SEPTUM MAGNETS FOR SECONDARY BEAMS AT NAL

R. Carrigan, Jr., J. Jagger, G. Michelassi,
K. Pretzl, J. Satti, S. Snowdon, & A. Wehmann
National Accelerator Laboratory
Batavia, Illinois*

Summary

Septum magnets have been built for the front ends of secondary beam lines M1 and M6 in the Meson Area. The septum sizes are 1.742 in (1.248 in) for the M1 (M6) magnet. Field quality is reasonably good, as measured, although not as good as the design goals of 0.3% (0.1%) for M1 (M6).

In the Meson Experimental Area at NAL, septum bending magnets are used in the front ends of secondary beam lines M1 and M6[1] in order to separate beam channels as quickly as possible. Design according to this concept proceeded through several phases and finally settled on two similar magnets. (See Figures 1 and 2.) The pole length in each is 123 in. Table I illustrates operating parameters. Saturation effects appear in the M1 magnet at about 2800 A; for the M6 magnet this is not a problem.

A laminated design was chosen in order to make use of existing accelerator magnet technology at NAL. The laminations for both were punched from existing B2 laminations.[2] The septum conductors were made by rolling Booster magnet copper originally sized 0.46 in square (with a 0.25 in diameter cooling hole). The larger coil conductor is existing B2 inner or outer coil copper, which had a 0.340 inch diameter cooling hole. The connections at the return end of the magnet were made simply by bending the smaller copper appropriately, machining its ends to fit in the cooling hole of the larger copper and brazing. At the opposite end, where power and water connections are made, the same technique was used. Special fittings (see Figure 3) were used to make the water connections. There was no difficulty with brazing this number of connections. For the M1 (M6) magnet there are six (eight) water circuits.

The choice of position and size of the conductors within the allowed septum region was done using the LRL program LINDA[3]. This program uses a relaxation process with a rectangular grid.

In fabrication a rigid "half-core" was made by stacking laminations, adding end packs, pressurizing, and then welding on outer steel angles on both sides. Straightness along the side and pole face was ≤ 0.015 inch. The upper and lower halves of the coil were separately wrapped as shown in Table II. The B-stage mica tape was cured in a special clamping fixture; both coil halves were then joined together and ground wrapping was done. After this the coil and two half cores were assembled together with the vacuum chamber and the septum keeper plate was welded in place; plates joining the angles on the other side were welded on at this point. The entire magnet was then vacuum impregnated with epoxy to fill voids and complete the insulation.

Measurements of constancy of the internal magnetic field across the aperture were made using a 50 turn split-coil, 24 in long, and by integrating the output of both the probe coils together as they were moved transversely.

The width of this probe was .344 in. The effect of drift in the integrator was minimized by the sequence of the measurements. The end effects of the magnet were removed by taking the difference of readings at two different longitudinal positions. The resulting curve is compared to the LINDA results in Figure 4 for the first M1 septum magnet.

Because the measured field change in the first M1 septum magnet exceeded 0.3%, an attempt was made to improve the field quality by adding 0.004 in to the height of the septum keeper plate. Measurement on the second magnet produced did not indicate a great improvement.

For the M6 septum magnet the same coil insulation thicknesses used for the M1 magnet were planned. This and the desired field quality of 0.1% made it necessary to add a notch to the B2 pole face shaping, as shown in Figure 1. It was found, however, after making the first set of M6 coils and measuring them, that the insulation thickness was less than the nominal due to the curing under pressure. Half-lapped, B-stage, cured mica tape nominally 0.014 in. thick was effectively 0.0124 in. Because the field quality is very sensitive to vertical position of the septum conductors (see Figure 5), this shrinkage would account for the excess of 0.3% in field deviation in the M1 septum magnets at 3000 A.

Measurements of the first M6 septum magnet have been made (see Figure 6). From the "short" coil measurements one can see the effect of the ends of the magnet. In overall effect this end contribution equals the rise of the field inside the magnet.

For the second M6 septum magnet we are replacing the 0.015 G-10 fiberglass shim between the two half coils by a 0.040 in shim. With this the internal field will fall off toward the septum coil in such a way that it should balance out the rise of the end field. This shim change also counterbalances the shrinkage in effective size of the mica insulation.

*Work performed under the auspices of the United States Atomic Energy Commission.

References

[1]J. R. Orr, A. L. Read, et al, "Preliminary Design Report for the Meson Laboratory", NAL publication, 1971, for background information

[2]H. Hinterberger & R. Sheldon, 3rd International Conference on Magnet Technology, 1970, DESY, Hamburg, Germany, p.490; H. Hintergerger, et al, 1971 Partical Accelerator Conference, IEEE Trans. Nucl. Science, NS-18, June, 1971, p. 853

[3]G. Parzen & K. Jellett, BNL 15107 (AADD-165) give literature references to papers that use or describe in a limited way LINDA and the earlier version SIBYL

Table I: Operating Characteristics

	M1 Septum	M6 Septum
Bend angle per magnet	$4.4 \cdot 10^{-3}$ rad	$4.3 \cdot 10^{-3}$ rad
Approx. Field at 200 GeV/c	9.25 kG	9.02 kG
Approx. Current at 200 GeV/c	3120 A	4560 A
Approx. Operating Water Pressure Drop	210 lbf/in^2	210 lbf/in^2
Measured Flow at ~180 lbf/in^2	12.5 gal/min	11 gal/min
ΔT at noted Current	14° C 3240 A	36° C 4672 A
Power at noted Current	116.7 kW at 3240 A	177.5 kW at 4672 A

Table II: Insulation Schedule
(units = inches)

Upper & Lower Coil Wrapping Prior to Curing in Fixture

Large Conductor: .007 half-lap B-stage mica each conductor, install 0.015 G-10 spacers between vertical layers, wrap 4 conductor group with 0.007 half-lapped B-stage mica.

Small Conductor: 0.007 half-lap B-stage mica each conductor. Install 0.015 G-10 spacers between rows. Wrap 4 conductor group with 0.007 half-lapped B-stage mica.

Wrap both sides with tedlar tape. Cure upper and lower coils in fixture ME-20894.

Final Coil Wrapping and Assembly - Large and Small Conductor

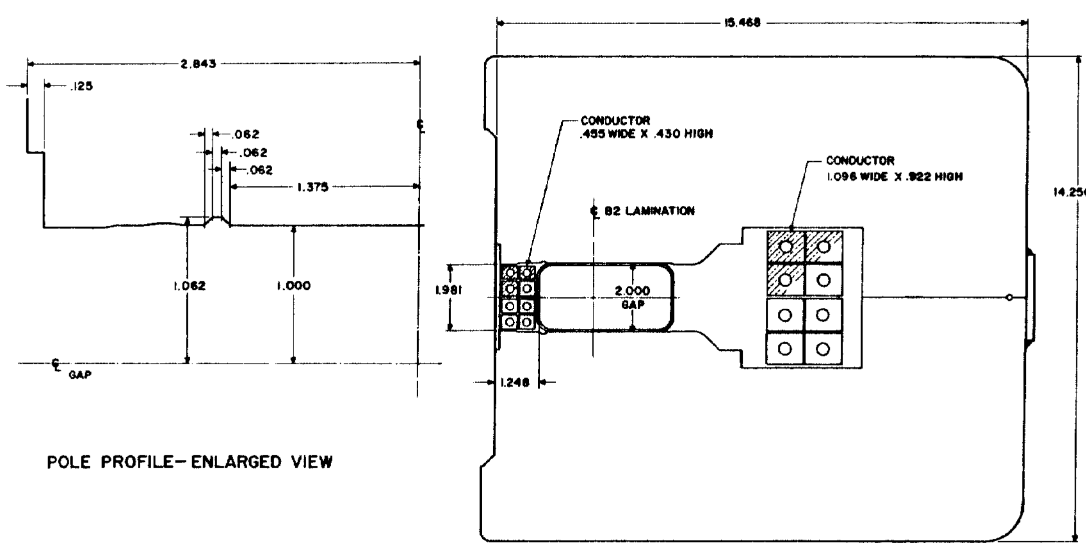
Install 0.015 G-10 midplane spacer on lower coil. Place upper coil on lower coil. Make final braze joint & clean thoroughly.

Ground Wrap Assembly

Large Conductor: .007 dry mica, half-lap
.007 dry glass, half-lap
.005 kapton, butt-lapped

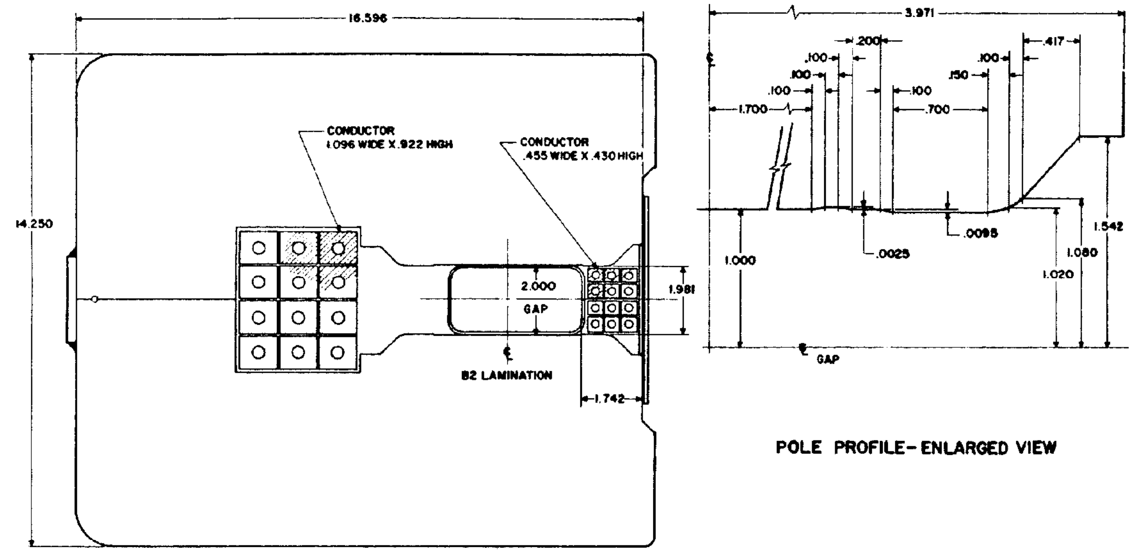
Small Conductor: .007 dry mica, half-lap
.007 dry glass, half-lap
.005 kapton, butt-wrapped

Ground wrap lead and return ends similar to small conductor above. Use dry glass tape to fill all voids to prevent cracking.



M6 SEPTUM CROSS SECTION

Figure 1. The first of this type is 80.9 ft from the target at its front end and is the first element in the beam line. At that point the separation of the M6 beam from the M2 beam line is 1.47 inches. The notch shown was added to the B2 lamination pole profile in order to improve field quality, based on LINDA Runs. In fabrication it was done restamping the B2 lamination. The width of the septum keeper plate is 0.125 in. Leakage flux at 200 GeV/c setting at 0.6 in from the keeper plate is 33 gauss, without magnetic shielding. The innermost copper layer in the septum starts 1.7 in from the B2 center line.



MI SEPTUM CROSS SECTION

Figure 2. The first of this type is 110.5 feet from the target at its front. Three half quadrupoles precede the three M1 septa. At the front of the first the separation of the M1 beam from the M2 beam line is 3.42 in. The pole profile shown is that of the B2 lamination. The magnetic shielding consists of 0.030 in of stainless steel next to the 0.111 in septum keeper plate, followed by 0.125 in of cold-rolled steel. This keeps the leakage flux at 3200 A in the region of the M2 beam down to the level of 50 gauss.

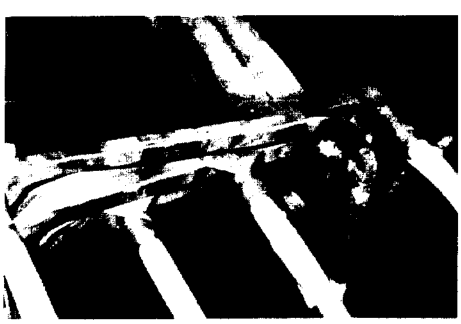


Figure 3. This photograph shows the manifold end of the M6 upper half coil. A straight portion of the large conductor is visible in the background.

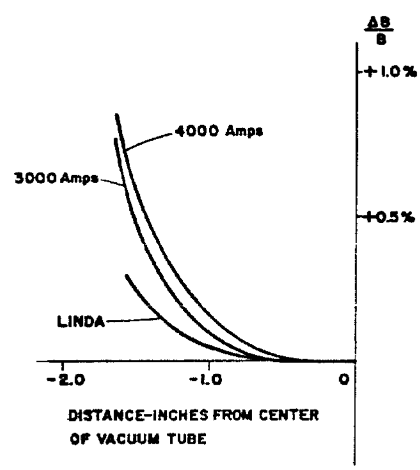


Figure 4. Shown here are two measured curves and a curve from the LINDA calculation of the M1 magnet. The different behaviour at the two currents is due to saturation effects at the higher current.

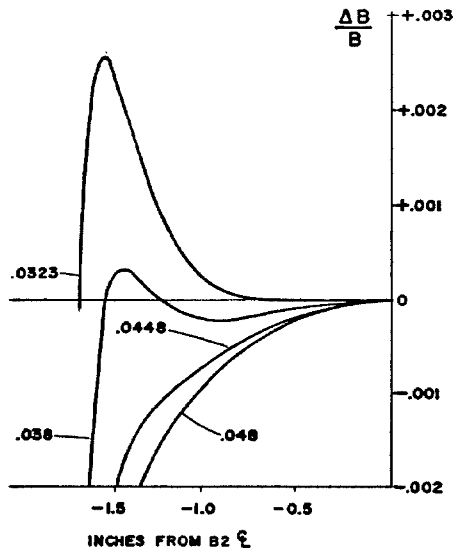


Figure 5. These curves illustrate the variation of the ΔB/B behaviour with changes in the size of the shim between the upper and lower halves of the septum coil. The label is the half-size of the shim in inches.

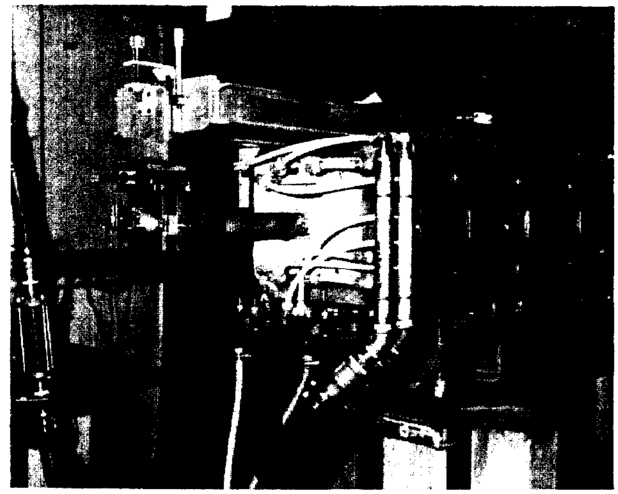


Figure 7. This photograph shows the manifold end of the M6 magnet, during magnetic measurements with a long coil. The long coil support frame, with its micrometer adjustment head, can be seen resting on the top of the magnet.

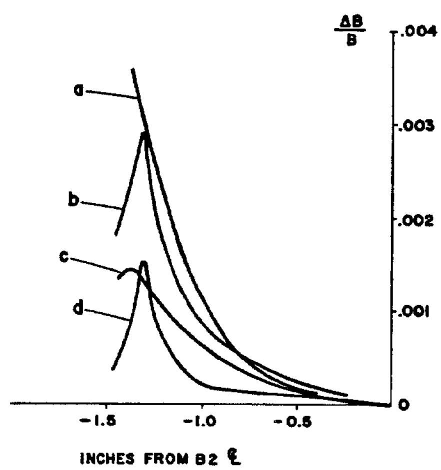


Figure 6. These curves represent measurements made on the first M6 magnet produced. Measurements were made with a 24 inch long probe coil and with a probe coil that consisted of two wires stretched throughout the entire length of the magnetic field. The long coil was 0.25 in wide. Curves b, c, d correspond to short coil measurements. Curve d represents the internal field, curve c represents mostly end effects of one end, and curve b represents behavior of ∫Bdl. Curves b, c, d are all normalized to ∫Bdl, so that they may be directly compared. Curve a is the result of the long coil measurement. For the most part it agrees quite well with the short coil curve b. In magnitude curve d is not unreasonable compared to the 0.0323 curve on Figure 5 (that corresponding to the insulation thicknesses on the first M6 magnet build), remembering the 0.384 width of the probe coil. In shape the agreement is not as reasonable. Measurements on the second M6 septum should help to clarify this comparison.