Magnetic Field Safety Guide

Environmental Health and Safety

1.0 Purpose and Requirements

This guide will present a summary of the basics of magnetic field safety, biological effects, and exposure limits to be used at The University of Alabama. Figures 1 and 2 list some typical magnetic field strengths that once can find in everyday life. This may be useful when exposure limits are discussed.

2.0 Scope

This guide applies to all users of devices and equipment designed to generate magnetic fields, both static and time varying. Examples include MRI (magnetic resonance imagining), SQUID (superconducting quantum interface device), particle accelerators, computer drive erasers, etc. Shielded equipment have greatly reduced field levels at normal distances from the shielding surface but may still exceed safety limits at close ranges.

In addition, large motorized equipment may generate spurious magnetic fields that may exceed safety limits.

A magnetic field survey can determine where or if equipment exceeds safety limits. Contact Environmental Health & Safety to request a survey.

3.1 Definitions

- B Field
  Magnetic flux density or magnetic induction. This quantity is considered the better measure of health hazards than the H field. The units are tesla (T) and gauss (G).
- H Field
  Magnetic field strength, measured in amps per meter (A/m).
- E Field
  Electric field strength, measured in volts per meter (V/m).

- μ_0
  Permeability of free space and is the ratio of B to H. For free space and (for practical purposes) for tissue, it has a value of $4\pi \times 10^{-7}$ weber/A-m.
- Tesla
  See B field. 1 T = 10,000 G = 1 weber/m^2.

3.2 Conversions

Some useful conversions between units are:

- 1 μT = 0.7958 A/m
- 1 A/m = 1.257 μT
- 1 T = 10,000 gauss

4.1 Biological Effects of Magnetic Fields

Effects are broken into two broad groups: physical effects where mechanical action occurs and biological effects that occur at the chemical and cellular level.

4.2 Physical Effects – Static Fields

By far the most important effect here is from the attraction of magnetic objects in or on the body by the magnetic field. Objects such as pacemakers, surgical clips and implants, clipboards, tools, jewelry, watches, mops, buckets, scissors, screws, etc. have all been documented as being potential hazards. Even low mass items can become hazardous when moving at high speed. Much of this experience has come from medical MRI systems. Magnetic objects will try to align themselves with the magnetic field lines. If an implanted object tries to do this, the torquing may cause serious injury.

In general, the quantity of ferritic or martensitic steel in an object will affect it's magnetic ability: the greater the quantity of these components, the greater the ferromagnetism. Austentitic steel is not magnetic. In addition, iron, nickel, and cobalt are magnetic and add to the items magnetic ability. All types of 400 series stainless steels are magnetic. Most, but not all, series 300 stainless steels are austentitic and not magnetic.

Modern pacemakers are designed to be tested or reprogrammed with the use of a small magnetic external to the body. Static fields can close reed switches and cause the pacemaker to enter test, reprogram, bypass, etc. modes with possible injury.

4.3 Physical Effects – Time Varying Fields

Effects of time varying fields are similar to those of static fields with a few major differences. First, an electric current can be induced when a conductor is in a time varying field. The human body is a conductor and so is moving blood. In such a field small currents not normally present in the body can be produced. Usually this is not a concern, but pacemaker users could be at reisk. The induced currents may cause the pacemaker to incorrectly start pacing or even prevent pacing when it is actually needed.

A general rule of thumb is 1 T/sec can induce about 1 $\mu A/cm^2$ in the body. Ambient current densities in the heart are about 10 mA/m^2 (1 $\mu A/cm^2$). At this level or less biological effects have not been demonstrated. At 100 to 1000 mA/m^2 changes in the threshold for nerve and muscle action occur, with a potential health hazard. However, the magnetic field necessary to generate 100 mA/m^2 is very large.

Induced currents can cause local heating, the major effect from time varying fields. Resistance heating in local areas of the body has caused burns in some medical MRI patients. The cause is the radiofrequency range time varying field. Low frequency fields usually do not contribute greatly to this effect. The ambient heat load of the body while resting is about 1 – 2 watt/kg. MRI examinations at about 0.15 – 2 T and millisec pulsing could add about 0.4 – 2 W/kg extra. While various parts of the body dissipate heat differently, it is this locally deposited extra heat that causes the burns.

4.4 Biological / Other Effects – Static Fields

The ability of static fields to cause cancer and other bio effects is greatly disputed. Much more work must be done in this area before a consensus opinion can be found. However, some conservative limits are proposed based on the best available data.

Based on data from MRI usage, static fields may cause a small, reversible effect on electrocardiogram data. The cause is the interaction of moving blood (a conductive medium) and the field in the heart. The effect was minimal below about 2 T (but was seen as low as 0.1 T) and is not considered a concern.

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An interesting effect that has only been reported at very high fields (e.g. >4 T) is magnetophosphenes. Light flashes can be seen when the eye moves in a very strong field. It is thought that the induced current in the optic nerve causes this effect. Current densities of about 17 $\mu A/cm^2$ are associated with this. No magnetophosphenes have been reported at 1.95 T or less, but have been seen at 4 T on an experimental MRI system.

Specifically at 50/60 Hz, minor effects have been reported at 0.5 to 5 mT (5 to 50 gauss). At 5 to 50 mT (50 to 500 G) some visual and nervous system effects have been reported. At 50 to 500 mT (500 to 5000 G) stimulation of nerve and muscle tissue has been reported. Above 500 mT (5000 G) the induced currents can upset cardiac rhythm or cause ventricular fibrillation. All of these effects are from induced currents (IRPA, 1990).

Also at 50/60 Hz there has been no positive link proven between cancer or leukemia and magnetic fields. Some studies show a link and some show no link but all are based only on statistical analysis.

5.1 Magnetic Field Exposure Limits

Because there are no regulatory limits and much biological data is unclear, the most conservative limits from recognized organizations will be used. Limits are primarily from the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) data. The International Radiation Protection Association (IRPA) published a guide in 1990 and is used here.

Limits will be updated by EH&S as new data is published.

< 60 mT
8 Hr Avg

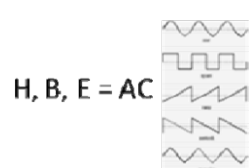
< 600 mT
8 Hr Avg

< 0.5 mT

5.2 Static Fields (ACGIH TLVs 2008)

- Routine occupational exposures should not exceed 60 mT (600 G) to the whole body on an 8 hr time weighted average.
- Routine occupational exposures should not exceed 600 mT (6000 G) to the extremities on an 8 hr time weighted average.
- A maximum ceiling (i.e. maximum value at any time) should be 2 T for the whole body and 5 T for the extremities.
- Pacemaker users or others with magnetic implants should not exceed 0.5 mT (5 gauss) at any time.

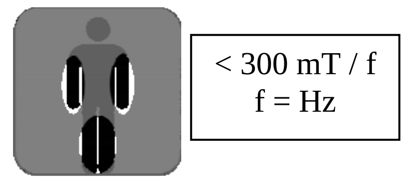
5.3 Time Varying Fields (ACGIH TLVs 2008)

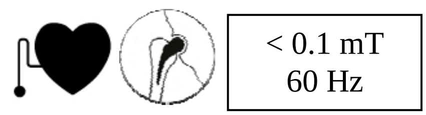


- At 1 Hz to 300 Hz the ceiling exposure should not exceed:
  Whole body = 60 mT / f where f =

frequency in Hz and
Arms and legs = 300 mT / f and
Hands and feet = 600 mT / f.

- From 300 Hz to 30 kHz the ceiling whole or partial body exposure should not exceed 0.2 mT.
- Fields at 1 Hz or less are considered static (see Section 5.1).
- For 50/60 Hz fields specifically, the occupational exposure for an 8 hr work day is 0.5 mT (5 gauss).
- For pacemeaker users at 60 Hz specifically the limit is 0.1 mT (1 G).
- For fields over 30 kHz, contact EH&S.





5.4 Public Areas

- All public spaces are limited to less or equal to 5 G for static fields and less than or equal to 1 G for 50/60 Hz fields.

6.0 General Safety Consideration

6.1 Magnetic Objects

The obvious safety action is to prevent any magnetic material from entering the work area. Because the hazard from flying objects depends on many factors, users must be continuously watchful. Do not underestimate the rapid increase in field strength as one approaches the source; a gradual pull may not always be felt first.

Please be sure that your magnet will not generate a hazard area or affect equipment outside your work area. EH&S can help you survey the area if requested. Of particular concern are surrounding lab and office areas, especially if the magnet is unshielded.

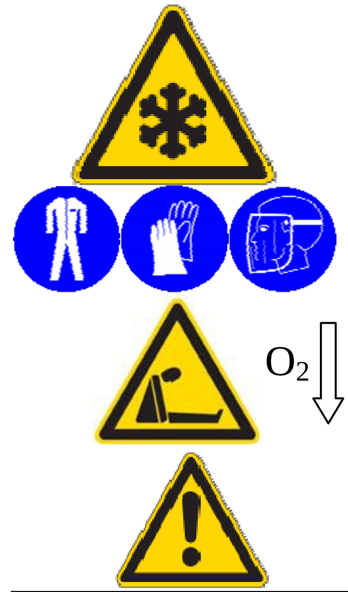
6.2 Posting and Sign Requirements

A warning sign is required to be posted at the entrance to labs or spaces where magnetic fields exceed any of the limits listed above. An example sign is shown in Figure 3. A Powerpoint version of the sign is available from EH&S for custom editing.

In addition to the warning signs posted at the doorways, some method to indicate the 5 gauss line around the magnet is required. For example, a painted line or tape placed on the floor around the magnet where the field is 5 gauss could be used. Another example is a chain, rope, or fence indicating the 5 gauss line around the magnet. Whatever method is used, egress from the area in the event of an emergency shall not be blocked or prevented.

6.3 Cryogenic Safety

Superconducting magnets using liquid helium and/or nitrogen present an additional safety concern with the handling of cryogenic liquids. Safety glasses or goggles, cryogenic gloves and body protection are required when handling these substances.



N_2 = -196°C	-321°F
He_2 = -269°C	-452°F

With helium vapor, prolonged exposure can cause frostbite. EH&S offers a cryo safety class which is recommended if you will work with liquid He or N.

In some lab or space configuration, oxygen displacement is a serious concern. The gas to liquid volume ratio for helium is 700 to 1 and 695 to 1 for nitrogen. Exposure to pure inert gas environments for 5 to 10 seconds is sufficient to cause unconsciousness. Longer exposure will cause asphyxiation and death. Oxygen monitoring may be required; contact EH&S for assistance.

7.1 References

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