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MECHANICAL DESIGN OF LAMBERTSON MAGNETS FOR INJECTION INTO THE ENERGY SAVER

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The injection Lambertson magnets for the Fermilab Energy Saver had several design challenges compared to other Lambertson magnets which were built for the 400 GeV machine. In the design of the previous Lambertsons, an outer frame was used for support and to straighten the magnet, along the septum region. Because of the limited space allowed for the Energy Saver magnets, it meant that the Lambertson magnets needed to be completely self-supporting in addition to having the capability of being motor driven. This, the design illustrated in Fig. 1.

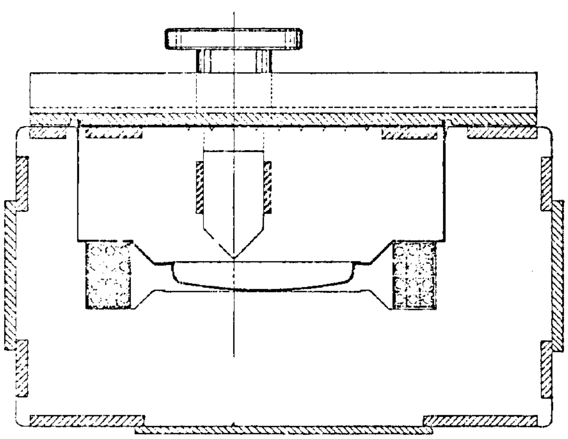

Fig. 1 Cross Section - Injection Lambertson

The design concept that was adopted, was to build the outer lamination stack straight and rigid and let the inner vacuum stack conform to the outer lamination stack. This cross section view of the injection Lambertson demonstrates several of the special design features. The first aspect is that the field free region, which is enclosed in a vacuum skin and shares the same vacuum as that of the dipole field, plugs into the outer lamination stack. This feature permits the outer set of laminations to form somewhat of a box structure with the use of tie plates bridging the two side extensions. This gives the magnet great strength - the strength needed to make the magnet self-supporting and hold tolerances of ±.005 along the septum (x axis) and ±.015 vertically (y axis). In order to insure straightness in the outer lamination stack, the following steps were taken. The position of the neutral axis of the moment of inertia in the x and z axis of the tie bars was matched to the position of the moment of inertia of the laminations. This reduced the amount of bend in the lamination stack due to built-in moments which could have otherwise been generated. The laminations, since they are not symmetrical, had special manufacturing specifications written which required that every roll of material have half of the laminations stamped in the opposite direction. This technique helped to eliminate most of the bending in the lamination stack due to the crowning effect of material coming out of the rolling mills. The last step taken to insure a straight magnet was to make the lamination stacks in 3-foot long modules which can be aligned to a high degree of accuracy and then put together to form the 15-foot magnet.

The fact that the inner region plugs into the outer lamination stack has several important consequences. The amount of lamination steel in the vacuum enclosure has been reduced by 30% compared to the old Lambertson design. This, of course, reduces the residual out-gassing rate and hence leads to a significantly better vacuum. Another benefit is the fact that the lamination stack does not have to be made rigid. It need only be made with no discontinuities. Upon assembly into the outer lamination package it is made to conform to the straightness of the outer lamination stack. The fact of not having to make a field free stack rigid, permits the lamination stack to have its' tie bars, which are stainless steel, placed in the low field regions. The fact that there is an .008 air gap and a .030 stainless steel sheet going through the magnetic field of the magnet, is compensated for by changing the magnetic gap width.

The design of the Lambertson ends illustrated in Fig. 2 brings up some other interesting features.

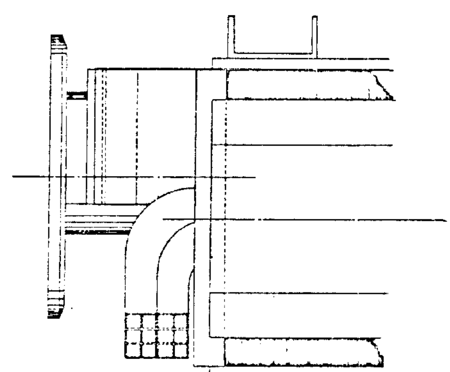

Fig. 2 End View - Injection Lambertson

First, the inner lamination stack is extended 3" beyond the end of the outer lamination stack. This permits the circulating beam in the field free region to be shielded from most of the dipole fringe fields (a factor of 5 reduction was measured). The coils are bent in the same direction - away from the field free region; this makes assembly of the magnet very simple. The coils can be packaged into the outer lamination stack and then the inner lamination stack with vacuum chamber can be lowered into the outer stack for final assembly.

The last design feature of the magnet which needs to be discussed is its vacuum capabilities. Because this magnet is put into the same vacuum system as the superconducting magnets, it has to be able to sustain a vacuum pressure of at least 1×10^{-8} Torr. In order to accomplish this, the following steps were taken. All steel parts - namely the laminations and the end plates, were vacuum degassed for one hour at 800°C and

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a pressure of 1×10^{-5} Torr. The other parts involved in the inner lamination stack are all stainless steel. These parts were degreased and rinsed in an alcohol bath. White gloves were used in the stacking and assembly procedure. The lamination stack, with its stainless steel skin in place was then baked under vacuum to 350°C until such a point that the assembly had completely outgassed at this temperature level and restabilized at a new vacuum level. The heat source was then removed and the lamination stack cooled down slowly to room temperature. Using this procedure we were able to obtain a vacuum of 3×10^{-9} Torr throughout the vacuum chamber. If it became necessary to vent the magnet up to atmospheric pressure, a dry nitrogen atmosphere was used. To recover from venting up, a bake out 120°C would restore the magnet to 3×10^{-9} Torr. Without this bake the magnets' vacuum would only reach 1×10^{-7} Torr.