THE MAGNETIC SHIELDING SYSTEM FOR THE STANFORD TWO-MILE ACCELERATOR*

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Summary

The magnetic shielding system for the Stanford two-mile accelerator consists of a 0.006-inch-thick layer of high quality commercial magnetic shielding material wrapped around the accelerator. It is surrounded by a system of degaussing wires, consisting of two orthogonal sets of four wires spaced to provide uniform fields to cancel the vertical and transverse horizontal components of the earth's magnetic field.

General

If the accelerator were not shielded, the earth's magnetic field could cause the electron beam of the Stanford two-mile accelerator to strike the walls of the disk-loaded waveguide. A system of wires and magnetic shielding is used to attenuate the external magnetic fields. Slow, time-varying fields, which are the hardest to shield against, are attenuated by an average factor of 10. Ordinary ac magnetic fields and dc fields are attenuated by an average factor of 100 or more.

The magnetic shielding system is shown in Fig. 1. The outer set of wires is designed to create a pair of orthogonal uniform magnetic fields perpendicular to the axis of the accelerator. The resultant field should be equal and opposite to the earth's magnetic field.

A layer of commercial magnetic shielding is wrapped around the disk-loaded waveguide to attenuate variations in the earth's field which are not cancelled by the magnetic fields from the wire system. There are large variations in the earth's magnetic field along the length of the accelerator. There are also diurnal fluctuations in the earth's field and ac fields caused by the proximity of power lines and other sources of magnetic fields.

Under the magnetic shielding there is another set of four wires which are used to demagnetize the shielding material.

Design Considerations and Tests

The magnetic field from a set of four parallel wires spaced as shown in Fig. 2 can be shown to be uniform near the center. The system is analogous to a Helmholtz coil and is uniform to terms of $(r/R)^4$ where R is the radial distance from the center to the wires and r is the distance from the center to some arbitrary point. The spacing for optimum uniformity is as shown where the long side of the rectangle is normal to the field. The current required to cancel a field H_o is

$$I = 1.44\ H_o R \text{ amperes}$$

where R is in centimeters and H_o is the magnetic intensity of the field component in oersteds.

The wire sets are one sector, or approximately 100 meters long. Over this length, with all the reinforcing steel and other magnetic material in the structure, the earth's field is highly nonuniform in both intensity and direction. It is only possible to adjust the current to cancel an average field. The variations are typically of the order of 25% of the nominal field, which is about 0.4 gauss in the vertical plane and about 0.2 gauss in the horizontal plane.

From calculations of the steering and focusing of the electron beam, a nominal value of one milligauss was set as the allowable residual field. However, because of the presence of various supports, waveguide couplers, and other irregularly shaped components, it is economically feasible to shield only about 95% of the accelerator. Even if perfect shielding were to be applied around that percentage of the length, the remaining unshielded 5% of the length would limit the effective shielding factor to 20. A reasonable match of shielding quality to the existing geometry was made by specifying that the shielding material should exhibit a shielding factor of 20 for slow, time-varying fields. The tests were conducted at one cycle-per-second, which is low enough so that the attenuation due to the copper in the disk-loaded waveguide is negligible. At 60 cps the combined shielding effect of the copper and the shielding material is well above 100, and it is over 10 for the copper alone without additional shielding.

Shielding materials from various manufacturers were evaluated in the actual geometry in which the shielding will be used. The best results were obtained with materials known as moly-permalloys. The highest shielding factors and the most consistent results were obtained with an alloy called by the brand name HYMU-80 and made by the Carpenter Steel Co. The material purchased is 0.006-inch thick and is cut in short strips which are loosely wrapped once around the disk-loaded waveguide and lightly clamped in place. For testing the shielding, the wire sets were used both to cancel most of the earth's field and to apply the oscillating component to the field. The oscillations were added to the field by modulating one of the dc power supplies. The measurements were made by noting the output from a flux-gate magnetometer placed in the disk-loaded waveguide.

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The dc shielding factor of the complete shield can be increased by demagnetizing the shielding.[1] The explanation of this effect is that the act of demagnetizing actually magnetizes the shield to exactly cancel the external dc field. The demagnetizing worked best when a slowly decreasing 60-cps current was passed through the inside of the shield or even through the shielding material itself. The set of four demagnetizing wires is installed along the accelerator before the shielding material is put in place. Up to 100 amperes of ac current are passed through the four wires in parallel (i.e., 25 amperes per wire) and slowly decreased to zero in about 30 seconds. After the shielding is demagnetized, the field inside the shielded volume is generally well below one milligauss. In laboratory tests with thicker shielding, it was possible to get down to 5×10^{-5} gauss consistently. These tests were with 0.020-inch-thick moly-permalloy.

Results

Preliminary tests of the first two sectors of the accelerator indicate that the magnetic shielding system is satisfactory. The demagnetizing operation is performed after any interruption or readjustment of the currents through the wire sets. In an emergency, if the dc power supply for the wire sets fails, it is still possible to operate the accelerator by demagnetizing the shielding in the presence of the earth's full field. However, this reduces the effective dc shielding factor to a maximum of 20 owing to the 5% of the accelerator that is unshielded. The resulting field is above the specified tolerance and would affect the operation of the accelerator by making the steering energy-sensitive. It is planned to operate the accelerator with as many as six different energies on consecutive beam pulses. If steering becomes energy-dependent, the steering coils will have to be programmed on a pulse-to-pulse basis, which greatly complicates the system.

References

1. W. B. Herrmannsfeldt and B. L. Salsburg, Rev. Sci. Instr. 35, 906(N) (1964).

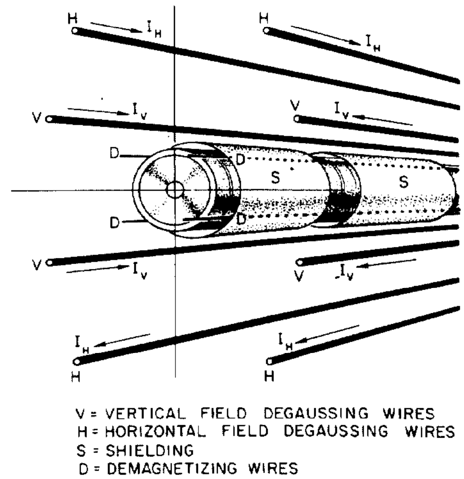

Fig. 1. Magnetic shielding system.

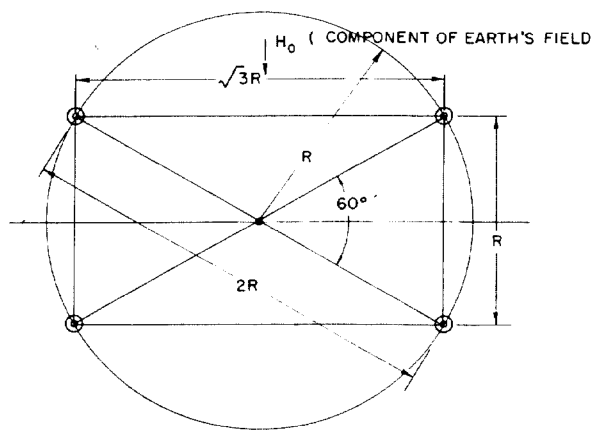

Fig. 2. Wire configuration.