ACCEPTANCE SUMMARY FOR LHC MAGNETS BUILT AT BNL

Magnet D3L103

Date of this summary: April 5, 2006

This document contains a short summary of the acceptance status (in italics, just below), the minutes of the acceptance meeting, and actions taken after the acceptance meeting [in square brackets within the text of the minutes, or as footnotes].

Acceptance status:

The BNL Acceptance Committee met on December 13, 2005. The approvals needed for acceptance were completed on December 15. The field quality data and survey data were sent to CERN before the meeting. The ID card was sent to CERN on December 15. Data from the final electric check were sent by air to CERN on Dec. 28.

In January, CERN reported that D3L102 failed hipot during incoming inspection. This failure was traced to abrasion of the kapton insulation of the leads, abraded by the inside wall of the end dome during transit. A plan was developed to cover the region of abrasion with additional insulation in all three D3's (waiver M0345). CERN requested that BNL verify that the repaired magnet would satisfy CERN requirements for magnet lifetime. Documentation of this work is appended to these minutes [2], [3]. This magnet was accepted by CERN on March 14.

MINUTES OF ACCEPTANCE MEETING

Date of acceptance meeting: December 13, 2005

Present at acceptance meeting: Cozzolino, Escallier, Hocker, Jain, Muratore, Pilat, Plate, Porretto, Wanderer

Quench Data: Muratore discussed the quench performance of the magnet. The magnet was cooled with liquid helium for the quench tests and field quality measurements (rather than forced flow), to overcome the limitations discussed in the acceptance minutes for D3L102. Muratore noted that the quench performance of this magnet was not as good as that of the other D1 and D3 magnets. Since the magnet was tested in liquid helium, with the bore tube evacuated, magnet cooling was not the source of the quenches. (His summary quench plot includes quenches in the first two D1's that are due to poor cooling. These quenches are to be excluded when comparing the quench performance of the magnets.) The quenches originated in three of the four half-coils. Muratore said that all the quenches had precursor voltage spikes, indicative of a mechanical origin. The azimuthal coil sizes are larger than those in D3L102, so low coil preload is not the source of the problem in any obvious way.

The magnet did operate at the current maximum specified current, 6500 A, without quenching. However, it sometimes quenched 20 A to 50 A below that. The quench performance was discussed with R. Ostojic at the time of the test. Since the quench currents were still well above the 7.56 TeV operating current, 6300 A, this performance was accepted by R. Ostojic. Muratore's slides are available at www.bnl.gov/magnets/LHC_Acceptance

Field Quality: Jain showed the warm and cold data from the magnet. (His talk is available at the address given above.) The warm integral transfer function (ITF) was measured both before and after cold testing (slide 4), by ramping the magnet and using a long stationary coil. The difference between the "before" and "after" ITF's is the same as the difference between the warm "before" ITF's of the D3's and the "after" ITF's of the D1's, indicating that difference between the warm ITF's of the D1's and D3's is an artifact of the test conditions.

Warm body TF's were measured with a 1m long rotating coil. The D1's were measured at currents up to ± 20 A, whereas the D3's (which had twice the resistance) could only be measured up to ± 15 A. Measurements on D3L103 showed that the difference in current produces a difference in measured TF which is opposite in sign and essentially equal to the difference in the "before" and "after" effect (slide 5). This is the reason that the D1 and D3 warm TF's are measured to be the same, whereas the warm ITF's are not.

The harmonics are generally small and close to measurements made on the other magnets in the series. However, the warm integral normal even-n harmonics of the left aperture were more negative than expected by about two standard deviations. The reason for this (expected to be a left-right asymmetry) is not known. However, the actual values of the harmonics are small.

Pilat said that the field quality of the magnet was satisfactory.

The Field Quality data were loaded into the CERN database on August 1.

Engineering: Escallier reported that the data from the final electric check had an anomalously low value of the inductance, ~ 4 mH, compared to the expected ~ 27 mH. The value of Q was also much lower than expected. Escallier conjectured that these low values would be measured if the voltage taps had been accidentally connected together during the measurement. This might have occurred because the measurement immediately prior to the inductance measurement was a hipot.

L and Q were measured immediately after the acceptance meeting, and the expected values found. It was concluded that the low values were a wrong measurement, not a magnet fault. A DR has been written to document this.

Cozzolino and Plate reported that the mechanical construction of the magnet was acceptable.

QA: Hocker reported that all, except for the anomalous inductance result reported by Escallier, all outstanding DR's were of the "use as is" type that did not need concurrence from CERN. The waiver describing changes to the "prep to ship" for the D3's (to ship with dry nitrogen inside) is not yet completed.

Safety: Durnan reported by email that the documentation for the magnet met the safety specifications [1].

Survey: Cozzolino said that he had reviewed the survey data and found them acceptable. The data were sent to R. Ostojic on December 5.

These notes written by P. Wanderer

[1] Email from Durnan to Wanderer, 14 December 2005:
Re: D3L102 magnet acceptance
I have reviewed my records and have no safety concerns with this magnet.
Jim Durnan

[2] CHECKING THAT THE REPAIR OF THE D3 EXPANSION JOINT INSULATION MEETS THE LHC REQUIREMENTS FOR MAGNET LIFETIME.

Feb 27, 2006 – P. Wanderer

1. 25 thermal cycles.
We are setting up to test the resistance of the Nomex to abrasion by the inside of the end volume. We will use a RHIC CQS expansion joint, which is almost identical to the D3 expansion joints. After the Nomex is put on the expansion joint, the expansion joint will be mounted inside a spare section of end volume in the same way that the expansion joints are situated in the D3 end volumes (i.e., with the Nomex against the inside surface of the end volume). The expansion joint will be cycled 250 times ± 0.5 inches (~ 12 mm), a distance nearly a factor of two larger than the expected ± 0.3 inches (~ 7.5 mm).

2. 10 to 100 quenches.
The concern here is expansion joint flexing due to the sudden rush of gaseous helium. The section of expansion joint that rubs against the end volume is near the end of the volume, about as far as possible from any gusts of helium, which will come from the bypass holes in the yoke and the beam tube. The effect of any motion due to quenching will be taken account of by the large number of simulated thermal cycles.

3. 12,000 power cycles.
We need to establish an upper limit to the magnetic field where the expansion joint touches the end volume. The negative and positive leads are separated by ~ 20 – 30 mm in this region, so the Lorentz forces on the expansion joint are largest here. Ramesh is checking his previous calculations of RHIC fields.

[3] EFFECT OF CYCLING ON D3 EXPANSION JOINT INSULATED WITH NOMEX.
P. Wanderer, 6 March 2006

Ramesh Gupta estimates that the magnetic field near the point where the insulated expansion joint touches the end volume is at most a few mT. The distance between this point and the beam position at end of the magnet is about 250 mm (10”) along the axis, 150 mm (6") along the radius, and about 45º below the horizontal. Ramesh estimates this based on his experience modeling RHIC arc dipoles. In calculating the force on the conductor, it is assumed that the field is 10 mT and oriented perpendicular to the current in the expansion joint at the point of contact.

Near the point of contact, the two conductors of the expansion joint are separated by about 25 mm (1") over a distance of about 75 mm (3"). The conductors are approximately vertical. At 6.5 kA (slightly above the maximum current in the D3's), the force on a single conductor is at most

$$F = I \times L \times B = 6.5\ kA \times 75\ mm \times 10\ mT = 4.9\ N \sim 5\ N\ (1\ pound)$$

If the field is the same at both conductors, there will be no net force on the expansion joint. The field will have at least some gradient. For this note, it is assumed that the net force is 1 N directed along the axis of the beam. (The direction chosen is the one that produces the greatest motion.) The effect of cycling the lead in response to this force is discussed below.

Note that the lead end of the D3 magnets will not be spliced to another device. Instead, the D3 leads will be spliced to a round cable and the splice insulated and longitudinally anchored to the m/c tube. The round cable will be passed through a flexible hose to the feedbox.

To estimate the torque, it is assumed that the field is the same at both conductors. There would be a torque of maximum value

$$\text{Torque} = 2 \times 5\ N \times 10\ mm = 0.1\ Nm\ (1\ \text{inch-pound}).$$

This is a small value. Over most of its length, the two conductors are tightly bound together with Kapton tape insulation. Near the point of contact, where the conductors are separated by 25 mm, they are also held together by a G10 assembly at one end of the region of separation. Because the superconducting cable is double and soldered to stabilizing copper in this region, it is quite stiff. Cycling the magnetic field may cause a small amount of motion inside the Nomex tube but seems unlikely to cause the Nomex to move slide against the end volume. (The expansion joints of RHIC magnets are essentially the same in this region. Cycling to 5 kA has not caused the conductors to separate.)

In preparation for the test of cycling, the spring constant of the leads in D3L103 was measured. It was found that the leads just began to move along the surface of the end volume when the axial force reached 3 pounds (13 N). Recalling that the lead will be anchored against axial motion at a location just outside the end volume, it was concluded that an axial motion of ± 0.125 inches (± 3.2 mm) was several times greater than the motion that the lead would make when the magnet was cycled.

The same Nomex sleeve used for checking the effects of thermal cycles was installed on the CQS lead. The insulated lead was then installed in the spare end volume (as for the thermal cycling test) and cycled 12,000 times over a distance of ± 0.125 inches (± 3.2 mm). Only a small amount of additional wear was seen on the Nomex sleeve (photo number 63). The lead passed the same hipot test given previously (5 kV, leakage current $< 5\ \mu A$).