TEST PERFORMANCE OF THE QSE SERIES OF 5cm APERTURE QUADRUPOLE MODEL MAGNETS

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INTRODUCTION

A 5 cm aperture quadrupole design, the QSE series of magnets were the first to be tested in the Short Magnet and Cable Test Laboratory (SMCTL) at the SSCL. Test performance of the first two magnets of the series are presented, including quench performance, quench localization, strain gage readings, and magnetic measurements.

Both magnets behaved reasonably well with no quenches below the collider operating current, four training quenches to plateau, and good training memory between thermal cycles. Future magnets in the QSE series will be used to reduce the initial training and to tune out unwanted magnetic harmonics.

QUENCH PERFORMANCE

Training

The training behavior of QSE101 is shown in Figure 1. Four training quenches were needed to reach a plateau current of about 8660 A at 16 A/s during the first thermal cycle. The first training quench is at 7120 A, 6% above the collider operating current of 6714 A. All four training quenches occurred in the end parts of the magnet, with plateau in the inner coil, pole turn, straight section. Because of various problems that occurred during the testing of QSE101, the first magnet tested at the SMCTL, the quenches in the second and third thermal cycles could not be localized. The magnet shows good retraining behavior with one, or perhaps two, training quenches during the second thermal cycle. Retraining behavior during the third thermal cycle was obscured by trouble with the power supply

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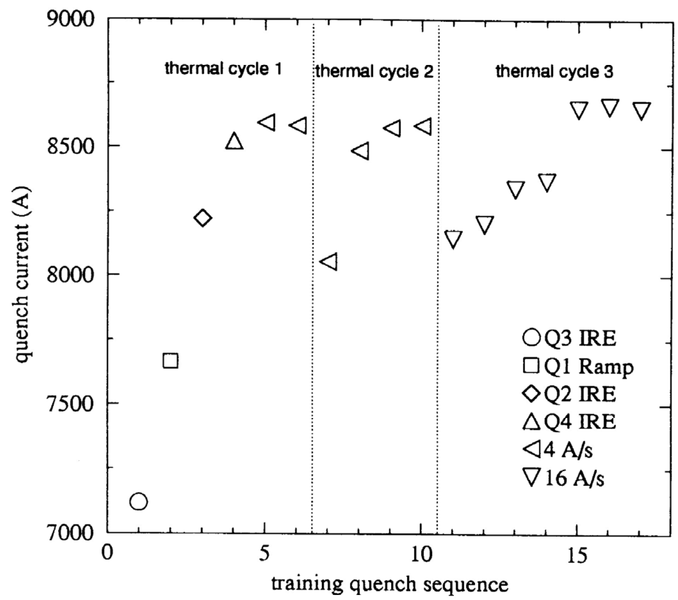

Figure 1. QSE101 training history for each of the three thermal cycles. IRE stands for inner coil, return end.

and a heat leak caused by the magnetic measurement warm bore, thus, the retraining is not thought to be representative.

QSE102 training behavior is shown in Figure 2. There are four training quenches during the first thermal cycle, all occurring in the end parts. The plateau current is about 8670 A at 16 A/s. As the magnet was being warmed up at the end of the first thermal cycle it was accidentally warmed to at least 358 K, or 85° C. The resultant thermal stresses are believed to have returned the magnet to an essentially virgin state, resulting in the complete lack of training memory exhibited by thermal cycle two. Thermal cycle three has only one training quench, demonstrating that the magnet does retain training memory between thermal cycles.

The training performance is good for both magnets, especially the training memory between thermal cycles. Almost all the training quenches occurred in the ends of the magnets, pointing to a need to refine the end parts, which were modified by hand.

Ramp Rate Sensitivity

Figure 3 shows that QSE101 has little ramp rate dependence, whereas, QSE102 exhibits a strong dependence at ramp rates above 50 A/s. At ramp rates of 75 A/s and above the quench location for QSE102 is in the ramp between the inner and outer coils in quadrant 3. The tooling for making the ramp was changed between QSE101 and QSE102 to prevent tubing of the cable in the ramp, which apparently succeeded in keeping the strands in contact with a resultant reduction of interstrand resistance in QSE102. QSE101 style ramp tooling is being used for all further QSE magnets.

QSE102 had no quenches when ramped down from 6500 A to 4000 A at ramp rates of 100 A/s, 200 A/s, 300 A/s, and 400 A/s.

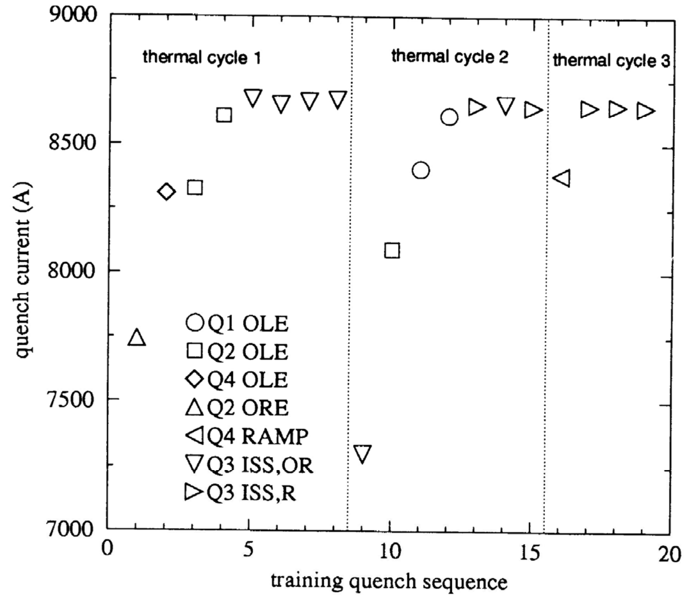

Figure 2. QSE102 training history for each thermal cycle. OLE stands for outer coil, lead end, ORE stands for outer coil, return end; ISS,OR stands for inner coil, straight section pole turn, opposite ramp; ISS,R is inner coil, straight section pole turn, ramp side.

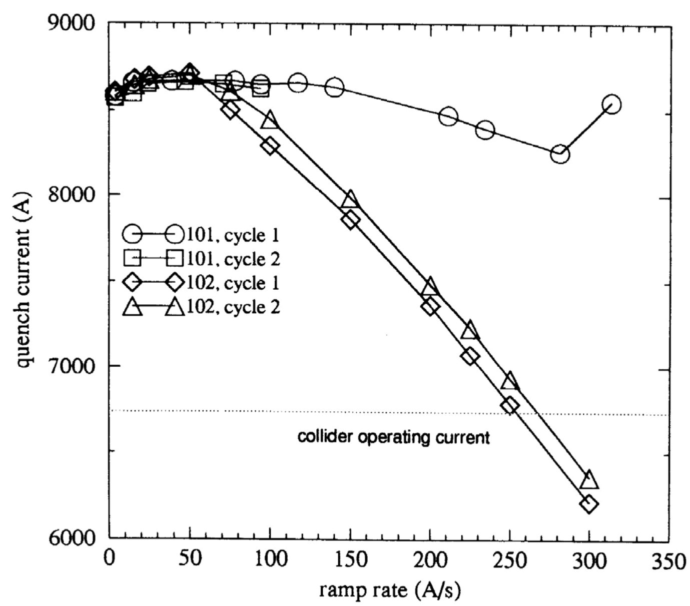

Figure 3. Ramp rate dependence of QSE101 and QSE102.

STRAIN GAGES

Average prestress measurements for QSE101 and QSE102 are shown in Table 1. The

Table 1. Average prestress measurements for QSE101 and QSE102.

	QSE101		QSE102	
	avg inner (MPa)	avg outer (MPa)	avg inner (MPa)	avg outer (MPa)
After collaring and yoking	89	95	85	86
After collaring and yoking, theory	63	45	63	45
After cool down	39	35	48	57
After cool down, theory	30	18	30	18
Energize loss (6500 A)	8	11	13	8
Energize loss, theory	10	8	10	8
Prestress loss from thermal cycle 1 to 2	-	-	26	23

prestress after collaring and yoking, and after cooldown, are greater than expected perhaps because the outer coils are oversize by about 0.2 mm. Prestress loss due to energization is about as expected. The temperature excursion experienced by QSE102 caused a loss of about 25 MPa, both warm and cold, due to either ground plane insulation creep or cable deformation.

MAGNETIC MEASUREMENTS

Magnetic harmonics measured for QSE101 and QSE102 using a 25 cm rotating coil are shown in Table 2. Coil size mismatch causes the a_2 and b_2 components, whereas, the

Table 2. QSE101and QSE102 warm magnetic harmonics in "units" at 10 A.

	QSE101		QSE102	
n	a_n	b_n	a_n	b_n
2	1.88 ± 0.04	-2.59 ± 0.04	-1.42 ± 0.03	2.27 ± 0.03
3	-1.95 ± 0.01	0.53 ± 0.01	-0.28 ± 0.01	0.52 ± 0.01
4	-0.01 ± 0.01	-0.07 ± 0.01	-0.07 ± 0.01	-0.07 ± 0.01
5	-0.10 ± 0.01	0.55 ± 0.01	0.15 ± 0.01	0.02 ± 0.01

significant a_3 and b_3 indicate that the collars have become slightly oval due to the dipole collaring technique used for the QSE magnets. Reliable cold magnetic measurements are not available.

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