SHIELDING ALLOYS CAN PROTECT DEVICES IN MAGNETIC FIELDS

Stray radiation and magnetic interference can cause failure and false signals in operating electronic equipment. Metal alloy shields can be chosen to direct the fields around the equipment or to block field effects. Consider the following scenario.

Laboratory personnel gathered around to watch the final test as the long R&D project neared conclusion. But something was not quite right. A magnetic field was interfering and was preventing optimum performance of several components of the system. A long delay seemed inevitable; a dependable shielding supplier was neded in addition to a decision on the type of shielding material or shields to obtain.

Does this sound familiar to you? A quick solution would be for the Purchasing Department to phone any reliable magnetic shielding manufacturer and order a quantity of heat-treated, ready-to-use, magnetic shielding foil.

Off-the-Shelf Solution

A major advantage to any development engineer or technician using magnetic shielding foil is that only a few basic concepts are needed. No detailed, specialized knowledge is necessary to estimate how to obtain specified shielding effectiveness in static and low frequency shielding, provided that the model shop or stock room keep on hand both low permeability and high permeability shielding foils.

After hand shaping a foil shield, the researcher places it around the component or components to be shielded and holds it in place with ordinary adhesive tape (foil material can also be purchased with adhesive backing). The foils should not be sharply bent, welded or subjected to mechanical shock, and seams should be aligned parallel to magnetic flux lines (Figure 1).

When practical, it is preferable to shield the affected components from radiated fields. (However, other considerations could make it easier to suppress radiated fields at the source.) The amount of shielding is quickly determined on a trial-and-error basis, saving many days' time and avoiding frustration.

If a single layer of foil is not enough, it may be necessary to add one or more additional layers. If the high-permeability foil is saturating add a layer of low-permeability foil. Low-permeability foil close to the field source can divert a major portion of the field, allowing the high-permeability foil to operate in a lower reluctance mode. This arrangement increases the shielding capability of the system. Avoid compressing the layers tightly together, since a small air gap between layers enhances shielding.

In many research applications, the hand-cut, hand-formed foil magnetic shield will solve the entire shielding problem. The key to foil shielding convenience and economy lies primarily in the use of small quantities of foil.

Fabricated shields

In certain applications, fabricated shields are practical. The mobile shielding cylinders used in magnetism studies are one example (Figure 2). This type of shield safely transports rocks, after degaussing of the Earth's magnetic field effects, to the testing laboratory. There the researcher can accurately measure the rocks' initial magnetism to ascertain facts about the history of the magnetic fields in the rocks' previous Earth environments.

For a cylinder in a field transverse to its axis, the required attenuation is approximately 1,000 times. The geometric increase in shielding effectiveness of two cylinders vs. a single cylinder is expressed in the following equations:

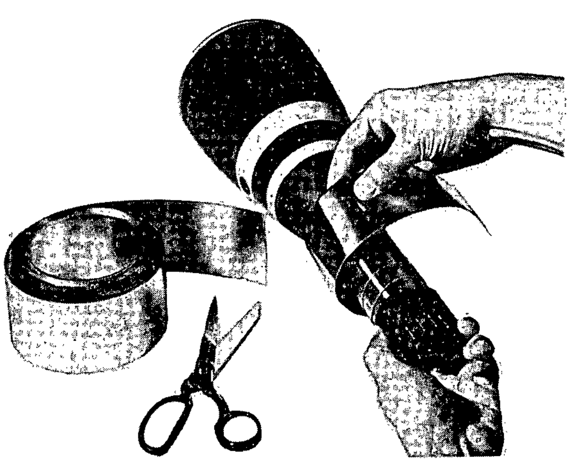

Figure 1. Scissors can cut magnetic shielding foils for quick application to protect any sensitive electronic equipment from field effects.

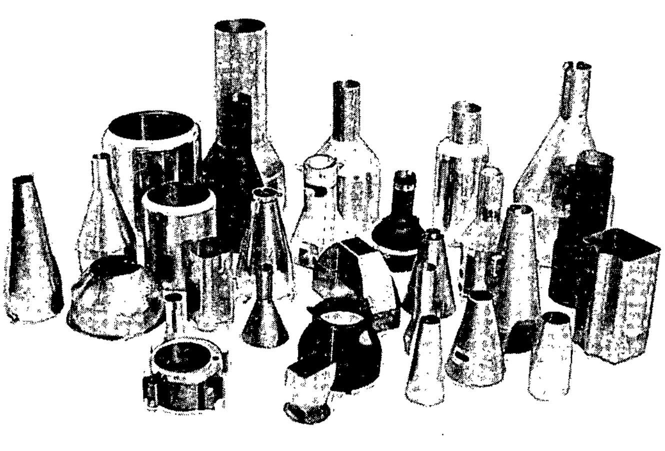

Figure 2. Custom-fabricated shields can be made to protect almost any kind of equipment in almost any configuration. Common applications include magnetic isolation chambers, shields for low-field research, and shields for many types of operating instruments and test chambers. When properly used, these shielding devices provide lasting protection.

For a cylinder in a field transverse to its axis, the required attenuation is approximately 1,000 times. The geometric increase in shielding effectiveness of two cylinders vs. a single cylinder is expressed in the following equations:

$$S_1 = 1 + (\mu t/2R)$$

where S_1 = one-cylinder static shield effectiveness.
μ = permeability of the foil alloy.
t = thickness of cylinder.
R = outer radius of cylinder.

Then, the double-cylinder static shield effectiveness is given by

$$S' = 1 + S_1 + S_2 + (S_1)(S_2)(1 - A_1/A_2)$$

where S' = double-cylinder effectiveness.
S_1 = shield effectiveness of first cylinder.
S_2 = shield effectiveness of second cylinder.
A_1 = cross-sectional area (normal to flux) of outer surface of first cylinder.
A_2 = cross-sectional area (normal to flux) of outer surface of second cylinder.

Usually, $(1 - A_1/A_2) = 0.5$.

A commercial, double-cylinder construction of 0.025-in. high permeability fabricated alloy provides both the strength and shape stability required. Aluminum-bar spacers separating cylinders have milled reliefs for demagnetizing coils. The outer cylinder radius is two times the radius of the inner cylinder. The thickness of the walls of both cylinders is the same.

For this type of shield, spun high permeability caps are tightly fitted over the ends of both cylinders, minimizing any attenuation loss through air gaps. End-cap uniformity of thickness and of fit in these large radii are the critical quality features in a shield of this type. These factors determine the quality of the residual field inside the shield. A commercially-available cylinder of this type has a convenient carrying handle attached by two brass screws. The overall length, including the end caps is 12.5 in. Outside diameter of the outer cylinder is 1.875 in. The weight is 1.25 lbs. (Figure 3).

Such a shield can provide lasting protection because the high permeability alloy does not saturate during normal use. In addition, the alloy will not suffer excessive permeability loss from minor shock. However, it does display minimum retentivity.

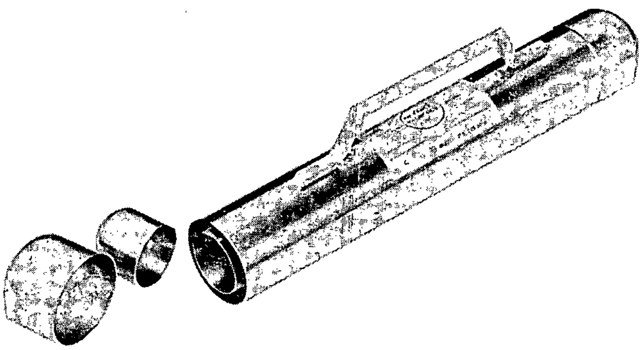

Figure 3. Double-cylinder construction of fabricated alloy provides strength and shape stability for transporting rocks for magnetism studies. A large sliding cap fits over the end of each cylinder to minimize any loss in magnetic attenuation from the air gaps.

Isolation chamber

Another example of a fabricated shield is a dual-purpose magnetic isolation chamber. This chamber is used both for low-level-field research and for production-line testing. It provides a low-level-field environment into which magnetically-sensitive devices can be placed to observe their characteristics while they are relatively unaffected by external magnetic fields.

One such device is a magnetometer probe that operates on a saturation or a reluctance principle. We could also use the chamber for testing of any other device capable of sensing magnetic perturbations, and for testing sensors that operate on magnetic principles. We can readily calibrate such sensors by installing Helmholz configuration coils. The chamber also can be used with a magnetometer for the detection of ferromagnetic contamination that often is found in nonferrous and nonmagnetic alloys.

The construction of the magnetic isolation chamber is fundamentally similar to that of the portable unit described above. It consists of a series of concentrically-positioned shielding chambers. One end of each cylinder is permanently closed. The other end of each cylinder is closed by a removable cover. Holes through the cover permit manual access to components under study. The magnetic attenuation is enhanced by non-magnetic spacing between the cylinders (Figure 4).

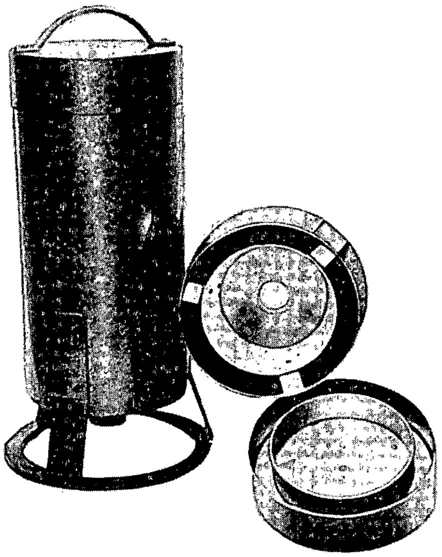

Figure 4. For low-level-field research and for production testing, a magnetic isolation chamber provides an environment in which magnetically-sensitive devices may be observed without interference by external magnetic fields. An operator can also determine the presence of ferromagnetic contaminants in nonmagnetic materials.

Choosing alloys

In the chamber, magnetic isolation requirements are the sole determining factor defining the number of concentric shield systems and the types of shielding alloys used. The entire assembly is mounted horizontally by two aluminum channel structures attached to the outermost shield. Plastic mounting feet prevent any possible marring of the work surface. The chamber could be designed for a degaussing coil system.

The user's application defines the choice of alloys used in manufacture of the chamber. For the inner shield and for the next layer or layers, a high-permeability alloy that displays a maximum initial permeability, μ is usually specified. If the magnetic-field environment is intense to the point of creating saturation, the outermost shield is constructed of the low-permeability alloy.

All seams are welded by a tungsten-inert-gas (TIG) process. After fabrication, annealing in either a temperature-cycled hydrogen atmosphere or a vacuum optimizes and stabilizes the permeability characteristics of each alloy.

Rotating the assembly through 360 degrees orients the shield's axis in the ground, enabling the user to find the position giving the minimum magnetic field. Using this technique, we can assure ourselves that fields not exceeding 100 gamma (0.08 A/m) will be attained.

Proper degaussing of the inner shield structure can lower the field to the 10-gamma level. In favorable environments, fields as low as 2 gammas have been attained.

Puzzling interference

The uses for magnetic shielding sometimes appear in unexpected places. When a laboratory moves into a new concrete structure, there can be a mysterious magnetic field interference that was not present in the old laboratory. There, the equipment worked normally. In the new facility, research is hampered by the unidentified, unwelcome field.

Today, we know that the problem probably is caused by modern concrete construction, characterized by many reinforcing bars, steel beams, and low ceilings. These often are factors that can create undesired magnetic fields. The interference is amplified by the lower ceilings, with their internal steel beams, which are much closer to laboratory equipment than they are in the older buildings.

Steel footers for buildings, in their concrete castings, not only create strong local gradients in the Earth's field, but usually provide antenna coupling to any communication or broadcast transmission that originates within a mile or so of the building. Such situations are the daily challenge to EMC specialists in their on-the-spot surveys.* Alloy foil and sheets of high-permeability including cable shielding, play their part in localized and area shielding solutions to such interferences.

What's most convenient?

In applications such as these, fabricated shielding enclosures are exactly tailored to a specific research requirement. Shield shapes may range from simple to quite complex—conical, cylindrical, and box configurations are the most common. For lower-intensity fields, a single layer of shielding may suffice; higher-intensity fields can require two or more shielding layers.

In situations in which the magnetic field conditions are known, or in which the problems expected are more or less standard, a custom-designed shield or a standard shield probably will be adequate. In other cases, the best answer may be a foil shield.

The foils offer the convenience of instant availability, as well as cost savings in experimental and production situations. For such applications, the prudent researcher or prototype builder will recognize the value of ready-to-use shielding foil as a time-saving research tool.

With a supply of foil always on hand, the researcher or prototype builder will need only minutes with ordinary scissors to eliminate interference from a magnetic field. The quick solution of forming and applying the needed protective shield avoids costly delays and permits the project to proceed on schedule.

*R.A. Tell, D.L. Lambden & E.D. Mantiply, "Hospital Proximities to Nearby Broadcast Stations," IEEE 1978 Int'l Symposium Record on Electromagnetic Compatibility, June 20-22, 1978.

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