BOOSTER SEXTUPOLE PRODUCTION MEASUREMENTS

I

BOOSTER TECHNICAL NOTE
NO. 182

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INTRODUCTION

This note is a report on the Booster sextupoles and follows the format of earlier reports on the Booster quadrupoles, BTN 174 and BTN 176. It consists of three parts. Part A reports on production measurement results on all of the 52 sextupoles. Part B is an example of a detailed report which is generated for each magnet. These reports will not be given wide circulation, but they will be stored as part of the permanent record for each magnet. Part C is a data sheet for the Booster sextupole. It is intended as a replacement for Table 3-6 of the Design Manual. This data sheet is being built into the Booster data base, which should provide for easy updating and distribution.

A. Booster Sextupole Production Measurement Results

This note reports on results from 52 Booster sextupoles. The magnets were measured by the AD Group and the results were reported in their TMG Series of notes as well as being made available to us on the VAX computer.

The nomenclature we shall use is as follows:

$$B_y(X) = B_o + B_1{*}X + B_2{*}X^2 + B_3{*}X^3 + \ldots$$

$$B_x(X) = A_o + A_1{*}X + A_2{*}X^2 + A_3{*}X^3 + \ldots$$

In a sextupole the only allowed terms are B_2 and B_8 etc.

All the measurements are DC, and are made with a rotating coil, 44 millimeters in diameter and 36.5 inches long, which projects well outside the ends of the magnets. Therefore, all our data are in the form of integrated field values, written as $B_2{*}L_{eff}$ etc. Figure 1 shows a typical plot of $B_2{*}L_{eff}$, the integrated sextupole field, versus the current, I. Figure 2 is a more interesting plot of the integrated sextupole field divided by I versus I. This shows the saturation effect at high currents and the residual field effects at low currents.

This curve represents averaged results from the 52 magnets. Table 1 lists the data points. This data should be used to characterize the DC performance of these magnets. The individual magnets vary from this curve with an rms spread to three parts in 1000. However, above 200 Amperes, all the magnets display the same shape as this curve to an accuracy of three parts in 10,000. Thus, any magnet can be parameterized as a function of current by adding to the data of Table 1 a small constant, given for each magnet in Table 2. For completeness, Figure 3 and Table 3 give the current, I, as a function the integrated sextupole field divided by I.

It should be noted that these measurements are DC production measurements and that the actual sextupole in the Booster will be determined in addition by the AC behavior of these magnets, as well as by the AC behavior of the dipoles, the dipole vacuum chambers, and the dipole correction coils. Thus, although we could easily use our data to specify the exact variability in DC strength of the sextupole strings as they are installed around the ring, the other sources of variability are unknown in detail and may be larger, making such an effort questionable. However, the information is available if it is desired.

The accuracy required in manufacturing the magnets is that the rms spread in the fractional variation in the value of the integrated field be less than one part in one hundred. This corresponds to a spread in the average value of the radius of the sextuples of 0.011 inches or in the length of the sextupoles of 0.030 inches. These requirements are easily met. Figure 4 is a histogram of the offsets from Table 2, divided by the mean value, B2*Leff/I = 0.00656 (T/m^2)*m/A. The rms spread here is 3.5 parts per 1000 well within the specified 1%. The total spread here is a four parts in 240 and our best guess is that much of this difference is due to the total number of laminations in the magnet varying from the required 240 by plus or minus 2. We do not have the data to test this hypothesis.

The field shape results are summarized in Table 4, the same data being shown in two different formats for convenience. The relatively large values for the dipole and quadruple terms are presumably due to measuring coil placement, otherwise the field shape is very good.

Our conclusions are that the magnets are identical to within the specified tolerance. The manufacturer did a good job.

B. Standard Measurement Report

The appended report will be generated and permanently stored for each magnet. It is intended to be self-explanatory. Therefore, no explanation will be given.

C. Data Sheet for Booster Main Sextupole

The appended data sheet is an attempt to provide a fairly complete description of the magnet. It will be incorporated into the Booster data base (E. Auerbach).

ACKNOWLEDGEMENTS

This note is a report on the analysis of recent measurement results for the Booster sextupole. The analysis and the conclusions are the responsibility of the author alone and represent his sole contribution to this effort. The measurements were carried out by the Measurement Group of the Accelerator Development Division, using a system developed over many years by many people, with a particular effort having been expended over the past several years to adapt the system to the present application. Our particular gratitude goes to Erich Willen and Peter Wanderer who gave generously of their time in overseeing this program.

The conclusion of this note, that the Booster sextupole is more than satisfactory, is a tribute to Gordon Danby, John Jackson, Rudy Damm, and John Brodowski who designed and developed this magnet.

TABLE 1
STANDARD SEXTUPOLE EXCITATION CURVE

I Amperes	[B2]*Leff/I [T/M^2]*M/A
25	6.685E-03
50	6.602E-03
75	6.580E-03
100	6.573E-03
200	6.568E-03
300	6.566E-03
400	6.563E-03
500	6.558E-03
600	6.549E-03
700	6.536E-03
800	6.513E-03

TABLE 2
STANDARD SEXTUPOLE EXCITATION CURVE

[B2]*Leff [T/M^2]*M	I/{[B2]*Leff} A/{[T/M^2]*M}
0.167	149.598
0.330	151.468
0.494	151.967
0.657	152.135
1.314	152.249
1.970	152.291
2.625	152.367
3.279	152.493
3.930	152.689
4.575	152.991
5.211	153.536

TABLE 3
OFFSET TO BE ADDED
TO TABLE 1

MAGNET NUMBER	OFFSET [T/M^2]*M/A 10^-5
BMS 1	0.9
2	-1.1
3	0.5
4	-1.5
5	0.4
6	0.1
7	-0.1
8	0.4
9	-1.4
10	-0.6
11	-0.0
12	0.6
13	1.8
14	2.7
15	1.8
16	1.4
17	1.6
18	1.6
19	-4.6
20	-0.6
21	-2.1
22	1.8
23	2.4
24	2.3
25	-0.8
26	2.8
27	-0.8
28	-2.2
29	-1.5
30	0.0
31	-1.9
32	-0.8
33	-1.6
34	2.2
35	-0.9
36	-0.2
37	-4.5
38	0.7
39	2.0
40	-4.3
41	1.8
42	-1.9
43	-1.8
44	5.3
45	0.6
46	1.7

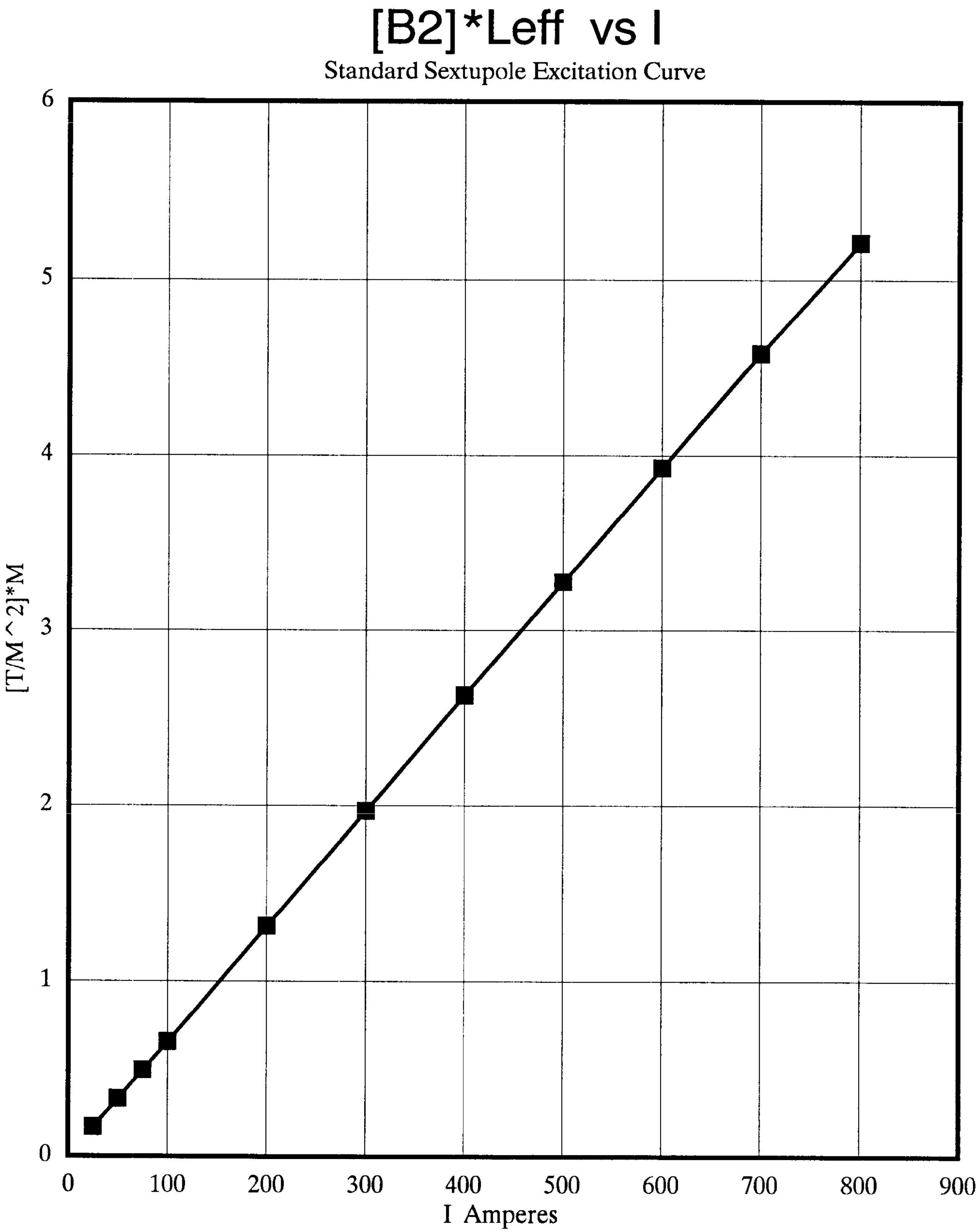
TABLE 4 FIELD SHAPE ANALYSIS

A. DATA RELATIVE TO B2

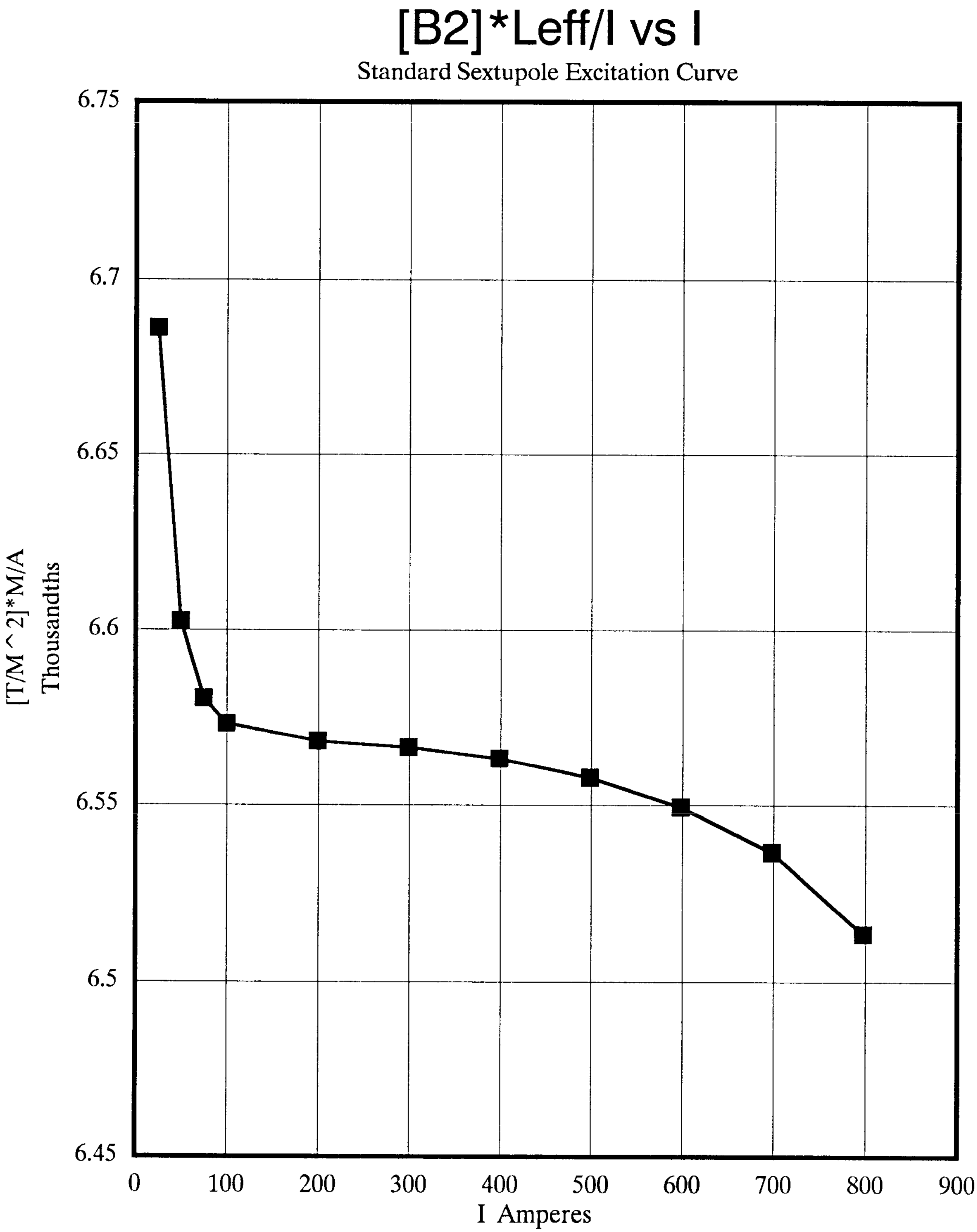
	Systematic Errors			Random Errors		
	Tolerance m^-(n-2)	Measured m^-(n-2)	meas/toler	Tolerance m^-(n-2)	Measured m^-(n-2)	meas/toler
B0/B2				2.7E-05	1.8E-05	0.7
B1/B2				3.0E-04	2.4E-04	0.8
B2				8.9E-03	3.4E-03	0.4
B3/B2	5.9E+00	1.3E-02	0.002	3.0E+00	2.0E-02	0.007
B4/B2	8.9E+00	-7.2E-01	-0.08	1.8E+01	7.5E-01	0.04
B5/B2	1.2E+05	1.9E+01	0.000	3.0E+02	2.3E+01	0.08
A0/B2				2.7E-05	2.4E-06	0.09
A1/B2				3.0E-04	2.8E-04	0.95
A2/B2	8.9E-02	-2.4E-02	-0.3	8.9E-03	2.2E-03	0.25
A3/B2	5.9E+00	2.8E-03	0.000	3.0E+00	2.5E-02	0.009
A4/B2	8.9E+00	1.0E+00	0.1	1.8E+01	8.4E-01	0.05
A5/B2	1.2E+05	-1.1E+01	-0.000	3.0E+02	1.9E+01	0.06

B. DATA RELATIVE TO B0

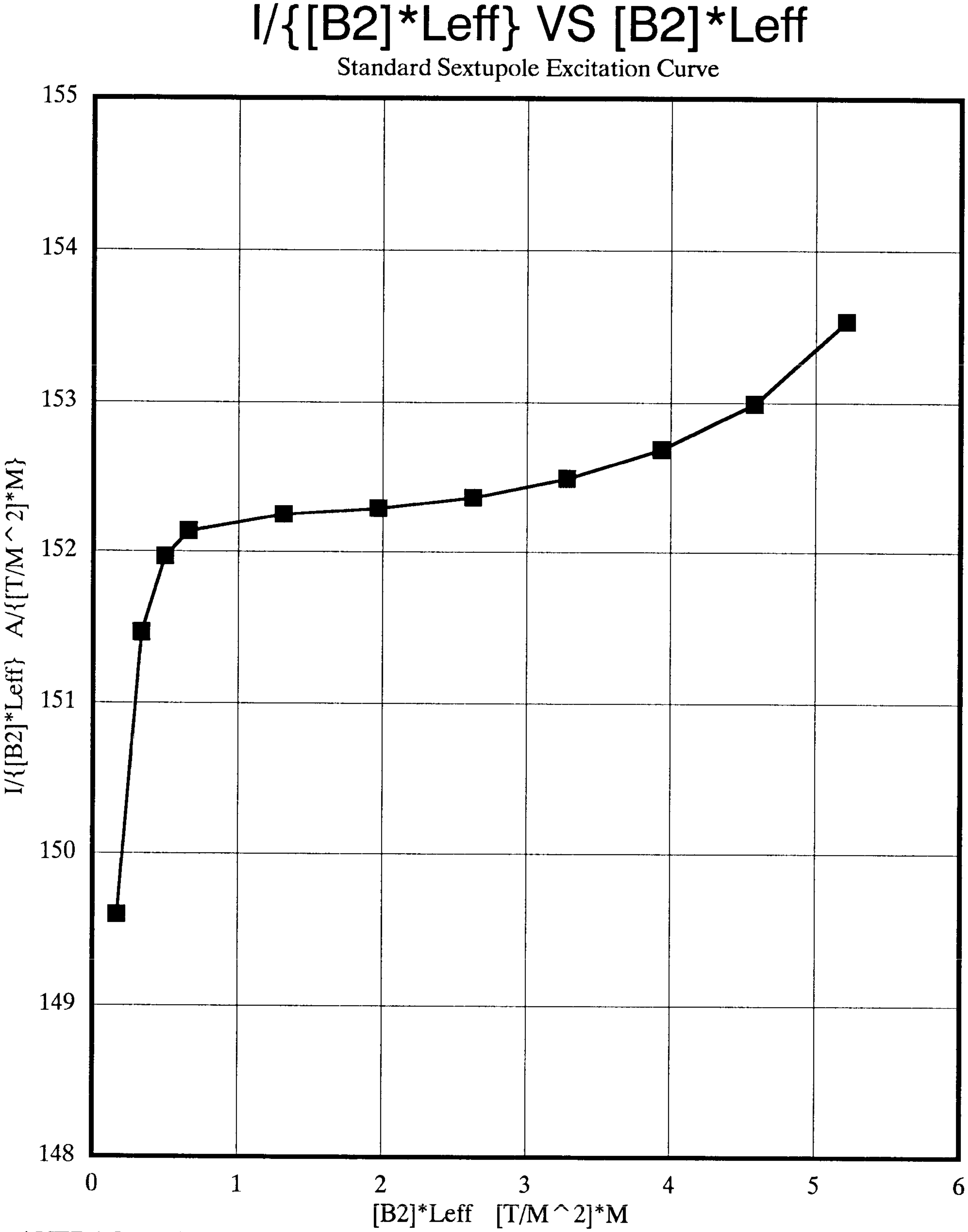
	Systematic Errors			Random Errors		
	Tolerance m^-n	Measured m^-n	meas/toler	Tolerance m^-n	Measured m^-n	meas/toler
b0				9.0E-04	6.2E-04	0.7
b1				1.0E-02	8.2E-03	0.8
b2				3.0E-01	1.2E-01	0.4
b3	2.0E+02	4.4E-01	0.002	1.0E+02	6.6E-01	0.007
b4	3.0E+02	-2.4E+01	-0.08	6.0E+02	2.5E+01	0.04
b5	4.0E+06	6.5E+02	0.000	1.0E+04	7.6E+02	0.08
a0				9.0E-04	8.1E-05	0.09
a1				1.0E-02	9.5E-03	0.95
a2	3.0E+00	-8.2E-01	-0.3	3.0E-01	7.4E-02	0.25
a3	2.0E+02	9.3E-02	0.000	1.0E+02	8.5E-01	0.009
a4	3.0E+02	3.4E+01	0.1	6.0E+02	2.8E+01	0.05
a5	4.0E+06	-3.8E+02	-0.000	1.0E+04	6.2E+02	0.06



Averaged over 52 Sextupole Magnets
08–Mar–91

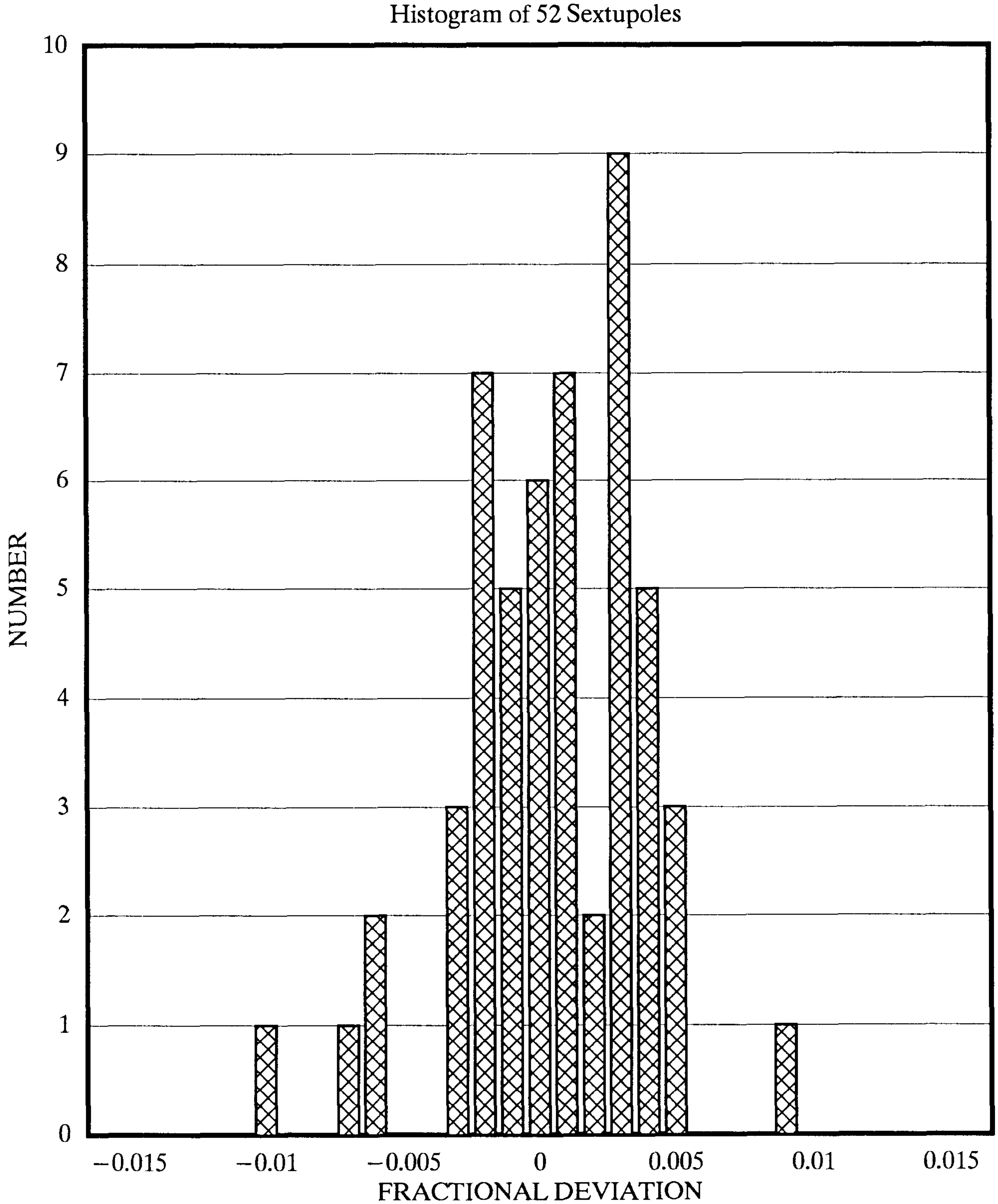


Averaged over 52 Sextupole Magnets
08–Mar–91



AVERAGED OVER 52 SEXTUPOLE MAGNETS
08–Mar–91

DEVIATIONS from the MEAN for [B2]*Leff/I



STD = 0.0035
08−Mar−91

ANALYSIS of FIELD SHAPE MEASUREMENTS

MAGNET TYPE	BOOSTER SEXTUPOLE
MAGNET NUMBER	BMS025
RUN NUMBER	BMS025.101(raw)
DATE of MEASUREMENT	2 Aug 90 15:25:15
DATE of ANALYSIS	20-Feb-91

SHORT SUMMARY of MAGNET QUALITY

SUMMARY of PRIMARY FIELD RESULTS

B2*Leff/I @ 400 A	0.00656	(T/M^2)*M/A
B2*Leff/I @ 800 A	0.00651	(T/M^2)*M/A

SATURATION EFFECT 1.0076

SUMMARY of HARMONIC CONTENTS

	AVG	STD DEV	UNITS
B0/B2	-7.27E-05	5.1E-07	M^2
A0/B2	1.18E-06	2.0E-07	M^2
B3/B2	2.00E-02	3.4E-03	M^-1
A3/B2	-5.98E-03	2.4E-03	M^-1
B4/B2	-5.24E-01	5.0E-02	M^-2
A4/B2	4.59E-01	4.4E-02	M^-2
B5/B2	2.0E+01	2.7E+00	M^-3
A5/B2	-8.6E+00	1.3E+00	M^-3

SUMMARY of ALIGNMENT PARAMETERS

xo	5.90E-05	1.4E-06	M
	2.3	0.1	0.001 INCHES
yo	-4.75E-04	3.7E-06	M
	-18.7	0.1	0.001 INCHES
Theta	-7.19E-03	1.2E-05	radians

SUMMARY of RESIDUAL FIELDS

Bo*Leff	1.4E-04		T*M
Ao*Leff	-2.9E-06		T*M
B2*Leff	5.8E-03		(T/M^2)*M
A2*Leff	-1.9E-04		(T/M^2)*M

BASIC MEASUREMENT RESULTS

	I AMPS	B2*Leff (T/M^2)*M	Bo*Leff T*M	B1*Leff (T/M)*M	B3*Leff (T/M^3)*M	B4*Leff (T/M^4)*M	B5*Leff (T/M^5)*M
1	0.002	0.006	1.4E-04	5.2E-05	-5.7E-03	-1.2E-02	-2.79E-01
2	24.593	0.165	1.3E-04	6.5E-05	3.0E-03	-2.5E-01	-6.43E+00
3	49.54	0.327	1.2E-04	8.1E-05	9.0E-03	-2.1E-01	3.89E+00
4	74.486	0.490	1.1E-04	1.0E-04	8.2E-03	-2.0E-01	1.15E+01
5	99.409	0.653	9.5E-05	1.2E-04	6.6E-03	-2.2E-01	8.07E+00
6	199.16	1.307	4.7E-05	2.0E-04	2.9E-02	-7.7E-01	2.35E+01
7	298.804	1.960	6.7E-07	2.8E-04	3.6E-02	-8.5E-01	4.95E+01
8	398.534	2.613	-4.6E-05	3.7E-04	3.7E-02	-1.3E+00	4.38E+01
9	498.326	3.264	-9.4E-05	4.5E-04	5.0E-02	-1.8E+00	6.94E+01
10	598.144	3.913	-1.4E-04	5.0E-04	6.9E-02	-2.2E+00	7.71E+01
11	697.713	4.555	-1.9E-04	5.7E-04	8.4E-02	-2.4E+00	9.18E+01
12	797.507	5.188	-2.5E-04	6.7E-04	7.4E-02	-3.1E+00	1.14E+02

	I AMPS	A2*Leff (T/M^2)*M	Ao*Leff T*M	A1*Leff (T/M)*M	A3*Leff (T/M^3)*M	A4*Leff (T/M^4)*M	A5*Leff (T/M^5)*M
1	0.002	-0.000	-0.000	1.7E-04	7.2E-04	-1.5E-01	-6.152234
2	24.593	-0.004	-0.000	2.9E-05	1.3E-03	-1.1E-01	-11.48617
3	49.54	-0.007	-0.000	-1.2E-04	-5.0E-03	-4.3E-02	-8.852036
4	74.486	-0.010	-0.000	-2.6E-04	-3.1E-03	2.2E-01	-5.013184
5	99.409	-0.014	-0.000	-4.1E-04	8.0E-04	2.9E-01	-4.467261
6	199.16	-0.028	-0.000	-1.1E-03	-7.2E-03	5.6E-01	-16.37456
7	298.804	-0.042	-0.000	-1.7E-03	-1.8E-02	6.8E-01	-21.53754
8	398.534	-0.056	-0.000	-2.3E-03	-1.9E-02	1.1E+00	-26.65769
9	498.326	-0.070	0.000	-2.9E-03	-1.5E-02	1.3E+00	-42.37914
10	598.144	-0.085	0.000	-3.6E-03	-2.4E-02	1.5E+00	-34.3978
11	697.713	-0.098	0.000	-4.2E-03	-7.3E-03	1.8E+00	-49.0289
12	797.507	-0.112	0.000	-4.8E-03	-2.4E-02	2.1E+00	-52.22543

GRADIENT and POSITION ANALYSIS

			Residual Field Subtracted			
	I AMPS	B2*Leff/I (T/M^2)*M/A	B2*Leff/I (T/M^2)*M/A	Theta A2/(3*B2) radians	xo B1/(2*B2) M	yo A1/(2*B2) M
1	0.002					
2	24.593	0.00669	0.00646	-7.38E-03	4.07E-05	-4.33E-04
3	49.54	0.00660	0.00649	-7.34E-03	4.49E-05	-4.40E-04
4	74.486	0.00658	0.00650	-7.04E-03	5.18E-05	-4.37E-04
5	99.409	0.00657	0.00651	-7.04E-03	4.89E-05	-4.46E-04
6	199.16	0.00656	0.00653	-7.20E-03	5.82E-05	-4.69E-04
7	298.804	0.00656	0.00654	-7.19E-03	5.90E-05	-4.70E-04
8	398.534	0.00656	0.00654	-7.20E-03	6.08E-05	-4.75E-04
9	498.326	0.00655	0.00654	-7.19E-03	6.09E-05	-4.77E-04
10	598.144	0.00654	0.00653	-7.20E-03	5.78E-05	-4.79E-04
11	697.713	0.00653	0.00652	-7.17E-03	5.73E-05	-4.78E-04
12	797.507	0.00651	0.00650	-7.21E-03	5.99E-05	-4.77E-04
	AVG(2-700)	6.55E-03	6.53E-03	-7.19E-03	5.90E-05	-4.75E-04
	STAND DEV	1.2E-05	7.1E-06	1.2E-05	1.4E-06	3.7E-06

HARMONIC CONTENT
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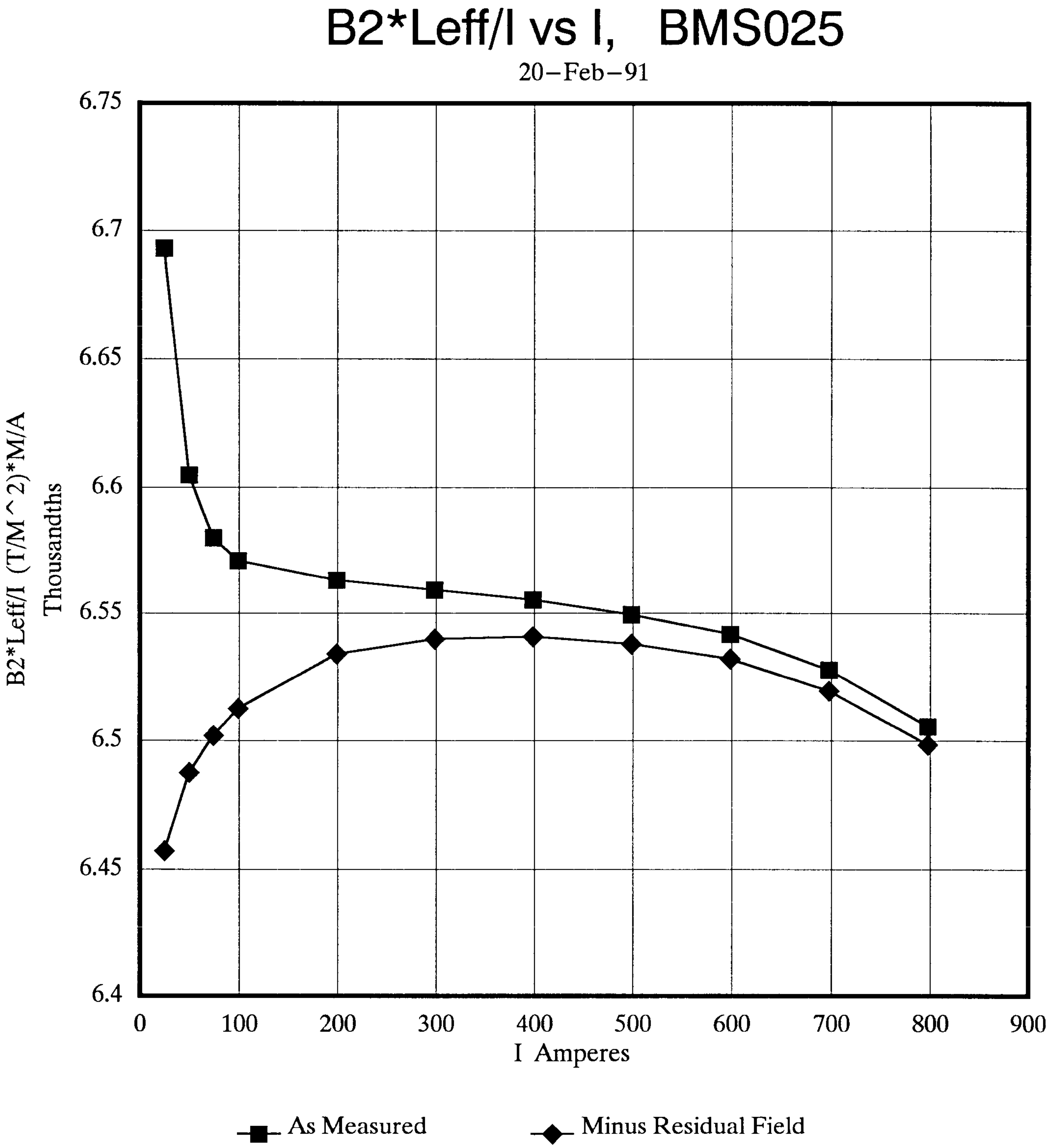
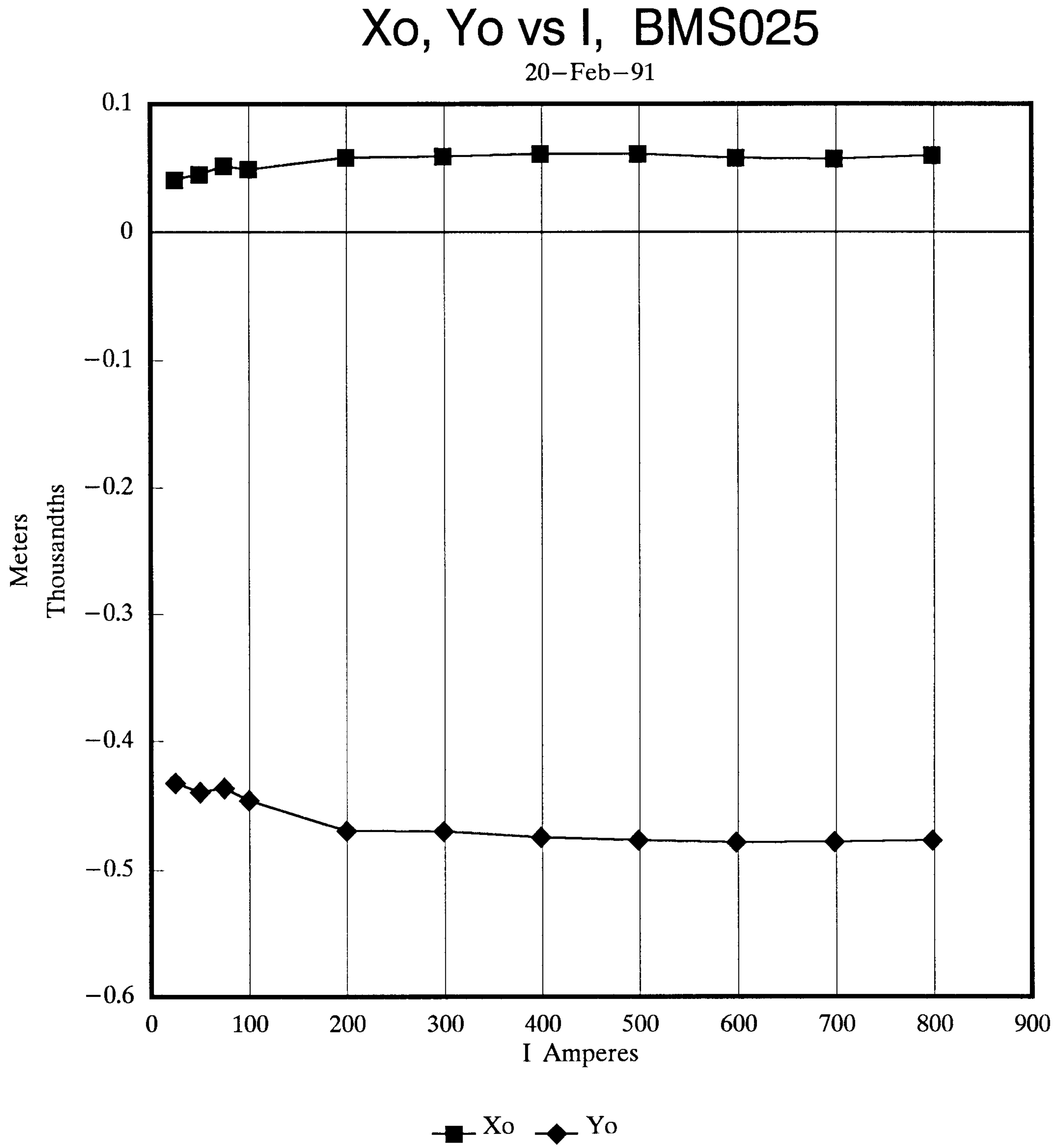
	I AMPS	B2*Leff/I (T/M^2)*M/A	Bo/B2 M^2	B1/B2 M	B3/B2 M^-1	B4/B2 M^-2	B5/B2 M^-3
1	0.002						
2	24.593	6.693E-03	-6.89E-05	8.14E-05	5.52E-02	-1.5E+00	-3.9E+01
3	49.54	6.605E-03	-7.24E-05	8.98E-05	4.59E-02	-6.1E-01	1.3E+01
4	74.486	6.580E-03	-7.26E-05	1.04E-04	2.88E-02	-3.8E-01	2.4E+01
5	99.409	6.571E-03	-7.24E-05	9.78E-05	1.91E-02	-3.2E-01	1.3E+01
6	199.16	6.563E-03	-7.29E-05	1.16E-04	2.66E-02	-5.8E-01	1.8E+01
7	298.804	6.559E-03	-7.23E-05	1.18E-04	2.13E-02	-4.3E-01	2.5E+01
8	398.534	6.555E-03	-7.20E-05	1.22E-04	1.65E-02	-5.1E-01	1.7E+01
9	498.326	6.550E-03	-7.24E-05	1.22E-04	1.70E-02	-5.6E-01	2.1E+01
10	598.144	6.542E-03	-7.29E-05	1.16E-04	1.91E-02	-5.5E-01	2.0E+01
11	697.713	6.528E-03	-7.35E-05	1.15E-04	1.97E-02	-5.1E-01	2.0E+01
12	797.507	6.506E-03	-7.56E-05	1.20E-04	1.54E-02	-5.9E-01	2.2E+01
	AVG(2-700)	6.55E-03	-7.27E-05	1.18E-04	2.00E-02	-5.24E-01	2.03E+01
	STAND DEV	1.2E-05	5.1E-07	2.8E-06	3.4E-03	5.0E-02	2.7E+00

	I AMPS	A2/B2	Ao/B2 M^2	A1/B2 M	A3/B2 M^-1	A4/B2 M^-2	A5/B2 M^-3
1	0.002						
2	24.593	-2.2E-02	-1.83E-06	-8.66E-04	3.42E-03	2.5E-01	-3.4E+01
3	49.54	-2.2E-02	-4.52E-07	-8.80E-04	-1.79E-02	3.5E-01	-8.4E+00
4	74.486	-2.1E-02	4.82E-07	-8.73E-04	-7.88E-03	7.8E-01	2.4E+00
5	99.409	-2.1E-02	5.41E-07	-8.92E-04	1.21E-04	6.9E-01	2.6E+00
6	199.16	-2.2E-02	7.93E-07	-9.39E-04	-6.08E-03	5.5E-01	-7.9E+00
7	298.804	-2.2E-02	1.35E-06	-9.40E-04	-9.58E-03	4.3E-01	-7.9E+00
8	398.534	-2.2E-02	1.03E-06	-9.49E-04	-7.39E-03	4.7E-01	-7.9E+00
9	498.326	-2.2E-02	1.31E-06	-9.54E-04	-4.81E-03	4.6E-01	-1.1E+01
10	598.144	-2.2E-02	1.28E-06	-9.57E-04	-6.24E-03	4.3E-01	-7.2E+00
11	697.713	-2.2E-02	1.32E-06	-9.56E-04	-1.77E-03	4.2E-01	-9.4E+00
12	797.507	-2.2E-02	1.08E-06	-9.54E-04	-4.74E-03	4.4E-01	-8.9E+00
	AVG(2-700)	-2.16E-02	1.18E-06	-9.49E-04	-5.98E-03	4.59E-01	-8.56E+00
	STAND DEV	3.54E-05	2.04E-07	7.38E-06	2.39E-03	4.38E-02	1.32E+00



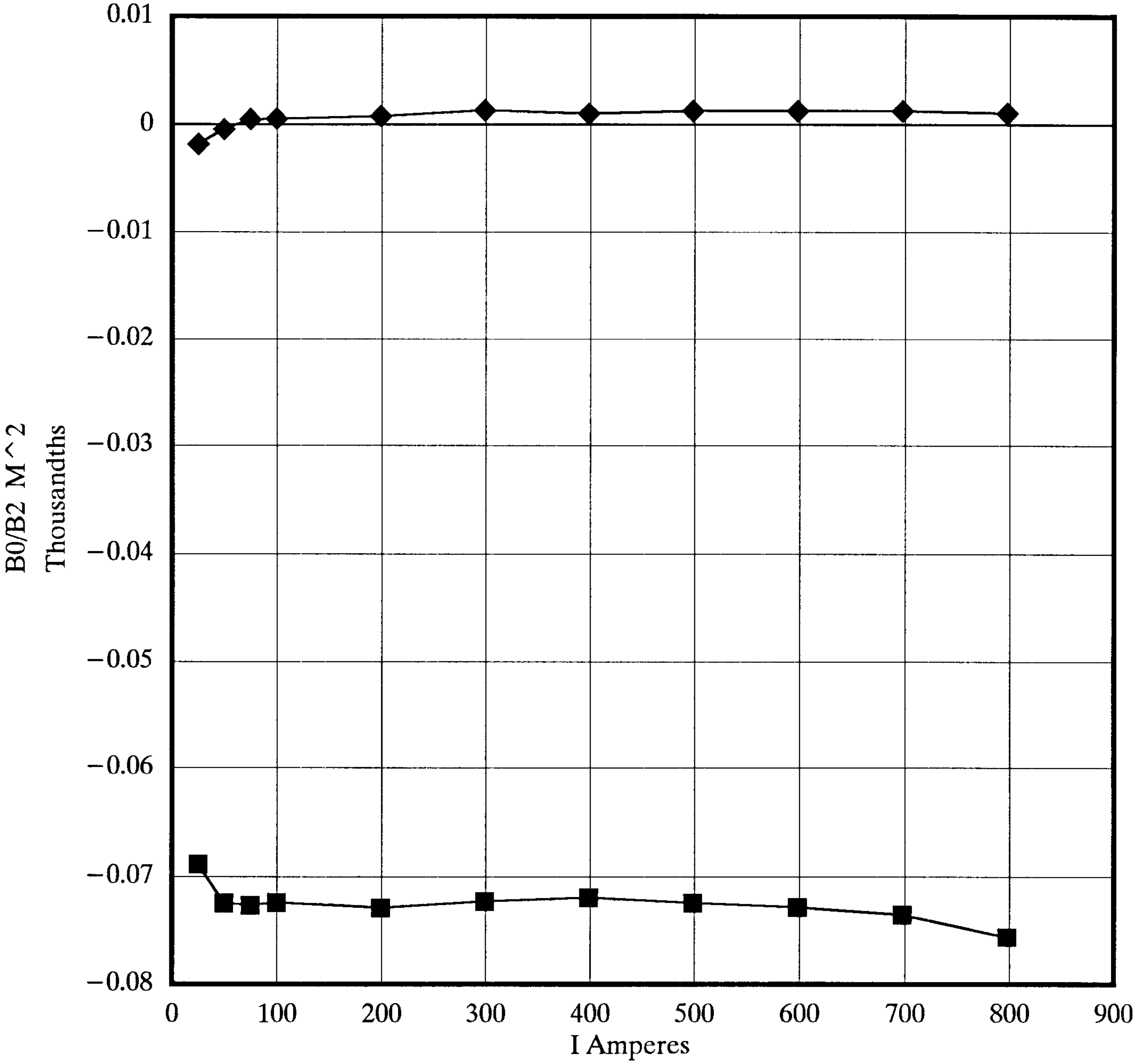
B2*Leff/I at 400 Amps = 0.00656
B2*Leff/I at 800 Amps = 0.00651



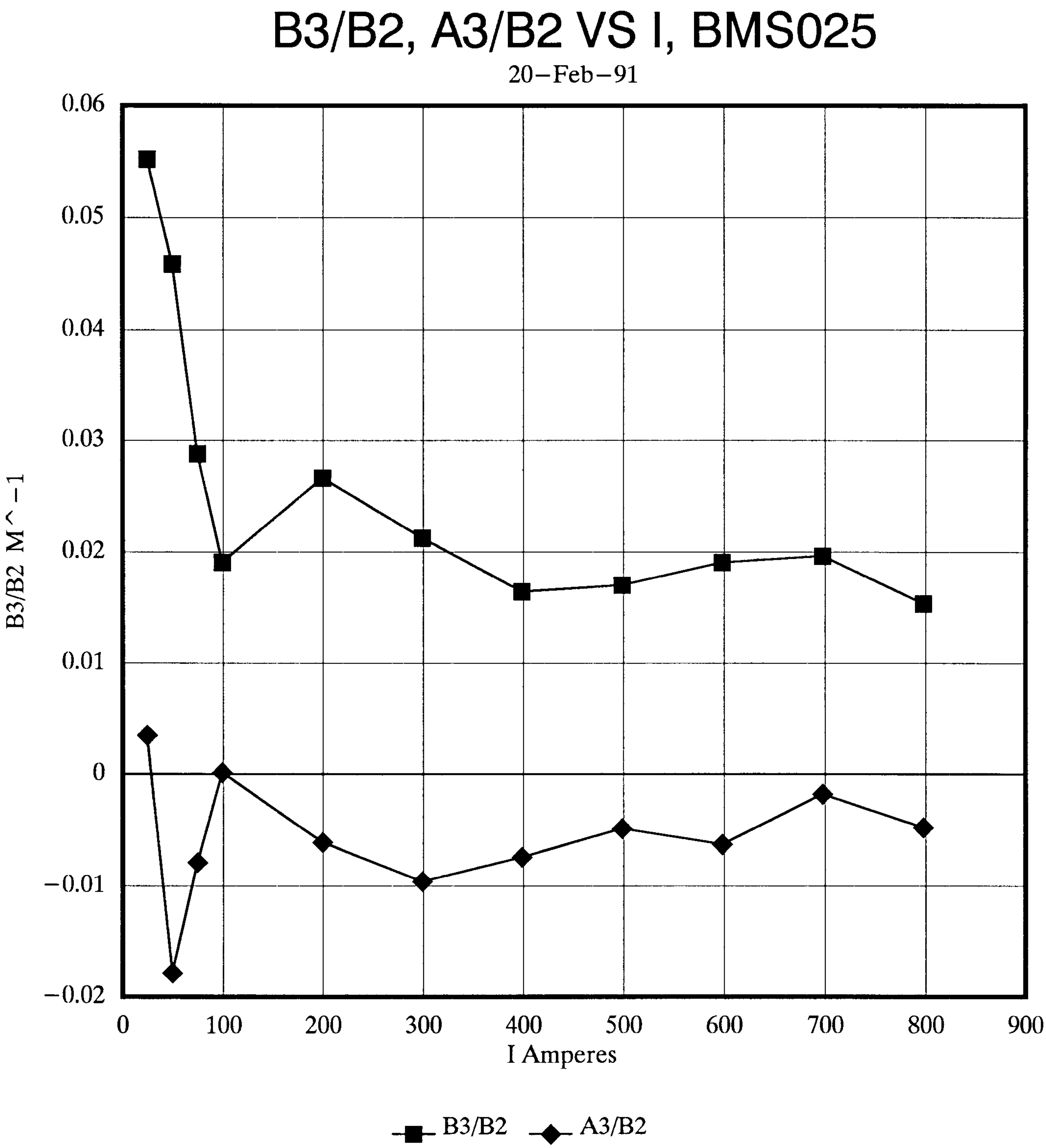
Xo = 0.0023 inches
Yo = −0.0187 inches

B0/B2, A0/A2 VS I, BMS025

20–Feb–91



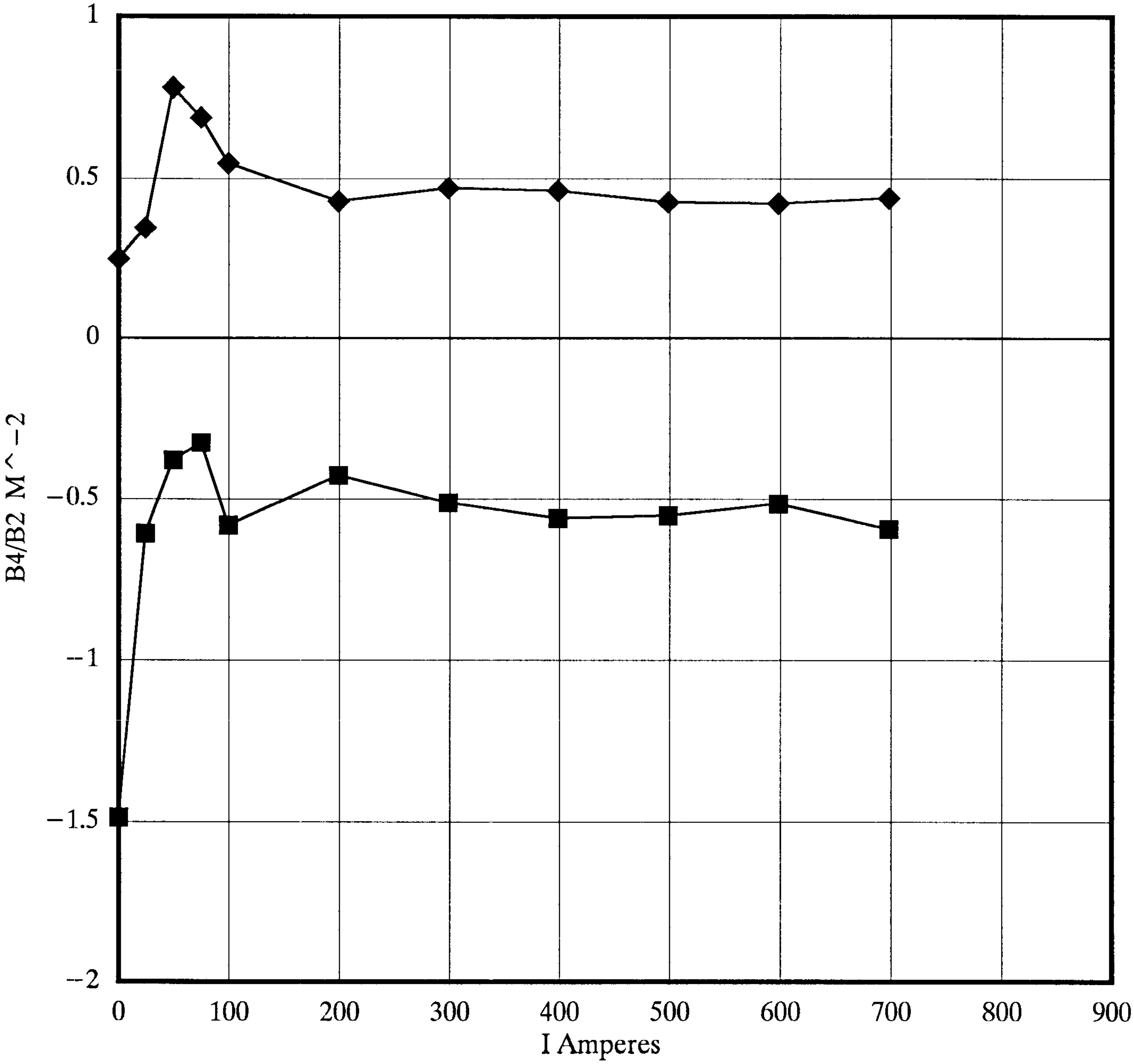
B0/B2(FROM 200 TO 700 AMPS) = –0.000073
A0/B2(FROM 200 TO 700 AMPS) = 0.000001



B3/B2(FROM 200 TO 700 AMPS) = 0.020019
A3/B2(FROM 200 TO 700 AMPS) = −0.005981

B4/B2, A4/B2 VS I, BMS025

20–Feb–91



B4/B2(FROM 200 TO 700 AMPS) = −0.524194997
A4/B2(FROM 200 TO 700 AMPS) = 0.459094123

PARAMETER SHEET FOR BOOSTER SEXTUPOLE

Issued February 21, 1991

PROTOTYPE NAME	BMS (BOOSTER MAIN SEXTUPOLE)
MAGNET CLASS	SEXTUPOLE
NUMBER OF MAGNETS	48 PLUS 4
VENDOR	Everson Electric-Complete Magnet

	INCHES	METERS	OTHER	REF
MECHANICAL				
CORE				
Lamination Length	3.000	76.2 E-3		a
Tolerance Specified	0.005	0.137 E-3		a
Tolerance Measured	0.011	0.28 E-3		e
Structural Length	3.5	89. E-3		a
Coil Length	5.2	132		a
Overall Length	8.5	216		a
Aperture Shape	Round			
Radius at Pole Tip	3.250	82.55 E-3		a
Tolerance Specified	0.002	0.05 E-3		d
Tolerance Measured	0.001	0.02 E-3		e
Pole Width	2.45	62.2 E-3		a
Core Height	8.89	226. E-3		a
Core Width	8.89	226. E-3		a
LAMINATIONS				
Material	Armco M-36			a
Coating	AISI Type - C5			a
Coating Thickness	0.0002	0.005 E-3		a
Overall Thickness	0.025	0.6 E-3		a

	INCHES	METERS	OTHER	REF
Approx. Lams Per Block	120			
Block Weight	NA	NA		
Tolerance Specified	NA	NA		
Tolerance Measured	NA	NA		
VACUUM PIPE				
Height - Outside	6	152 E-3		b
Width - Outside	6	152 E - 3		b
Wall Thickness	0.063	1.6 E-3		b
Tolerance Specified	0.003	0.1 E-3		b
Tolerance Measured	NA	NA		
Half Height - Inside	2.937	74.6 E-3		
Half Width - Inside	2.937	74.6 E-3		
Material	Inconel 625			b
Resistivity	1.29 E-6		Ohm-m	b
Tolerance Specified	0.02 E-6		Ohm-m	b
Tolerance Measured	NA			

	INCHES	METERS	OTHER	REF
MAIN COIL				
COIL				
Turns per Pole	8			
Poles per Magnet	6			
Resistance per Magnet	7.58 E-3		Ohms	f
Inductance Per Magnet - DC	0.37 E-3		Henry	f
Inductance Per Magnet - 1 k	0.37 E-3		Henry	f
CONDUCTOR				
Material	Copper - Alloy 0102			a
Shape	Square			
Width	0.315	8.0 E-3		a
Height	0.315	8.0 E-3		a
Cooling Hole Diameter	0.197	5.0 E-3		a
Area	0.067	43 E-6		a
Length per Pole	126	3.2		a
Length per Magnet	756	19.2		
INSULATION				
Material	Epoxy Fiberglas			a
Thickness	0.04	1. E-3		a
Tolerance	0.01	0.25 E-3		a
Ground Test	2000		Volts	c
Impulse Test	1500		Volts	c
COOLING				
Circuits per Magnet	2			a
Flow Rate per Magnet	0.6		Gallons/Minute	a
Input Pressure	50		PSI	a
Temp Rise @ RAMP to Imax	20		Degrees F	a
CURRENT				
Imax (PS Limit)	300		Amperes	c
Current Density @ Imax	4500	7 E+6	Amperes/Area	
DC Power @ Imax	680		Watts	
Stored Energy @ Imax	17		Joules	

	INCHES	METERS	OTHER	REF
ONE TURN TRIM COIL				
COIL				
Turns per Pole	1			a
Poles per Magnet	6			
Resistance per Magnet	7.93 E-3		Ohms	g
Inductance per Magnet-DC	0.01 E-3		Henry	g
Inductance per Magnet-1 k	0.01 E-3		Henry	g
CONDUCTOR				
Material	Copper - ETP #110			a
Shape	Round #8 Wire			a
Width	0.129	3.28 E-3		a
Height	0.129	3.28 E-3		a
Cooling Hole Diameter	None	None		
Area	0.013	8.4 E-6		
Length per Pole	16	.41		a
Length per Magnet	136	3.45		
INSULATION				
Material		Epoxy - Fiberglas		a
Thickness	0.06	1.5 E-3		a
Tolerance	NA	NA		
Ground Test	1000		Volts	c
Impulse Test	NA			
COOLING				
Circuits per Magnet	None			
Flow Rate per Magnet	None			
Input Pressure	None			
Temp Rise @ RAMP to Imax	NA			
CURRENT				
Imax (PS Limit)	50		Amperes	c
Current Density @ Imax	3826	6 E+6	Amperes/Area	
DC Power @ Imax	20 [illegible]		Watts	
Stored Energy	0.013		Joules	

	INCHES	METERS	OTHER	REF
TWO TURN TRIM COIL				
COIL				
Turns per Pole	2			a
Poles per Magnet	6			
Resistance per Magnet	11 E-3		Ohms	f
Inductance per Magnet - DC	17 E-6		Henry	f
Inductance per Magnet - 1 k	17 E-6		Henry	f
CONDUCTOR				
Material	Copper - ETP #110			a
Shape	Round #8 Wire			a
Width	0.129	3.28 E-3		a
Height	0.129	3.28 E-3		a
Cooling Hold Diameter	None	None		
Area	0.013	8.43 E-6		
Length per Pole	32	0.813		
Length per Magnet	222	5.64		
INSULATION				
Material		Epoxy - Fiberglas		a
Thickness	0.033	0.84 E-3		a
Tolerance	NA			
DC Test	1000		Volts	c
1 kHertz Test	NA			c
COOLING				
Circuits per Magnet	None			
Flow Rate per Magnet	None			
Temp Rise @RAMP to Imax	NA			
CURRENT				
Imax (PS Limit)	50		Amperes	c
Current Density @ Imax	3826	6 E+6	Amperes/Area	
DC Power @ Imax	28		Watts	
Stored Energy	0.021		Joules	

MAGNETIC PROPERTIES OF THE MAIN COIL					
FIELD SHAPE					
bn = Bn/B0, an = An/B0 B0 from main dipole					
SYSTEMATIC TOLERANCES					
	SPECIFIED	MEASURED		UNITS	REF
		bn	an		
n = 2	3	--	- 0.83	m^{-2}	d,e
n = 3	200	0.32	0.022	m^{-3}	d,e
n = 4	300	- 28	31	m^{-4}	d,e
n = 5	4.0 E+06	540	-330	m^{-5}	d,e
n = 6	3.0 E+04	NA	NA	m^{-6}	d
RANDOM TOLERANCES					
		bn	an		
n = 0	9.0 E-4	--	--		d
n = 1	1.0 E-02	7.5E-03	9.4 E-03	m^{-1}	d,e
n = 2	0.3	0.11	0.058	m^{-2}	d,e
n = 3	100	0.59	0.79	m^{-3}	d,e
n = 4	600	0.24	0.28	m^{-4}	d,e
n = 5	1.0 E+04	7.3E+02	6.0 E+02	m^{-5}	d,e
n = 6	3.0 E+05	NA	NA	m^{-6}	d
EXCITATION FUNCTION					
TYPICAL DC MEASUREMENTS			MEASURED	UNITS	REF
B2*Leff @ I = 0			6.4E-03	$(T/m^2)*m$	e
B2*Leff/I					
@ 100 AMPS			6.572E-03	$(T/m^2)*m/A$	e
@ 200 AMPS			6.566E-03	$(T/m^2)*m/A$	e
@ 600 AMPS			6.561E-03	$(T/m^2)*m/A$	e
@ 800 AMPS			6.511E-03	$(T/m^2)*m/A$	e
Saturation Effect					
800/400			0.76%		

CALCULATIONS		CALCULATED	UNITS	REF
B2/I		0.10722	(T/m^2)*m	e
Leff				
@ 100 AMPS		.0613	(T/m^2)*m/A	e
@ 200 AMPS		.0612	(T/m^2)*m/A	e
@ 400 AMPS		.0612	(T/m^2)*m/A	e
@ 800 AMPS		.0607	(T/m^2)*m/A	e
Pole Tip Field				
@ 100 AMPS		0.0731	Tesla	
@ 200 AMPS		0.1461	Tesla	
@ 400 AMPS		0.2923	Tesla	
@ 800 AMPS		0.5845	Tesla	
MAGNETIC PROPERTIES OF THE ONE TURN TRIM COIL				
Typical DC Measurements				
B2*Leff/I		8.22 E-04	(T/m^2)*m/A	
Calculations				
B2/I		1.34 E-02	(T/m^2)/A	
MAGNETIC PROPERTIES OF THE TWO TURN TRIM COIL				
Typical DC Measurements				
B2 Leff/I		1.64 E-03	(T/m^2)*m/A	
Calculations				
B2/I		2.68 E-02	(T/m^2)/A	

References:

a. J. Koehler, Private Communication
b. H. C. Hseuh, Private Communication
c. A. Soukas, Private Communication
d. A. Ruggiero, Memo to W. Weng, 1/23/90
e. E. Bleser