MULTIPARTICLE SPECTROMETER MAGNET (MPS)

Eugene E. Halik
Brookhaven National Laboratory
Upton, L.I., N. Y.

Abstract

During the last few years more and more Spectrometer Magnets were employed in high energy physics experiments. Most of these experiments detected a relatively small number of particle secondaries because the apertures of the magnets were not satisfactorily large. For this reason an attempt is being made at BNL to build a spectrometer which could accommodate experiments on more complicated types of interactions with detection of many secondaries. Obviously this spectrometer, in order to perform properly, will be large and with an acceptable magnetic field; it must have better resolution, and a wide solid angle acceptance. The basic idea is a large aperture C-magnet. High resolution digitized spark chambers, low mass proportional chambers and scintillation counter hodoscopes will be located and operated within the magnetic field volume which will be 4-ft high by 6-ft wide by 15-ft long. The main spectrometer is to be followed by a set of large digitized spark chambers, scintillation counter hodoscopes, and Cerenkov counter hodoscopes to provide improved momentum resolution and particle identification for those particles which emerge through the downstream aperture of the magnets. This magnet spark chamber combination will give the experimenter freedom to move to a new class of experiments.

I. Magnet Spectrometer Design

The design of this magnet is as flexible as feasible and budget-wise permissible. This approach was selected to make possible the adaptation of this magnet to a large number of experiments. An angular displacement of $\pm 15^{\circ}$ of this instrument was also incorporated in the design and will be achieved by using Hydrostatic Thrust Bearings. The total weight of the Spectrometer Magnet will be more than 1,300,000 lb. This design was decided upon to satisfy the following requirements:

1. Maximum flexibility for mounting inside the field volume systems of spark chambers, counters and targets in various configurations.

2. Freedom to accommodate a liquid hydrogen or deuterium target in the magnetic field volume with cylindrical chambers and other detectors surrounding it.

3. Ability to extract through side apertures particles which originated at the target and should be detected outside the magnet.

*Work performed under the auspices of the U.S. Atomic Energy Commission.

The parameters are:

Magnet Aperture	48-in. high by 72-in. wide (with additional 2 ft of free space on each side) by 180-in. long
Excitation	9.7×10^{5} A turns
Current	6,300 A
Magnetic Field	10,000 G which provides a high enough field integral (approx. 150 kG ft overall)
No. of Pancakes	14
Turns/Pancake	11
Power	1.6 - 2 MW
Cooling Water Flow	275 gpm approx.
Total Wt of Steel	1.3×10^{6} lb
Wt of Coils	5.8×10^{3} lb

As shown in Figures 1, 2 and 3, the magnet proper consists of a lower horizontal yoke which is made up of 6 large forgings (Fig. 2, No. 1), and an upper horizontal yoke which is constructed of 11 plates and 24 spacers (see Fig. 2, No. 3), providing room for spark chambers, and two large cross members (see Fig. 2, No. 2) and one vertical yoke which consists of 2 heavy beams and 3 large forgings spaced one foot apart. The upper arm of the C-magnet is supported on three 8-in. diam columns which must withstand the weight of the upper horizontal yoke and the attracting magnetic forces which are approximately 1,100,000 lb total. The lower pole consists of two 15-in. thick plates (see Fig. 3, No. 4). The upper pole consists of eleven 6-in. thick plates which are separated by short 5-in. thick plates (all structural parts of the upper yoke) and two half-moon shaped pieces (Fig. 3, No. 3).

This instrument, because of its weight and size, will be a permanent facility and will be placed in the northeast corner of the Brookhaven National Laboratory EEBA building.

As mentioned in the first paragraph this Spectrometer Magnet will have provisions for rotating it $\pm 15^{\circ}$ around a center (Fig. 2, No. 5) which is located on the longitudinal centerline 18-in. downstream from the face of the magnet. The support on which this spectrometer will stand and slide is somewhat unusual. It is a four-point support. Again we have to say that it is an unusual four-point support because it consists of two 20-in. by 20-in. by 180-in. long beams each having its own two-point support which will be located in strategic positions. These beams are

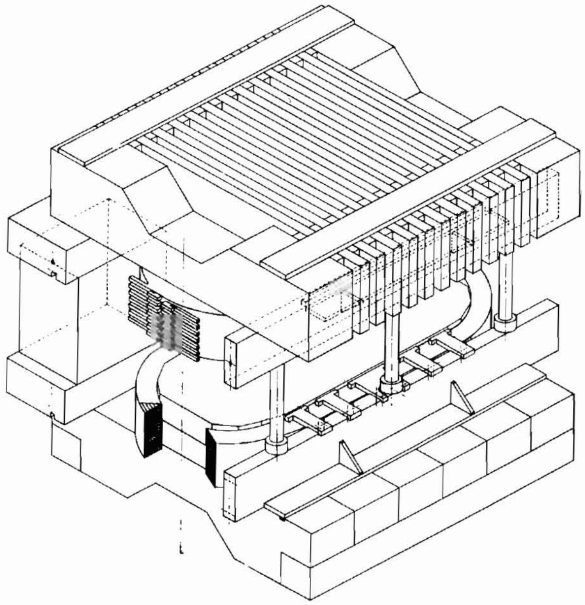

FIGURE - 1

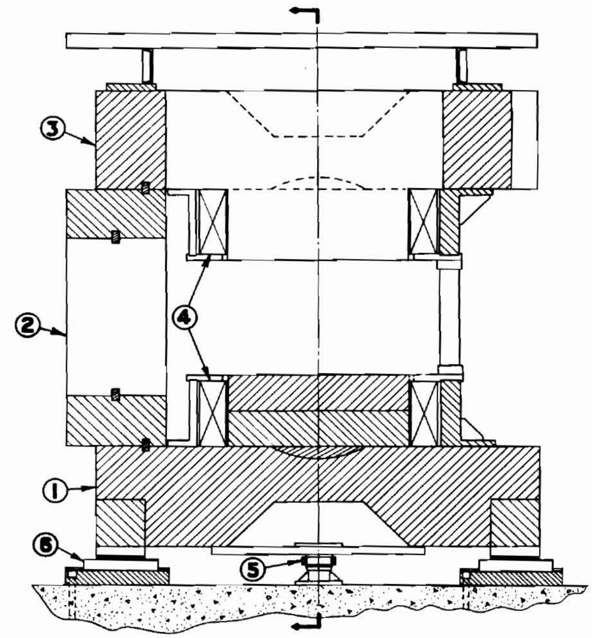

FIGURE 2

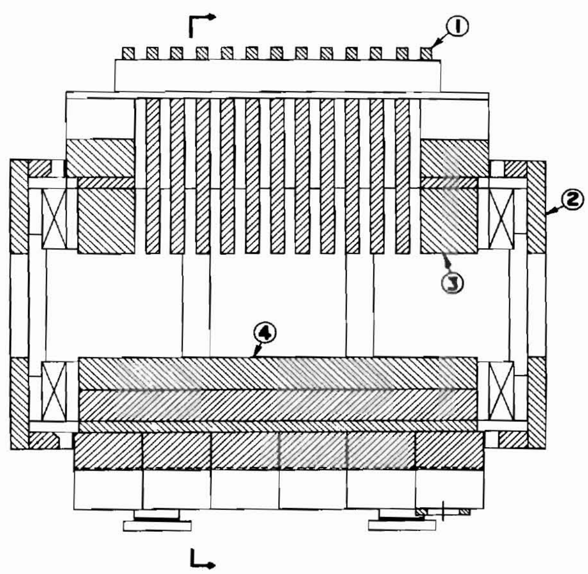

FIGURE 3

loosely connected merely by the magnet structure which is quite flexibly attached to these beams and therefore they will react independently, i.e., like two individual two-point supports. These two beams will be supported by two Hydrostatic Bearings each. Above each Hydrostatic Bearing there will be a jacking device, which will serve as a level and elevation adjuster. Each Hydrostatic Bearing will be a 30-in. diam disk with four recesses (Fig. 2 No. 6). Each bearing will have freedom to assume a parallel position relative to the bearing plates on which it will float. The total oil flow will be approximately 15 gpm. The emerging oil from the bearings will be redirected into pipes returning it through the concrete foundation to a "dirty" tank, out of which it will be pumped through a filter into a "clean" tank, which in turn will serve the Hydrostatic Bearings. It is planned to float this magnet on a 0.005-in. oil film. When floating, the magnet will be frictionless;or better, it is calculated that the coefficient of friction will be approximately 9.8×10^{7} when all design parameters are achieved. Two cylinders will move the magnet. These cylinders must be capable of supplying a much larger force than will be necessary to overcome the negligible friction, because any deviation from a horizontal plane will result in a much larger force requirement for rotation of the Spectrometer. The four Hydrostatic Bearings will slide or float on four 6-in. thick bearing plates located on a foundation pad or slab the dimensions of which are 27-in. by 20-in. by 5-ft thick. The pad itself is a heavily reinforced concrete slab. The reaction forces on the concrete through the Hydrostatic Bearings and Bearing Plates are on the closed side approximately 4×10^{5} lb and on the other side(column side) 3×10^{5} lb; therefore the Spectrometer centerline is displaced by approximately 1½ ft with respect to the concrete pad centerline. The concrete slab is 3 ft under the floor level and is independently suspended. There will be a pit on one side of the foundation, approximately 14-ft long by 5-ft wide and 6-ft deep, which will accommodate the hydraulic machinery. As mentioned before there will be two tanks there; one of 60 gal capacity and the second of 100 gal, and two electric motors driving two hydraulic pumps. One of these will be of the centrifugal type coupled to a 2-hp motor and the second will be a positive displacement, pressure compensated piston pump coupled to a 40 hp electric motor. Flow control valves will be located on the magnet main body as near to each Hydrostatic Bearing recess as feasible. Directional valves,and other hydraulic auxiliaries will be located in the pit.

II. Magnetic Shielding

The Spectrometer Magnet will have three magnetic shields. Front and rear magnet shielding as shown in Fig. 4 is of a C-shape and is manufactured out of an 8-in. plate. There are upper and lower magnetic flux-return paths attached to this shielding. The two 8-in. C-plates also serve in this design, as basic structural elements. Without these plates it would probably not be feasible to erect this type of Spectrometer and it would be very hazardous to energize this magnet without front and rear shielding plates. The third shield is located on the top of the upper horizontal yoke. It consists of thirteen 6-in. by 5-in. by 17-ft long bars which are connected with the upper yoke through two non-magnetic supports (Fig.3, No. 1).

III. Coil Design

The coil is designed in 14 pancakes each wound with 11 turns of hollow square copper bar (see Fig. 2, No. 4).

The coil parameters are given below:

Excitation (as designed)	3.080×10^{6} A turns
Actual Excitation	9.7×10^{5} A turns
Number of Pancakes	14
Turns/Pancakes	11
Power (as designed)	10 MW (total)
Actual Power	1.6 - 2 MW
Current (as designed)	20,000 A
Actual Current	6,300 A
Voltage (as designed)	500 V
Actual Voltage	250 V
Resistance	0.02500 Ω
Water Flow (as designed)	1266 gal/min (total)
Actual Water Flow	275 gal/min (approx.)
Water Pressure	160 psi (approx.)
Water Temperature Rise	30°C
Straight Section	112.00 in.
Bend Radius	37.00 in.
Total Weight Copper	27.919 tons
Total Length	6317 ft
Conductor Width	1.7385 in.
Water Hole Diam	0.9545 in.
Copper Area	2.2945 sq. in.
Pancake Thickness	3.78 in.
Radial Width	10.93 in.
Pancake Weight	3988 lb
Length of conductor for Pancake	451 ft
Overall Length, Outside	205.86 in.
Overall Width, "	95.86 in.
Overall Length, Inside	186.00 in.
Overall Width, "	74.00 in.
Half-Section Height	26.44 in.
Coil Plan Area	5321 sq. in.
Current Density (as designed)	8716 A/sq. in.
Actual Current Density	2745 A/sq. in.

The epoxy used consists of Furane 10 parts and Shell 8-26 100 parts.

IV. Conclusion

In conclusion it must be mentioned that because of tight money and funding difficulties it was decided to use as a base for this design the steel and coils which were originally designed, but never used, by Midwestern Universities Research Association for the MURA Heavy Liquid Bubble Chamber. It is therefore obvious that there were encountered some unusual difficulties which had to be overcome and therefore that some compromise had to be made. From a technological point of view the engineering was thereby made more difficult and therefore more interesting. Nearly all of the "old" steel was used and about 700,000 lb of "new" steel had to be added. All steel is of AISI C1010 steel. About half of it is in the form of steel forgings and the second half is of steel plate. The coils are used as originally designed, since any modification would have been too costly. From the Physics point of view this Spectrometer Magnet should fulfill the calculated expectations; none of the compromises made were such as to endanger this goal. The total price, excluding the Midwestern Universities Research Association's original expense, is about $250,000 including foundation, and it is therefore believed that this will probably be the cheapest Spectrometer Magnet of this size ever built.

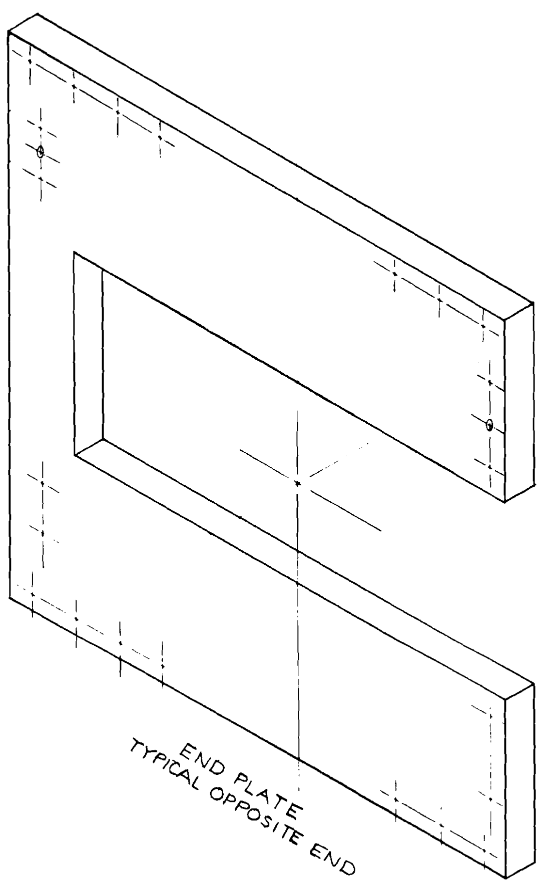

FIGURE-4