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Calibration of the internal hall probes in A1D5 & A1D6 (Beam spectrometer magnets)

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NO. 84

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CALIBRATION OF THE INTERNAL HALL PROBES IN A1D5 & A1D6
(BEAM SPECTROMETER MAGNETS)

During the FEB run of early 1978, Hall probes were installed in the HEUB magnets A1D5 and A1D6. The probe for each magnet is located at the longitudinal center, 2½" below the axis, and is therefore outside the regions covered by the adjacent PWC's (± 2" vertically). It is felt that, when calibrated, these internal Hall probes will give a reliable indication of the field on the axis of the magnet, largely independent of magnet history.

The initial calibrations were carried out with both magnets operating in "B" polarity (for a negative beam), using an NMR probe (D_2O) located on the magnet axis about 18" from the magnet center. (The 6 and 10 pole correcting coils were not energized.) The resonant frequency was measured by means of a Hewlett-Packard frequency counter. When compared with another precision frequency counter, the two agreed to within ± 0.01 kHz. Assuming that this represents the accuracy of the frequency measurements, the contribution of this error is negligible in comparison to those of other sources. The following table summarizes the estimated errors in these calibration measurements. $\{B = (1.5299\ \mathrm{G/kHz})f\}$

Source	A1D5	A1D6
Freq. Counter	± 0.01 kHz	± 0.01 kHz
E_H (DVM Reading Accuracy)	± 0.000015 V	± 0.000015 V
I_H (From variations during run)	± 0.000015 A	± 0.000018 A
Resonance Position	± 0.30 kHz	± 0.30 kHz
Field Stability (During probe readout)	± 0.40 kHz	± 0.19 kHz
Overall RMS: $I_H \cong 0.200$ A		
@ E_H = .220 V, B ≙ 6.6 kG	± 0.016%	± 0.014%
@ E_H = .915 V, B ≙ 25.2 kG	± 0.008%	± 0.010%

During this calibration, the internal Hall probe current (I_H) and output voltage (E_H) were measured and recorded via the cross-bar scanner-DVM system in the MPS control room. (All available magneto-resistive (MR) probes in each magnet were also monitored through this system.) Hence, the "reading" accuracies of the Hall probes will be very good, depending only on the stability of making relative voltage and current measurements, assuming that the same Hall current generator, with its internal current measuring shunt, is always used.

The most important factors, then, in using these Hall probes will be the temperature stability achieved by the Hall generator temperature control, and the long term radiation and aging effects of the Hall crystals themselves. Of course, we have no experience yet with the new Hall probes, but calibrations done on other Hall probes indicate that reproducibilities of about 0.1% can be expected over a period of a year.

Figure 1 illustrates the dependence of field on the magnet axis (B_{axis}) on the Hall voltage output. The encircled points represent measurements taken while raising the field continuously from the lowest circle to the highest. The crossed points were then measured while lowering the field continuously from the highest circle. Time was allowed at each point for the magnetic field to come to equilibrium (usually 12-15 minutes) before reading the probes. The resonant frequency was recorded before and after the probe readings, which were repeated if the field had drifted too much.

The curves of Fig. 1 indicate that there is very little relative hysteresis between the field on axis and that at the Hall probe, at least for the one up-down cycle done for each magnet. The data for A1D5 are quite smooth and a 4th degree polynomial fits them with an RMS deviation of 0.007%, the maximum deviation being 0.014%. For A1D6, one or two points at the high end seem to be a bit out of place, but no reasons for this can be found in looking back over the raw data. The 4th degree polynomial fits these points to within 0.014% RMS, with a maximum deviation of 0.038%. Overall, it appears that these internal Hall probes should make good field monitors if their long term stability proves to be good.

Table I lists the coefficients of the polynomial fits of B_{axis} vs. E_H, while Table II contains the coefficients for L_{eff} vs. B. (See EP&S Tech Note #83.) Figure 2 illustrates the dependence of L_{eff} on B_{axis}.

The MR probe readings recorded at this time are compared to the earlier (1977) MR probe calibrations (EP&S Technical Note #83) as shown in Figures 3-9. For A1D5, the previous data are systematically higher than the new measurements. Even the previous NMR data on MR2 is higher (by $\sim$ 0.1%). On the other hand, the new data on the A1D6 MR probes agrees, within the measurement accuracy, with the previous data except for the mid-range of MR3 and for the 2nd and 14th points, which clearly picked up some pathological noise. This suggests that the field measurements for the previous and present calibrations are probably correct and that there has been some systematic change in the A1D5 MR probe response. However, nothing definite on this question can be said at present.

The user should remember that the internal Hall probe calibration described is for "B" polarity (Negative Beam) only; an "A" polarity calibration must be made in the future, probably during the early fall shutdown of 1978.

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TABLE I

$$B(kG) = \sum_{k=0}^{4} a_k \, E_H^k \qquad \{E_H \text{ in Volts}\}$$

Coeff.	A1D5	A1D6
a_0	.37218301 E-1	-.13864450 E-1
a_1	.32844722 E+2	.32606400 E+2
a_2	-.10708287 E+2	-.10351194 E+2
a_3	.82434243 E+1	.79937429 E+1
a_4	-.23476081 E+1	-.22813475 E+1

TABLE II

$$L_{eff} = \sum_{k=0}^{5} c_k \, B^k \qquad \{B \text{ in kG}\}$$

Coeff.	A1D5	A1D6
c_0	90.150420	90.31457
c_1	- .82048386 E-2	- .52849413 E-2
c_2	.20079110 E-3	.13692339 E-2
c_3	0.	- .11733735 E-3
c_4	0.	.38463944 E-5
c_5	0.	- .39420306 E-7

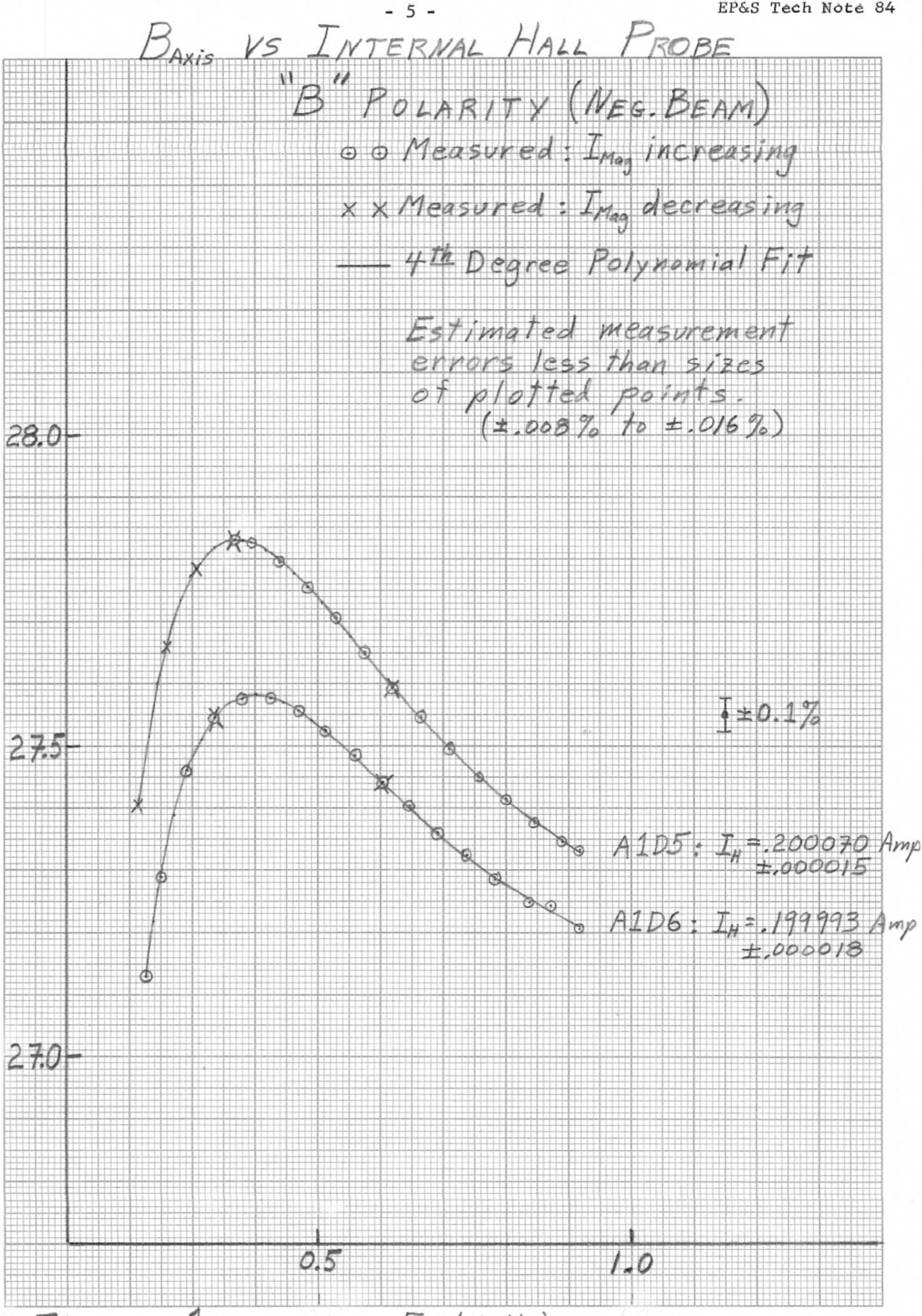

BAxis VS INTERNAL HALL PROBE
"B" POLARITY (NEG. BEAM)
⊙ ⊙ Measured: IMag increasing
x x Measured: IMag decreasing
— 4th Degree Polynomial Fit
Estimated measurement errors less than sizes of plotted points. (±.008% to ±.016%)
±0.1%
A1D5: IH = .200070 Amp ±.000015
A1D6: IH = .199993 Amp ±.000018
28.0
27.5
27.0
0.5
1.0
(Baxis / (EH + .02875)) (kG/Volt)
EH (Volts)

Figure 1

19 Apr 78

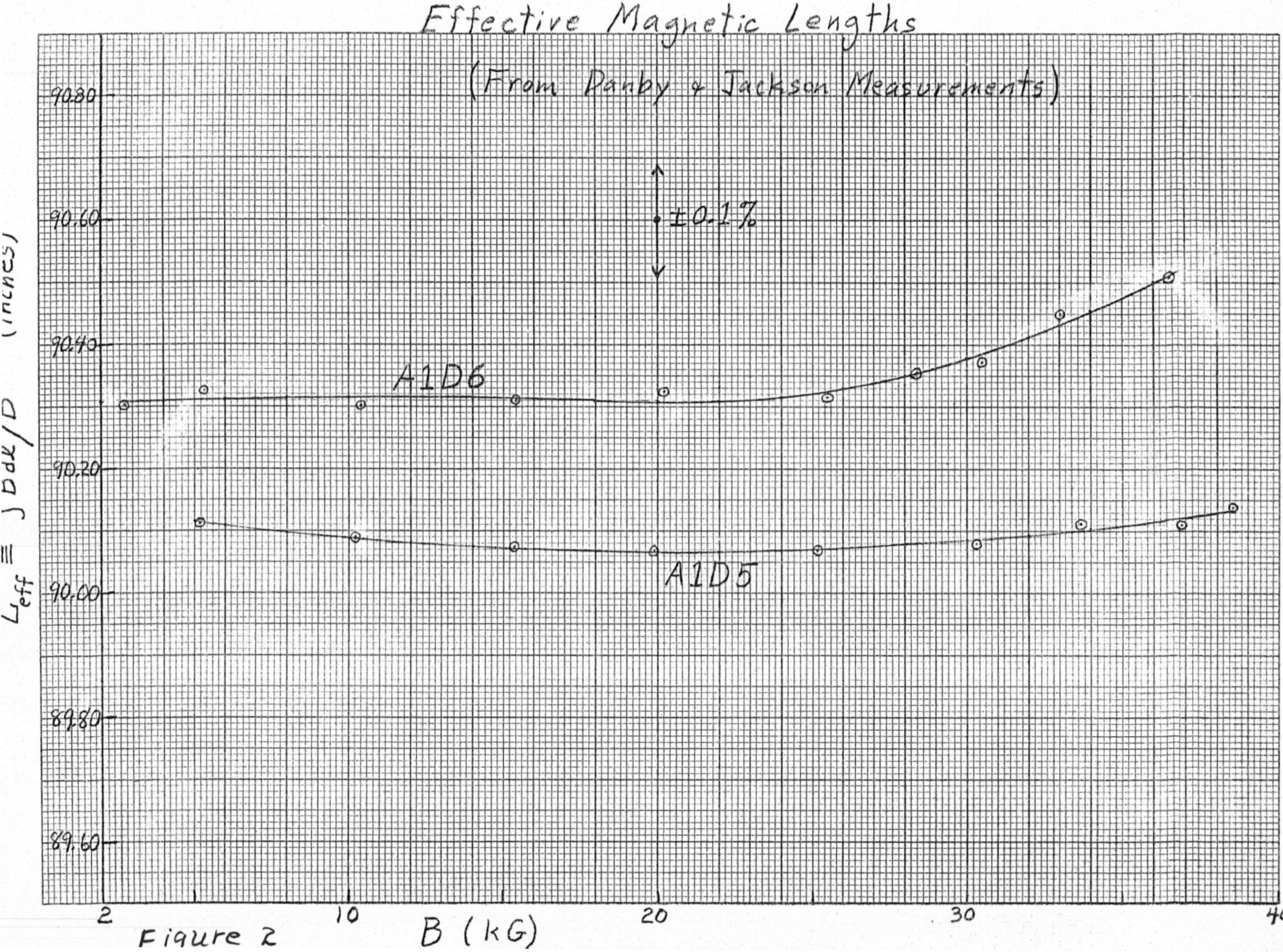


Figure 2

20 APR 78

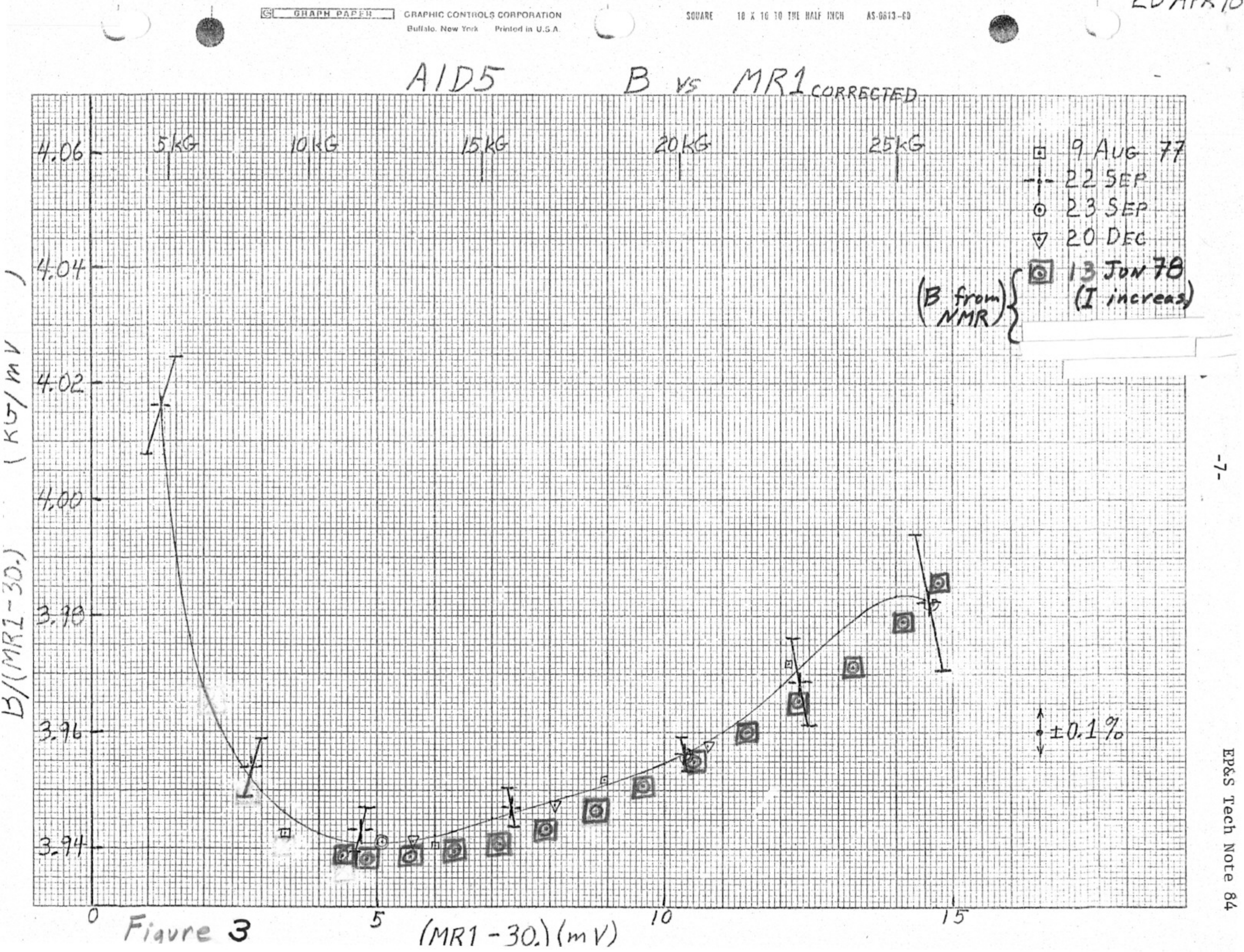


Figure 3

-7-

20 APR 78

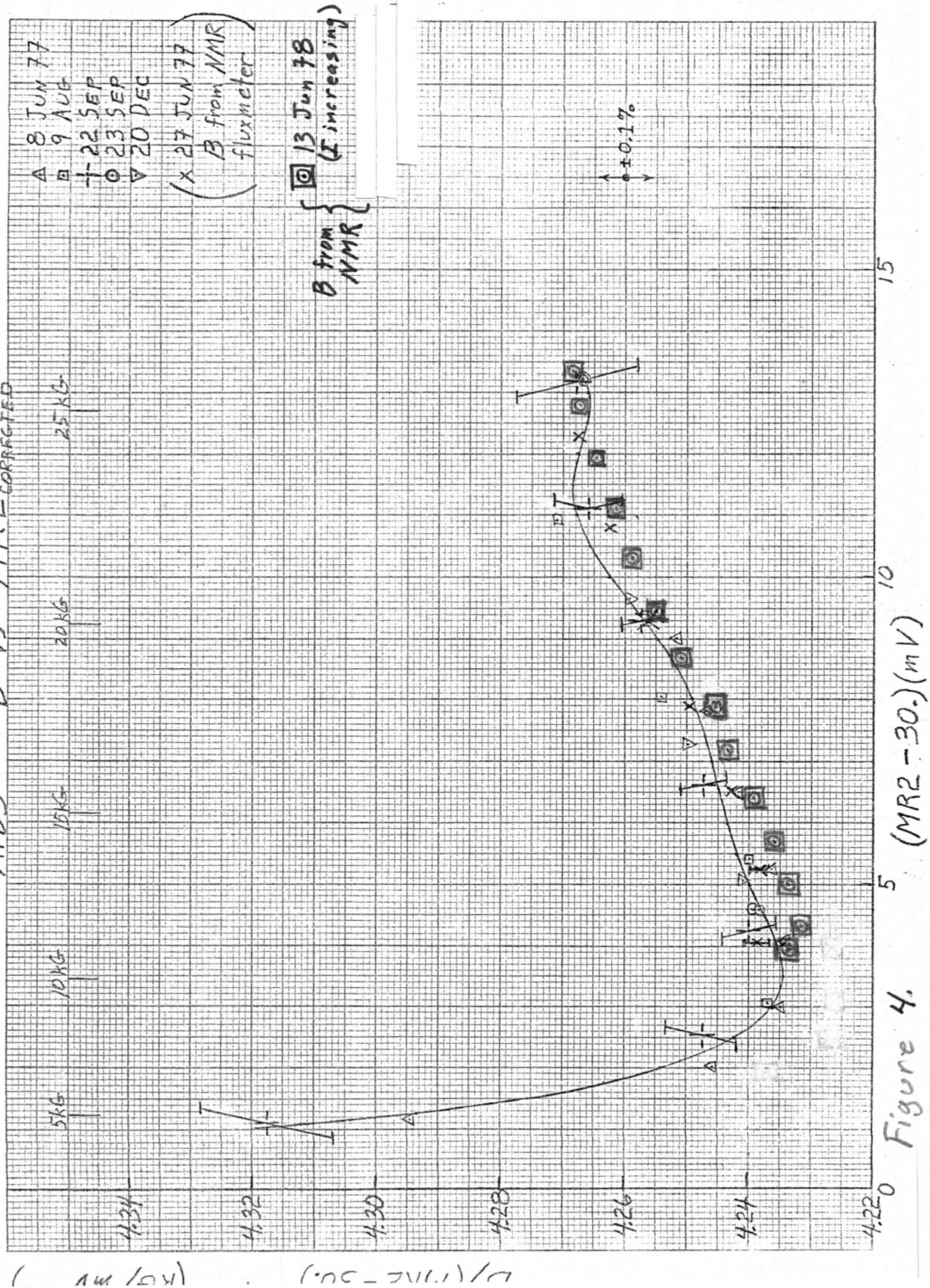


Figure 4.

20 APR 78

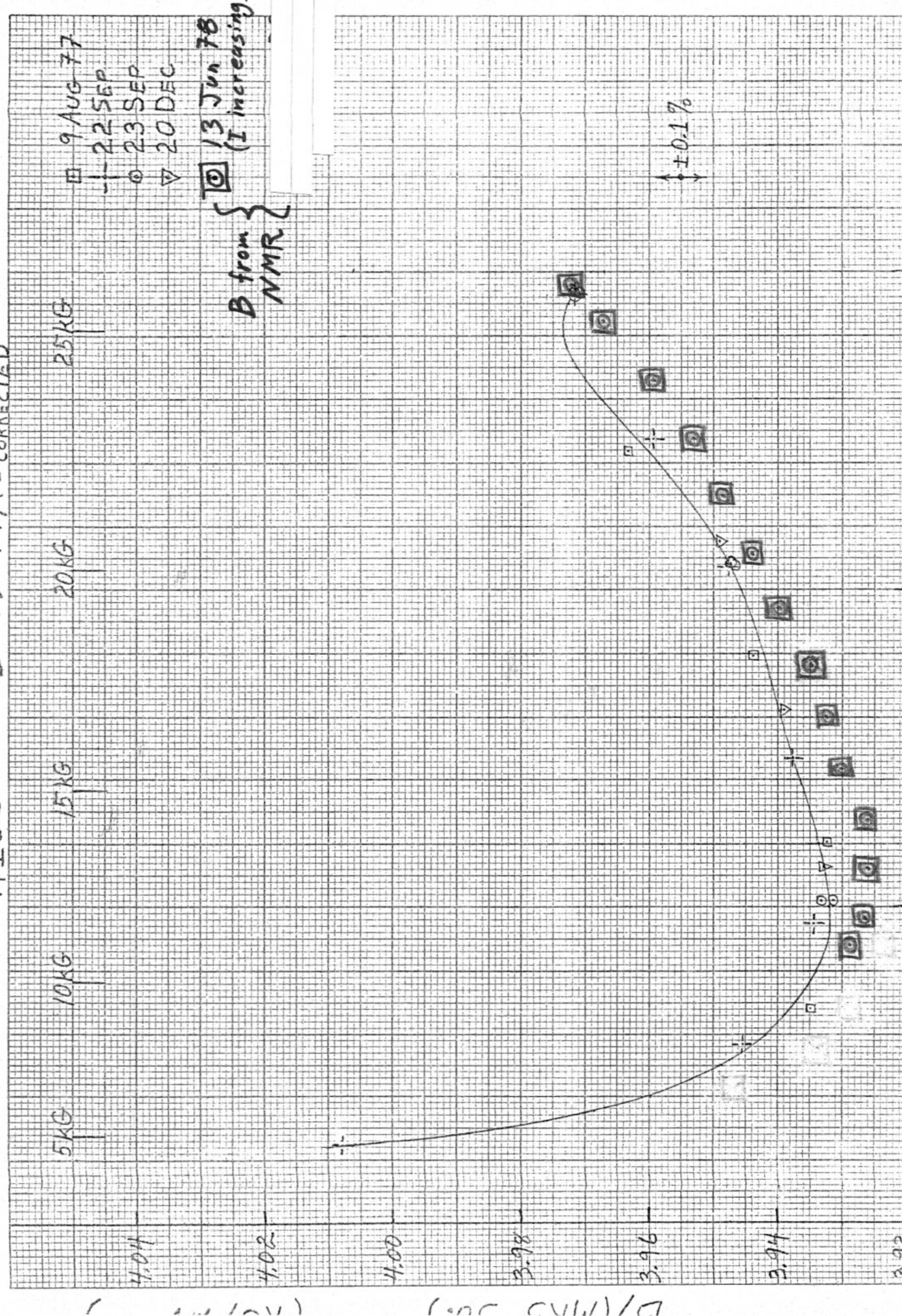
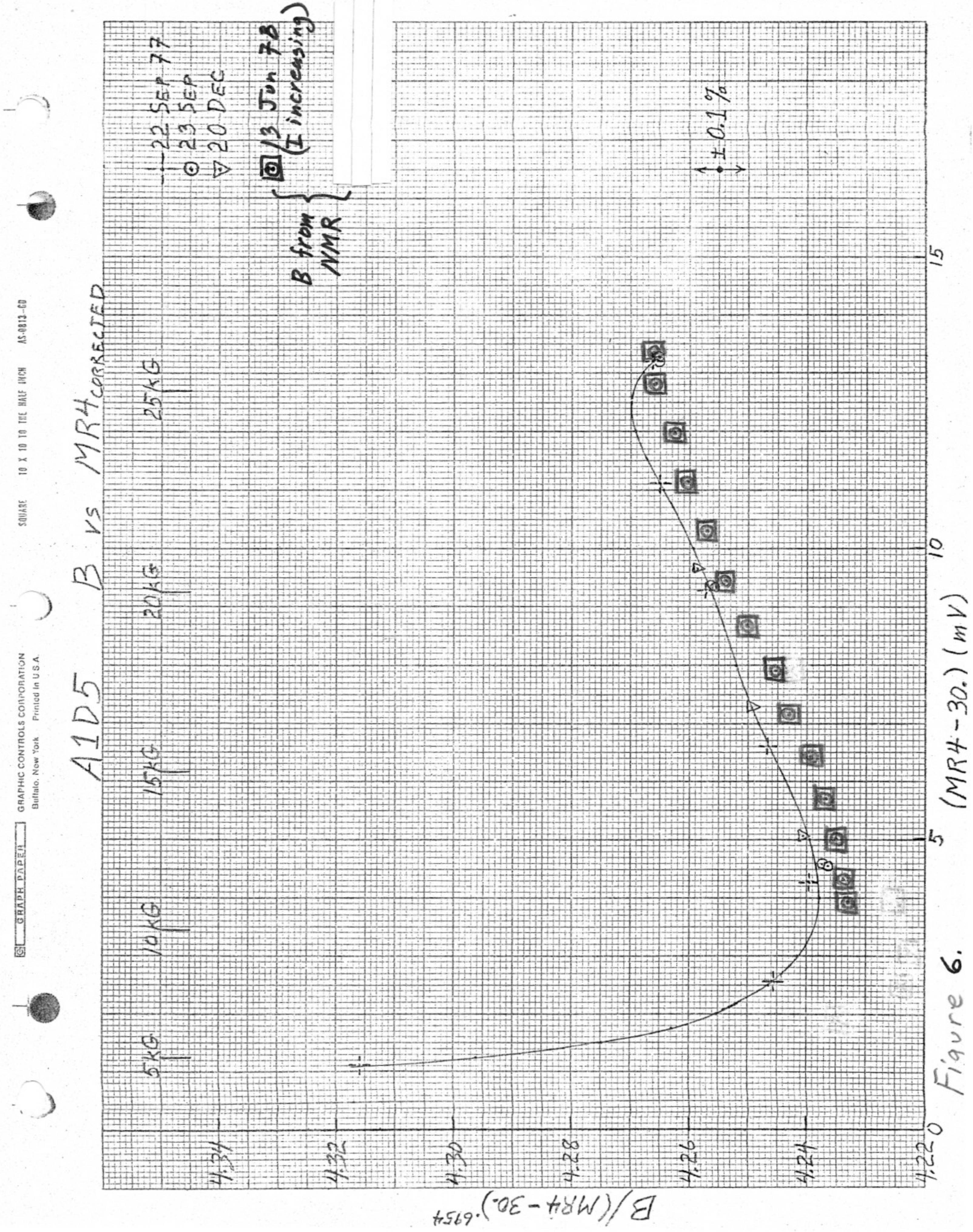


Figure 5.


A1D5 B vs MR4 CORRECTED
5kG
10kG
15kG
20kG
25kG
22 SEP 77
23 SEP
20 DEC
13 Jun 78 (I increasing)
B from NMR
±0.1%
0
5
10
15
(MR4 - 30.) (mV)
4.22
4.24
4.26
4.28
4.30
4.32
4.34
B/(MR4 - 30.)^.6954
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SQUARE 10 X 10 TO THE HALF INCH AS-0813-CO

Figure 6.

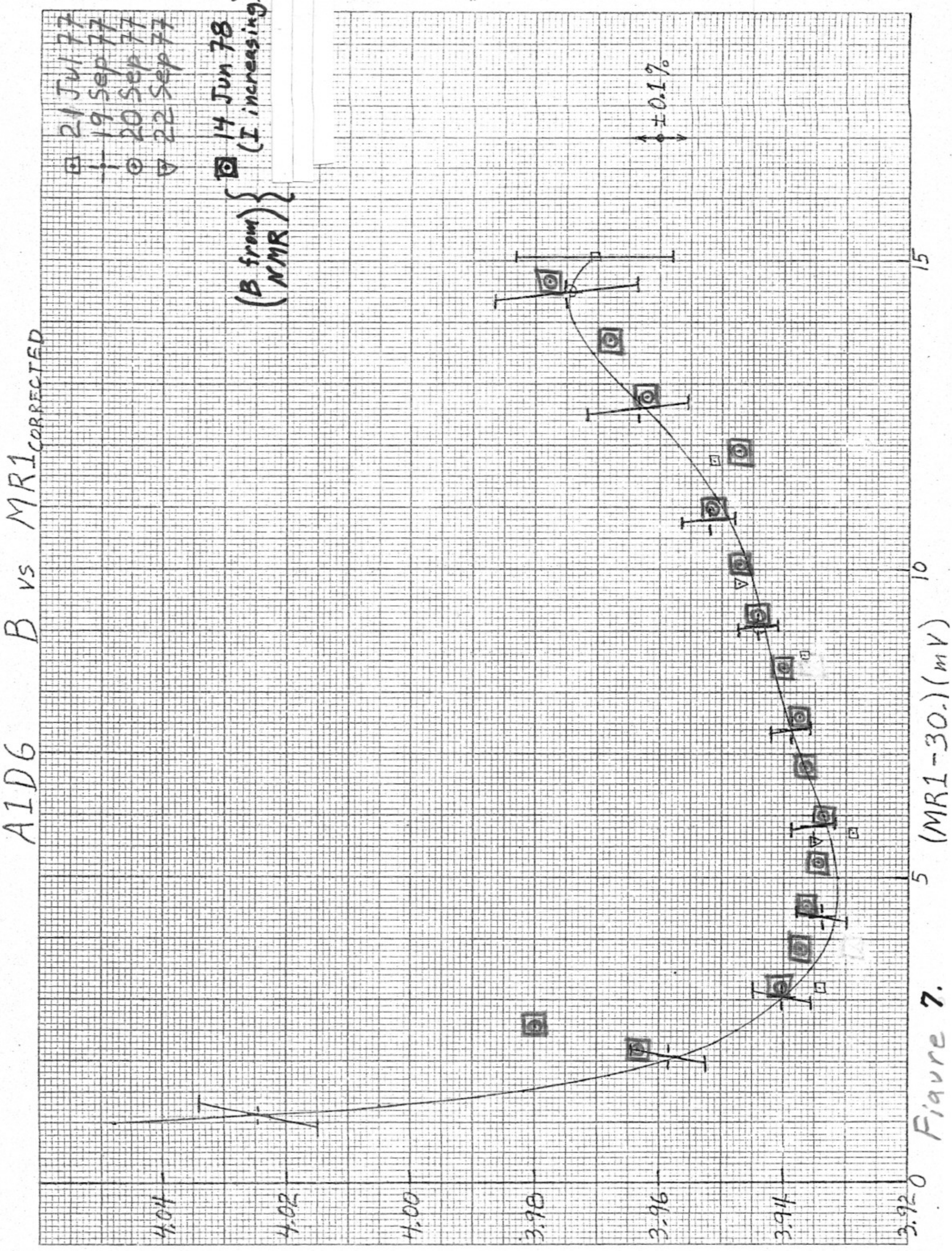

A1DG B vs MR1 CORRECTED
21 Jul 77
19 Sep 77
20 Sep 77
22 Sep 77
14 Jun 78 (I increasing)
(B from NMR)
±0.1%
(MR1-30.) (mV)
0
5
10
15
4.04
4.02
4.00
3.98
3.96
3.94
3.92

Figure 7.

20 Apr 78

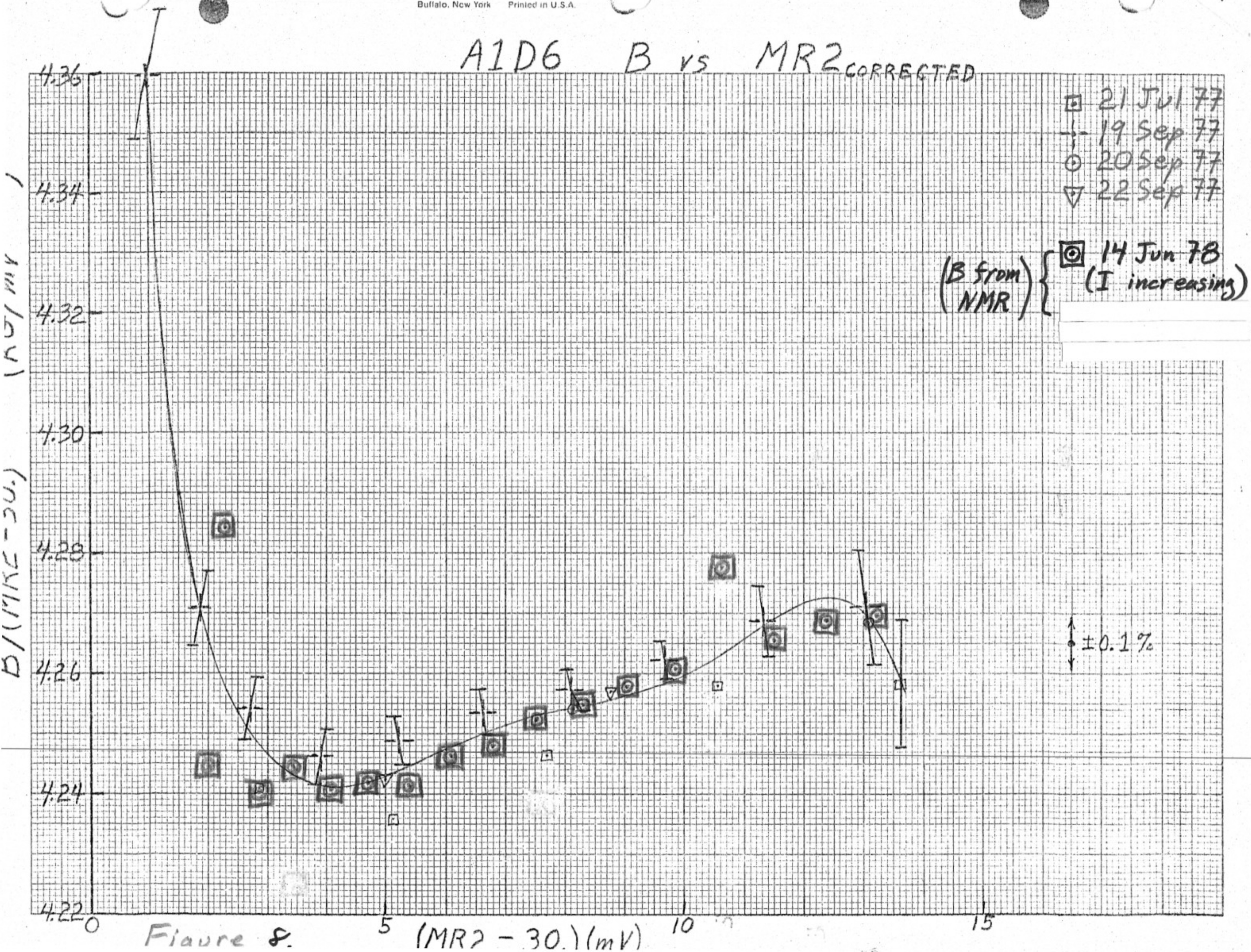
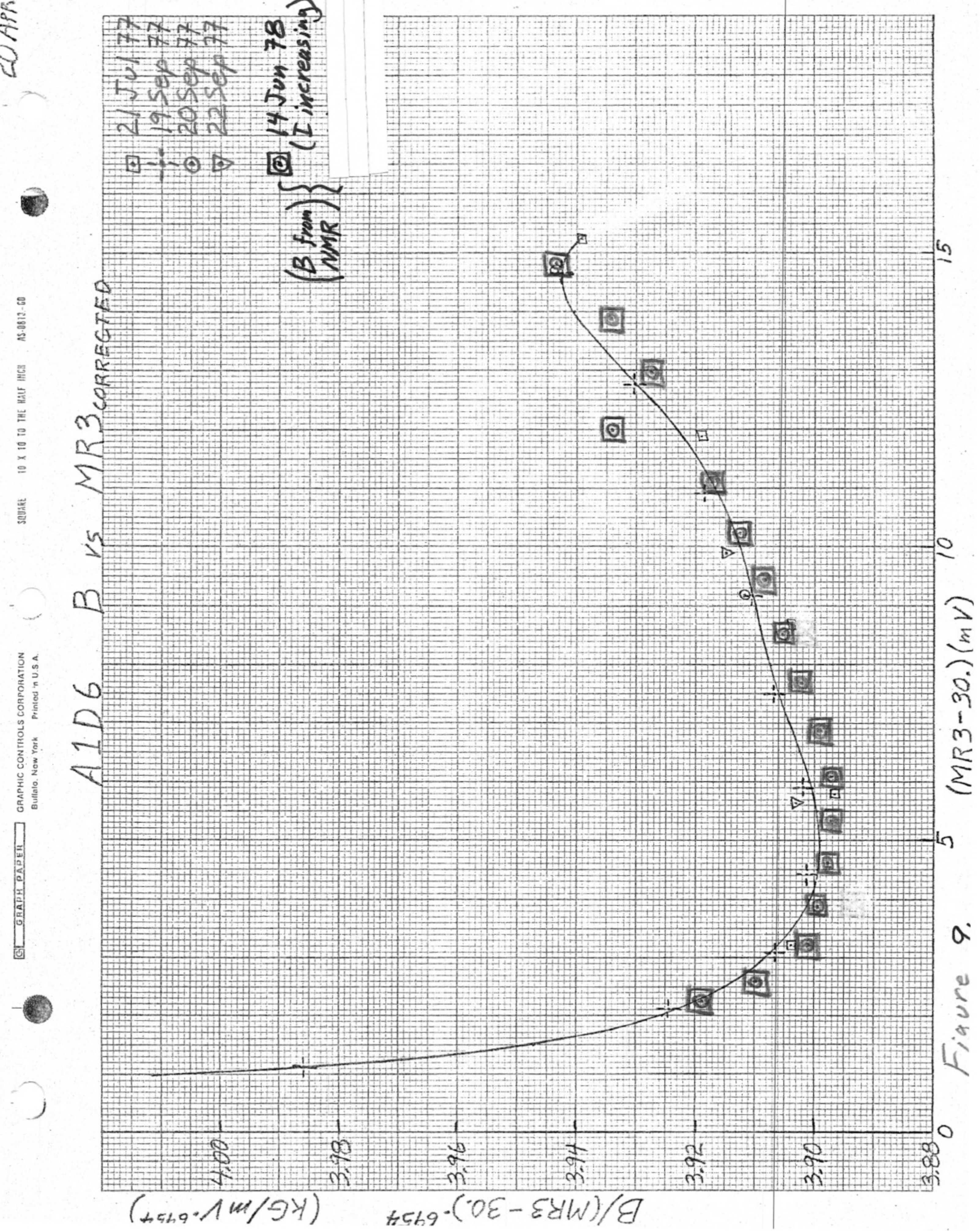


Figure 8.


20 APR 78
A1D6 B vs MR3 CORRECTED
21 Jul 77
19 Sep 77
20 Sep 77
22 Sep 77
14 Jun 78 (I increasing)
(B from NMR)
B/(MR3 - 30.)·6454 (KG/mV·6454)
(MR3-30.) (mV)
4.00
3.98
3.96
3.94
3.92
3.90
3.88
0
5
10
15
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SQUARE 10 X 10 TO THE HALF INCH

Figure 9.