



BNL Magnet Test Facility Updates

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BNL Magnet Test Facility

- Test Facility overview/refresher
- Test results since last workshop
- Cryogenics system updates
- Power supply updates
- Quench detection and protection updates
- DAQ updates

BNL Magnet Test Facility

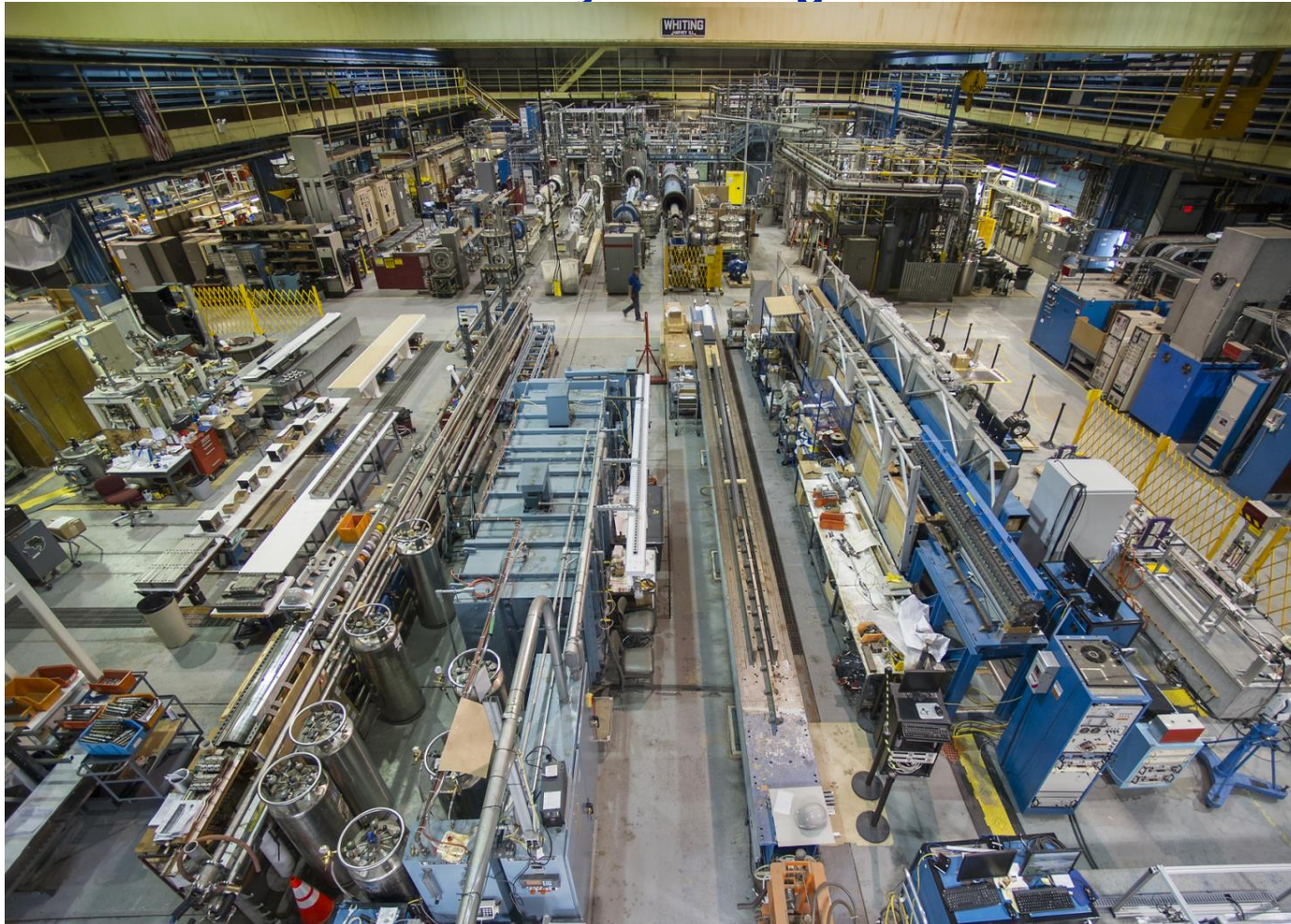
Since the last workshop at CERN in 2016, the following events, milestones, and upgrades have occurred:

- Operation at 1.9 K and lower, at 1 bar (nom)
- Powering of magnet to 19.4 kA (24 kA in power supply tests)
- Training of first long coil (mirror) and first long magnet (prototype), showing similar performance to the short versions of each
- Successful implementation of CLIQ at 500 V and 40 mF
- Operation of quench protection heaters satisfy LHC requirements or better
- Independent operations of EE, QPH, and CLIQ, with independent delays if needed
- Redundant quench detector systems
- Improvements to power supply and EE systems
- Upgrades to cryogenics quench He return system to mitigate loss of He gas due to high quench pressures
- Addition of second He liquefier after next test to meet 3 quench per day test rate.

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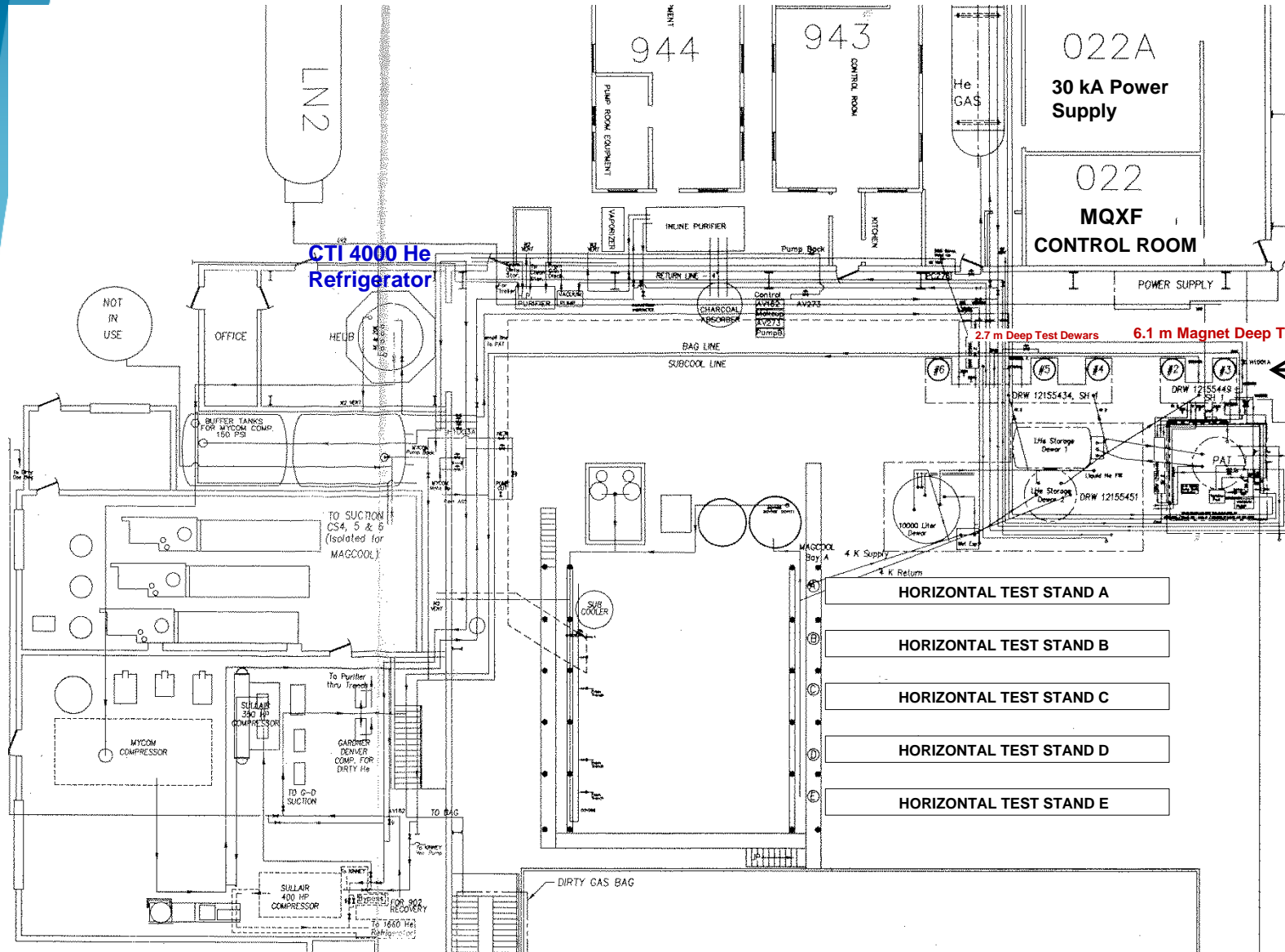
BNL Facility North (High) Bay Area (30 ton crane)

Test Facility in Background



BNL Magnet Test Facility

Nash "high capacity" vacuum Pump (1.9K)

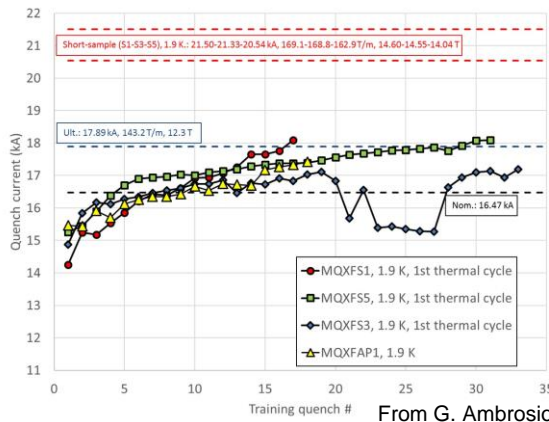
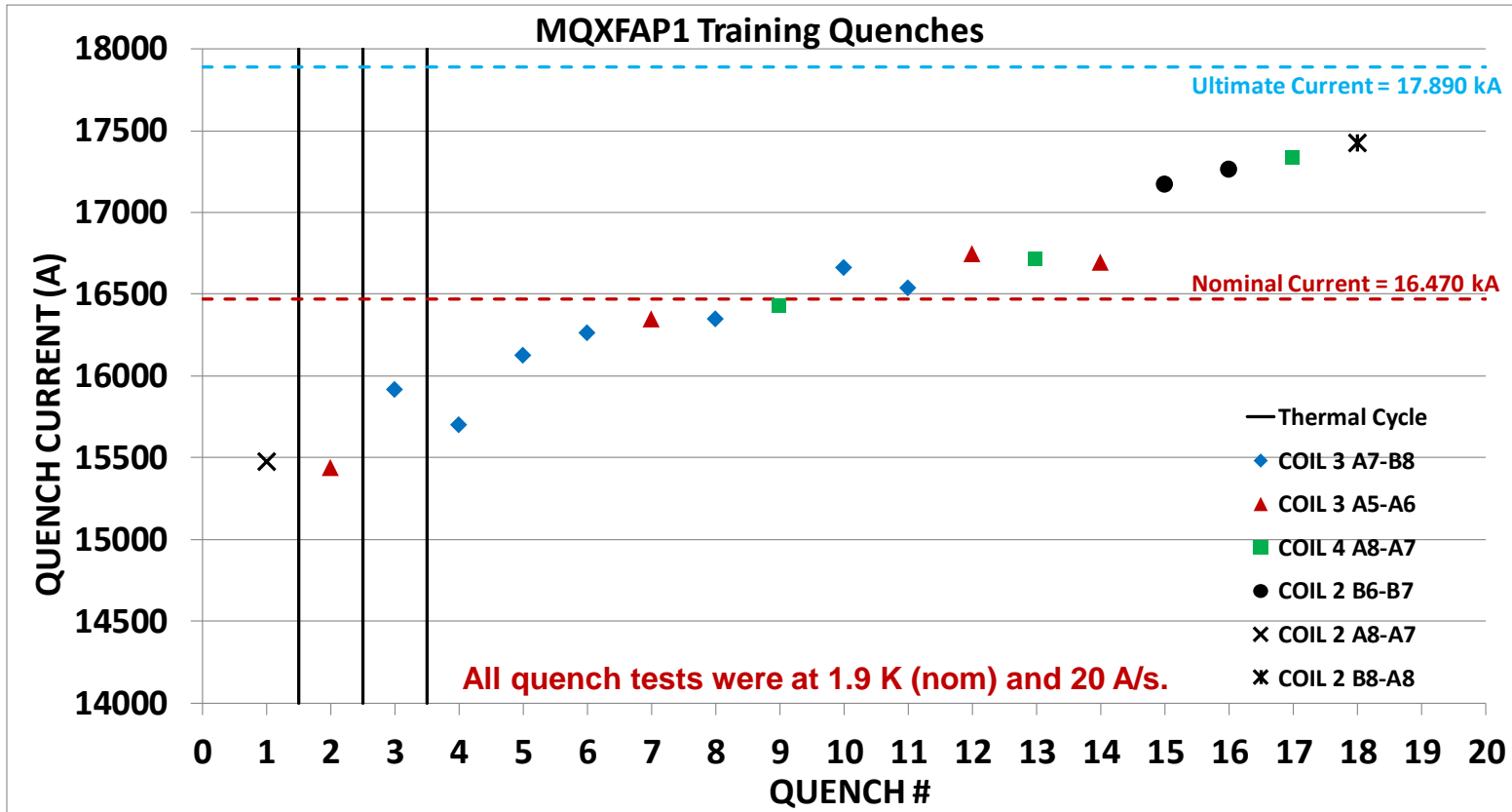


**Building 902
Test Facility
Floor Plan
and
Overview**

**Vertical Test
Dewars 2-6**

- HORIZONTAL TEST STAND A
- HORIZONTAL TEST STAND B
- HORIZONTAL TEST STAND C
- HORIZONTAL TEST STAND D
- HORIZONTAL TEST STAND E

Test Results – MQXFAP1 (1st Long Magnet)



Quench training results were similar to the short prototypes.

Testing was ended because Coil 5 developed a short to ground and to outer layer quench heaters. This is still being investigated.

Cryogenic System Upgrades

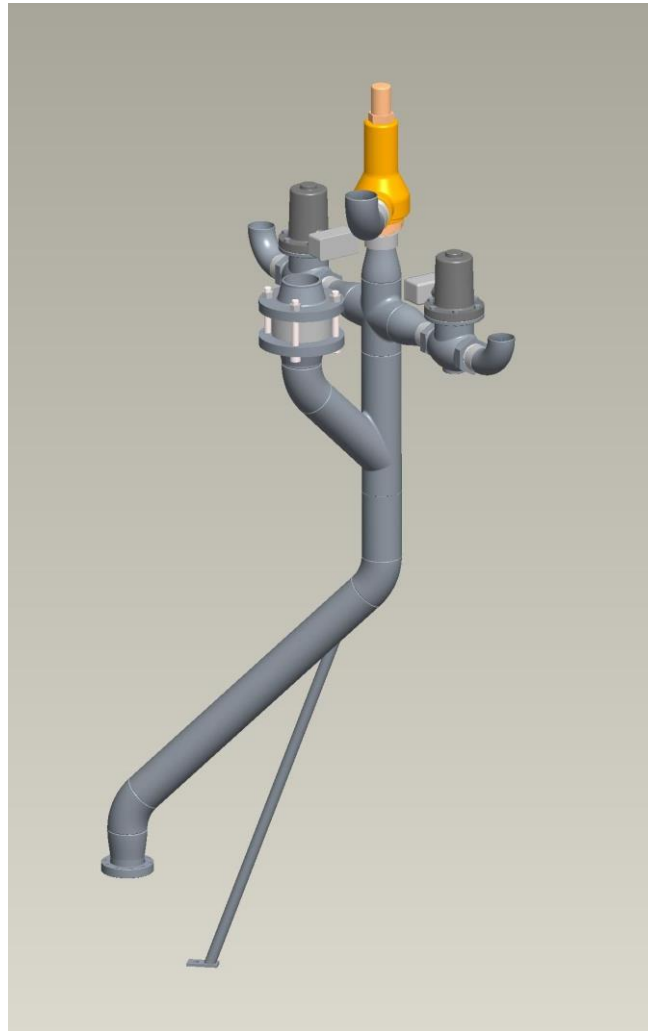
- Newly designed relief valve assembly – to mitigate burst disc problem and decrease loss of He gas at quench
- Use of Test Cryostat 3 as a cold buffer tank next to Test Cryostat 2 under test – all parts (including newly designed transfer line) ready for use in next test (July 2018)
- Future addition of two more buffer tanks (29874 L each) if needed
- Linde Model 1610 He Liquefier is being shipped to BNL from PNNL at minimal Project cost – to increase liquid He rate by 80-100 L/hr (in addition to CTI 4000 246 L/hr), and allow for 3 quenches/day and more efficient operation between tests
- Increased number of pressure transducers and thermometers to provide better diagnostics and control of valves
- **Total energy at quench - up to 6 MJ at 19kA (training quenches) with 33mH inductance – Need to be ready for this**

Cryogenic System Upgrades

Dewar Relief Systems

Test Dewar Relief Stack (Unchanged)

- Cash Relief Valve (1380g/s @ 30 PSIG)
- 3" Burst Disk (40 PSIG)
- 2" Solenoid Valve (1400 g/s @ 30 PSIG)
- 3" Solenoid Valve (2700 g/s @ 30 PSIG)



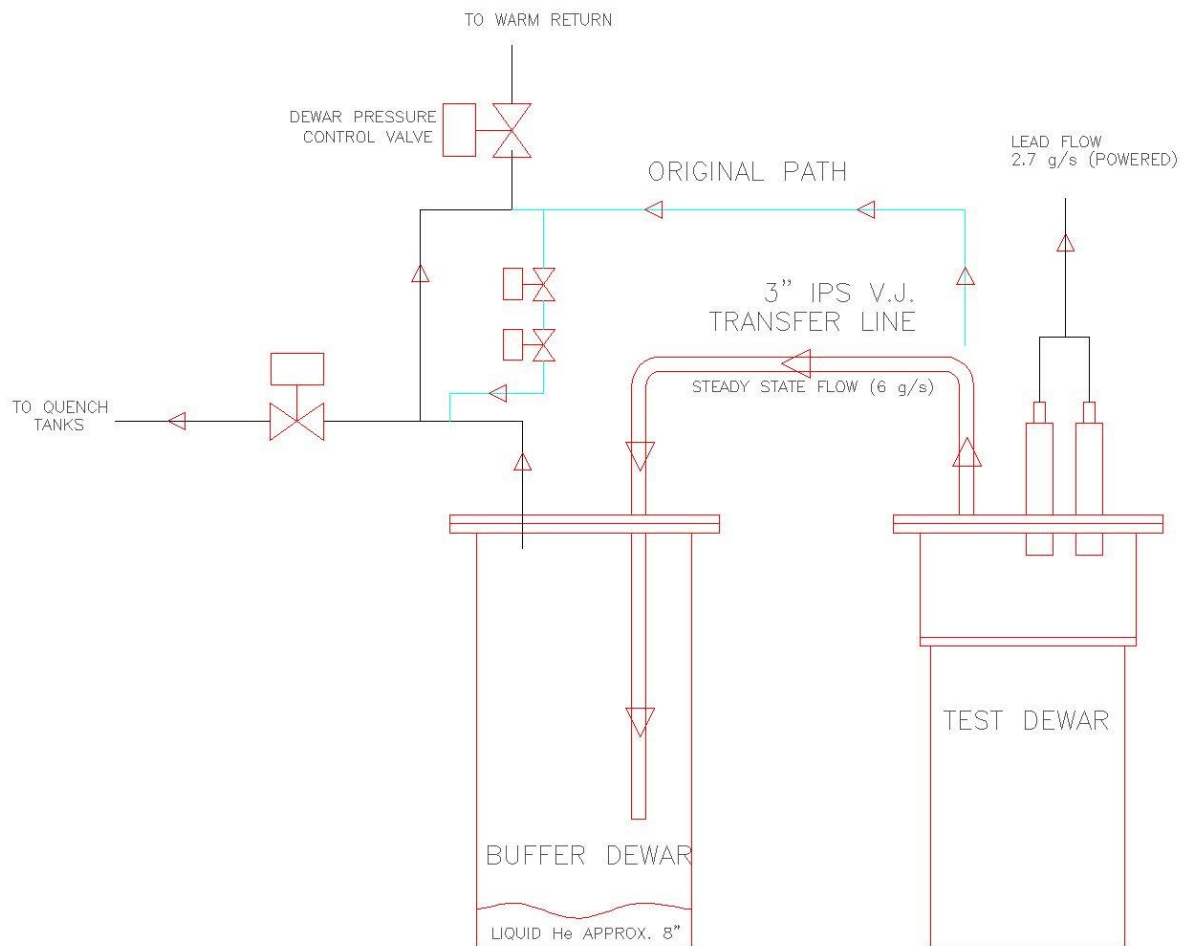
Buffer Dewar relief stack is identical except that it does not have the 3" solenoid valve.

- Solenoid valve activation time is approx. 1 s after signal.
- Cash relief valve full open @ 33 PSIG.

This slide courtesy of A. Marone

Cryogenic System Upgrades

Helium Flow Schematic Using 2nd Test Cryostat as Cold Buffer



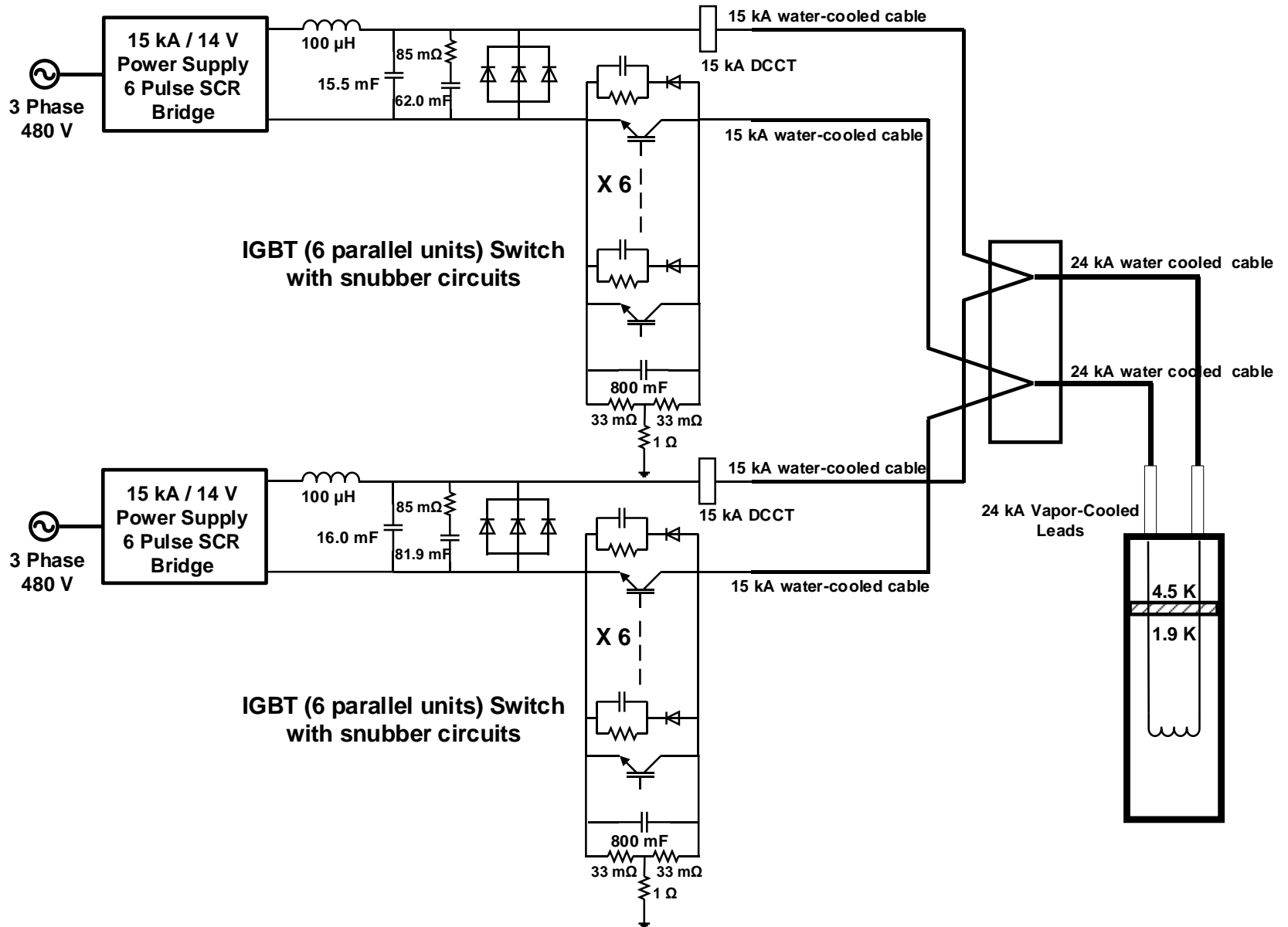
This slide courtesy of A. Marone

Cryogenic System Upgrades



- Linde Model 1610 He Liquefier
- Based on modified Claude cycle with two gas piston expanders
- In-line purifier
- 80 – 100 L/hr
- With main refrigerator CTI 4000, will allow liquefaction rate for 3 quenches / day

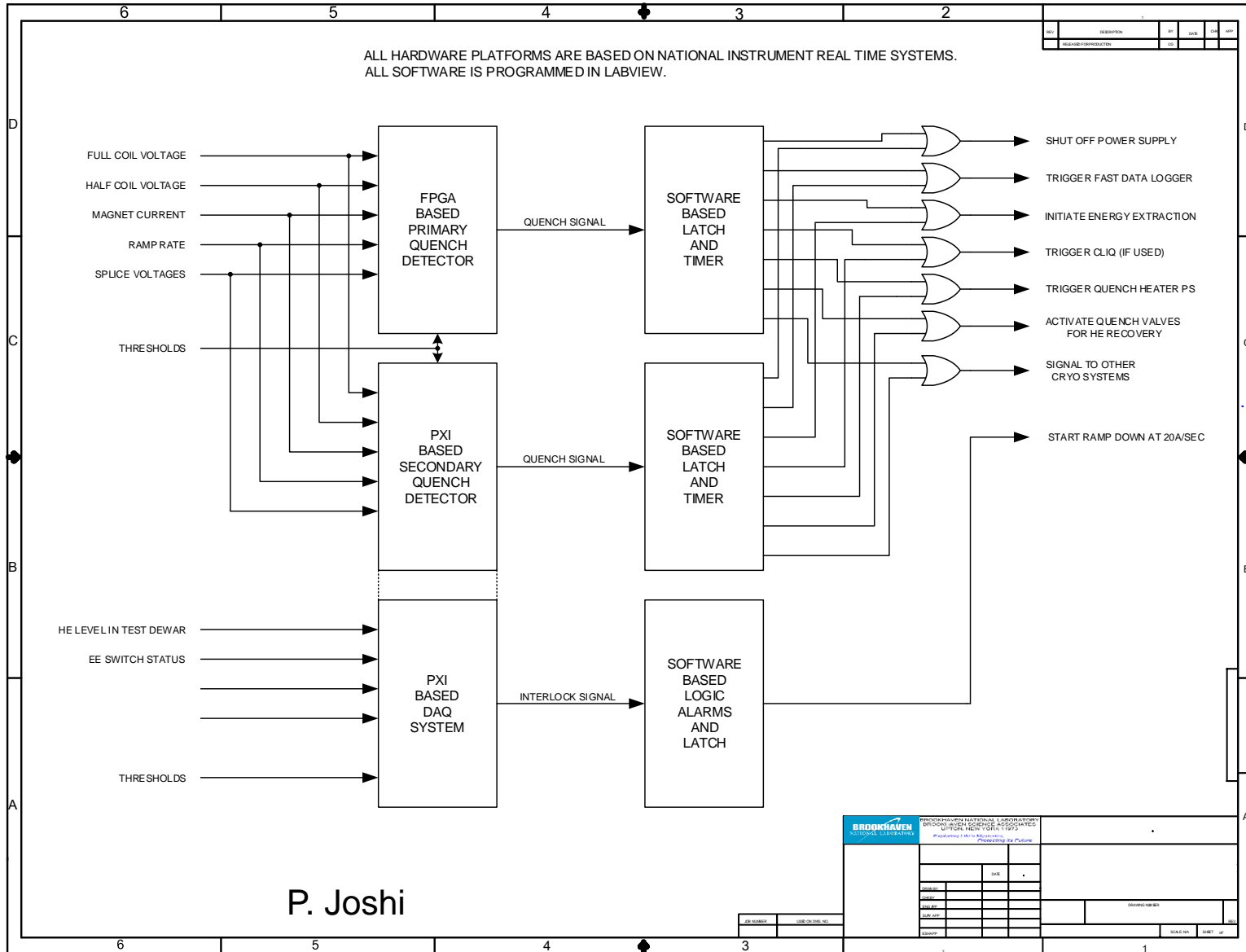
Power Supply System



Power Supply and Quench Protection Upgrades

- Ceramic non-inductive dump resistors have replaced the stainless steel resistors used during the mirror test – now have more options -
 $R_D = 30, 37.5, 50, 75, 150 \text{ m}\Omega$
- Upgrade of IGBT switches on PS#2 to 1700 V rating - allows for use of higher EE resistance at training quench currents
- Replacement of main 480 V switches for both power supplies to meet safety requirements
- Addition of FPGA-based quench detector for main quench signals – total coil, total coil-L(di/dt), $\frac{1}{2}$ coil difference, $\frac{1}{4}$ coil differences, SC leads
- PXIe quench detector also still being operated – as backup to FPGA-based QD and for signals which can trigger slow discharge, such as gas-cooled leads and LHe level, etc. (see following drawing)

Quench Protection Upgrades



P. Joshi

Quench Protection Upgrades

- 12 independent Quench Protection Heater firing units (8 600 V, 12 mF; 4 900 V 13 mF) with four charging systems
- Each QPH can be charged and time-delayed independently of each other and the EE and CLIQ triggers
- CLIQ has been implemented successfully and used during MQXFAP1 training
- CLIQ was operated at 500 V and 40 mF, with and without inner layer heaters

Instrumentation Upgrades

- HBM equipment to control and read 40 CERN-style strain gauges has been ordered and will be ready for next test
- Vishay/LARP-style gauges will now be divided among five current sources to minimize loss of data due to a gauge failure
- Quench fast data logger file has been expanded to include more coil signals with different gains
- All voltage tap, coil and layer main voltage, quench antenna, CLIQ, and protection heater signals are included in one data file, along with cryostat and buffer pressures, power supply voltages and currents, and other signals
- Strain gauge reads, FPGA detector, and power supply monitoring parameters are each written into separate data files
- All data files are generated using LabVIEW programs
- Magnetic field measuring transporter is being readied for next test in July.

BNL Magnet Test Facility

CONCLUSION

- Upgrades to the BNL test facility cryogenics, power supply, energy extraction, quench detection, and quench protection systems have been made or are in progress at this time.
- Next test is scheduled for July and will be the 2nd prototype MQXFAP2.

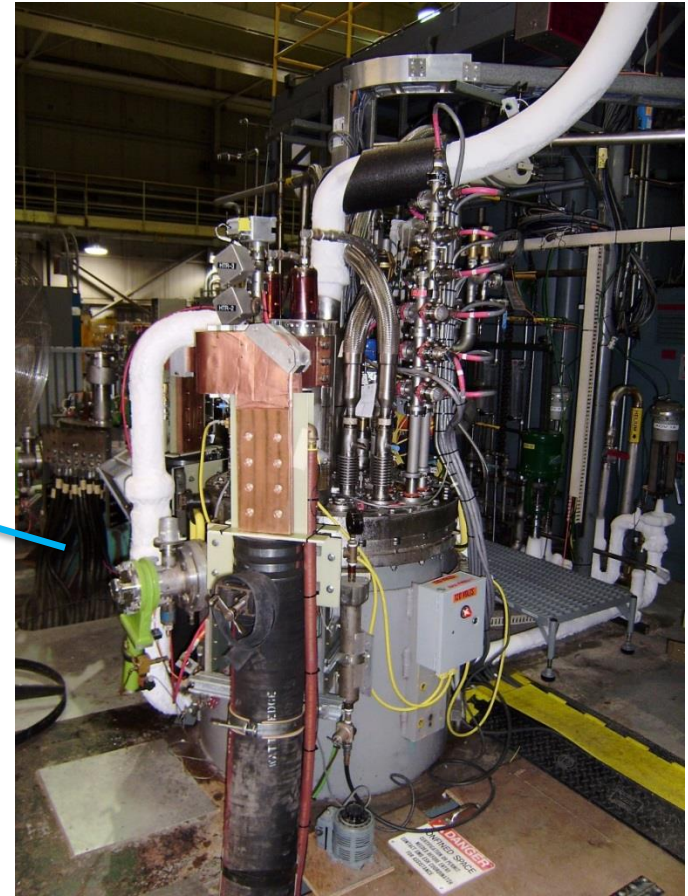
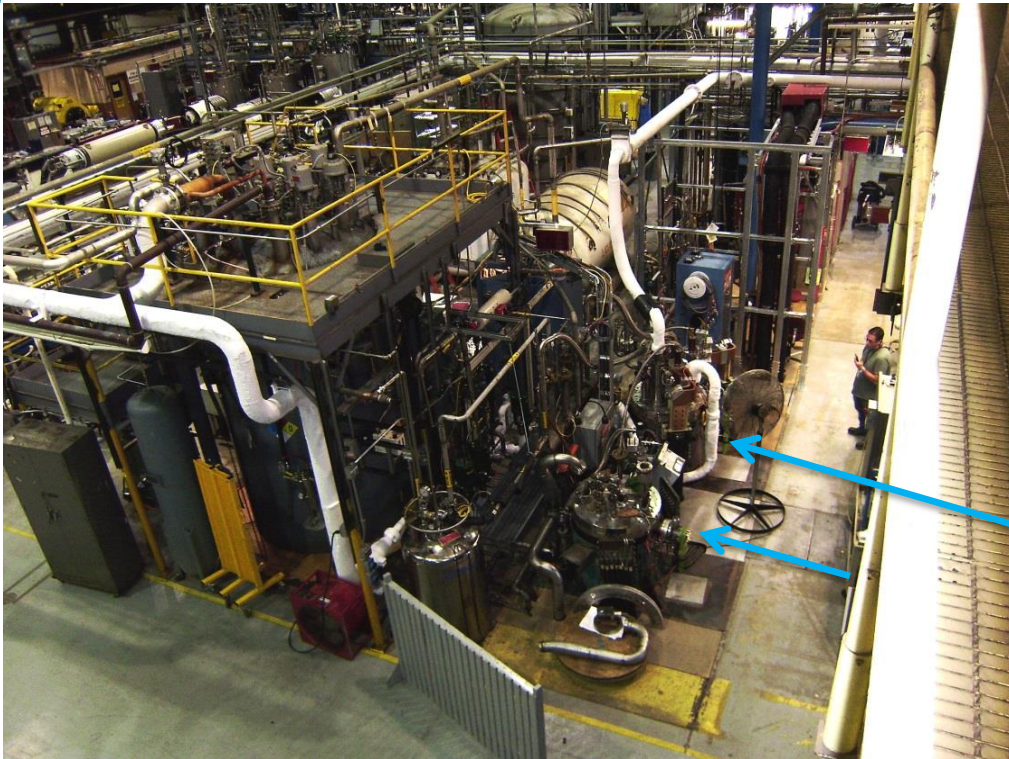
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Back-Up Slides



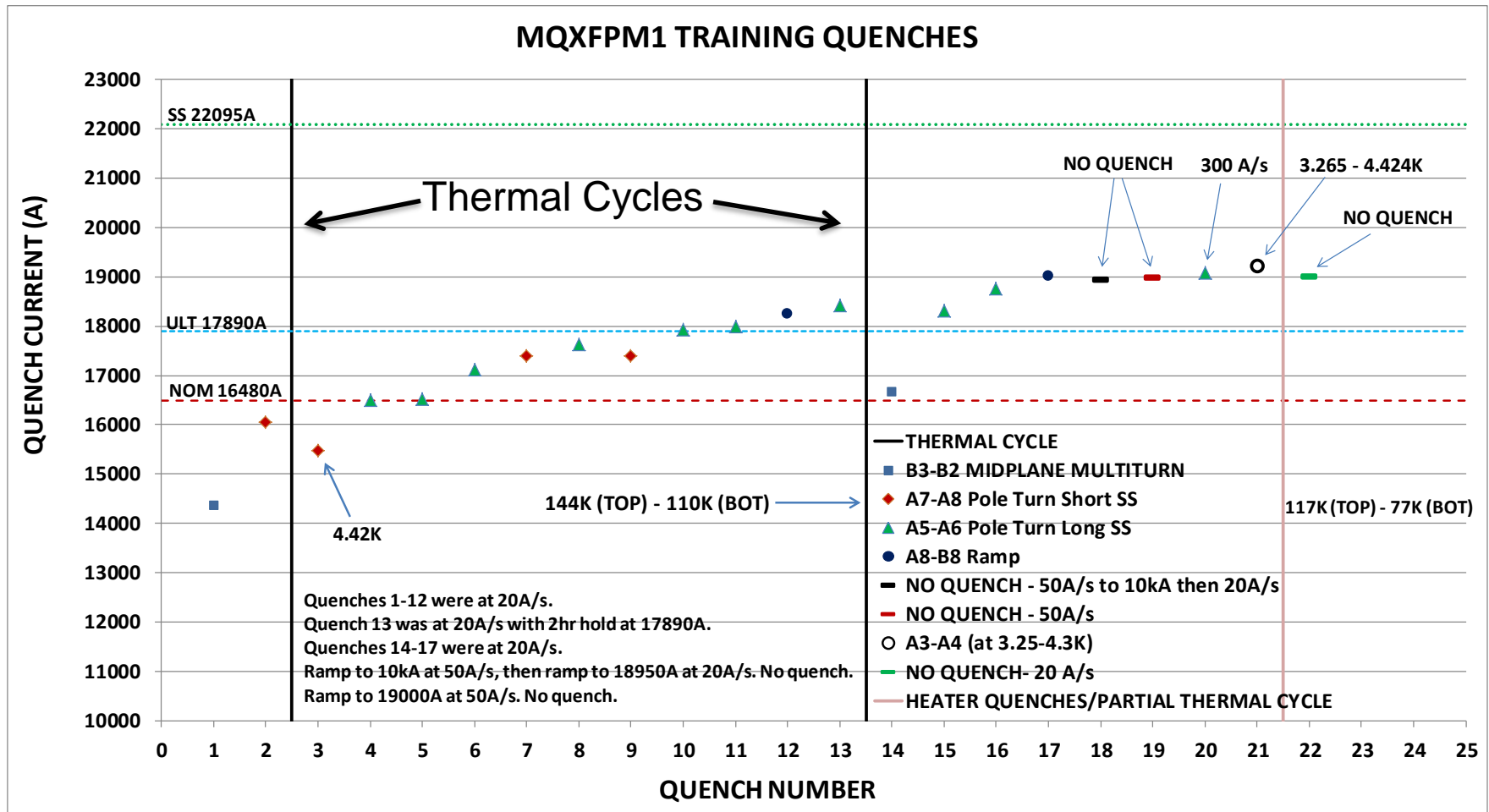
BNL Magnet Test Facility



Vertical Test Facility at BNL, showing two of the five test cryostats and the backup refrigerator. Long arrow points to **Vertical Test Cryostat 2 (1.9K and 24kA)**. Short arrow points to Test Cryostat 3, which will be used as cold buffer for the He return during quenches on future MQXFA tests.

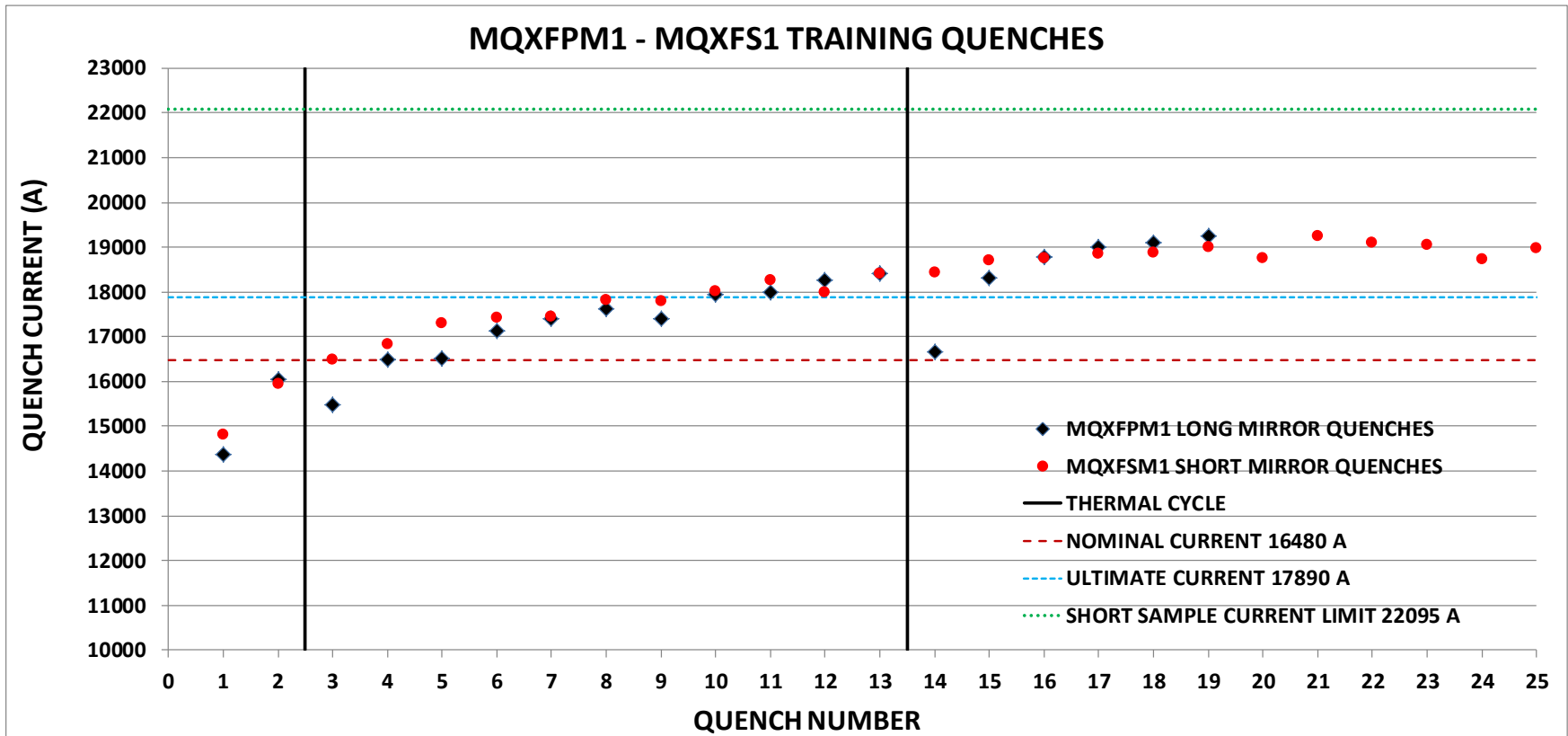
Vertical Test Cryostat 2, upgraded to provide 1.9 K at 1 bar (nom) and 24 kA, for testing of the 4.2 m-long MQXFA quadrupoles. The picture shows the test stand with the mirror MQXFP1 under test.

Test Results – Mirror (1st Long Coil)



Magnet was still training by end of test – locations of quenches varied and highest current quench at end was at 4.4 K. A quench at 300 A/s showed no change in quench current.

Test Results – Mirror (1st Long Coil)



Training of long mirror and short mirror are similar. No degradation in longer coil.

