Cryogenic Summary - Testing D1L105 in MAGCOOL

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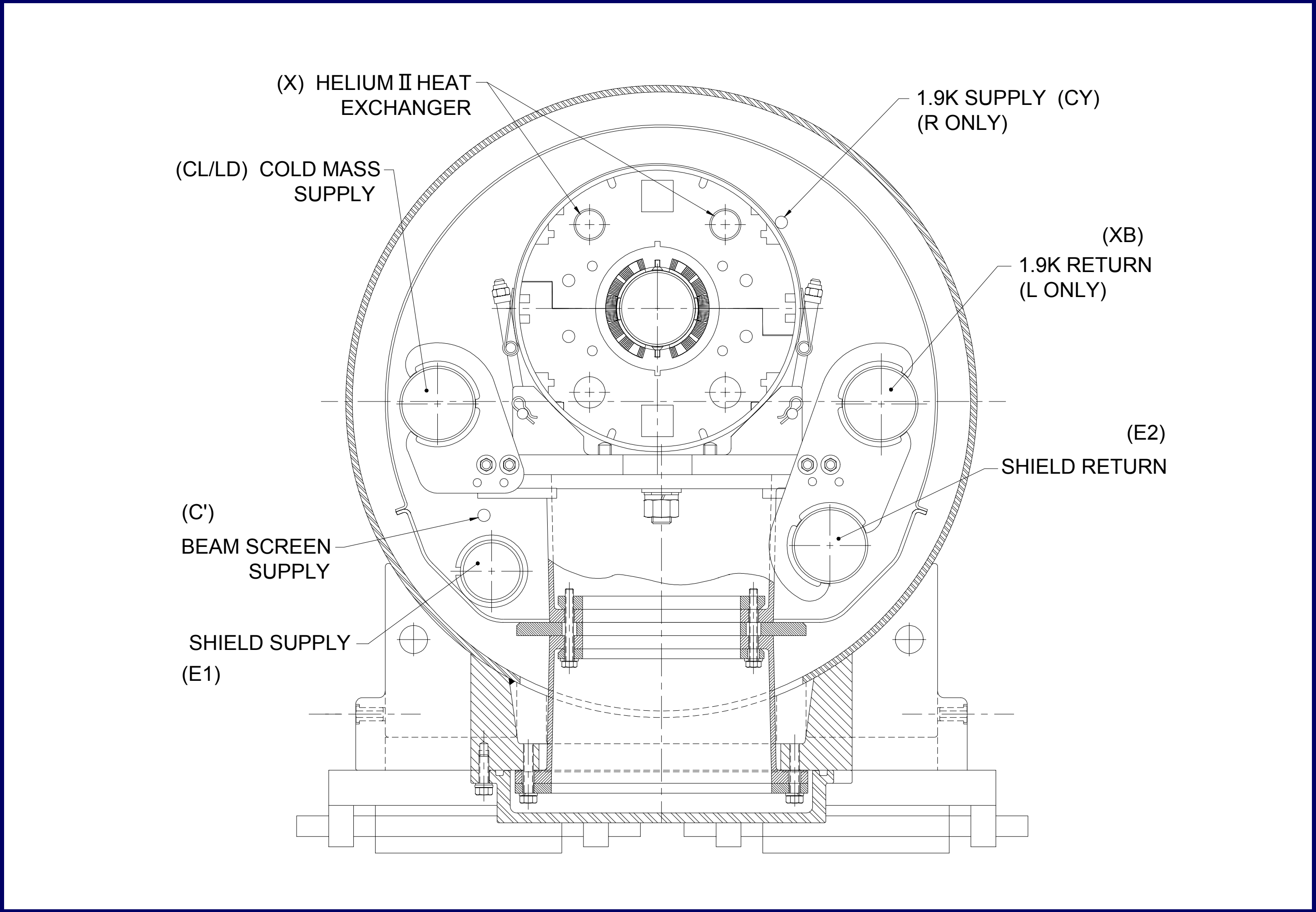
Nov. 01

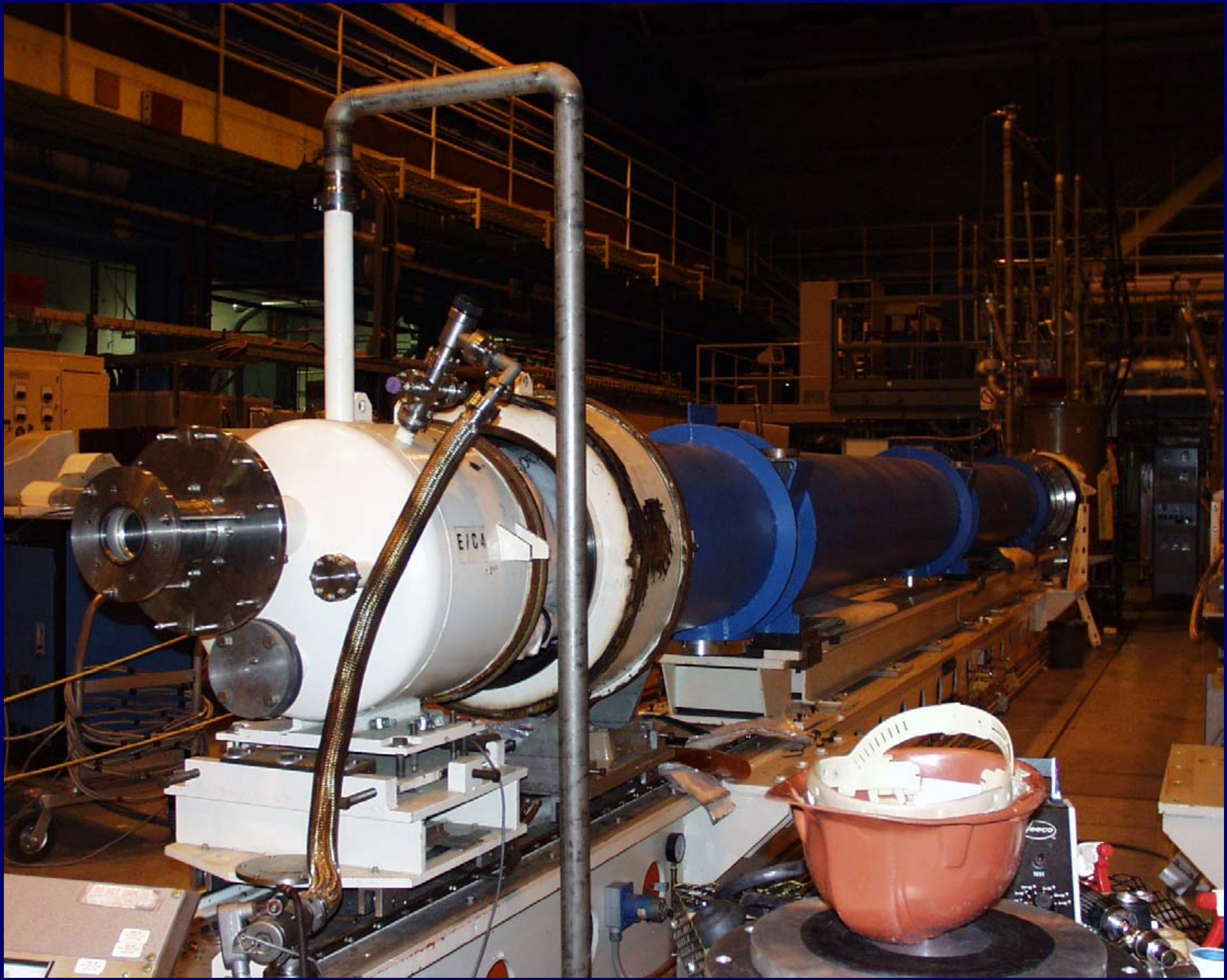
10/11/02 -rev

- System Overview
- Tests Performed
- Operating Condition
- Response to Quench
- Conclusion

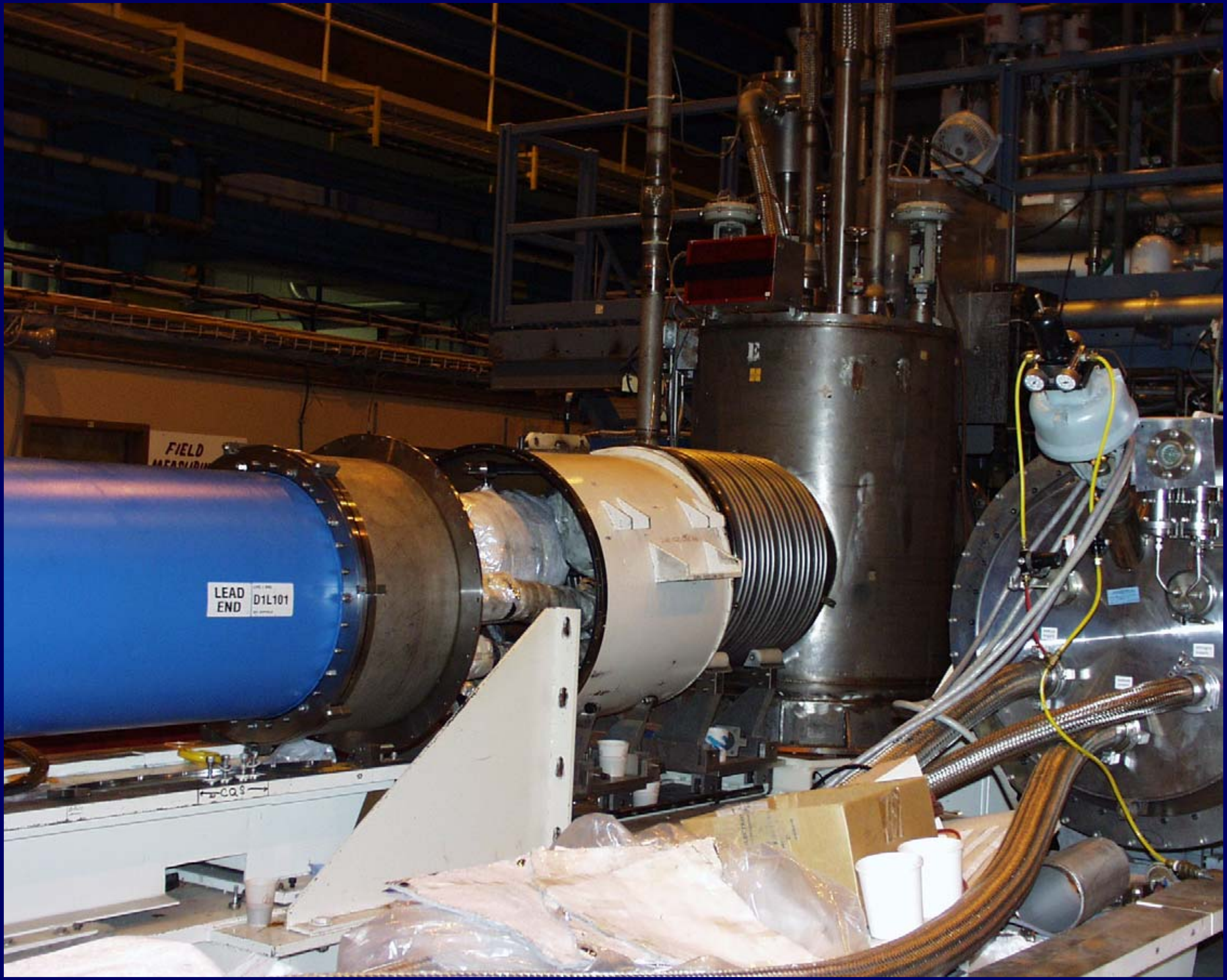
Sectional View of the D1 Magnet



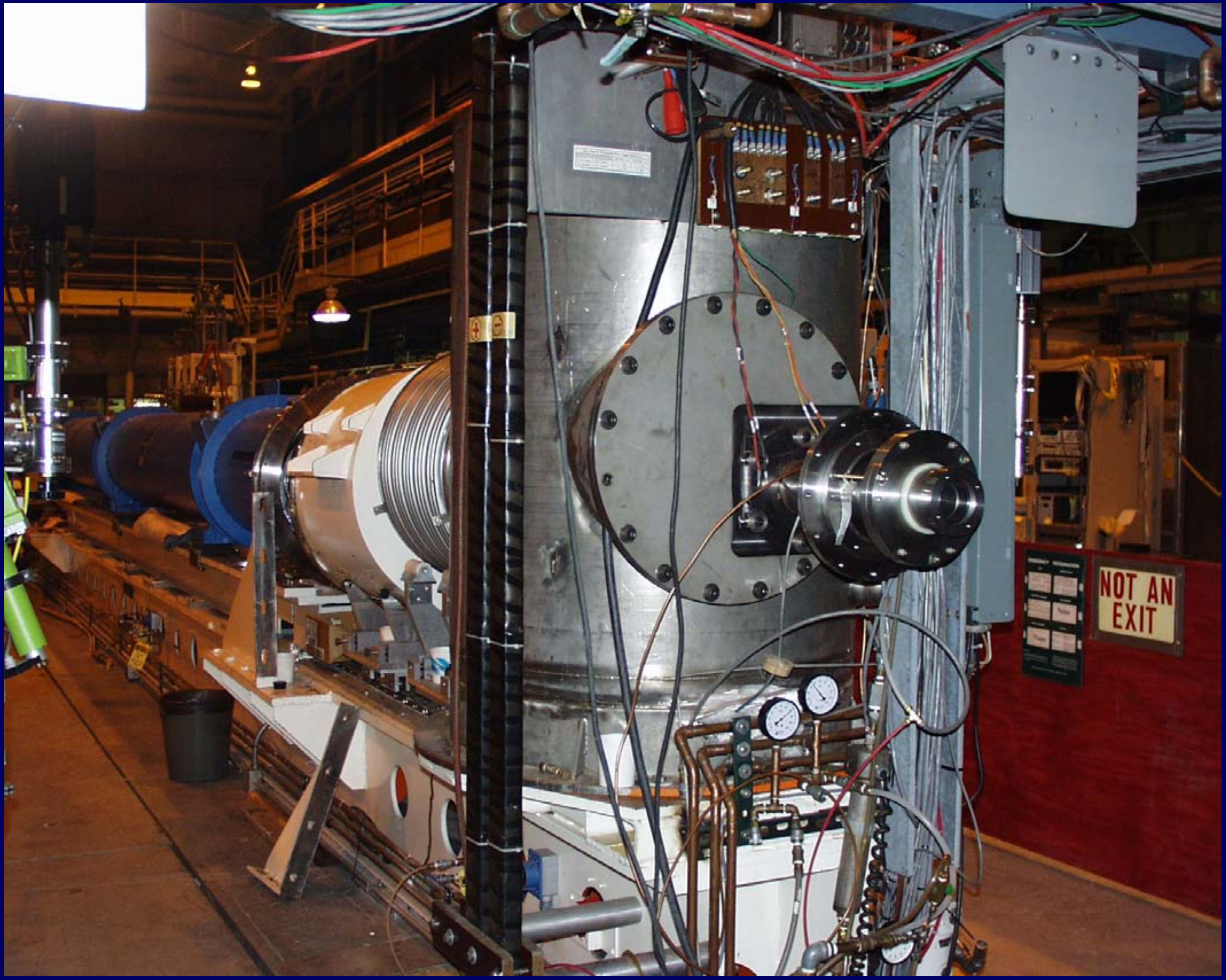
D1 on Test Bay viewed from End Can



D1 with Feed Can



End view of Feed Can showing penetration for warm bore tube



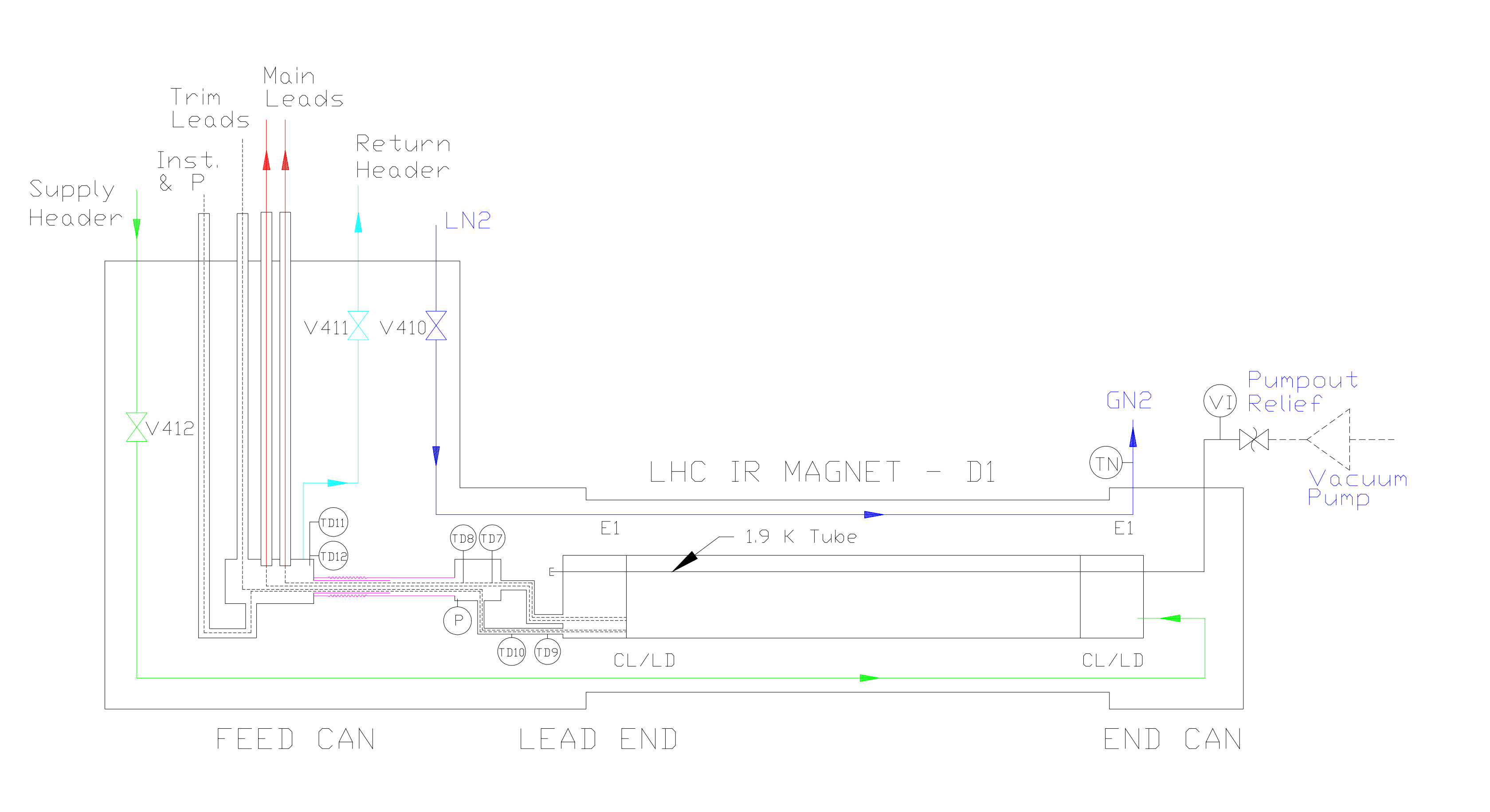
Primary Difference between cooling D1 and a RHIC Dipole

- RHIC Dipole
  - 4.5 K forced flow cooling
  - has a 3 millimeter passage between coil and beam tube
- D1 - In LHC
  - 1.9 K He II cooling
  - has two 1.9 K heat exchanger tubes
  - almost no gap between coil and beam tube

Design and Test Cooling Condition for D1

- Design Condition - LHC
  - 1.9 K Helium II cooling
- Test Condition - MAGCOOL
  - Forced flow cooling
  - 65 g/s, 12 atm, 4.5 K

Flow diagram for D1 with Feed Can and End Can



Cooling Flow

- Helium
  - MAGCOOL Supply
  - Feed Can
  - CL/LD
  - End Can
  - Enter D1
  - Exit D1 to Lead Pot
  - Return to MAGCOOL

Other Lines

- Use LN2 in heat shield
  - Feed Can, D1 and End Can
- One line to keep vacuum in the 1.9 K heat exchanger lines of D1

Three groups of tests

- September 19 - 21
  - Warm bore tube inserted and evacuated
  - Strip heater and natural quenches

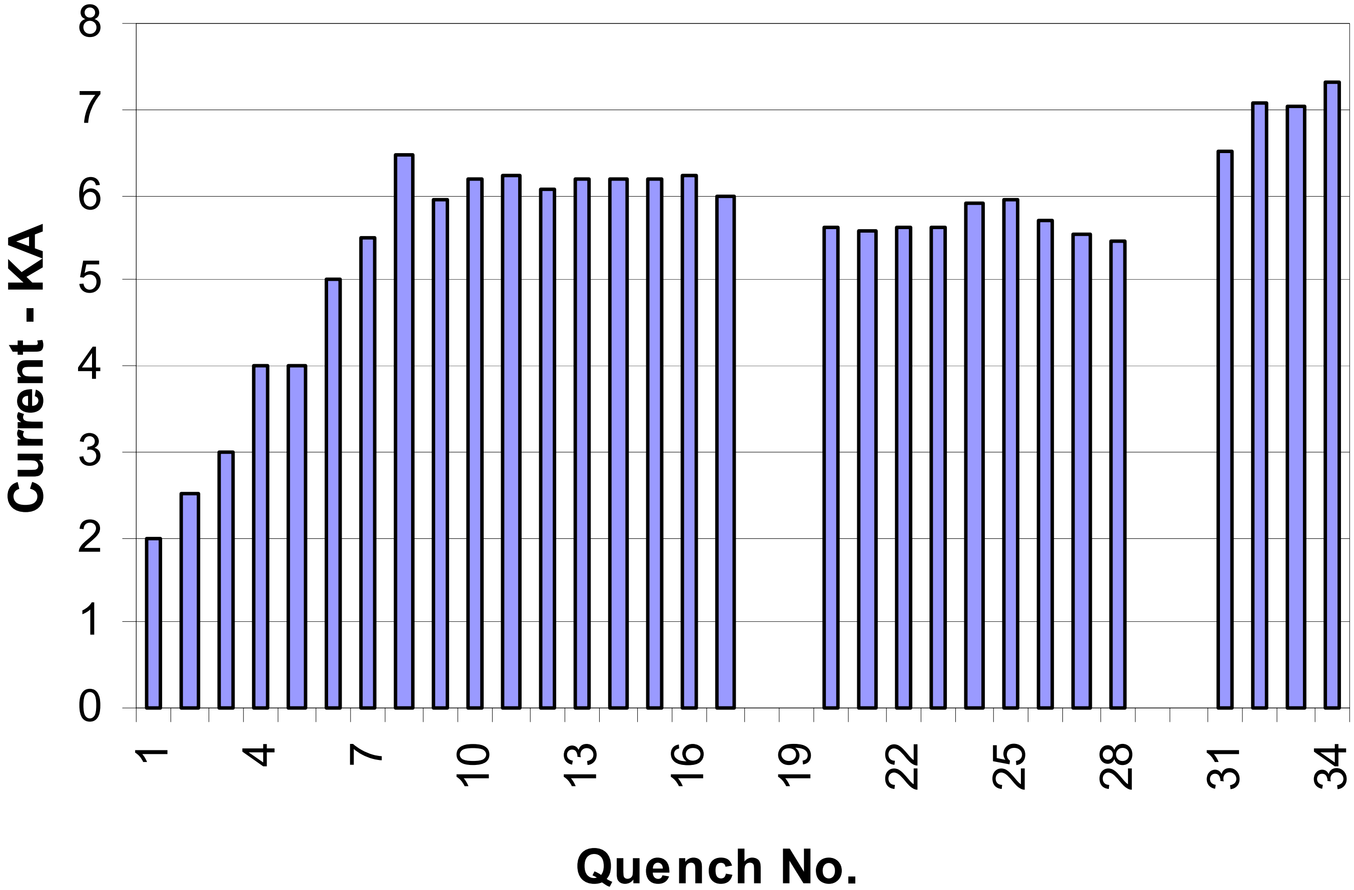
- October 10 - 11
  - Warm bore tube and measuring coil inserted
  - Natural quenches

- October 23
  - Warm bore tube removed
  - Natural quench

Main Results

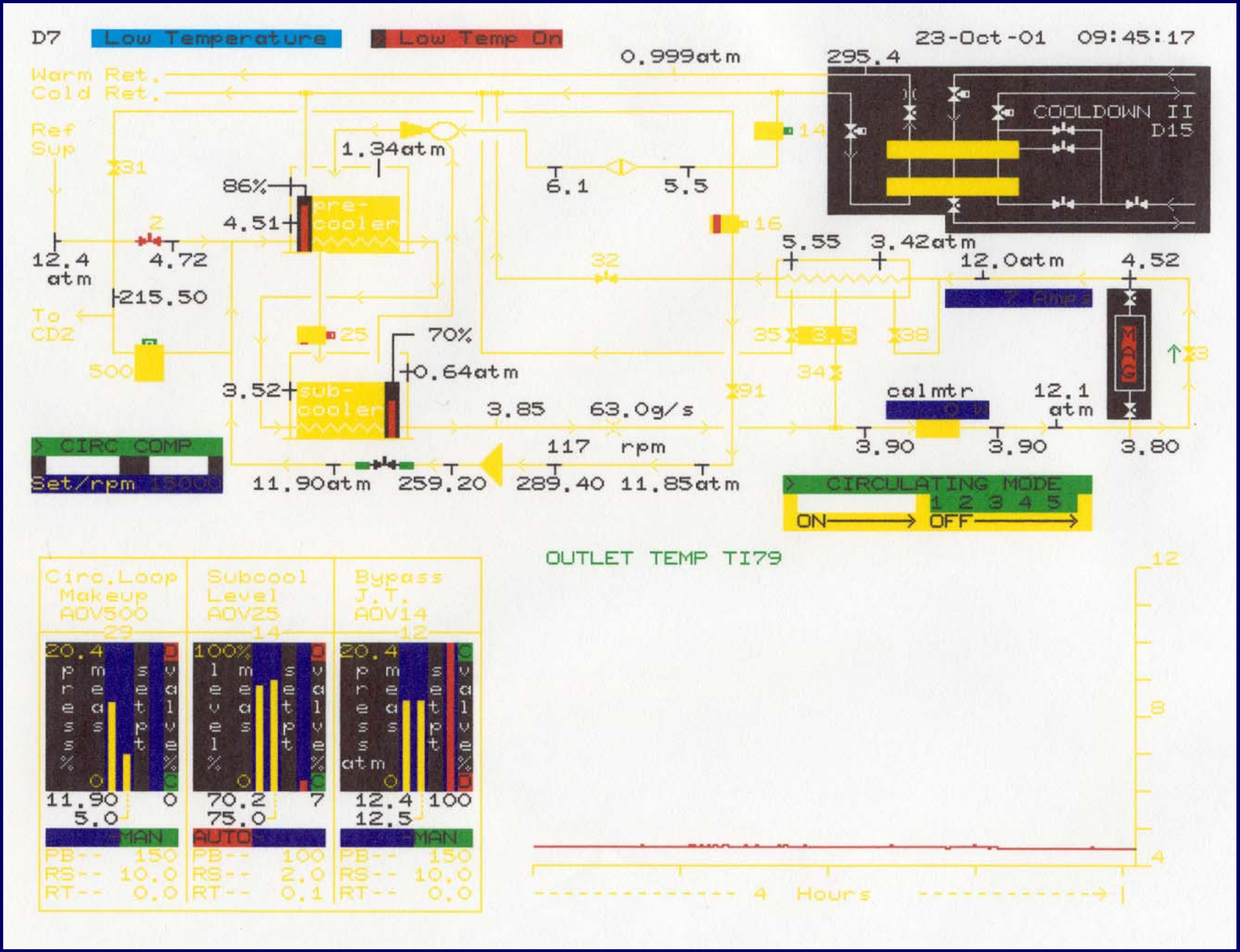
	Heat Load (from warm bore)	Coil Temp-erature	Quench Current
Sep. 19	Middle	Middle	Middle
Oct. 10	Highest	Highest	Lowest
Oct. 23	Lowest	Lowest	Highest

Quench Current for D1L105



No. 1 - 17, 9/19 warm bore evcuated (1 - 6 & 17 Heater)
No. 20 - 28, 10/10 warm bore with quench antena
No. 31 - 34, 10/23 warm bore removed

Flow diagram and typical operating condition for D1



MAGCOOL Low Temp Cold Box

- Precooler and Subcooler liquid helium bath
- Use Ejector to reduce temperature in Subcooler
  - ~ 4.5 K in Precooler
  - ~ 3.9 K in Subcooler

Two Types of Forced Flow Cooling

- Ejector Mode (Present Results)
  - Use high pressure helium from refrigerator
  - ~ 65 g/s, 12 atm and 4.3 K

- Circulator Mode
  - Use circulating compressor
  - ~ 100 g/s, 5 atm and 4.3 K

Cryogenic Operations

- Pump & Purge
- Cooldown I - 300 to 100 K
- Cooldown II - 100 to 4.5 K
- Test & Measure - 4.5 K
- Quench Venting - if pressure exceeds 13.7 atm
- Warmup - 4.5 to 300 K

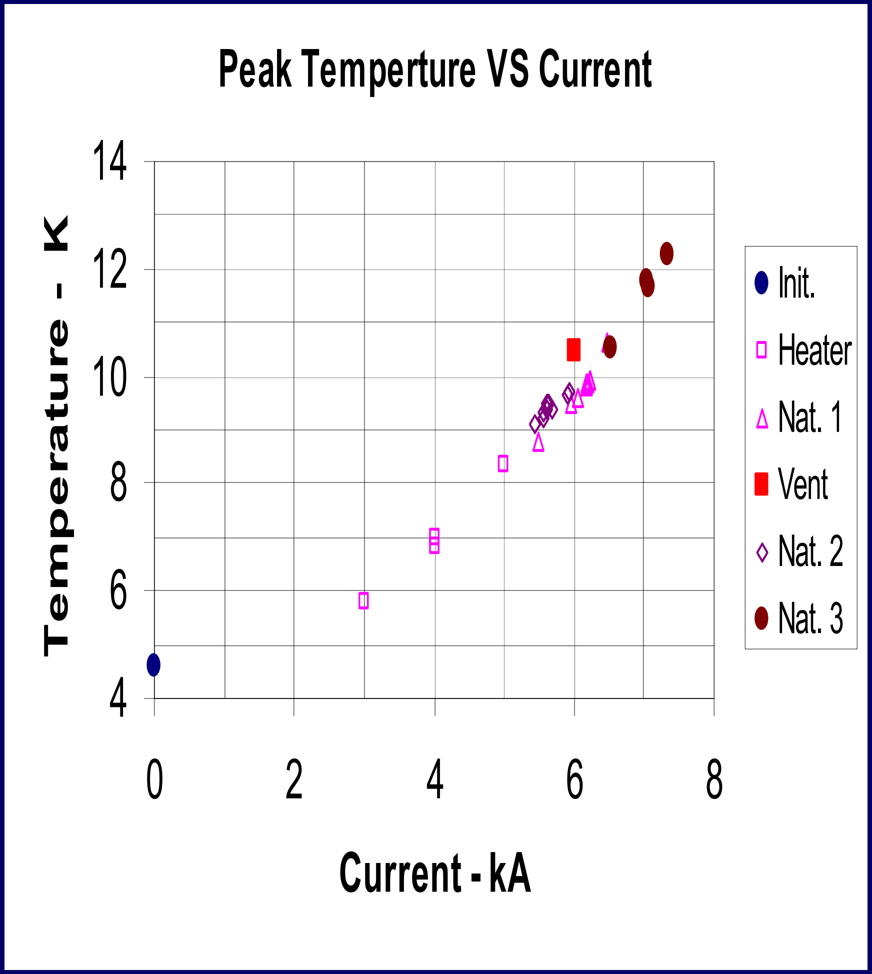
Effect of Quench on Cryogenic System

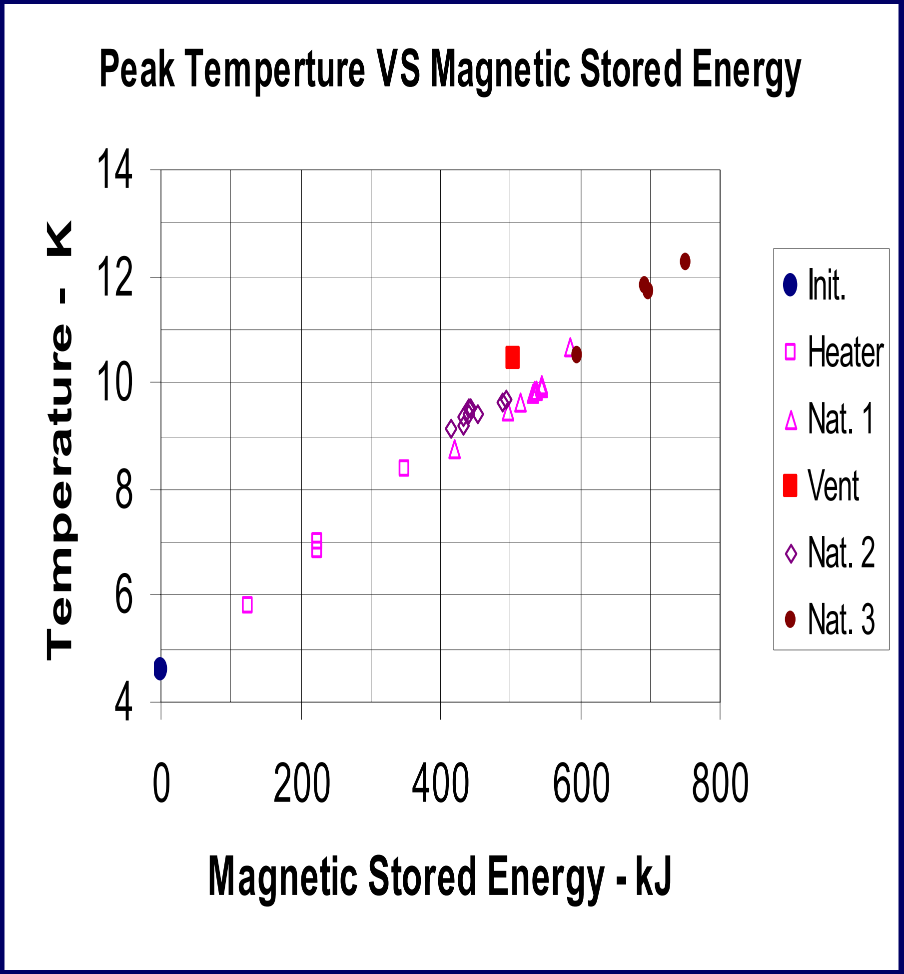
- Magnetic stored energy, $1/2\ L\ I^2$, released into cooling helium
- Pressure and temperature in helium flow increase
- Vent helium if pressure exceeds 13.7 atm
- Recovery time depends on flow rate and energy released

Magnetic Stored Energy and Liquid Helium Boil Off for D1

Quench Current A	Magnetic Stored Energy Kilo-joule	Liquid Helium Boil off Liter
2000	56	25
3000	126	56
4000	224	100
5000	350	156
6000	504	224
7000	686	306

Peak return temperature after D1 quenches

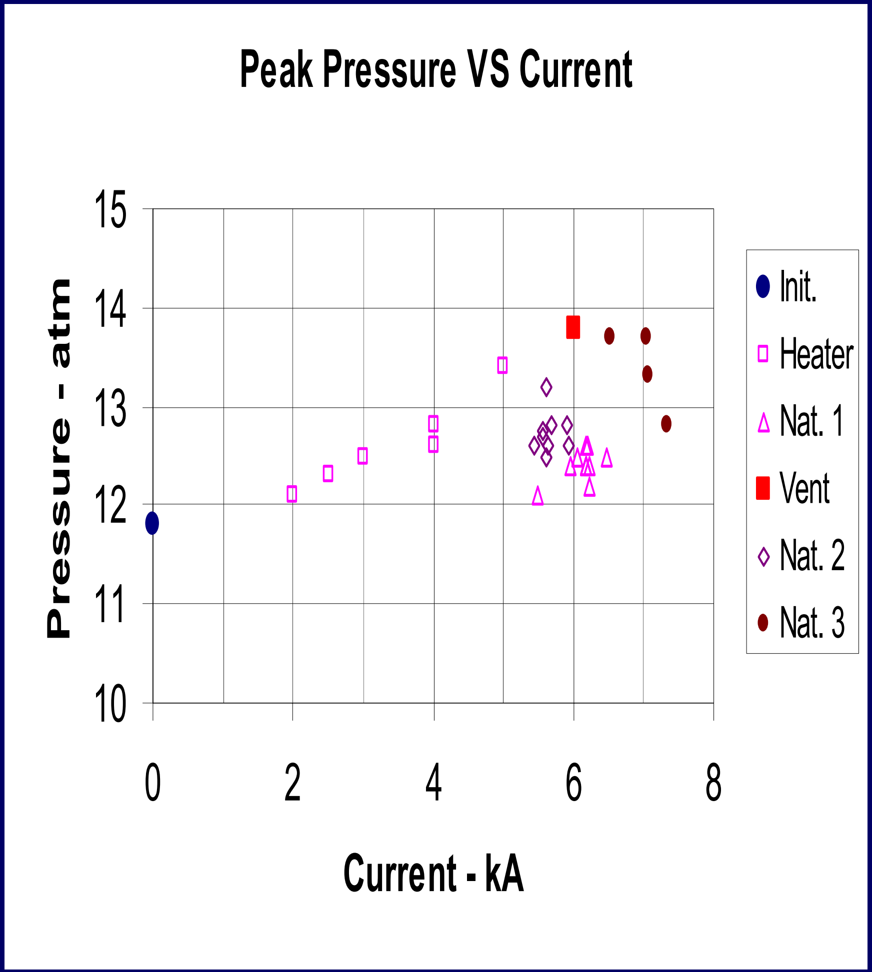


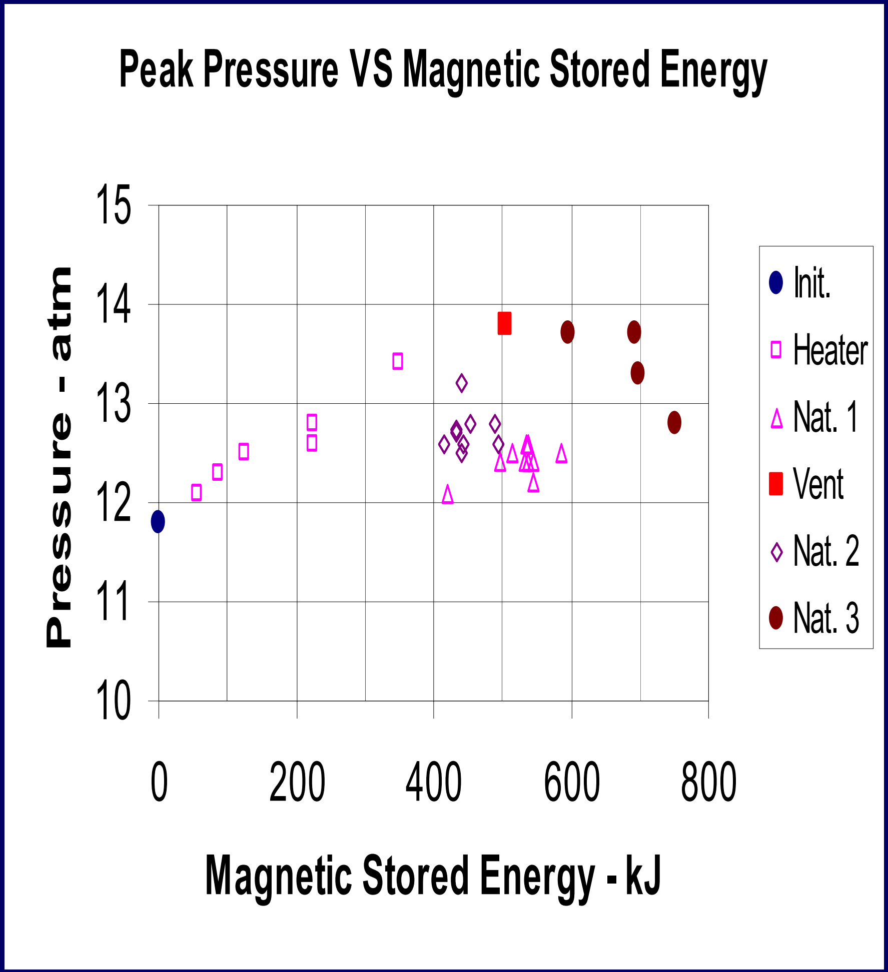


Peak return temperature

- Peak temperature increases linearly with magnetic stored energy, not current
- No distinction between Strip Heater quench and Natural quenches
- Effect due to quench venting is minor
- Max. peak temperature - 12.3 K at 7333 A (increased from 4.6 K prior to quench)
- Consistent with previous experience on RHIC and SSC magnets

Peak pressure after D1 quenches





Peak Pressure

- Peak pressure increases with current and energy release
- For 3 quenches above 6000 A, peak pressure exceeds 13.7 atm (increased from12.3 atm prior to quench) and vent valve opens to prevent over pressure
- Demonstrate the MAGOCOL quench handling mechanism
- Different patterns for Strip Heater and Natural quenches
- At the same current, Strip Heater quench produces higher peak pressure
- For Strip Heater quench, peak pressure increases linearly with energy and reaches 13.7 atm at 6000 A
- For Natural quench, peak pressure spread over a range and reach 13.7 atm for 2 out of 4 quenches above 6500 A
- Results not consistent with previous experience maybe due to change of the cooling passage between coil and beam tube

Problem Encountered

- Found two leaks in 1st group of tests
  - One in the Feed Can
  - One from the 1.9 K line to insulation vacuum
- Only the 1.9 K line leak reoccur in the 2nd and 3rd tests
  - Identify leak from a temporary joint for the test (after D1 warmed up and vacuum vessel opened)
  - No effect on the vacuum integrity of D1

Conclusion

- Forced flow cooling is successfully carried out
- D1 quenched above design current
- Response of cryogenic system to D1 quench is given
- Heat load from warm bore is excessive ~ 80 W
- Modification on warm bore is in progress
- Test for 2nd D1 will be conducted in December, 2001