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memorandum
Accelerator Technology Division
Magnet Mapping Lab

To: Distribution
From: Barlow, Duffy, Lobb, Ruminer
Phone: 5-2813
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Rotating Coil and Point Maps of the GTA Exp 2D Quads

The four electro magnet quads designed and built for GTA Exp 2D have been tested and mapped. The magnetic design of these magnets was the work of Dave Barlow and the detailed mechanical design was done by Glory Yost. These quads have a 52 mm ID, 10 cm long pole tip, and were designed to produce a gradient of 30 T/m at a current of 206 A. Before mapping the resistance and coolant flow of the coils were checked and compared to what they were calculated to be. The measured and calculated coil resistance were 0.21 Ω and 0.20 Ω respectively, and at 90 psi the measured and calculated water flow through the coils was 1100 cc/min and 1500 cc/min respectively. The difference in flow rates is most likely the result of a slight reduction of the conductor ID that occurs as the coil is wound on the mandrel. The cooling capacity of the assembled magnets was measured near the peak designed operating current. For a 40 psi pressure drop, and current of 200 A, the temperature rise of the water was measured to be 18 C, which agrees with the calculated temperature rise of 13 C, if you correct for the reduced water flow through the coils.

After these checks were complete the integral field was mapped with a rotating coil. The gradient-length product (GL) of all four magnets was found to agree within 2% of one another. A plot of the average GL vs current is shown in Fig. 1. Also shown in Fig. 1 is the GL calculated using the two-dimensional design code FLUX2D assuming a 12 cm effective pole tip length. The agreement between the measured and calculated results is quite good for currents below 200 A, but for currents of 200 A and above it appears that the magnet is saturating more than predicted. The systematic error of the coil's measurement of the GL is estimated to be ±2% due to uncertainties in the location of the coil windings, while the random error of the coil measurements should be small (<1%). The current was known to better than ±0.25%. The rotating coil was also used to measure the harmonic content of the quadrupoles. The amplitude and phase of the harmonics were found to be constant with current. The harmonic content in percent of the quadrupole field at a reference radius of 20.8 mm (80% aperture) is listed in Table I. The n=3 to n=5 harmonics were all quite small indicating that there were no errors in fabrication. The ~1% first allowed (n=6) harmonic is most likely due to the finite width of the hyperbolic pole tips. The error in determining the magnitude of the harmonics is estimated to be on the order of 0.1% of the quadrupole field.

Finally a Hall probe was used to measure the radial component of the quadrupole field, B_r, at a fixed radius along the z axis for one of the quads (Fig. 2). This data was taken to determine the extent of the fringe field and to double check the rotating coil measurements and FLUX2D calculations. The slight slope in the plot of B_r vs z is the result of a small misalignment of the axis of the Hall probe with respect to the axis of the magnet. The distance of the Hall probe's active area from the axis of the magnet was measured to be 14.9±0.5 mm. The absolute uncertainty in determining the z position is about ±0.5 mm while the relative uncertainly is less than ±0.05 mm. The error in the Hall probe's measurement of B_r is about ±1 G. The radial field at z=0 was measured to be 0.414±0.014 T at 200 A. This corresponds to a gradient of 28.6±1.0 T/m at 206 A which is somewhat less than the calculated gradient of 30 T/m. However the point map measurement of the GL at 200 A is 3.47±0.12 T which agrees within error of both the rotating coil measurement of 3.36±0.07 T and the FLUX2D calculation of 3.50 T.

Tabulated results of the data are available upon request.

Table I

Harmonics measured at 200 A.

Harmonics in % of n=2 at R=20.8 mm.

Magnet	n=3	n=4	n=5	n=6
Quad 1	0.11	0.09	0.17	1.05
Quad 2	0.15	0.05	0.06	1.09
Quad 3	0.02	0.03	0.01	1.06
Quad 4	0.05	0.03	0.12	1.09

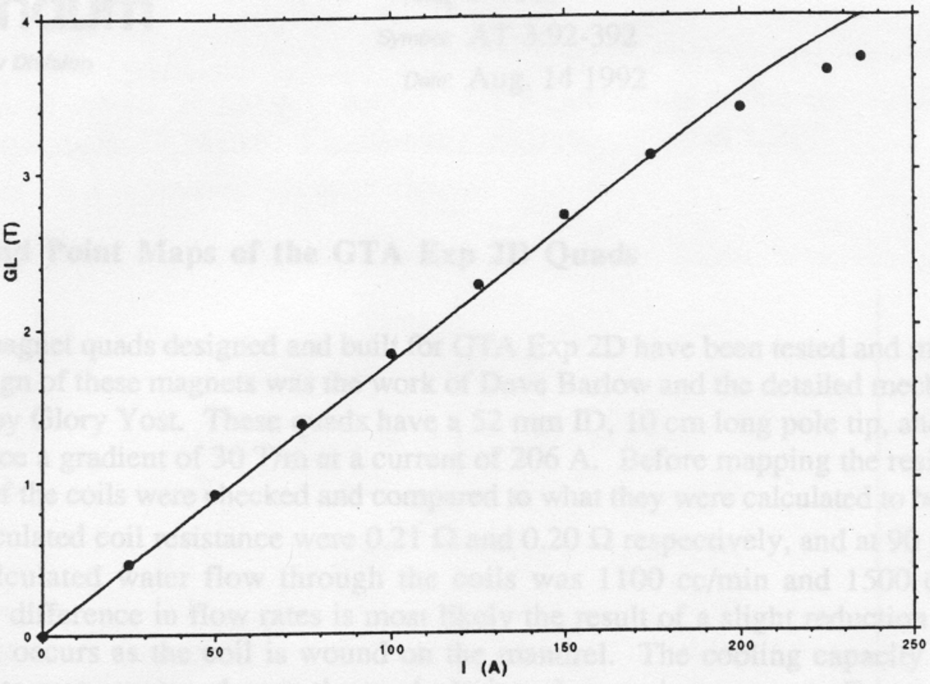

Fig. 1 Average GL vs I measured for the Exp 2D Quadrupoles (solid points). Also shown is the GL predicted by FLUX2D assuming a 12 cm long effective pole tip length (smooth curve).

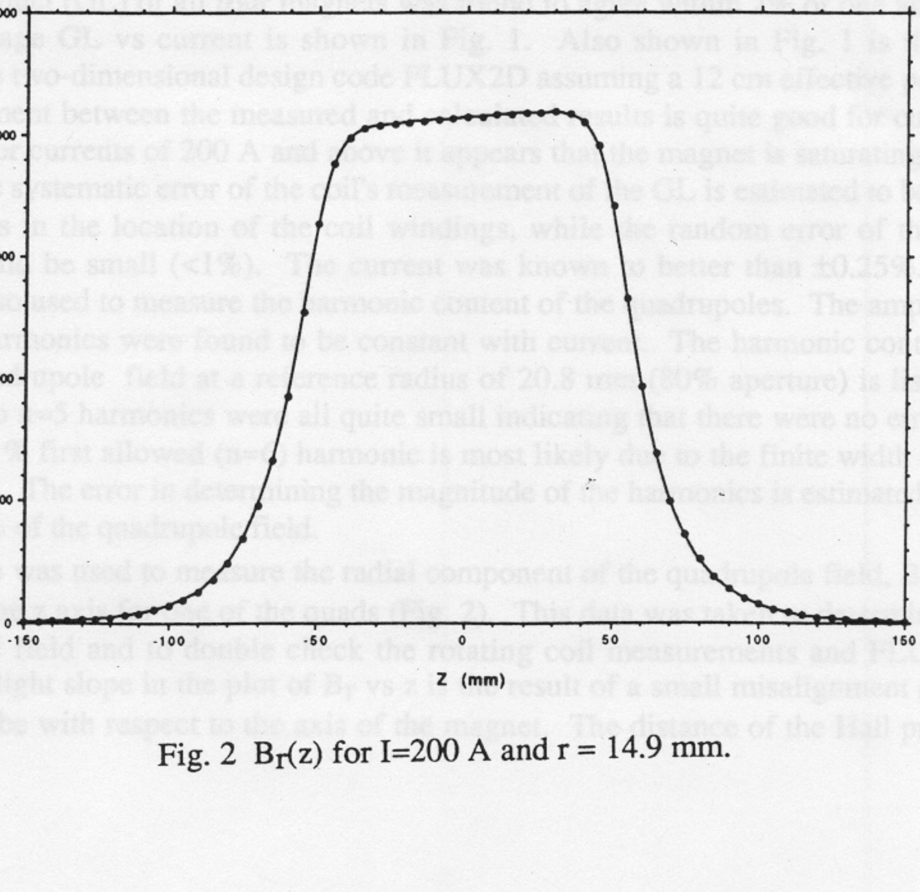

Fig. 2 $B_r(z)$ for I=200 A and r = 14.9 mm.