Brookhaven National Laboratory
Superconducting Magnet Division
27-Oct-2004
(revised 2-Dec-04)
(revised 21-Jan-05)
J. F. Muratore

TEST PROCEDURES FOR D3 (PRODUCTION DUAL APERTURE LHC DIPOLES) IN HORIZONTAL TEST BAY C

RUN PLAN

The dual aperture D3 consists of two D1-type cold masses in a single cryostat, different from a D2 or D4, which have two coils in a common cold mass. However, the two cold masses will be run in series, so most procedures and operations will not change from the run plans of the D2 and D4 magnets. Electrically it will look the same except for extra taps since there are four leads instead of two.

The lead flow controller scheme may need some modifications at the beginning. Also, there may be some deviations in quench testing if only one cold mass quenches since a quench must be performed on both during the course of testing.

As for the other LHC magnets, this note documents the procedures (e.g., cold checkout, quench testing) used during magnet testing in Horizontal Test Bay C. The test history (quench currents, number of cooldowns, etc.) is recorded in a separate note.

Note: In the following run plan, some parameters, such as data logger sampling rate, quench detector settings, and ramp rate, may have been varied according to testing conditions and needs.

NOTES:
Warm bore tubes installed.
Cold magnetic field measurements are to be done.
Energy extraction with dump resistor (SCR voltage nonzero) is to be used.

I. INITIAL ROOM TEMPERATURE CHECKOUT AND MEASUREMENTS

Note: All warm and cold checks must be okayed at each step by appropriate personnel

I.1. Leak check of cryostat by vacuum group.

I.2. Standard electrical checkout by electrical and test groups.
Verify that the magnet is not under vacuum or not being pumped on when doing the shift test. There should be at least one atmosphere present.

1. Hipot of main coils to ground; all other systems grounded
2. Hipot of each quench (strip) heater circuit to ground
3. With ohmmeter, measure the following resistances:
   a. Coil to ground, to strip heaters.
   b. Strip heaters to ground.

c. Across all strip heaters.
d. Check main taps for continuity by measuring the resistances of all taps (each tap has 200 ohm resistor).
e. Series resistance check of all taps.

I.3. Record the total coil resistance for use later while monitoring the warmup.

I.4. Warm level shift test (1 A)
Make sure that the strip heater power supplies are properly set up before initiating the shift test. The strip heater power supplies should be on a dummy load and set to not more than 20V during this test. Verify that the magnet is not under vacuum or not being pumped on when doing the shift test. There should be at least one atmosphere present. Set loggers at 1kHz. Note: After the first D2 magnet, and if no changes were made to the data acquisition system or signal connections, the level shift test may be omitted if time does not allow.

I.5. Warm magnetic field measurements in Bay C
NOTE: Before installing a mole into either aperture, the straightness of the warm bore tube must be verified by passing a dummy of the correct dimensions through.
Also, take reads in the permanent magnet before and after each z-scan.
There are 10 z positions for z-scans.
1. Install the mole into the right or left aperture.
2. Perform full z-scan. Take read of +/- 10A at each position.
3. Repeat in other aperture.
4. Data from z-scans must be analyzed before beginning cooldown.

I.6. Miscellaneous checks
1. If any work has been performed on the main power supplies, such as repair of water leaks, make sure that all control equipment and buckets have been returned to nominal operational status. Operate the power supply in short circuit to 8.5KA to verify nominal operation.
2. Check the quench protection heater (strip heater) power supplies and verify that both are set to maximum voltage (about 500V) and that the interlock voltage is correctly set for this voltage. Also make sure the plate which covers the interlock voltage pot dial is correctly installed. The strip heater power supplies are to be left at the maximum setting for the remainder of cold testing.

COOLDOWN TO 4.5K BY FORCED FLOW COOLING AT 12 ATM

II. COLD CHECKOUT (PRELIMINARY MEASUREMENTS AT 4.5K, 12 atm)

NOTE: The cold checks in II.1 - II.5 (resistances, voltage tap checks, etc) can be done when the magnet temperature is 7K or less if this benefits the test schedule. Remember that all power supply shutoffs and strip heater quenches must be done only when the magnet has reached 4.5K.

II.1. Cooldown magnet to 7K or less. Prior to cooldown, the operators should verify that
a) cold mass leak check has been done by cryogenics group;

b) there is water to the leads; and
c) the fans and heaters for the leads are operating.

II.2. Make sure that SCR voltage is set to prescribed voltage for all tests. Dump resistor should be set as prescribed.

II.3. Hipot tests by electrical group.
It is OK to perform this test at 7K, but verify that there is at least 2 atm He pressure.
1. 500V hipot of main coils to ground; all other systems grounded
2. 500V hipot of each quench (strip) heater circuit to ground

II.4. With ohmmeter, measure the following resistances:
1. Coil to ground, to strip heaters.
2. Strip heaters to ground.
3. Across all strip heaters.
4. Check main taps for continuity by measuring the resistances of all taps (each tap has a 200 ohm resistor).
5. 1A ac measurements of coil inductances

II.5. 1A level shift test (to be done only if there was an unusual result in the cold checks in Part II.4). Set LeCroy fast data loggers to 1kHz. Leave strip heater power supplies set at minimum voltage and connected to heaters.

II.6. Connect magnet to main power supply at link box.

NOTE: The magnet must be at 4.5K for the remainder of the cold checks.

II.7. Balance Idot quench detection circuit for ramp rate of 20A/s.

II.8. Standard test conditions:

1. Quench Detection Circuit (QDC) Threshold

1: Left-Right Magnet (delta)	0.6 V
2: Magnet - Idot	4 V
	10V (when turning on power supply)

2.

Function	Delay
Delta QDC	1 ms
Idot QDC	1 ms
Strip heaters	1 ms (minimum setting)

3. Threshold for gas-cooled lead voltages:
Set flags on monitor page to 80mV.
Critical threshold is 150mV.

4. Strip heater power supply capacitance at 21,700 uF.

5. Dump resistor at 35 mohms.

NOTE: A fuse in the power supply circuitry protects the power supply from ground faults and ground fault currents are indicated by a warning light in the control room. Ground fault current is fully instrumented to both fast and slow data loggers.

II.9. Crash button tests at 25A (if necessary).

II.10. Power Supply Shutoffs

1000A power supply shutoff:

Purpose: to check quench detection, power supply, and data acquisition systems before actually initiating a quench.

1. Set LeCroy logger time base to 1kHz.
2. Set SCR voltage to 500V.
3. Set strip heater delay to 1ms.
4. Set strip heater power supply voltages. Use minimum voltage (about 20V) on both heaters.
5. Ramp magnet to 1000A at 20A/s.
6. Manually trip the delta (voltage difference) quench detector circuit.
6. Examine all quench signals for proper behavior.

4000A power supply shutoff:

Purpose: to obtain baseline coil voltage signals before performing the 4000A strip heater quench.

5. Set LeCroy logger time base to 1kHz.
6. Set SCR voltage to 1200V.
7. Set strip heater delay to 1ms.
8. Set strip heater power supply voltages. Use minimum voltage (about 20V) on both heaters.
5. Ramp magnet to 4000A at 20A/s.
6. Manually trip the delta (voltage difference) quench detector circuit.
7. Examine all quench signals for proper behavior

III. TEST OF STRIP HEATERS

III.1. Strip heater quench at 4000A:

Purpose: to check strip heater performance at 4000A.

1. Set LeCroy logger time base to 1kHz.
2. Set SCR voltage to 1200V. Dump resistor at 35 mohms.
3. Set strip heater delay to 1ms.
4. Set both strip heater power supplies to a voltage determined by the results from previous strip heater tests on earlier magnets. For D2L105 and later magnets, use maximum voltage (about 500V) on both heaters.
5. Ramp magnet to 4000A at 20A/s.
9. Manually trip the delta (voltage difference) quench detector circuit.
7. Examine all quench signals for proper behavior.
8. Verify that the four coils quench <200 ms after heater firing. Check current and voltage waveforms. Use the baseline coil voltage signals from the 4000A power supply shutoff in Part II.10 above to help verify that all four coils have quenched.
9. Calculate the MIITs value for this quench and verify that it does not exceed the maximum safe value for this magnet's conductor.
10. If the criteria in (7) and (8) are not satisfied, further quench tests should be postponed until this is resolved.

IV. QUENCH TESTS AT 4.5K, 12 atm

IV.1. Quench Tests
Strip heater power supplies should be set at maximum voltage (about 500V for all cold testing.
Set SCR voltage to 1700V. Dump resistor at 35 mohms.
For the first quench, ramp up to 5000A at 20A/s, and remain at 5000A and carefully monitor lead voltages until lead voltages are at safe levels. Then continue to ramp at 20A/s to 6500A or until the magnet quenches, whichever comes first.
During the entire ramp, observe the lead voltages carefully and verify that they are at safe levels. Also watch for unusual increases in lead voltages. Take monitor page reads during the entire ramp and 5000A step. Fast data loggers at 1kHz sampling rate.

If the magnet quenched before reaching 6500A, then continue training the magnet, by repeating the above quench test, until it can reach 6300A without quench.

NOTE: If the magnet reached 6500A without any quenches, then continue ramp at 20A/s to quench.

IV.2. 5 power cycles to 6500A (if time allows).
SCR voltage at 1700V. Dump resistor at 35 mohms.
Fast data loggers at 1kHz sampling rate.
Perform five current cycles at 20 A/s ramp rate.
For each cycle wait at 6500A flattop for 5 min.
Take monitor reads during cycles and flattops.

IV.3. Operation at 6500A (if time allows).
SCR voltage at 1700V. Dump resistor at 35 mohms.
Fast data loggers at 1kHz sampling rate.
Ramp magnet to 6500A at 20A/s.
Take monitor reads during 1 hour flattop.

IV.4 Quench test with one warm bore tube open (if needed).
NOTE: If, during the above quench tests, one aperture did not quench, then open the warm bore of the one which did not quench and allow it to warm up. Then ramp at 20A/s to quench, as described above. Hopefully the magnet that did not quench before will quench this time.

V. QUENCH TESTS AT 4.5K, 1.4 atm liquid He

Note: This test may be done after the magnetic field measurements if it benefits the schedule efficiency.

V.1. Switch to liquid helium bath cooling (pool boiling) at 4.5K, 1.4 atm.

V.2. Repeat quench test procedure in IV.1.

V.3. If magnet quenches at 6000A or above, then stop.
If magnet quenches below 6000A then train as above until it reaches 6000A.

VI. LEFT MAGNETIC FIELD MEASUREMENTS WITH MOLE RA2 AT 4.5K, 12 ATM

Open warm bore tubes and allow them to reach nominal operating

temperature before insertion of the mole.

Take reads in the permanent magnet before starting measurements and after finishing measurements for the day.

VI.1. Set up the transporter and install the mole RA2 into the left warm bore tube.

VI.2. Perform the following DC loop at position #5 and a DC loop up ramp at each of the other 9 axial z positions. These should be the same positions that were used for the warm z-scan.

DC loop to 5900A.
Specific current levels should include the following: 200A; 300A; 350A; 400A; 600A; 800A; 1200A; 1600A; 2000A; 2400A; 2800A; 3200A; 3600A; 4000A; 4400A; 4800A; 5200A; 5600A; 5900A.

The same set of currents should be used for the down ramp at one axial position (#5), and for the up ramp at all 10 positions.

1) AC cycle to 5900A at 10A/s.
2) DC loop to 5900A at 10A/s.

Note: The Imax current may vary depending on the magnet quench performance with the warm bore tube open and warm.

VII. RIGHT MAGNETIC FIELD MEASUREMENTS WITH MOLE RA2 AT 4.5K, 1.4 ATM

VII.1. Remove the mole from the left aperture, reposition the transporter, and install the mole in the left aperture.

Remember to take reads in the permanent magnet before inserting the mole into the other aperture. And as before permanent magnet reads should be taken before measurements start for the day and after measurements end for the day.

VII.2. Repeat measurements done in Part VI above.

VIII. DYNAMIC MAGNETIC FIELD MEASUREMENTS WITH FAST COIL #71 AT 4.5K, 1.4 ATM IN ONE APERTURE (This is to be done on one D3 magnet only)

VIII.1. Quench magnet at 20A/s, 1kHz logger speed
VIII.2. Take fast measurements during various ramps, which will be specified at the time of testing. A specific run plan for dynamic measurements will be provided at time of testing and will follow the D1 dynamic measurements run plan. It will include time decay, snapback, and AC loop measurements.

Note: The Imax current may vary depending on the magnet quench performance with the warm bore tube open and warm.

IX. WARMUP

IX.1. Monitor the total magnet coil resistance as warmup proceeds.

IX.2. When the total magnet coil resistance reaches the value measured in Part I.1, stop the warmup.