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Calibration of magneto-resistive probes in A1D5 and A1D6 (Beam spectrometer magents)

H. N. Brown

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Collider Accelerator Department

Brookhaven National Laboratory

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CALIBRATION OF MAGNETO-RESISTIVE PROBES IN A1D5 AND A1D6 (BEAM SPECTROMETER MAGNETS)

The vertical magnetic field in each magnet was measured with Hall Probe #731, operated at $I_H = 0.200000 \pm 0.000005$ Amps, placed on the bore axis about 27" inside the effective edge of the magnetic field (this is $\sim$ 18" from the center of the magnet). This Hall Probe was calibrated against an NMR fluxmeter in early 1977 by J. Weisenbloom. It was recalibrated by him against the NMR on 3 Dec. '77. This data went to about 20 kG. The calibration was "extended" to $\sim$ 25 kG by using 3 Hall voltages measured in AID6 on 19 Sept. '77 and by deducing the corresponding fields B from the Danby, Jackson, Weisenbloom (DJW) measurements of B/I on that magnet. Due to uncertainties in current relationships between the DJW measurements and the present ones, the uncertainties in the extended calibration points increase to $\sim$ 0.25% from 20 to 25 kG.

All of these calibration points (48 in all) were fitted to a 7th degree polynomial which was then used to convert all measured Hall Probe voltages to magnetic field. The fitting procedure minimized the squares of the relative deviation of the polynomial value from the measured field, i.e.

$$\sum_i \left(\frac{B(E_i) - B_i}{B_i} \right)^2$$

where B_i is the field measured at the corresponding Hall voltage E_i, and $B(E_i)$ is the value of the polynomial for the argument E_i. The resultant RMS deviation is $\pm$ 0.56 (10^{-3}) for the 7th degree fit. This deviation is due primarily to a systematic difference between the first and second calibration runs, with the latter giving lower field values at the same

Hall voltage, by about 0.1%. This is plainly shown by the plot of $\left(\frac{B_i}{B(E_i)}\right)$ vs E in Fig. 1.

Measurements of B and the magneto-resistive probes (MR) in AID5 and AID6 were made at several different times between June and December 1977. The Hall voltages observed, after small corrections for probe current drifts, were all converted to kG via the polynomial described above. The MR probe voltages (4 in AID5 and 3 in AID6) were recorded, and the probe currents were monitored as well. The initial adjustment of the MR probe currents was made by setting them such that the probe voltage was close to 30 mV at zero magnetic field (really, zero current) in the magnet, i.e., MR(B=0) $\approx$ 30.000 mV. The corresponding probe current I_o was also recorded. Both these observed values were used for later corrections.

The field measurement made by these probes is, of course, derived from the dependence of the resistance of the copper wire on B. However, the calibration curves and fits given here are in terms of the potential which <u>would</u> exist across the probe at the field B <u>if</u> the current inthe probe were such that the potential would be <u>exactly</u> 30.000 mV at zero field. Therefore, since the initial setting MR(B = 0) was not always exactly 30. and since the probe current drifted slightly anyway, all observed MR readings were corrected as follows.

$$MR_{corr.}(B) = 30.\ \frac{R(B)}{R(B=0)} = 30.\ \left(\frac{MR_{obs}(B)}{I_{obs}}\right)\left(\frac{I_o}{MR(B=0)}\right)$$

It is this MR_{corr} which applies to the accompanying graphs and polynomial fits. In the graphs, in order to display the data with greater resolution, the field B has been divided by the empirical normalizing factor $(MR_{corr}-30)^{.6954}$ and plotted as the ordinate versus $(MR_{corr}-30.)$ on the abcissa. Representative estimated errors in the measured points are shown. At low fields, they are due mostly to the reading accuracy of MR(B) and of MR(B = 0). This was taken to be an RMS value of 2.8 μV for the DVM employed. At intermediate fields, the error is mostly due to the $\pm$ 0.056% deviation from the fit to the Hall probe calibration data. Above 20 kG, the estimated error grows to $\pm$ 0.25% due to uncertainty in the "extended" calibration points derived from the DJW data.

The solid curves in the graphs are from 6th or 7th degree polynomial fits of B as a function of (MR_{corr}-30.). The coefficients for these polynomials are listed in the tables.

To make use of these graphs or polynomials to their ultimate accuracy, the observed MR(B) voltage must first be corrected, as described above, before being converted to magnetic field B.

Finally, having determined the central field on axis from these calibrations, one can get the integrated field by multiplying by $L_{eff} \equiv \left(\int Bd\ell\right)/B$. The effective lengths of D5 andD6 are plotted in the last graph as a function of B. This data is taken directly from simultaneous measurements of $\int Bd\ell$ and B by DJW in the two magnets. Fits to those points are also plotted, and the polynomial coefficients listed in the tables.

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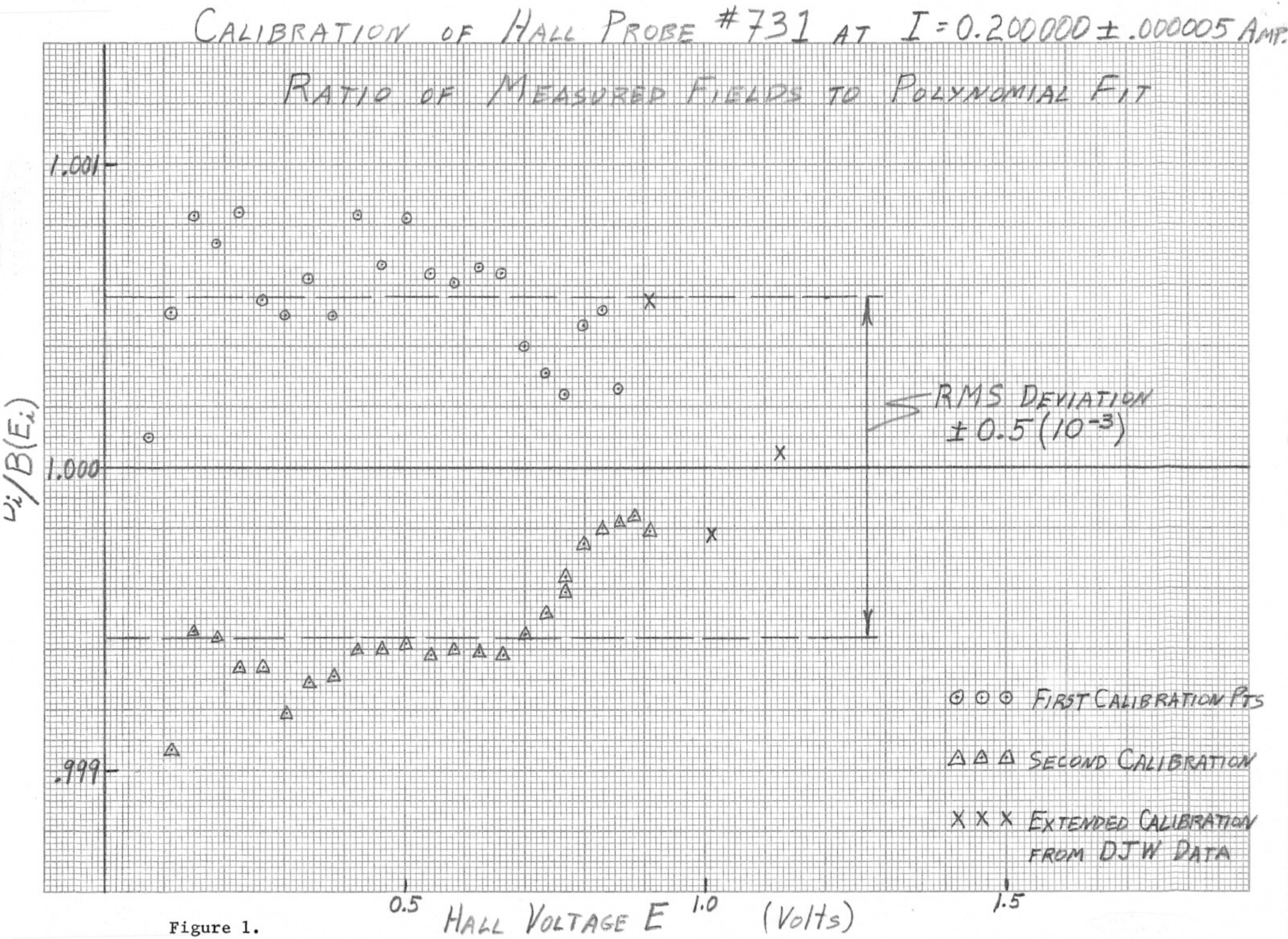
CALIBRATION OF HALL PROBE #731 AT I = 0.200000 ± .000005 AMP.
RATIO OF MEASURED FIELDS TO POLYNOMIAL FIT
1.001
1.000
.999
$\nu_i / B(E_i)$
RMS DEVIATION ± 0.5 (10⁻³)
FIRST CALIBRATION PTS
SECOND CALIBRATION
EXTENDED CALIBRATION FROM DJW DATA
0.5
1.0
1.5
HALL VOLTAGE E (Volts)

Figure 1.

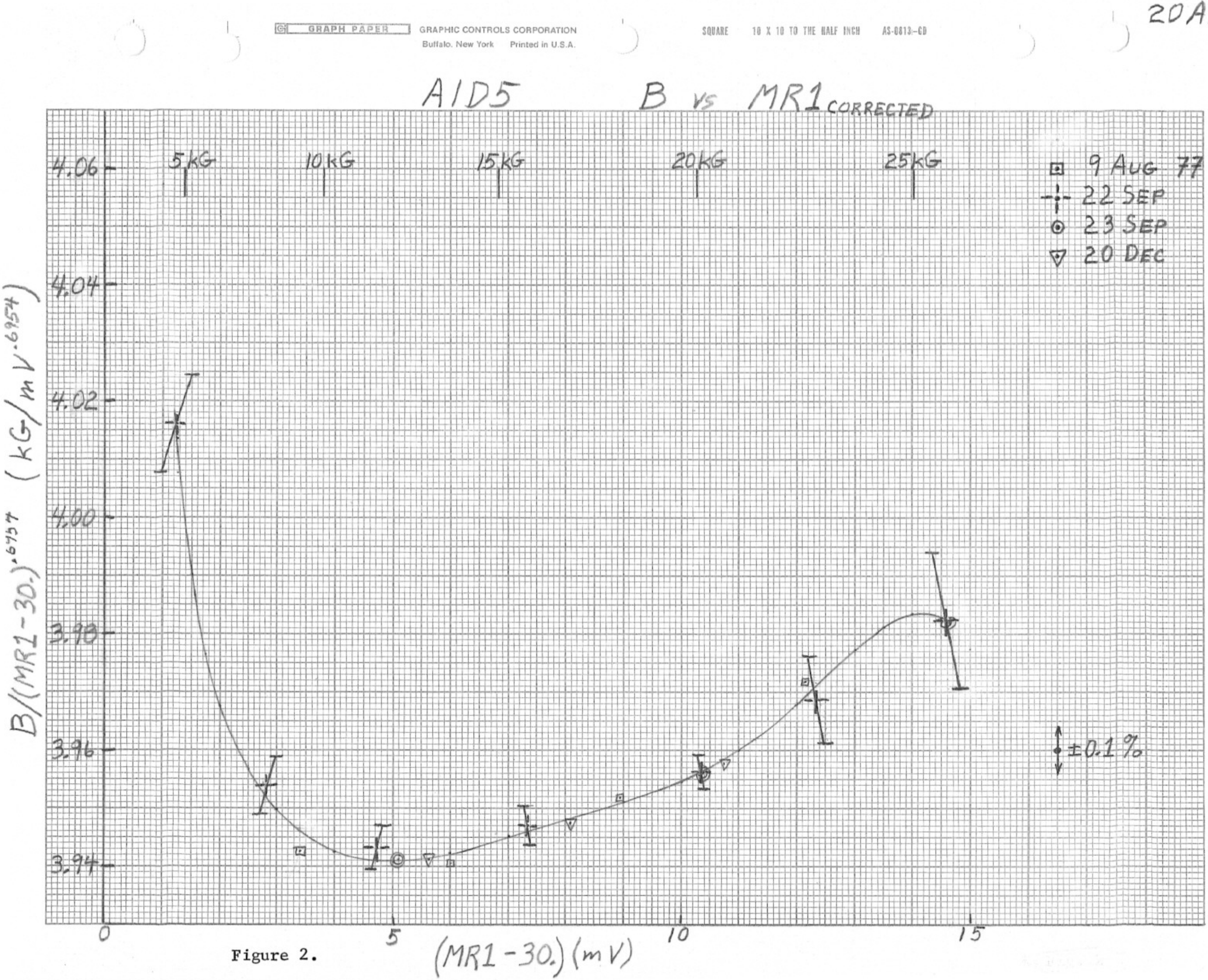
GRAPH PAPER GRAPHIC CONTROLS CORPORATION Buffalo, New York Printed in U.S.A.
SQUARE 10 X 10 TO THE HALF INCH AS-0813-GD
20 APR 78
A1D5 B vs MR1 CORRECTED
5kG
10kG
15kG
20kG
25kG
9 AUG 77
22 SEP
23 SEP
20 DEC
4.06
4.04
4.02
4.00
3.98
3.96
3.94
B/(MR1-30.)^.6954 (kG/mV^.6954)
±0.1%
0
5
10
15
(MR1-30.)(mV)

Figure 2.

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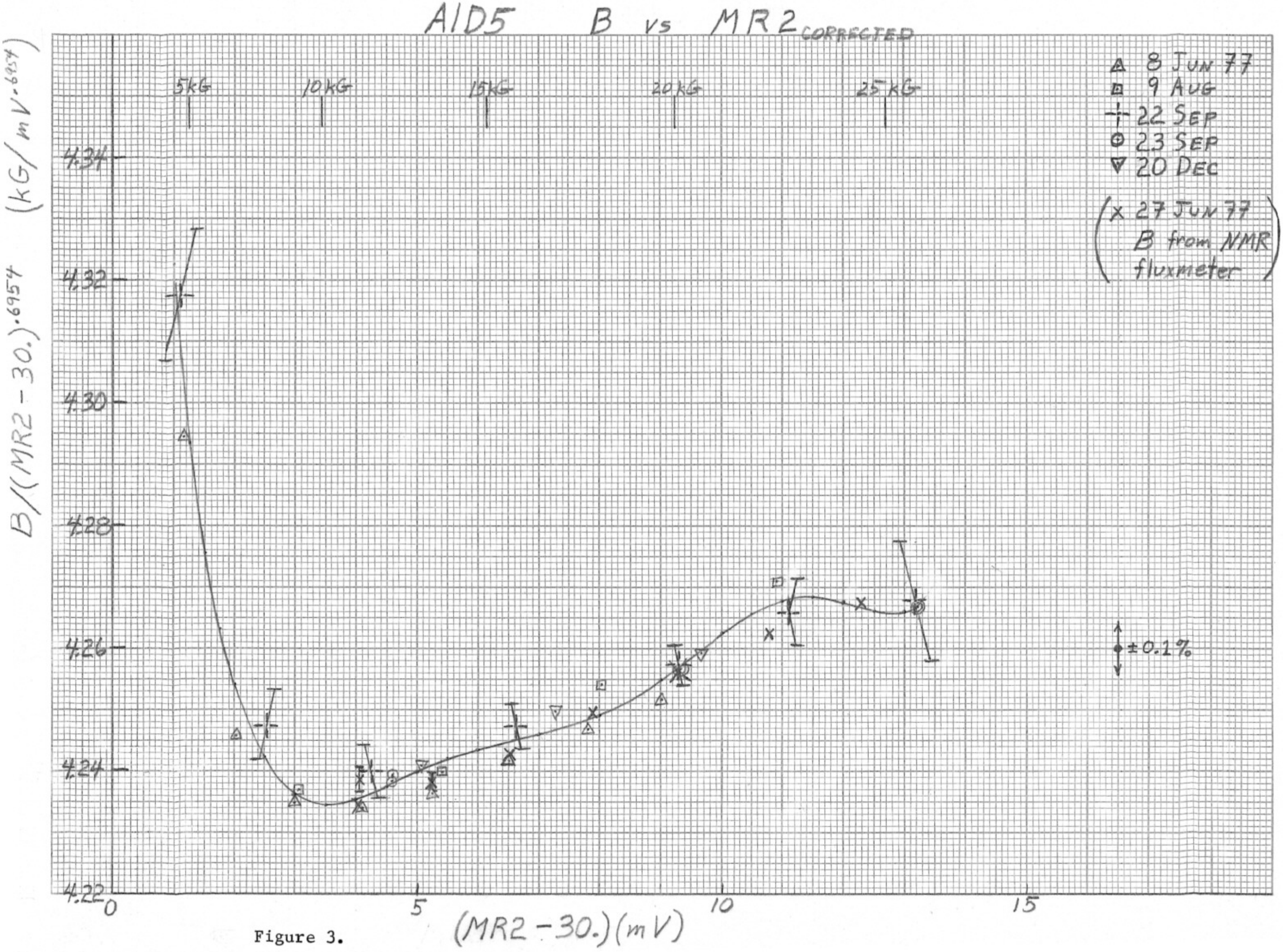

Figure 3.

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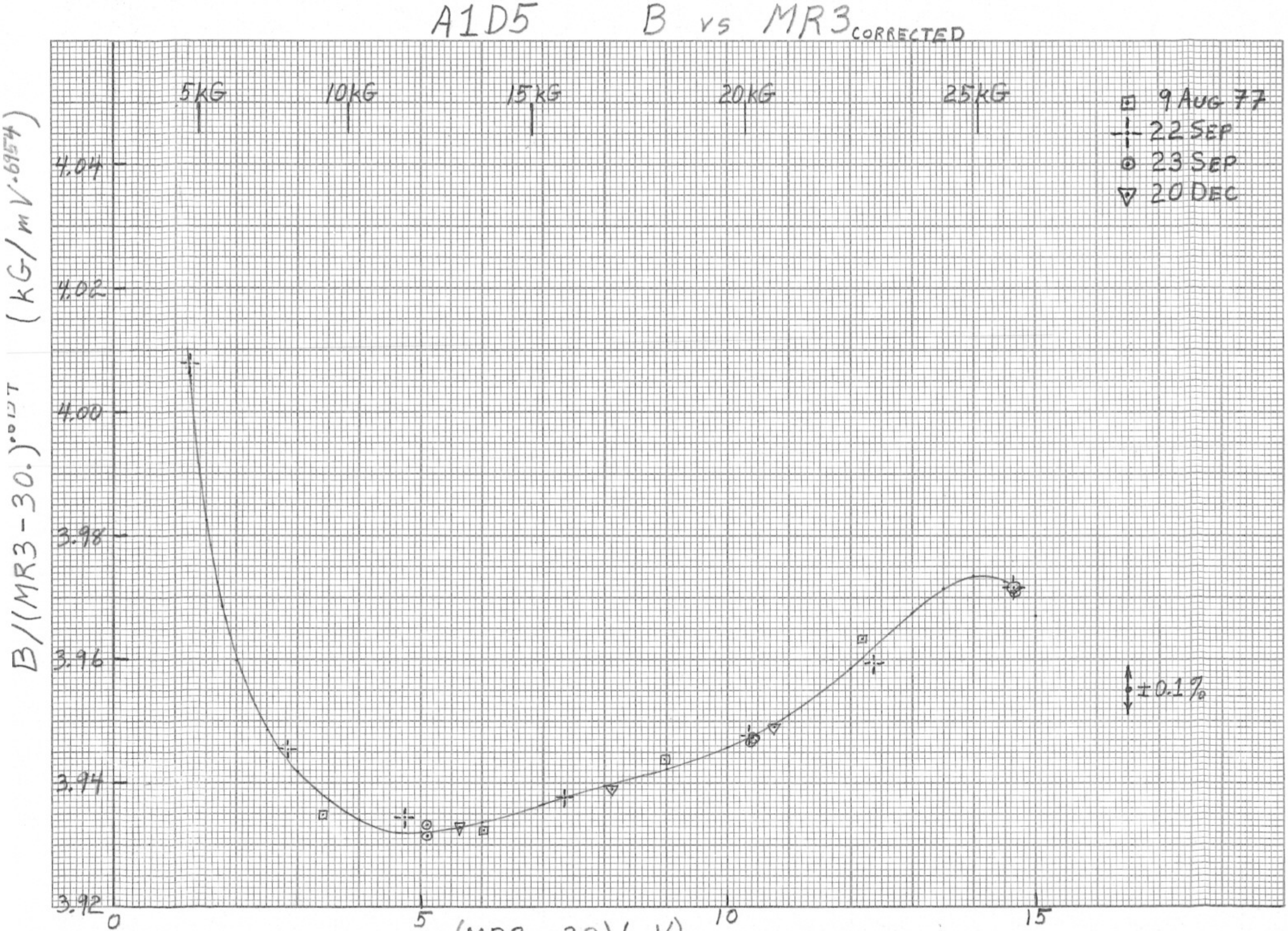
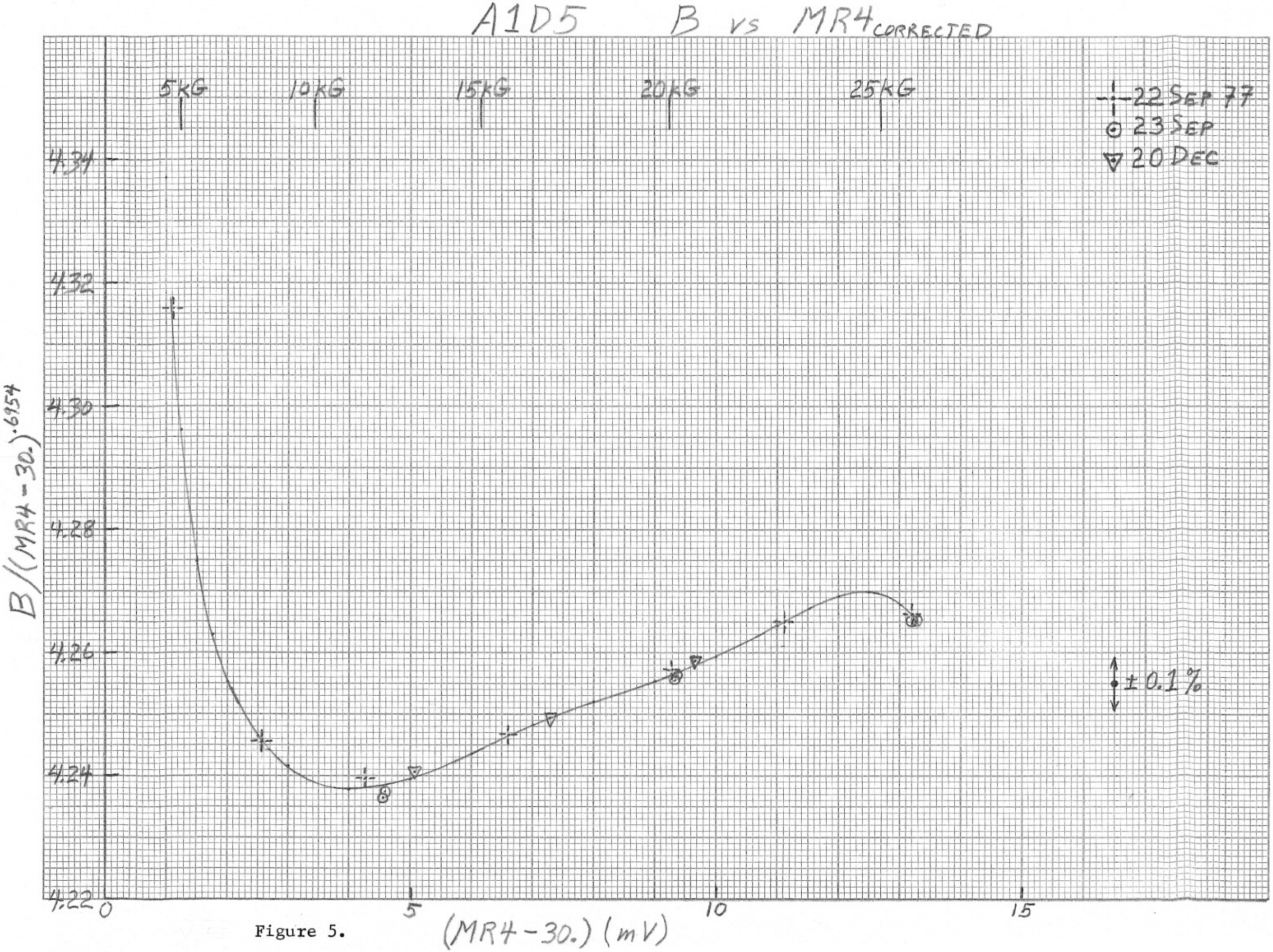


Figure 4.



A1D5 B vs MR4 CORRECTED
5kG
10kG
15kG
20kG
25kG
22 SEP 77
23 SEP
20 DEC
±0.1%
4.34
4.32
4.30
4.28
4.26
4.24
4.22
0
5
10
15
B/(MR4-30.)^.6954
(MR4-30.) (mV)

Figure 5.

Table I

A1D5

$$B=\sum_{k=0}^{7} a_k (MR_{corr} -30.)^k$$

Coeff.	MR1	MR2	MR3	MR4
a_0	1.19031090	1.00293220	1.18639170	1.22780620
a_1	3.20094900	3.91640470	3.19794770	3.48769200
a_2	-.38512745	-.74724211	-.38626856	-.44009803
a_3	.55883734E-1	.17463480	.56153340E-1	.67896426E-1
a_4	-.51064311E-2	-.26486434E-1	-.51309232E-2	-.66301727E-2
a_5	.25151483E-3	.23654323E-2	.25241344E-3	.35018683E-3
a_6	-.50472288E-5	-.11250805E-3	-.50572813E-5	-.75861938E-5
a_7	0.	.21888998E-5	0.	0.

$$L_{eff}=\sum_{k=0}^{2} c_k B^k$$

c_0	90.150420
c_1	-.82048386E-2
c_2	.20079110E-3

A1D6 B vs $MR1_{CORRECTED}$

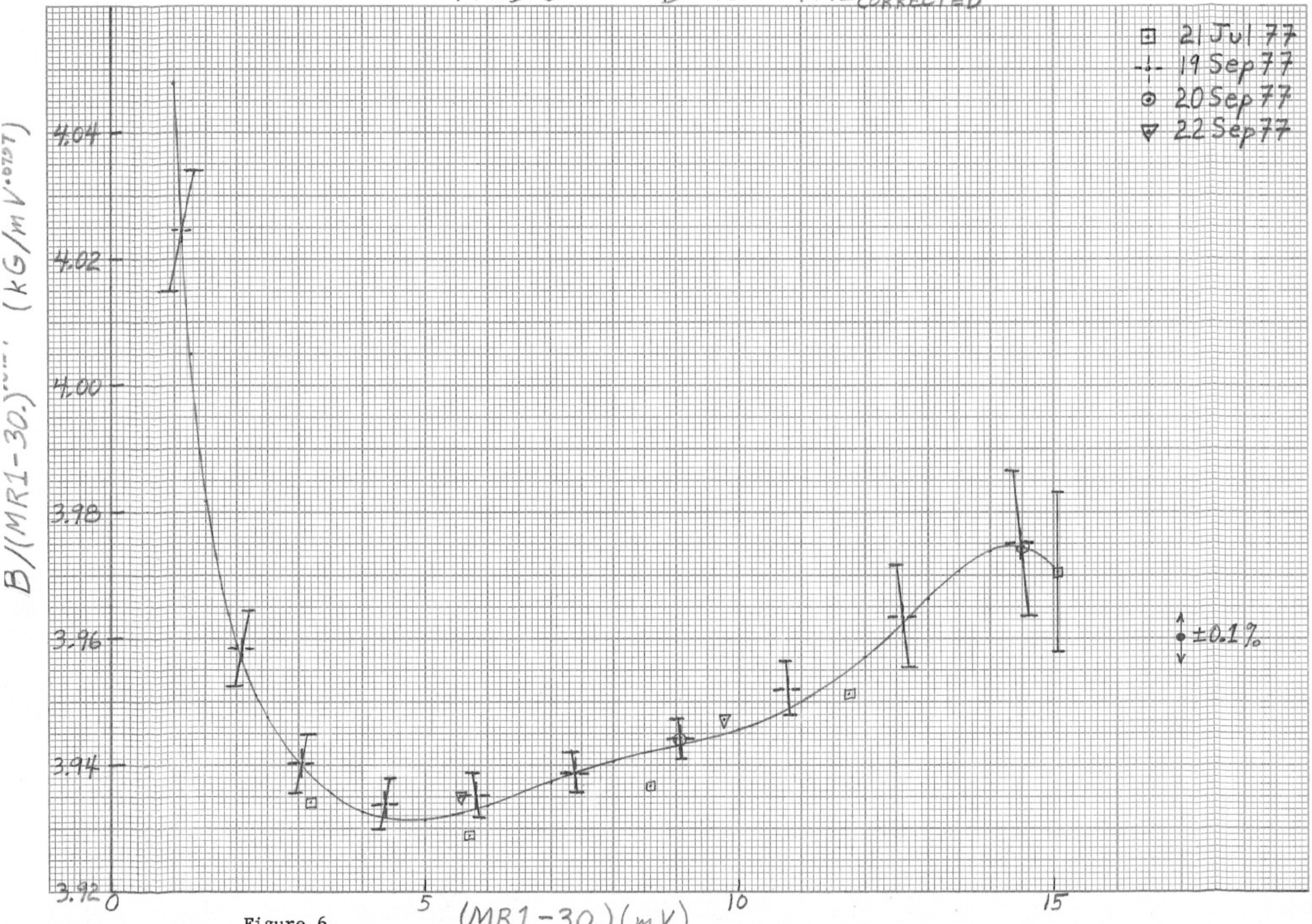


Figure 6.

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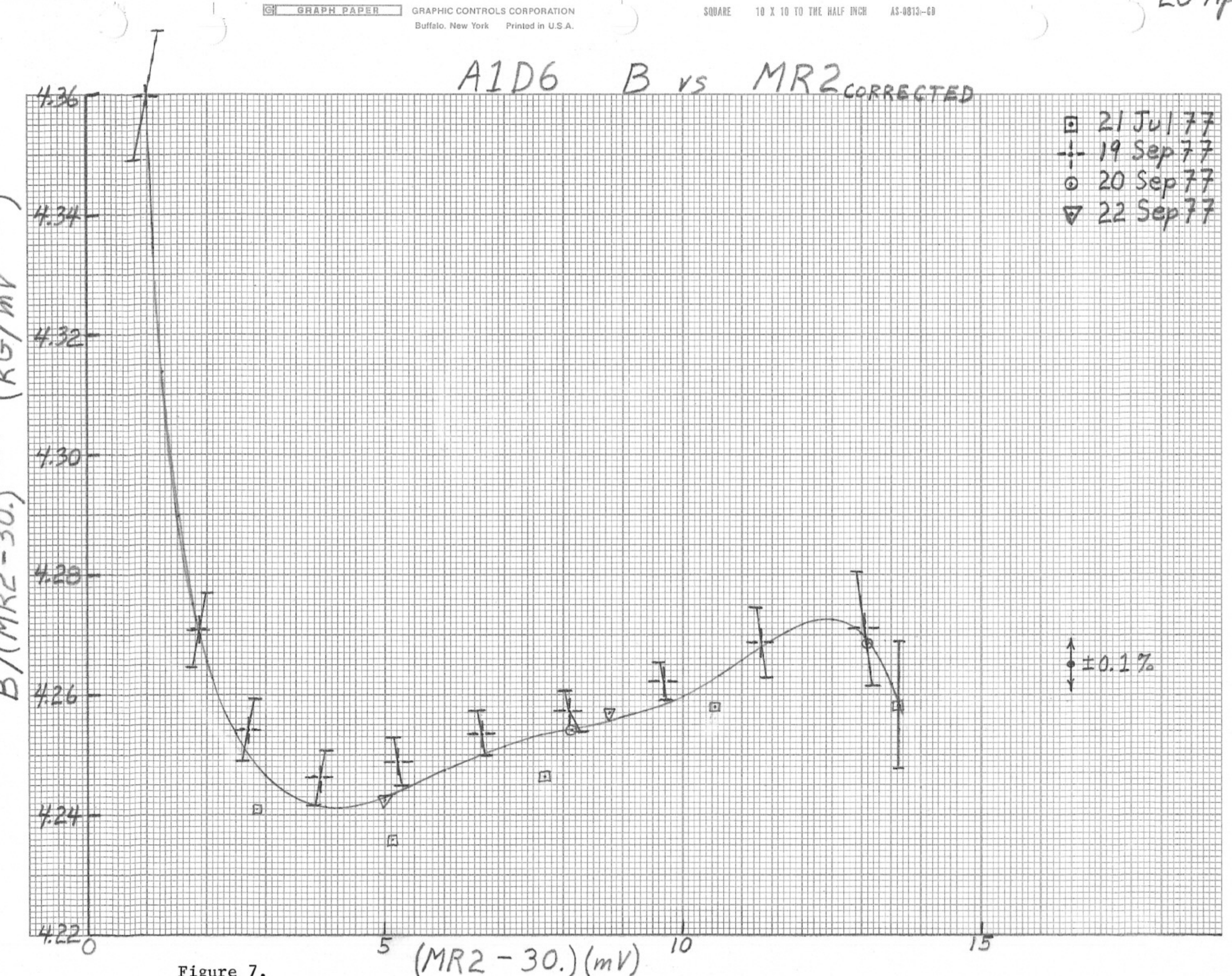

Figure 7.

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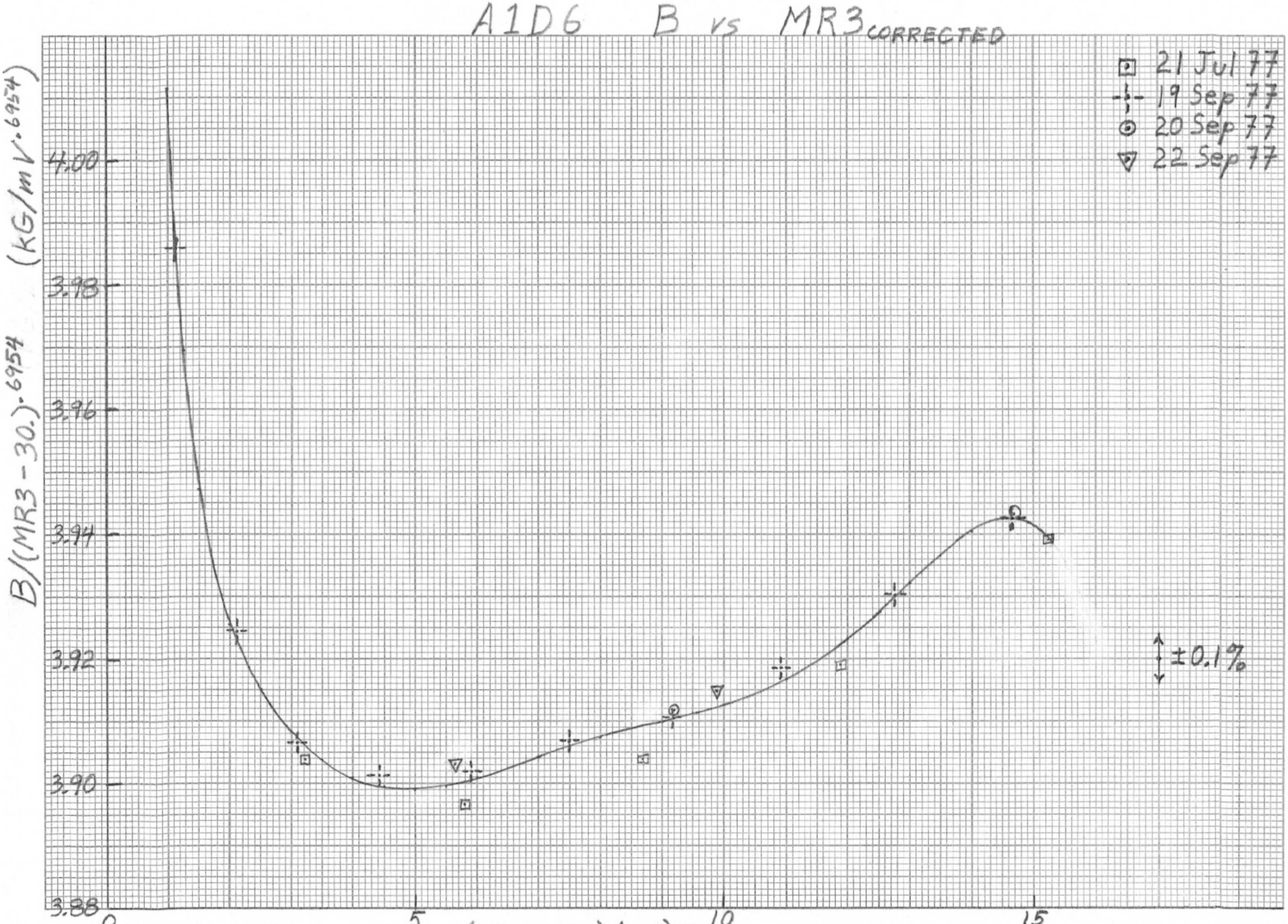

Figure 8.

Table II

A1D6

$$B = \sum_{k=0}^{6} a_k (MR_{corr} - 30.)^k$$

Coeff.	MR1	MR2	MR3
a_0	1.1771051	1.2343549	1.1687542
a_1	3.2123958	3.5215448	3.1749166
a_2	-.39471131	-.46639309	-.38265095
a_3	.58125372E-1	.75758873E-1	.55075684E-1
a_4	-.53332795E-2	-.77308508E-2	-.49462335E-2
a_5	.26124214E-3	.42238829E-3	.23766812E-3
a_6	-.51796952E-5	-.93749348E-5	-.46301468E-5

$$L_{eff} = \sum_{k=0}^{5} c_k B^k$$

c_0	90.31457
c_1	-.52849413E-2
c_2	.13692339E-2
c_3	-.11733735E-3
c_4	.38463944E-5
c_5	-.39420306E-7

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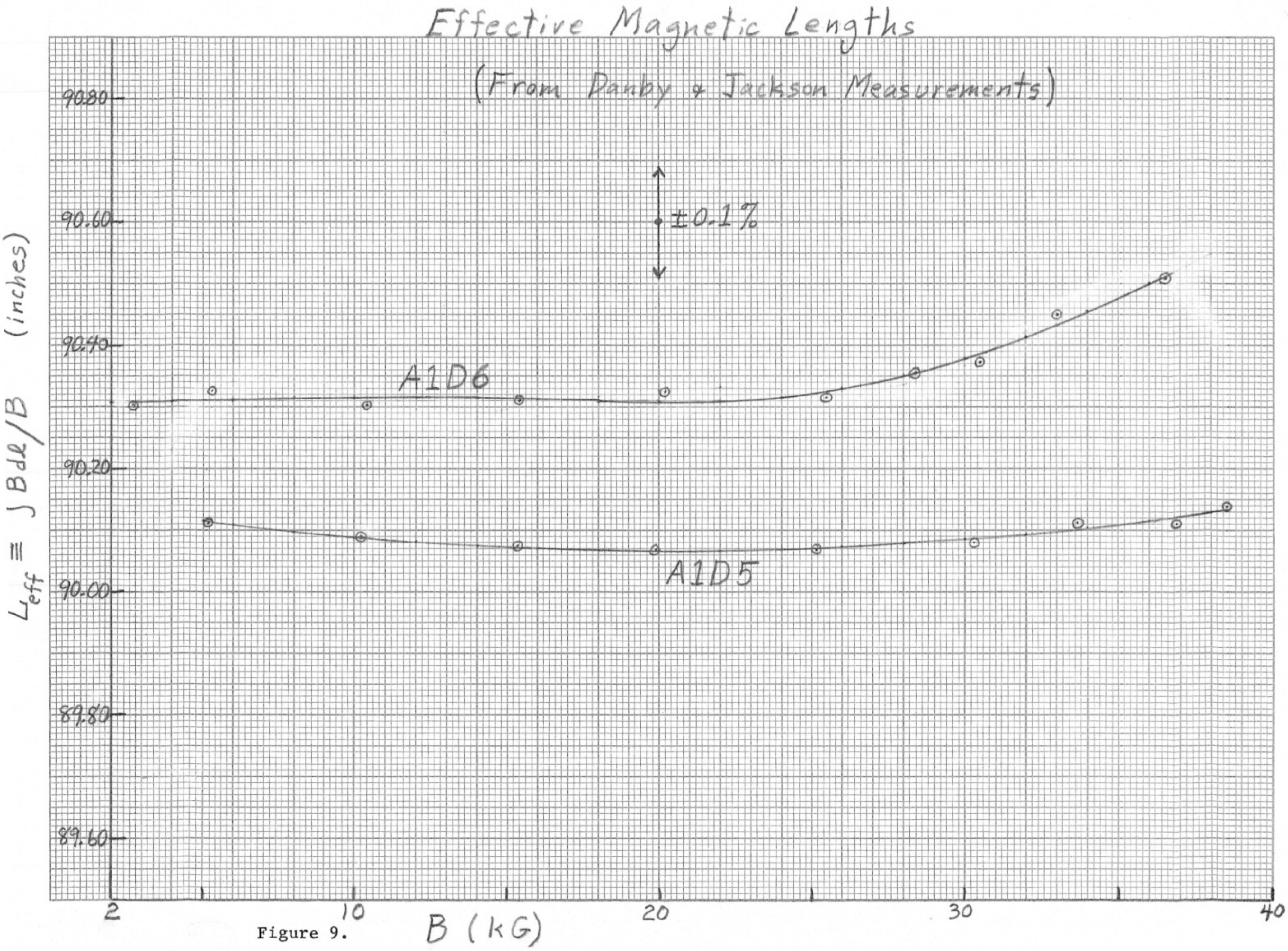

Figure 9.