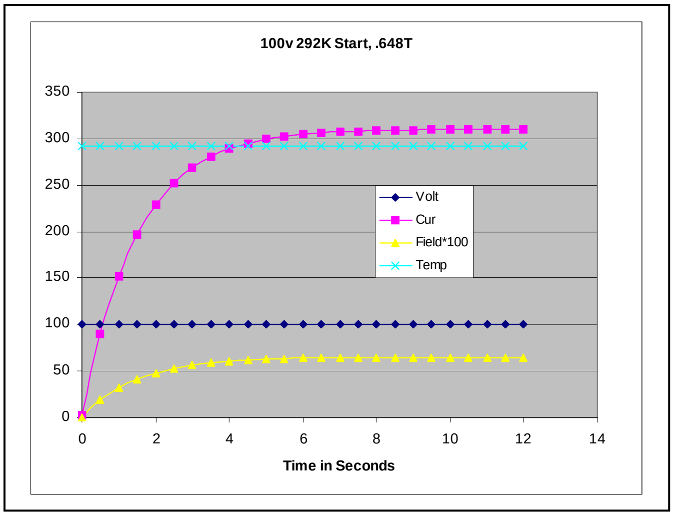
Our agreement with Alcator is that they will provide the labor to re-activate our control cabinet and we will provide the replacement component parts. Bill said that he will check the price and availability of needed components again and send that to us. –We have an earlier estimate, that has been included in the proposal cost estimate

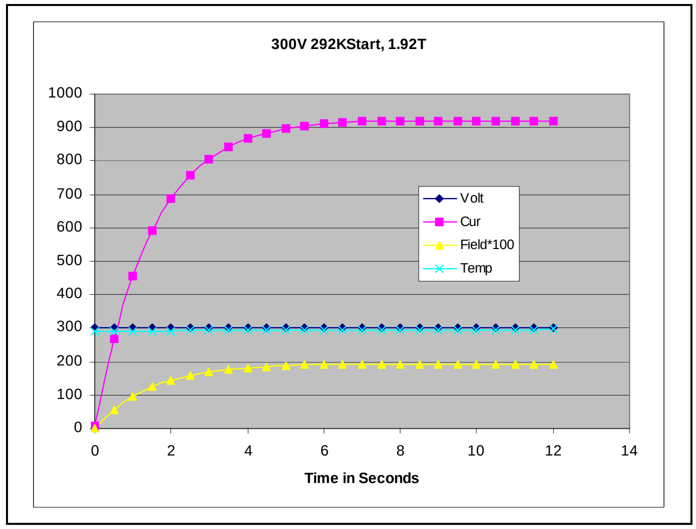
The issue of resetting the transformer connections to the higher voltage tap setting is a different matter. Phil indicated that the labor for this work would likely run to six technician days (two guys for three days) and perhaps one engineering supervision day. Probably the engineering supervision will be at no cost. Check out of system performance following the repairs and switch would likely be two to three engineer days. Work on the computer end of control and data acquisition could reasonably run five engineer days. I think these are realistic estimates before application of the Minervini correction factor.

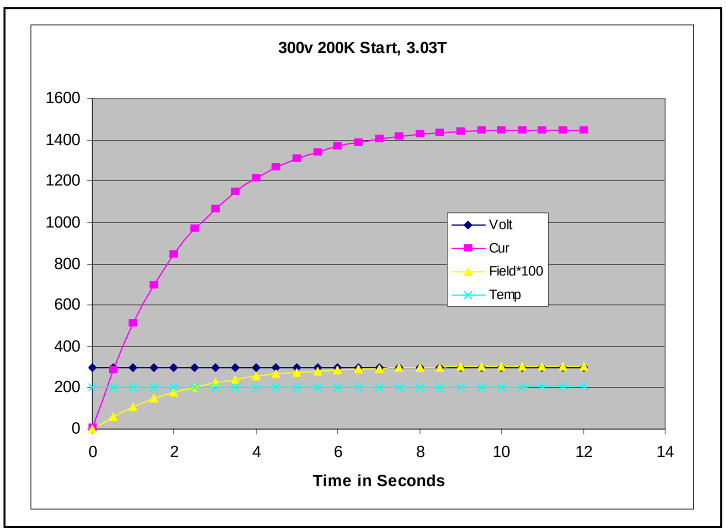


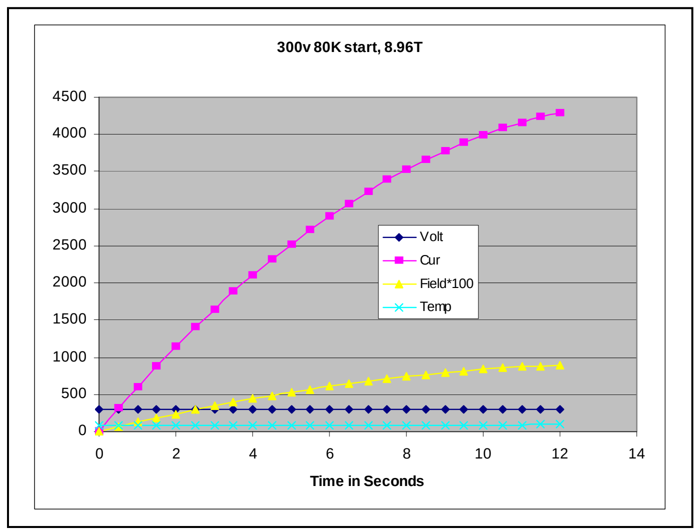
Bob Weggel’s 10-14-04 analysis of the LN2 magnet operation – With Sub Cooling. –Currently no longer planned .

Possible Lower Voltage Scenarios:









Over Voltage Protection for the Converters

The following is a list of the materials and the approximate cost of each component that will be needed to upgrade the overvoltage protection in the six power convertors that are located in the west-cell. I have also included the quantity required and a grand total for all material. In addition, I have included some vendor contact information regarding the instrumentation of the DC load current.

Power Convertor Transient Overvoltage Protection Component Parts List:

1. Ferraz-Shawmut MOV Protector Fuse, Part # VSP40-2, Quantity 36, Price/Unit $8.88, Vendor-Standard Electric.

2. Ferraz-Shawmut MOV Protector Fuse Holder, Part # US3J1, Quantity 36, Price/Unit $13.33, Vendor-Standard Electric.

3. LittelFuse High Energy Varistor-DA series, Part # V661DA40, Quantity 36, Price/Unit $ 48.69, Vendor-Newark.

4. Molex High Barrier Terminal Strip, 76 series, 20Amp, 5 point, Part # 14F2602, Quantity 36, Price/Unit $ 1.23, Vendor-Newark.

5. Molex 76 series Barrier Strip Jumpers, Part # 94F8420, Quantity 200, Price/Unit $ 0.08, Vendor-Newark.

6. T&B Sta-Kon Vinyl Insulated Fork Terminals (#6 Bolt-12-10 AWG), Part # 33F1337, Quantity 300, Price/Unit (50/Box) $ 35.98, Vendor-Newark.

7. S.S. Slotted Machine Screw (10-32 x 1.25"L), Part # 91792A835, Quantity 72, Price/Unit (100/Box) $ 6.78, Vendor-McMaster-Carr.

8. S.S. Slotted Machine Screw (8-32 x 5/8"L), Part # 91792A196, Quantity 72, Price/Unit (100/Box) $ 4.02, Vendor-McMaster-Carr.

9. S.S. Slotted Machine Screw (6-3 x 3/4"L), Part # 91792A151, Quantity 144, Price/Unit (100/Box) $ 3.37, Vendor-McMaster-Carr.

10. S.S. Slotted Machine Screw (6-32 x 1/2"L), Part # 91792A148, Quantity 36, Price/Unit (100/Box) $ 3.01, Vendor-McMaster-Carr.

11. S.S. Flat Washer (#10), Part # 92141A011, Quantity 72, Price/Unit (100/Box) $ 1.35, Vendor-McMaster-Carr.

12. S.S. Flat Washer (#8), Part # 92141A009, Quantity 72, Price/Unit (100/Box) $ 1.15, Vendor-McMaster-Carr.

12. S.S. Flat Washer (#6), Part # 92141A007, Quantity 180, Price/Unit (100/Box) $ 1.23, Vendor-McMaster-Carr.

11. S.S. Lock Washer (#10), Part # 92146A550, Quantity 72, Price/Unit (100/Box) $ 1.60, Vendor-McMaster-Carr.

12. S.S. Lock Washer (#8), Part # 92146A545, Quantity 72, Price/Unit (100/Box) $ 1.42, Vendor-McMaster-Carr.

12. S.S. Lock Washer (#6), Part # 92146A540, Quantity 180, Price/Unit (100/Box) $ 1.42, Vendor-

McMaster-Carr.

13. Nylon Spacer (1/2"OD x 1/4"L x #10 hole ID), Part # 94639A139, Quantity 72, Price/Unit (100/Box) $ 5.07, Vendor-McMaster-Carr.

14. Electrical Grade Fiberglass Sheet (GP03), (1/2" Thick x 24"H x 36"L), Part # 8549K78, Quantity 2, Price/Unit $81.24, Vendor-McMaster-Carr.

15. 10AWG, 600V PVC Hookup Wire (Blk), Part # C2107B-100-ND, Quantity 500', Price/Unit (100'/Roll) $ 35.18, Vendor-Digi-Key Corp.

16. 10AWG, 600V PVC Hookup Wire (Red), Part # C2107R-100-ND, Quantity 500', Price/Unit (100'/Roll) $ 35.18, Vendor-Digi-Key Corp.

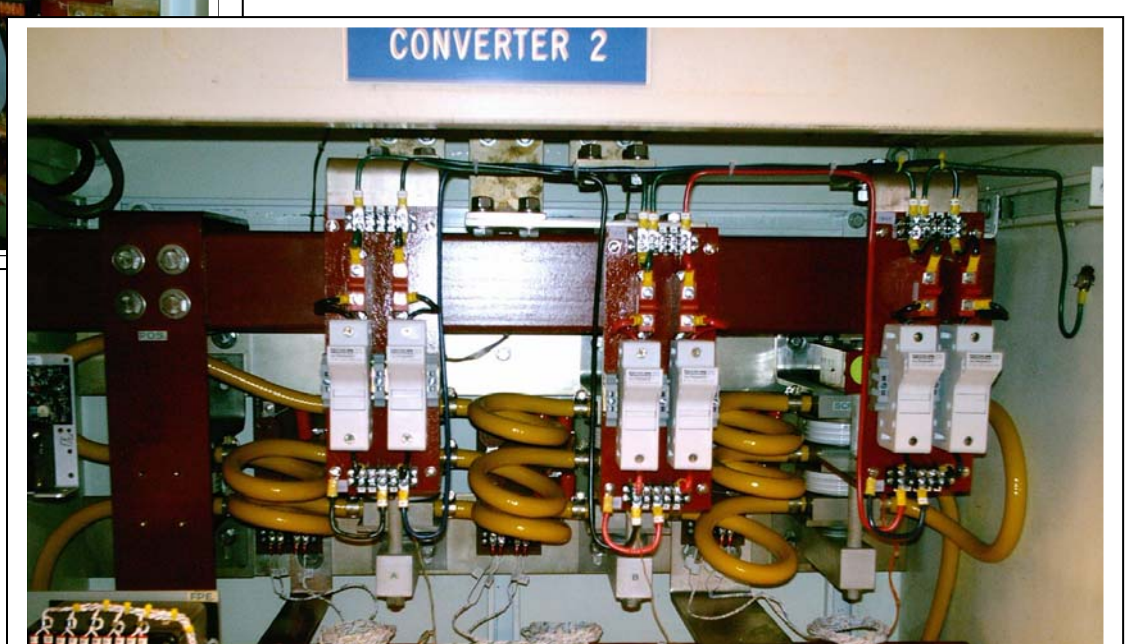
17. 10AWG, 600V PVC Hookup Wire (Blue), Part # C2107L-100-ND, Quantity 500', Price/Unit (100'/Roll) $ 35.18, Vendor-Digi-Key Corp.

18. 10AWG, 600V PVC Hookup Wire (Grn), Part # C2107G-100-ND, Quantity 500', Price/Unit (100'/Roll) $ 35.18, Vendor-Digi-Key Corp.

19. Phoenix Terminal Block End Bracket, Part # 277-1523-ND, Quantity 72, Price/Unit $1.13, Vendor-Digi-Key Corp.

20. Steel DIN Rail, Part # ADR3575-U4800-ND, Quantity 4, Price/Unit $ 7.97, Vendor-Digi-Key Corp.

21. Clear Shellac Sealant, 12oz Aerosol Can, Part # 7655T1, Quantity 4, Price/Unit $ 6.74, Vendor-McMaster-Carr.



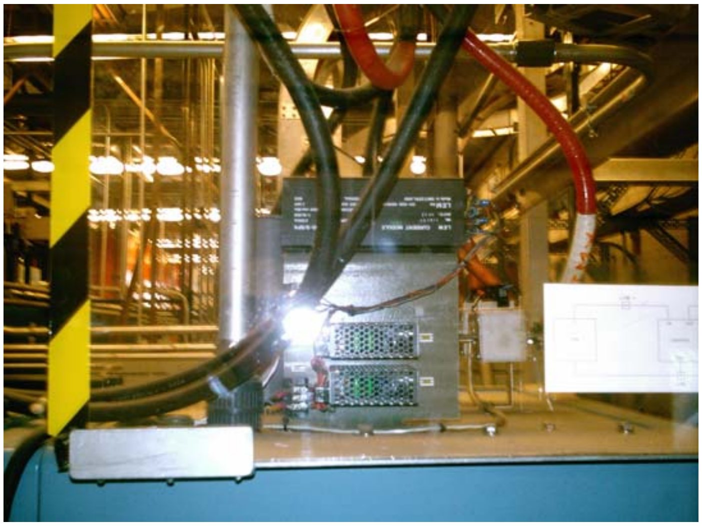
Current Shunt, Current Calibration

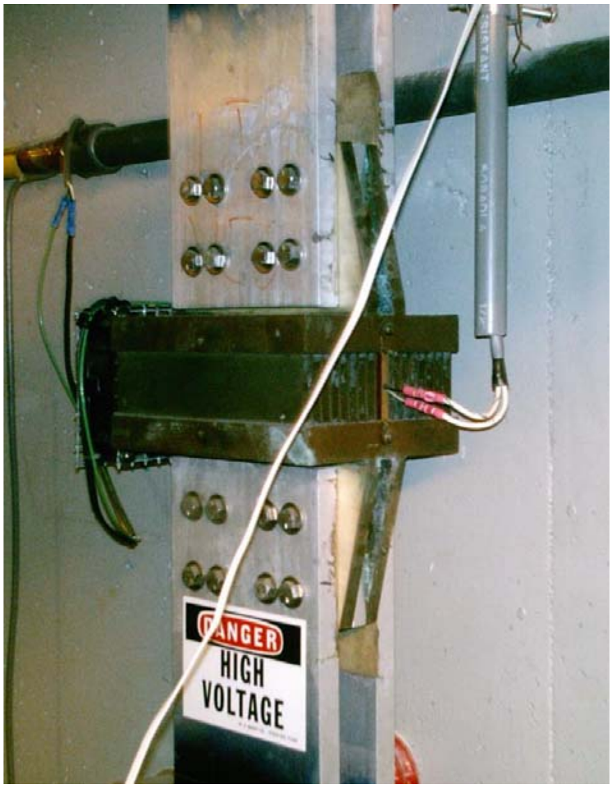
Instrumentation Vendor Contact Info:

High Current Shunts:
T&M Research Products
139 Rhode Island NE.
Albuquerque, NM 87108
Phone# (505)-268-0316
Fax# (505)-255-9594
Engineer/Owner: Buck Ingram Ph.#(505)-449-1671
Sales: Pete

EmproShunts Mfg. Co., Inc
Phone: 317-823-4478
Fax: 317-823-4835

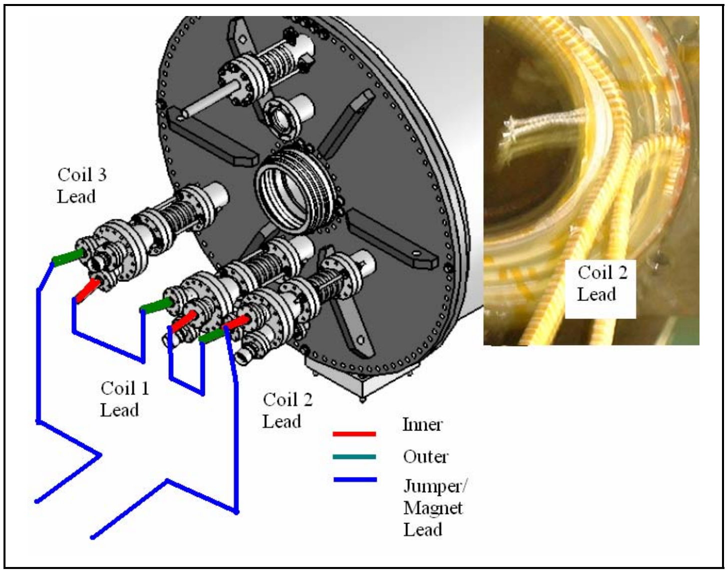
Current Transducers
LEM USA, Inc.
6643 W. Mill Road
Milwaukee, WI, 53218
Phone: 414-353-0711
800-236-5366
Fax: 414-353-0733


LEM



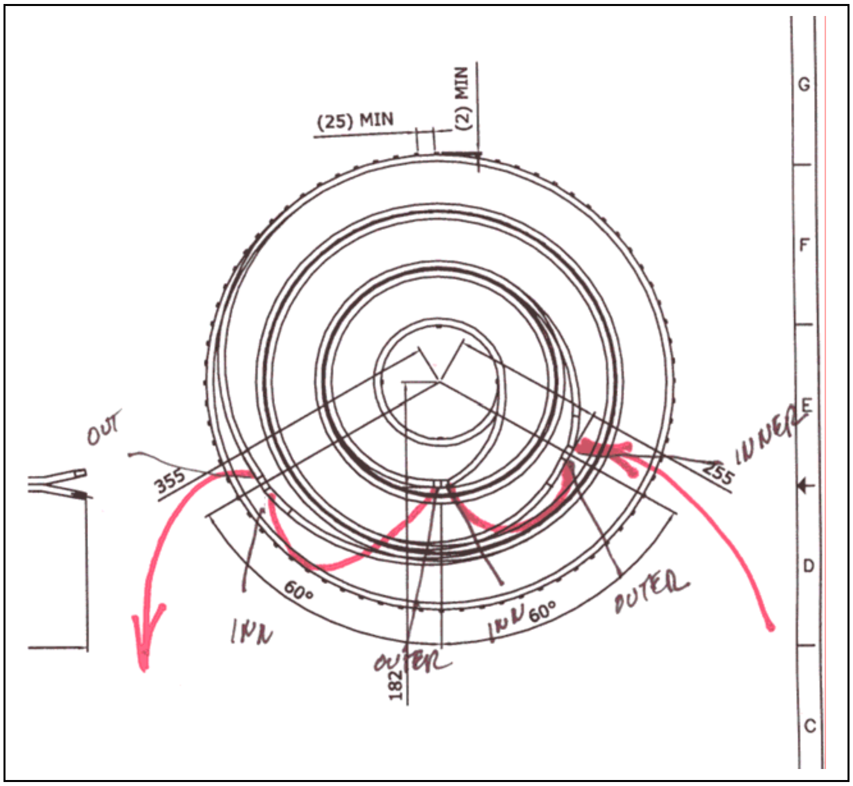
Buss Bar and Jumper Connections.

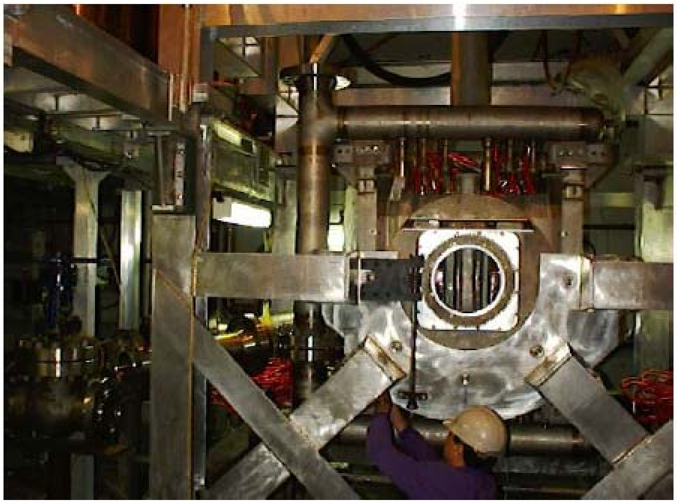
The magnet will be shipped without jumpers to connect the three coils in series. These will have to be fabricated at MIT. Additional support for the jumpers and for the bus bar connections may be needed.

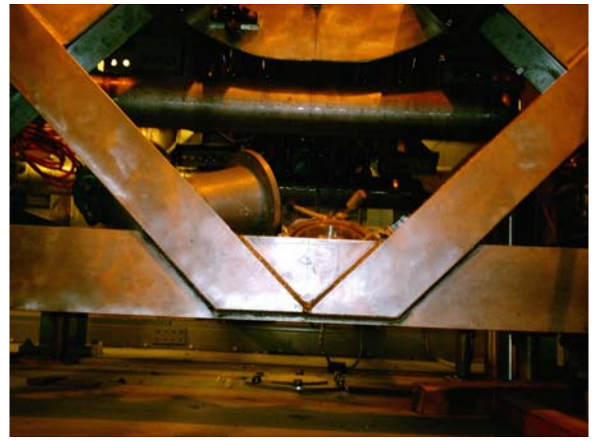


Jumpers used with the BNL Magnet

These Will also be designed and fabricated at MIT prior to the tests. Buss and jumpers should have a maximum resistance of 1 milliohm to be consistent with Bob Weggels simulation .



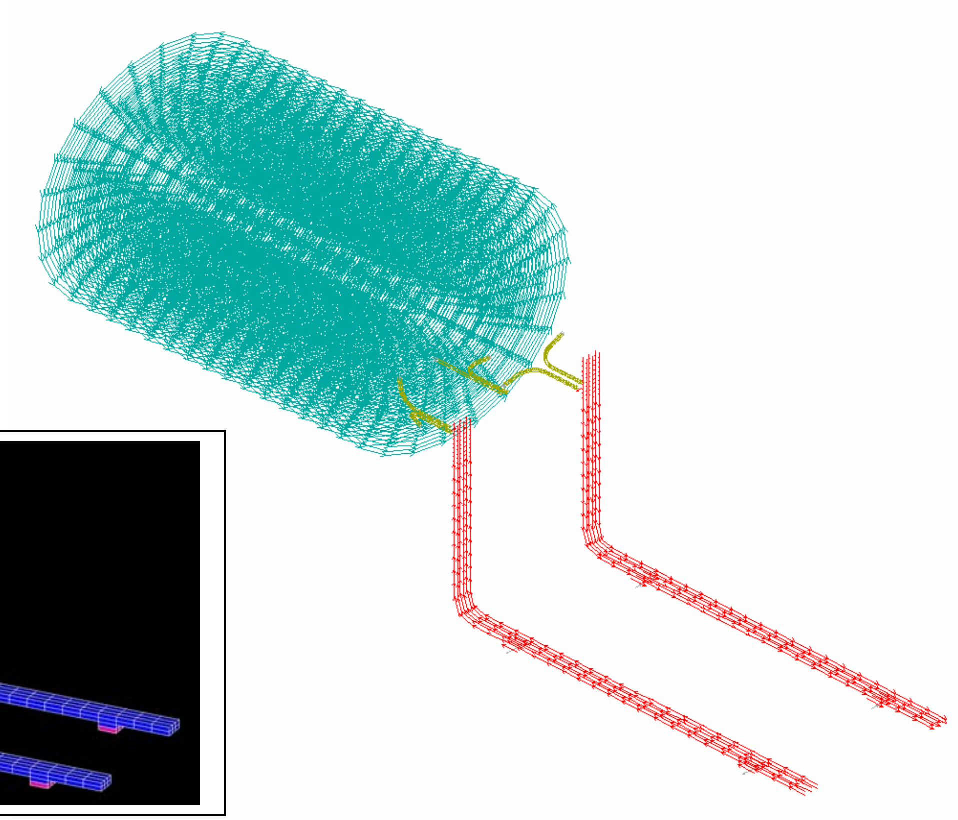




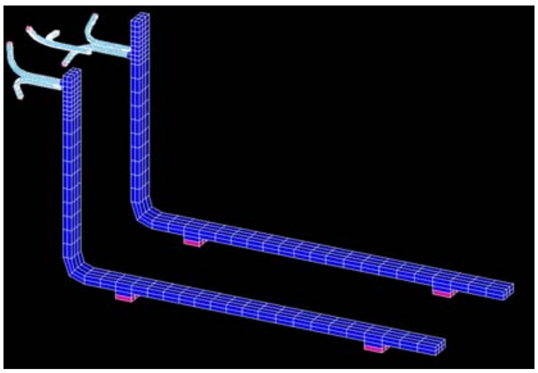
Bus bars can run under the PTF split pair

Loads on the Bus Bar Extensions

The leads are modeled as 1 X 3 inch bar/strap.



Biot Savart Model of leads and Bus Bar Extensions

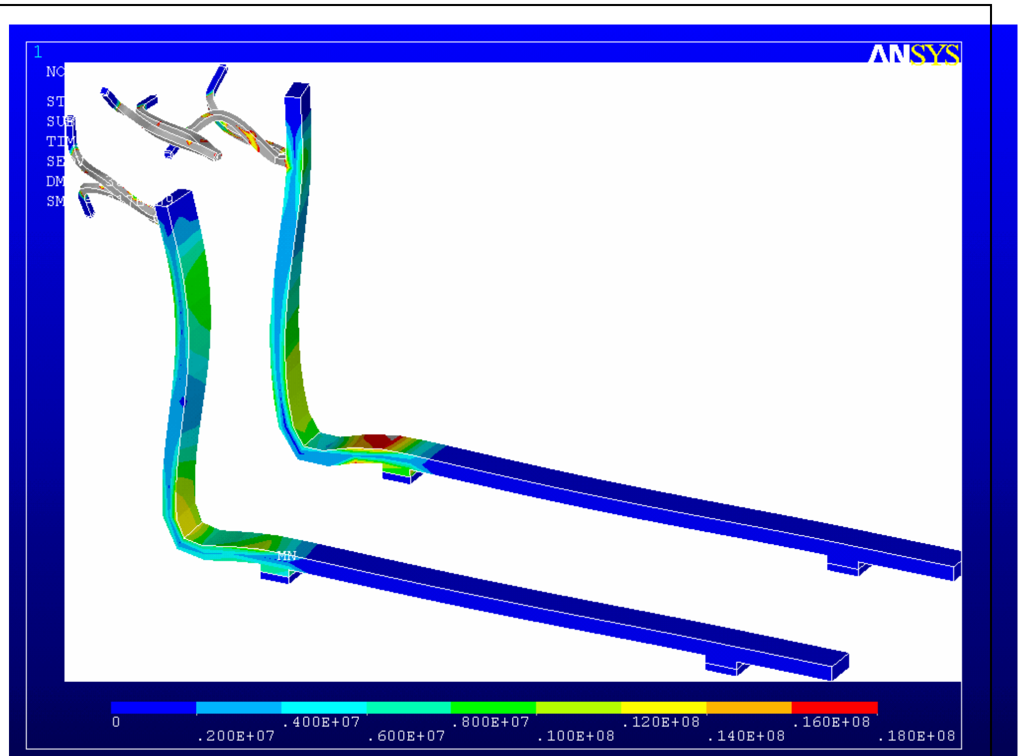


The total reaction for the 2 pads on the rear lead are:

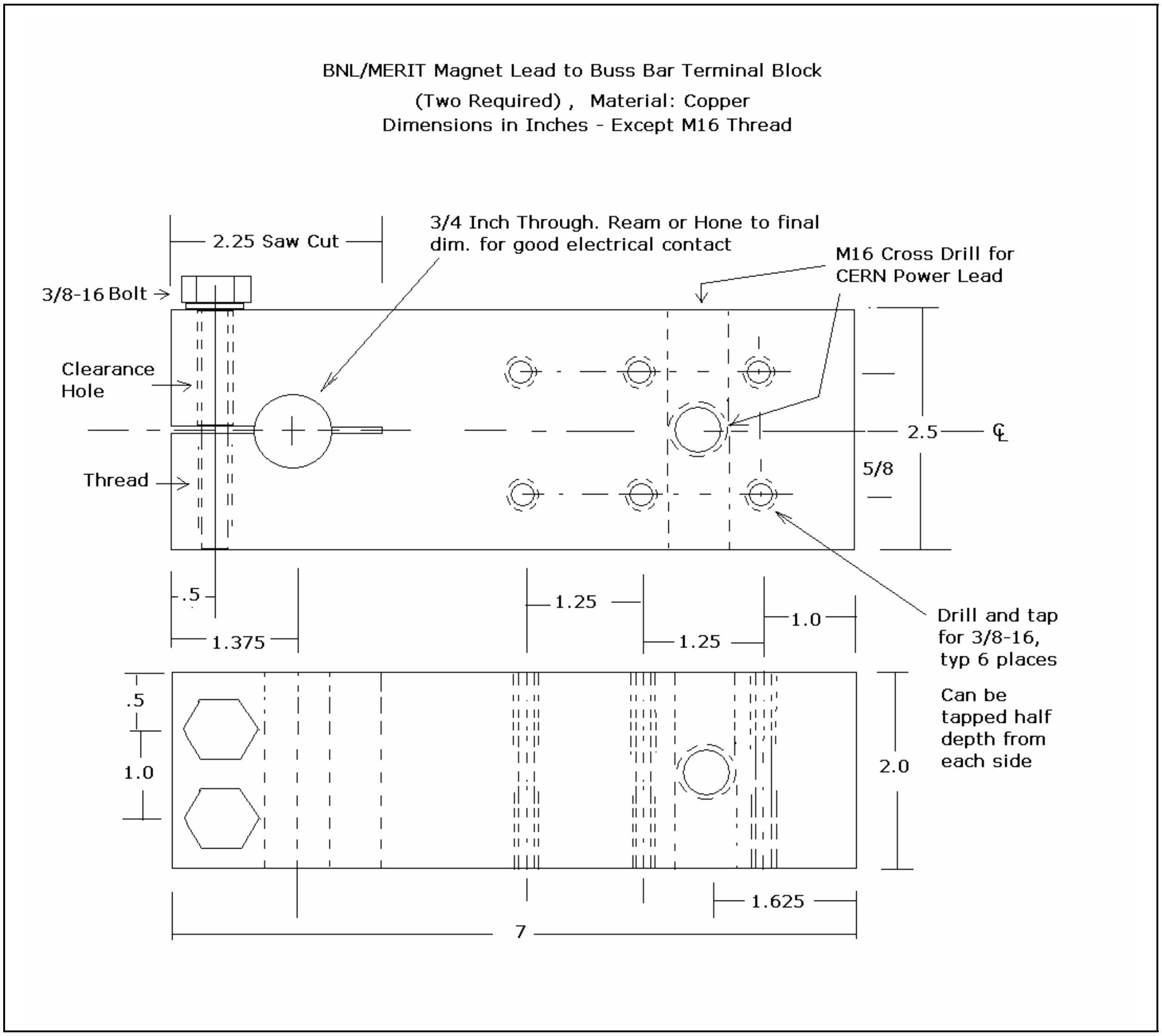
FX 113.73N
FY 1982N
FZ –24.5N

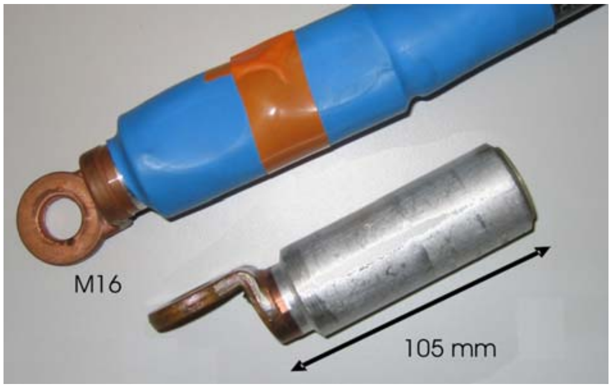
The total reaction for the 2 pads on the front lead are:

FX 627N
FY 1714N
FZ –17.25N

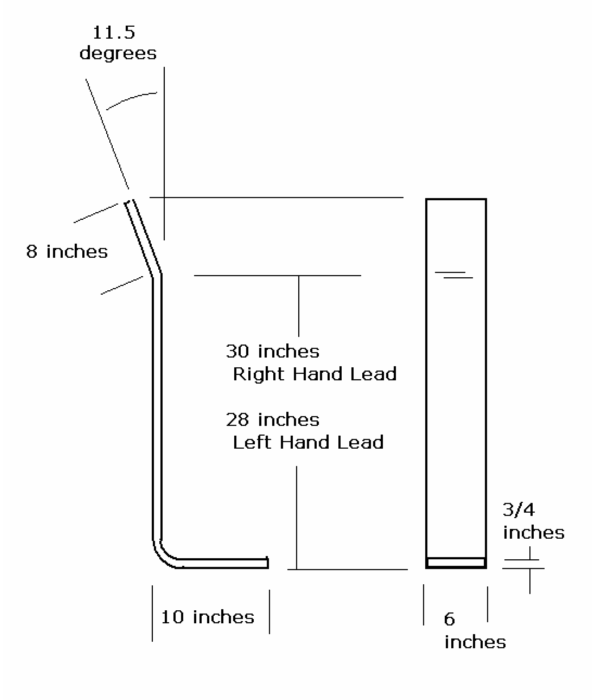


Strap Stress is only 18 MPa.

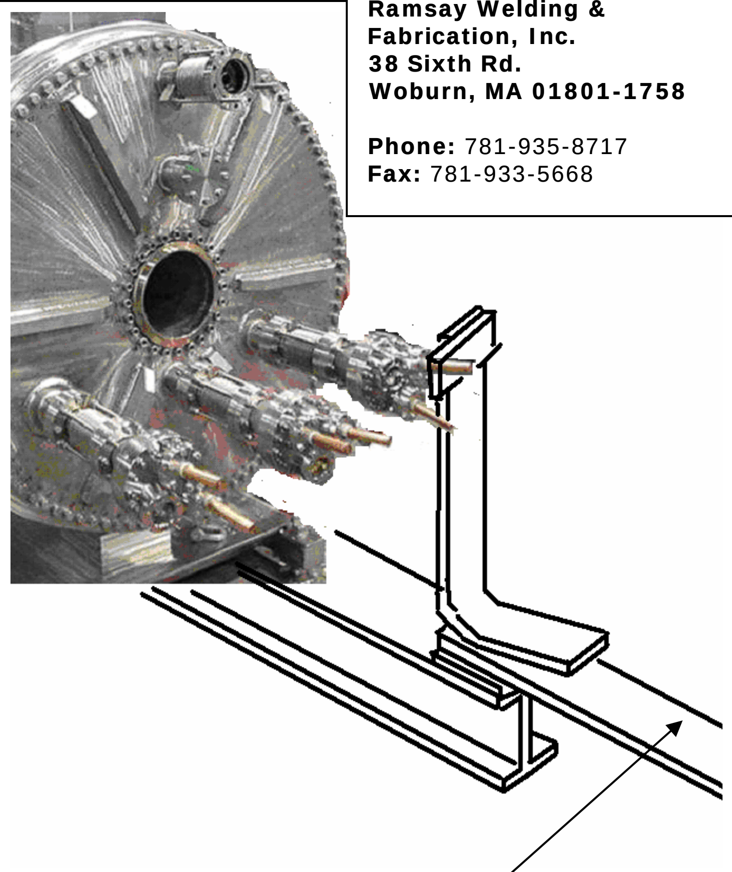




CERN Power Lead Termination



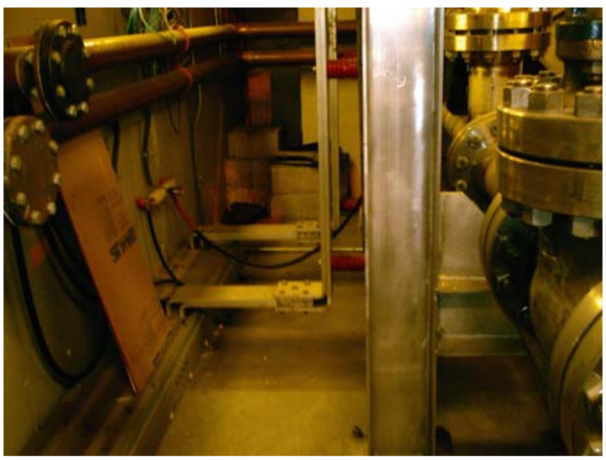
Dimensions and Bend Specs for Vertical Bus Bars



Bending of the Leads:

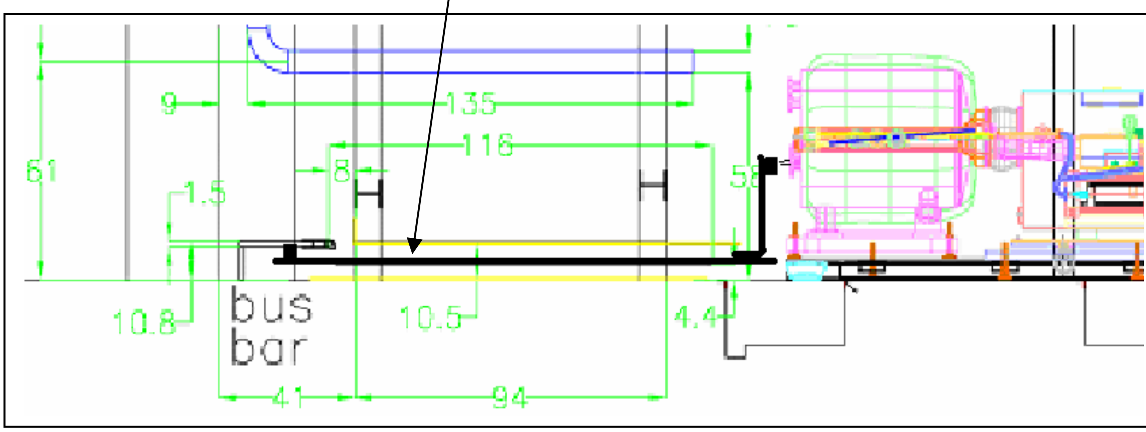
Ramsay Welding & Fabrication, Inc.
38 Sixth Rd.
Woburn, MA 01801-1758

Phone: 781-935-8717
Fax: 781-933-5668



Bus connection to the PTF Split Pair

12 foot ¾ X 6 6061T6 Aluminum ordered Feb 4 and received from Pierce Feb 7 2006



Power Lead Gland Seal Design and Tests

These are reported in the Test Results Document, PSFC JA-06-18

Inductance Measurement

One early test should measure the inductance of the magnet to benchmark the simulations. Measurement of the current rise at a known (low) static voltage, and resistance can be used to calculate the inductance.

An alternate is to impose the current time trace for simulations based on the calculated inductance and compare the measured voltage with the voltage in the simulations. This was done for many current time traces during the tests.

Low Current Field Mapping.

The power supply should be capable of producing a stable 100 amp level current for low field mapping of the magnet.

6.0 Cryogenic System for the Test

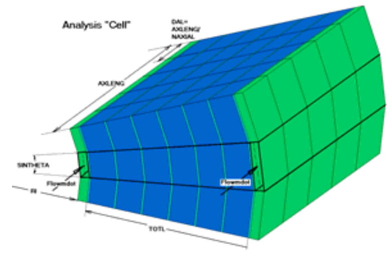
Two approaches were considered:

Flood and Wait - Then Drain and Pulse.

Develop and implement a “skid mounted” , deliverable Controlled LN2 Cooling System.

This second system is un-necessarily complex for use in the preoperational test.

Only liquid nitrogen cooling will b employed during pre-operational testing at MIT, although the system is intended to retain the capability to be cooled using gaseous Helium.



6.0-1 Finite Difference Cooling Model.

The arrangement drawings, particularly BNL-001 and 002 have the MDC part numbers for the flanges that the cryogenic system will connect to. There are three “fluids only” ports on the cover. The top port is being used as the gas exhaust. The one below that was intended as the exhaust, but is now to be blanked off. The lower port was the drain port, and is being enlarged to allow it’s use as the LN2 fill and drain port. The remaining ports are associated with the leads for the three segments. Each of these ports had a “tri-Port” that allows addition of instrumentation feedthroughs which includes 19 pin connectors for the CERNOX and discrete sensors and one port for the COAX feeds for the capacitive level sensor.

There is no identified problem with testing the magnet immersed in LN2. The requirement to remove the LN2 during the experiments in CERN stems from the radiation environment causing activation of Nitrogen, and the creation of Ozone. Neither of these problems exist during preoperational testing. This allows a further simplification of the system planned for CERN. The system at MIT initially was proposed as a simple feed and open exhaust. This has been expanded to simulate the draining of the cryostat via pressurization and back filling a dewar sitting on the floor. The updated system is shown in figure 6.0-3. Liquid level changes in time can be used to estimate magnet surface heat flux, which then can be used to benchmark the cooldown simulations.

The C-Mod main LN2 Supply Tank will be used with the LDX /VTF/PTF supply line, If the supply line presently routed to LDX for it’s LN2 shields, can be either extended or returned to the PTF area. Use of a LN2 dewar is also possible. The staging floor, from which the control of the test is anticipated, is readily accessed from the loading dock. .

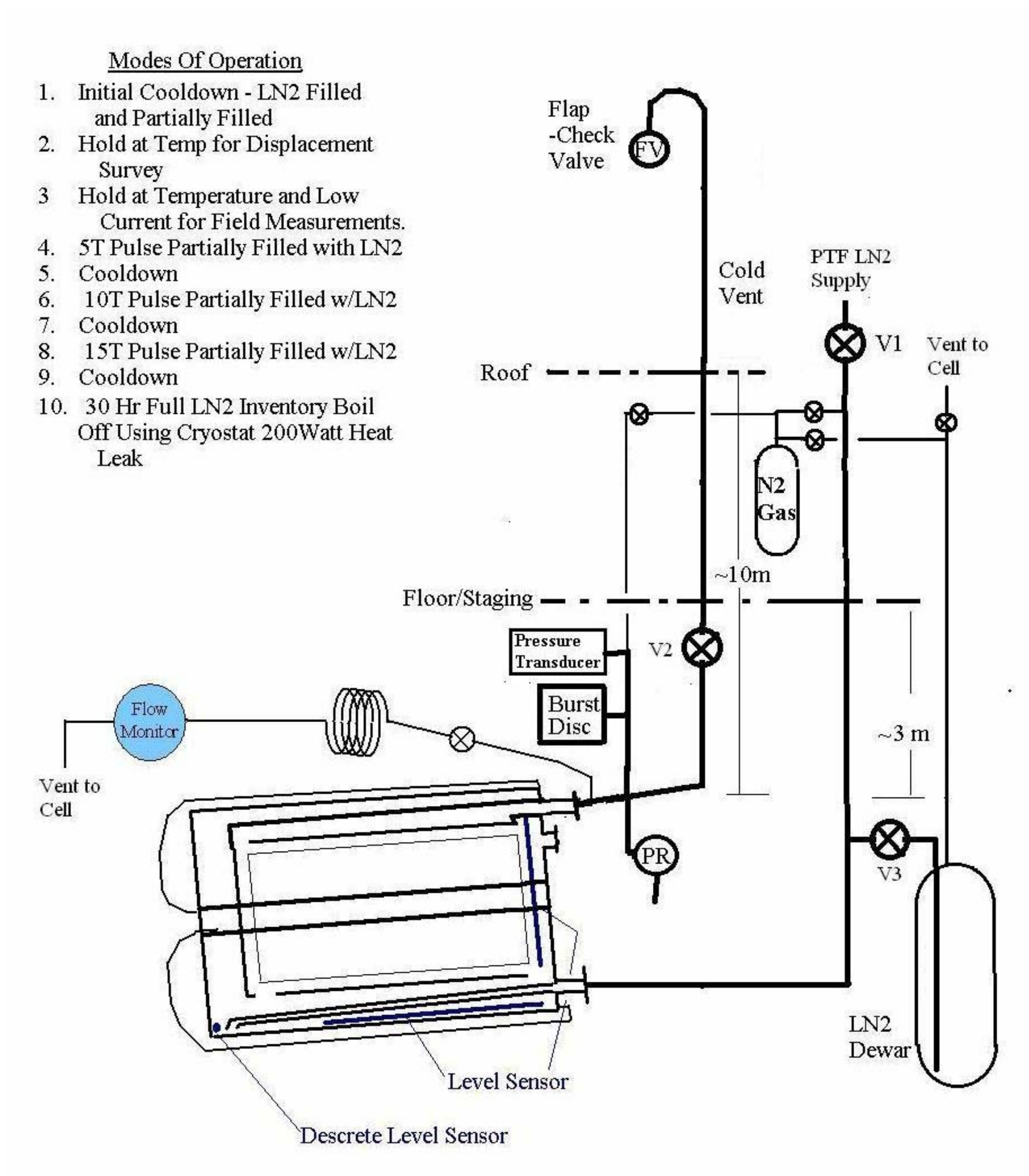


Figure 6.0-3 Cryogenic System Planned for Use at MIT

Cryogenic System Connections to the Magnet at MIT and CERN:

The upper port in the magnet is a 4 5/8 CF. This port provides the connection to the N2 gas exhaust. The tube extension which was intended for Helium gas service has been cut back inside the bellows so that gas vents from both ends of the magnet.

The middle port is not used, and is blanked off with a blind flange

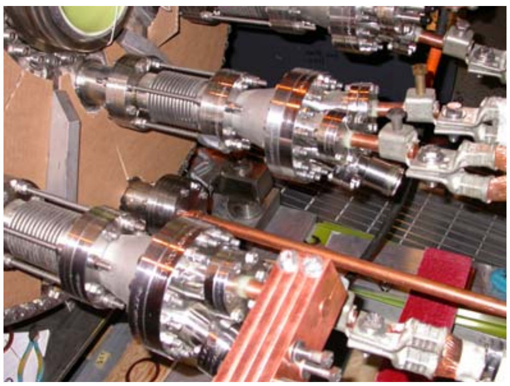
The terminal ports have no fluid or gas connections

The lower LN2 fill/drain port is a 4.5" CF flange.

The initial cooldown to 77K requires:

(292-77)*.4618*2183978/(199000+2042*(180K-77)) -= 530 Kg of LN2 assuming an exhaust gas temperature of 180K

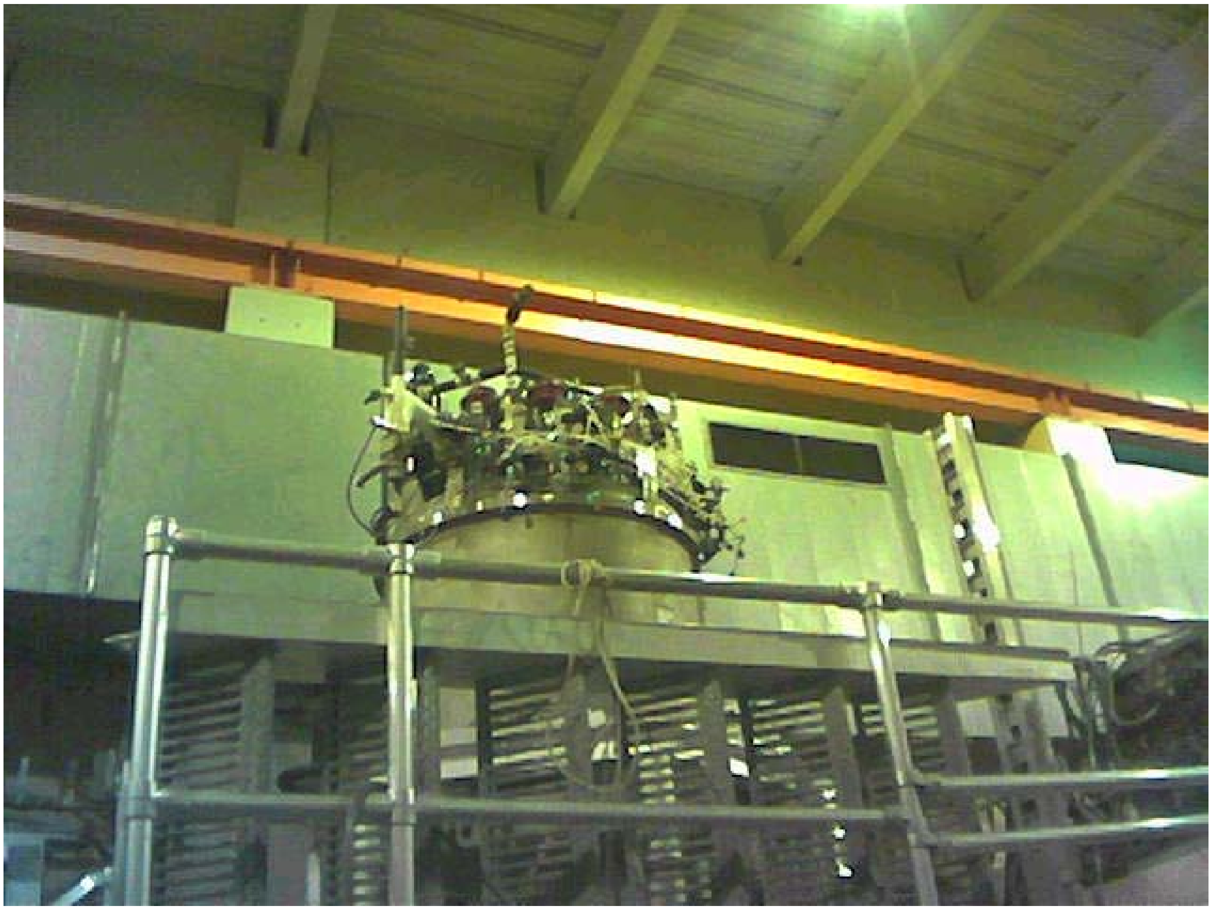
To cool the magnet down from 100 to 69 K, 22 MJ is required. This will be done using 66K subcooled LN2. Approximately, this will vaporize 22e6/199000 = 110 kg of liquid. At 66K, and 1 atm, the specific volume of the gas is .937 M^3/kg. 103.6 m^3 of 66K gas would be produced. Using the ideal gas law, this will be 103.6*292/66= 458 cu meter at room temperature. This would fill an 8m cube, or a big percentage of the LDX cell.


Magnet LN2 Feed Line


LN2 Supply. –This was disconnected by LDX and will be re-connected.

6.2 Vent Line

A 4 to 6 inch vent line is planned as an addition to the PTF test area. It will be insulated, and possibly heat traced to reduce ice build-up. Air intrusion from the outside is a concern because of the possibility of ice build up inside the vent with a resulting flow restriction.



One approach is to run the vent line inside up behind the crane rail, and through the roof.

The plan is to run the vent line up through the roof. The roof has a 5 inch thick concrete slab that must be core drilled to pass the vent line. There is a "penthouse" above this, and the vent must continue up through the roof of this structure. From **http://www.globaltecheng.com/alupipe.htm** :

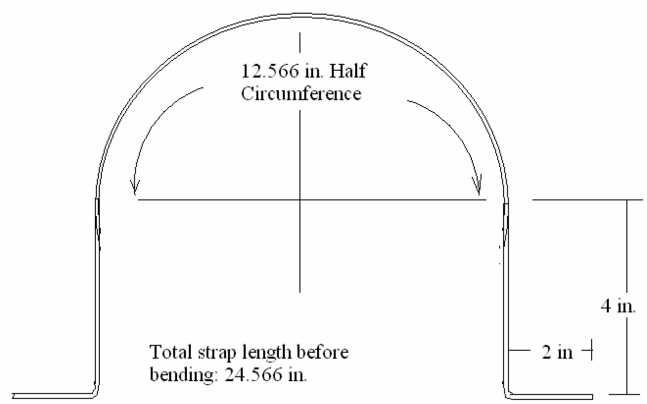
Aluminum Pipe is stocked in 20' lengths. We can ship less than 20' sticks, however, a cutting charge per cut is required. Price listed is Per Foot (USD)

Size	Schedule 5		Schedule 10		Schedule 40	
4"	$3.35	Buy Now	$4.85	Buy Now	$9.25	Buy Now
5"			$6.65	Buy Now	$12.55	Buy Now
6"			$8.00	Buy Now	$16.25	Buy Now
8"			$11.50	Buy Now		

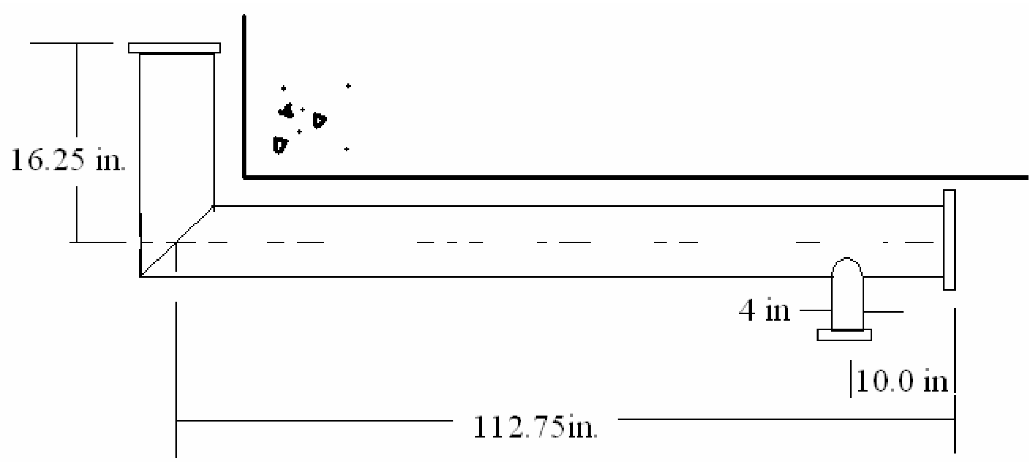
Roof penetration

Armaflex insulation on a ring section of the vent pipe Two segments of smaller diameter pipe insulation is used for the 6 inch vent

Portion of the vertical run being welded



Vent Line Hanger Straps

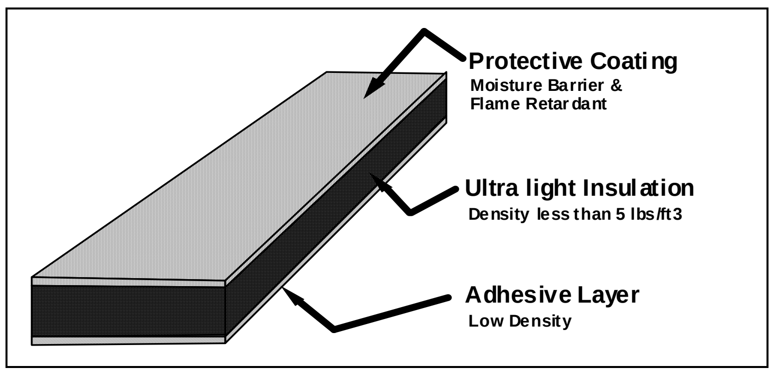


Dimensions given to Dave Arsenault for horizontal vent run along wall

The flow/energy during vent to the vacuum pump should be:

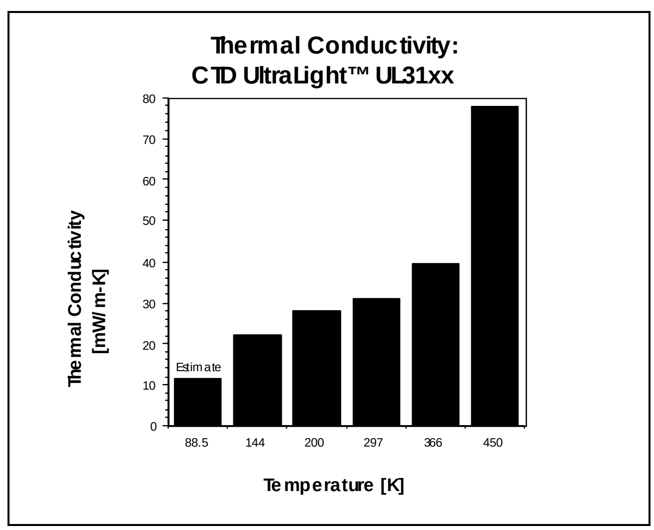
```
!mass flow= .05 kg/sec
!volume flow= 144 cu-m/hr        ( Mike calculated a larger number. I am not sure how he got it)
!volume flow =  1.4125782 cu ft/sec
!Exhaust Pipe Flow Velocity, 4in pipe= 16.515614 feet/sec
!Exhaust Pipe Flow Velocity, 6in pipe= 7.1942017 feet/sec

  !   **  Calculations   ****
clear
let mflow=.05   !kg/sec   Vacuum Pump Flow
let N2gasden=1/.7996   !kg/m^3 STP ref air liquide web site
let N2gasspht=1.04   !kJ/kg/degc   ref air liquide web site
print "Gaseous Nitrogen Density=";N2gasden;"kg/m^3"
print "Gaseous Nitrogen Specific Heat=";N2gasspht;"kJ/kg/degC"
let N2gasden=1.25   !kg/m^3 STP ref air liquide web site
let vflow=mflow/N2gasden*60*60    ! cu meter/hr
print "mass flow=";mflow;"kg/sec"
print "volume flow=";vflow;"cu-m/hr"
let vflow= vflow*(39.37^3/12^3)/60/60      !cu ft/sec
print "volume flow = " ;vflow; "cu ft/sec"
let area6=.5^2*pi/4
let area4=.33^2*pi/4
print "Exhaust Pipe Flow Velocity, 4in pipe=";vflow/area4;"feet/sec"
print "Exhaust Pipe Flow Velocity, 6in pipe=";vflow/area6;"feet/sec"
let heatpower=mflow*N2gasspht*(292-88)      !kJ/sec or KW
print"Heater Power=";heatpower;"kW"
end
```



6.3 Applcation of Cryogenic Sheet and Spray Foam

Foam wrap, similar to that used by C-Mod is intended for wrapping the cylindrical surface of the vacuum jacket near the bellows at the cover end of the magnet. The complex surfaces of the cover and the penetrations will be covered temporarily with sheet foam, during initial tests in case the cover needs to be removed. When we are satisfied that the magnet is not going to be opened, the spray foam will be applied in accordance with CTD's application instructions. (See the test results, PSFC/JA-06-17the cryofoam slumped during trial applications and was replaced with bonded foamglas)

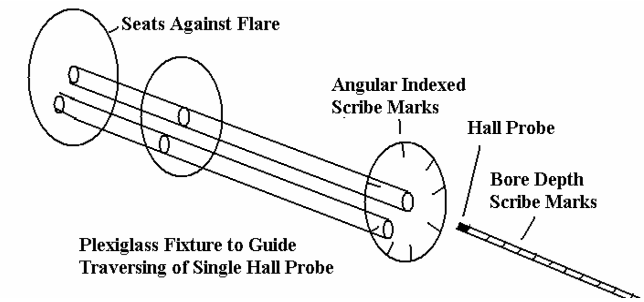


7.0 Instrumentation

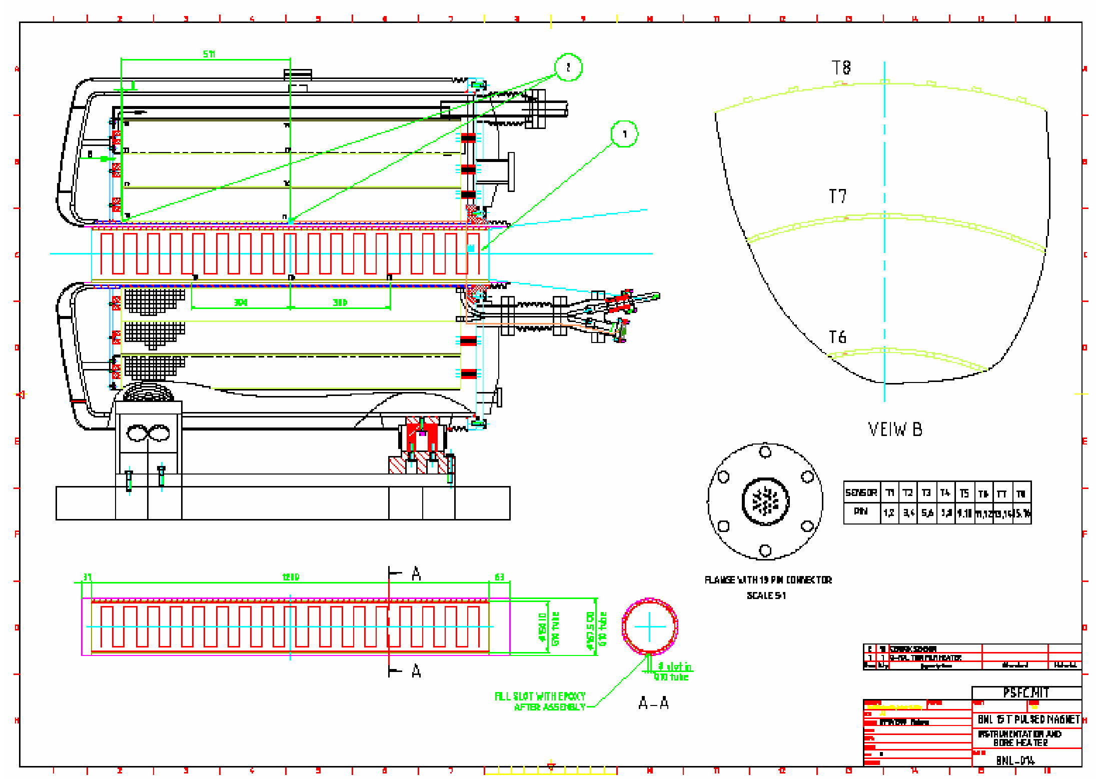
MIT PSFC T&E (Chen Yu Gung) has a MAC based data/instrumentation system with 16 channels that can be used with the CERNOX temperature sensors. There is an issue with respect to calibration of the CERNOX units. I need to check what is provided ,

Field Measurements/Field mapping

The magnet is to be shown capable of producing the required 15T. The magnetic field in the bore and at the solenoid ends where the leads break out needs to be mapped to characterize any potential effects on the mercury jet. Field mapping will be performed at low current. It probably should be performed cold



15T field demonstration:
Calibrated Hall probes are expensive, and it may be prohibitive to have one calibrated to 15T. The intention is to used an available Hall probe that is calibrated to 3 T (we may have one available that is calibrated to 10 T) Once the field is calibrated to the magnet current, the magnet performance should be linear with respect to current, however the accuracy of the field reported in the CERN tests will be a function of how accurately the power supplies at MIT and CERN with repeat the same current level. Purchase of a 10 kA shunt is recommended to go with the magnet. You read voltage across the shunt and with a known shunt resistance the current is known. Using the same shunt at CERN and MIT would guarantee the same current measurements.



The array of temperature sensors are only at the top half of the magnet at present. This drawing is being updated to place some of these at the bottom, add discrete level sensors and to add the capacative level sensors.

Temperature Sensors:

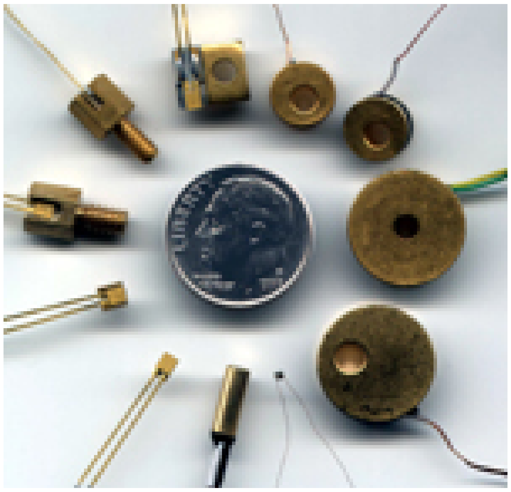
For the "Fill, Drain and Pulse" test, instrumentation requirements are minimal. The temperature sensors in the magnet should be read, but there is no need to read the temperature sensors during a pulse. This eliminates the concern over small currents in the leads in very high fields. Not all are needed to be read at any one time, but the system should have the capability to connect and disconnect the sensors.

http://www.lakeshore.com/temp/sen/crtd.html

Cernox

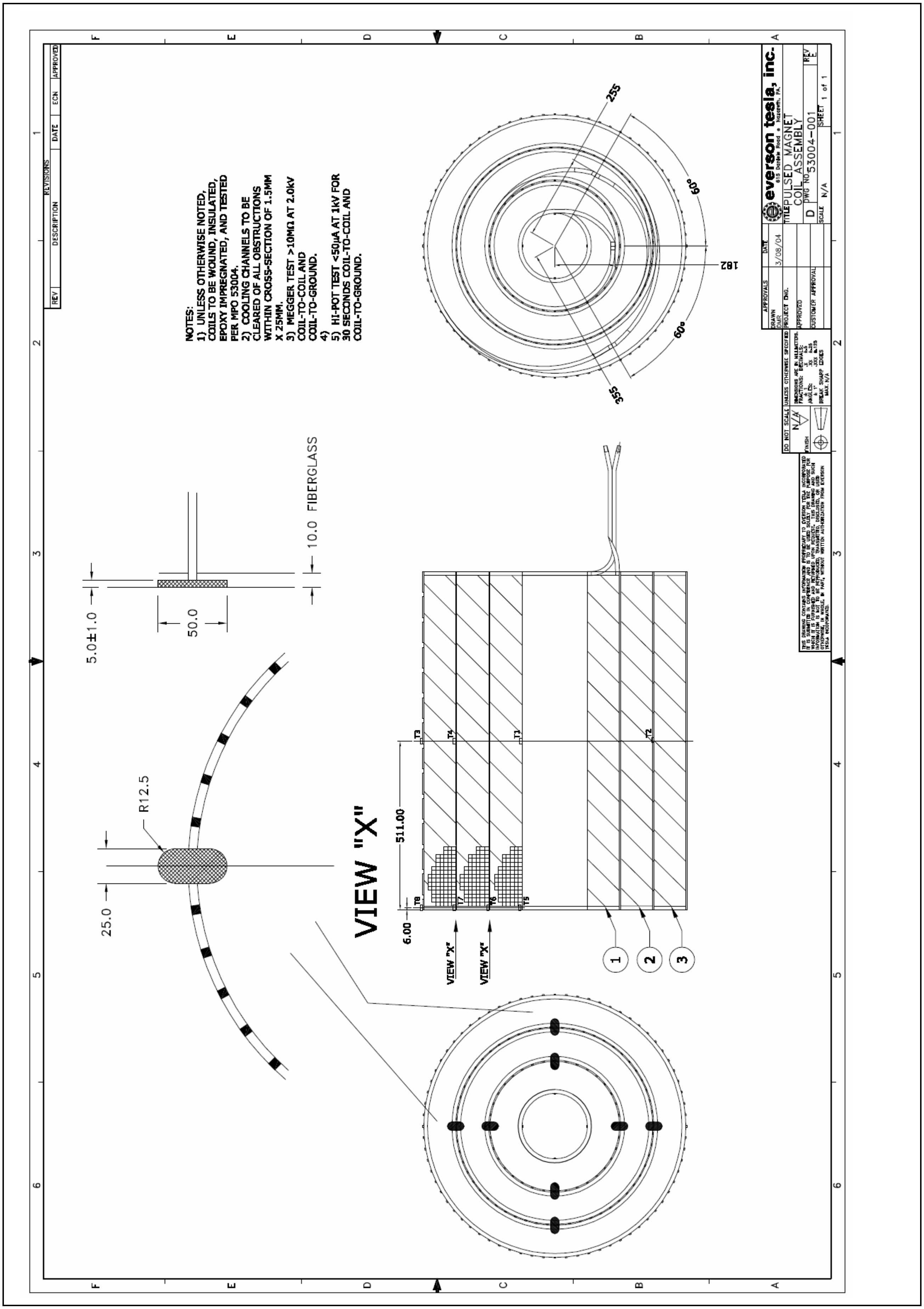
Thin film resistance temperature sensors offer a negative temperature coefficient, monotonic response over a wide temperature range, low magnetic field induced errors and high resistance to ionizing radiation. Instrumentation to read temperatures from these sensors may be found on the LakeShore site, above.

- Low magnetic field-induced errors
- High sensitivity at low temperatures and good sensitivity over a broad range
- Excellent resistance to ionizing radiation
- Fast characteristic thermal response times: 1.5 ms at 4.2 K; 50 ms at 77K (in bare chip form in liquid)
- High Temperature Cernox offers a wide temperature range from 0.3 K to 420 K
- Broad selection of models to meet thermometry needs
- Manufactured by Lake Shore, insuring control over wafer level quality and yield for the future
- Excellent stability
- Variety of packaging options



CERNOX Data on Resistance vs Temperature and Voltage vs. Temperature may be found in Appendix A. Measured resistances at

ISI Insulator Seal used for pass through of the temperature sensor voltage taps

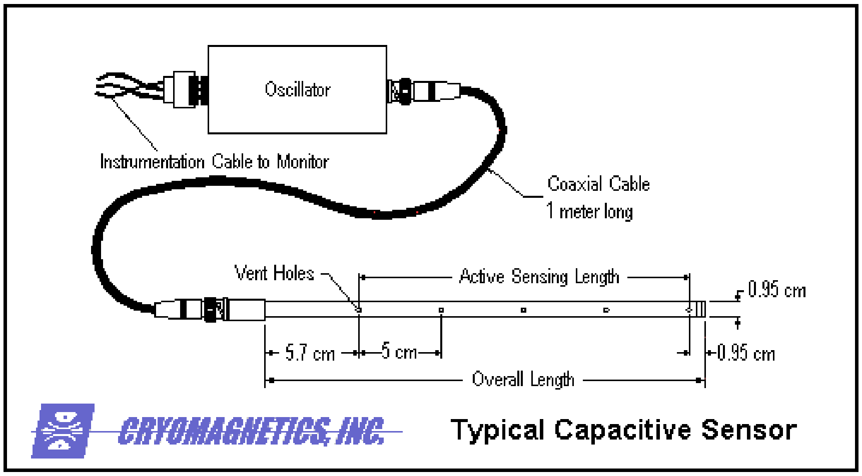

NOTES:
1) UNLESS OTHERWISE NOTED, COILS TO BE WOUND, INSULATED, EPOXY IMPREGNATED, AND TESTED PER MPO 53004.
2) COOLING CHANNELS TO BE CLEARED OF ALL OBSTRUCTIONS WITHIN CROSS-SECTION OF 1.5MM X 25MM.
3) MEGGER TEST >10MΩ AT 2.0kV COIL-TO-COIL AND COIL-TO-GROUND.
4)
5) HI-POT TEST <50μA AT 1kV FOR 30 SECONDS COIL-TO-COIL AND COIL-TO-GROUND.
VIEW "X"
R12.5
25.0
5.0±1.0
50.0
10.0 FIBERGLASS
511.00
6.00
VIEW "X"
255
60°
182
60°
355
everson tesla, inc.
TITLE PULSED MAGNET COIL ASSEMBLY
DWG NO 53004-001
SCALE N/A
SHEET 1 of 1
DRAWN 3/08/04
DO NOT SCALE

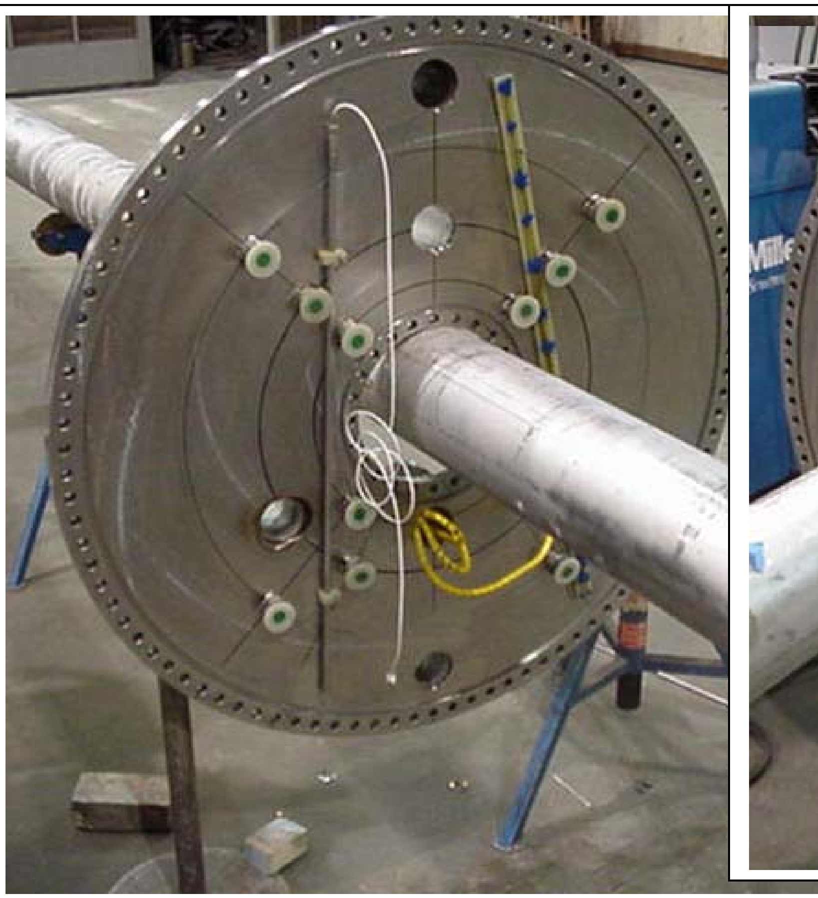
Feb 8 2006
CERNOX leads have been soldered and the 20 pin connector has been closed up with a new copper gasket. Wires have been wrapped with Kapton sheet to insulate exposed surface of power lead.

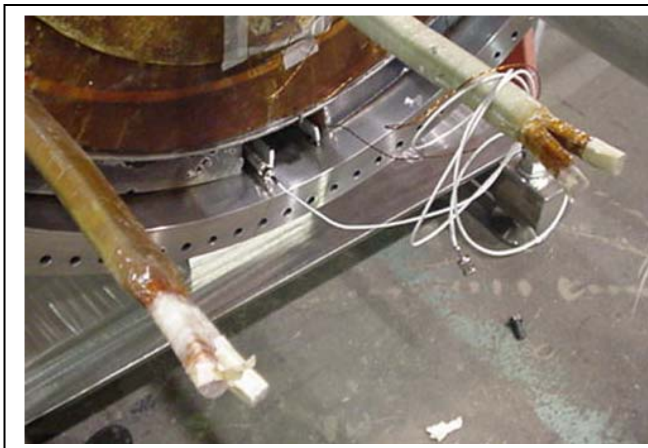
CVIP/Dave Nguyen and Jeff Dorn have supplied CERNOX Calibration documentation.

T2 and T4 are shorted. – No remaining CERNOX on the interior of the assembled coils. We are looking into resistance measurements wit a small current supplied by the power supply – I have an outstanding request to Gary Dekow/Phil Michaels to know if the large power supplies can produce a stable 100 amps for 30 seconds .

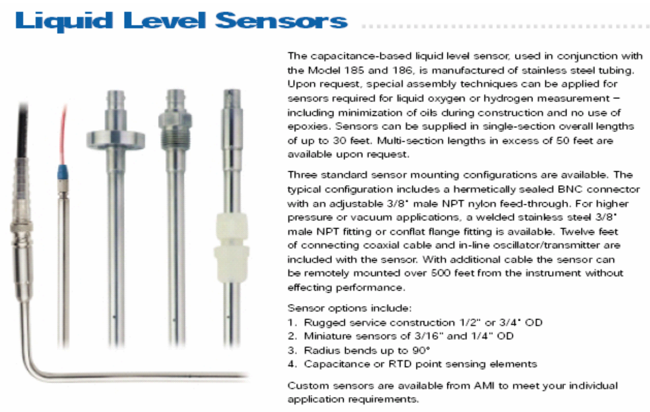
Level Sensors







Model 186 Liquid Level Controller


Liquid Level Sensors

The capacitance-based liquid level sensor, used in conjunction with the Model 185 and 186, is manufactured of stainless steel tubing. Upon request, special assembly techniques can be applied for sensors required for liquid oxygen or hydrogen measurement – including minimization of oils during construction and no use of epoxies. Sensors can be supplied in single-section overall lengths of up to 30 feet. Multi-section lengths in excess of 50 feet are available upon request.

Three standard sensor mounting configurations are available. The typical configuration includes a hermetically sealed BNC connector with an adjustable 3/8" male NPT nylon feed-through. For higher pressure or vacuum applications, a welded stainless steel 3/8" male NPT fitting or conflat flange fitting is available. Twelve feet of connecting coaxial cable and in-line oscillator/transmitter are included with the sensor. With additional cable the sensor can be remotely mounted over 500 feet from the instrument without effecting performance.

Sensor options include:
1. Rugged service construction 1/2" or 3/4" OD
2. Miniature sensors of 3/16" and 1/4" OD
3. Radius bends up to 90°
4. Capacitance or RTD point sensing elements

Custom sensors are available from AMI to meet your individual application requirements.

The leads for the sensors must be the Coax type.

The American Magnetics, Inc. (AMI) Model 186 Liquid Level Controller system is an advanced, microprocessor-based solution designed to provide accurate and reliable level monitoring and control of virtually any cryogenic liquid.

<u>Capacitance-based level sensing</u>

<u>Simple calibration</u>

Automated fill and alarm functions

The Model 186 fill control and alarm functions are front panel programmable from 0 to 100 percent of the active sensing length. Two independent control band setpoints, "A" and "B", activate a power receptacle on the rear panel. When the liquid level drops below the "B" setpoint, the power receptacle is energized and remains energized until the liquid level rises to the "A" setpoint. The Model 186 also provides a fail-safe timer feature that automatically de-energizes the power receptacle once a user programmed maximum time interval of up to 600 minutes is reached. The Model 186 is ideal for unattended systems where automated fill is required.

In addition, the Model 186 provides "High" and "Low" alarm setpoints to activate front panel LED warning indicators and rear panel relay outputs in the event of an overfill or liquid loss condition. The "Low" level alarm also energizes an audible warning which can be silenced from the front panel.

Convenient display

The instrument is equipped with a 4-digit LED display which provides liquid level indication in inches, centimeters, or percent as selected by a front panel switch. A front panel switch allows the user to easily adjust the instrument's length setting for a specific active sensor length. The sensor active length can be entered in either inches or centimeters.

Customer Configuration Sheet

Passcode: 0 5 0 4   Model 286CE Serial Number: 05-0428-10

Channel	Assigned to Sensor Input: A, B, C, or D	Active Calibration 1, 2, 3, or 4	Setpoints (%)				Rate (%/min)	Analog Output Option
			HI	A	B	LO		
Ch. 1	C	1	90	60	40	20	–	☐ 10V ☐ 4-20 mA
Ch. 2	D	1	90	60	40	20	–	☐ 10V ☐ 4-20 mA
Ch. 3								
Ch. 4								

Sensor Input	Cal Mem	Active Length (inches)	Sensor Serial Number	Oscillator Serial Number	Target Liquid	Operating Pressure (psia)	ACF	Zero Offset (%)
A	1							
	2							
	3							
	4							
B	1							
	2							
	3							
	4							
C	1	28.43	05-0428-11	102	LN2	ATM	–	–
	2							
	3							
	4							
D	1	24.5	05-0428-12	103	LN2	ATM	–	–
	2							
	3							
	4							

RS-232 Baud Rate: N/A

HI/LO Relay Outputs Assigned to: ☒ Ch 1 & 2 ☐ Ch 3 & 4 Display Contrast Setting: 100 %

☑ Normal Mode

Channel	Fill Mode	Fill Time	Inhibit
Ch. 1	Auto	0.0	None
Ch. 2	Auto	0.0	None

☐ Auto-Changeover Mode

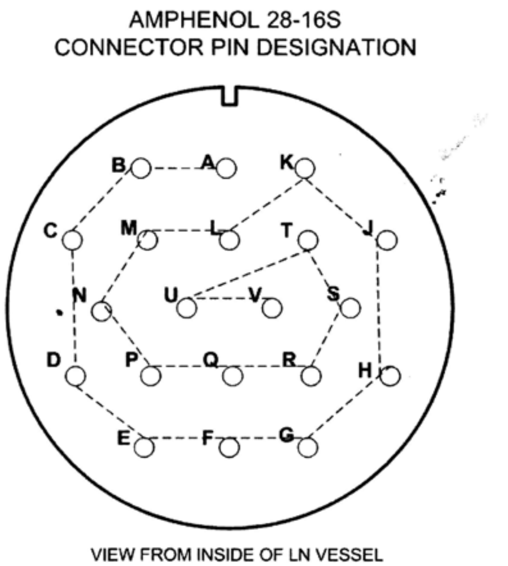
Empty Detection:	
Changeover Time:	

☐ Pre-Cool Mode

Pre-Cool Time:	
Fill Timeout:	

Discrete Level Sensor

Amphenol Connectors used in the discrete level sensor



Pin Designations used for Voltage Measurements

Resistance Between DIODE Leads / Pins

DIODE	LEAD PAIR	R [OHM]	PIN PAIR	R [OHM]
D1	D1+ :: D1-	680	A::B	680
D2	D2+ :: D2-	686	C::D	680
D3	D3+ :: D3-	678	E::F	678
D4	D4+ :: D4-	679	G::H	679
D5	D5+ :: D5-	679	J::K	679
D6	D6+ :: D6-	680	L::M	681
D7	D7+ :: D7-	678	N::P	678
D8	D8+ :: D8-	679	Q::R	679
D9	D9+ :: D9-	679	S::T	679
D10	D10+ :: D10-	679	U::V	679

DIODE WIRING SCHEME

DIODE LEAD	PIN
D1 +	A
D1-	B
D2 +	C
D2 -	D
D3 +	E
D3 -	F
D4 +	G
D4 -	H
D5 +	J
D5 -	K
D6 +	L
D6 -	M
D7+	N
D7-	P
D8+	Q
D8-	R
D9 +	S
D9 -	T
D10 +	U
D10 -	V

Feb 9 2006 test of the discrete level sensor –mV

Discrete Level Sensor Bench Top Tests, Feb 8 2006

Discrete Level Sensor electronics have been powered up (with 115V). –Seems to be OK. Single diode dunk test this afternoon. Level sensor leads are being soldered to the feedthroughs

Discrete Level Sensor Bench Top Tests, Feb 9 2006

The system was tested with a small quantity of LN2 in a styrofoam cup. It did not seem to be able to detect when the diode was immersed or when it was in cold N2 gas just above the liquid. Voltage changed about 1mV out of 30mv. Instructions were requested from CERN to improve the sensitivity. These follow, but they haven't been implemented in the MIT tests.

```
Hello Peter.
>
>Here is all the documentation about the level sensors.
>For the little problem of sensitivity, it can be adjusting using
>potentiometer P1 on the card. Only one potentiometer on each card for
5
>diodes. But sensitivity need to be adjust when you cool down the diode
>by approaching it from the liquid, and not by tanking it out because
it
>take a time to warm up.
>If when using P1 you are not able to adjust the sensitivity because
you
>are at the end of the potentiometer, you can move the strap SW21 from
it
>position and coming completely backward with P1 . This will change the
>polarity of the reference on the amplifier. But normally you will not
>move the strap until you have 100m of cable.
>See  EDA-00279-V2_sch.pdf for schematic of the card.
>
>Hope this will be helpful for you.
>
>Regarding,
>
>Jean-Marc Quetsch
>
```

8.0 Safety, Operational Controls

There are other experiments in the vicinity of the PTF area that may be affected by stray fields. LDX, VTF, particularly its control equipment, and Rick Tempkin's accelerator will either need to be shown insensitive to the field produced by the magnet, or there will be operational controls on the BNL tests to preclude concurrent operation of the BNL magnet and the other experiments.

Magnetic materials will have to be kept clear of the magnet. We should probably consider limited access to the ground floor are near the magnet because of the electrical, cryogenic and magnetic hazards.

Oxygen Depletion Sensors

Catherine Fiore indicated that C-Mod has a number of portable sensors that are used during C-Mod operation. The will be beginning operation in Feb 2005 and these will not be available to us. I need to check with LDX to see if they have fixed monitors in the cell, but Two portables in the PTF "pit" are needed. These cost around $600 apiece. Maybe we can borrow them from Brookhaven, Rutherford or CERN. Catherine will accept this kind of equipment from a collaborating lab.

eter,

We have been obtaining Oxy Plus or Oxy2
(Single Sensor Gas Detector)
made by Biosystems, Inc from
Dick Fornier at Hazmat Safety Eqpt Sales
978-922-9682, Box 616,
Beverly, MA 01915.

Catherine

The Toxi Vision from Biosystems is a durable, single-sensor gas detector that offers consistent long-term protection and low cost of ownership. The Toxi Vision features a rugged metal-plated case that is immune to both RFI and the elements. One-button operation keeps it simple. A few minutes of training is all it takes to ensure proper operation. The large liquid crystal display can be easily seen from several feet away. A manually-activated backlight ensures the visibility of the readings even in low light conditions. An audible alarm and bright LED alarm light warn users of dangerous conditions, while an optional vibrating alarm is available for use in high-noise environments. Each set of 2 easily-changed AA alkaline batteries provides months of continuous operation.

Magnet Component Magnetic Survey Feb 7 2006

316 components:
Most of the heat effected zones are slightly magnetic. Where the ribs are welded to the cover is slightly magnetic. The cover bolts on the outer bolt circle are slightly magnetic, the high strength bolts at the inner bolt circle are not

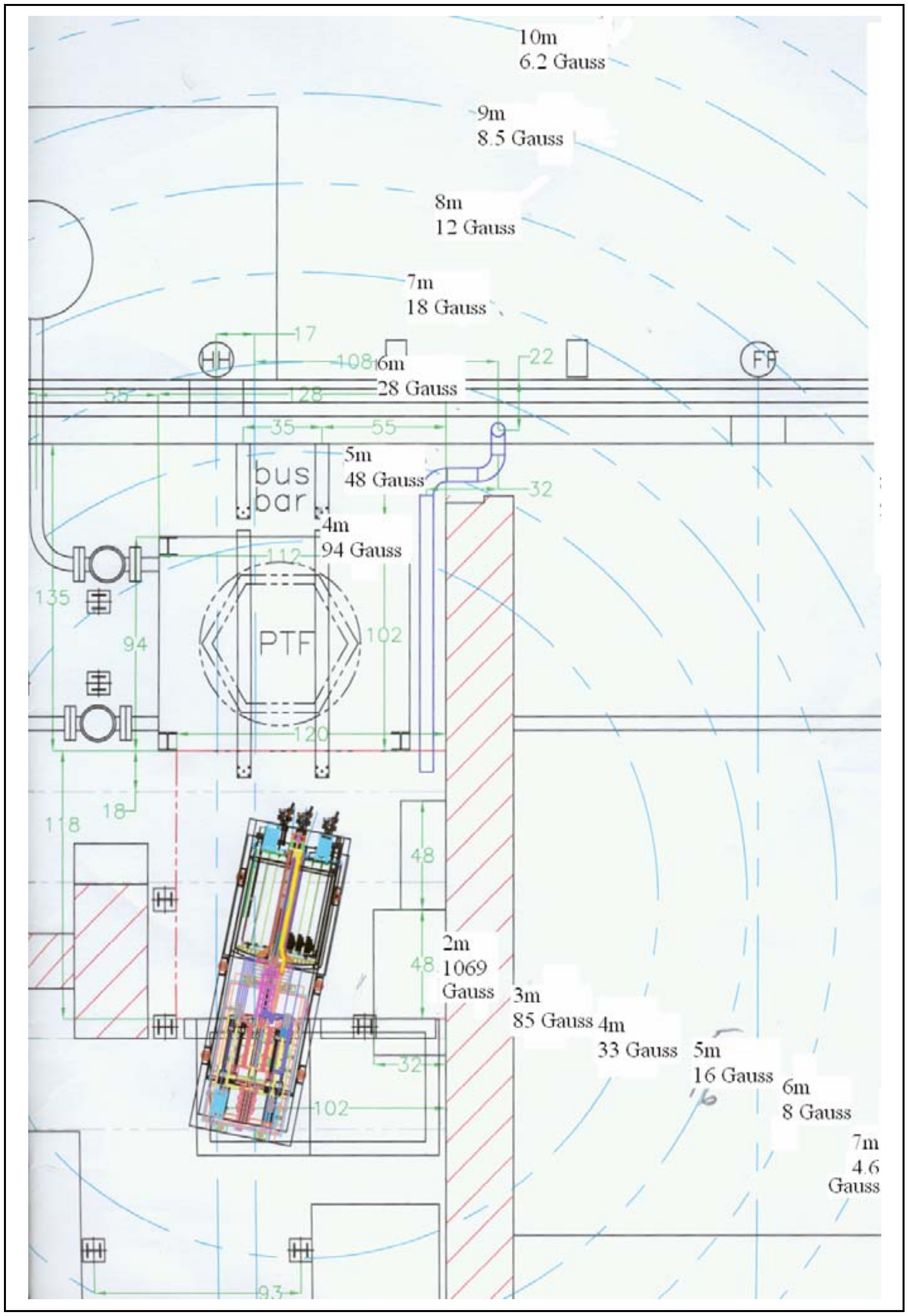
304 components
The Vacuum jacket dished head is magnetic. The rolled shell of the vacuum jacket is not magnetic. The loads on the dished heads may be significant.

PTF Test Area Magnetic Materials

In the Test Area

Large Valves Operator Wheels	Magnetic	Remove
Split Pair Ring Gear and Worm Assembly	Magnetic	Stay in Place
Large Embedded studs in concrete pillar	Non-Magnetic	
PTF water circulating pump	Magnetic	Stay in place, do not brace

Stray Field at 15 T



9.0 Contract Test Procedure

Receipt Inspection and Tests

Vacuum Measurements

Initial Set-Up

Set up bore dimensional gauges. Record RT baseline bore locations

Stabilize temperatures at RT (No LN2, wait overnight) Take temperature readings, record temperature baseline

Perform Electrical tests as an initial un-loaded RT baseline

Use of the Megger tester: Red is +, to the coil, Black is Negative to the cryostat, green is to a good ground. Select a voltage then press the test button. The needle moves to 100 on the top scale, and then settles to infinity. Then ground the coil to remove any residual charge. The initial movement of the needle representing the current flow due to the capacitance in between the magnet and the cryostat. The needle moves to infinity later on means your leakage current is below detection.

Initial Cooldown, Dimensional Characterization

Initial Cooldown, will require a total of 550 liters of LN2, and may take a couple of days

Purge system with dry Nitrogen gas

Open LN2 Supply Valve, watching level sensors, and temperature sensors. Slowly bring the level of the LN2 up to about 1/3 the height of the inner vessel volume

Benchmark Capacitative level sensors and discrete sensors.

Inspect roof flapper valve for proper venting of Gaseous Nitrogen

Inspect Electrical connections and Vent lines for ice build up.

Cryostat Pressure should be no more than ____ atms during cooldown. If pressure exceeds ____ shut off LN2 feed.

If there is excessive ice build up, shut off LN2 supply, and allow system to warm. – Re-apply foam as needed.

Initial cooling should take 3 or 4 hours.

Turn on Bore heater system. Maintain at RT

Confirm Magnet temperature is at 80 K, At equilibrium (no temp change overnight), record temperature data. Use RT and 80 K measurements to calibrate temperature sensors. Add only as much LN2 as needed to maintain temperature. Cooling mode is to be primarily gaseous. Keep level below 1/3 of the cryostat depth. Find the LN2 feed valve setting that just matches the heat leak loading. Mark or otherwise record the valve setting.

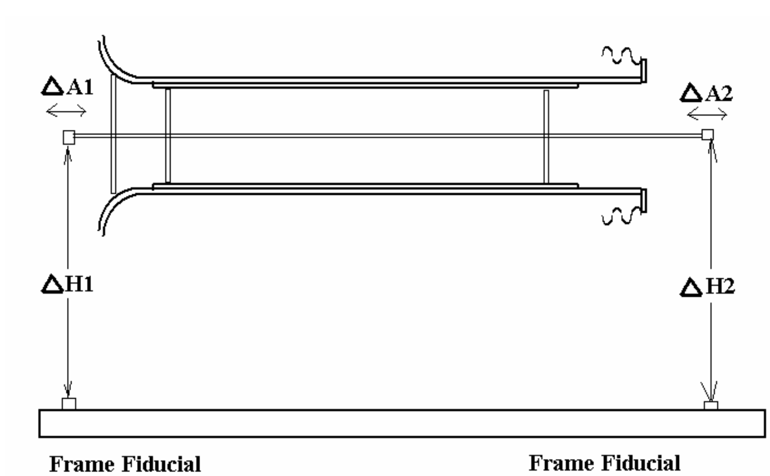
Visually inspect for leaks around the cover gasket ,bellows and magnet lead gland seals.

Boil-Off – Heat Leak Test

Measuring the level change with respect to time will give a measure of the magnet's heat leak.Use of a flow meter is not planned. Level changes in the dewar or magnet will need to be used. If the Magnet level change is used, the change is level with respect to change in LN2 volume is a complex geometric calculation of coolant space with respect to level in the magnet. As an estimate consider the annular coolant channels at the equatorial plane, and consider the head and outer annulus filled with fiberglass epoxy. There are eight 2mm "slots" at the equatorial plane. The heat leak would be:

Heat Leak= Level change rate(m/sec)*8*.002* 1 m *804.3kg/m^3* 199000 Joule/kg

The heat leak is expected to be around 250 Watts. The level change rate is then .097mm/sec or about 6mm/minute. If the LN2 volumes in the plenums at the face and backside of the magnet and the effects of the circumferential grooves, and voids around the annular and head fiberglass fillers, 3mm/minute might be more representative. Record the level, and the level change in five minute intervals.



The fixture is a rod or tube with circular disks that fit against the bore and one disk at the end that rests against the flare in the vacuum jacket. The flare is the entry point for the mercury jet cassette

Record Cold Dimensional Changes

Insert Hall Probe Gauge, Check instrumentation

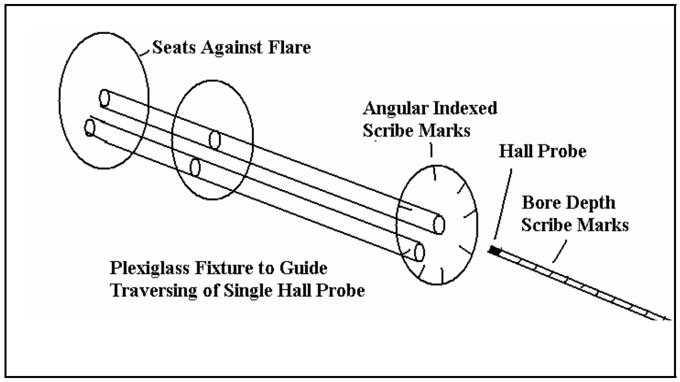
Check interference with operation of LDX, VTF , Rick Temkin's RF photocathode electron gun.

Power to 100 amps, maintain a steady current. Measure voltage drop to obtain the 80 K resistance

For 100 Amp power supply, the central field in bore should be .208333T.

For a 10 volt power supply , and with the magnet at room temperature, . We should get 31 amps, and 65 millitesla, and it should take about 12 seconds to get up to the steady state current..

Map Field values traversing the bore and rotating the gauge. Fill in Data sheets (later)



Inductance Measurement

Measure temperature. Stabilize at 80 K with more LN2, or re-measure 100 amp steady state voltage drop to obtain the resistance at test temperature. Add only as much LN2 as needed to maintain temperature. Cooling mode is to be primarily gaseous.

Check Interference with operation of LDX, VTF , Rick Temkin's RF photocathode electron gun.

Apply 10 Volts, Obtain a current trace. Compute Inductance from 10 v= L*dI/dt+I*R
Lin Henries is:___________

5T Test

Set Power Supply for 5T test, Stabilize temperature to 77 to 80 K overnight. Add only as much LN2 as needed to maintain temperature. Cooling mode is to be primarily gaseous. Keep level below 1/3 of the cryostat depth. Record measured Temperatures

Check Interference with operation of LDX, VTF , Rick Temkin's RF photocathode electron gun.

Run Test watching buss bars and Reese cables for excessive motion. Obtain Voltage/Current Plots

For an initial temp of 80 K the final coil temp should be _____ in all three coils. Fill in coil temperature data sheet(later). Temperatures in each of the three segments should be nearly identical.

Monitor and record pressure. Pressure in the inner vessel should be approximately ______Pa. The intention is to approach the intended operational surface heat flux in steps.

Add only as much LN2 as needed to maintain temperature. Cooling mode is to be primarily gaseous.

10T Test (First)

Set Power Supply for 10T test, Stabilize temperature to 77 to 80 K overnight. Record measured Temperatures –

Run Test watching buss bars and Reese cables for excessive motion. Add support if needed. Obtain Voltage/Current Plots

For an initial temp of 80 K the final Coil temp should be _____ in all three coils. Fill in data sheet(later) Temperatures in each of the three segments should be nearly identical.

Keep LN2 level about 1/3 height. Cooling mode is to be primarily gaseous. For the second 10T pulse, Cool only long enough to bring the three coils down to 85K or below. Record time to cool

Monitor and record pressure. Max pressure in the inner vessel should be approximately ______Pa. The intention is to approach the intended operational surface heat flux in steps.

Visually inspect for leaks around the cover gasket , bellows and magnet lead gland seals.

10T Test (Second)

Set Power Supply for 10T test, Coils should be below 85K. Record measured Temperatures .

Run Test watching buss bars and Reese cables for excessive motion. Add support if needed. Obtain Voltage/Current Plots

For an initial temp of 80 K the final Coil temp should be _____ degrees higher than initial temp in all three coils. Fill in data sheet(later) Temperatures in each of the three segments will be different by a bit more than the start temperature differences.

Keep LN2 level about 1/3 height. Cooling mode is to be primarily gaseous. For the second 10T pulse, Cool only long enough to bring the three coils down to 85K or below. Record time to cool

Monitor and record pressure. Pressure in the inner vessel should be approximately ______Pa. The intention is to approach the intended operational surface heat flux in steps.

Visually inspect for leaks around the cover gasket , bellows and magnet lead gland seals.

Second Room Temperature Electrical Tests

Cease adding LN2 . Warm to RT. Perform Electrical tests, Compare with initial baseline. Perform visual inspections of pressure boundaries, insulation, and instrumentation lines.

10T Test (Third)

Purge system with dry Nitrogen gas

Open LN2 Supply Valve, watching level sensors, and temperature sensors. Slowly bring the level of the LN2 up to about 2/3 the height of the inner vessel volume. Cooling mode after this pulse will be primarily pool boiling. For the third 10T pulse, Cool long enough to bring the three coils down to 80K and stabilize the temperature. Record time to cool.

Set Power Supply for 10T test, Coils should be at 80K. Record measured Temperatures .

Run Test watching buss bars and Reese cables for excessive motion. Add support if needed. Obtain Voltage/Current Plots

For an initial temp of 80 K the final Coil temp should be _____ degrees higher than initial temp in all three coils. Fill in data sheet(later) Temperatures in each of the three segments will be different by a bit more than the start temperature differences.

Allow LN2 level to drop to 1/3 height. Initial cooling mode is pool boiling then turning to gaseous. For the first 15T pulse, Cool long enough to bring the three coils down to 80K or below. Obtain time-temperature plots for the three coil segments.

Monitor and record pressure. Pressure in the inner vessel should be higher in this cooldown, approximately ______Pa. The intention is to approach the intended operational surface heat flux in steps.

Visually inspect for leaks around the cover gasket ,bellows and magnet lead gland seals.

15T Test (First)

Set power supply for 15T test, Coils should be at 80K. Record measured Temperatures .

Check interference with operation of LDX, VTF , Rick Temkin's RF photocathode electron gun.

Run Test watching buss bars and Reese cables for excessive motion. Add support if needed. Obtain Voltage/Current Plots

For an initial temp of 80 K the final coil temp should be _____ degrees higher than initial temp in all three coils. Fill in data sheet(later) Temperatures in each of the three segments will be different by a bit more than the start temperature differences.

Keep LN2 level about 1/3 height. Cooling mode is to be primarily gaseous. For the second 15T pulse, Cool long enough to bring the three coils down to 80K or below. Record temperatures and time to cool

Monitor and record pressure. Pressure in the inner vessel should be approximately ______Pa. The intention is to approach the intended operational surface heat flux in steps.

Visually Inspect for Leaks around the cover gasket and bellows.

15T Test (Second)

Set power supply for 15T test, Coils should be at 80K. Record measured Temperatures .

Check interference with operation of LDX, VTF , Rick Temkin's RF photocathode electron gun

Run Test watching buss bars and Reese cables for excessive motion. Add support if needed. Obtain Voltage/Current Plots

For an initial temp of 80 K the final coil temp should be _____ degrees higher than initial temp in all three coils. Fill in data sheet(later) Temperatures in each of the three segments will be different by a bit more than the start temperature differences, and possibly by the magneto-resistive effects..

Keep LN2 level about 2/3 height. Cool long enough to bring the three coils down to 80K or below. Obtain time-temperature plots for the three coil segments.

Monitor and record pressure. Pressure in the inner vessel should be the highest of all the tests or approximately ______Pa.

Visually inspect for leaks around the cover gasket ,bellows and magnet lead gland seals.

<u>Third Room Temperature Electrical Tests</u>

Cease addingLN2 . Warm to RT. Perform Electrical tests, Compare with initial baseline. Perform visual inspections of pressure boundaries, insulation, and instrumentation lines.

<u>Report Test Results</u>