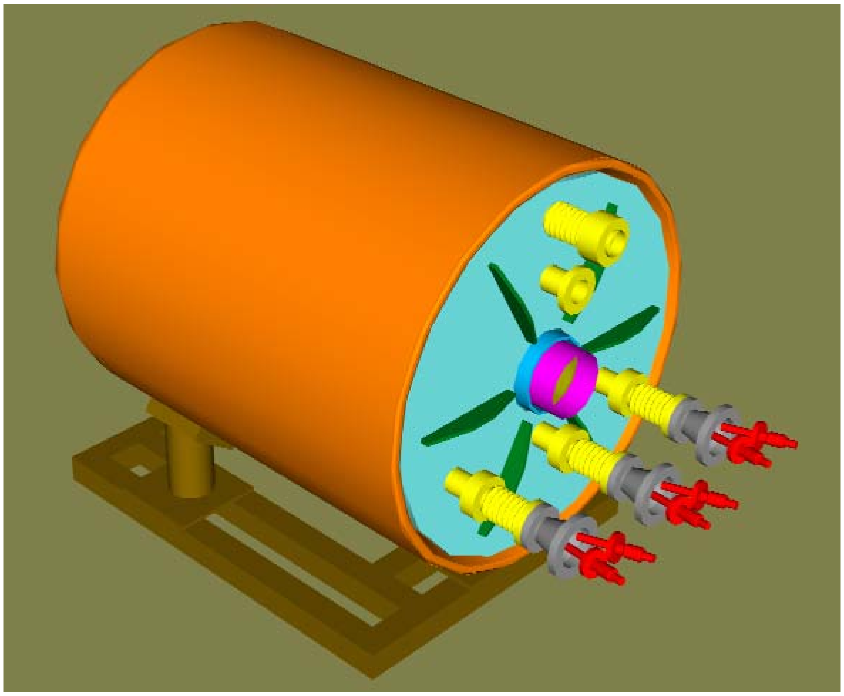
Draft Test Plan For:
MIT Plasma Science and Fusion Center
Pre-Operational Testing of:

BNL - E951 15T Pulsed Magnet for Mercury Target Development
Neutrino Factory and Muon Collider Collaboration

P.H.Titus, March 2005
6896066



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

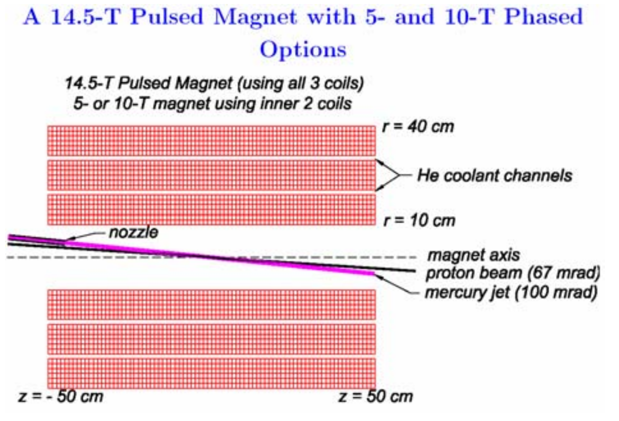
1.3 Table of Contents

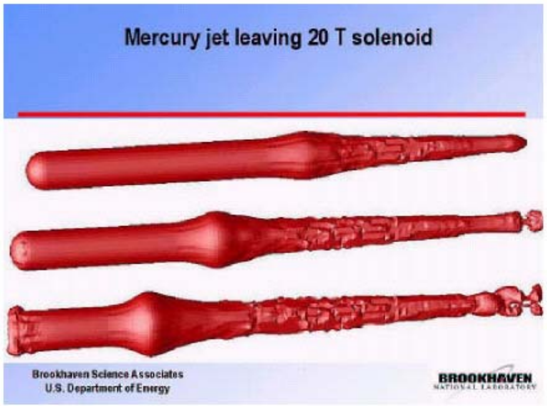
1.0 Administrative
    1.1 Review and Approval
    1.2 Revision Status
    1.3 Table of Contents
    1.4 Introduction
    1.5 References
2.0 Objectives
3.0 Test Location
4.0 Critical Lifts
5.0 Power Supplies
6.0 Cryogenic System for MIT Tests
7.0 Instrumentation
8.0 Safety and Operational Constraints
9.0 Detailed Test Procedure

1.4 Introduction

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 will be epoxy impregnated.





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

1.5 References

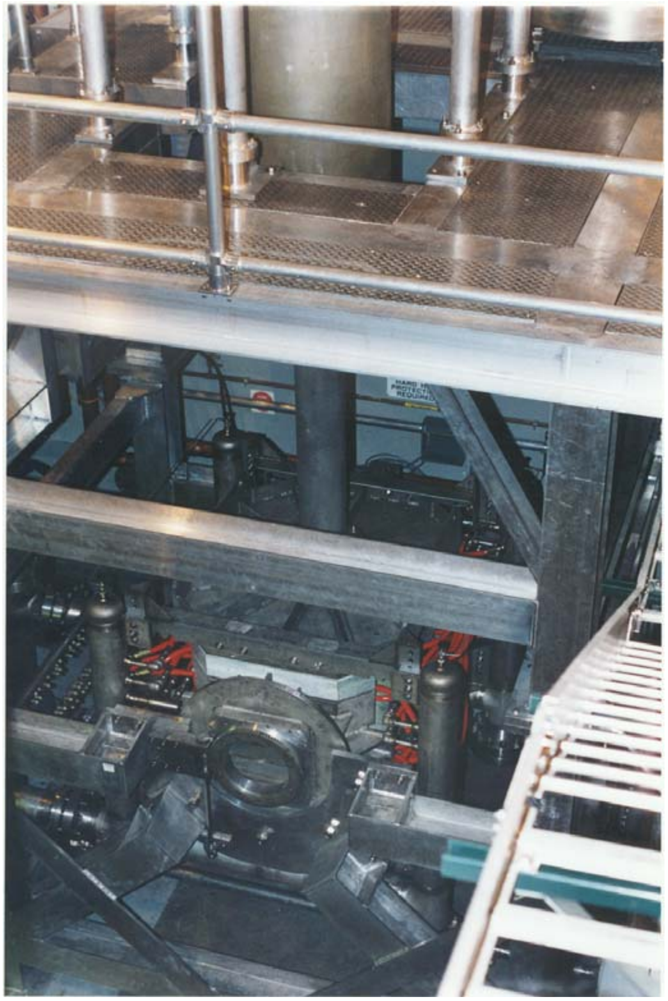
2.0 Objectives

- 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(?).

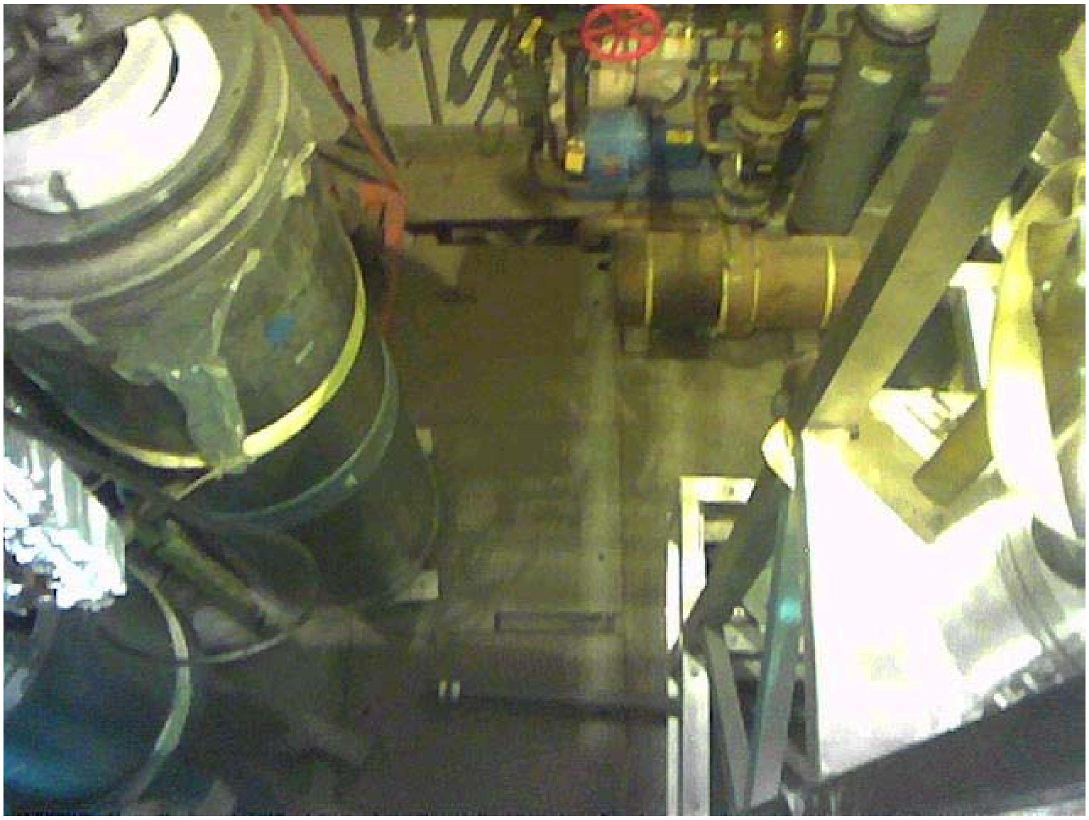


Lower Water Cooled Split Pair Copper Magnet - The BNL Pulsed Magnet will be in front of this
Where the HXC Prototype cryostat is now positioned

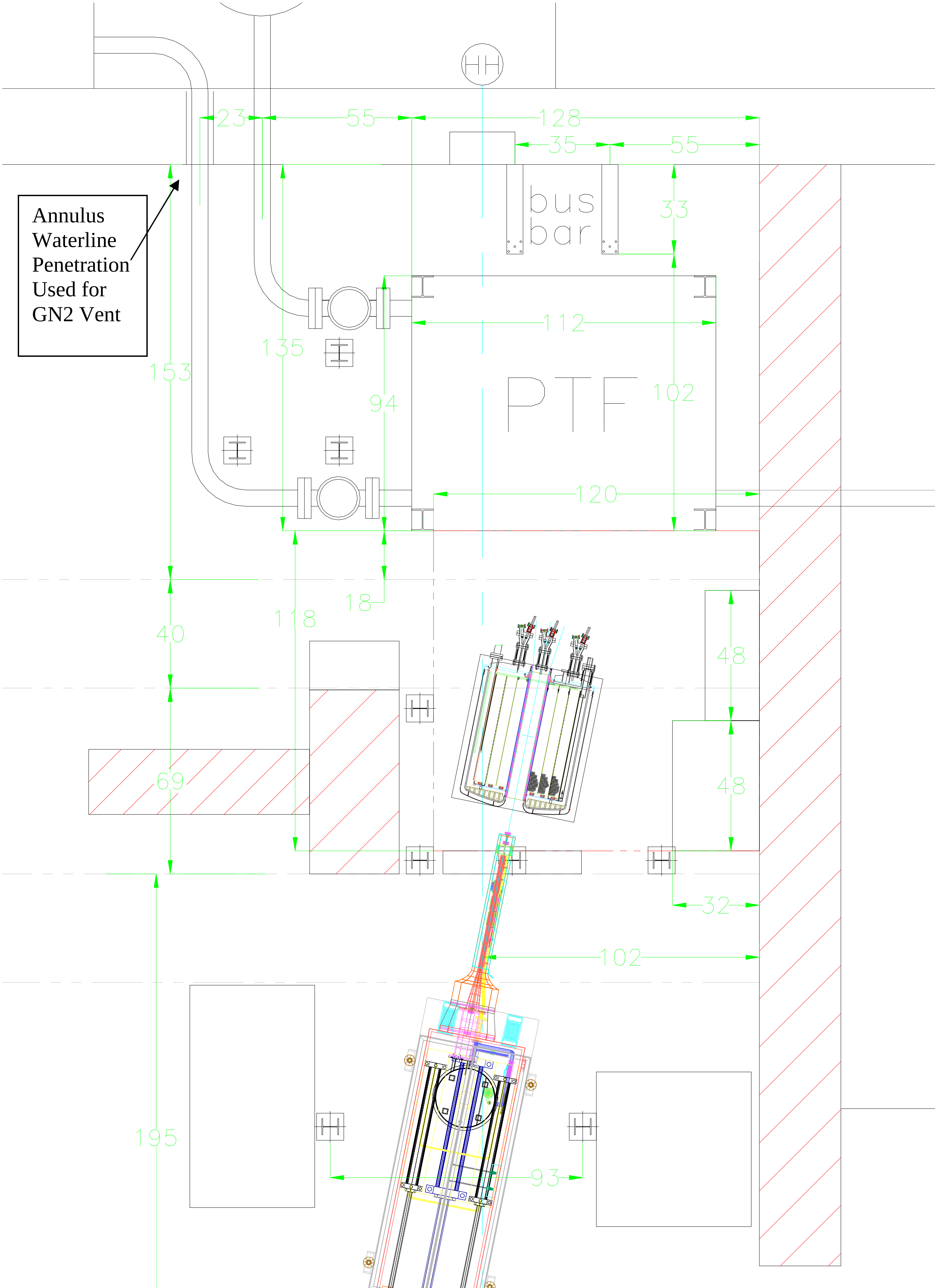
PTF Upper Cryostat

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

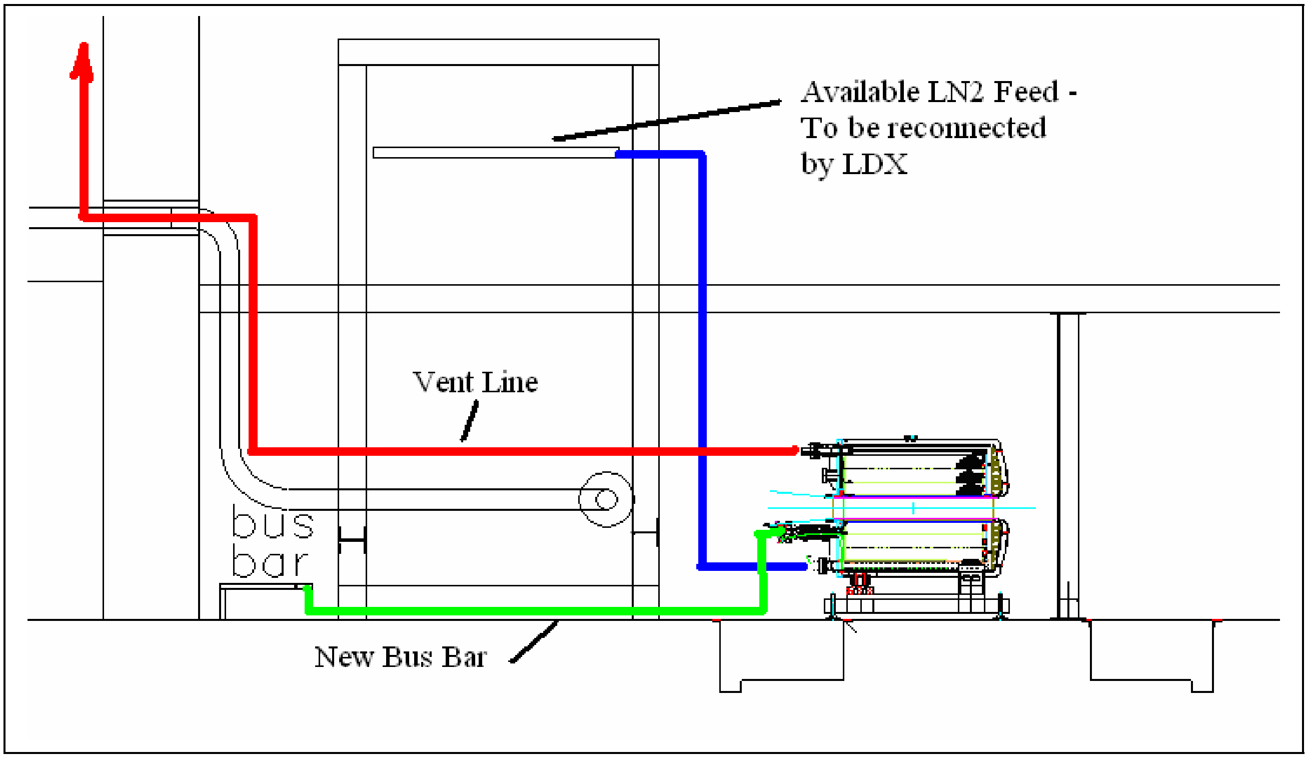
View of test area at floor level



View of the test area floor. The dewars at left and HCX components at right need to be removed

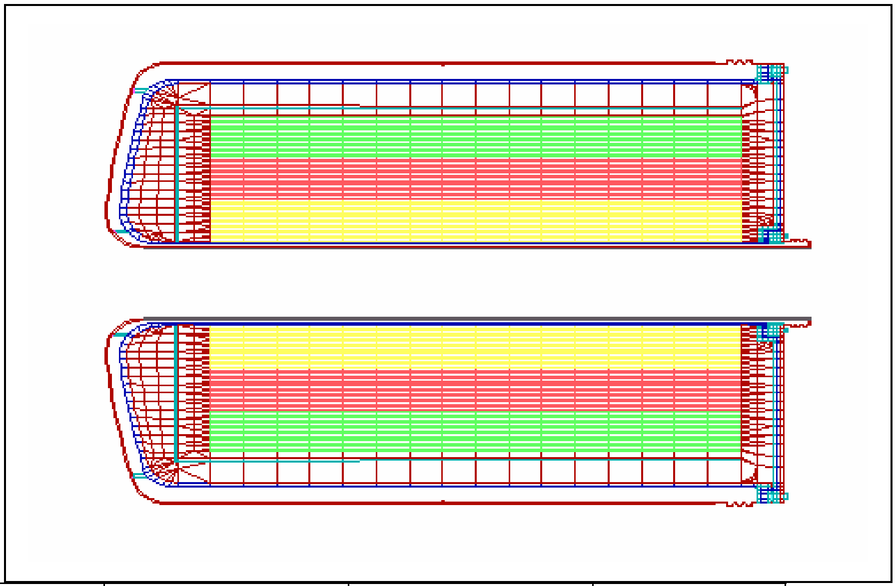


Annulus
Waterline
Penetration
Used for
GN2 Vent



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

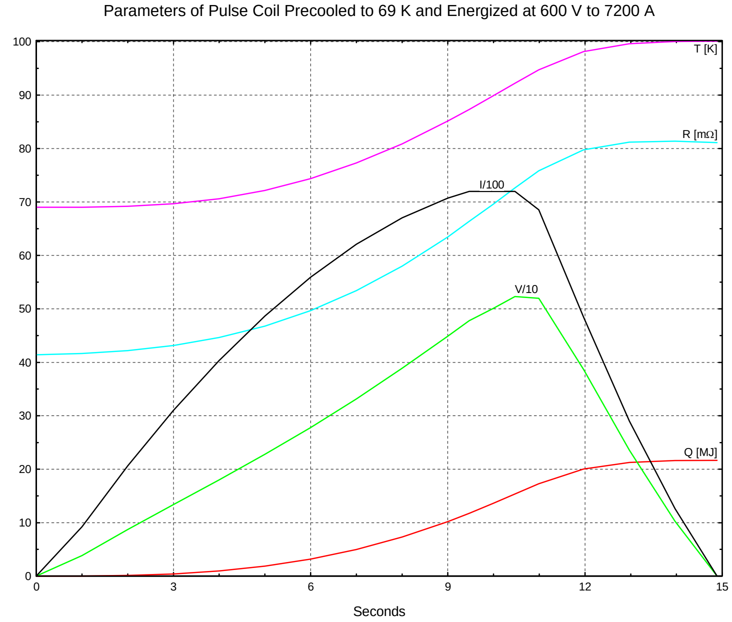
Component	FEM Mat#	Volume	Density Kg/m^3	Mass kg
Coil	1 3 5	.4618	8900	4110
Vessels		.1119	8700	973
G-10 Filler	91	.3119	1794	559
Total				5642

A 6 ton lift should be planned for .

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

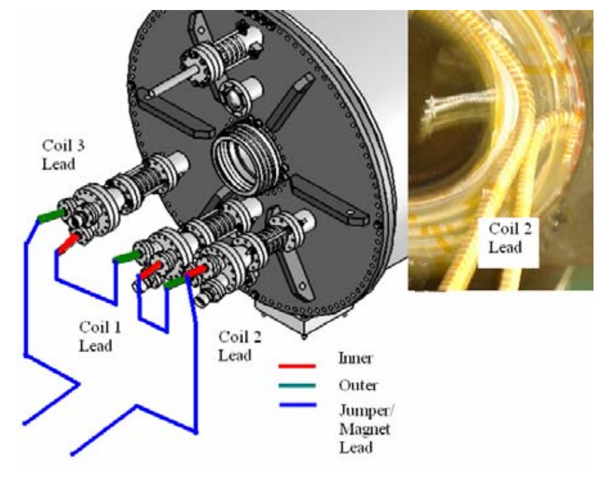


Bob Weggel’s 10-14 analysis of the LN2 magnet operation

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

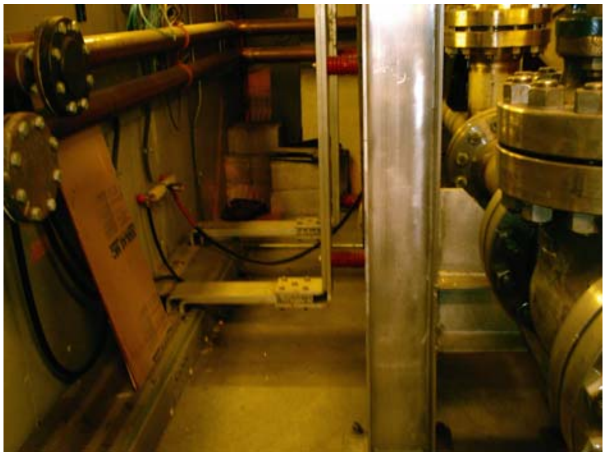
Our agreement with Alcator is that they will provide the labor to re-activate our control cabinet and we will provide the replacement component parts. Bill said that he will check the price and availability of needed components again and send that to us. –We have an earlier estimate, that has been included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

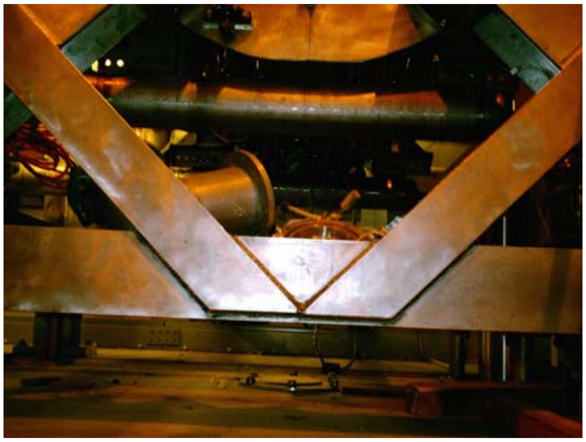


Buss Bar and Jumper Connections.

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. 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



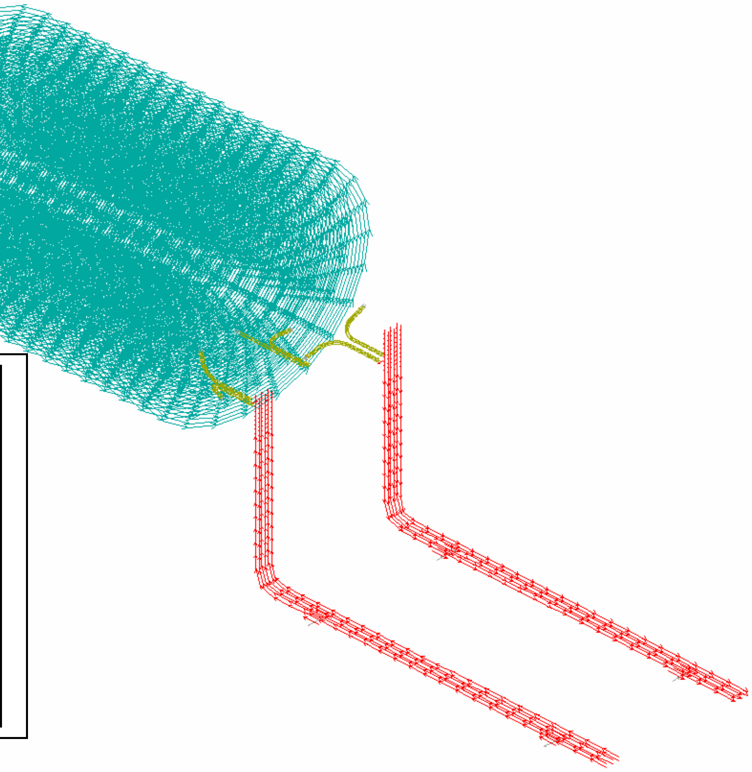
Bus connection to the PTF Split Pair



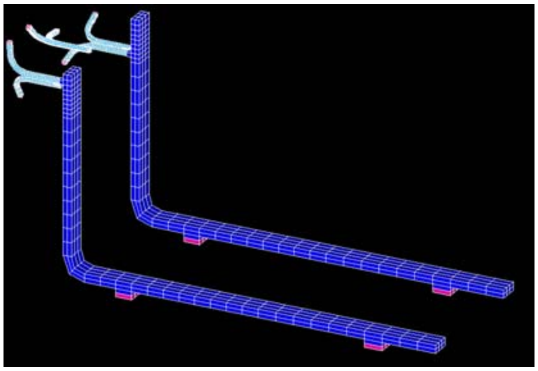
Bus bars can run under the PTF split pair

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

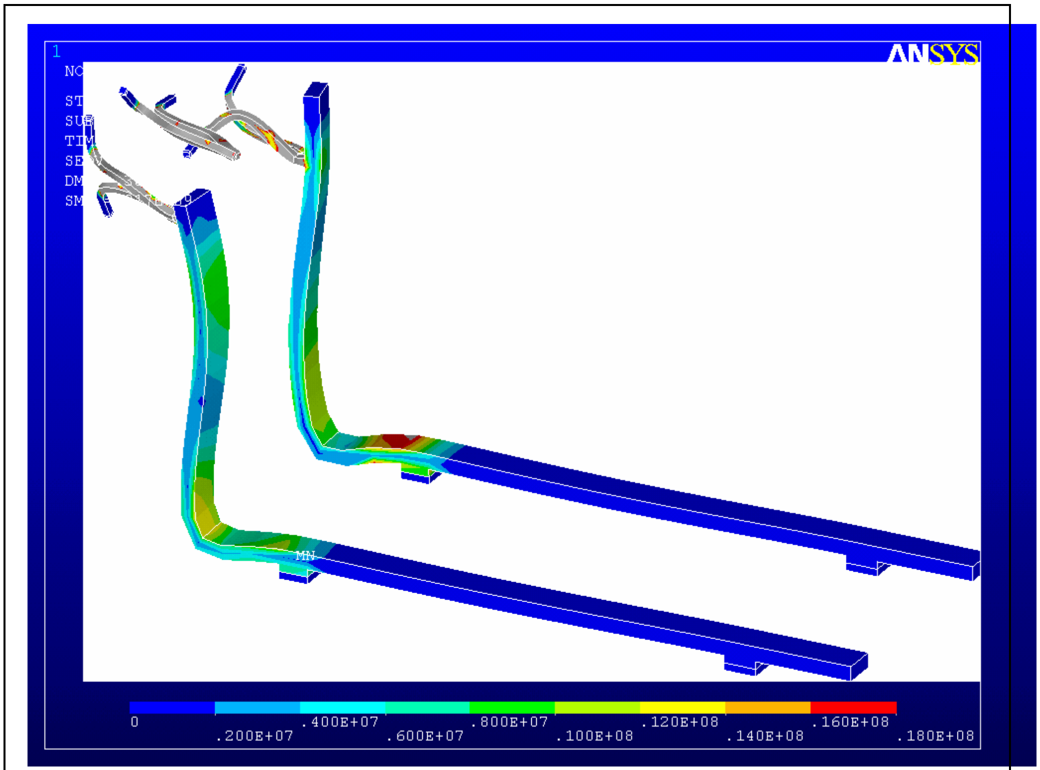


The total reaction for the 2 pads on the rear lead are:

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.

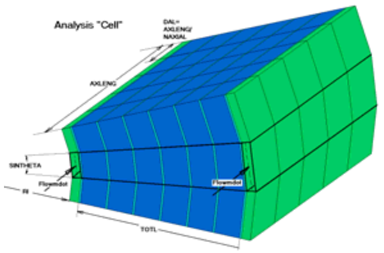
Inductance Measurement

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 .

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



6.0-1 Finite Difference Cooling Model.

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 tsting at MIT, although the system is intended to retain the capability to be cooled using gaseous Helium. 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. .

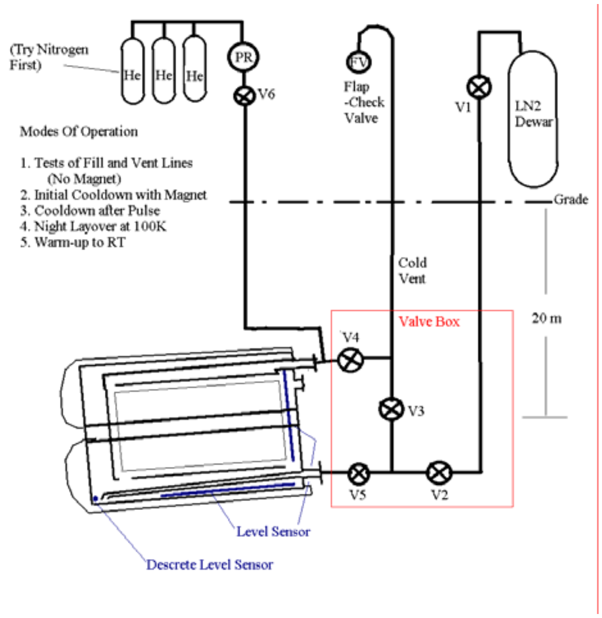
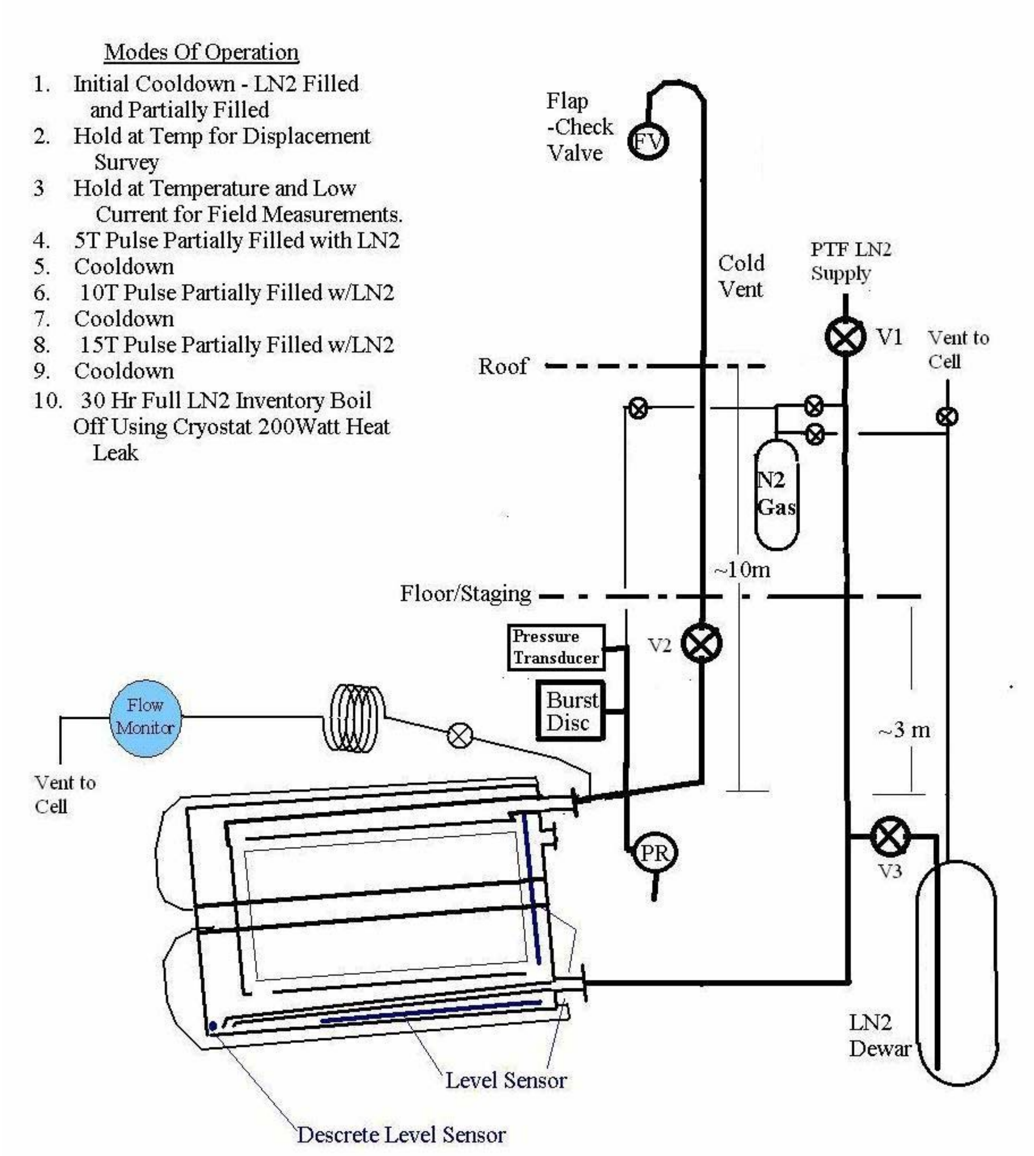


figure 6.0-2 Cryogenic System Planned for use at CERN – As of November 23, 2004



Modes Of Operation

1. Initial Cooldown - LN2 Filled and Partially Filled
2. Hold at Temp for Displacement Survey
3 Hold at Temperature and Low Current for Field Measurements.
4. 5T Pulse Partially Filled with LN2
5. Cooldown
6. 10T Pulse Partially Filled w/LN2
7. Cooldown
8. 15T Pulse Partially Filled w/LN2
9. Cooldown
10. 30 Hr Full LN2 Inventory Boil Off Using Cryostat 200Watt Heat Leak

Figure 6.0-3 Cryogenic System Planned for Use at MIT

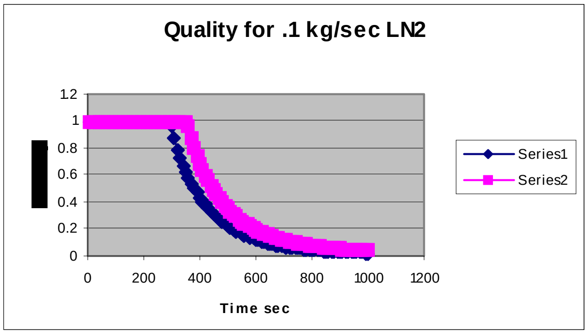
The initial cooldown to 77K requires:

(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.

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

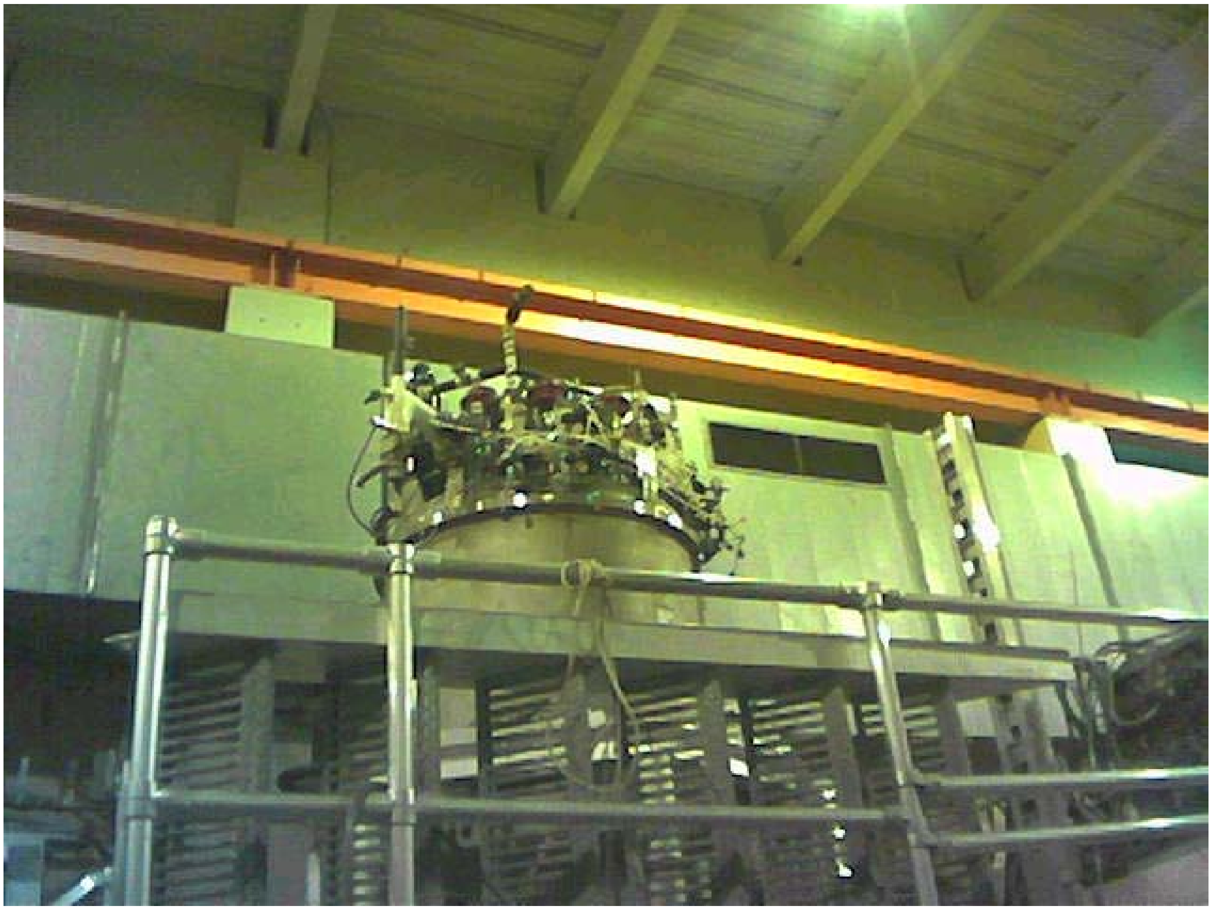
Magnet Lab’s LN2 Supply Tank



The intention is to control the LN2 flow 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

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)

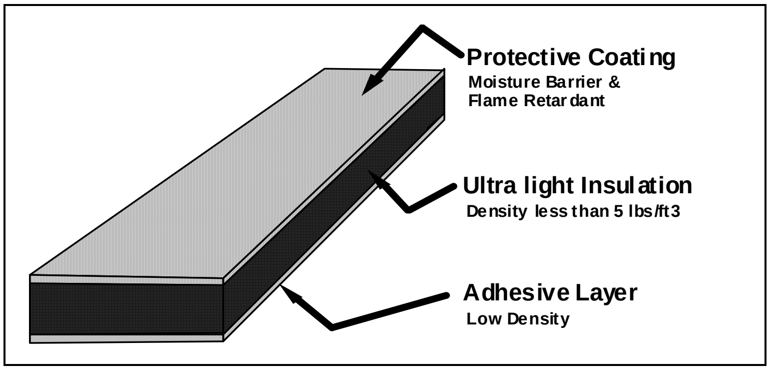
Size	Schedule 5		Schedule 10		Schedule 40	
4"	$3.35	Buy Now	$4.85	Buy Now	$9.25	Buy Now
5"			$6.65	Buy Now	$12.55	Buy Now
6"			$8.00	Buy Now	$16.25	Buy Now
8"			$11.50	Buy Now		

Annular space around water line proposed for use with the gaseous N2 vent.

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

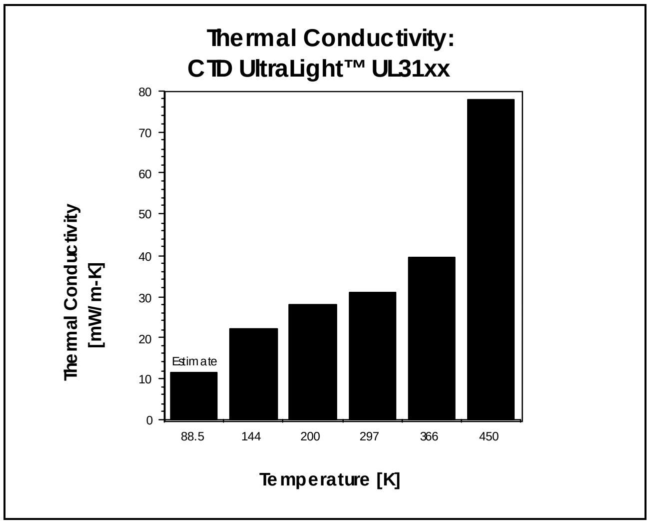
```
!mass flow= .05 kg/sec
!volume flow= 144 cu-m/hr        ( Mike calculated a larger number. I am not sure how he got it)
!volume flow =  1.4125782 cu ft/sec
!Exhaust Pipe Flow Velocity, 4in pipe= 16.515614 feet/sec
!Exhaust Pipe Flow Velocity, 6in pipe= 7.1942017 feet/sec

  !   **  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
```



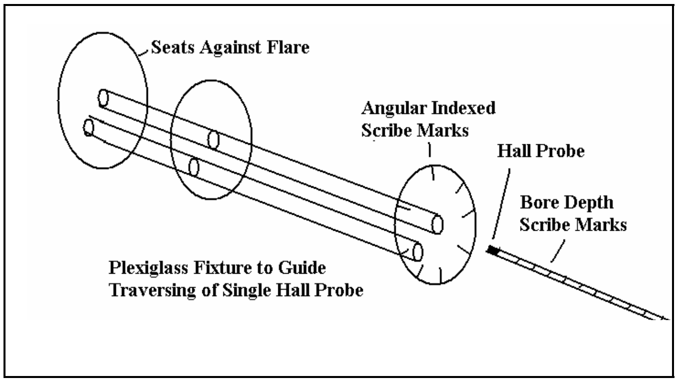
6.3 Applcation of Cryogenic Sheet and Spray Foam

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.



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 ,

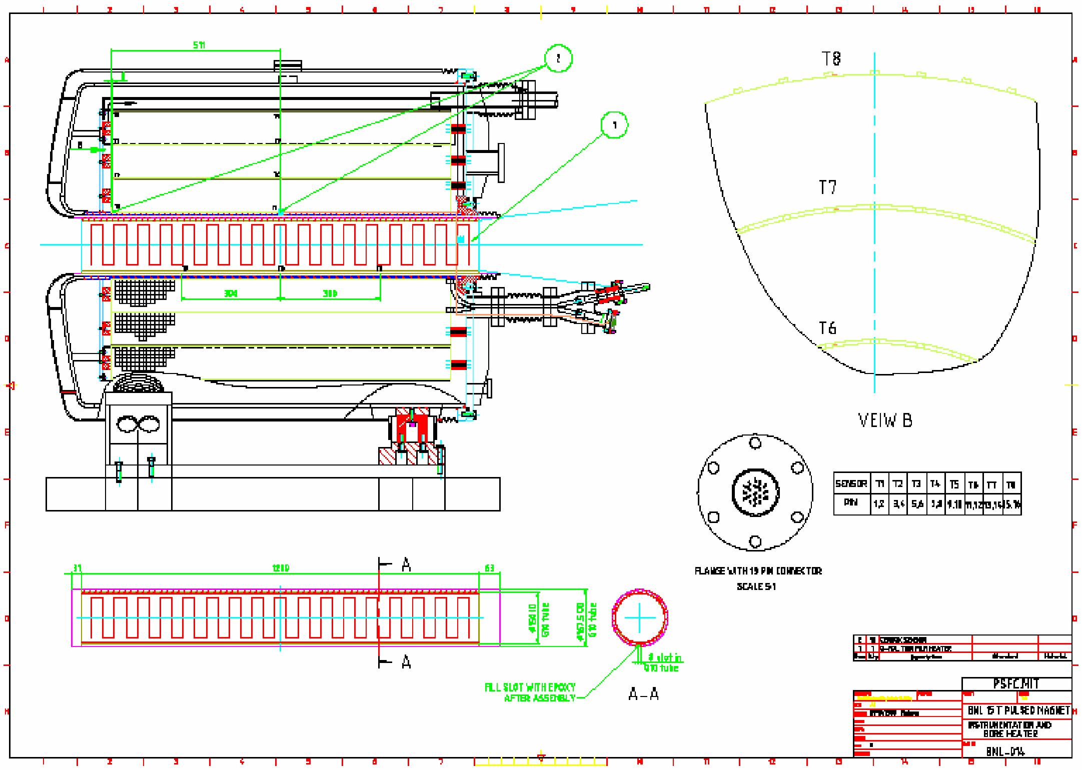


Field Measurements/Field mapping

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:

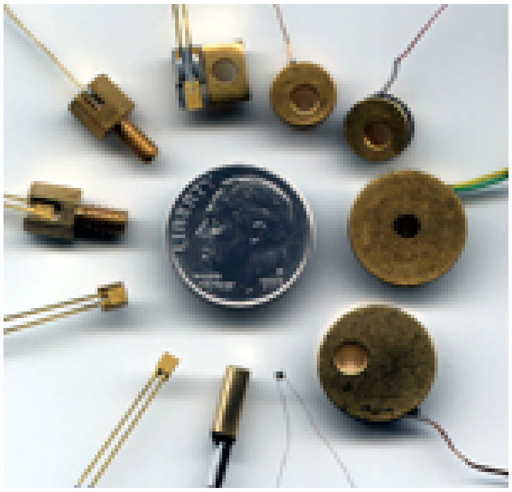
For the “Fill, Drain and Pulse” test, instrumentation requirements are minimal. The temperature sensors in the magnet should be read, but there is no need to read the temperature sensors during a pulse. This eliminates the concern over small currents in the leads in very high fields. Not all are needed 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

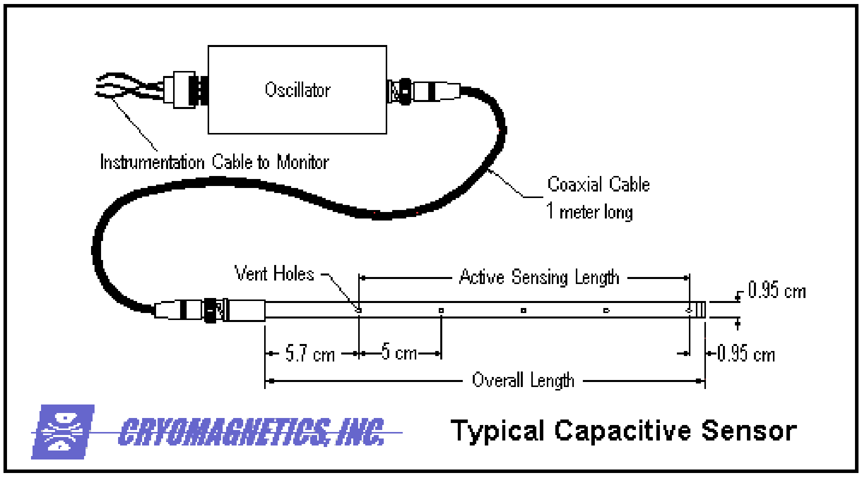
Cernox

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



Level Sensors



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

Model 186 Liquid Level Controller

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

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 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.

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.

9.0 Test Procedure

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

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.

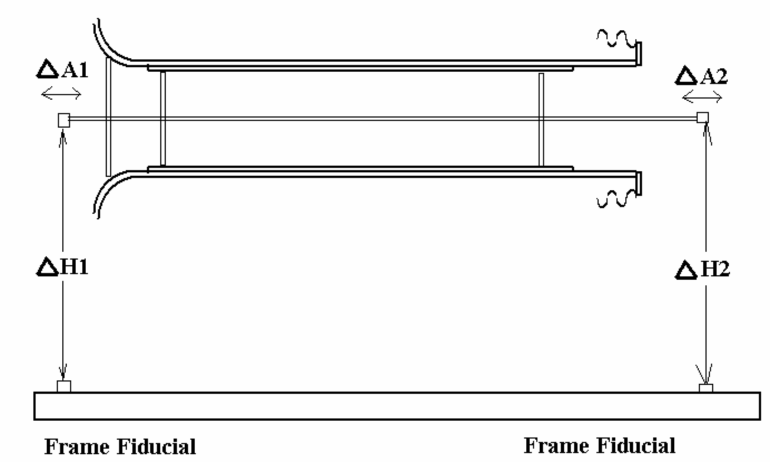
Visually inspect for leaks around the cover gasket ,bellows and magnet lead gland seals.

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

Central Field in Bore should be .208333T

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 addingLN2 . 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.

Third Room Temperature Electrical Tests

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

Report Test Results