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BOOSTER SHORT QUADRUPOLE PRODUCTION MEASUREMENTS

E. Bleser

September 1990

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

BOOSTER SHORT QUADRUPOLE PRODUCTION MEASUREMENTS

I

BOOSTER TECHNICAL NOTE
NO. 174

E. BLESER

SEPTEMBER 12, 1990

ALTERNATING GRADIENT SYNCHROTRON DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

BOOSTER SHORT QUADRUPOLE PRODUCTION MEASUREMENTS
I.

E. Bleser
July 2, 1990

INTRODUCTION

This note consists of three parts. Part A is a progress report on the recent production measurement results for the short Booster quadrupoles. Similar reports will be issued periodically. Requests for additional information in such reports will be thoughtfully considered. 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. Any suggestions or comments will be gratefully received. Part C is a data sheet for the Booster short quadrupole. It is intended as a replacement for Table 3-5 of the Design Manual. This data sheet is being built into the Booster data base, which should provide for easy updating and distribution. Any comments for criticisms will be promptly acted upon.

A. PRELIMINARY REPORT ON RECENT RESULTS

This note reports on results for four Booster short quads: BMQ003, BMQ005, BMQ006, BMQ007. 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 use on the VAX computer. This measurement effort is intended to monitor the production effort of the factory.

The nomenclature we shall use is as follows:

$$B_y(X) = B_o + B_1 \cdot X + B_2 \cdot X^2 + B_3 \cdot X^3 + \ldots$$
$$B_x(X) = A_o + A_1 \cdot X + A_2 \cdot X^2 + A_3 \cdot X^3 + \ldots$$

In a quadrupole the only allowed terms are B_1, B_5, etc.

All the measurements are DC and are made with a rotating coil, which is 36.5 inches long and projects well outside the ends of the magnets. Therefore, all our data are in the form of integrated field values, written as $B_1 \cdot L_{eff}$ etc. Figure 1 shows a typical plot of $B_1 \cdot L_{eff}$, the integrated gradient, versus the current, I. Figure 2 is a more interesting plot of the integrated gradient divided by I versus I. This shows quite clearly the saturation effect at high currents and the residual field effects at low currents. The relative measurement accuracy is shown in Figure 3 which compares the results on the same magnet of two separate measurements between which the measuring apparatus was disassembled. We claim a relative accuracy of one part in ten thousand.

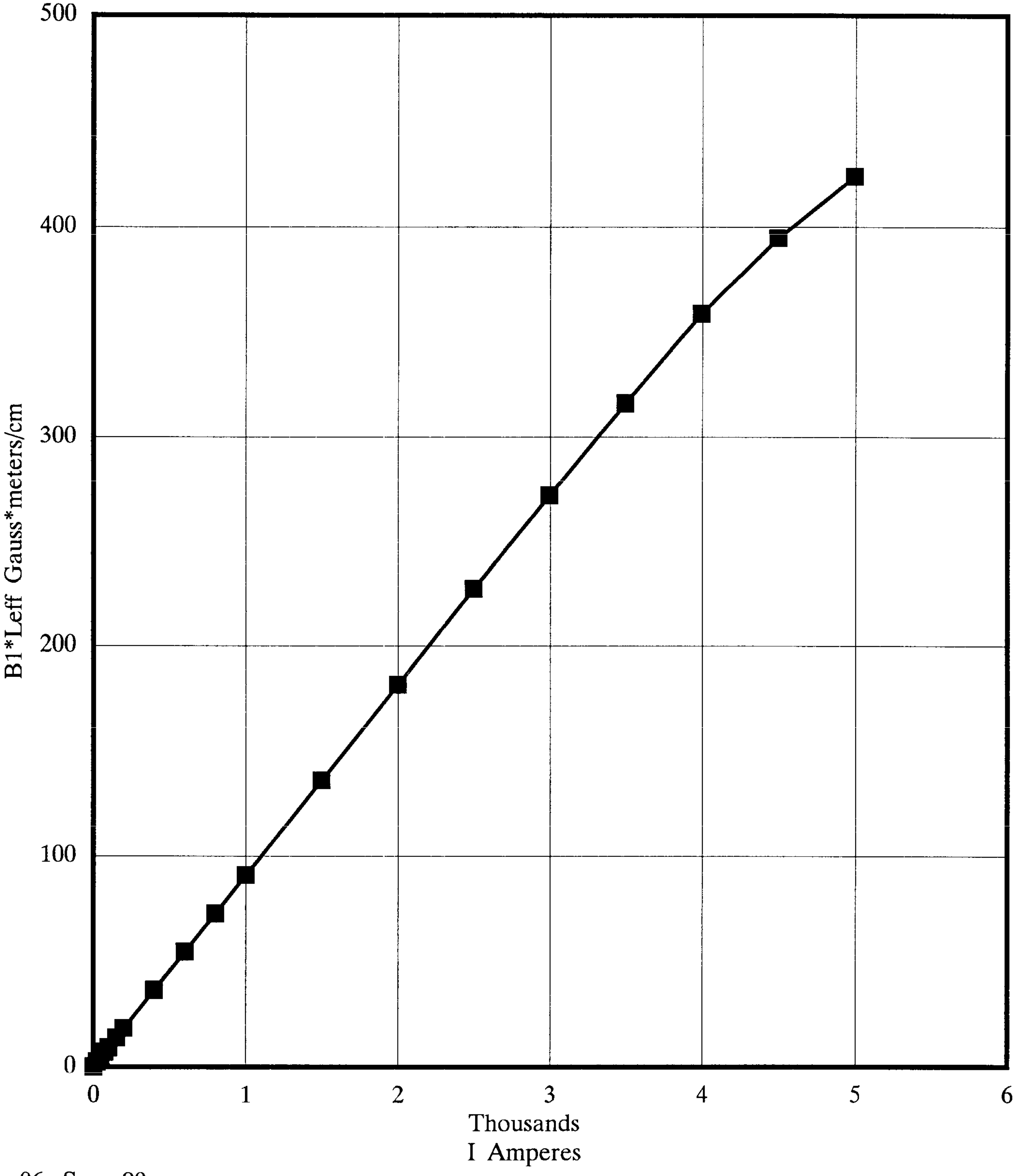
The accuracy required in manufacturing the magnets is that the rms spread in the fractional variation in the value of the integrated field be less than one part in one thousand. This corresponds to a spread in the average value of the radius of the quadrupoles of 0.001 7 inches. Figure 4 shows the standard deviation of the fractional differences from the mean of the integrated gradient of these four magnets. We conclude that up to 4000 amps the magnets agree to 2 parts in ten thousand. Above 4000 amps the spread is 4 parts in ten thousand. This could be real or instrumental. Thus, we are beating the allowed tolerance by factor of five. The assembly procedure is producing magnets that are good to 0.000 3 inches.

Since the quadrupoles are so very precise we also find that the higher order field terms are also very good. Figure 5 shows the average value and the standard deviation of the measured higher harmonic fields as a fraction of the theoretically specified tolerance. Note that except for B_5 and A_3 all these terms are on the average consistent with zero as they should be. Note also that they are all at the level of a few per cent of the allowed tolerance. Since B_5 is an allowed term it might well differ from zero. That A_3 differs from zero is interesting and is being studied with all the urgency that we can devote to an one per cent problem.

Our conclusions are that the magnets are identical and that the field shape is very good. The factory is running well. Questions we must still deal with are the absolute value of the integrated field, the eddy current effects, and some loose ends similar to the A_3 problem.

B1*Leff vs I

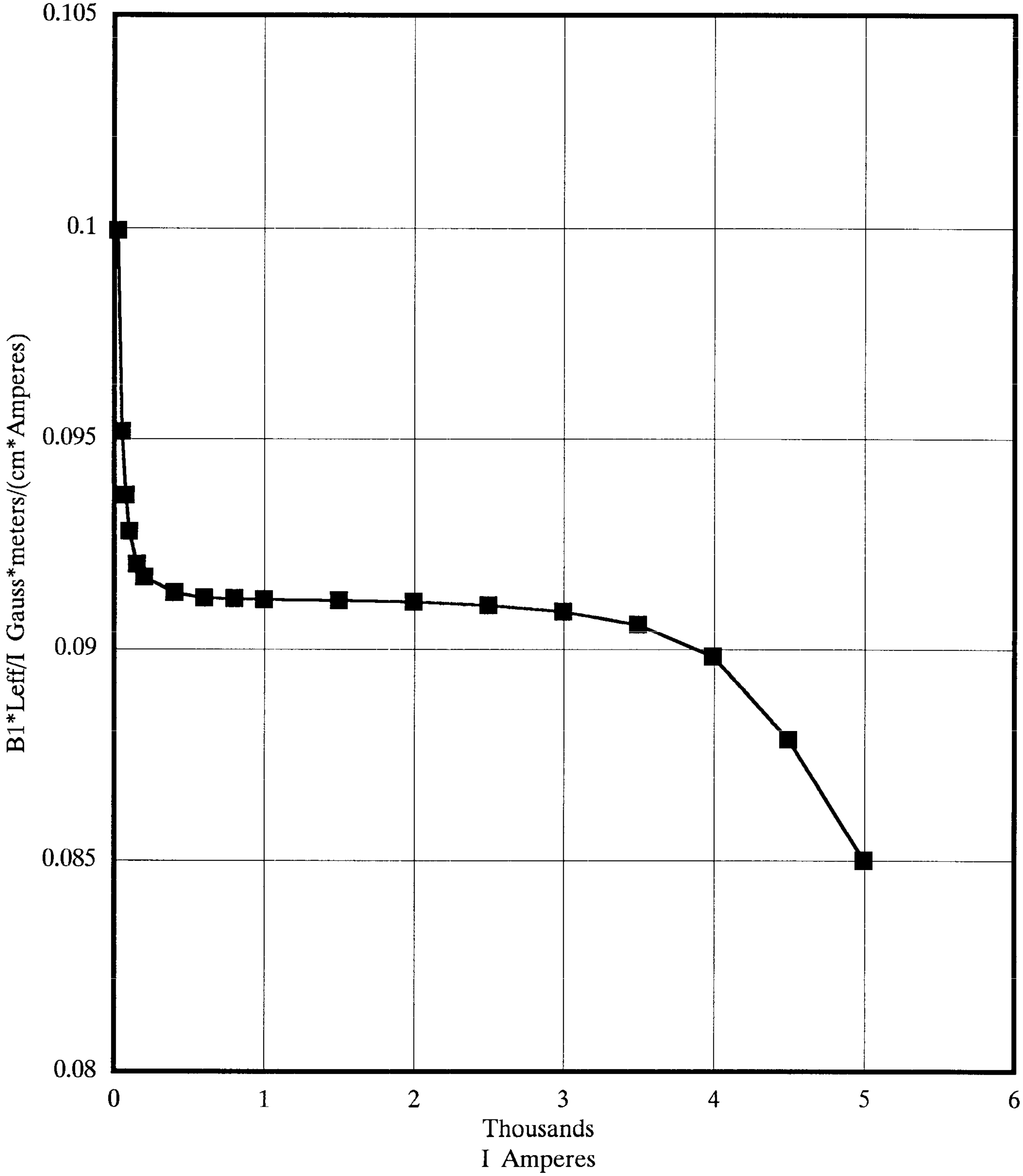
BMQ006 Fig 1



06–Sep–90

B1*Leff/I vs I

BMQ006 Fig 2



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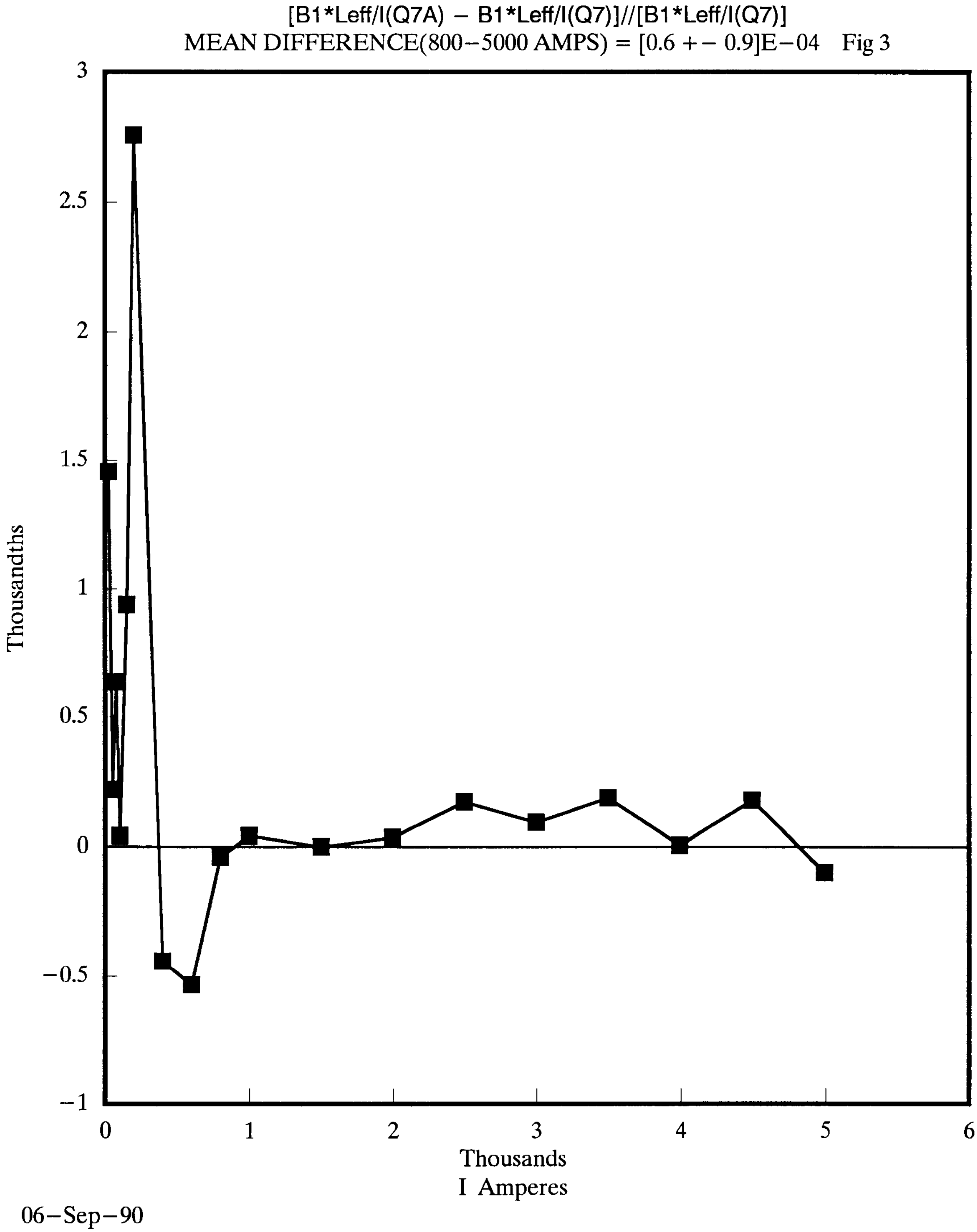
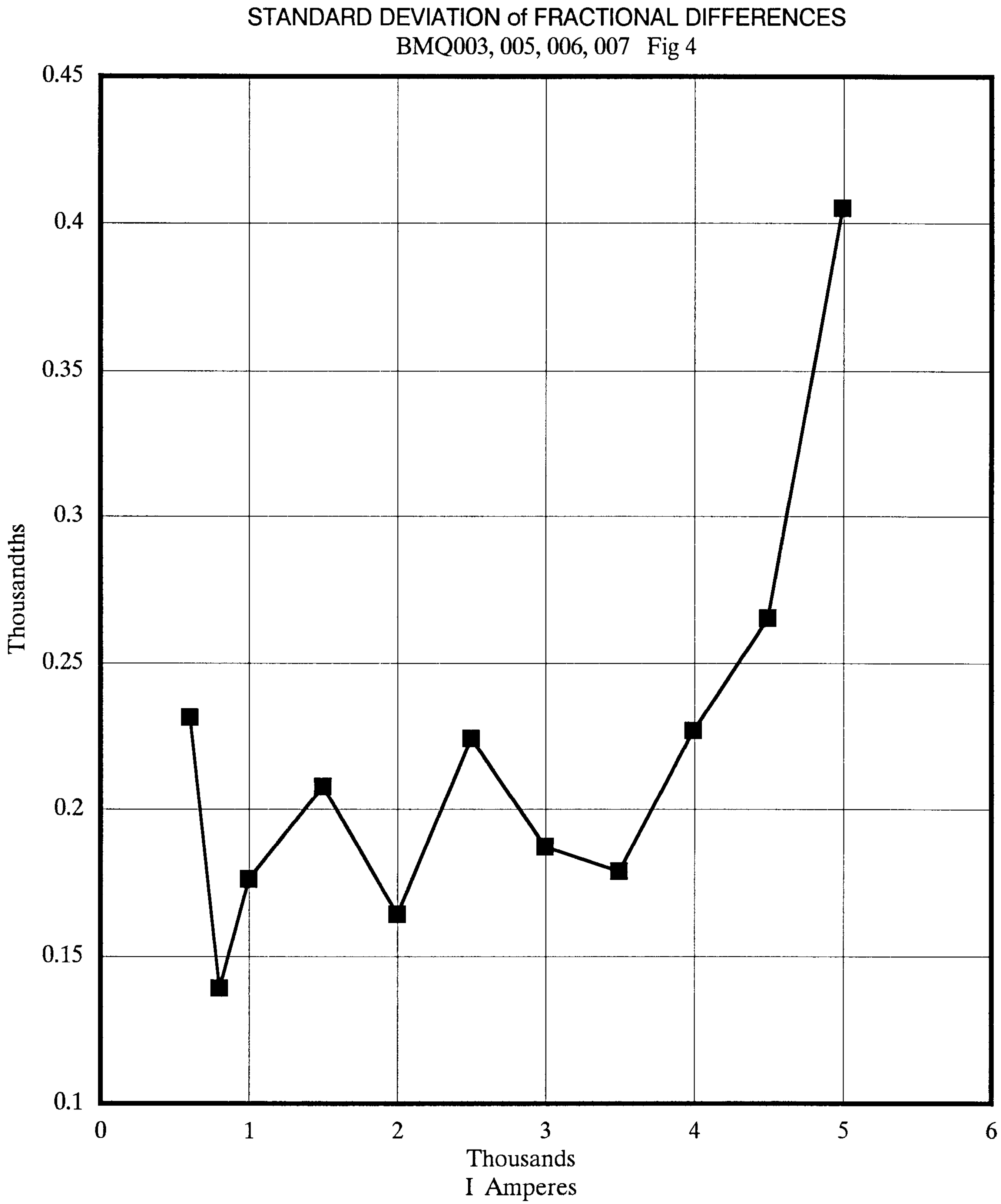
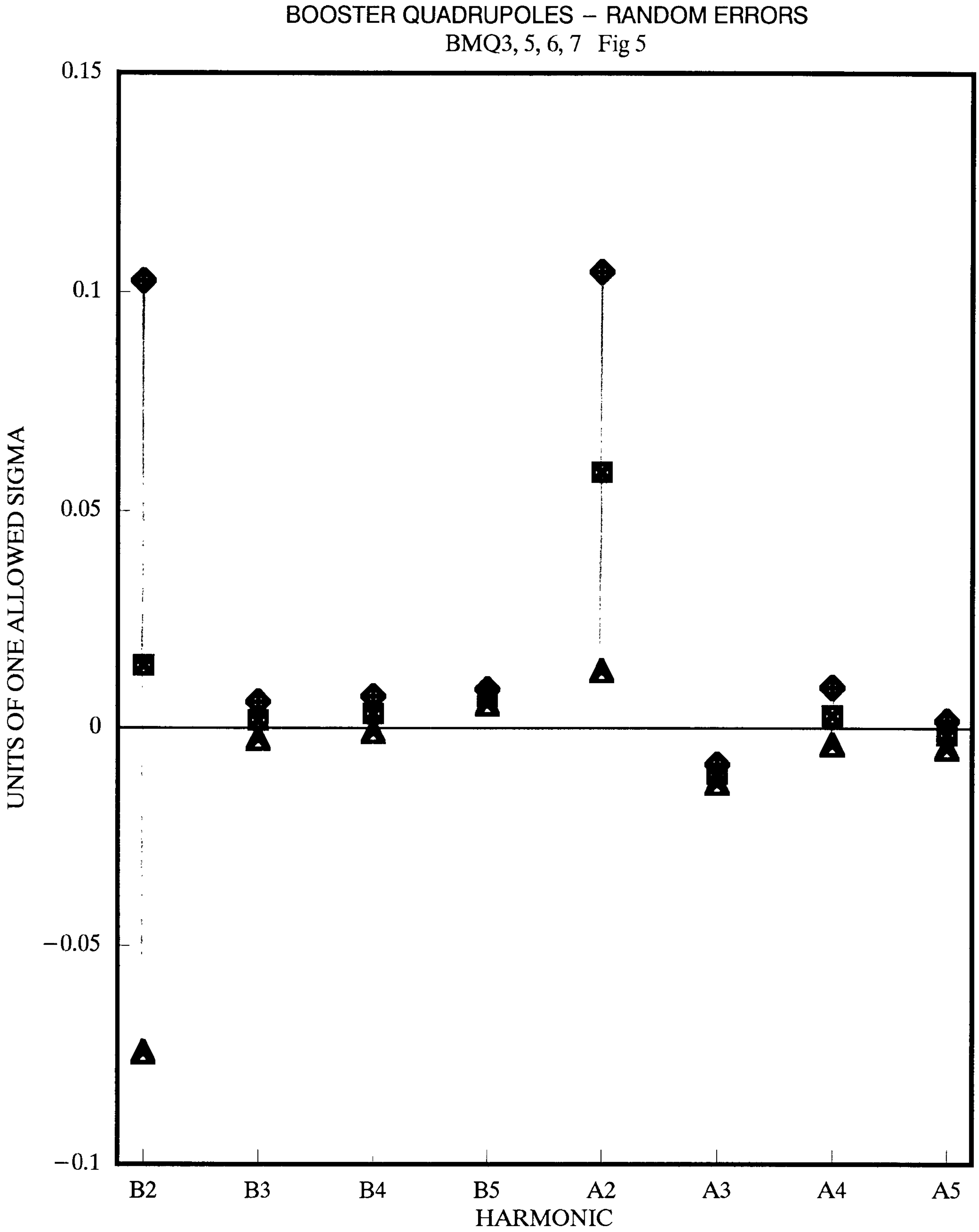

[B1*Leff/I(Q7A) – B1*Leff/I(Q7)]//[B1*Leff/I(Q7)]
MEAN DIFFERENCE(800–5000 AMPS) = [0.6 +– 0.9]E–04 Fig 3
3
2.5
2
1.5
1
0.5
0
–0.5
–1
Thousandths
0
1
2
3
4
5
6
Thousands
I Amperes
06–Sep–90



[B1*Leff/I−(B1*Leff/I)avg]/(B1*Leff/I)avg
06−Sep−90



BOOSTER QUADRUPOLES – RANDOM ERRORS
BMQ3, 5, 6, 7 Fig 5
0.15
0.1
0.05
0
−0.05
−0.1
UNITS OF ONE ALLOWED SIGMA
B2
B3
B4
B5
A2
A3
A4
A5
HARMONIC

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. If you do not understand it, please address your questions to the author who may well have lapsed into incomprehensible jargon.

ANALYSIS of FIELD SHAPE MEASUREMENTS

MAGNET TYPE	BOOSTER SHORT QUADRUPOLE
MAGNET NUMBER	BMQ007
RUN NUMBER	BMQ007.1035Y
DATE of MEASUREMENT	10 Apr 90
DATE of ANALYSIS	29-Jun-90

SHORT SUMMARY of MAGNET QUALITY

SUMMARY of QUADRUPOLE FIELD RESULTS

B1*Leff/I @ 2500 A	0.09108	G*m/(cm*A)
B1*Leff/I @ 5000 A	0.08497	G*m/(cm*A)

SATURATION EFFECT 1.07187

SUMMARY of HARMONIC CONTENTS

	AVG	STD DEV	UNITS
B2/B1	-3.18E-06	2.2E-06	cm^-1
A2/B1	6.22E-06	2.3E-06	cm^-1
B3/B1	1.79E-07	3.4E-07	cm^-2
A3/B1	-1.16E-05	3.0E-07	cm^-2
B4/B1	2.77E-07	8.5E-08	cm^-3
A4/B1	3.44E-07	9.8E-08	cm^-3
B5/B1	8.60E-08	1.8E-08	cm^-4
A5/B1	-8.53E-08	2.7E-08	cm^-4

SUMMARY of ALIGNMENT PARAMETERS

xo	-1.76E-02	8.0E-04	cm
	-6.9	0.3	0.001 INCHES
yo	5.95E-03	1.1E-03	cm
	2.3	0.4	0.001 INCHES
Theta	-6.32E-05	5.1E-05	radians

SUMMARY of RESIDUAL FIELDS

Bo*Leff	0.513	Gauss*m
Ao*Leff	0.009	Gauss*m
B1*Leff	0.244	Gauss*m/cm
A1*Leff	0.007	Gauss*m/cm

BASIC MEASUREMENT RESULTS
============================

	I AMPS	B1*Leff Gauss*m/cm	Bo*Leff Gauss*m	B2*Leff G*m/cm^2	B3*Leff G*m/cm^3	B4*Leff G*m/cm^4	B5*Leff G*m/cm^5
1	0.005	0.244	0.513	-5.1E-06	-6.0E-05	-6.6E-06	-3.91E-06
2	-0.011	0.242	0.511	1.5E-04	-5.2E-05	-6.0E-06	-7.40E-06
3	24.586	2.453	0.472	3.0E-05	-3.6E-05	-2.9E-06	7.92E-06
4	49.522	4.699	0.432	-1.7E-06	-3.3E-05	5.6E-06	-3.71E-06
5	74.484	6.965	0.390	2.6E-04	-5.4E-05	-7.8E-06	8.36E-06
6	99.391	9.218	0.352	3.4E-05	-3.1E-05	1.1E-05	2.72E-06
7	149.206	13.748	0.279	4.3E-06	-5.4E-05	8.2E-06	-3.66E-06
8	199.167	18.272	0.207	1.5E-04	-5.6E-06	5.1E-06	0.0000103
9	398.579	36.397	-0.092	1.8E-05	-2.4E-05	1.3E-05	5.92E-06
10	598.228	54.562	-0.450	-1.3E-04	-1.1E-05	2.0E-05	-1.63E-06
11	797.531	72.750	-0.725	-1.9E-04	-4.0E-05	7.5E-06	6.46E-06
12	997.262	90.966	-1.007	-1.5E-05	-1.7E-05	1.9E-05	2.15E-06
13	1495.95	136.418	-1.774	-3.5E-05	-8.6E-05	2.6E-05	0.000011
14	1995.08	181.863	-2.635	-6.2E-04	-8.2E-05	4.5E-05	0.0000124
15	2494.14	227.170	-3.500	-9.5E-04	-4.7E-05	5.1E-05	0.0000185
16	2993.4	272.156	-4.073	-1.6E-03	-6.6E-05	5.3E-05	0.0000137
17	3492.57	316.457	-4.977	-2.1E-03	-4.0E-05	7.4E-05	6.34E-08
18	3991.86	358.632	-5.841	-3.8E-03	-2.7E-05	5.8E-05	-3.21E-06
19	4491.09	394.599	-6.714	-7.7E-03	-4.7E-05	7.0E-05	-1.58E-05
20	4990.72	424.084	-7.808	-1.2E-02	6.6E-06	8.6E-05	-4.59E-05

	I AMPS	A1*Leff Gauss*m/cm	Ao*Leff Gauss*m	A2*Leff G*m/cm^2	A3*Leff G*m/cm^3	A4*Leff G*m/cm^4	A5 G*m/cm^5
1	0.005	0.007	0.009	1.3E-05	-1.1E-05	-1.5E-05	1.80E-06
2	-0.011	0.007	0.015	6.9E-05	9.3E-06	-4.3E-06	-2.54E-06
3	24.586	-0.008	0.023	1.4E-04	2.2E-05	-4.1E-06	-2.48E-06
4	49.522	-0.003	0.040	2.3E-04	-5.1E-05	-1.9E-05	-5.90E-06
5	74.484	0.029	0.059	-3.7E-05	-7.1E-05	-3.1E-06	2.82E-07
6	99.391	0.003	0.055	3.4E-04	-4.3E-05	5.5E-06	3.15E-06
7	149.206	0.003	0.102	2.2E-04	-1.1E-04	8.4E-06	1.63E-06
8	199.167	-0.007	0.138	2.0E-04	-1.9E-04	1.1E-05	-4.44E-06
9	398.579	-0.008	0.253	3.6E-04	-4.0E-04	-5.9E-06	3.64E-06
10	598.228	0.005	0.345	6.3E-04	-6.2E-04	-2.0E-06	-1.02E-05
11	797.531	0.011	0.498	4.9E-04	-8.5E-04	2.5E-05	-4.29E-06
12	997.262	0.004	0.644	5.6E-04	-1.0E-03	2.6E-05	-6.31E-06
13	1495.95	-0.003	0.846	3.5E-04	-1.7E-03	2.8E-05	-1.62E-05
14	1995.08	-0.006	1.078	1.0E-03	-2.1E-03	5.0E-05	-9.45E-06
15	2494.14	-0.022	1.368	1.5E-03	-2.6E-03	4.3E-05	-1.10E-05
16	2993.4	-0.028	1.880	1.7E-03	-3.2E-03	6.2E-05	-2.17E-05
17	3492.57	-0.016	2.097	1.7E-03	-3.6E-03	8.4E-05	-1.63E-05
18	3991.86	-0.020	2.226	4.0E-03	-4.0E-03	1.0E-04	-2.99E-05
19	4491.09	-0.032	1.874	1.1E-02	-4.5E-03	8.6E-05	-1.46E-05
20	4990.72	0.006	1.330	1.7E-02	-5.0E-03	7.0E-05	-2.39E-05

GRADIENT and POSITION ANALYSIS

	I	B1*Leff/I	Residual Field Subtracted B1*Leff/I	Theta A1/B1	xo Bo/B1	yo Ao/B1
	AMPS	G*m/(cm*A)	G*m/(cm*A	radians	cm	cm
1	0.005					
2	-0.011					
3	24.586	0.09977	0.08986	-6.99E-03	-1.88E-02	6.59E-03
4	49.522	0.09489	0.08997	-2.32E-03	-1.83E-02	7.08E-03
5	74.484	0.09352	0.09025	3.22E-03	-1.83E-02	7.42E-03
6	99.391	0.09275	0.09030	-5.41E-04	-1.80E-02	5.13E-03
7	149.206	0.09214	0.09051	-3.56E-04	-1.73E-02	6.90E-03
8	199.167	0.09174	0.09052	-8.17E-04	-1.70E-02	7.18E-03
9	398.579	0.09132	0.09071	-4.37E-04	-1.67E-02	6.75E-03
10	598.228	0.09121	0.09080	-3.73E-05	-1.77E-02	6.18E-03
11	797.531	0.09122	0.09091	4.85E-05	-1.71E-02	6.74E-03
12	997.262	0.09122	0.09097	-3.90E-05	-1.68E-02	7.00E-03
13	1495.95	0.09119	0.09103	-7.86E-05	-1.68E-02	6.15E-03
14	1995.08	0.09116	0.09103	-7.37E-05	-1.73E-02	5.89E-03
15	2494.14	0.09108	0.09098	-1.31E-04	-1.77E-02	5.99E-03
16	2993.4	0.09092	0.09084	-1.31E-04	-1.69E-02	6.88E-03
17	3492.57	0.09061	0.09054	-7.48E-05	-1.74E-02	6.60E-03
18	3991.86	0.08984	0.08978	-7.52E-05	-1.77E-02	6.19E-03
19	4491.09	0.08786	0.08781	-1.01E-04	-1.83E-02	4.73E-03
20	4990.72	0.08497	0.08493	-2.92E-06	-1.96E-02	3.12E-03
	AVERAGE(600 to 5000 Amps)=			-6.32E-05	-1.76E-02	5.95E-03
	STANDARD DEVIATION =			5.1E-05	8.0E-04	1.1E-03

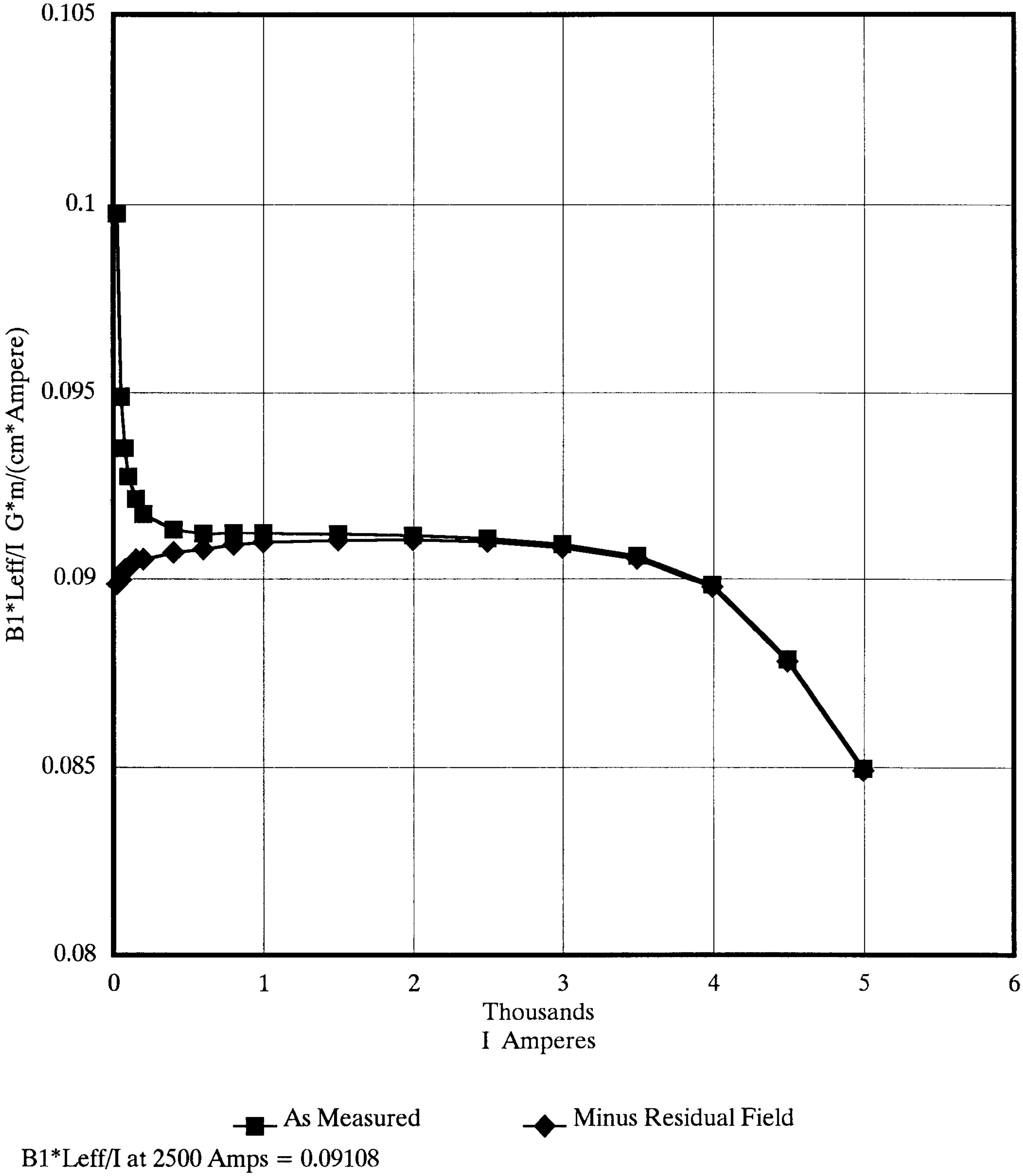
HARMONIC CONTENT
================

	I AMPS	B1*Leff/I G*m/(cm*A)	Bo/B1 cm	B2/B1 cm^-1	B3/B1 cm^-2	B4/B1 cm^-3	B5/B1 cm^-4
1	0.005						
2	0.001						
3	24.586	0.09977	-0.019	1.60E-05	1.10E-05	1.7E-06	5.4E-06
4	49.522	0.09489	-0.018	7.67E-07	6.15E-06	2.7E-06	4.6E-08
5	74.484	0.09352	-0.018	3.93E-05	9.16E-07	-1.8E-07	1.8E-06
6	99.391	0.09275	-0.018	4.37E-06	3.19E-06	2.0E-06	7.4E-07
7	149.206	0.09214	-0.017	6.98E-07	4.38E-07	1.1E-06	1.8E-08
8	199.167	0.09174	-0.017	8.74E-06	3.01E-06	6.5E-07	7.9E-07
9	398.579	0.09132	-0.017	6.49E-07	1.01E-06	5.4E-07	2.7E-07
10	598.228	0.09121	-0.018	-2.37E-06	8.92E-07	4.9E-07	4.2E-08
11	797.531	0.09122	-0.017	-2.54E-06	2.77E-07	1.9E-07	1.4E-07
12	997.262	0.09122	-0.017	-1.09E-07	4.74E-07	2.8E-07	6.7E-08
13	1495.95	0.09119	-0.017	-2.21E-07	-1.88E-07	2.4E-07	1.1E-07
14	1995.08	0.09116	-0.017	-3.37E-06	-1.20E-07	2.8E-07	9.0E-08
15	2494.14	0.09108	-0.018	-4.18E-06	5.71E-08	2.6E-07	9.9E-08
16	2993.4	0.09092	-0.017	-5.86E-06	-2.38E-08	2.2E-07	6.5E-08
17	3492.57	0.09061	-0.017	-6.77E-06	6.18E-08	2.6E-07	1.3E-08
18	3991.86	0.08984	-0.018	-1.06E-05	9.08E-08	1.8E-07	2.0E-09
19	4491.09	0.08786	-0.018	-1.95E-05	3.22E-08	1.9E-07	-3.0E-08
20	4990.72	0.08497	-0.020	-2.73E-05	1.57E-07	2.2E-07	-9.9E-08
	AVERAGE(600 to 3500 Amps)=			-3.18E-06	1.79E-07	2.77E-07	8.60E-08
	STANDARD DEVIATION		=	2.2E-06	3.4E-07	8.5E-08	1.8E-08

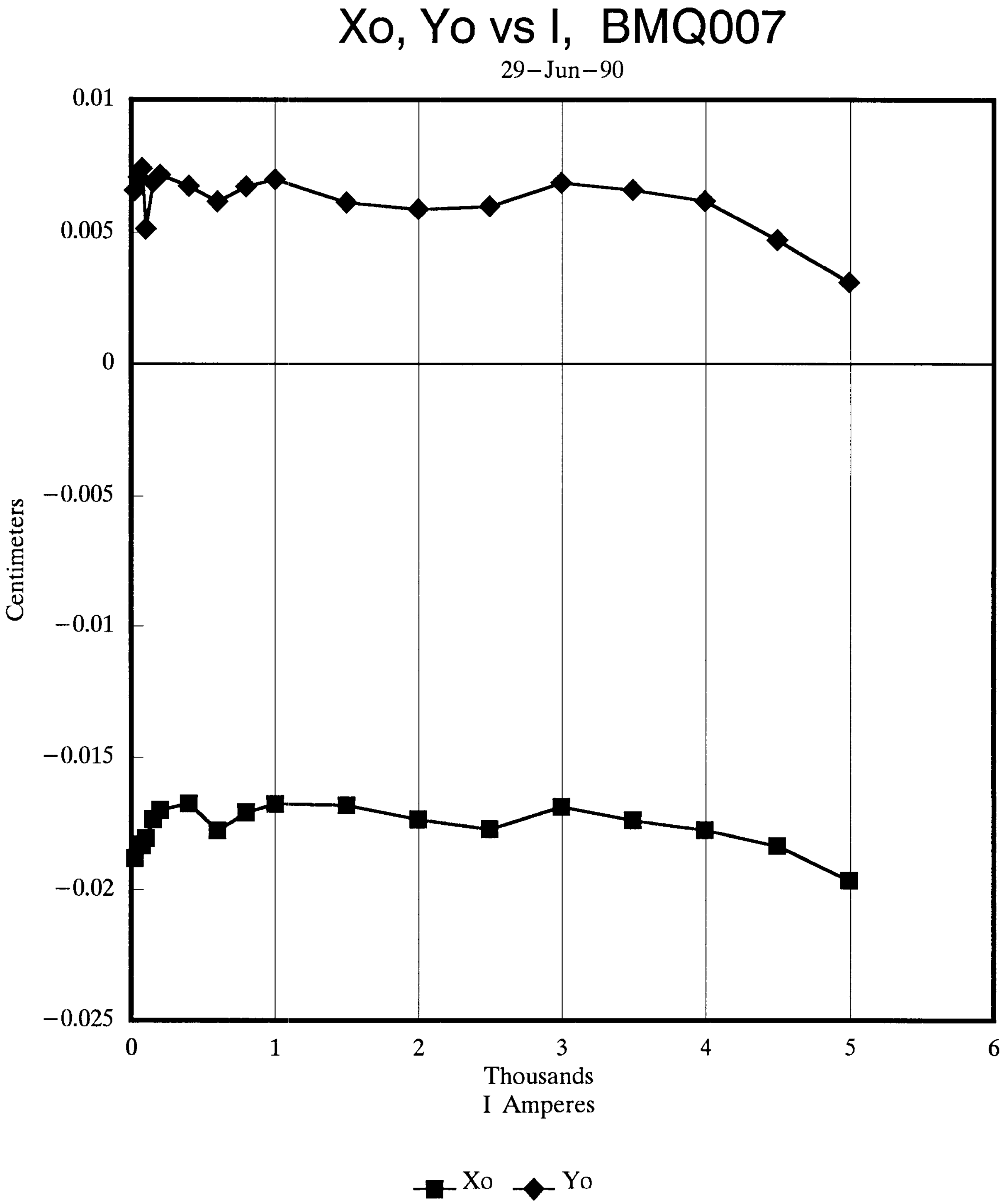
	I AMPS	A1/B1 radians	Ao/B1 cm	A2/B1 cm^-1	A3/B1 cm^-2	A4/B1 cm^-3	A5/B1 cm^-4
1	0.005						
2	-0.011						
3	24.586	-7.0E-03	0.007	5.70E-05	1.49E-05	4.9E-06	-1.9E-06
4	49.522	-2.3E-03	0.007	4.89E-05	-9.09E-06	-9.3E-07	-1.7E-06
5	74.484	3.2E-03	0.007	-7.46E-06	-8.93E-06	1.8E-06	-2.3E-07
6	99.391	-5.4E-04	0.005	3.67E-05	-3.56E-06	2.3E-06	1.5E-07
7	149.206	-3.6E-04	0.007	1.53E-05	-7.28E-06	1.7E-06	-1.3E-08
8	199.167	-8.2E-04	0.007	1.02E-05	-1.00E-05	1.4E-06	-3.5E-07
9	398.579	-4.4E-04	0.007	9.48E-06	-1.08E-05	2.5E-07	5.1E-08
10	598.228	-3.7E-05	0.006	1.14E-05	-1.13E-05	2.4E-07	-2.2E-07
11	797.531	4.9E-05	0.007	6.52E-06	-1.15E-05	5.4E-07	-8.4E-08
12	997.262	-3.9E-05	0.007	5.99E-06	-1.13E-05	4.5E-07	-8.9E-08
13	1495.95	-7.9E-05	0.006	2.47E-06	-1.22E-05	3.1E-07	-1.3E-07
14	1995.08	-7.4E-05	0.006	5.58E-06	-1.17E-05	3.6E-07	-6.2E-08
15	2494.14	-1.3E-04	0.006	6.45E-06	-1.15E-05	2.6E-07	-5.6E-08
16	2993.4	-1.3E-04	0.007	6.16E-06	-1.16E-05	2.8E-07	-8.6E-08
17	3492.57	-7.5E-05	0.007	5.21E-06	-1.13E-05	3.1E-07	-5.7E-08
18	3991.86	-7.5E-05	0.006	1.13E-05	-1.12E-05	3.3E-07	-8.8E-08
19	4491.09	-1.0E-04	0.005	2.70E-05	-1.13E-05	2.6E-07	-4.2E-08
20	4990.72	-2.9E-06	0.003	4.08E-05	-1.18E-05	2.0E-07	-6.1E-08
	AVERAGE(600 to 3500 Amps)=			6.22E-06	-1.16E-05	3.44E-07	-8.53E-08
	STANDARD DEVIATION		=	2.3E-06	3.0E-07	9.8E-08	2.7E-08

B1*Leff/I vs I, BMQ007

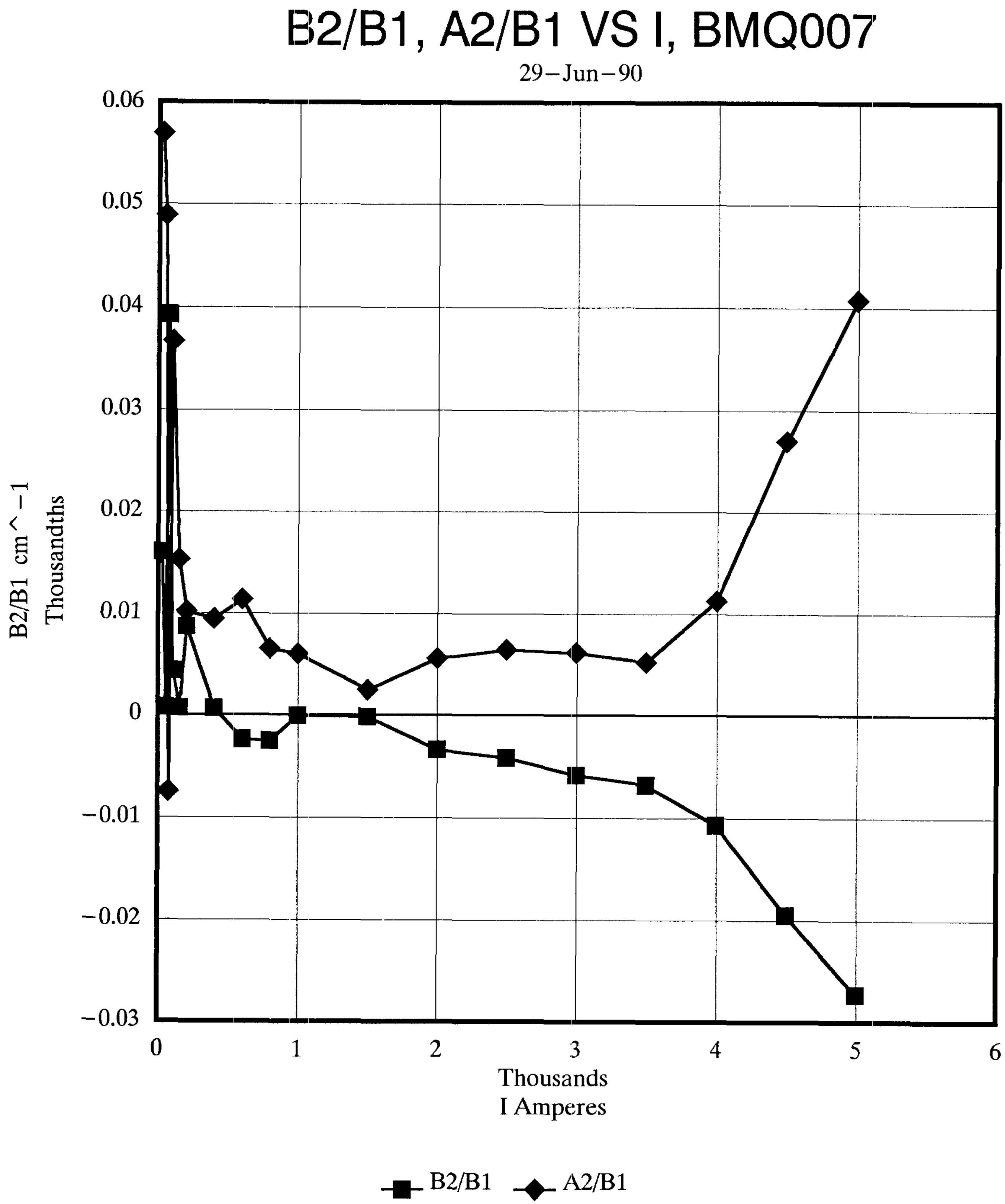
29–Jun–90



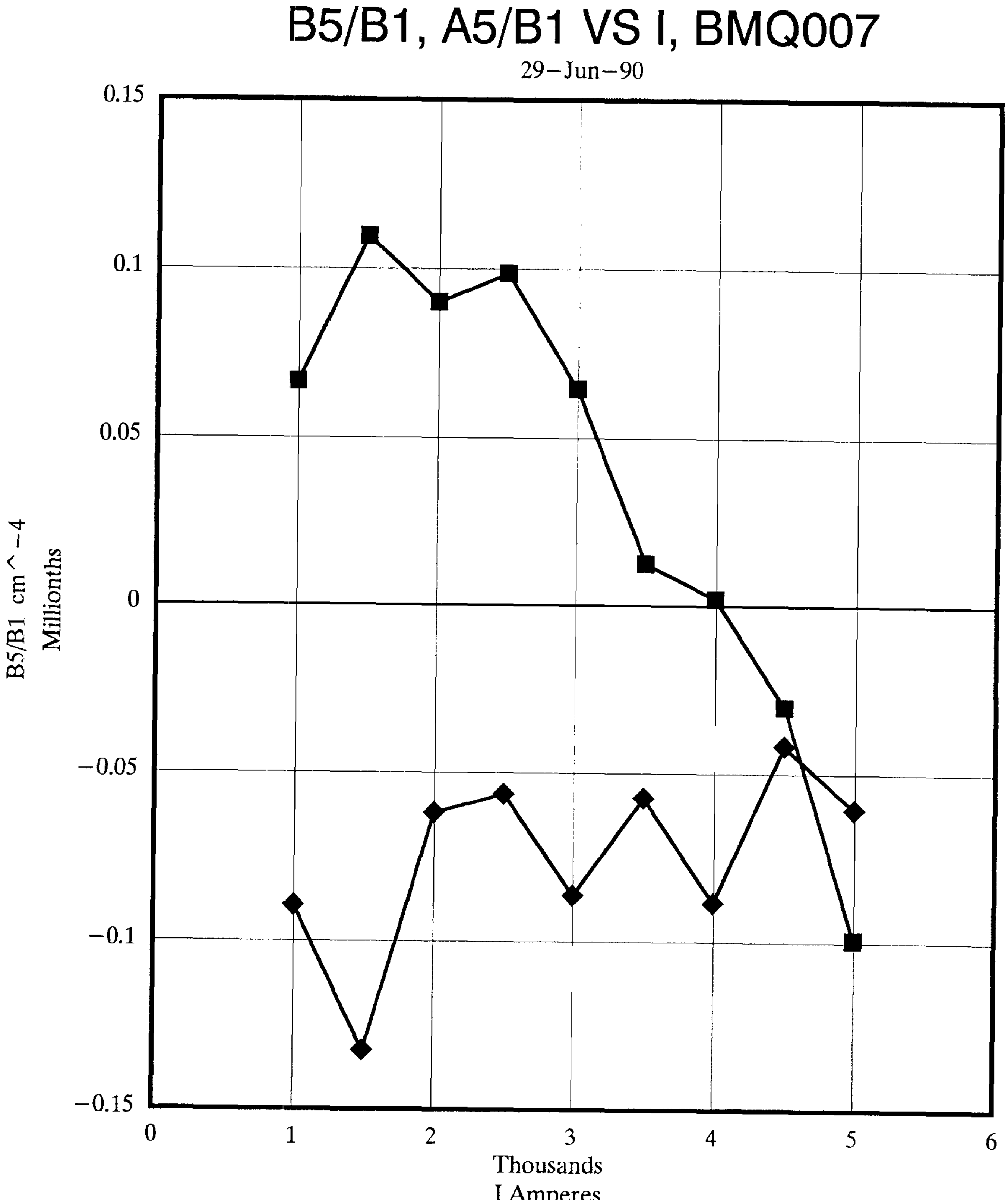
B1*Leff/I at 2500 Amps = 0.09108
B1*Leff/I at 5000 Amps = 0.08497



Xo = -0.007 inches
Yo = 0.002 inches



B2/B1 = –0.000003
A2/B1 = 0.000006



B5/B1(FROM 1000 TO 3000 AMPS) = 0.000000086
A5/B1(FROM 1000 TO 3000 AMPS) = –0.000000085

C. DATA SHEET FOR SHORT QUAD

The appended data sheet (which at press time may still contain some blanks to be filled in, labelled NA) is an attempt to provide a fairly complete description of a magnet. It will be incorporated into the Booster data base (E. Auerbach). If the categories are not clear, if the data is in error or incomplete, or if their are insufficiencies or redundancies please comment to the author.

ACKNOWLEDGEMENTS

This note is a report on the analysis of recent measurement results for the Booster quad. 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 Measurements 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 systems to the present application. To mention a dozen individuals would be insufficient, so we shall acknowledge just one, Rich Riesen, who is personally setting up and carrying out the measurements on every one of the Booster main magnets.

The conclusion of this note, that the Booster quadrupole is very good, is a tribute to Gordon Danby and John Jackson who designed and developed this magnet, to those people who carried out the engineering of it, and to the careful group that is building it.

PARAMETER SHEET FOR BOOSTER SHORT QUADRUPOLE

Issue Date: September 1, 1990

PROTOTYPE NAME	BMQ (BOOSTER MAIN QUADRUPOLE (Short))
MAGNET CLASS	QUADRUPOLE
NUMBER OF MAGNETS	24 PLUS 1

	INCHES	MILL-METERS	OTHER	REF
MECHANICAL				
CORE				
Lamination Length	16.75	425.5		a
Tolerance Specified	0.003	0.076		a
Tolerance Measured	0.0013	0.033		a
Structural Length	19.125	485.8		a
Coil Length	26.1	662.9		a
Overall Length	28.1	713.7		a
Aperture Shape	ROUND			
Radius at Pole Tip	3.25	82.55		a
Tolerance Specified	0.0013	0.033		d
Tolerance Measured	0.0003	0.008		e
Pole Width	5.125	130.2		a
Core Height	25.3	642.6		a
Core Width	25.3	642.6		a
LAMINATIONS				
Material	ARMCO M-36			a
Coating	AISI TYPE - C5			a
Coating Thickness	0.0002	0.005		a
Overall Thickness	0.025	0.6		a
Approx. Lams per Block	670			
Quadrant Block Weight	356.25	161.6	POUNDS,KG	a
Tolerance Specified	0.03	0.01	POUNDS, KG	a
Tolerance Measured	0.03	0.01	POUNDS, KG	a

	INCHES	MILLI-METERS	OTHER	REF
VACUUM PIPE				
Height - Outside	6	152.4		b
Width - Outside	6	152.4		b
Wall Thickness	0.063	1.6		b
Tolerance Specified	0.003	0.1		
Tolerance Measured	NA	NA		
Half Height - Inside	2.937	74.6		
Half Width - Inside	2.937	74.6		
Material	INCONEL 625			b
Resistivity	129		MICRO-OHM CM	b
Tolerance Specified	2		MICRO-OHM CM	b
Tolerance Measured	NA			
MAIN COIL				
COIL				
Turns Per Pole	5			
Poles Per Magnet	4			
Resistance Per Magnet	0.83		MILLIOHMS	g
Inductance Per Magnet - DC	0.38		MILLIHENRY	g
Inductance Per Magnet - 1 k	0.35		MILLIHENRY	g
CONDUCTOR				
Material	COPPER - ALLOY 0102			a
Shape	SQUARE			
Width	1.122	28.50		a
Height	1.122	28.50		a
Cooling Hole Diameter	0.375	9.52		a
Area	1.134	731.6	IN. SQ. mm SQ.	a
Length Per Pole	295	7493		a
Length Per Magnet	1180	29972		

	INCHES	MILLI-METERS	OTHER	REF
INSULATION				
Material	EPOXY FIBERGLASS			a
Thickness	0.152	3.86		a
Tolerance	0.012	.30		a
Ground Test	27		kVOLTS	c
Impulse Test	5		kVOLTS	c
COOLING				
Circuits Per Magnet	2			a
Flow Rate Per Magnet	1.6		GAL-LONS/MINUTE	a
Input Pressure	50		PSI	
Temp Rise @ Ramp to Imax	20		DEGREES F	a
CURRENT				
Imax (PS Limit)	5700		AMPERES	c
Current Density @ Imax	5026.5	7.8	AMPERES/AREA	
DC Power @ Imax	27		kWATTS	
Stored Energy @ Imax	6.2		kJOULES	
TUNE TRIM COIL				
COIL				
Turns Per Pole	1			a
Poles Per Magnet	4			
Resistance Per Magnet	0.63		MILLIOHMS	g
Inductance Per Magnet - DC	NA		MICROHENRY	
Inductance Per Magnet - 1 k	16		MICROHENRY	g
CONDUCTOR				
Material	COPPER - ETP			a
Shape	RECTANGULAR			a
Width	1.5	38.10		a
Height	0.1872	4.75		a
Cooling Hole Diameter	NAPP	NAPP		
Area	0.2808	181.2	IN. SQ. mm SQ.	

	INCHES	MILLI-METERS	OTHER	REF
Length Per Pole	52	1321		a
Length per Magnet	232	5893		
INSULATION				
Material	G10 EPOXY			a
Thickness	0.033	0.84		a
Tolerance	NA	NA		
Ground Test	5		kVOLTS	c
Impulse Test	3		kVOLTS	c
COOLING				
Circuits Per Magnet	NAPP			
Flow Rate Per Magnet	NAPP			
Input Pressure	NAPP			
Temp. Rise @ RAMP to Imax	NA		DEGREES F	
CURRENT				
Imax (PS Limit)	700		AMPERES	c
Current Density @ Imax	2493	3.9	AMPERES/AREA	
DC Power @ Imax	0.31		kWATTS	
Stored Energy @ Imax	3.9		JOULES	
STOP BAND TRIM COILS				
COIL				
Turns Per Pole	2			a
Poles Per Magnet	4			
Resistance Per Magnet	300		MILLIOHMS	
Inductance Per Magnet - DC	NA		MICROHENRY	
Inductance Per Magnet - 1 k	64		MICROHENRY	
CONDUCTOR				
Material	COPPER - ETP			a
Shape	ROUND #8 WIRE			a
Width	0.129	3.28		a
Height	0.129	3.28		a

	INCHES	MILLI-METERS		OTHER	REF
Cooling Hole Diameter	NAPP	NAPP			
Area	0.01307	8.4		IN. SQ. mm SQ.	
Length Per Pole	104	2640			
Length Per Magnet	444	11280			
INSULATION					
Material	G10 EPOXY				a
Thickness	0.033	0.84			a
Tolerance					
DC Test	5			kVOLTS	c
1 kHERTZ Test	3			kVOLTS	c
COOLING					
Circuits Per Magnet	NAPP				
Flow Rate Per Magnet	NAPP				
Input Pressure	NAPP				
Temp. Rise @ RAMP to Imax	NA			DEGREES F	
CURRENT					
Imax (PS Limit)	50			AMPERES	c
Current Density @ Imax	3826	5.9		AMPERES/AREA	
DC Power @ Imax	.75			kWATTS	
Stored Energy	.08			JOULES	
MAGNETIC PROPERTIES OF THE MAIN COIL					
SYSTEMATIC TOLERANCES	SPECIFIED	MEASURED		OTHER	REF
bn = Bn/B0, an = An/A0		bn	an		
n = 1	$4x10^{-4}$	NA	NA		d
n = 2	$1x10^{-4}$	$1x10^{-7}$	$6x10^{-7}$	cm^{-2}	d,e
n = 3	$3x10^{-4}$	$1x10^{-7}$	$-7x10^{-7}$	cm^{-3}	d,e
n = 4	1x10-6	$6x10^{-9}$	$6x10^{-7}$	cm^{-4}	d,e
n = 5	$6x10^{-6}$	$7x10^{-9}$	$-2x10^{-9}$	cm^{-5}	d,e
n = 6	$1x10^{-8}$	NA	NA		d

RANDOM TOLERANCES	SPECIFIED	MEASURED			
bn = Bn/B0, an = An/A0		bn	an		
n = 0	0.0004	NA	NA		d
n = 1	$8x10^{-5}$	$2x10^{-5}$	NA	cm^{-1}	d,e
n = 2	$1x10^{-5}$	$9x10^{-7}$	$5x10^{-7}$	cm^{-2}	d,e
n = 3	$7x10^{-5}$	$3x10^{-7}$	$2x10^{-7}$	cm^{-3}	d,e
n = 4	$2x10^{-6}$	$8x10^{-8}$	$1x10^{-8}$	cm^{-4}	d,e
n = 5	$1x10^{-6}$	$2x10^{-9}$	$3x10^{-9}$	cm^{-5}	d,e
n = 6	$1x10^{-7}$	NA	NA		d
TYPICAL MEASUREMENTS					
B1 x Leff @ I = O	0.25	(G/cm)xm			e
B1 x Leff/I					
@200 AMPS	0.09172	(G/cm)xm/A			e
@600 AMPS	0.09123	(G/cm)xm/A			e
@2500 AMPS	0.09105	(G/cm)xm/A			e
@5000 AMPS	0.08494	(G/cm)xm/A			e
SATURATION EFFECT					
5000/2500	6.67%				
CALCULATIONS					
B1/I					
@200 AMPS	0.1845	(G/cm)/A			f
@600 AMPS	0.1851	(G/cm)/A			f
@2500 AMPS	0.1853	(G/cm)/A			f
@5000 AMPS	0.1817	(G/cm)/A			f
@5700 AMPS	0.178	(G/cm)/A			f
SATURATION EFFECT					
5000/2500	1.94%				
Leff					
@200 AMPS	0.497	meters			
@600 AMPS	0.493	meters			
@2500 AMPS	0.491	meters			
@5000 AMPS	0.467	meters			

@5700 AMPS	NA			
POLE TIP FIELD				
@200 AMPS	305	G		
@600 AMPS	917	G		
@2500 AMPS	3824	G		
@5000 AMPS	7500	G		
@5700 AMPS	8375	G		
MAGNETIC PROPERTIES OF THE TUNE TRIM COIL				
TYPICAL MEASUREMENTS				
B1 x Leff/I	NA			
B5 x Leff/I	NA			
CALCULATIONS				
B1/I	0.03706	(G/cm)/A		
Leff	NA			
MAGNETIC PROPERTIES OF THE TUNE TRIM COIL				
TYPICAL MEASUREMENTS				
B1 x Leff/I	NA			
B5 x Leff/I	NA			
CALCULATIONS				
B1/I	0.07412	(G/cm)/A		
Leff	NA			

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