



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

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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  $\pm 1/32$  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  $\pm 0.2\%$ .

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

| <u>Current (A)</u> | <u><math>\int Bdl</math> (kG-m)</u> |
|--------------------|-------------------------------------|
| 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.

| <u>x (in.)</u>    | A. $\Delta B/B$ % |                 |
|-------------------|-------------------|-----------------|
|                   | <u>y = 0</u>      | <u>y = +0.3</u> |
| 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 <sup>a</sup> | -22.36            | -19.33          |

<sup>a</sup>Data at  $x = -2.7$  in. is highly suspect since the probe may have contacted the coil at this point.

| <u>y (in.)</u> | B. $\Delta B/B$ % |                 |
|----------------|-------------------|-----------------|
|                | <u>x = 0.0</u>    | <u>x = +2.7</u> |
| +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  $y = \pm 0.3$  to be equal to within 0.1%.

The fringe field has been measured at 3 points along the outside of the septum,  $z = 0, 1, \text{ and } 2$  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  $\pm 2.0\%$ . 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.

| <u>d (in.)</u> | <u>Fringe Field (gauss)</u> |               |               |
|----------------|-----------------------------|---------------|---------------|
|                | <u>z = 0</u>                | <u>z = 1m</u> | <u>z = 2m</u> |
| 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

| <u>Z (in.)</u> | <u>Fringe Field (gauss)</u> |
|----------------|-----------------------------|
| 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 =  $30130 \Omega$ ; capacitance =  $1 \mu\text{f}$  ( $\pm 0.1\%$ )
2. Stretched wire probe, 1 turn, width = 0.504 in., coil resistance =  $78 \Omega$
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.

SUBJECT

R-1 SEPTUM MAGNET  
Final Design

NAME  
J. Bywater

DATE  
7/8/71

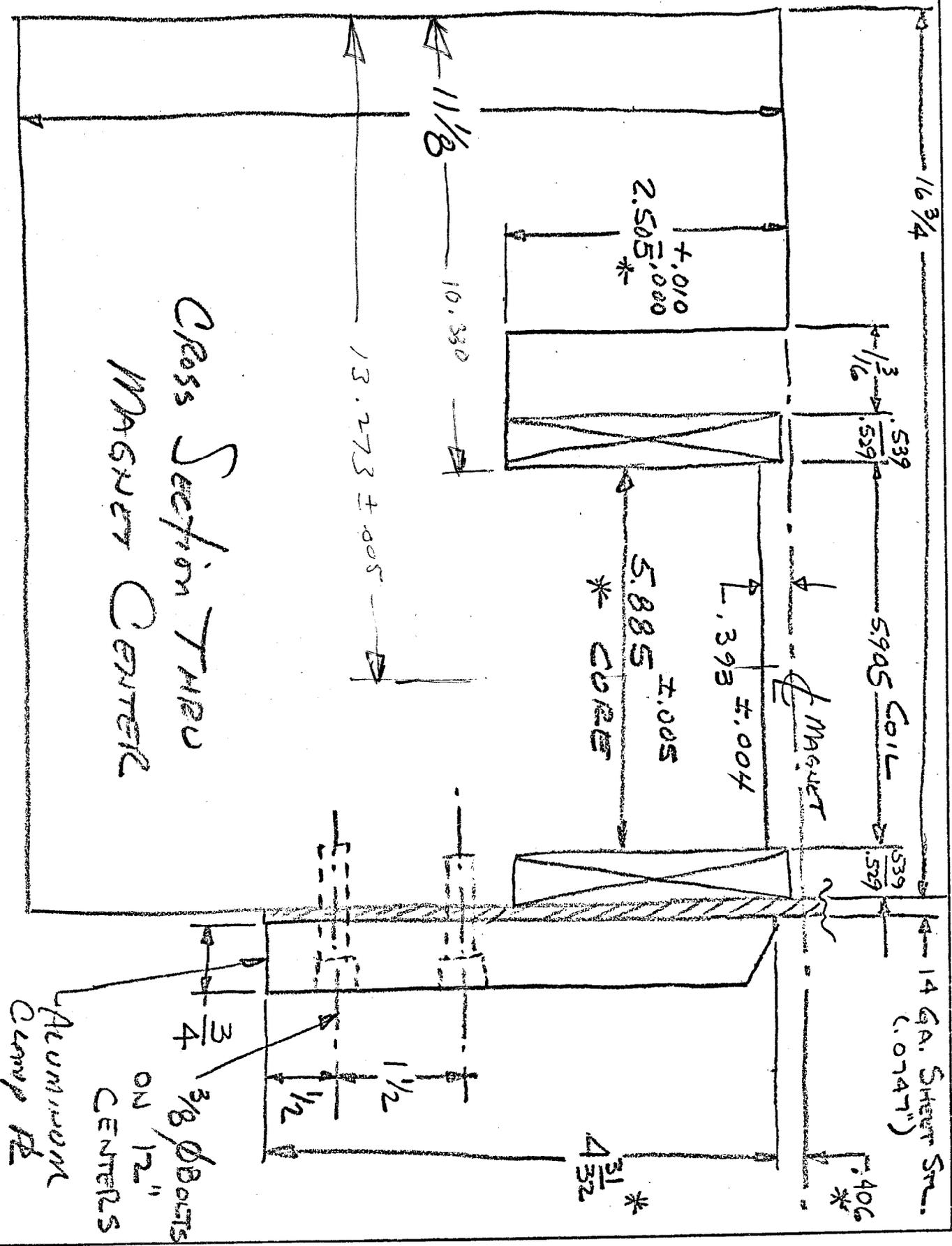
REV. DATE  
8/27/71

## 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 <sub>2</sub> O CIRCUITS _____      | 10  |              |
| POWER PER H <sub>2</sub> O CIRCUIT _____ | 8.6 KW                                      |              |
| H <sub>2</sub> O 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 <sup>2</sup>                    |              |
| CONDUCTOR DATA                           |   |              |
| SIZE _____                               | .450" x .220" O.D.<br>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"                                      |              |

SUBJECT R-1 SEPTUM MAGNET  
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NAME J. Bywater  
DATE 7/8/71 REV. DATE

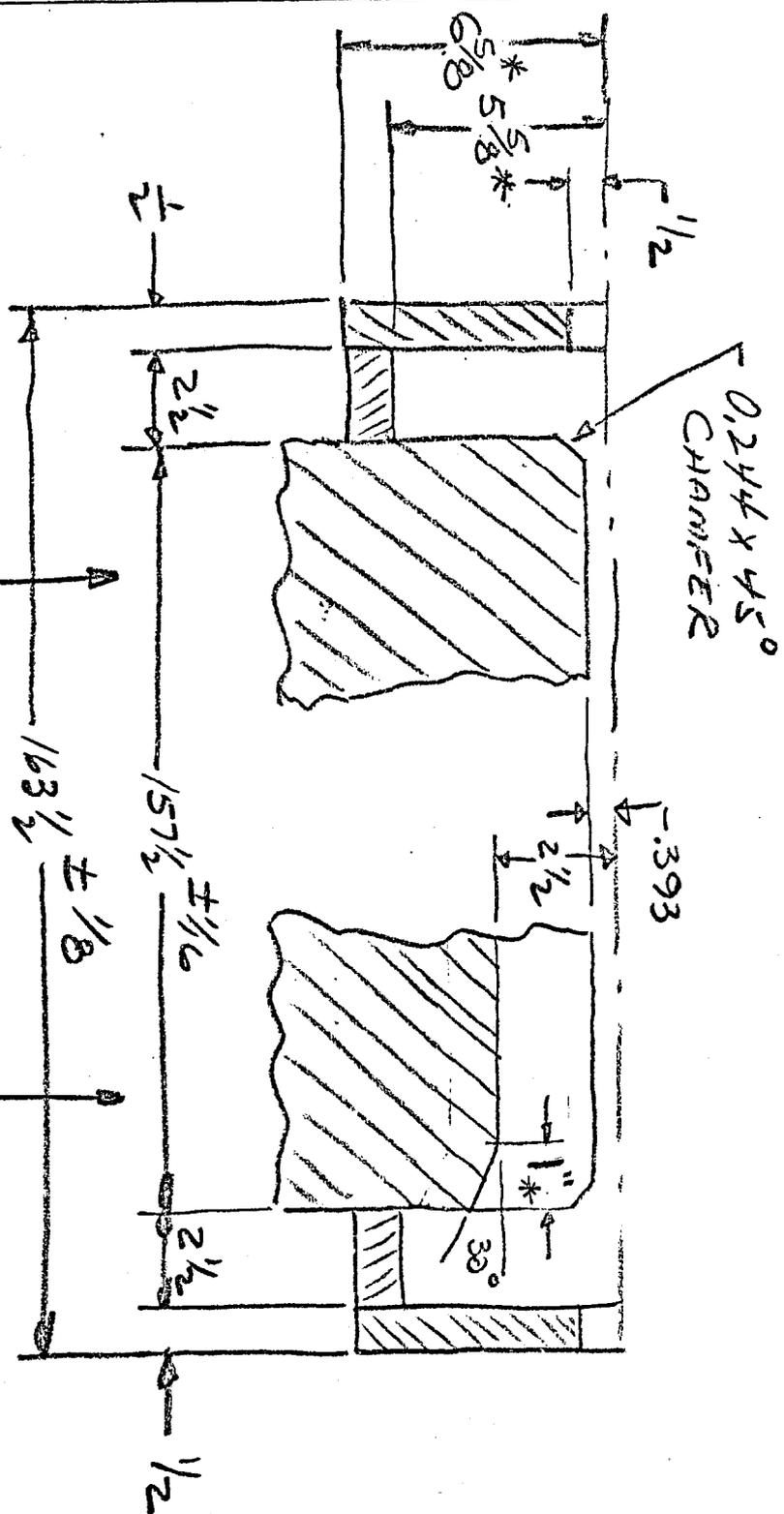


Cross Section THRU  
MAGNET CENTER

\* REV. 8/27/71

SUBJECT **R-1 SEPTUM MAGNET**  
 Final Design

NAME  
J. Bywater  
 DATE  
7/8/71  
 REV. DATE



(BM-109 END CHAMFER = 2 1/2" FOR 4" HALF GAP HEIGHT)

Section Thru  
Mag. Gap.

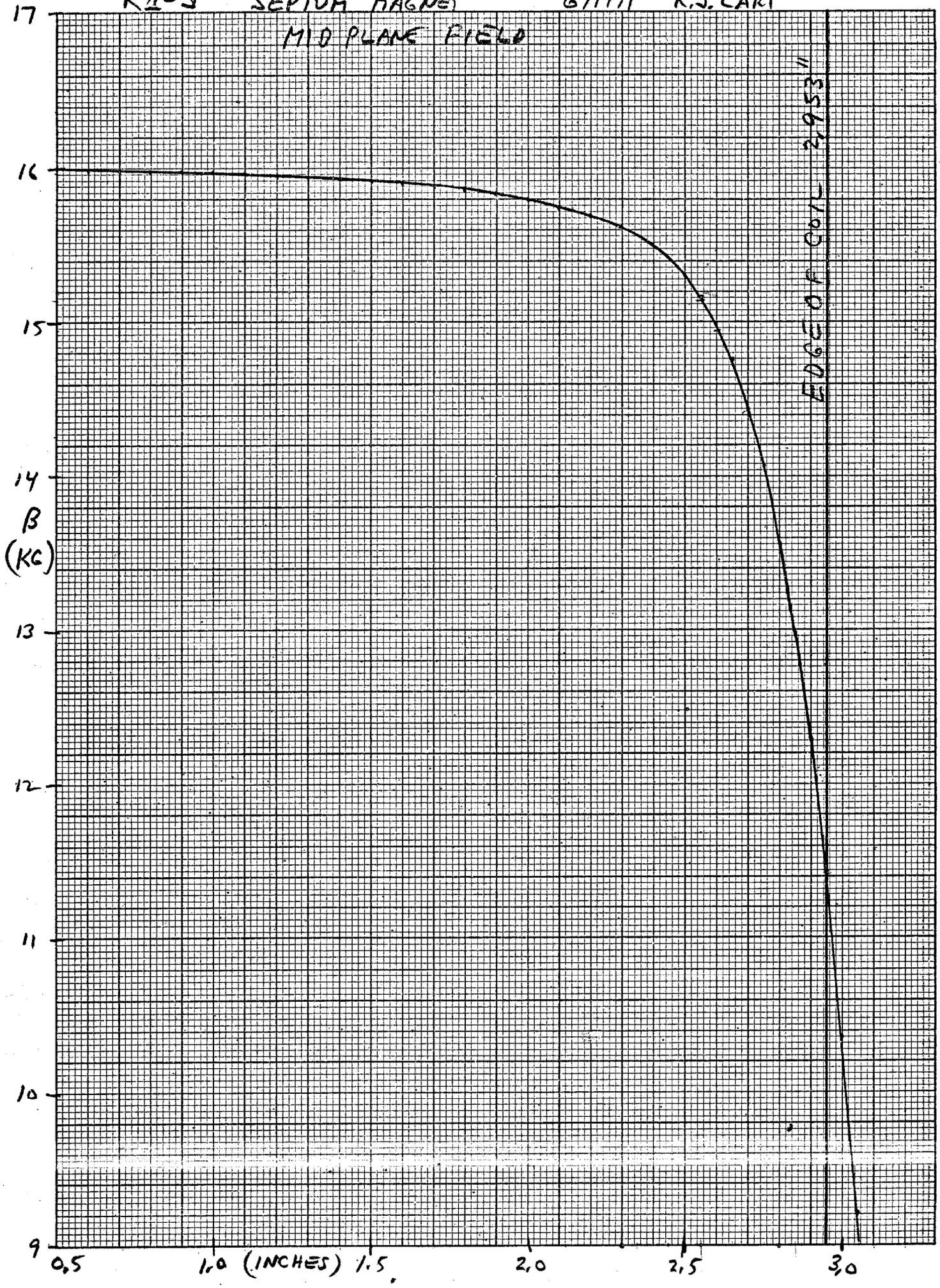
Section Thru  
Coil Slot

Core Length Dimensions

\* Rev. 8/27/71

R1-5 SEPTUM MAGNET 6/1/71 R.J. LARI

MID PLANE FIELD



R1-6 SEPTUM MAGNET

6/1/71 R.J. LARI

LEAKAGE FIELD

FOR HALF MAGNET

$NI = 1,0636 (12742.07)$

FOR  $N=10$  ;  $I=1355$  ANPS

$B_{YOKE} \approx 12000$  GAUSS

