THE DESIGN AND CONSTRUCTION OF THE PERMANENT MAGNET LAMBERTSON FOR THE RECYCLER RING AT FERMILAB

M. P. May, G. W. Foster, G. P. Jackson, and J. T. Volk
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

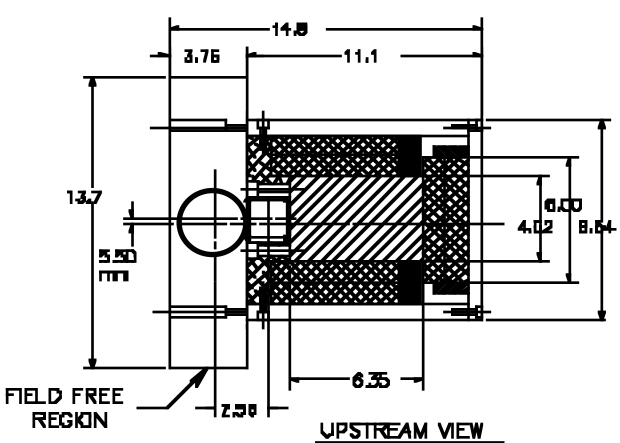
Abstract

This paper will show and discuss the simple design of a permanent magnet Lambertson used to extract and inject 8 GeV. beam from the Fermilab Main Injector Ring to the Recycler Ring, and from the Recycler Ring to the Main Injector. Pictures will show how four different magnets used to form the injection and extraction double dog legs are made from one universal design. Detailed assembly drawings will illustrate the construction techniques using solid pieces of steel instead of laminations. The field strength in both the bending region and the field free region will be discussed along with temperature compensation of the strontium ferrite magnetic bricks.

1 INTRODUCTION

The idea of using permanent magnet Lambertsons for injection and extraction from the Main Injector ring to the Recycler ring was an extension of the idea to use permanent magnets wherever we have a fixed energy of 8 GeV. The Recycler storage ring will be installed in the Main Injector ring at a nominal height of 84 inches from the floor. The Main Injector ring is at 27 inches from the floor.

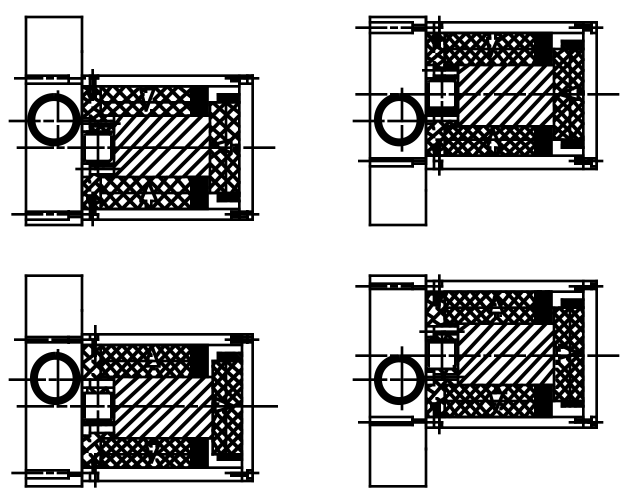
The Recycler ring was the first large scale machine built with permanent magnets. We built a couple of successful prototypes for the Recycler ring and concluded that it would be a good idea to use as many permanent magnets as seemed reasonable in our 8 GeV transfer line which runs from the Booster ring to the Main Injector ring. The permanent magnets that were constructed for the 8 GeV transfer line and the Recycler ring have strengths which range from 1.5 to 2.0 Kg-m. The more permanent magnets we built, the wiser we became in the methods of building these types of magnets, and from this the permanent magnet Lambertson evolved.



2 THE PERMANENT MAGNET LAMBERTSON

The permanent magnet Lambertson is unique in that it uses solid bar stock and plates for its construction. The field free region is constructed using a gun boring technique. In laminated magnet construction, the field free region is located at a fixed point in relation to the bending region, and the bending region has to be designed with a wide enough aperture to bend the beam in the good field region. Having the field free region made in a separate piece of steel allows the bending region to be positioned bending upward or downward in relation to the field free region. Since we are able to angle the bending region in the direction of the bend, the width of the bending region is greatly reduced.

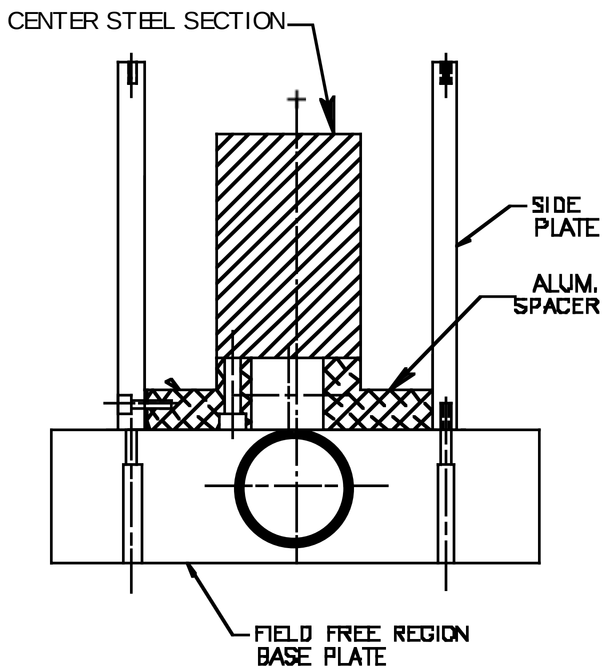
Having this mechanical capability of bending up or down, the permanent magnet bricks can be arranged such that the field direction of all the bricks is pointing in the direction of the center poll piece or away from the center pole piece. Thus, with one mechanical design, four different Lambertson configurations can be constructed. The specifications of the permanent magnet Lambertson are as follows: The pole tip length is 160 inches. The base plate length is 168 inches. The bending angle is 22mr, and the field strength is 1,607kg-m. The field free region has a 3 inch OD X .049 wall steel vacuum tube, and the bending region has a 2 X 2 X .065 wall stainless steel vacuum tube. (See the illustrations of the four types of magnets.)



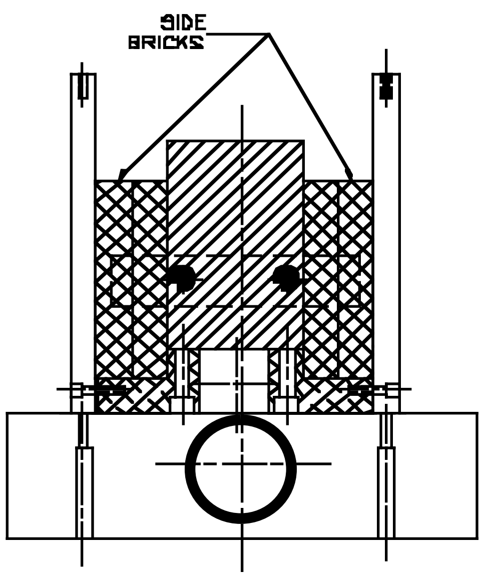
3 LAMBERTSON ASSEMBLY SEQUENCE

The sequence for assembling a permanent magnet Lambertson goes in the following manner:

1. The 1X4X6 strontium ferrite bricks are fully magnetized.
2. The type of Lambertson to be constructed is selected: Extracting protons or anti-protons. Bending up or bending down.
3. The center pole piece and the side plates are assembled to the base plate which has the field free region in it, in the appropriate bending direction.

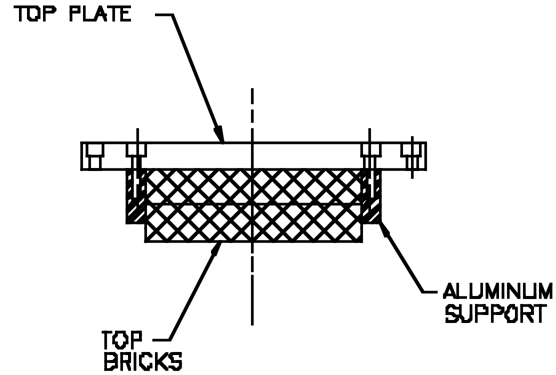


4. The side bricks are slid into the magnet between the side plates and the center pole piece, working equally on both sides and starting at one end of the magnet.



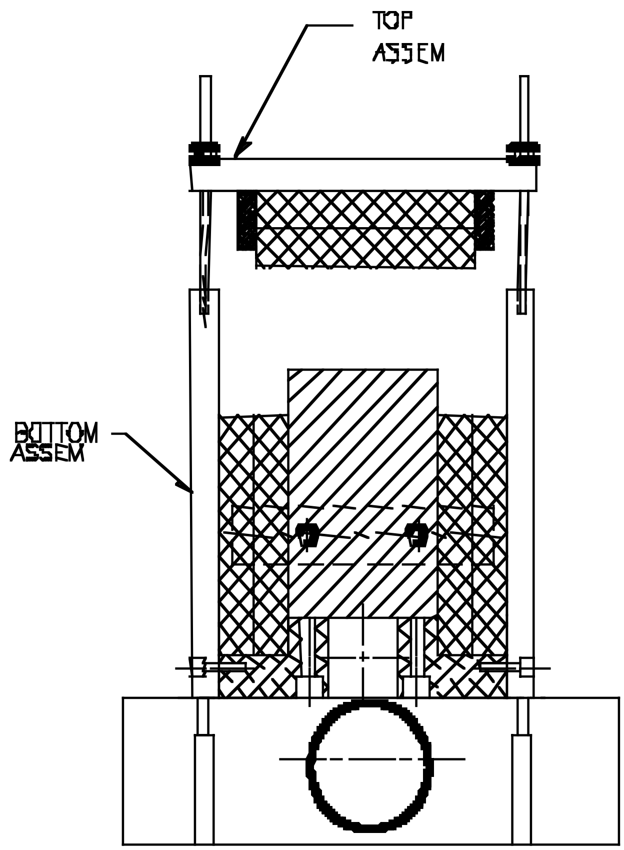
ADD SIDE BRICKS

5. The top plate is a sub-assembly which is constructed on a separate table. The magnetized bricks are glued to each other and then glued to the top plate. They are located on the steel top plate by aluminum bars which run down the length of the top plate.

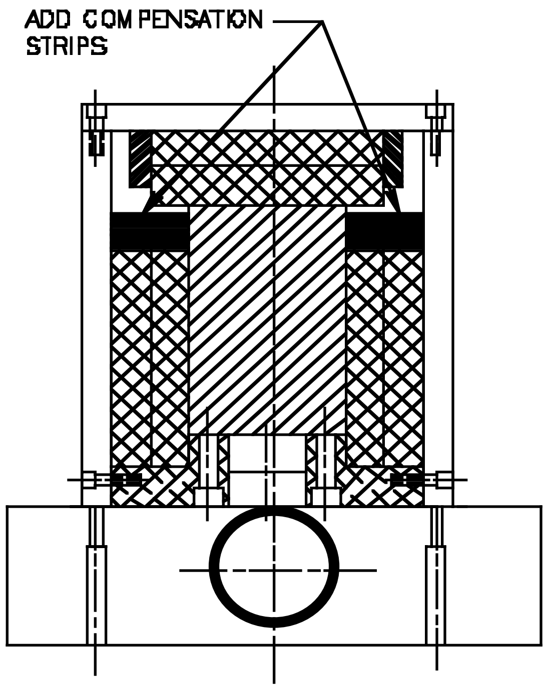


TOP PLATE W/ BRICKS

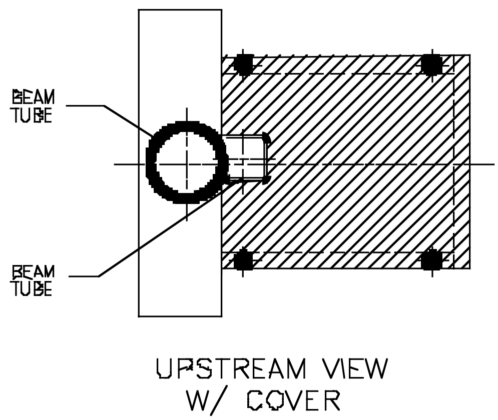
6. The top plate is rotated 180 degrees, and lowered on to the magnet sub-assembly. Guide rods are used to keep the top plate centered as it is forced into its final position. There is a very strong repulsion force until the top plate and the side plates get close enough to make magnetic contact. At this point the magnetic circuit is completed and the force becomes one of attraction.



7. The magnetic compensation strips are now installed, and the end plates are added.



8. The magnet is now magnetically measured for field strength using a flip coil. After measurements, the magnet is place in a freezer where it's temperature is lowered to 32 degrees F. The magnet is again measured at this temperature to insure that the correct amount of temperature compensating material has been added to the magnet. Once the magnet has warmed up to room temperature, another set of measurements are again taken to finalize the magnet strength and temperature compensation of the magnet.
9. The magnet is now ready for a final painting and the vacuum beam pipes are installed.



4 ACKNOWLEDGMENTS

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