MQXFAP2 TEST STATUS UPDATE

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16-Oct-2018

BROOKHAVEN NATIONAL LABORATORY

OUTLINE

1. Present status of MQXFAP2 test at 1.9 K.

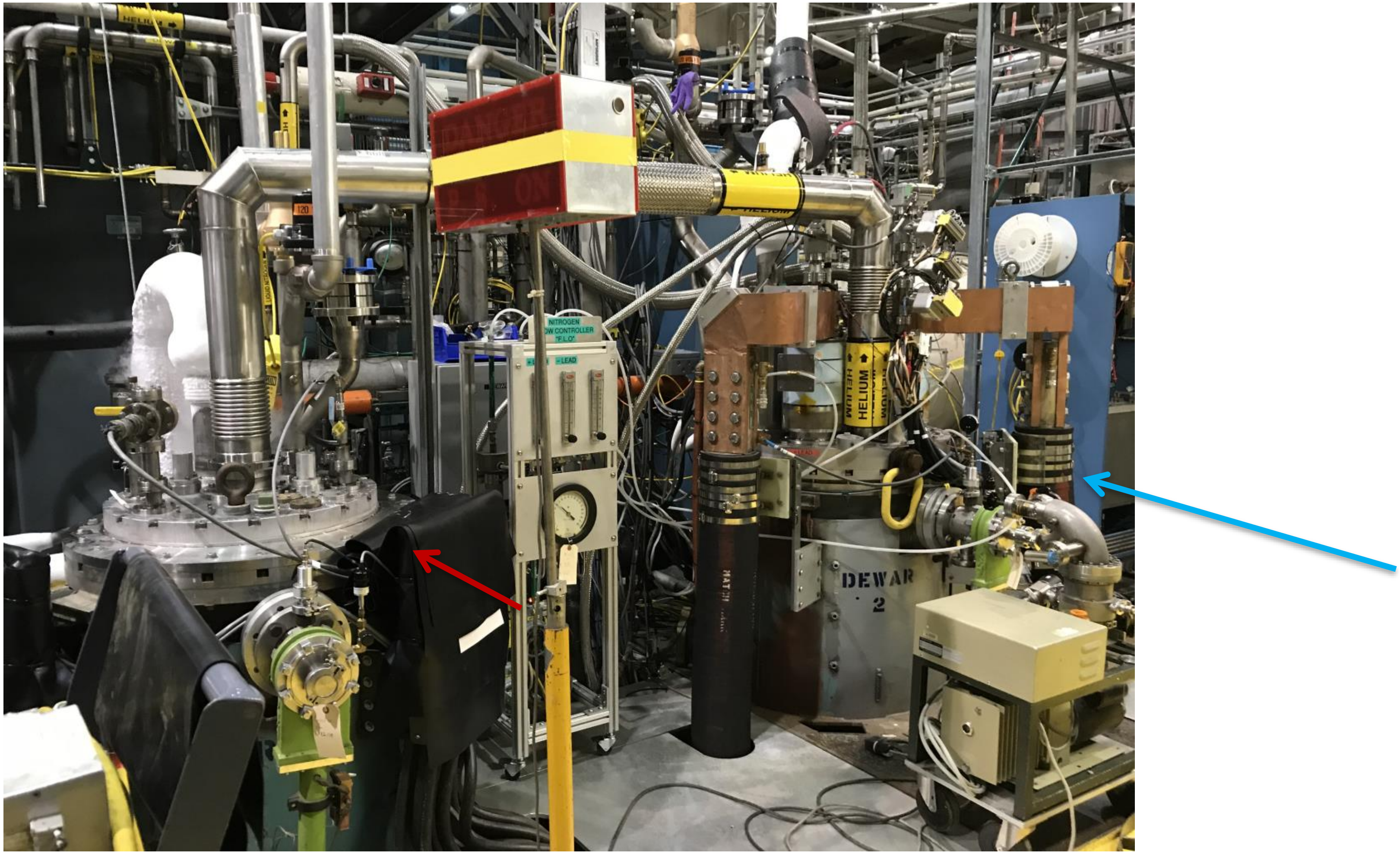
2. MQXFAP2 quench performance so far.

3. Quench precursor spikes.

4. Flux jump spikes.

5. Test facility modifications implemented to mitigate He losses due to high fast pressure increases.

STATUS



Vertical Test Facility at BNL. The picture shows the test stand with MQXFPM2 being tested. Long arrow points to **Vertical Test Cryostat 2 (1.9K and 24kA)**. Short arrow points to **Test Cryostat 3**, which is being used as cold buffer tank for the He return during quench tests.

STATUS

1. Room temperature and cold electrical checkouts were good.

2. High voltage withstand tests (hipots) at room temperature – 1.66 kV magnet coils and heaters to ground.

3. High voltage withstand tests (hipots) at cold - coils to ground 1.1 kV, heaters to coil and to ground 2.3kV.

4. MQXFAP2 is cold and testing is underway – presently at 4.5K and is being cooled to 1.9 for test this afternoon.

5. As of Mon 15-Oct, 10 quench tests have been done.

6. Quenches have occurred in all four coils, all in inner layer pole turns.

STATUS

7. Numerous pole turn taps have opened, so determining locations on the pole turn with voltage taps is problematic.

8. However, quench antenna analysis (by M. Marchevsky) has shown that most quenches have originated in or near the nonlead end section.

9. The new magnetic field measurement system has been commissioned successfully. Measurements have been performed at room temperature and at various temperatures during cooldown and the results are being analyzed.

10. Spike detection measurements are being done.

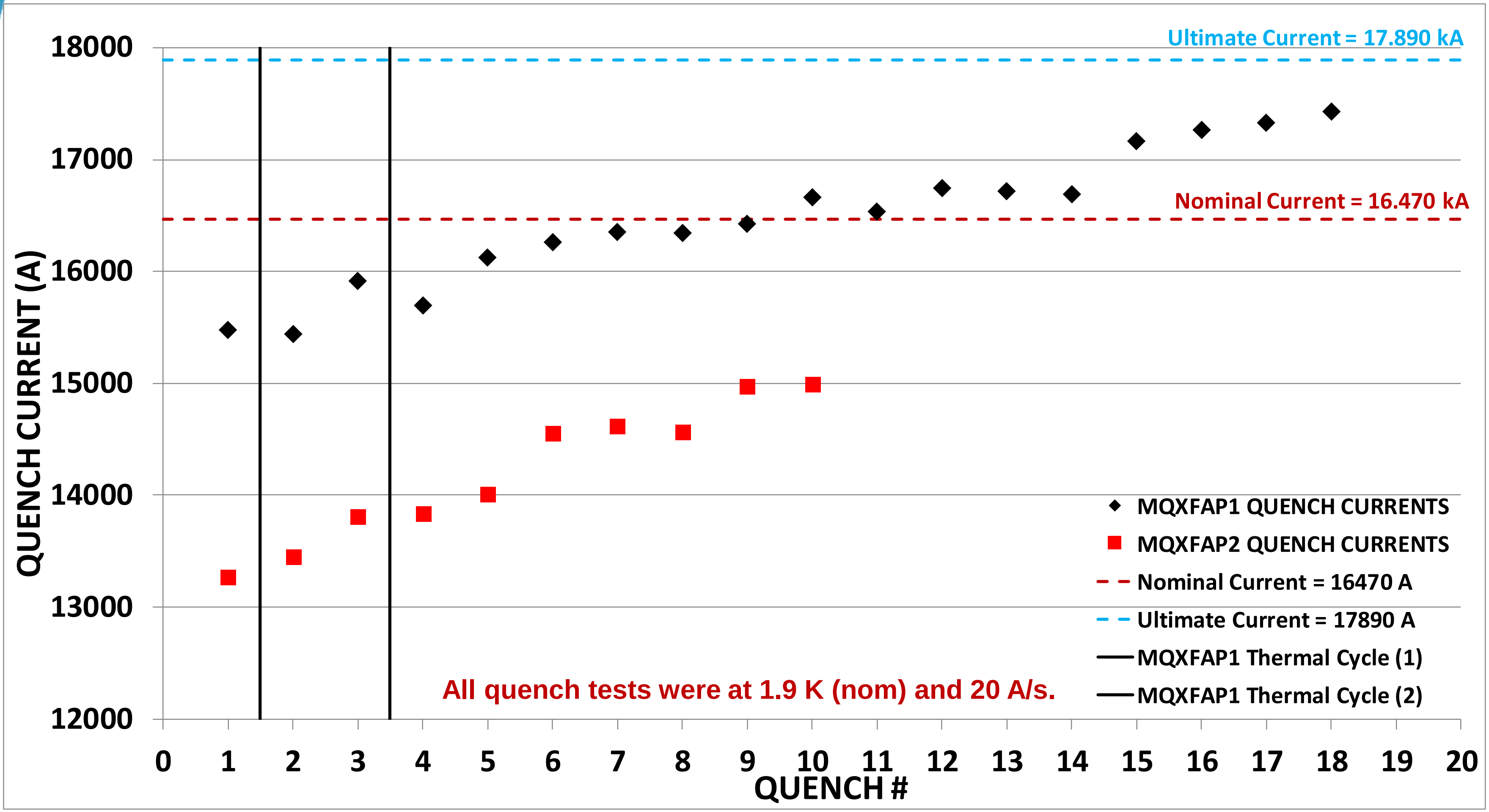
11. Strain gauge (shell, coil, rods) are running continuously

TEST PARAMETERS

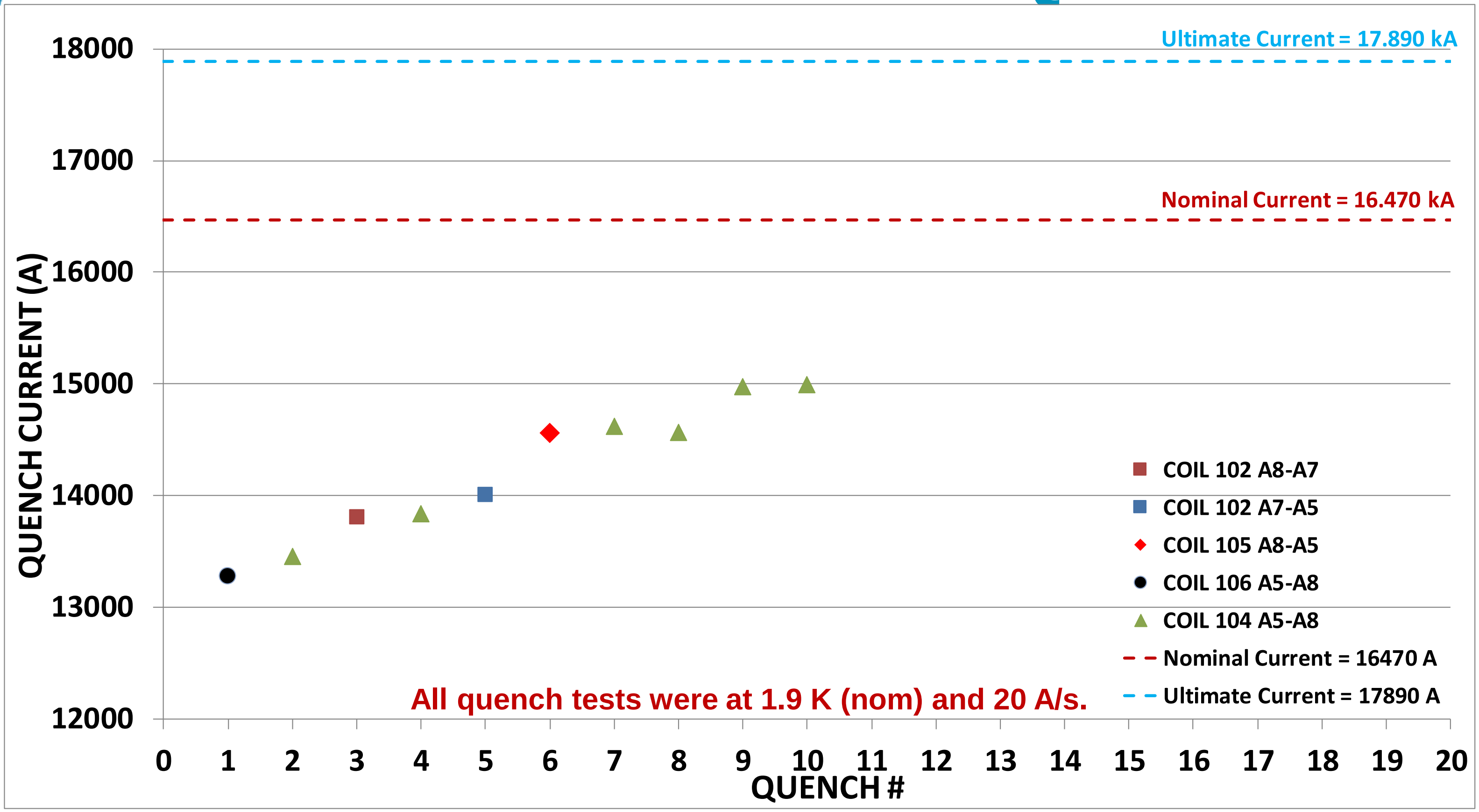
For all quench tests so far:

1. Magnet half difference voltage threshold = 150 mV (>8000 A).
2. Validation time = 4 ms (>8000 A).
3. Outer layer protection heaters only; 465 V (nom), 12.4 mF.
4. CLIQ at 500 V and 40 mF.
5. Energy extraction at 37.5 mΩ with 10 ms delay.

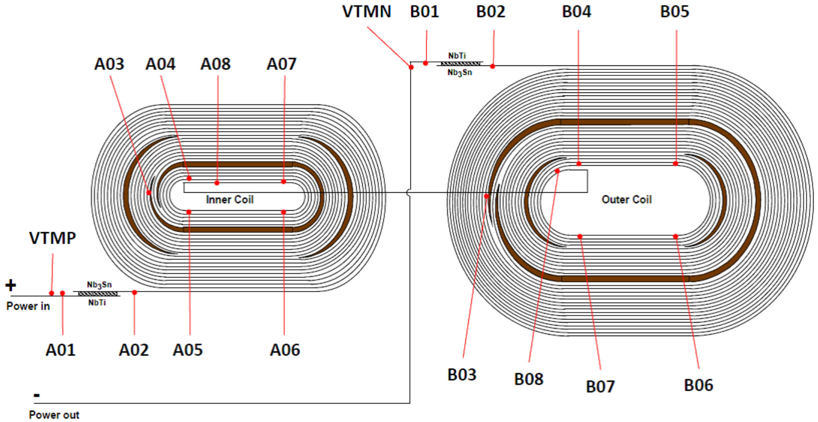
Test Results – MQXFAP1 / MQXFAP2



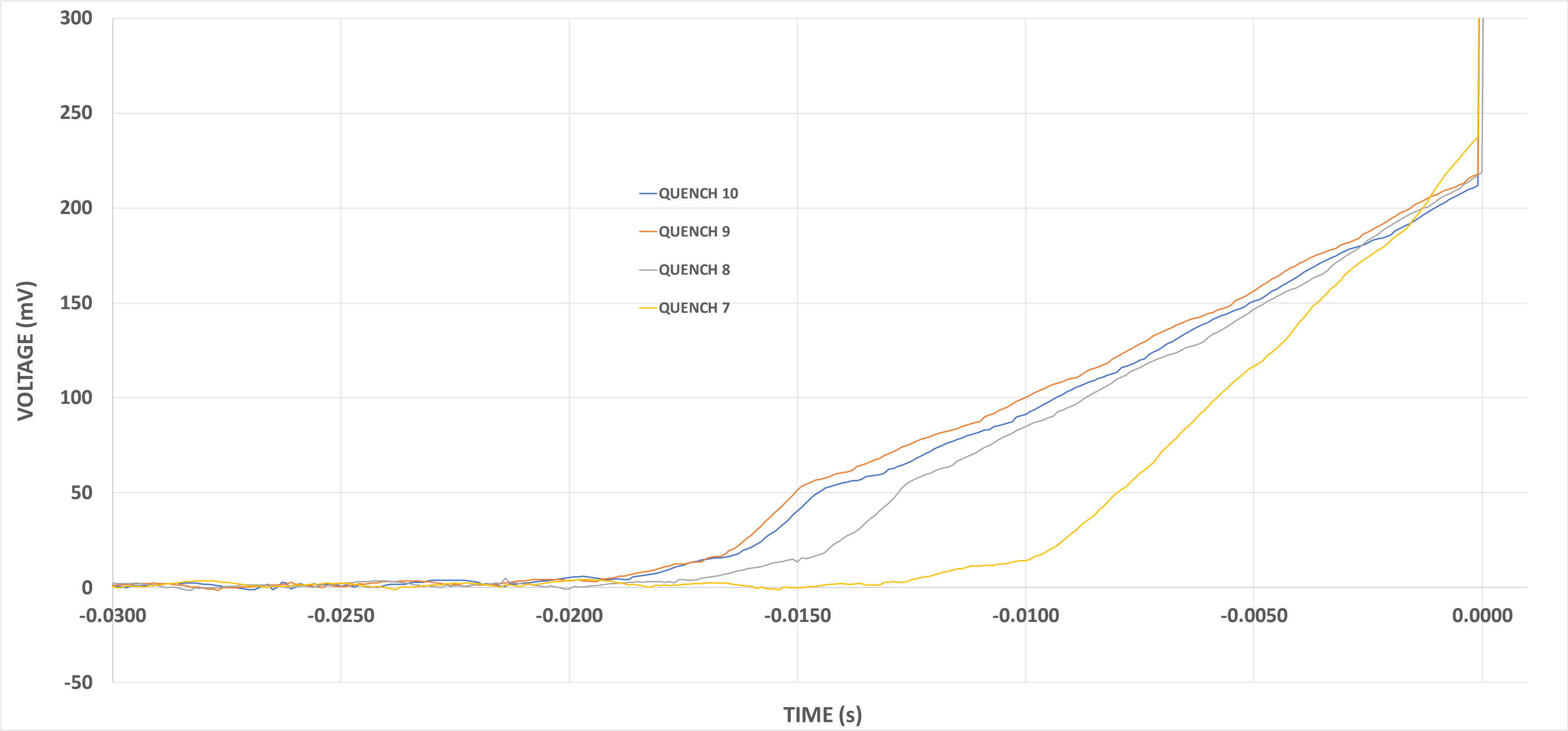
Test Results – MQXFAP2



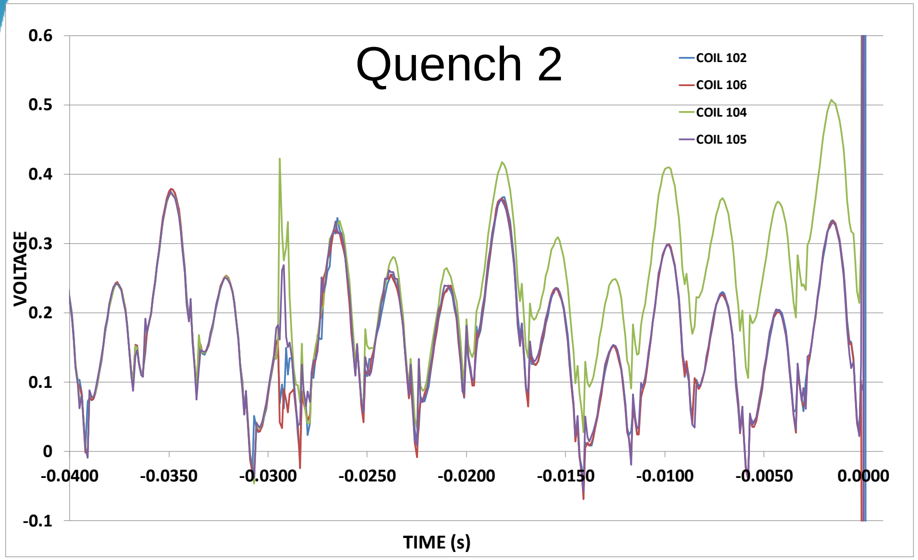
Quench integral values range from 25 – 28 MIIts (~170 – ~200 K). Threshold for training is 250 K.

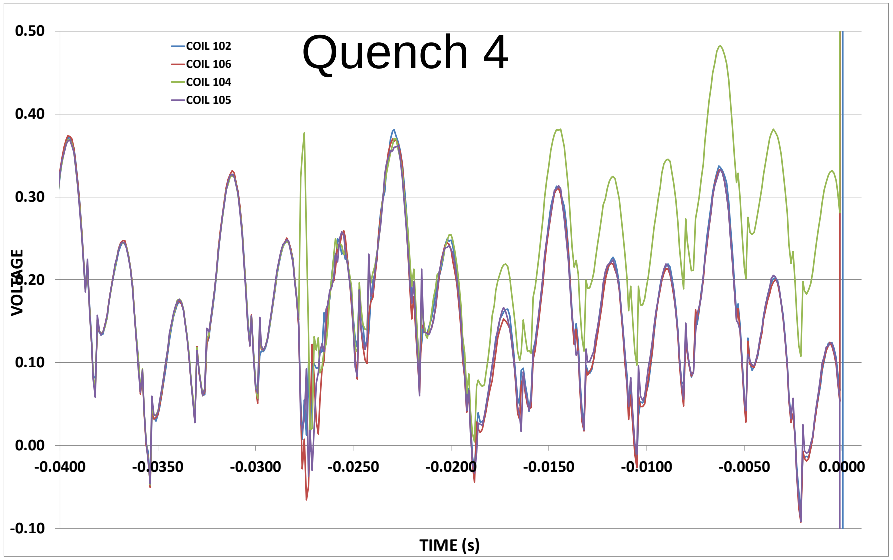


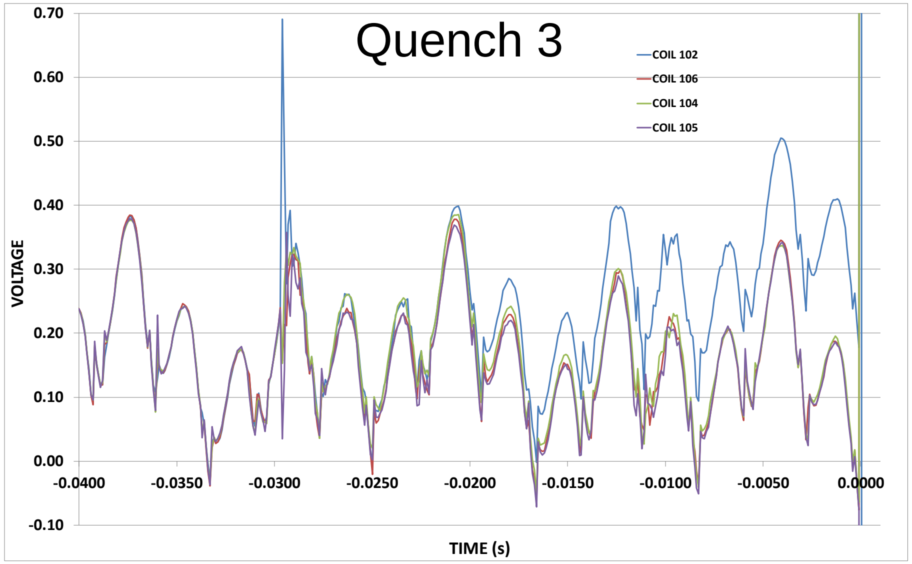
Quenches 9-10 A5-A8 Voltages



Test Results – Precursor Spikes







Precursor spikes were observed in Quenches 1-7 and 9, and occur typically 0 – 8 ms before quench start.

Test Results

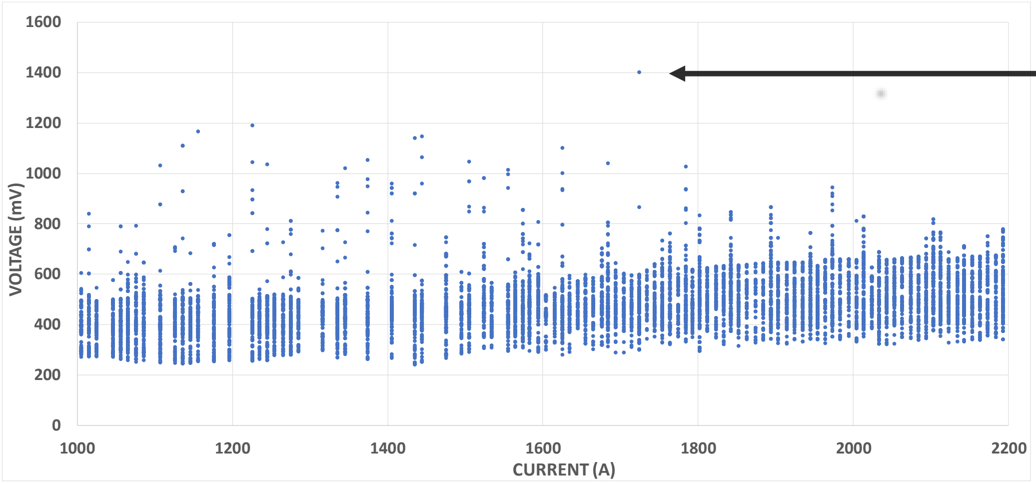
Up to now the following observations can be made:

1. All quenches originated in the inner layer pole turn, as determined by the voltage taps, and in or near the nonlead end section, as determined by the quench antenna (except not known for Quenches 1 and 2, for which the quench antenna had not yet been installed).

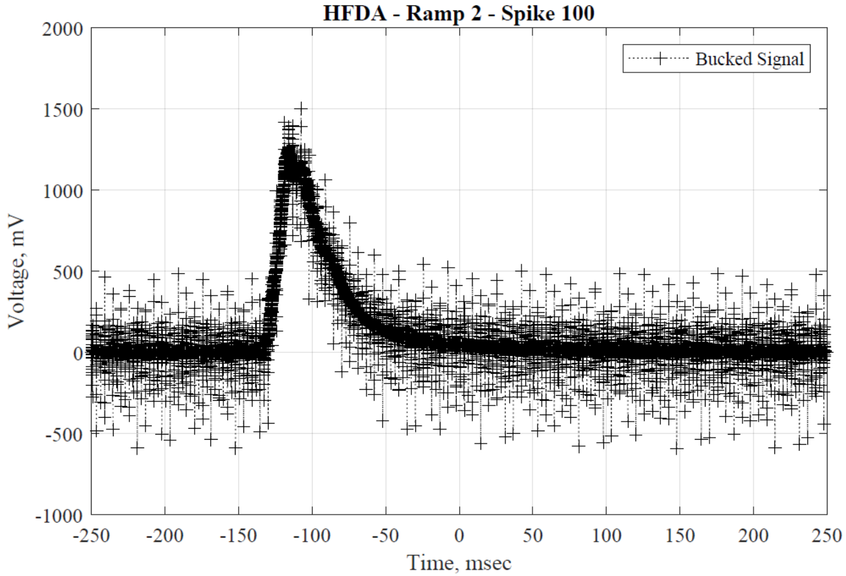
2. For all coils, the taps A6 and A7, which bracket the nonlead end section in the inner layer pole turn, have opened up.

3. For all quenches except #8 and #10, a precursor spike is observed 0-8 ms prior to the quench start.

Test Results - Flux Jump Spikes



1400 mV spike at 1724 A during a 6000 A ramp



Plot by M. Baldini

US HL-LHC AUP

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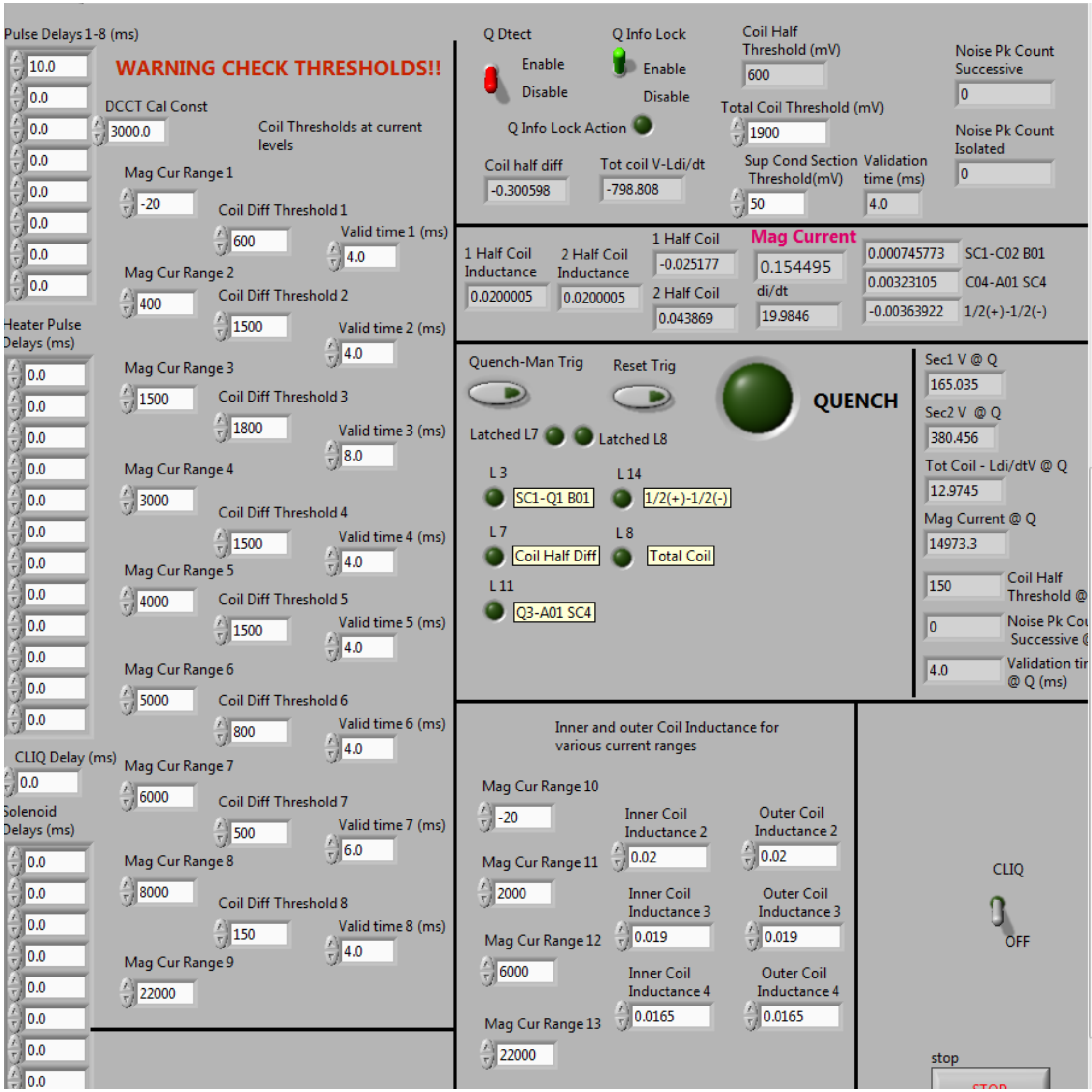
Test Results - Flux Jump Spikes

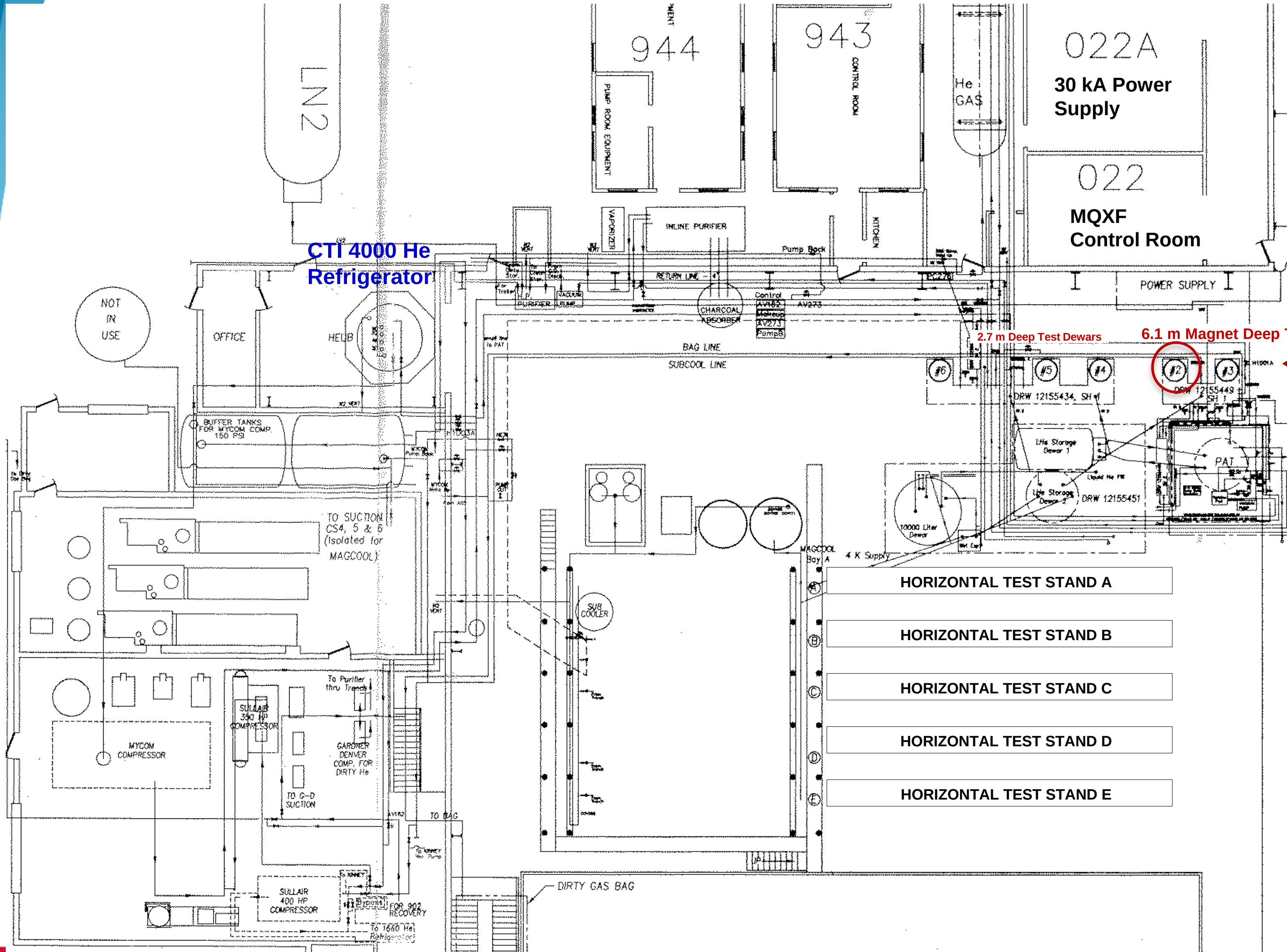


Voltage thresholds during ramps have been lowered as a result of the spike data. Also validation times have been varied as well.

Test Facility Infrastructure

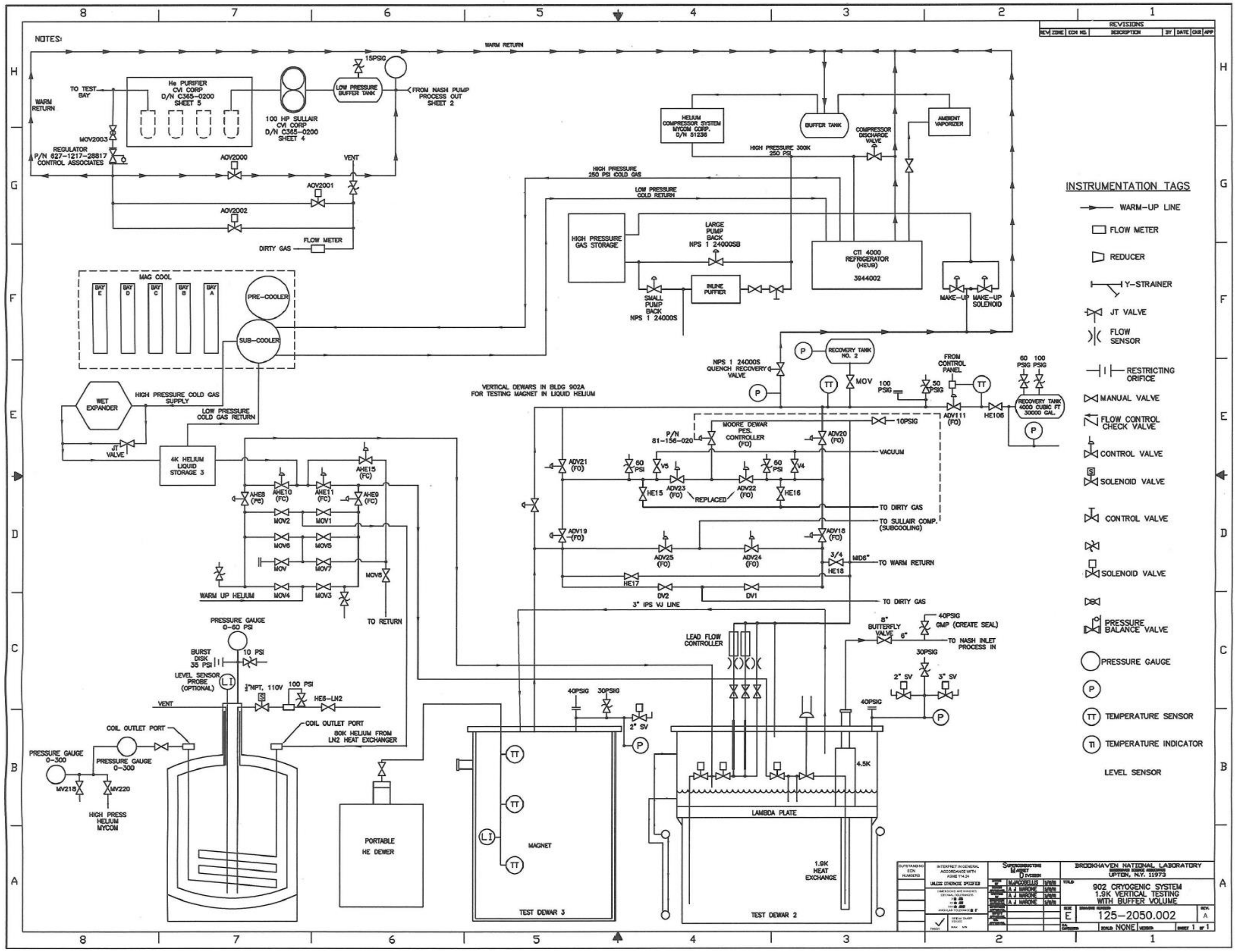
Nash "high capacity" vacuum Pump (1.9K)

Building 902 Test Facility Floor Plan and Overview



Vertical Test Dewars 2-6

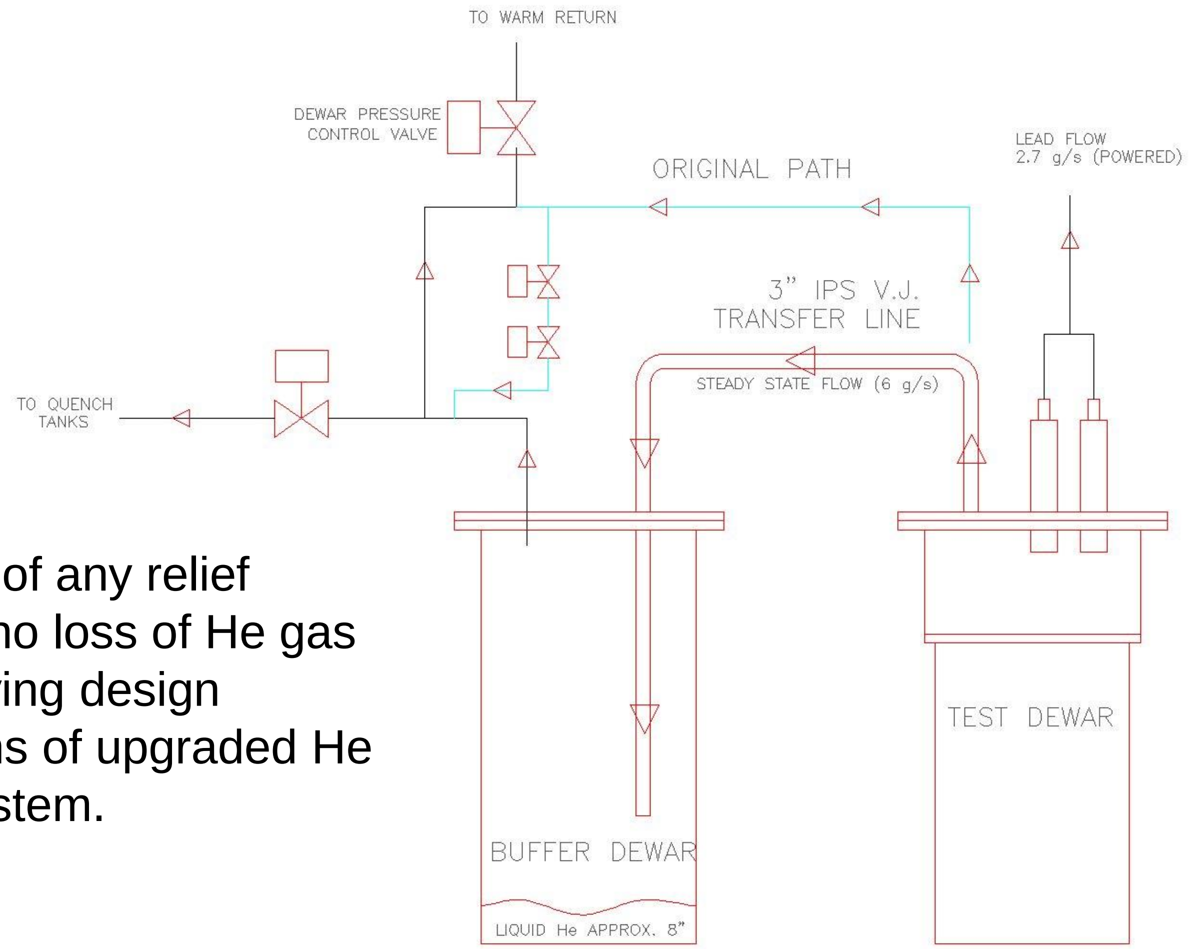
Cryogenic System Upgrades



Upgrades to the He gas recovery system after quench were made to minimize or prevent the loss of He gas after a quench at the high energies of the MQXFA magnets and resulting rapid and high gas pressure increase.

Cryogenic System Upgrades

Helium Flow Schematic Using 2nd Test Cryostat as Cold Buffer



No opening of any relief valves and no loss of He gas so far, verifying design computations of upgraded He recovery system.

This slide courtesy of A. Marone

SUMMARY

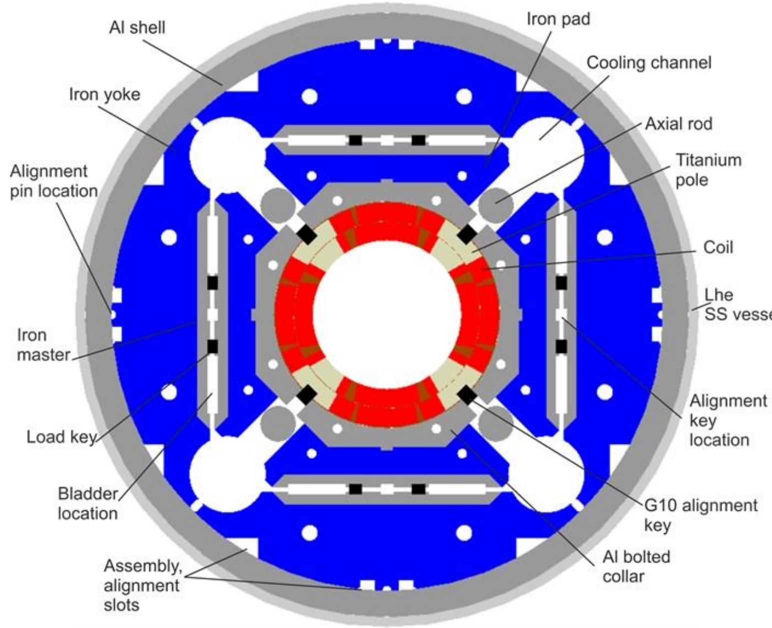
1. So far, 10 training quenches 1500 – 2000 A lower than MQXFAP1.
2. All four coils have quenched, with Coil 104 being the most frequent and in the last 4.
3. Quench antenna and voltage taps show that all quenches are located in the inner layer pole turn and most probably near or in the nonlead end section.
4. MIIts values have been within safe threshold.
5. Power supply ground currents have been nominal with no anomalies.
6. So far, relief valves have not opened after quench, resulting in no loss of He gas, verifying the design of the upgraded He recovery system.
7. Measurement of flux jump spikes have been successful and have allowed the lowering of voltage thresholds during ramps.
8. Magnetic field measurement system has been commissioned and operated successfully.
9. MQXFAP2 cold testing is still underway at present.

THANK YOU FOR YOUR ATTENTION

EXTRA SLIDES

Scope and Deliverables

MQXFA NOMINAL PARAMETERS AND DESIGN



Coil inner aperture :	D = 150 mm
Coil magnetic length:	L = 4.2 m
Coil actual length:	L = 4.523 m
Yoke length	L = 4.5629 m
Total length with end plates	L = 5 m (nom)
Operational temperature	**T = 1.9 K**
LHC nominal operating current (1.9 K)	**I_{nom} = 16.470 kA**
LHC ultimate operating current (1.9 K)	**I_{ult} = 17.890 kA**
Maximum current (300 K)	I_{300} = 15 A
Conductor limit at 1.9 K:	I_{ss} = 21.000 kA
Conductor limit at 4.5 K:	I_{ss} = 19.017 kA
Peak field in the coil at I_{nom} (1.9 K):	B_{nom} = 11.4 T
Peak field in the coil at I_{ult} (1.9 K):	B_{ult} = 12.3 T
Field Gradient at I_{nom} (1.9 K):	G_{nom} = 132.6 T/m
Field Gradient at I_{ult} (1.9 K):	G_{ult} = 143.2 T/m
Magnet resistance at room temperature:	R = 2.37 Ω
Magnet inductance (at 1.9 and 1 kA) :	L = 43.0 mH
Magnet inductance (at 1.9 and I_{nom}=16.5 kA) :	L = 34.4 mH
Operating stored energy (at B_{nom}, I_{nom}):	E_{max} = 4.67 MJ assuming L=34.4 mH
Ultimate stored energy (at B_{ult}, I_{ult})	**E_{max2} = 5.50 MJ assuming L=34.4 mH and I_{ult}=18 kA**
Maximum allowed temperature at quench:	T_{max} = 250K (training); 350K (protection studies)
Maximum allowed voltage across magnet	V_{max} = 1000 V (500 V to ground) with 50 mΩ EE
Dump resistor (energy extraction) options	R_D = 30, 37.5, 50, 75, 150 mΩ

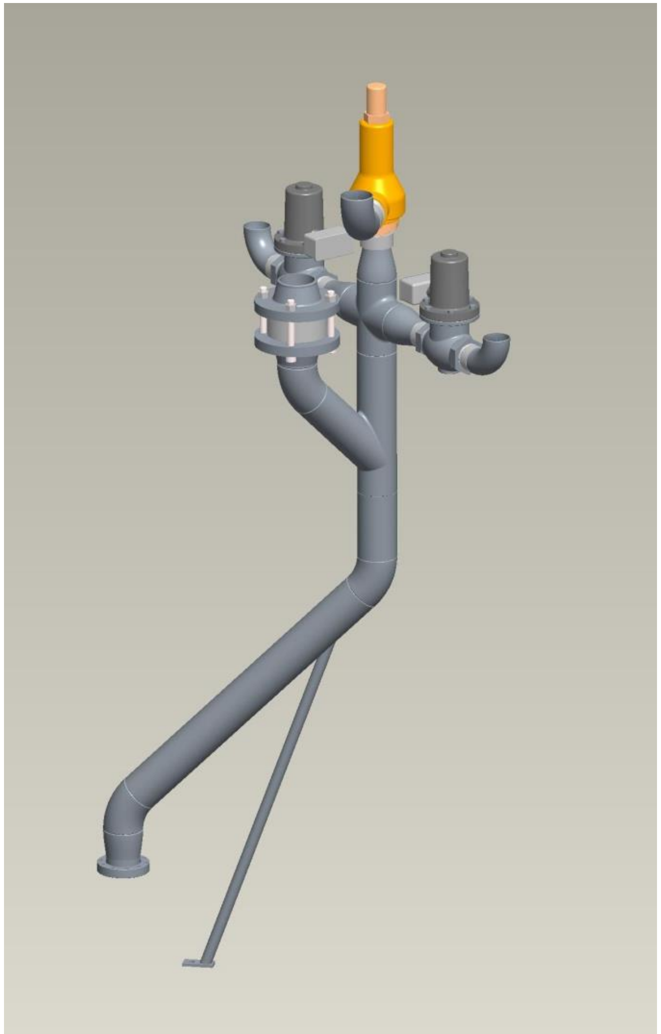
The four coils are connected in the following order from the positive lead (Tap WC+) to the negative lead (Tap WC-): 102 → 106 → 104 → 105.

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)

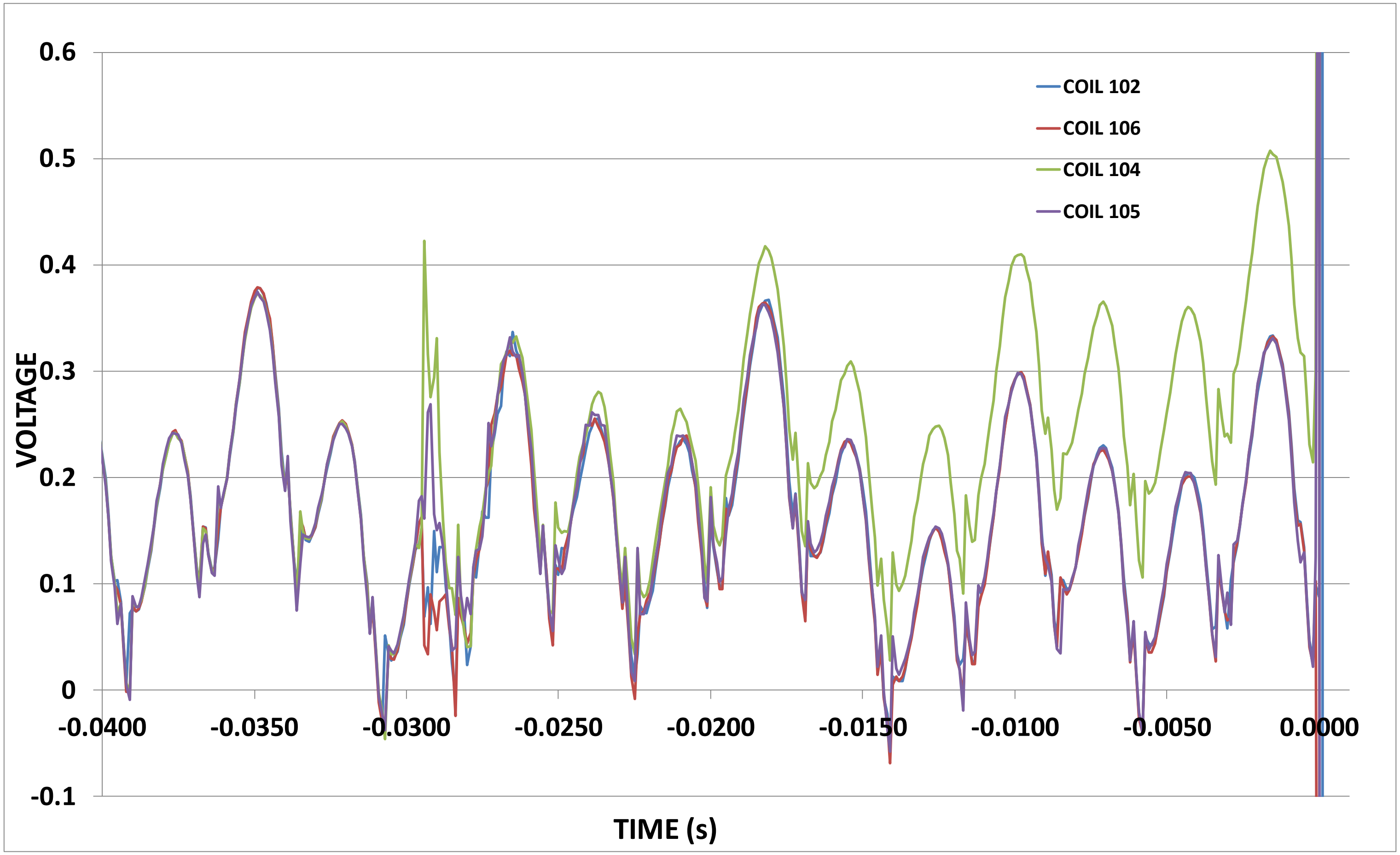


Buffer Dewar relief stack is identical except that it does not have the 3” solenoid valve.

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

This slide courtesy of A. Marone

Test Results – Precursor Spikes



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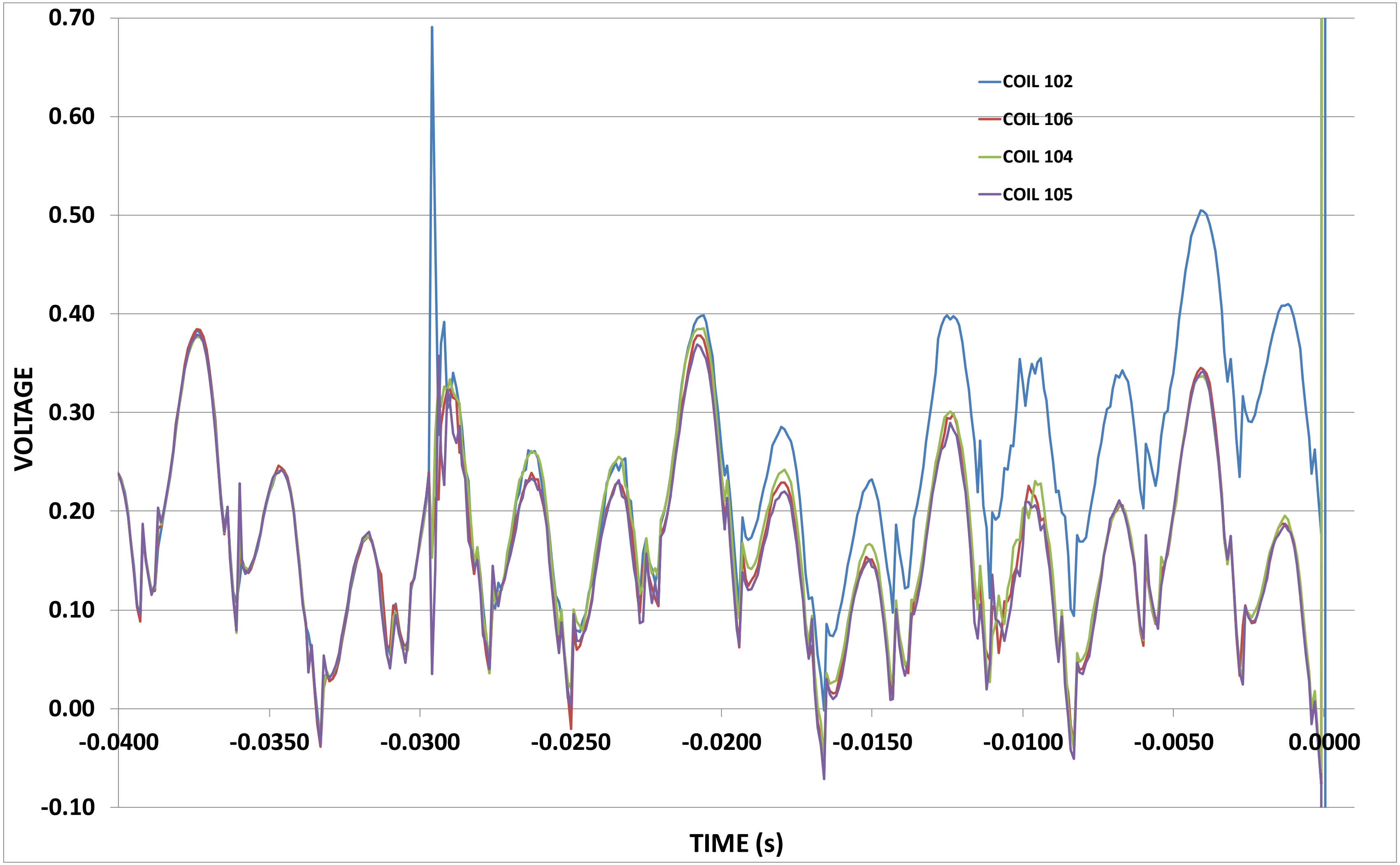

Test Results – Precursor Spikes