



US LHC Accelerator Research Program *bnl - fnal- lbnl - slac*

BNL MAGNET TEST FACILITY AN OVERVIEW

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BNL MAGNET DIVISION TEST FACILITY

1. Cryogenics System

Refrigerators and Associated Peripheral Systems

Compressors and Pumps

Liquid He Storage Dewars

Horizontal Test Bays

Vertical Test Dewars

1.8K Test Facility

2. Power Supplies

3. Data Acquisition and Analysis Systems

4. Magnetic Field Measuring Coils

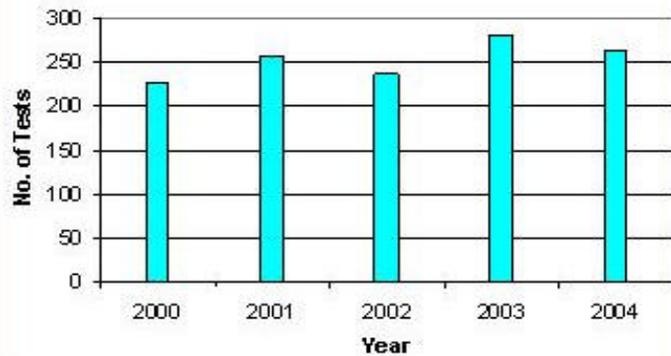


BNL CRYOGENICS SYSTEM

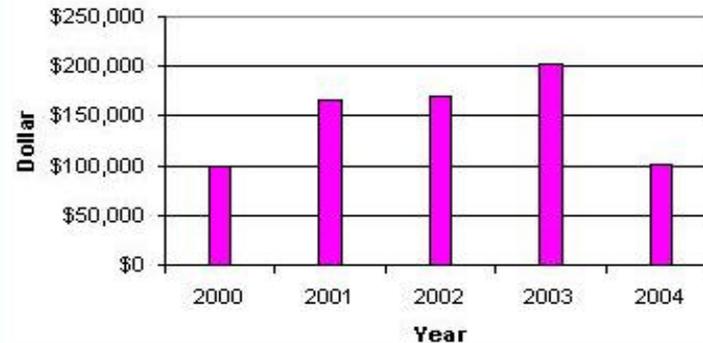
Magnitude of Recent Testing

5 Year Summary for Cryogenic Operation in B902

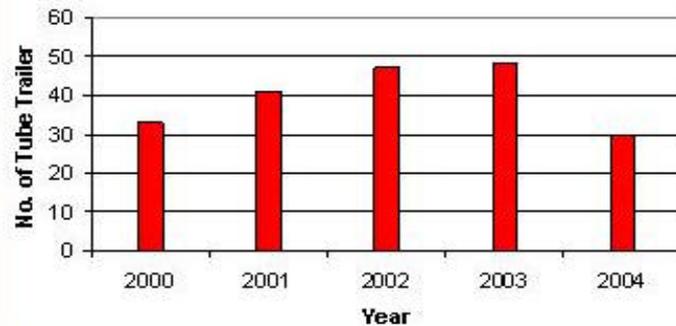
No. of Tests Performed in B902



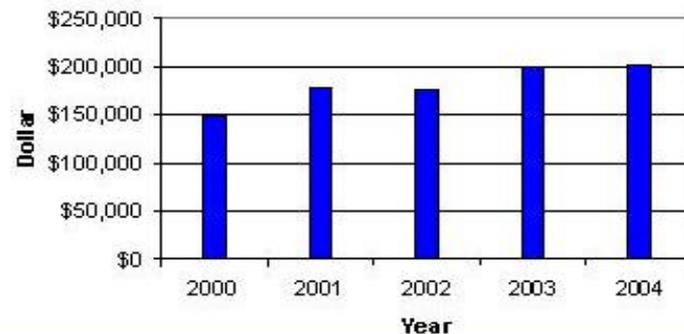
Annual Helium Usage (Dollar) in B902



Helium Usage (Trailers) in B902



Annual LN2 Usage (Dollar) in B902



Plots courtesy of KC Wu



BNL CRYOGENICS SYSTEM



CTI MODEL 4000
REFRIGERATOR/LIQUEFIER
Primary source of liquefaction

1500 W at 4.5K

Two reciprocating expansion engines rated at
250 rpm

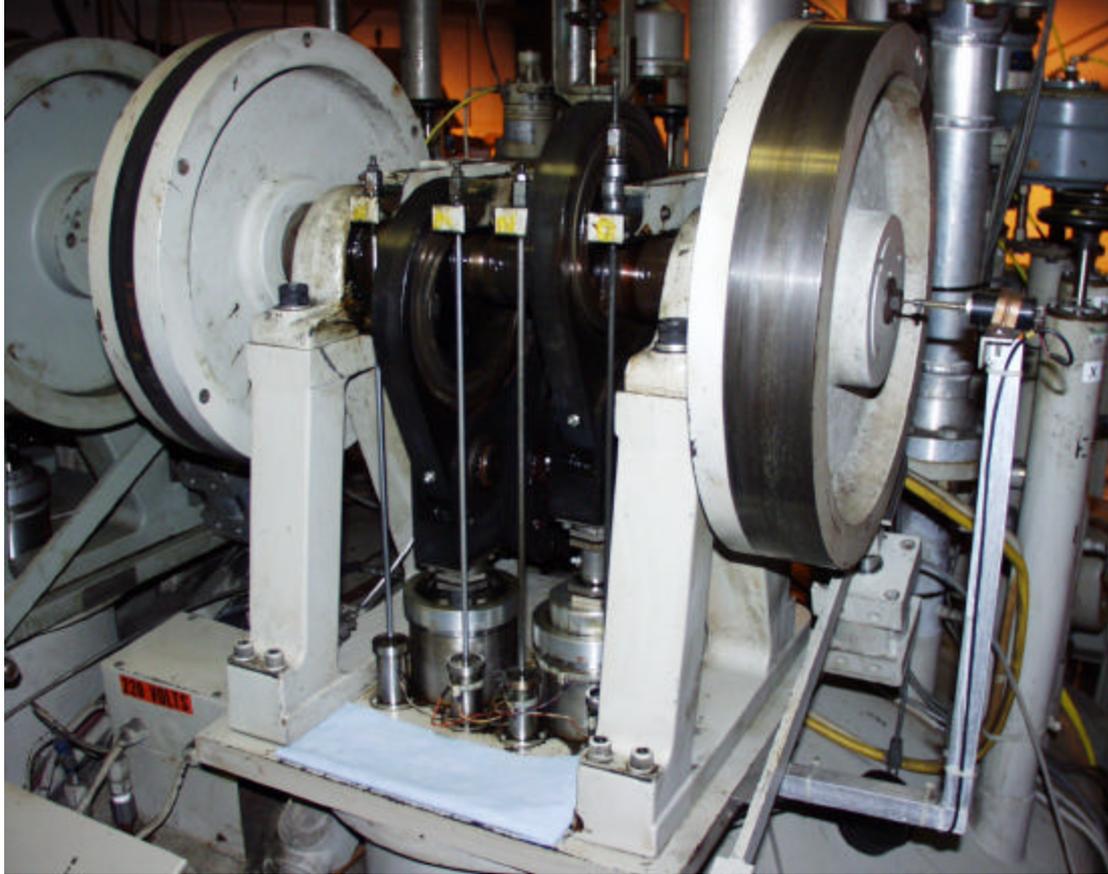
70 g/s (150g/s with circulator pump) forced
flow capacity at 5 - 12 atm in HTF-Magcool

He liquefaction: 320 L/hr (with both
expansion engines and a Koch Model 1600
Wet Expander)

Recently upgraded with a new LiN_2 heat
exchanger and diagnostics for expanders



BNL CRYOGENICS SYSTEM



**Model 4000 Refrigerator
Expansion Engines**

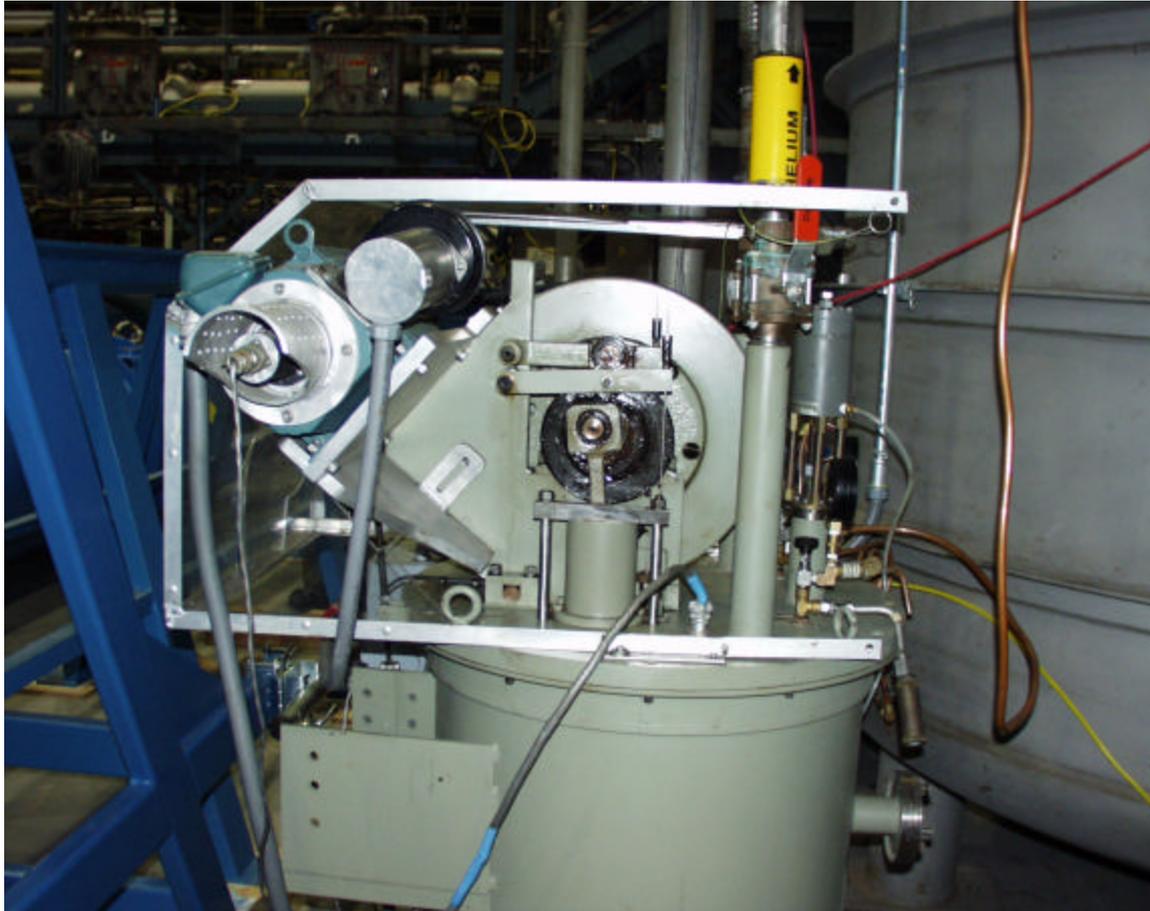
**Each has two cylinders: 9.1
cm bore; 7.6 cm stroke**

250 rpm

Largest in world



BNL CRYOGENICS SYSTEM



Koch Model 1600 Wet Expander

Largest in world

Has two cylinders

7.6 cm bore; 5.1 cm stroke

60 rpm

Low maintenance



BNL CRYOGENICS SYSTEM



**CVI – L'AIR LIQUIDE
REFRIGERATOR/LIQUIFIER**

1000 W at 4.5K (used at 700 W)

Two turbine expanders rated at 130000 rpm

In-line gas purifier

**Recently upgraded with new instrumentation
and PLC controls for turbine protection**

Routinely produces 160 L/hr

**Total facility liquefaction rate (both
refrigerators) is 480 L/hr**





BNL CRYOGENICS SYSTEM

PRIMARY COMPRESSORS

Mycomm

Power = 559 kW

Discharge pressure = 18atm = 1.83MPa

Delivers 160 g/s

Can supply either the CTI Model 4000 – Magcool or the CVI refrigerator

Dunham-Bush

Power = 522 kW

Discharge pressure = 14.5atm = 1.47MPa

Delivers 128 g/s

Supplies the CVI refrigerator – Vertical Test Facility; presently being refurbished

Sullair 350

Power = 261 kW

Discharge pressure = 18atm = 1.83MPa

Delivers 51 g/s

All-purpose, presently working in parallel with Mycomm; also used for subcooling vertical dewars (2K)

Sullair 100 (three units)

Power = 74.6 kW

Discharge pressure = 12 atm = 1.2 MPa

Delivers 20 g/s (80 g/s @ 8 atm input)

Presently used for Magcool operations:

- (1) Nitrogen cooldown (Cooldown I)
- (2) Warmup
- (3) Pump and purge

Creare circulator pumps



BNL CRYOGENICS SYSTEM

- LIQUID HELIUM STORAGE DEWARS
 - Storage Dewar #1 3785 L
 - Storage Dewar #2 3785 L
 - Storage Dewar #3 10000 L
 - Total liquid helium storage capacity is 17570 L
- Liquid nitrogen storage capacity is approximately 40000 L



BNL CRYOGENICS SYSTEM

Horizontal Test Facility – MAGCOOL

Five horizontal test stands – Bays A-E

CTI Model 4000 Refrigerator can provide 150 g/s forced flow supercritical helium at 5 atm or liquid helium cooling



Previous tests have included 15 m and 17m SSC arc dipoles and 10m RHIC arc dipoles and presently 10m LHC dual aperture dipoles

Test temperatures down to 3.5K with peripheral precooler and subcooler pots and cold pump system



BNL CRYOGENICS SYSTEM

VERTICAL TEST DEWARs

DEWAR #	DEPTH m	WIDTH cm	VOLUME L
2	6.1	60.96	1779
3	6.1	71.12	2422
4	2.68	60.96	753
5	2.74	60.96	801
6	2.68	60.96	786

Present configurations:

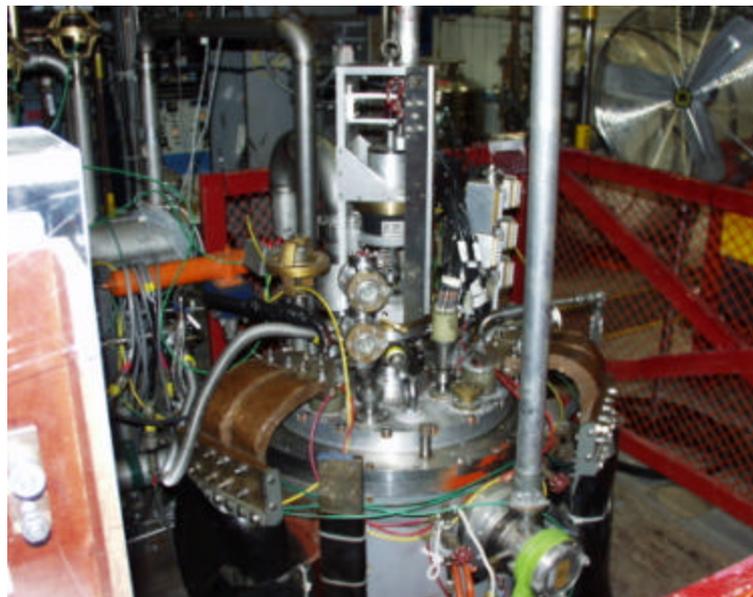
Dewars 2 and 3: magnets

Dewar 3 is wider to accommodate larger magnets

Dewars 4 and 5: cable short samples

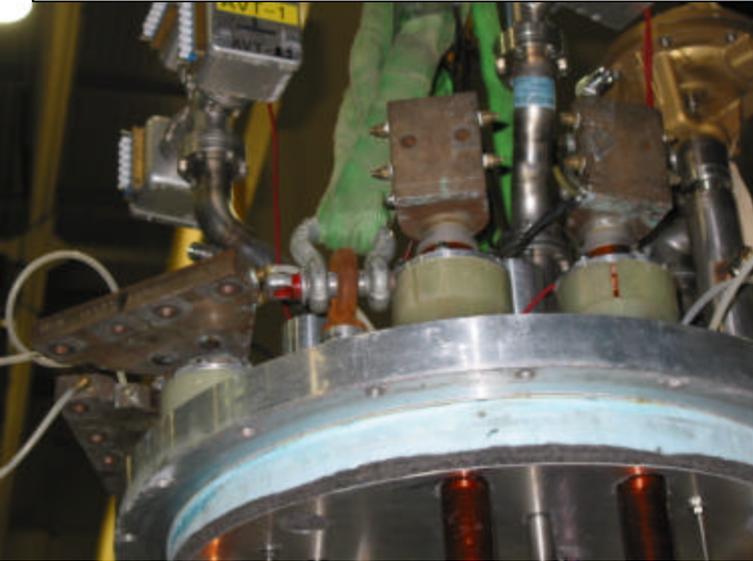
Dewar 6: common coil type magnets (Nb₃Sn and HTF)

Dewar 5 is part of a 1.8K (or less) 1 atm cable test facility.





BNL CRYOGENICS SYSTEM



- **VERTICAL DEWAR TOP PLATES**

- Presently seven top plates of various configurations in use
- Magnet hanging fixtures and parts for a wide range of magnet types
- Variety of feedthroughs and instrumentation connector assemblies
- Gas-cooled and liquid-injection power leads for all power applications
- Associated temperature sensors and level probes with each top plate





1.8K TEST FACILITY

Dewar 5 with 6.35cm G10 lambda plate and 3548 cm² surface heat exchanger.

For future magnet tests, a new simpler lambda plate will be made.

NASH-KINEMA Vacuum Pump

Two stages at 74.6 kW each

Suction pressure 8.37 kPa

Discharge pressure 117 kPa

14 g/s pumping capacity

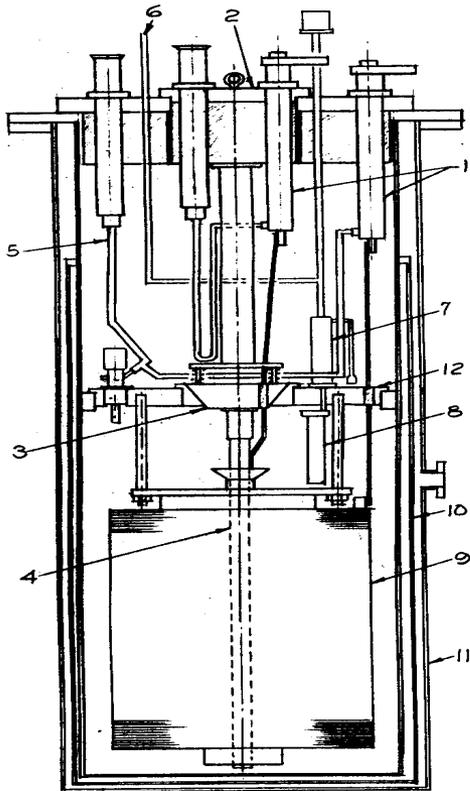


Fig 1. Vertical cryostat: (1) Liquid injection leads, (2) Sample holder, (3) Sample holder G-10 plug, (4) Conductor samples, (5) Fill line, (6) Pump line, (7) Upper counterflow heat exchanger, (8) J-T valve and lower heat exchanger, (9) Test magnet, (10) 10K shield, (11) Vacuum vessel, (12) Lambda plate.



BNL MAGNET DIVISION POWER SUPPLIES

PRIMARY POWER SUPPLIES

ALL SUPPLIES INCLUDE ENERGY EXTRACTION OR ARE PRESENTLY BEING UPDATED

- (1) 10kA @ 20VDC “HTF”, 10VDC, 30VDC, 40VDC, 50VDC)
- (2) 8.5kA (9.2kA) @15VDC “VTF”, 30VDC
- (3) 30kA @ 24VDC “Cable short samples”
- (4) 8kA @ 12VDC “Short sample test facility magnets”
- (5) 10kA @10VDC bipolar
- (6) 7.5kA @ 25VDC “Fast Ramp”, 50VDC, 100VDC (GSI ramp rates to 7800 A/s)
- (7) Dual Acme 5500A @ 125V “Room temperature field measurements and calibration magnets”
- (8) Variety of trim power supplies (bipolar and unipolar)

All power supplies can be configured for a wide range of magnet tests.



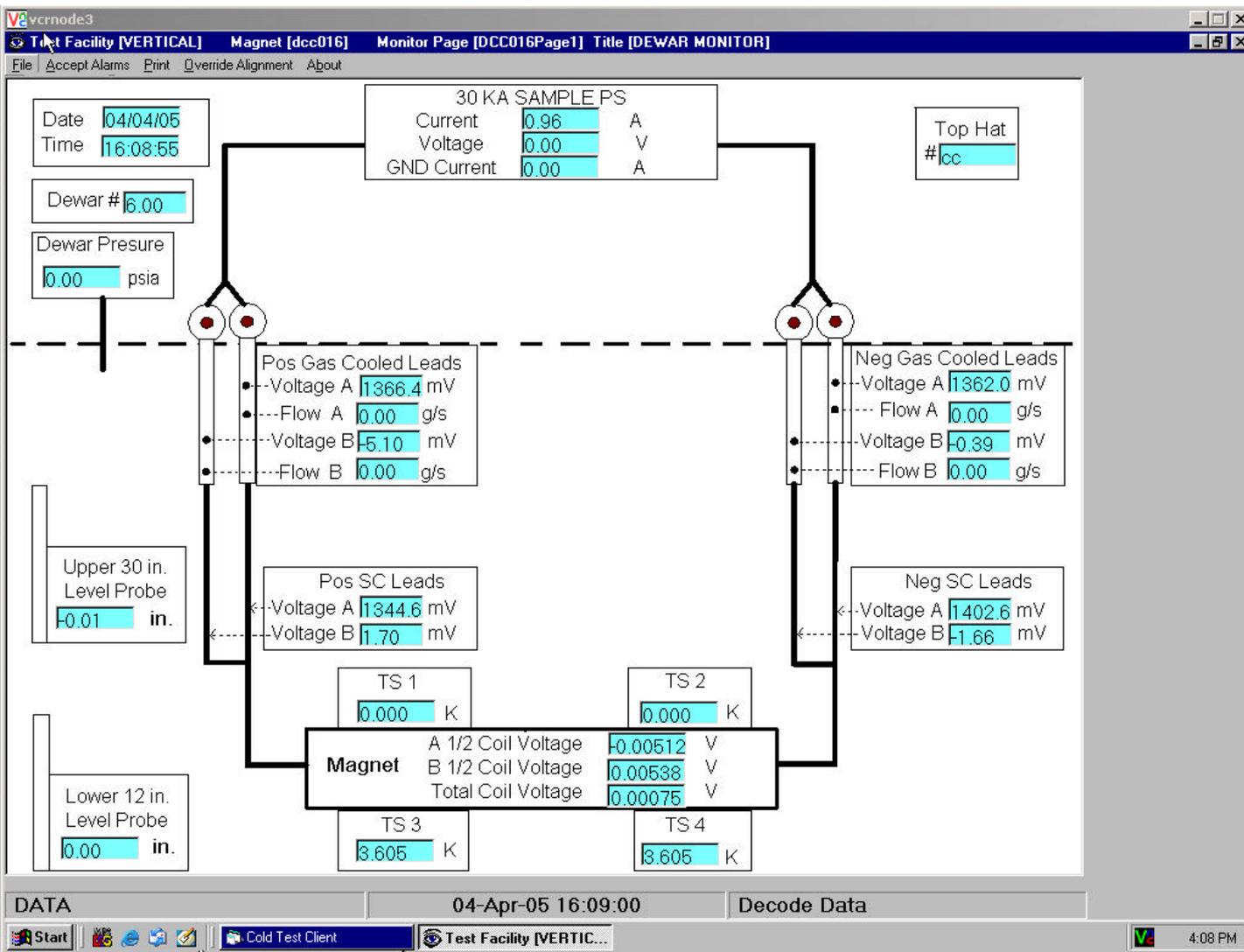
CONTROL & DATA ACQUISITION SYSTEMS

- **RECENTLY UPGRADED WITH ALL NEW PC-BASED SOFTWARE**
 - POWER SUPPLY CONTROL PROGRAMS
 - INSTRUMENTATION CONTROL PROGRAMS
 - DATA ANALYSIS PROGRAM “GRAFIX” includes:
 - DATA HANDLING, PLOTTING, AND ANALYSIS
 - UP TO EIGHT SIGNALS DISPLAYED
 - WAVEFORM CALCULATOR
 - INT ($I^2 dt$) CALCULATION
 - VERSATILE DATABASE CAN BE CONFIGURED TO ANY MAGNET



CONTROL & DATA ACQUISITION SYSTEMS

Database-generated monitor display page showing magnet status during testing.



The monitor status screen can be configured to accommodate any type of magnet and instrumentation system. The example here is from a Nb³Sn common coil magnet in vertical dewar 6.



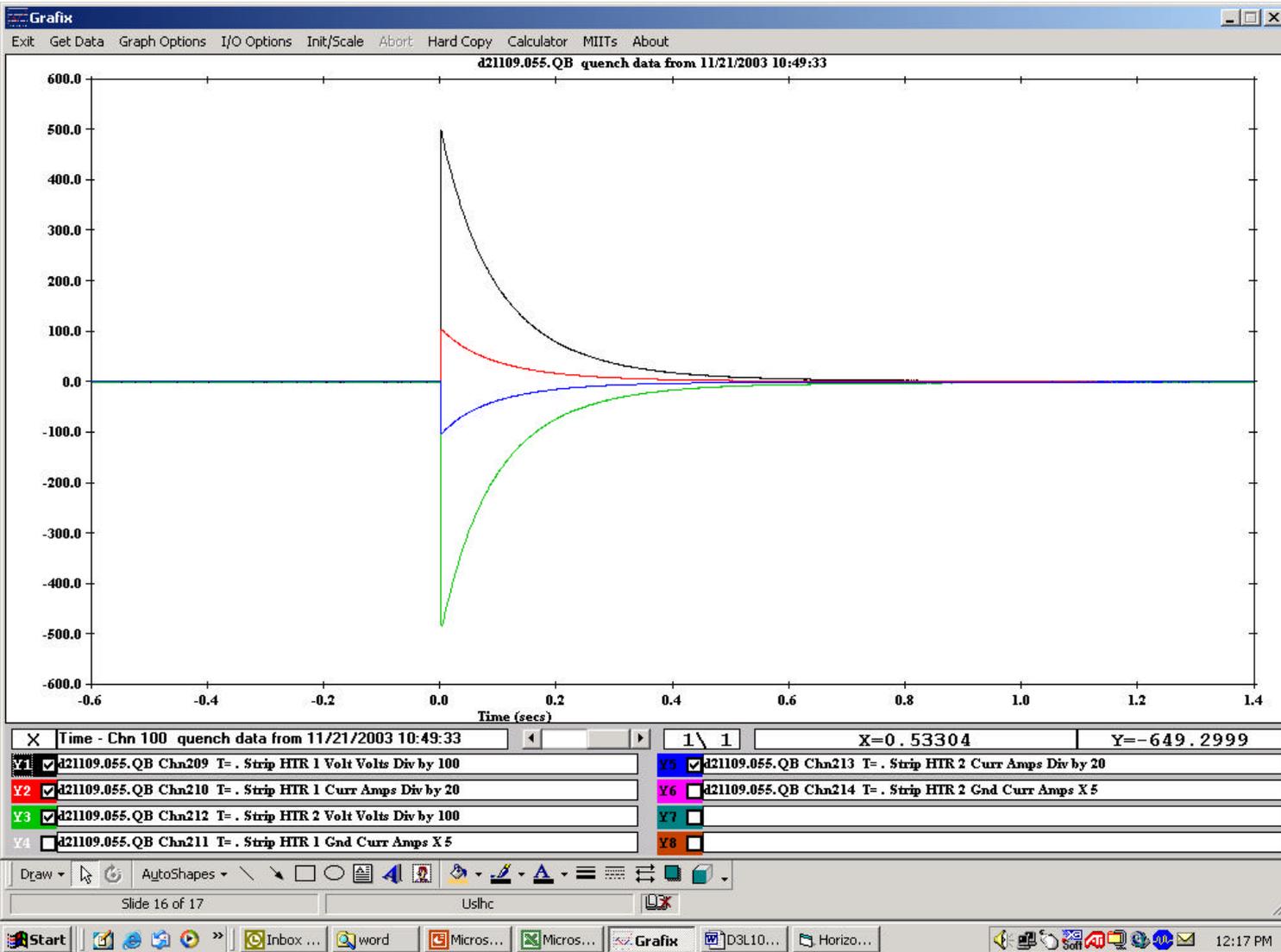
CONTROL & DATA ACQUISITION SYSTEMS

- **FAST DATA LOGGERS** up to 5kHz sampling rate, 4096 post and pre-trigger points per record, with vertical resolution of about 10 μV
 - **HTF 128 Channels**
 - **VTF 160 Channels**
 - **Mobile Outrigger Rack 96 Channels**
- **SLOW LOGGERS AND MONITOR (Cytec Scanners)**
 - **HTF 192 channels**
 - **VTF 128 channels**
- **DATABASE**
 - **Can be configured to any magnet type and geometry**



CONTROL & DATA ACQUISITION SYSTEMS

DATA ANALYSIS
PROGRAM GRAFIX
Up to 8 signals
Waveform calculator
Int(I²dt) calculation





MAGNETIC FIELD MEASUREMENT

Over 60 different Magnetic Field Measuring Coils available, various lengths and radii

External Drive Coils, some with warm bore tubes

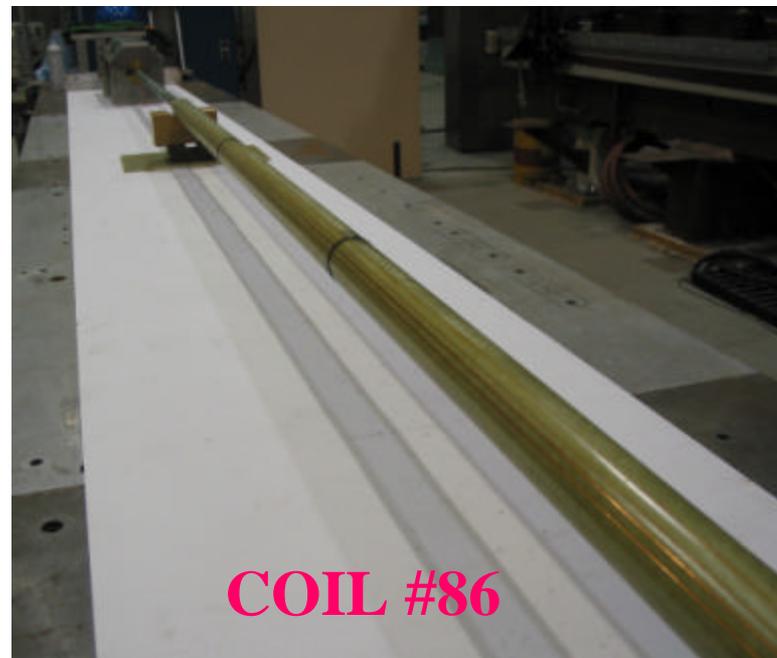
Moles

Coils 84 and 86: external drive coils for 8 cm aperture magnets

2 radial dipole windings

2 radial quadrupole winding

1 tangential winding





FACILITY UPGRADES

- Power supplies being equipped with Quench Protection Assemblies
 - IGBT switch, dump resistor circuit
 - Some power supplies already with energy extraction use SCR switches
- Upgraded data acquisition loggers and scanners
- Diagnostic and monitoring instrumentation and PLC for Model 4000 refrigerator
- Diagnostic and monitoring instrumentation and PLC for Dunham-Bush compressor



SUMMARY

- Cryogenics refrigerators, compressors, and other peripheral devices can be configured to provide for a variety of testing scenarios, including forced flow supercritical He or liquid He testing, and testing down to 1.8K.
- Magnet Division power supplies cover a wide range of testing applications for loads of various inductances and resistances, current and voltage levels, current ramp rates, and quench protection requirements.
- Data acquisition systems are designed for flexibility to accommodate many magnet and instrumentation configurations.
- There is a large inventory of magnetic field measuring coils of different sizes and design for a wide variety of applications.
- Further upgrades of facility systems are in progress.