Status of MICE Coupling Coil Tests

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Outline

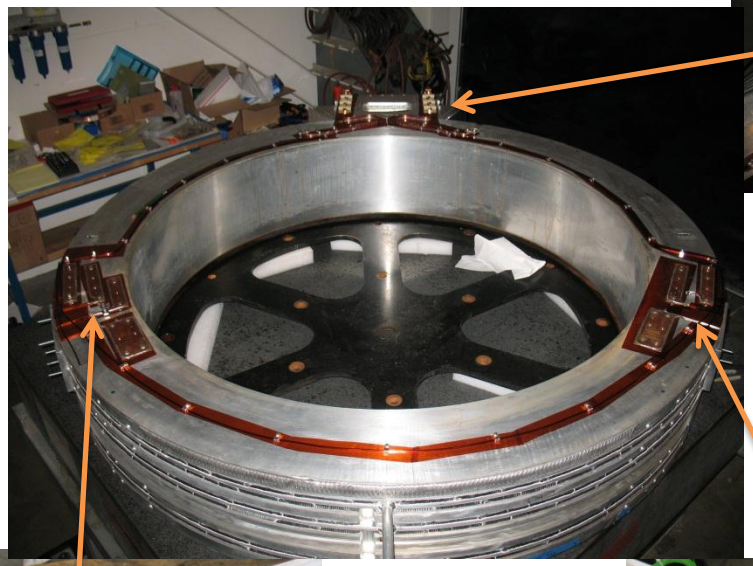
- Background and Introduction
- Test Facility Design And Fabrication
- Test Facility Commissioning/Test Results
- Next Steps
- Schedule

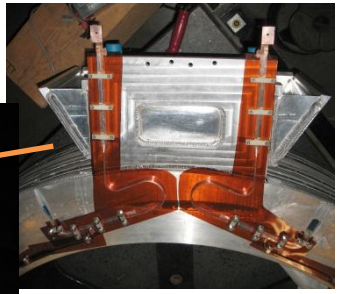
Background

- In the Fall of 2011, the MICE Collaboration asked Fermilab for urgent help to provide a cold test facility for the Coupling Coils.
- A plan was developed and approved by Fermilab's directorate on January 17, 2012. Main elements of the plan:
  - Use a SMES cryostat from the National High Magnetic Field Lab found by LBNL
  - Fabricate and Install a new "Solenoid Test Facility" at Fermilab's Central Helium Liquefier (CHL), with first use for MICE coupling coil solenoid testing
    - Example of a future possible use of this facility is for mu2e Transport Solenoids (with test stand upgrades)
- A Fermilab initial review of the test facility preparations took place on February 2012. The review committee agreed with the proposed approach. Work on this new facility quickly ramped up.

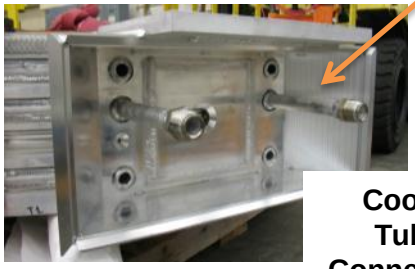
Fermilab Cold Mass Preparations (LBNL)

- Included cooling tubes welding, installation of leads stabilization, passive QP (cold diodes), instrumentation, etc.

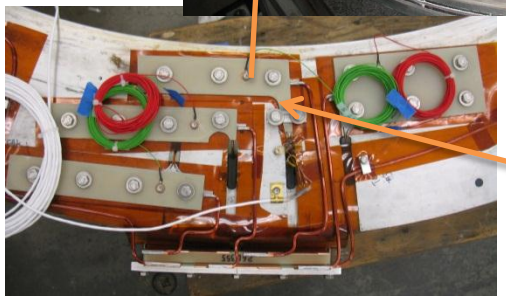




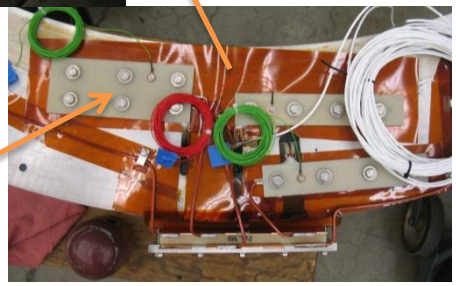
SC Leads Stabilization



Cooling Tubes Connections



Cold QP Diodes Leads Stabilization



Cooling Tube Leak (LBNL)

- Cooling Tube Vacuum Leak found during checkout
- Solution: a bypass pipe branch

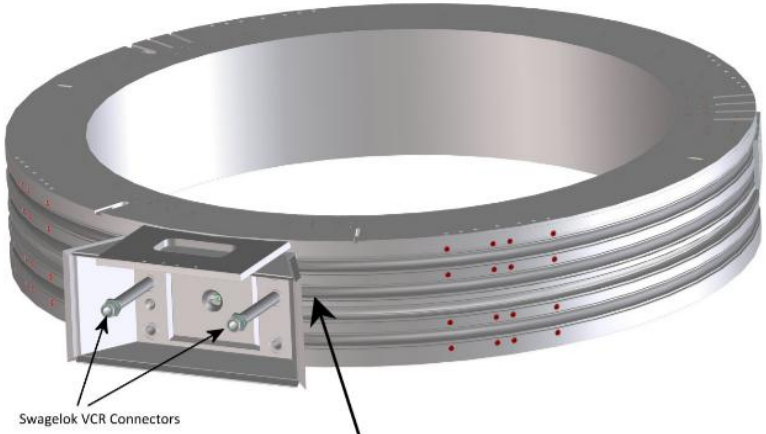
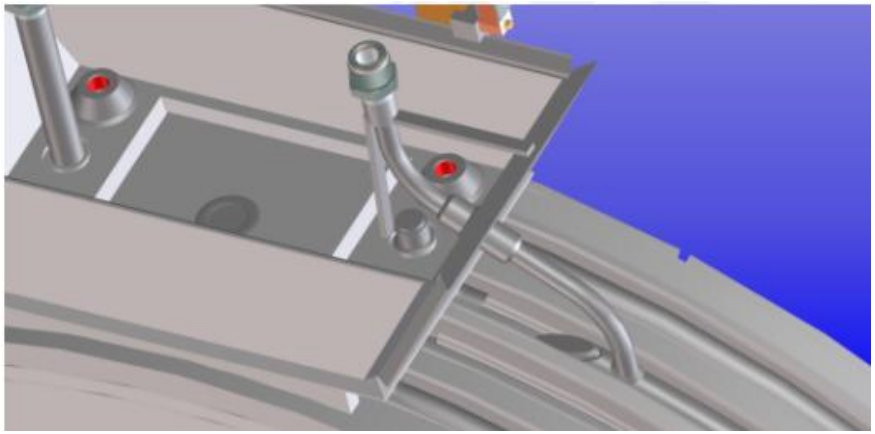
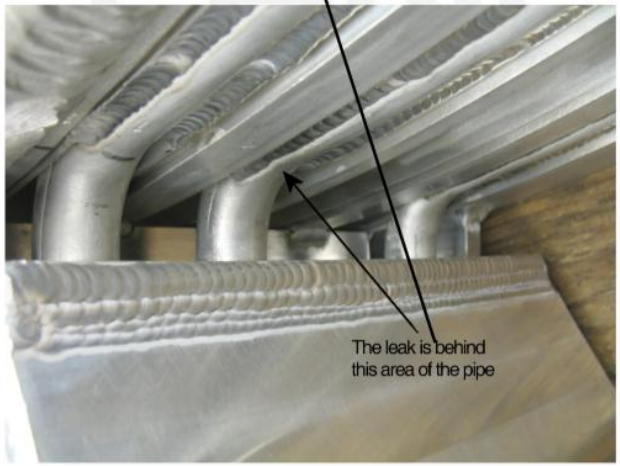


Figure 1 CAD model image of magnet showing approximate location of vacuum leak.



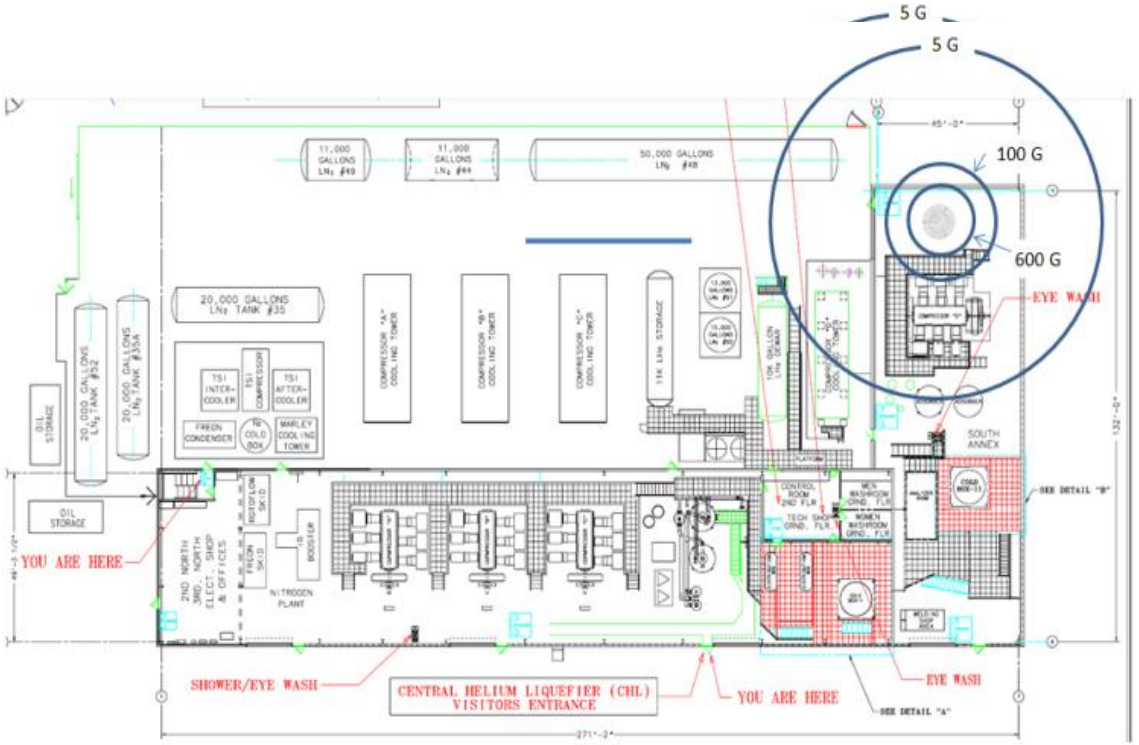


Fermilab First MICE CC Arrived at Fermilab

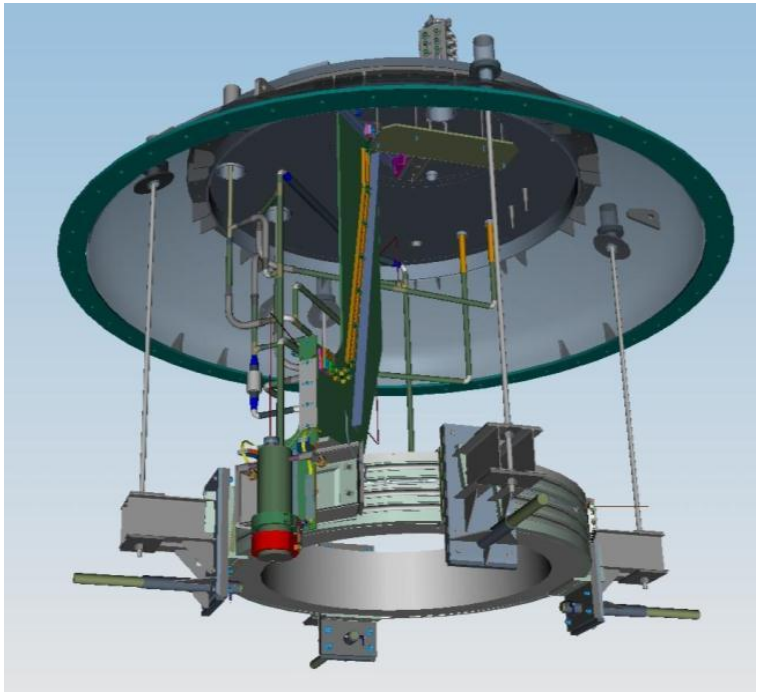
- First Coupling Coil arrived at Fermilab on 1/31/13
- Coil passed hipot, leak check, and instrumentation check

Test Cryostat

- The Test Cryostat was brought to Fermilab from the NHMFL in Florida and installed in the CHL building, South Annex
- Unnecessary internals were removed, and both the vacuum vessel and the top plate were leak checked and passed

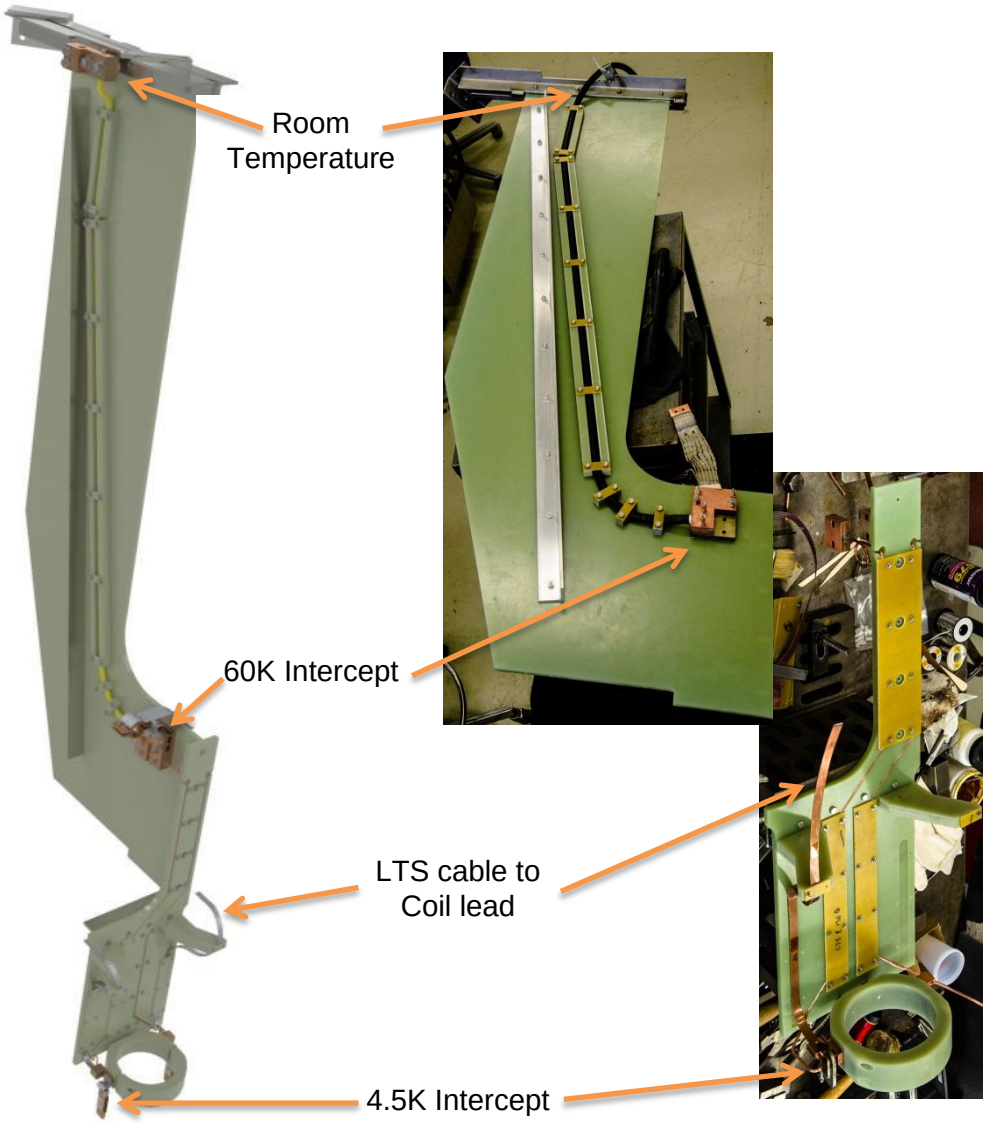


Top Plate Insert



- New Dished Head
- Mechanical Supports
- Cryo Piping
- Current Leads
- Valves, Instrumentation
- Pressure Test
- Leak Check
- Hipot

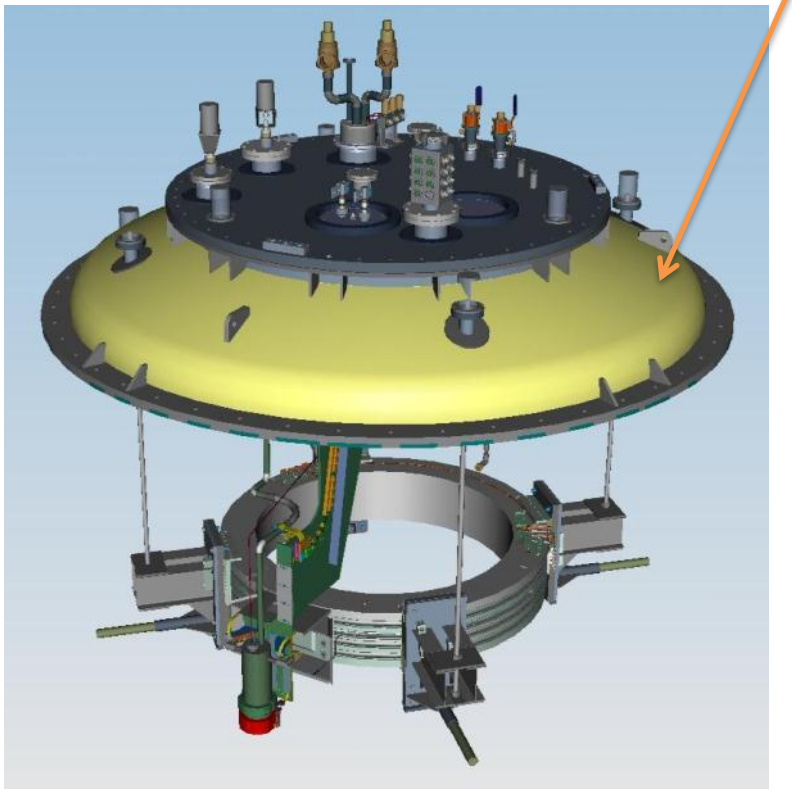
Current Leads

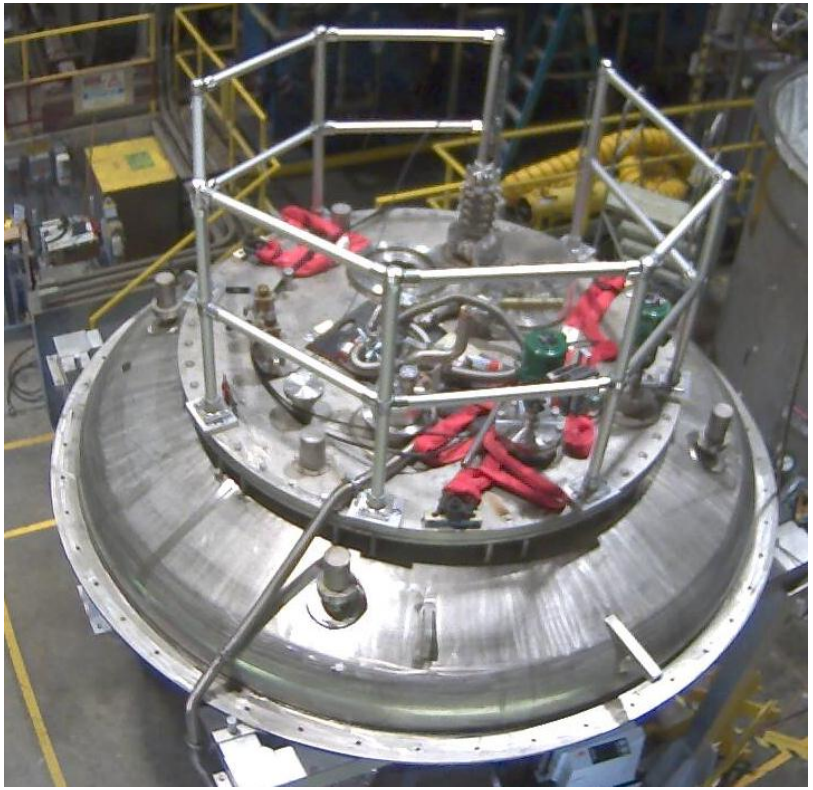


- Conduction-cooled, optimized for 220A
- Two thermal intercepts: 60K (thermal strap to 4.5K GHe return pipe) and 4.5K (Wang NMR intercept to 4.5K boiling He reservoir)
- Low Temperature Superconductor (LTS) section between 4.5K intercept and coil leads
- G-10 mechanical support for magnetic forces

Top Plate

- Valves and Instruments, Instrumentation Tree, U-Tubes Connections, Power Connections, etc.

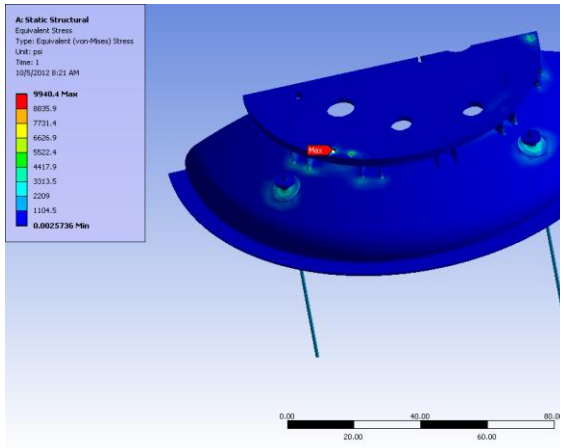


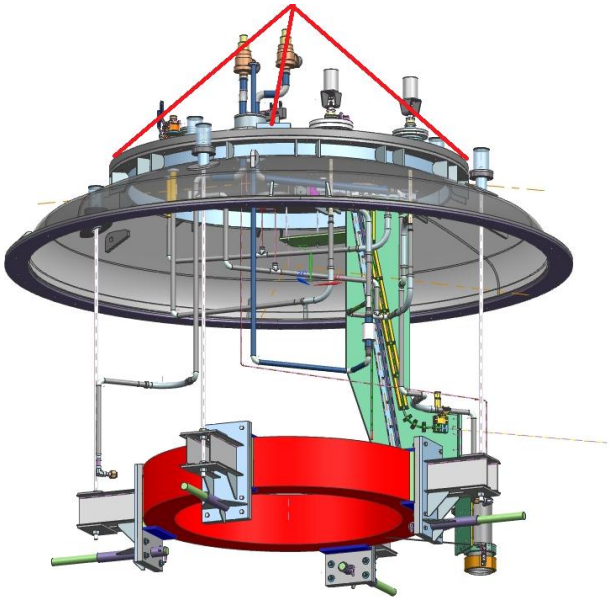


Dished Head Fabrication

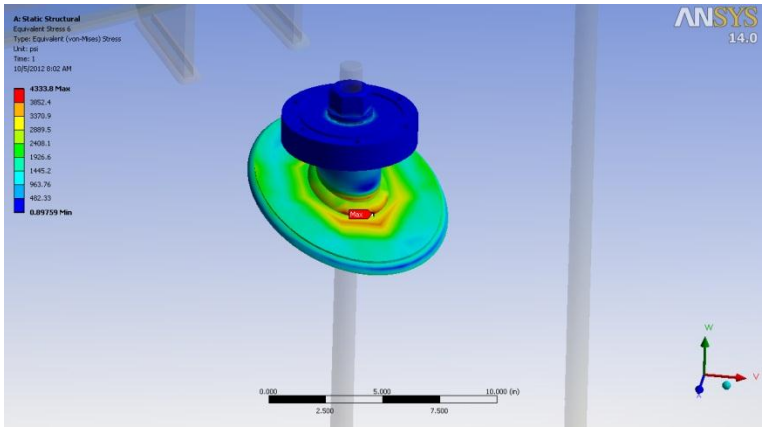
- Designed by Fermilab, fabricated by Meyer Tool

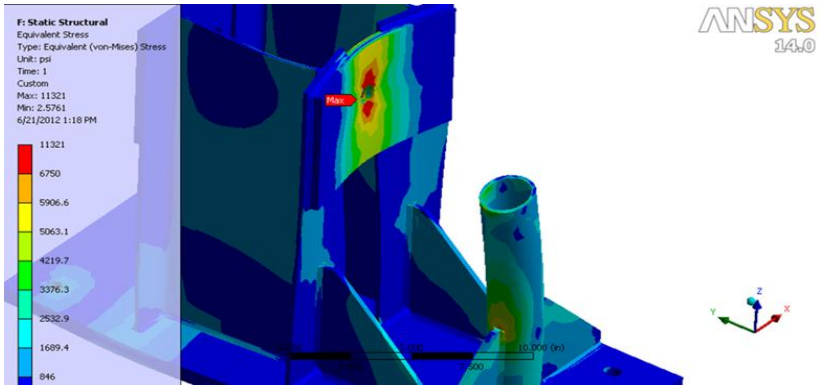
Coil Support System





Design takes into account cold mass weight and magnetic forces with building ferromagnetic structures





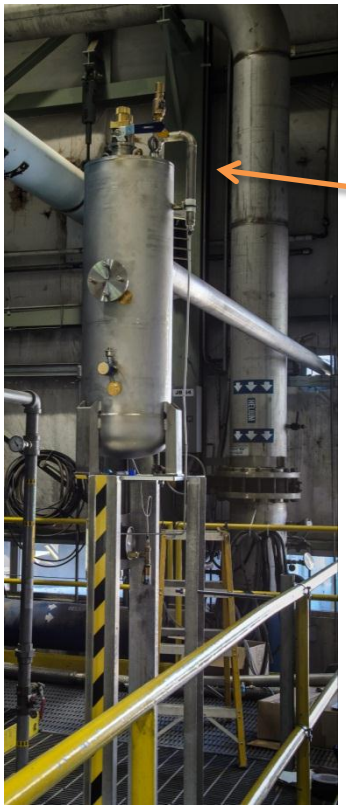
Cryogenic System

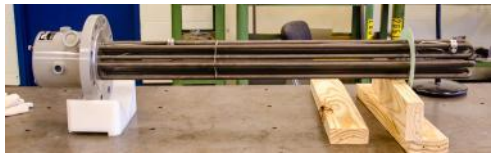
- Liquid Helium and Helium gas recovery provided by the Central Helium Liquefier (unused after the Tevatron shutdown in September 2011)
- Up to 10 g/s of liquid helium at 4.5K supply to the Coupling Coil cooling tube from a nearby CHL 10,000 Gallon liquid helium Dewar
- Helium inlet temperature during cooldown/warmup controlled to maintain a maximum cold mass gradient of 50K
- The return helium warmed up to room temperature before sending back to the CHL facility for recovery
- No venting to atmosphere expected during a quench (small LHe inventory in the cooling tube)

CHL Distribution System

- Liquid Helium (LHe)Transfer Line from 10,000 Gallon LHe dewar to Bayonet Can

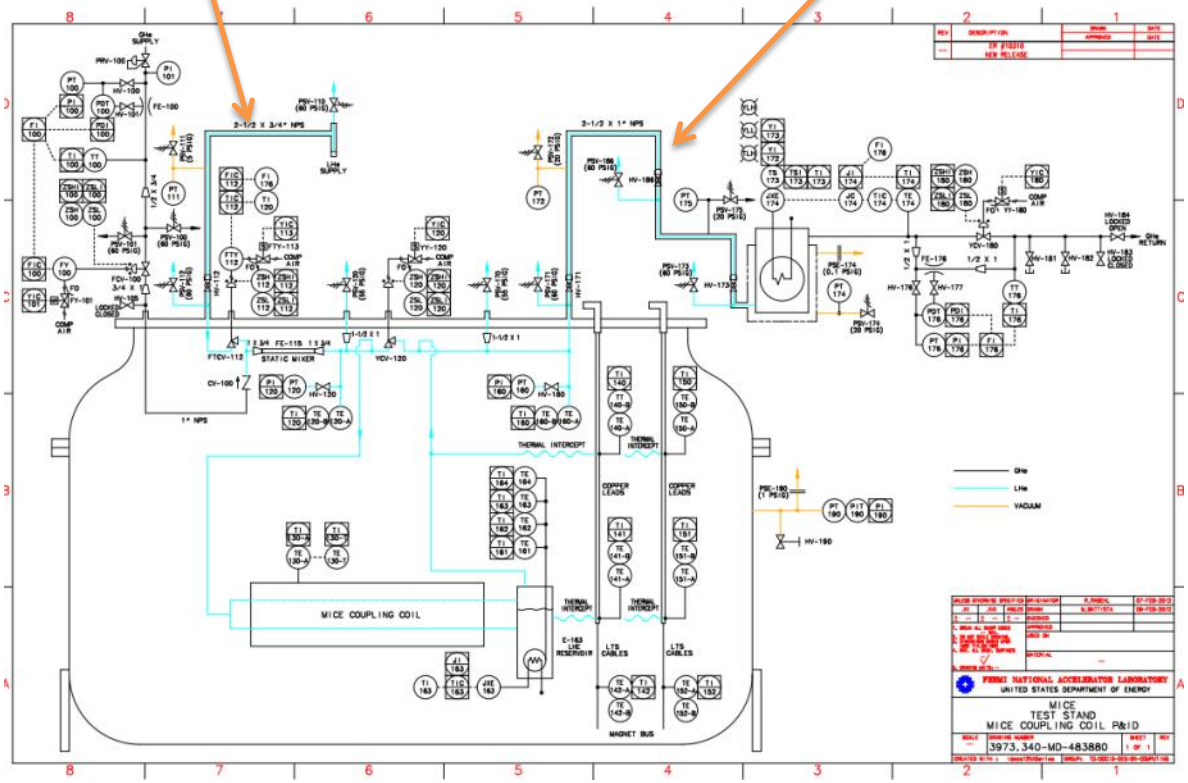
Cryogenic System P&ID



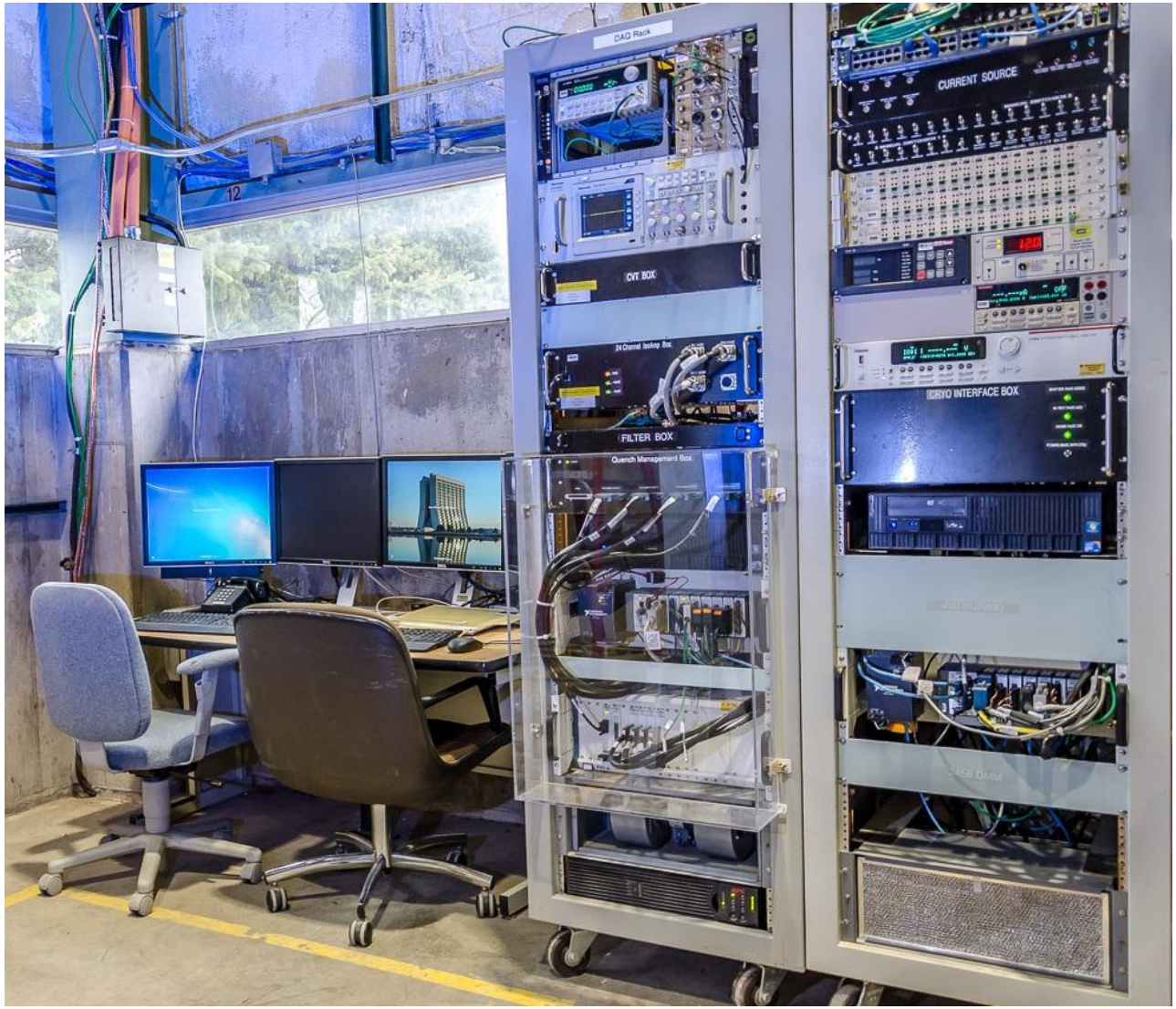


U-Tube to Bayonet Can

Return Gas to Warmup Heater



Controls, DAQ

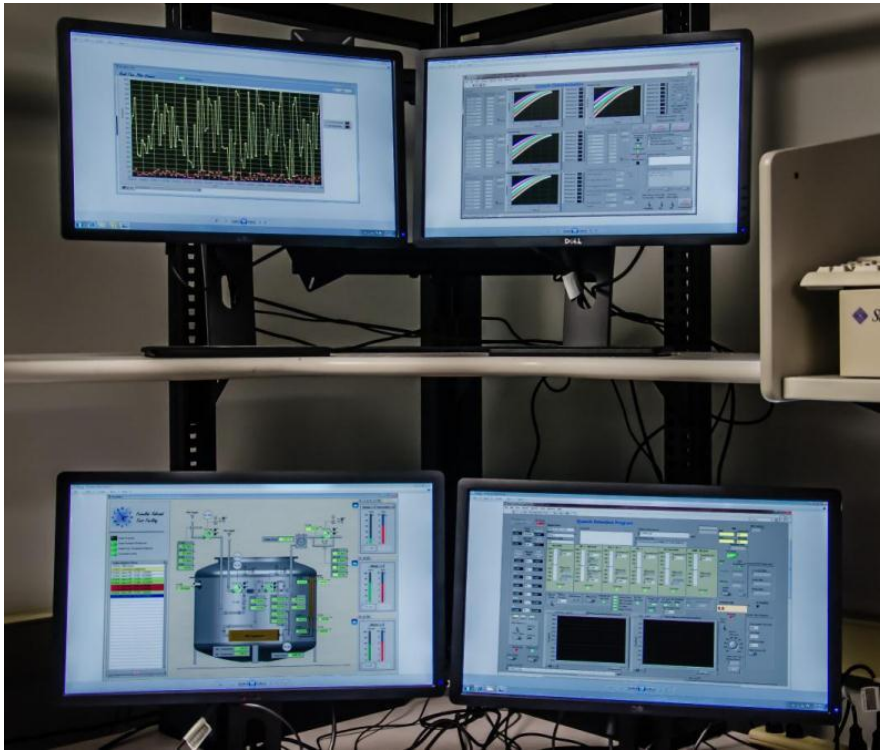


- DAQ and Control System Racks with Local Control Station near Test Cryostat

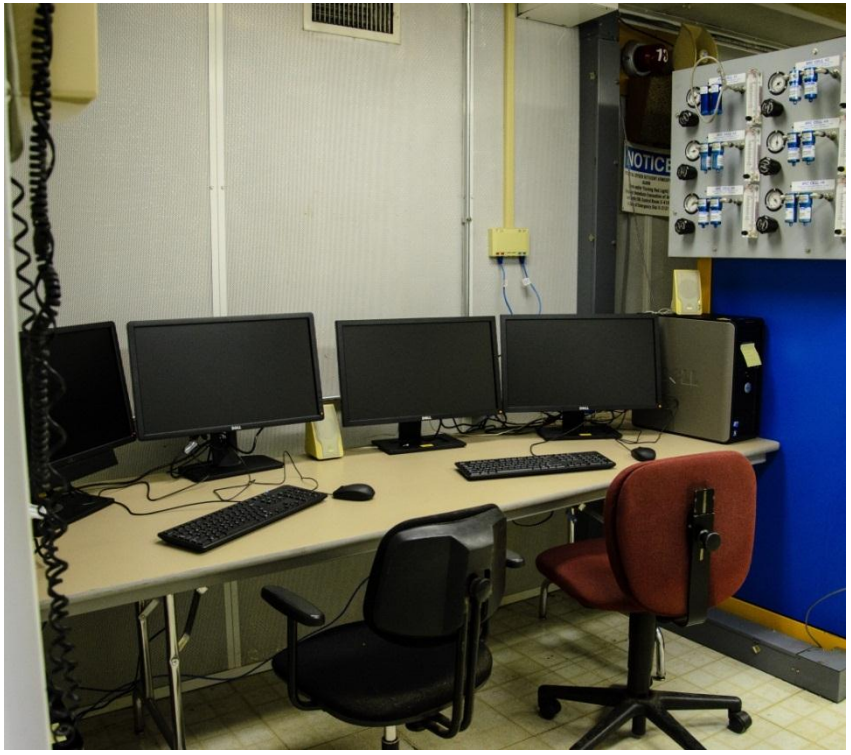
Remote Control Stations

- Local control station cannot be used under high magnetic field because personnel have to evacuate the area for safety reasons
- Two remote control stations installed: one in the CHL building, and another at the IB1 Magnet Test Facility
- E-log and measurement data available on a web interface

Remote Test Stand control station at IB1 Magnet Test Facility Control Room

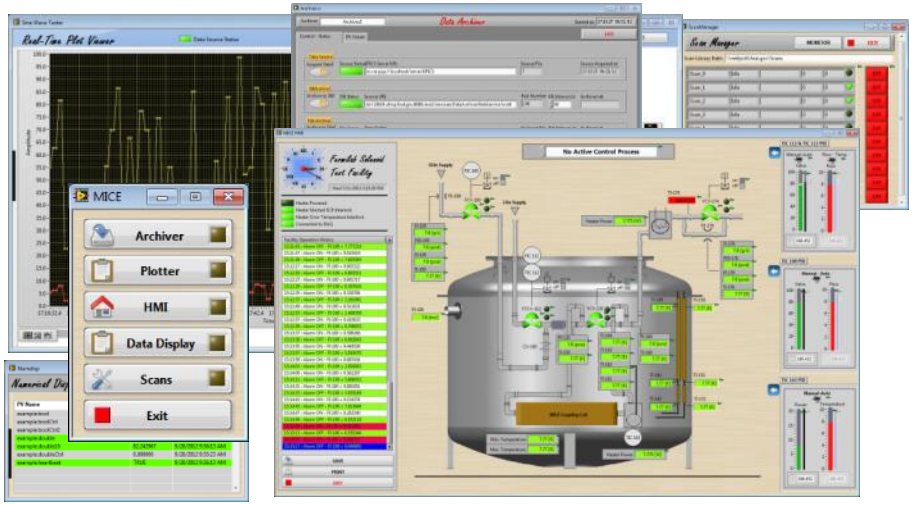


CHL Test Stand Control Room (Climate Controlled, Acoustically Insulated)

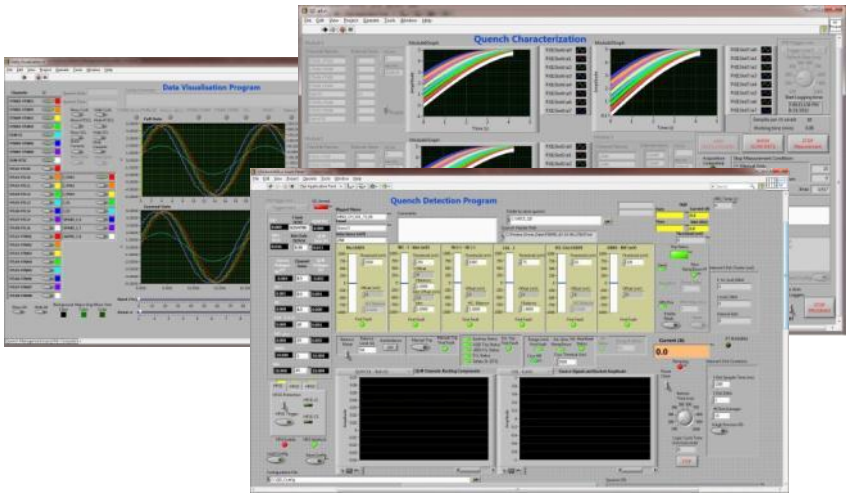


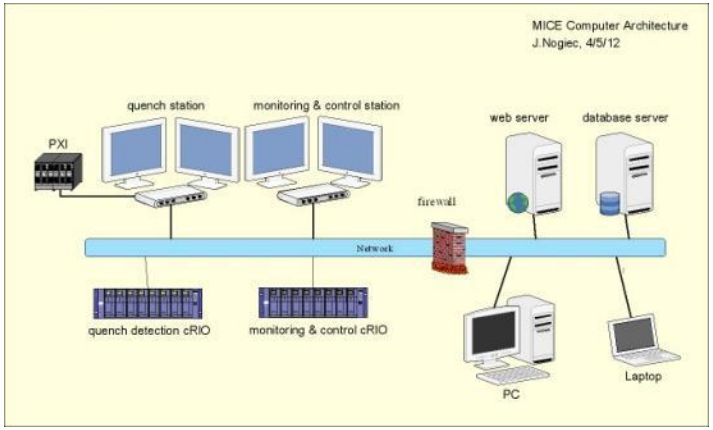
Software User Interface

Monitoring & Control Subsystem UI

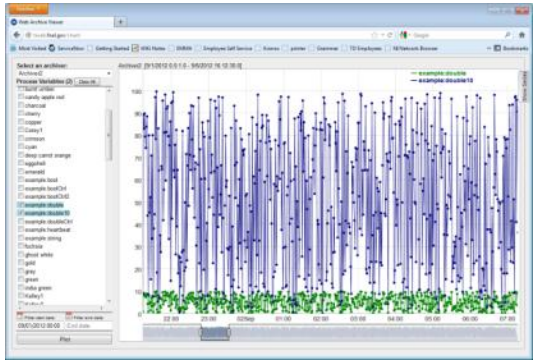


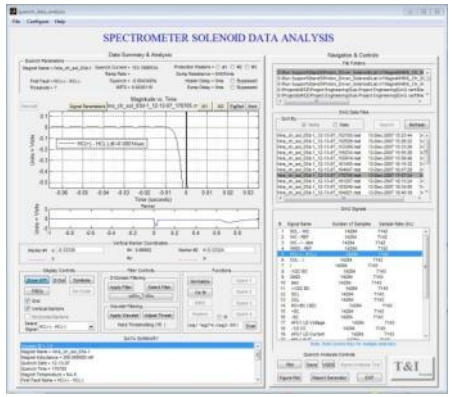
Quench Subsystem UI





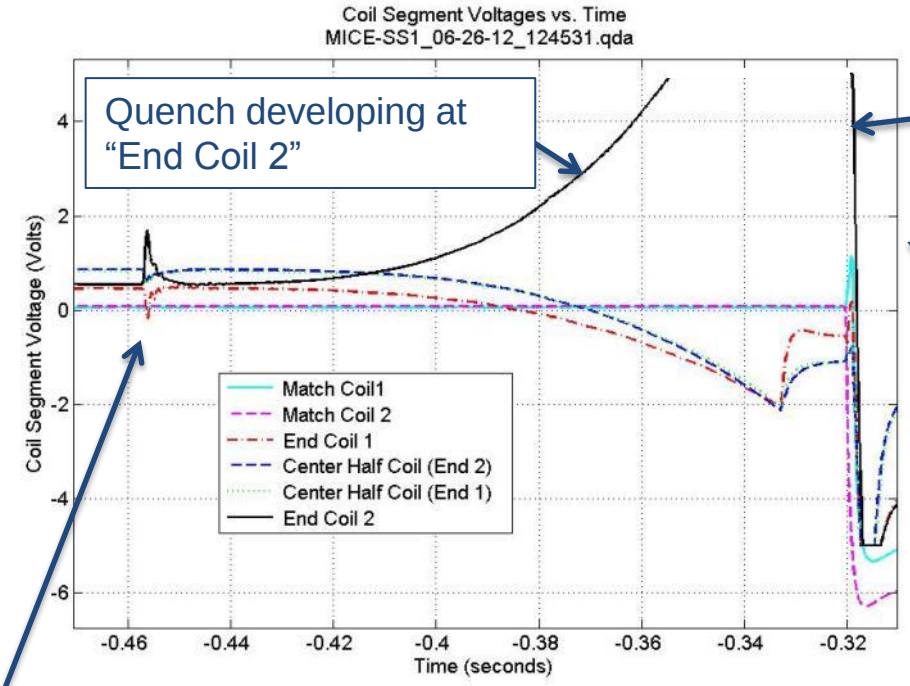
Web-based Data UI





Voltage Taps DAQ and Quench Detection System

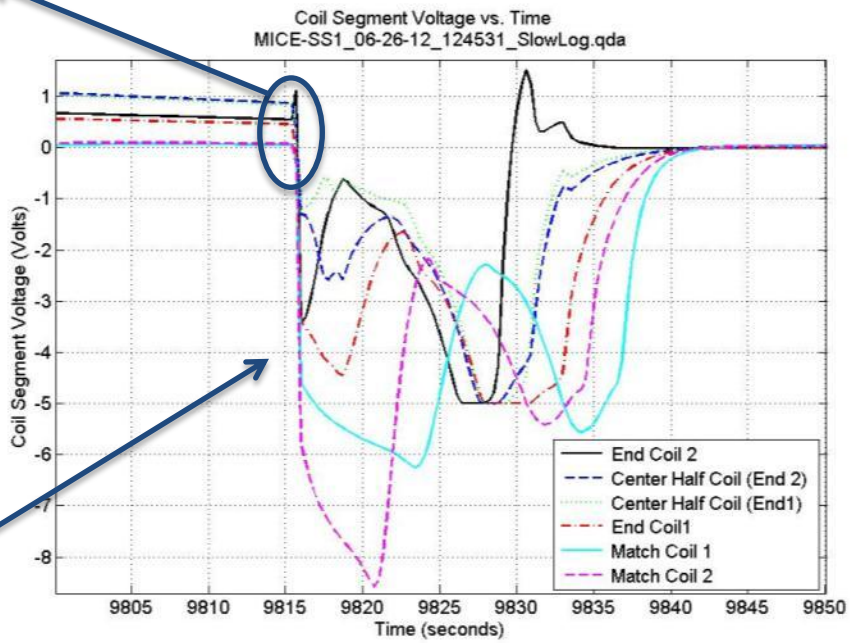
- Similar Fermilab system being used successfully for the MICE Spectrometer Solenoid Test at Wang NMR
- Example: Quench on 6/26/12, I = 215 A



Quench developing at "End Coil 2"

QD tripped power system when the 5.5 V threshold was exceeded after ~140ms from Quench Onset

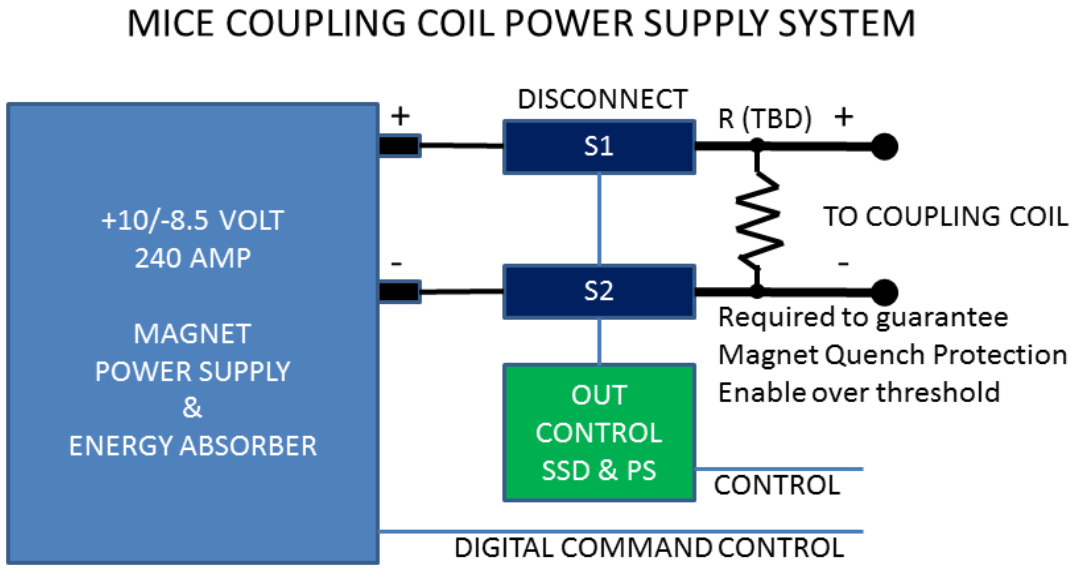
Quench Onset



Voltage tap signals recorded during ~30 sec current decay

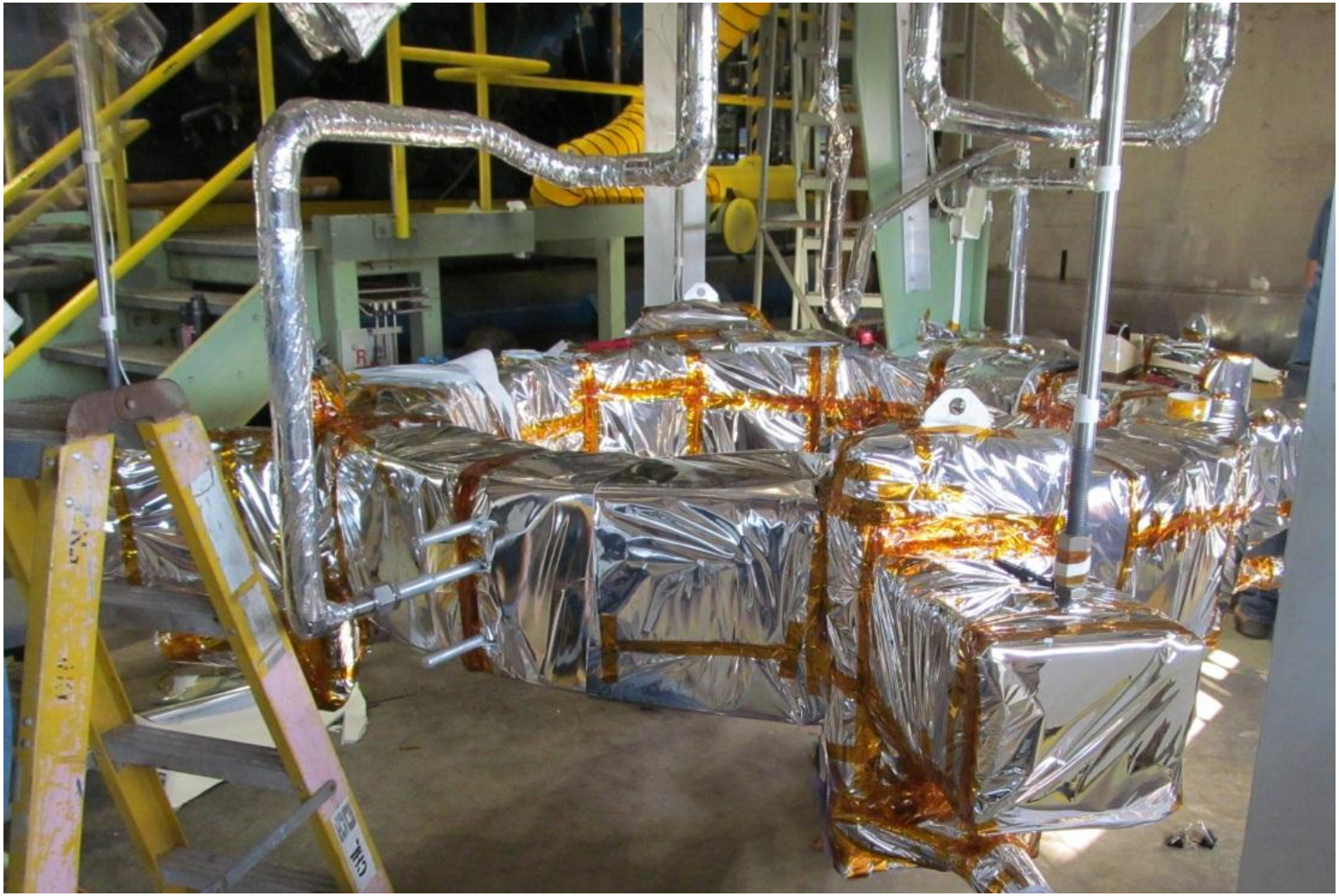
Power System

- The Test Facility Power System Rack delivered by LBNL
- Fermilab added personnel Emergency Trip System Box and current readout hardware to the rack



AC power and system grounding details not included

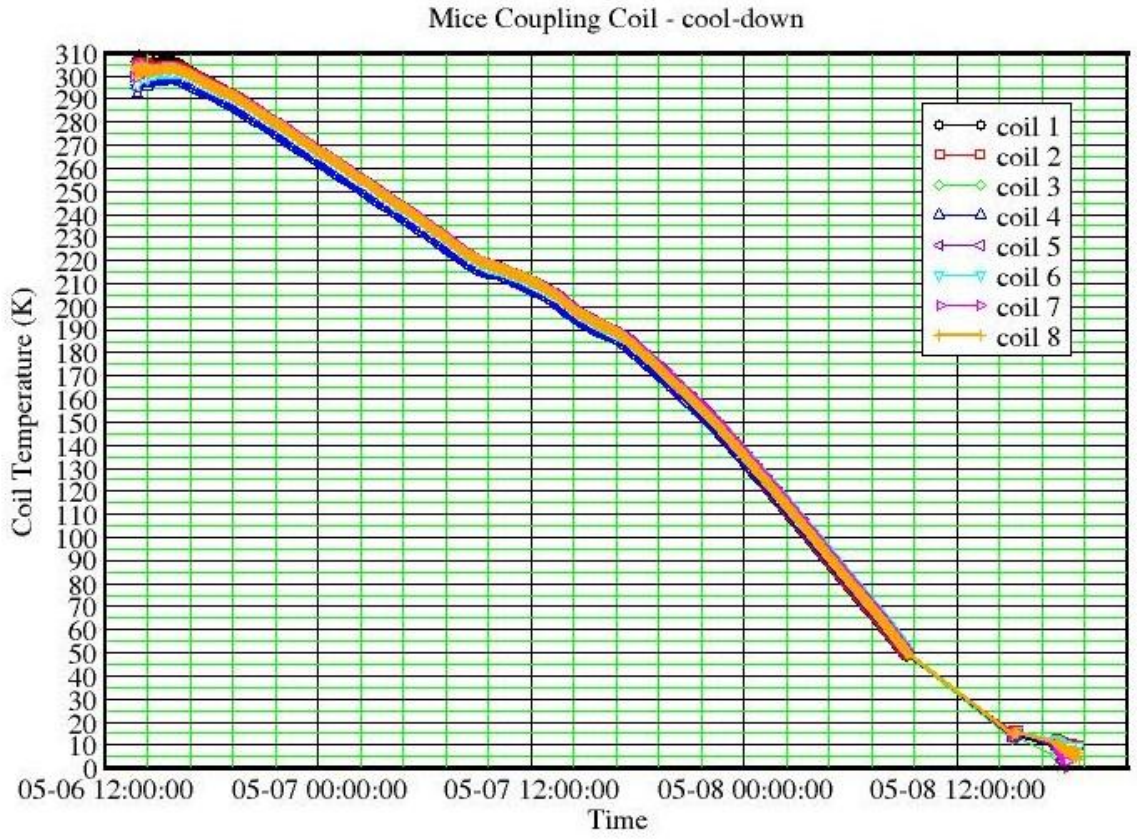
Coil Wrapped in MLI and Inserted in Vacuum Vessel



Operational Readiness

Operational Readiness Clearance (ORC) granted April 17, 2013

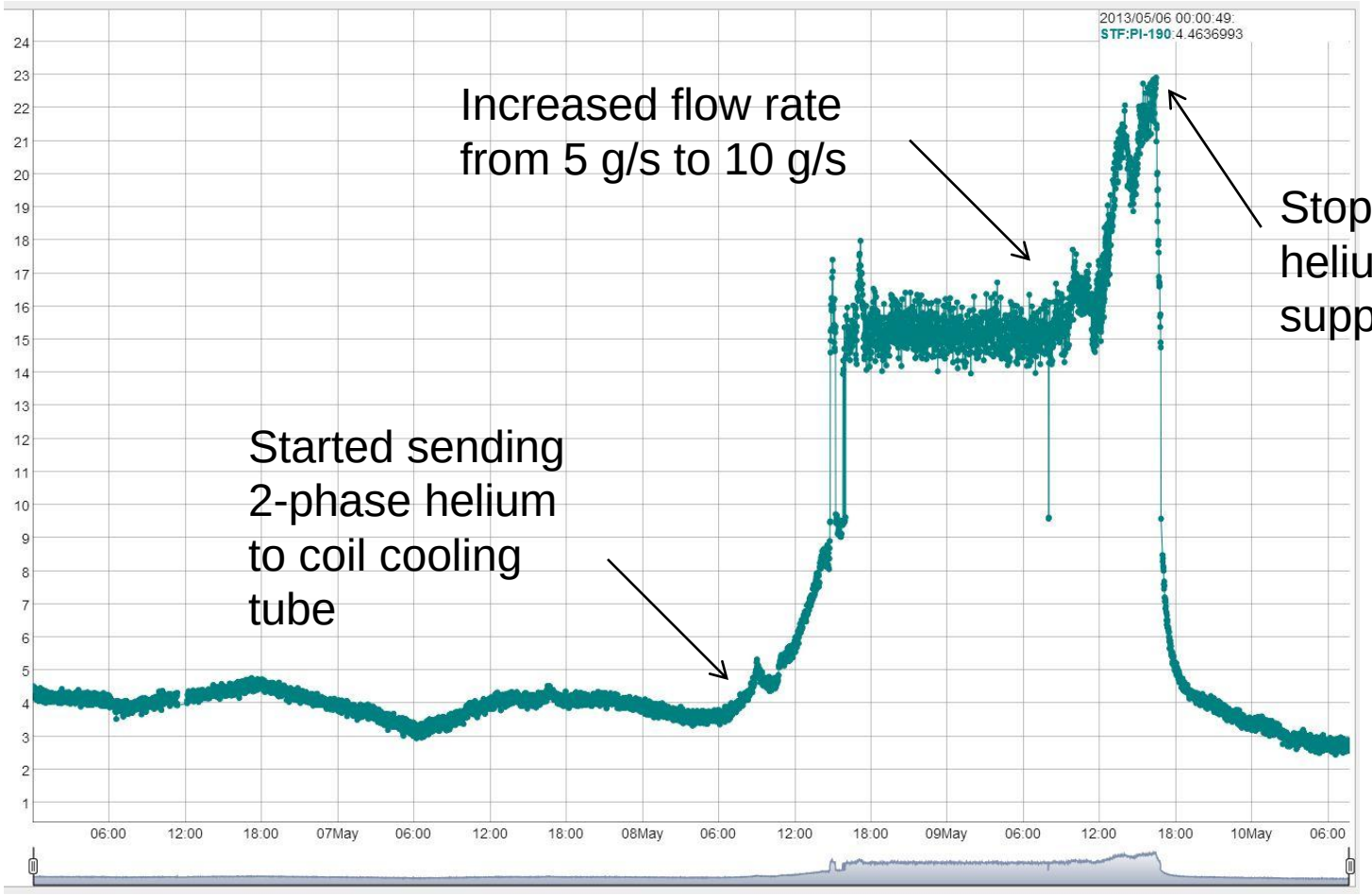
First Controlled Cooldown



- Started Monday 5/6/13 at noon
- Automatic cooldown with < 50 K Delta T proceeded very well
- Coil < 10 K by Wednesday 5/8/13 afternoon
- Shlomo Caspi from LBNL followed the cool down closely and analyzed strain gauge measurements

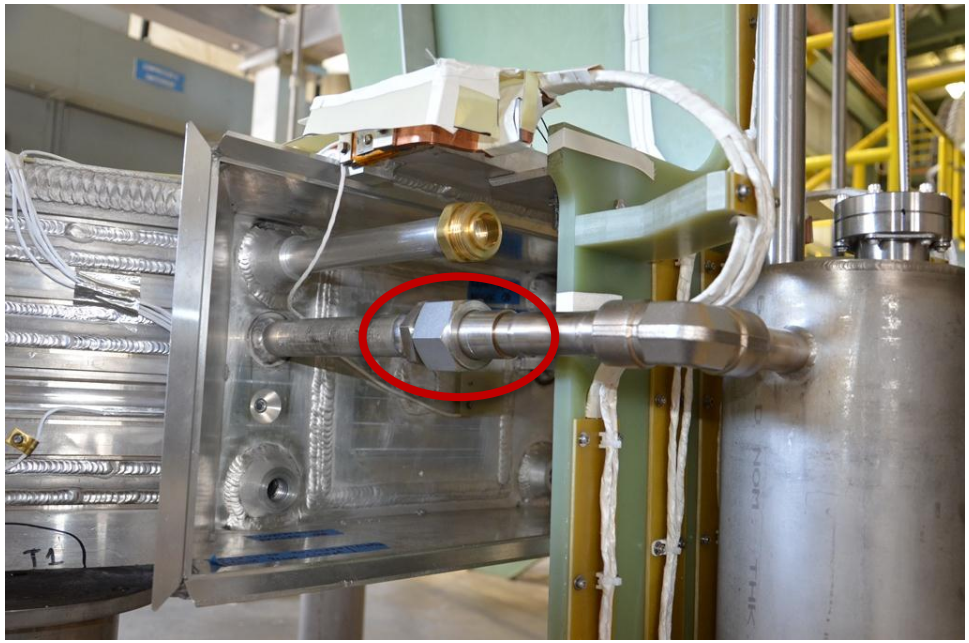
A Cold Leak!

- Insulating vacuum quickly degraded when we started sending two-phase helium to the coil cooling tube on Wednesday evening!



Leak Hunting

- After several attempts to overcome the cold leak, the best cooling conditions we could achieve were a cooling tube helium gas outlet temperature of 5.5 K at the maximum cooling flow rate of 10 g/s. Outer cold mass temperatures were between 8K and 11K. This was not sufficient to proceed with the test.
- A decision was made on 5/13/2013 to warmup the coil, and attempt to find and repair the leak at room temperature.
- After pressurizing the piping to 80 psig, a leak was found at one of the outlet VCR connections. All other joints did not show signs of a leak.



Any other leaks?

- According to the data, the leak location was never exposed to two-phase flow during cooldown:
  - A leak at this location does not explain the sharp dependence on two-phase flow conditions!
  - It does however explain a relatively poor insulating vacuum (~ 4 microns) during cooldown
- Is there another leak we could not find at room temperature?

Path Forward

- We have decided to first conduct an acceptance test of the test cryostat **without** the coil in the loop:
  - Install a coil bypass pipe between inlet and outlet
  - Short the power bus at the cold end
  - Cooldown and power the shorted bus to full current
- Once the cryo and power pass the acceptance test, then we connect the coil and proceed. If a leak is detected at that point, we can be fairly confident that it is in somewhere in the cold mass.
  - As a contingency, we are also considering having provisions for quickly switching to another cooling tube in the cold mass in case of problems

Tentative Schedule

- Due to various power outages and restrictions, the earliest CHL will be ready to support cold operations again is the week of July 8th.
- We are going to try to have everything ready to proceed with the test cryostat acceptance testing by that week
- We estimate about two weeks to conduct the acceptance test and minor repairs if needed
- If everything goes well, coil testing can start late July/early August and go on for about two months