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MAGNETIC MEASUREMENTS ON A MAIN RING TRIM QUADRUPOLE

D. Krause, R. Mills*, C. Moore & F. Turkot

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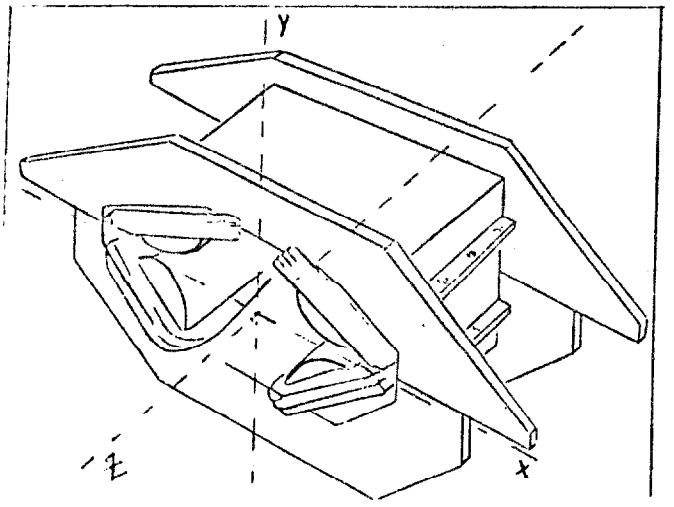
Magnetic measurements were made on a twelve inch Main Ring trim quadrupole[1] using two different instruments: a temperature stabilized Bell Hall probe and a four foot long double search coil connected to a voltage integrator. The coordinate system used in taking the data is sketched below. The quad was optically aligned with respect to a lathe bed which was used to move the various probes in the X and Z direction.



The main quantity of interest for the quad is $\int B'dZ$ as a function of excitation

*Summer Student, Southern University

[1] 1973 Magnet Technology Conf. - Brookhaven, "Correction Magnet System of NAL Main Accelerator," R. Juhala, A. W. Maschke, S. Mori and R. Yamada, National Accelerator Laboratory, Batavia, Illinois.

current. Using the search coil we have calculated the value of $\int B'dZ$ from the following equation: $\int B'dZ = \frac{RCV}{NW\Delta x}$, where

RC = time constant of the integrator = 3.7 $\pm$ .037 ms.

V = voltage change

N = 100 turns per coil

W = coil width = .512 $\pm$ .007 inches

Δx = coil separation = .526 $\pm$ .004 inches

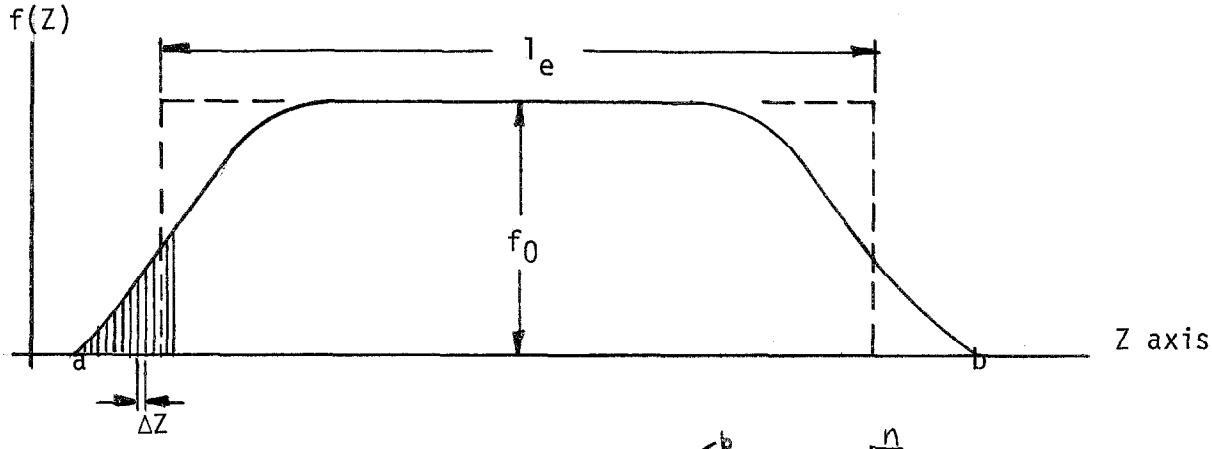
$B' = \frac{dB}{dx}$

Table I gives the measured voltages and calculated $\int B'dZ$ for 5 currents (at x = + 1 inch). A linear least squares fit to this data yielded a slope of 271 gauss/amp and an intercept of 14.2 gauss (at 0. amps). The value of the intercept is identified with the remnent field of the quadrupole.

A Hall probe was used for B versus x measurements from x = -2.5 inches to x = 2.5 inches for 2, 6, and 10 amps. The end of the Hall probe was 5 3/4 inches inside the magnet measured along the z axis. Table II gives the results for 2, 6, and 10 amps, and figure 1 shows the data along with a linear least squares fit to the data for the 6 amp data. Table III gives the measured slopes along with an effective magnetic length, l_e, calculated as $\int B'dZ$ (search coil)/B'(z = 5 3/4 inches).

The measured value of the magnetic length at 10 amps (the last entry in Table III) was determined by moving the Hall probe parallel to the Z-axis at X = $\pm$ 1 inch. The probe covered from 10 inches inside to 11 inches outside the magnet, with respect to the center Z = 6 inches, in 1/4 inch intervals, thus measuring B versus Z. This gives a view of the entire field and from this the effective magnetic length was calculated, by using graphical integration. The method determining the measured value is indicated below, and the

data is shown in figure 2.



We define l_e from the relationship $l_e * f_0 = \int_a^b f(z)dZ \simeq \sum_{i=1}^{n} f(Z_i)\ \Delta Z_i$, where $n = (b-a)/\Delta Z$. The average value of the calculated effective length of 13.7 inches agrees with the measured value at 10 amps of 13.4 inches to 2%. We have chosen to compare magnetic lengths since we have three sets of data (2, 6, and 10 amps) from which we can calculate a magnetic length, which enables us to look at the consistency of our data set. At 10 amps we have an equivalent method of presenting the data, i.e., we can multiply the measured magnetic length times the measured slope (both numbers obtained using a Hall probe), and compare this result to the value of $\int B'dZ$ (using the search coil). These two numbers are given in Table III, and show that the two measurements agree to 2%. Since the quoted errors on the search coil measurements are 1.5%, this independent check is quite satisfactory.

TABLE I

Current (Amps)	V (volts)	$\int B'dZ$ (gauss)
2A	.26465V ± .000357	5.64×10^2G ± 7.7G
4A	.5123V ± .00067	1.09×10^3G ± 15.G
6A	.77089V ± .00253	1.64×10^3G ± 23.G
8A	1.2047V ± .00077	2.18×10^3G ± 29.G
10A	1.27898V ± .00052	2.73×10^3G ± 37.G

TABLE II

X (inches)	2 AMPS B (gauss)	6 AMPS B (gauss)	10 AMPS B (gauss)
-2.5	-102.5	-246.9	-401.4
-2.0	- 82.51	-238.4	-395.2
-1.5	- 61.61	-177.9	-294.0
-1.0	- 40.68	-117.2	-193.0
- 0.5	- 19.83	- 56.3	- 92.7
0.0	.78	2.4	5.3
0.5	21.51	62.7	105.9
1.0	42.32	123.3	206.0
1.5	63.07	183.9	305.8
2.0	83.00	243.4	410.5
2.5	105.0	301.7	500.8

TABLE III

AMPS (A)	Effective Magnetic Length	Slope	$\int B'dZ$
2A	34.67 cm	16.25 gauss/cm	5.636×10^2 gauss
6A	34.85 cm	47.13 "	1.642×10^3 "
10A	34.90 cm	78.07 "	2.725×10^3 "
Measured value@10A	34.04 cm	78.07 "	2.657×10^3 "

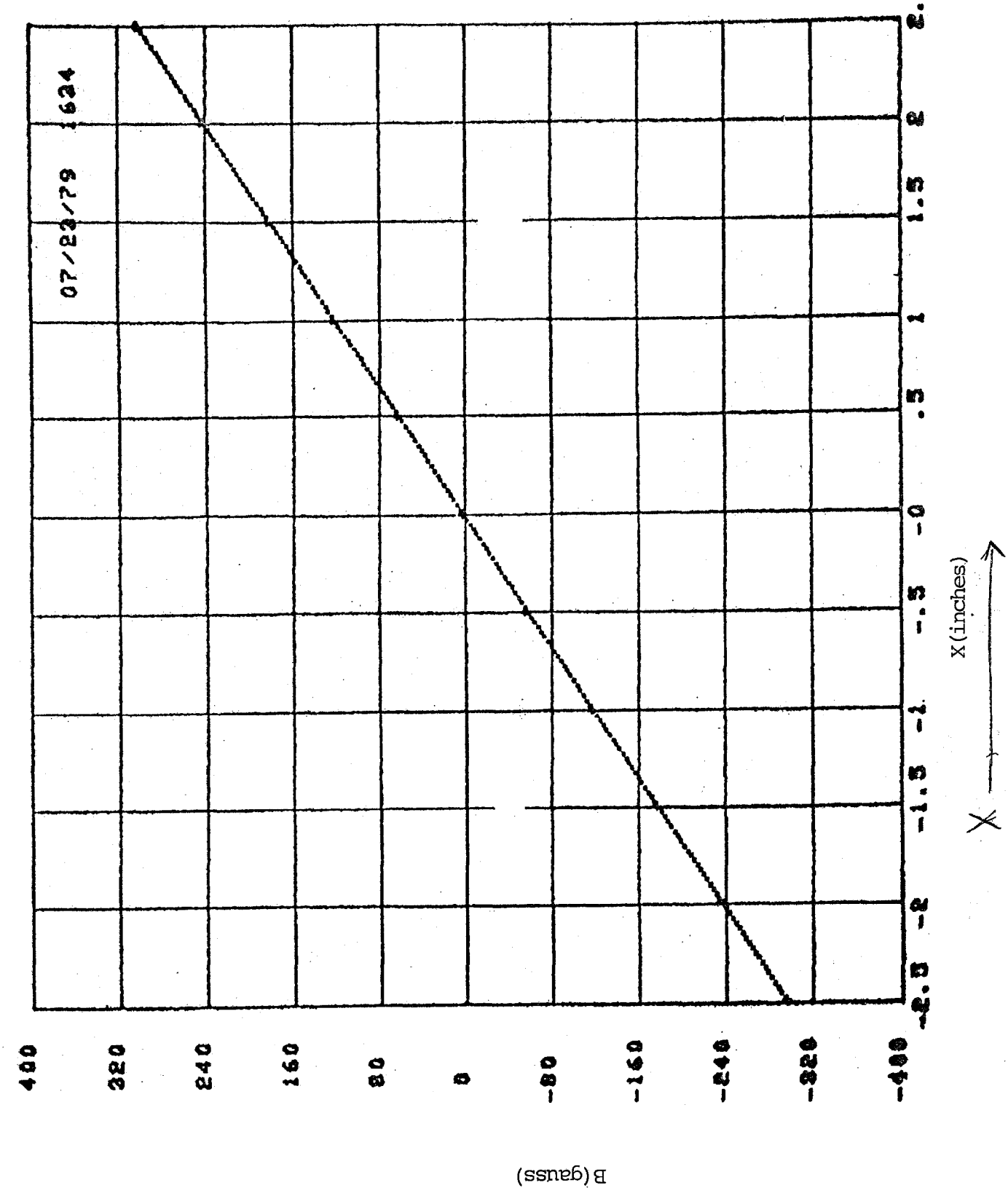

07/22/79 1624
400
320
240
160
80
0
-80
-160
-240
-320
-400
B (gauss)
-2.5
-2
-1.5
-1
-.5
-0
.5
1
1.5
2
2.
X (inches)

Figure 1

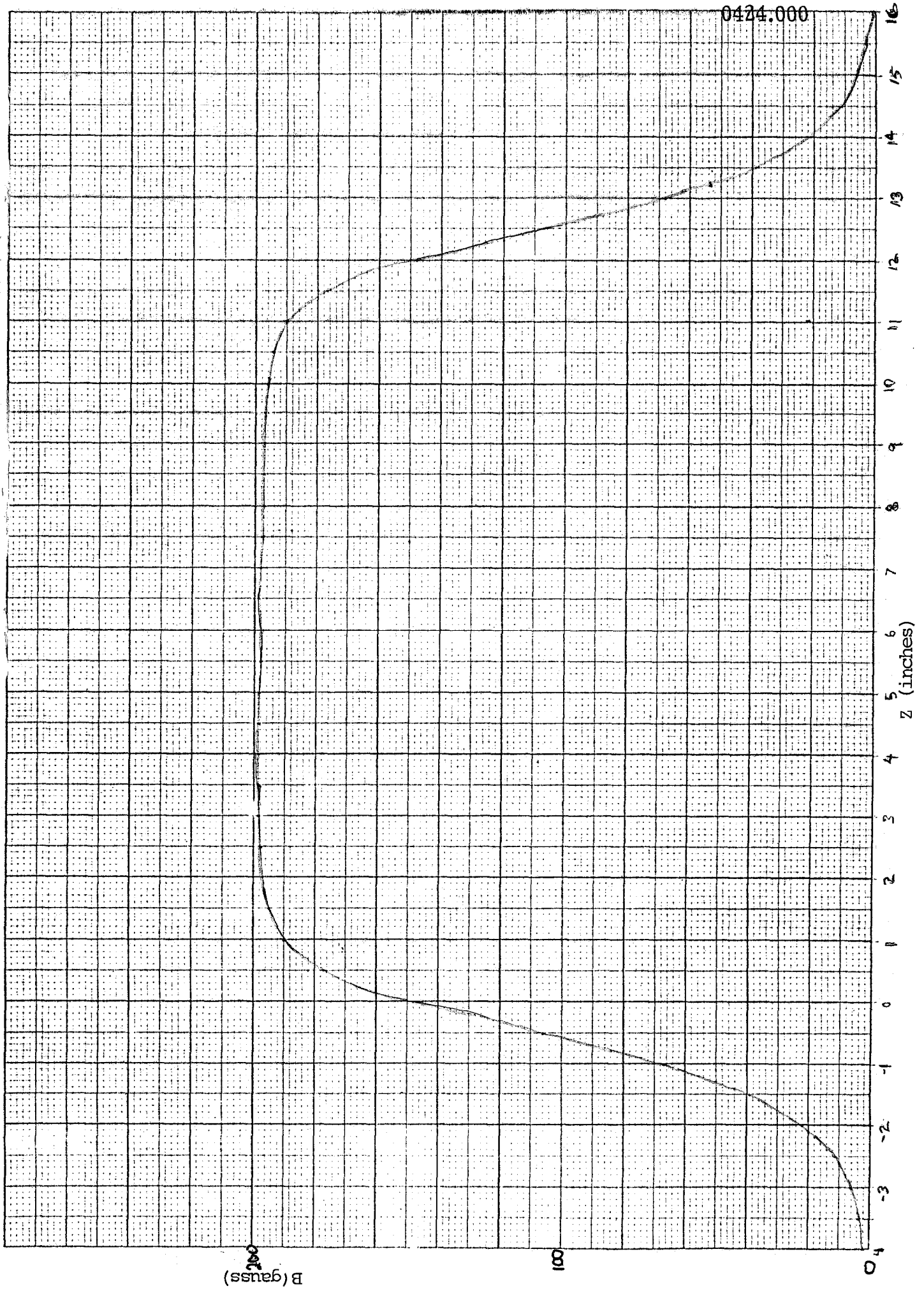


Figure 2 B versus Z @ x = 1 inch