national accelerator laboratory

TM-450
0650.5

FIELD MEASUREMENTS ON ANL R1-5 4-METER SEPTUM MAGNET

P. Baranov and S. Rusakov
P. N. Lebedev Physical Institute, Moscow, USSR

J. Orear
Laboratory of Nuclear Studies, Cornell University, Ithaca, NY

R. Juhala
National Accelerator Laboratory, Batavia, IL

and

R. Lari
Argonne National Laboratory, Argonne, IL

November 7, 1973

This report summarizes the results of field measurements that have been completed on a 4-meter septum magnet which was designed and built at ANL. This magnet has a gap height of 0.786 in., a pole width of 5.885 in., and a length of 4 meters. Customarily before measurement a magnet is optically aligned with respect to the field measuring probe to within 0.005 in. In this case, however, time did not permit this step to be completed before the measurement. For the most part the data are not significantly affected by this rough alignment in this case. The actual probe position was determined to within ± 1/32 inch. R. Lari of ANL has provided the design field values for this magnet as determined from the computer program TRIM. These data are included in an appendix. Measurements of the field as a function of current, the field uniformity within the gap, and

the fringe field at various locations outside the septum edge have been made.

Measurements of the quantity $\int Bdl$ as a function of current have been measured using a long stretched wire flip coil and voltage integrating device. The coil is a single loop of 0.004 in. diameter tungsten wire separated by 0.5000 in. glass spacers. The coordinate system used for measurement was as follows: the positive y axis antiparallel to the strong field component and the positive x axis in the horizontal plane toward the septum. The center of the coordinate system of measurement turned out to be 1/32 in. higher and 5/32 in. closer to the back leg than is the geometrical center of the aperture (this turns out to be 13.11 in. from the outside of the back leg). The data for the excitation are given in Table I. The accuracy of these data is ±0.2%.

Table I. Field as a Function of Current in the ANL 4-Meter Septum.

Current (A)	$\int Bdl$ (kG-m)
206.0	10.33
413.4	20.72
599.1	29.95
801.6	39.98
1007.2	49.92
1210.5	58.62
1417.6	65.79

Field uniformity was determined by moving the coil from $x = +2.7$ in. (approximately 0.4 in. from the inside of the septum) to $x = -2.7$ in. at $y = 0$ and $y = +0.3$ in., and also by moving the coil from

$y = +0.3$ in. to $y = -0.3$ in. at $x = +2.7$ in. and $x = 0$ in. These results are given in Table II (A and B). The quantity determined is $\Delta B/B = [\int B'(x)\,dz - \int B'(0)\,dz]/\int B'(0)\,dz$. The field is shown as a per cent of the field at $x = 0$, $y = 0$. The current was 1406 A.

Table II. Field Uniformity of the ANL 4-Meter Septum at 1400 A.

A. $\Delta B/B$ %

x (in.)	y = 0	y = +0.3
2.7	-6.58	+0.54
2.5	-2.85	-0.44
2.0	-0.72	-0.57
1.5	-0.27	-0.23
1.0	-0.06	-0.02
0.5	+0.02	+0.05
0.0	0.0	+0.03
-0.5	-0.09	-0.07
-1.0	-0.26	-0.22
-1.5	-0.56	-0.49
-2.0	-1.25	-0.86
-2.5	-6.17	+0.44
-2.7[a]	-22.36	-19.33

[a]Data at x = -2.7 in. is highly suspect since the probe may have contacted the coil at this point.

B. $\Delta B/B$ %

y (in.)	x = 0.0	x = +2.7
+0.3	+0.03	+0.56
+0.2	+0.01	-3.26
+0.1	0	-5.60
0.0	0	-6.58
-0.1	0	-6.30
-0.2	0	-4.71
-0.3	-0.01	-1.70

The fact that the horizontal plane of measurement does not correspond with the midplane of the magnet can be seen from the vertical

shape of the field at x = +2.7. Ordinarily one would expect the points at y = ±0.3 to be equal to within 0.1%.

The fringe field has been measured at 3 points along the outside of the septum, z = 0, 1, and 2 meters. A commercial gaussmeter (F. W. Bell Model 610) was used for this measurement. It is intended to be an order of magnitude measurement only. In fact, the probe was moved along a ruler in 1/4 in. steps by hand. Therefore, the field near the septum may be in error by several per cent. The gaussmeter itself is accurate to within ±2.0%. The data given in Table III (A and B) were taken at a current of 1406 A. The distance d is measured in inches moving away from the septum roughly on the midplane of the magnet.

Considering the z coordinate as parallel to the direction of the beam of particles as they pass through the septum magnet, the fringe field in Table IIIB is measured along this z direction with the first point taken at the end shield and each subsequent point at 1 in. intervals moving away from the magnet.

The dc resistance of the magnet coils and the series inductance have also been measured. These results are as follows:

dc resistance 0.0818 ohms

Series inductance

@ 1 kHz L = 0.572 mh Q = 1.26

@ 50 Hz L = 2.00 mh Q = 0.996

Table III.

A. Fringe Field Outside the ANL 4-Meter Septum at 1406 A

d (in.)	Fringe Field (gauss)		
	z = 0	z = 1m	z = 2m
0.120	1740	2228	2280
0.370	1090	1490	1500
0.620	740	1020	1000
0.870	516	740	708
1.120	370	518	505
1.370	262	378	360
1.620	192	285	2274
1.870	144	216	208
2.12	105	165	157
2.37	80	127	119
2.62	61	100	94
2.87	47	80	73
3.12	37	64	58
3.37	28	51	46
3.62	22	42	37
3.87	17	33	30
4.12	14	27	24
5.12	5	12	10
6.12	2	5	4
7.12	>1	2	1

Note: The polarity of the fringe field in Table IIIA is the same as that inside the magnet aperture.

B. Fringe Field Outside the Shield at the End of the Septum at 1406 A

Z (in.)	Fringe Field (gauss)
0.120	87
1.120	30
2.120	15
3.120	14
4.120	6
5.120	4
6.120	3

Note: The polarity of the frings fields in Table IIIB is opposite to that inside the septum.

Equipment List

1. Philbrick Integrator. Integrator resistance = 30130 Ω; capacitance = 1 μf (±0.1%)
2. Stretched wire probe, 1 turn, width = 0.504 in., coil resistance = 78 Ω
3. F. W. Bell gaussmeter, Model 610.

Appendix

Magnet design parameters and the calculated field in the aperture and outside the septum were provided by R. Lari of ANL.

ARGONNE NATIONAL LABORATORY	DIVISION	PROJECT	FILE NO.	PAGE
ENGINEERING NOTE	HEF/MME	NAL	50B.11	1/10

SUBJECT: R-1 SEPTUM MAGNET
Final Design

NAME: J. Bywater

DATE: 7/8/71 REV. DATE: 8/27/71

Coil Design Summary

Current	1400 Amps	Measured
No. Turns	20	
NI	28,000	
Resistance		
@ 68°F	.0757 Ω	.080 @ 73°F
@ Operation	.0878 Ω	
Voltage	123V	
Power	172 KW	
No. H_2O Circuits	10	
Power per H_2O Circuit	8.6 KW	
H_2O Pressure Drop	160 psi	170 psi
Temperature Rise	36°F	
Water Flow		
Per Circuit	1.63 gpm	≈ 2 gpm
Total Magnet	32.5 gpm	
Reynolds Number	60,234	
Current Density	22,727 A/in^2	
Conductor Data		
Size	.450" x .220" O.D. with .340" x .110" ID	
Wt. per Foot	.237 #/Ft	
Length per Turn	28.7 Ft	
Length per Magnet	574 Ft.	
Wt. per Magnet	136 #	
Est. Coil Weight	200 #	
Est. Steel Weight	16,500 #	
Est. Total Weight	16,700 #	
Pole length	157.5"	

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ENGINEERING NOTE

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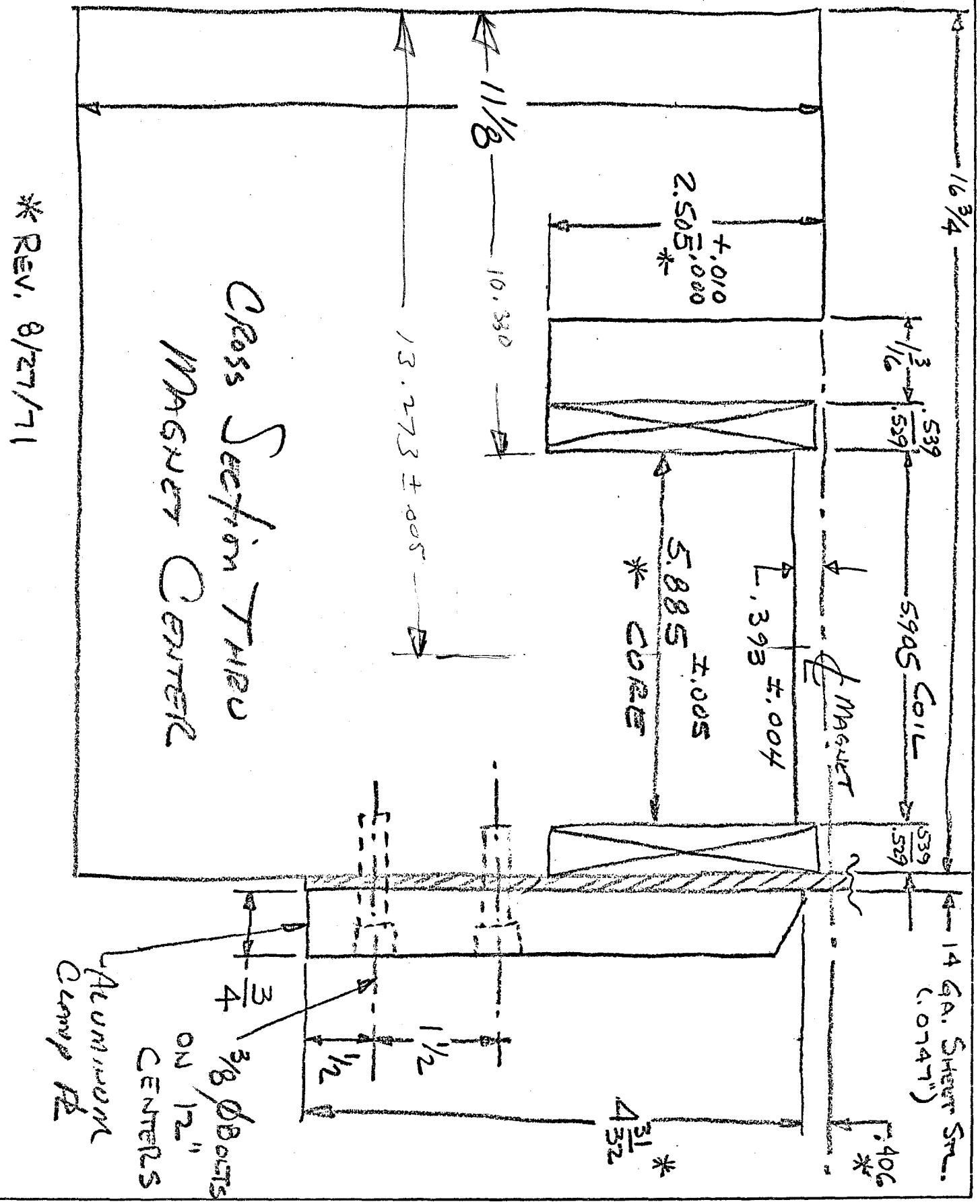
SUBJECT

R-1 SEPTUM MAGNET
Final Design

NAME: J. Bywater

DATE: 7/8/71

REV. DATE:



ARGONNE NATIONAL LABORATORY
ENGINEERING NOTE

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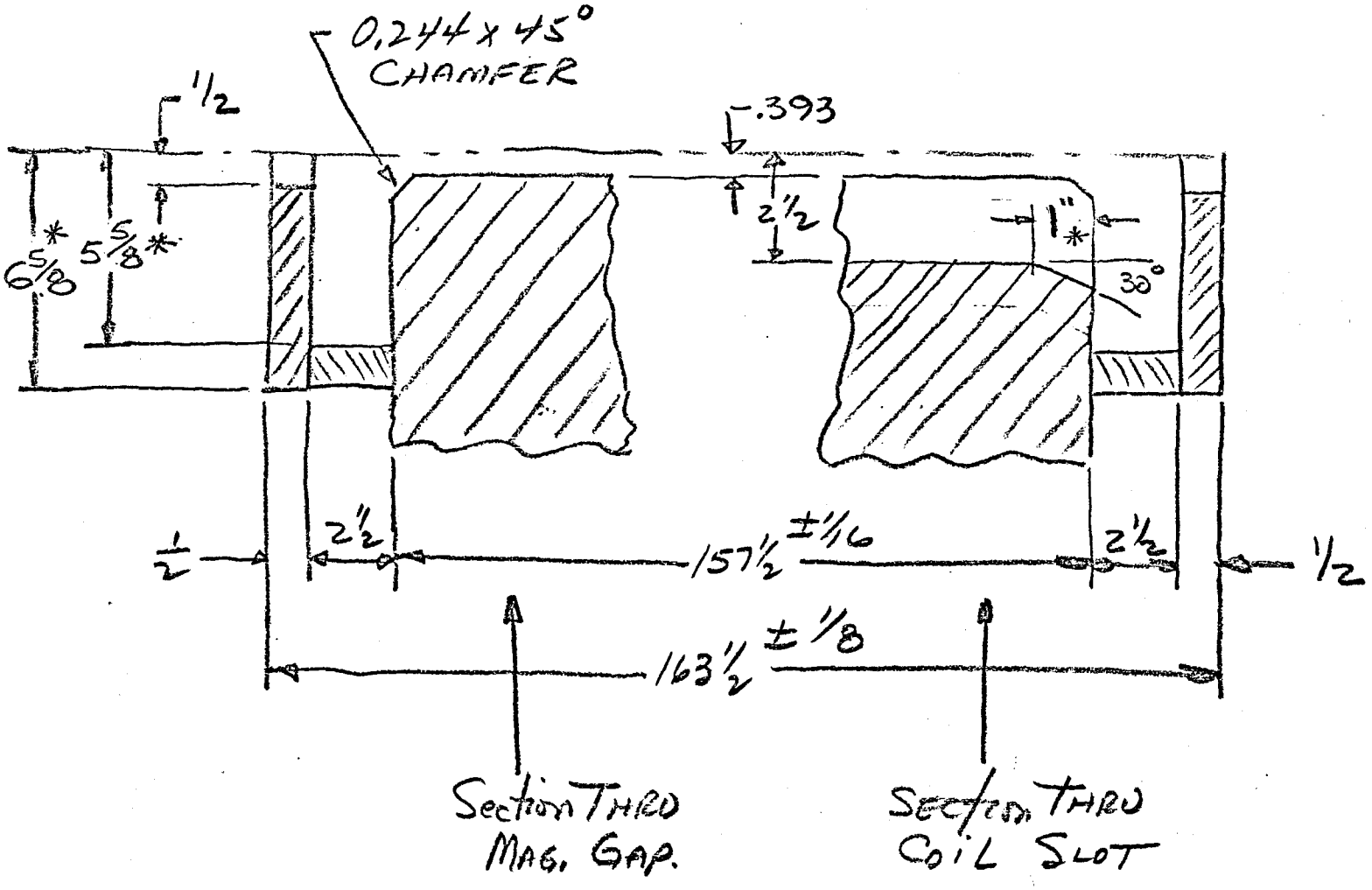
HEF/MME	NAL	50B. 11	7/10

NAME J. Bywater
DATE 7/8/71

REV. DATE

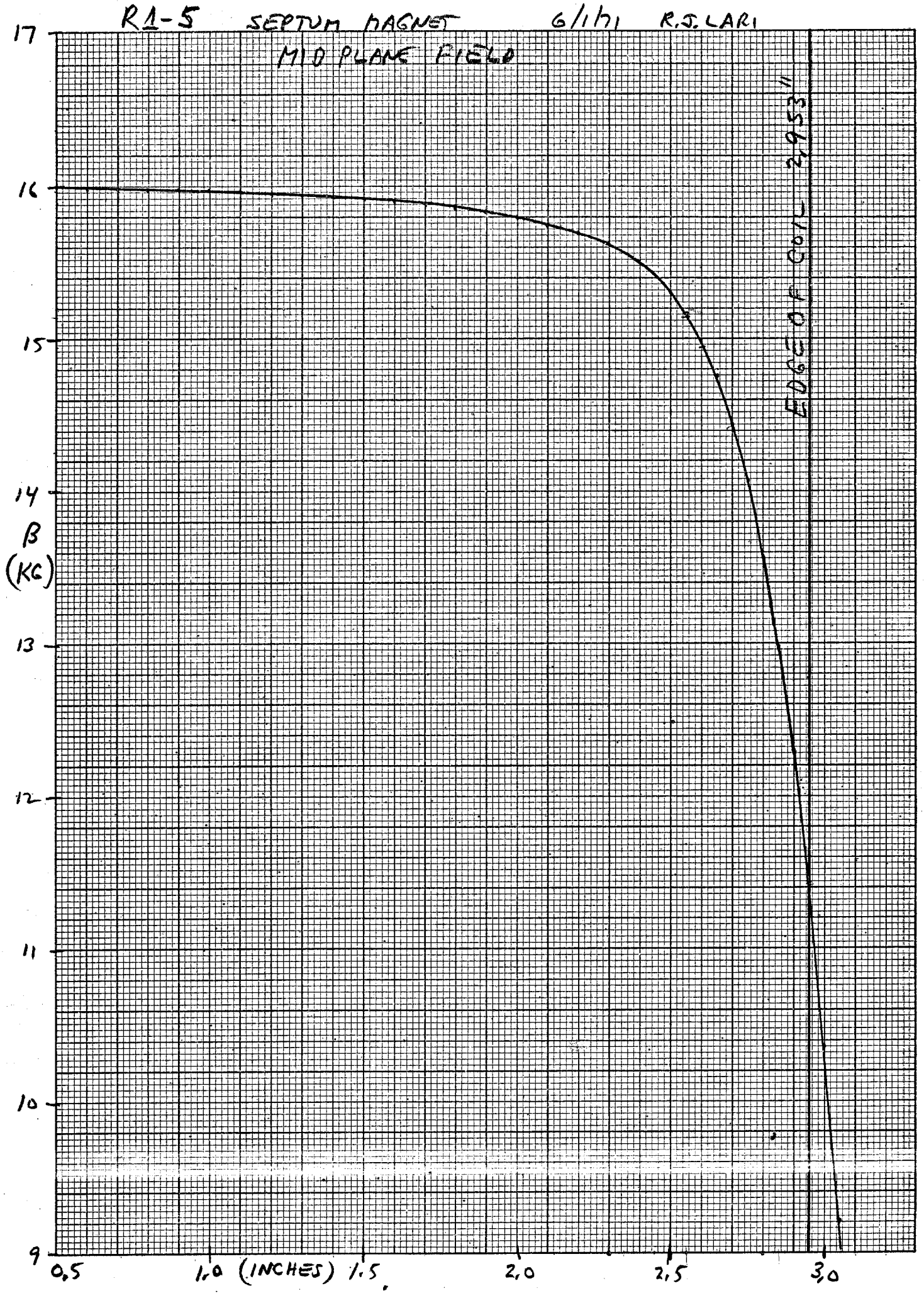
SUBJECT
R-1 SEPTUM MAGNET
Final Design

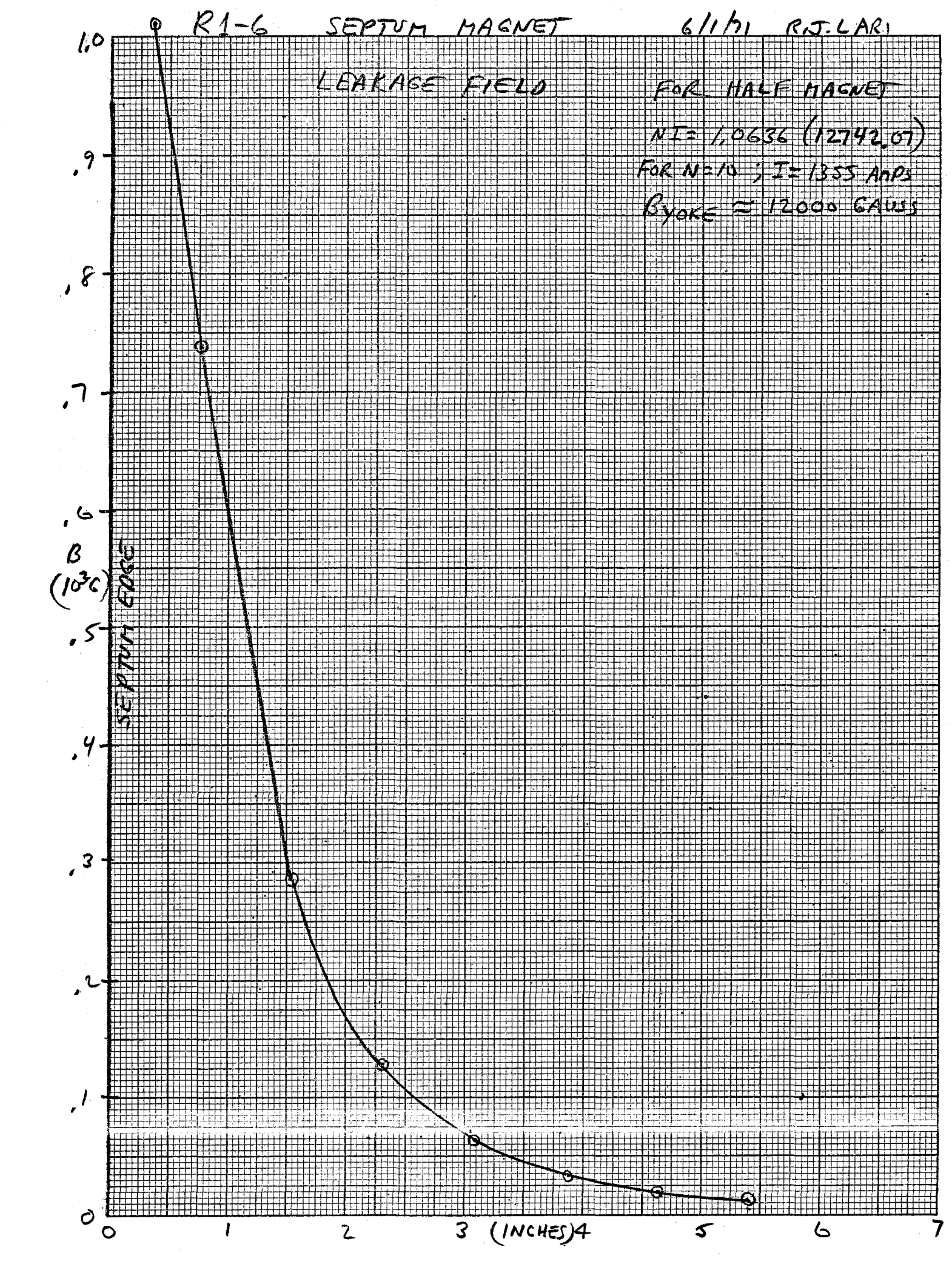
(BM-109 END CHAMFER = 2½" for 4" HALF GAP HEIGHT)



CORE LENGTH DIMENSIONS

* REV. 8/27/71


R1-5 SEPTUM MAGNET 6/1/71 R.J. LARI
MID PLANE FIELD
EDGE OF COIL 2.953"
17
16
15
14
B (KG)
13
12
11
10
9
0.5
1.0 (INCHES) 1.5
2.0
2.5
3.0


R1-6 SEPTUM MAGNET 6/11/71 R.J. LARI
LEAKAGE FIELD
FOR HALF MAGNET
NI = 1,0636 (12742.07)
FOR N=10 ; I = 1355 AMPS
B YOKE ≈ 12000 GAUSS
B (10³G)
SEPTUM EDGE
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
1
2
3
(INCHES) 4
5
6
7