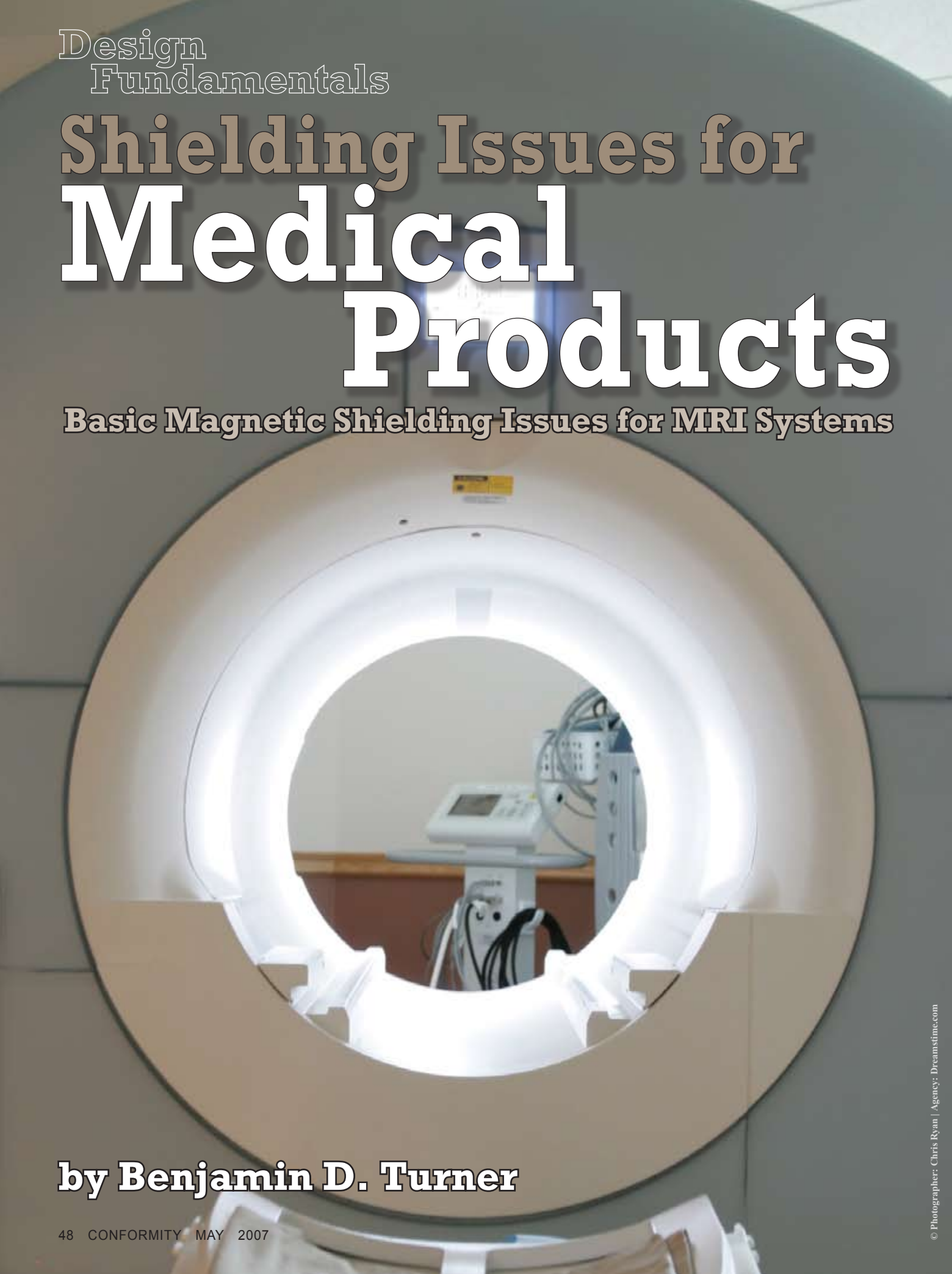
Design Fundamentals

Shielding Issues for Medical Products

Basic Magnetic Shielding Issues for MRI Systems



by Benjamin D. Turner

This article provides the reader with an overview of the basic principles of magnetic shielding for magnetic resonance imaging (MRI) systems. It pre-supposes only a rudimentary understanding of magnetic shielding as it relates to MRI systems, and will explain: 1) why magnetic shielding is needed for an MRI system; 2) what it can consist of; 3) how magnetic shielding can impact construction and a construction schedule; and finally and most importantly 4) what an end-user of the MRI equipment needs to do and/or consider when first starting to plan for an MRI system.

Why Magnetic Shielding Is Needed

First, not every MRI system needs magnetic shielding. There are many different types of MRI systems, and each location where an MRI system can be placed is different from the location chosen by some other hospital or clinic.

There are two basic reasons for magnetic shielding. First, magnetic shielding is needed when the proposed location of the MRI system allows the magnetic field of the MRI system to extend beyond the MRI scan room itself and into surrounding areas that could be adversely affected by the magnetic field from the system.

A typical example of this would be an MRI system that generates a 5 gauss field (gauss is a unit of measure of magnetic field) that extends into a public area. The U.S. Food and Drug Administration (FDA) has established guidelines that either require that the 5 gauss field be kept away from the unsuspecting public, or the posting of signs that notify the public of the possible exposure (such as, "you are entering an area of 5 gauss or higher"). The 5 gauss field has been established as the boundary line beyond which we should keep people with pacemakers and other metal implants away in order to prevent possible harm.

Second, magnetic shielding is needed when the proposed location of the MRI system is located such that the operation of the MRI system might be adversely affected by something around the MRI suite.

A typical example of this might be when an MRI system is placed in close proximity to automotive traffic, such that the traffic makes the operation of the MRI system less than ideal. This would be due to the fact that cars and trucks are made of ferrous magnetic metals, which can negatively impact the quality of images generated by an MRI system when too near to an MRI system. Consult the Site Planning Guide of your MRI vendor on the acceptable distance your MRI must be from moving vehicles.

The first cause, that of an MRI generating a field that affects a surrounding area, is by far the most common. Here are a few

considerations and examples of things to look for and plan against:

- Get the magnetic field plots of the MRI system which you are considering from the equipment manufacturer. You should get the "plan" or top view of the plots, as well as the "side" and "front" view plots. Many people forget to consider the vertical space they are planning to occupy. Magnetic field will extend vertically up and down and often this is a more difficult issue to address.

- Make sure the plots that you receive clearly show the 1 gauss, 5 gauss and 50 gauss lines. The 1 gauss field from the MRI will disrupt TV and/or computer monitors as well as some other medical equipment such as CT scanners. The 5 gauss is for protection of "the public," and the 50 gauss line is usually strong enough to erase magnetic media such as credit cards, facility access cards, computer hard drives, etc.

- Make sure you overlay the magnetic field plots onto your architectural plans, both the plan view drawings and the section or elevation drawings. It may seem obvious but make sure the plots and drawings are to the same scale!

- Identify the use and, if possible, the major types of equipment that will be in the rooms immediately around, above and below the MRI room.

- Common items adversely affected by the MRI fields include CT scanners, any medical equipment with an image intensifier, TVs or computer monitors, and any public area through which someone with a pace maker or metal implant could unknowingly pass.

If you know that the magnetic field from your MRI system will overlap into areas that will affect others around you, seek to move your system enough to eliminate this conflict. Alternatively, see if you can move or

change the area/equipment that will be harmed by the MRI's magnetic field. When these options are not possible, you will need to consider options for magnetic shielding.

What Magnetic Shielding Is Not

First, let's understand what magnetic shielding is not. It is not lead shielding and it is not radio frequency shielding. Lead shielding is for shielding against x-rays and is applied in a "line-of-sight" manner. In other words, lead shielding is placed directly between the x-ray device and you. Concrete can also help to shield against x-rays, but consultation with a physicist is recommended.

Radio frequency (RF) shielding blocks radio wave signals from entering or exiting a room. RF shielding must be a complete, 6-sided box in order to work. You must also understand that radio waves function over a very broad spectrum. Your MRI system functions in a very specific frequency; thus your RF shielding should be designed to be applicable for your frequency of interest.

What Magnetic Shielding Can Consist Of

Now that we know what magnetic shielding is not, let's understand what magnetic shielding is. Magnetic shielding is any ferrous metal that will attract magnetic fields. Galvanized steel, silicon steel, even structural I-beams and columns in a building can all attract magnetic fields. Can you use any ferrous metal for your magnetic shielding? Yes! The more important question is whether the metal you select is economical to use.

Different ferrous metals have quite different electromagnetic properties. A-36 structural steel behaves much differently than galvanized steel, in a magnetic sense. Different metals also have different costs. A high nickel alloy, often termed "mu-metal," is much more expensive on a per pound basis than is most grades of silicon steel.

So what metals should you use for MRI magnetic shielding? Low carbon steel is the best metal if you will be placing the material in a very strong magnetic field. For example, looking at the magnetic plots of the MRI you are purchasing, approximately what gauss level lies at the wall where your magnetic shield will be placed? In general, if the field is 30 gauss or higher, you may want to use low carbon steel. If that gauss level is less than 30 gauss, you may want to use a grade of silicon steel.

There are two principle properties that one considers when choosing what type of metal to use for a magnetic shield, permeability and saturation. Permeability is the ability of the metal to attract magnetic field to it. Saturation is the ability of the metal to absorb magnetic field within its wall. For simplicity, we will not differentiate here between magnetic field and magnetic flux; however, from a technical point of view, we would say "attract magnetic flux" and "absorb magnetic flux" over the term magnetic field. For the lay person, there is little difference between these terms.

Again, choices in magnetic shielding are driven by economics, that is, cost versus performance. You can use other metals, but you may need to use a greater quantity of one material to achieve the same performance of another. Thus, a less expensive metal may not be least expensive when you consider how much total material you may need to reach the same performance of a more expensive metal.

Further, you cannot always assume that if you use twice or three times the amount of one material, you will equal the

shielding effectiveness of another material. For example, it is a falsehood to say "if I use twice as much silicon, it will be the same as low carbon steel." While such a metric may have applied in a single instance or application, it cannot be assumed that it will always be true in other situations. This is a common mistake, but one that is easy to avoid.

Magnetic shielding is not only dependent upon what type of material you choose but also the physical geometry of the shield relative to your magnet. Also remember that there are many different types of magnets, including 0.23T, 0.5T, 1.0T, 1.5T, 3.0T, open, closed bore, and so on. Thus, a magnetic shield used for one MRI system at one location may not work for your MRI system or your location. The physical position of the magnetic shield metal and the amount of magnetic field that it is placed in and the goal of your magnetic shield may all be different from the situation in some other location.

In summary, MRI system magnetic shielding is typically done with low carbon steel or silicon steel. Low carbon steel works best if it is heat treated (also called "annealed"); however, if the material is too thin you will be unable to heat treat it, since the physical shape of the metal will be altered and thus not fit nicely in the construction. From a magnetic standpoint, the lower the carbon content, the better the material. The industry standard for MRI shielding is 0.08% maximum carbon content, which is denoted as "C1006 steel."

The most common form of silicon steel used for MRI shielding is transformer grade, and will range from M19 to M36. These are U.S. terms for the level of the transformer grade material. There are, obviously, equivalents for M19 and M36 in Europe and Asia. Unfortunately there are too many such equivalents to list here.

The Impact of Shielding on Construction and Schedule

Magnetic shielding can vary greatly depending upon your situation (MRI type, location, what you need to shield for around your MRI suite, etc.). Magnetic shielding can be as simple as a small amount of metal on a single wall, or multiple layers of shielding on some or all walls, ceiling and floor. Weights of magnetic shielding can vary from a few hundred pounds to over a hundred U.S. tons. Obviously, space limitations, as well as the ability to structurally support and to physically maneuver such material into your planned MRI site can be difficult.

Therefore, it is essential that you understand and define how much magnetic shielding you will need as early as possible in your planning process. In fact it should be one of, if not the very first step you take after selecting which MRI system you are purchasing.

Defining what you need for magnetic shielding can greatly impact your planned cost and construction schedule. For example, if you determine that you need magnetic shielding in large amounts above your MRI scanner, but you have already completed your ventilation, lighting and ceiling plans and have no space for the magnetic materials or the supports need

for the magnetic materials, you now have a bigger problem, particularly if you are already in the construction phase.

Failing to anticipate the need for magnetic shielding is only part of the problem. Magnetic shielding is not always a logistical challenge, but it can be. You may need forklifts, man-lifts, cranes, etc., or you may need to address the potential impact of welding fumes or the noise from hand tools within an actively functioning hospital or clinic all around the MRI suite.

You should plan for 4 weeks for manufacturing for any low carbon steel shielding that you need, while silicon steel typically will require between 2 and 4 weeks. But note that these are manufacturing times only, that is, after the design of the magnetic shielding has been completed. Installation of magnetic shielding can range from 2 additional days to as much as a month and a half, depending upon the extent of the magnetic shielding needed.

Planning Considerations for an MRI System

Finally, what should an end-user do or consider when starting to plan for an MRI system for his or her facility? The first step is to select an architect. Meet with and review the plans and proposals of the various companies manufacturing MRI systems. Each company should be able to give you an idea of what magnetic shielding will be needed before you settle on which MRI system you want to purchase. Certainly, they can provide you with a final magnetic shield design upon selecting their system for purchase.

Consult a shielding company either just before or just after your selection of an MRI system. You should consider contracting with the shielding company to assist you in the planning and budgeting of the shielding before it is finalized by the MRI company. This will enable you to realize the various cost, scheduling and logistic issues associated with the magnetic shield early on. With this information, you have a better chance of setting a firm construction budget and timeline.

Magnetic shielding for an MRI system is not a difficult thing to plan for. But it should not be overlooked and thrown in late in the construction process. Some shielding companies can provide magnetic shield design services prior to your selection of an MRI system, thus enabling you to take the shielding needs of one system versus another into consideration before finalizing your purchasing decision. □

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