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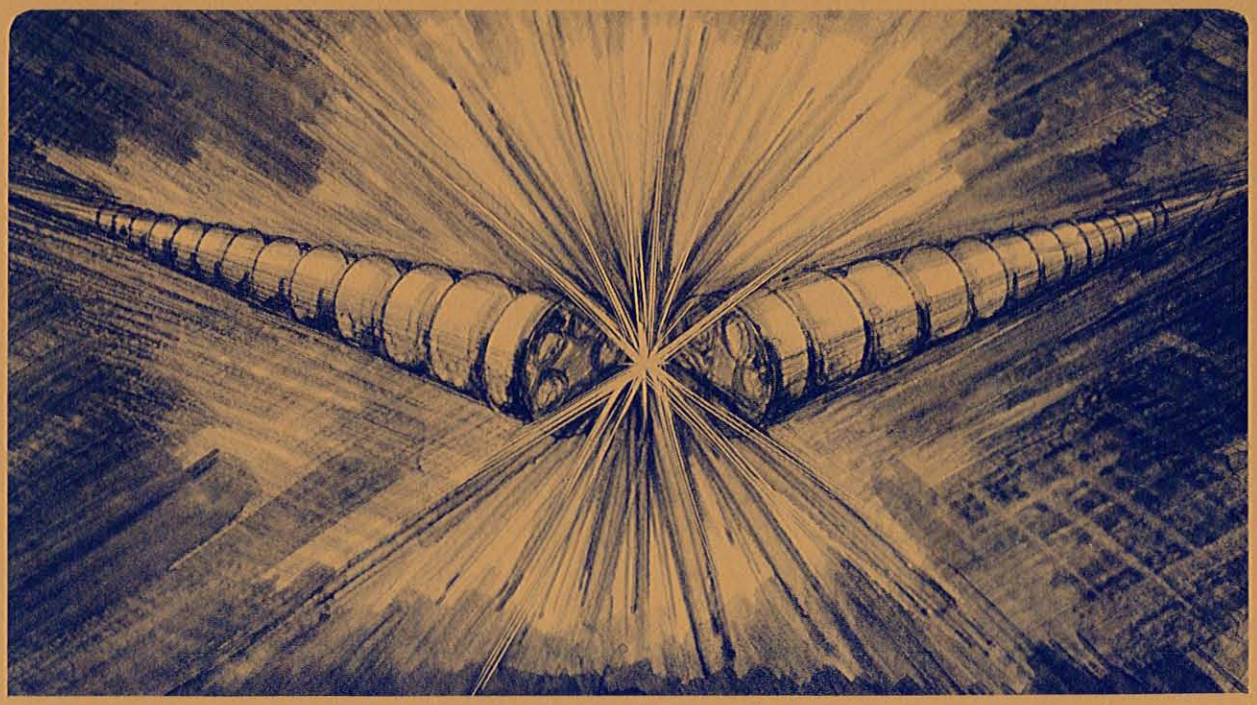
September 1990



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Introduction

Previous studies of magnetic field decay[1,2] in model SSC dipoles due to changes in magnetization currents caused by flux creep have used the assumed SSC injection energy of 1TeV, or 0.33 tesla central dipole field, and an excitation to the storage field of 6.6 tesla. More recently, it has been decided to inject at 2 TeV, or 0.66 tesla and so more recent tests have been carried out at the new injection field, or at both the new and old fields. Additionally, the effect of temperature changes and excitation cycles on the field decay have been studied.

Temperature Effect

A sextupole decay curve, at an injection field of 0.33 tesla, for dipole magnet D-15C-3 is shown in Fig. 1. The curve is roughly log linear with a slope of 0.6 unit/decade. The temperature is estimated to be 4.3K within ± 0.05K.

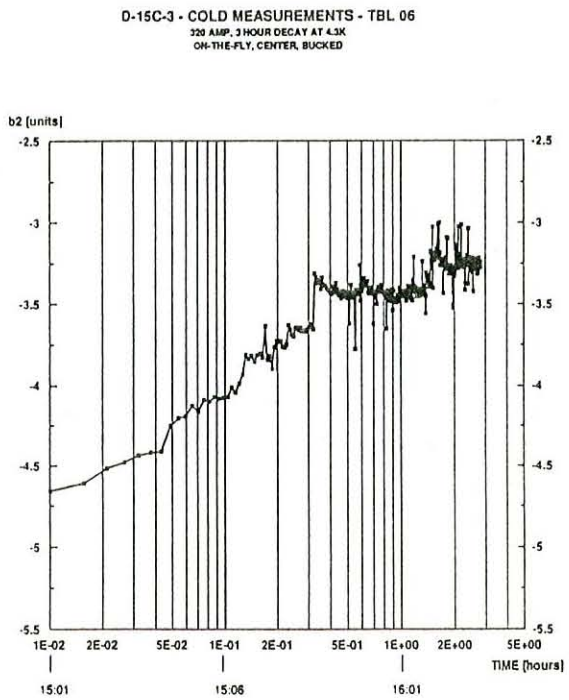

Figure 1. Sextupole Decay of Dipole D-15C-3 at 4.3K

One suggestion to prevent or reduce the field decay is to reduce the temperature after the excitation cycle has set up the magnetization sextupole field[3]. After setting up the injection field at 0.33 tesla 4.3K and allowing a half hour decay at 4.3K, we then cooled the magnet at the rate of 0.4K/hr. for the next four and a half hours. This is shown in Fig. 2. Fig. 3 is the bath temperature record. Not only did the decay stop, but the sextupole increased due to the increase in the critical current density at the lower temperature. We did not have the cryogenic control needed to quickly reduce the bath temperature a small amount and hold it constant at that lower temperature.

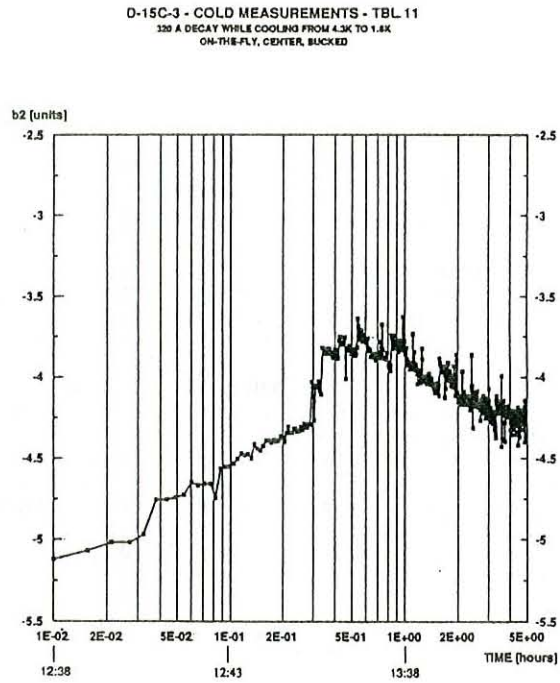

Figure 2. Sextupole Decay of Dipole D-15C-3 with Decreasing Temperature

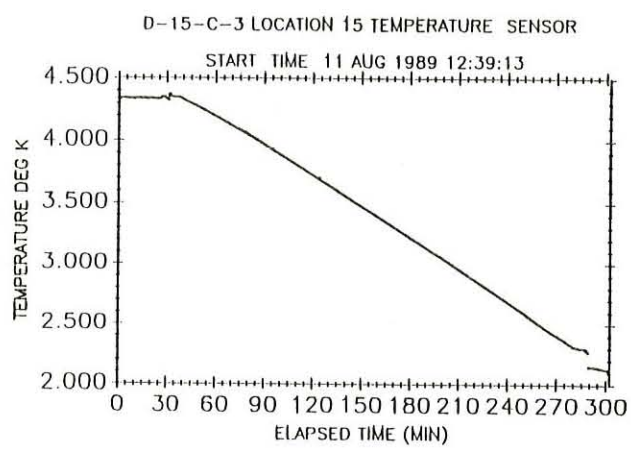

Figure 3. Temperature Record of Dipole D-15C-3

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There are arguments[4], based on tests of wire samples, that the flux creep is activated by temperature fluctuations. The experiment cited used a temperature rise of 0.5K after the magnetization currents have been set up and the authors observed a decay increase of a factor of three. Our temperature monitors in the helium bath and in the magnet body only indicate a temperature variation of ±0.05K over a one hour period. Therefore, we doubt that this is a principal cause of the observed field decay in the dipole magnets. Fig. 4 shows the temperature variation of one of the carbon glass sensors in the helium bath. The excursions between 25 and 35 minutes are due to the initiation of the HeII cooling cycle.

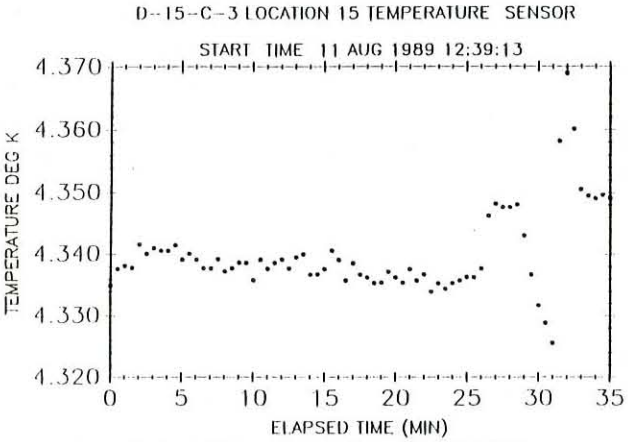

Figure 4. Initial Temperature Record of D-15C-3

We also have decay data on a SSC-model quadrupole. Fig. 5 shows the 12 pole decay with time. The decay is similar, though smaller in magnitude, to that seen in the dipoles. In this case, we have temperture data taken during the decay, both inside the magnet and in the helium bath. Both sensors are carbon glass. The helium bath is coupled to a helium refrigerator and fluctuations in the compressor return pressure result in changes in the bath temperature. This bath temperature record is shown as Fig. 6. The temperature sensor inside the magnet seems to lag the bath temperature by several minutes, and is shown as Fig. 7. Short term fluctuations are in the few millikelvin range, and over the longer time the maximum temperature change was less than 50 millikelvin. Fig. 8 shows the temperature inside the magnet for a portion of the set up cycles, to 6.6 tesla, for the first 35 minutes; and for the decay between 35 and 60 minutes.

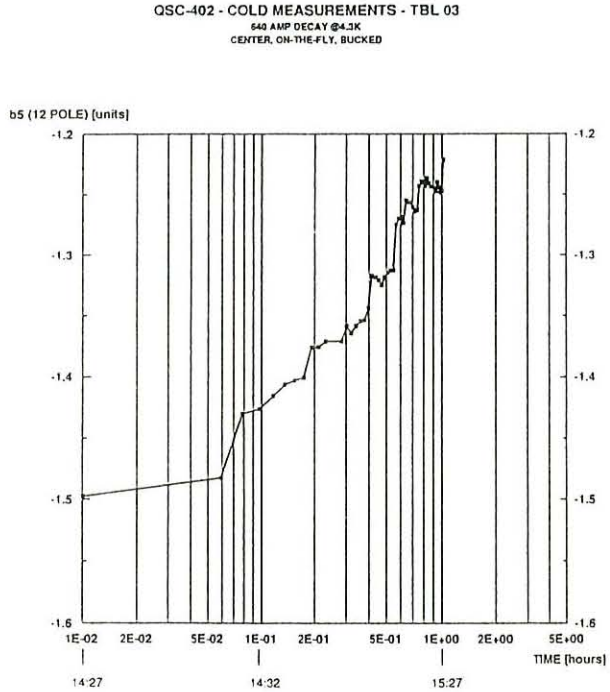

Figure 5. Cold Measurements QSC-402

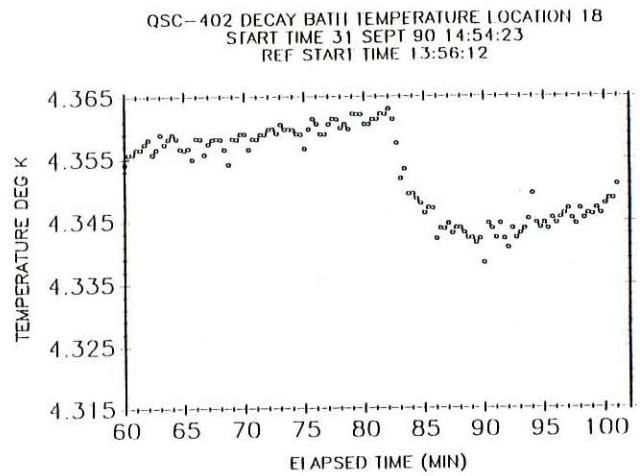

Figure 6. Decay Bath Temperature QSC-402

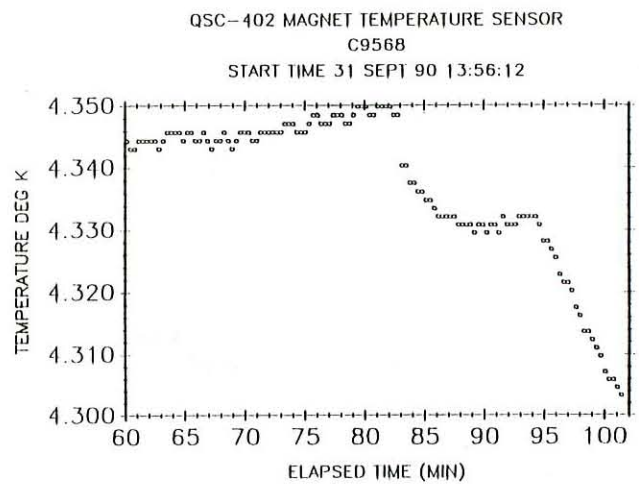

Figure 7. Magnet Tempertaure Sensor QSC-402

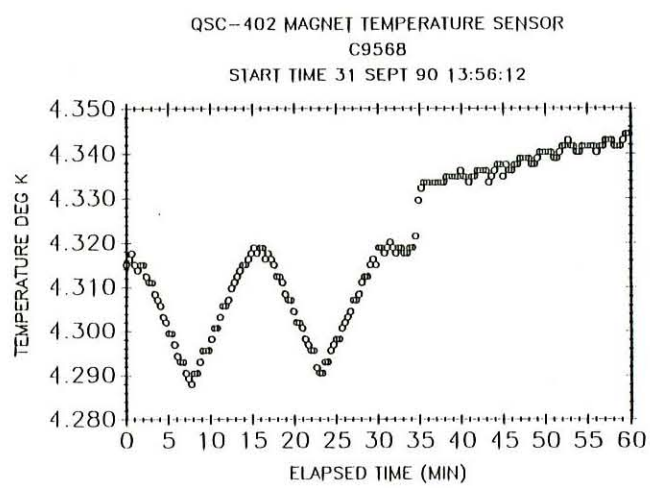

Figure 8. Magnet Tempertaure Sensor QSC-402

Effect of Maximum Magnet Field

It was observed, at DESY[5,6], that the observed field decay was influenced by the maximum field the magnet was cycled to before the injection field was measured for field decay. In our dipole D-15B-2, we cycled at 4.3K to different peak fields before measuring the decays at 0.33 tesla. The setup cycles are listed on Fig. 9. The maximum currents for the various cycles were 750, 1500, 3000, & 6000 amperes (6 tesla). The decay curves are shown as Fig. 9. The curves are not very good log linear, but if we assume straight line fits, we arrive at the decay rates of Table I.

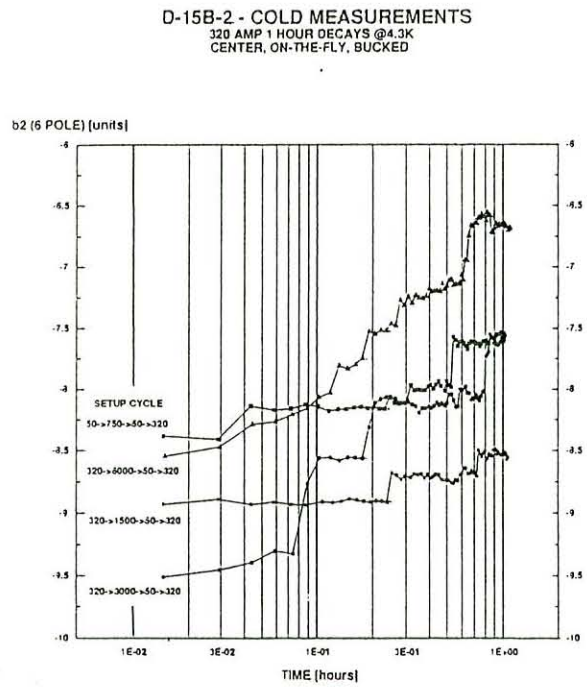

Figure 9. Sextupole Decay of D-15B-2 at 320A

Table I

0.33 Tesla Injection Field

Max I	Decay rate units/decade
750	0.25
1500	0.30
3000	0.90
6000	1.25

Fig. 10 shows the same type behavior for the 2 TeV injection energy, or 0.66 tesla. The decay rates are shown in Table II.

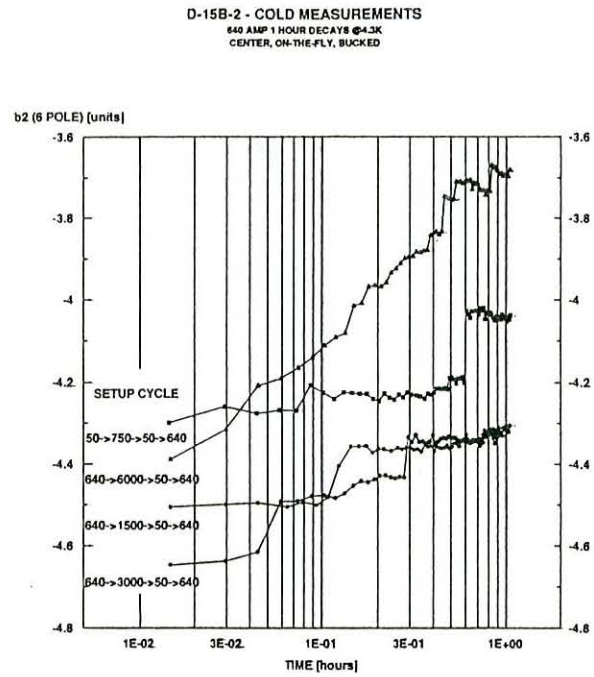

Figure 10. Sextupole Decay of D-15B-2 at 640A

Table II

0.66 Tesla Injection Field

Max I	Decay rate units/decade
750	.07
1500	.10
3000	.18
6000	.40

Clearly, we see that the decay rate is larger when the peak current, or peak field is higher. Also the decay rate, and magnetization, are less when the higher injection field is used.

Fig. 11 shows the sextupole field decay for a larger 5cm aperture dipole, D-16B-1 with peak current values of 3000 and 6000 amperes and an injection current of 640 amperes. In this particular magnet, a passive superconducting corrector was installed in the bore tube so a large portion of the magnetization sextupole and decay were corrected out. Even so, we see that the decay for the 6000A setup cycle was almost double that of the 3000A sextupole, 0.27 unit/decade vs. 0.14 unit/decade.

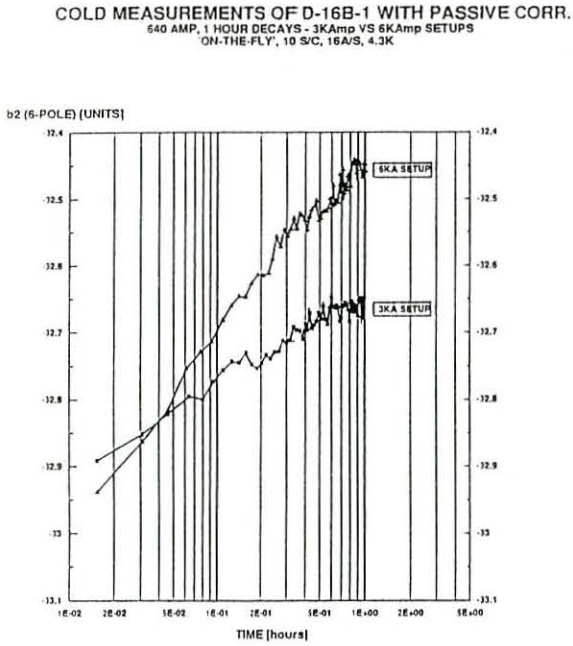

Figure 11. Sextupole Decay of D-15B-1

Summary

The roughly log linear decay of magnetization current multipole fields has been demonstrated in several new dipoles. A suggested mechanism of thermally induced activation in the additional 0.5 Kelvin range has been effectively countered by temperature measurements that show temperature fluctuation ten to thirty times lower, over a ninety minute time period. Decay of dipole fields still do not appear to quantatively agree with magnetization decay in wire samples.

It was found that multipole field decay in dipole magnets depended on the maximum field reached on magnet excitation, with the decay faster for the greater field reached.

References

1. W. S. Gilbert, R. F. Althaus, P. J. Barale, R. W. Benjegerdes, M. A. Green, M. I. Green, and R. M. Scanlan, "Magnetic Field Decay in Model SSC Dipoles", paper presented at the 1988 Applied Superconductivity Conference, San Francisco, CA, August 21-25, 1988, LBL-25139. IEEE Trans. Magnetics, vol. 25, No. 2, 1459, 1989.

2. W. S. Gilbert, R. F. Althaus, P. J. Barale, R. W. Benjegerdes, M. A. Green, M. I. Green, and R. M. Scanlan, "The Effect of Flux Creep on the Magnetization Field in the SSC Dipole Magnets", paper presented at the 1989 Cryogenic Engineering Conference/International Cryogenic Materials Conference, Los Angeles, CA, July 24-28, 1989, LBL-26598. Advances in Cryogenic Engineering 36A, 233, Plenum Press, NY, 1990.

3. Ray Stienning, SSCL, private communication.

4. R. W. Cross and R. B. Goldfarb, "Enhanced Flux Creep in NbTi Superconductors After an Increase in Temperature", paper submitted to the Applied Physics Letters, July 25, 1990.

5. P. Schmuser of DESY, private communication from slides of his presentation "Persistent Current Effects in the HERA Magnets", at a Topical Workshop on Magnetic Fields of Persistent Currents in Superconductors, Fermilab, March 5, 1990.

6. H. Brück, et al, "Time Dependent Field Distortions from Magnetization Currents in the Superconducting HERA", to be published in Proc. 13th International Cryogenic Engineering Conference, Beijing, PRC, April 25-28, 1990.