Cornell University

MAGNET SAFETY PROGRAM

Environmental Health and Safety

Contents

1 Purpose and Requirements

This program presents a summary of the basics of magnetic field safety, biological effects, and exposure limits to be used at Cornell University. Figures 1 and 2 list some typical magnetic field strengths that once can find in every day life. This may be useful when exposure limits are discussed.

Questions or comments concerning this program may be sent to radiation-safety@cornell.edu.

1.1 Scope

This program 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.

1.2 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.

1.3 Conversions

Some useful conversions between units are:

- 1 μT = 0.7958 A/m
- 1 A/m = 1.257 μT
- 1 T = 10,000 gauss = 1 weber/m^2

2 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.

2.1 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. Only nonferromagnetic tools and objects should be allowed in areas where the magnetic field may exceed 3 mT (30 gauss). 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.

2.2 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 μA/cm^2 in the body. Ambient current densities in the heart are about 10 mA/m^2 (1 μA/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.

2.3 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.

2.4 Biological / Other Effects – Time Varying Fields

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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 μA/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.

3 Magnetic Field Exposure Limits

Cornell recognizes thresholds primarily published by the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) data.

Limits will be updated by EHS as new data is published.

3.1 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.

3.2 Static Fields (ACGIH TLVs 2008)

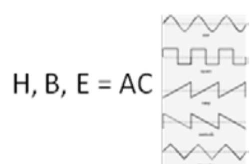
Any field with time-variation frequency less than 1 Hz is considered static.

- Routine occupational exposures to the whole body should not exceed:
  - 2 T maximum field exposure
  - 60 mT (600 G) time-weighted average over an 8-hour period.

- Routine occupational exposures to extremities should not exceed:
  - 7 T maximum field exposure
  - 600 mT (6000 G) time-weighted average over an 8-hour period.

- Pacemaker users or others with magnetic implants should not exceed 0.5 mT (5 gauss) at any time.

3.3 Time Varying Fields (ACGIH TLVs 2008)



- Routine occupational exposure to the whole body should not exceed:
  - 50/60 Hz: 0.5 mT (5 gauss) time-weighted average over 8 hours
  - 1 – 300 Hz: 60 mT/Hz
  - 300 Hz – 30 kHz: 0.2 mT
  - > 30 kHz: contact EHS at radiation-safety@cornell.edu

- Routine occupational exposure to the extremities should not exceed:
  - 50/60 Hz: 0.5 mT (5 gauss) time-weighted average over 8 hours
  - 1 – 300 Hz:
    - 300 mT/Hz (arms and legs)

        - 600 mT/Hz (hands and feet)
    - 300 Hz – 30 kHz: 0.2 mT
    - > 30 kHz: contact EHS at radiation-safety@cornell.edu
- Exposures to 50-60 Hz for those with pacemakers should not exceed 0.1 mT (1 G).

3.4 Magnetic field exposures outside the lab

The following tables are included to provide additional context for the above exposure thresholds.

Table 1: Typical magnetic field exposures in daily life

Exposure	*Frequency*	*Magnetic flux*	*Remarks*
Everyday life	DC	30 – 70 μT	Earth's field
	50/60 Hz	0.1 – 0.8 μT	Household
	50/60 Hz	1 – 30 μT	Near appliances
Power distribution	DC	10 – 25 μT	
	50/60 Hz	10 – 100 μT	
Transportation	DC	2 – 100 mT	Maglev
Medical	DC	0.5 – 3 T	Clinical MRI
	DC	7 – 11.7 T	Research MRI
	DC	0.1 T	Prosthetic devices
	1 – 75 Hz	1 – 30 mT	Bone healing
Electrolysis	DC	10 – 50 mT	Operator exposure
High-energy technologies	DC	1 – 100 mT	
	DC	0.6 – 1.5 T	A few minutes/day
Induction heating, welding, etc.	50/60 Hz	1 – 130 mT	Operator exposure
		0.1 – 10 mT	
Communication	10 – 100 kHz	1 – 50 μT	
Personnel identification	6 – 1000 kHz	0.1 mT	

- *Table 2: Magnetic flux density (in µT) at distance z from common objects*

Appliance	z = 3 cm	z = 30 cm	z = 1 m
Blenders	25 – 130	0.6 – 2	0.03 – 0.2
Can openers	1000 – 2000	3.5 – 30	0.07 – 1
Clothes dryers	0.3 – 8	0.08 – 0.3	0.02 – 0.06
Clothes washers	0.8 – 50	0.15 – 3	0.01 – 0.15
Coffee makers	1.8 – 25	0.08 – 0.15	0.01
Dish washers	3.5 – 20	0.6 – 3	0.07 – 0.3
Drills	400 – 800	2 – 3.5	0.08 – 0.2
Electric ovens	1 – 50	0.15 – 0.5	0.01 – 0.04
Electric ranges	6 – 200	0.35 – 4	0.01 – 0.1
Electric shavers	15 – 1,500	0.08 – 9	0.01 – 0.3
Fluorescenet lights	15 – 400	0.2 – 4	0.01 – 0.3
Hair dryers	6 – 2,000	0.1 – 7	0.01 – 0.3
Microwave ovens	75 – 200	4 – 8	0.25 – 0.6
Mixers	60 – 700	0.6 – 10	0.02 – 0.25
Portable heaters	10 – 180	0.15 – 5	0.01 – 0.25
Refrigerators	0.5 – 1.7	0.01 – 0.25	0.01
Sabre and circular saws	250 – 1,000	1 – 25	0.01 – 1
Televisions	2.5 – 50	0.04 – 2	0.01 – 0.15
Toasters	7 – 18	0.06 – 0.7	0.01
Vacuum cleaners	200 – 800	2 – 20	0.13 – 2

4 General Safety Consideration

At a minimum, signage, awareness, and vigilance is required to prevent magnetic material from entering areas where the magnetic field may exceed 3 mT (30 gauss). In cases where the combination of accessible fields and magnetic objects can present an imminent danger to life safety, metal detectors are required at the entrances.

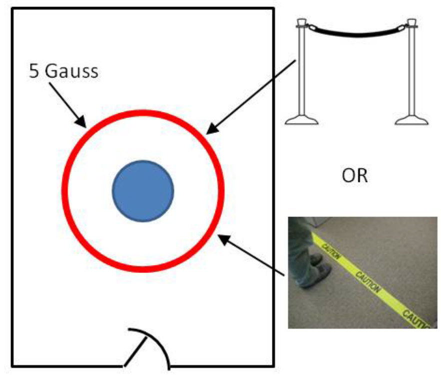
The hazard from flying objects depends on many factors. Do not underestimate the rapid increase in field strength as you approach the source; the field strength is inversely proportional to the cube of the distance ($1/R^3$), so gradients are large and can turn a magnetic object into a missile or a pinning or crushing hazard. What at first appears to be a small force can quickly yield a dangerous physical hazard.

Please be sure that your magnet will not generate a hazard area or affect equipment outside your work area. Lock-out-tag-out procedures may be required. Of particular concern are surrounding lab and office areas, especially if the magnet is unshielded. Contact EHS at radiation-safety@cornell.edu for assistance with surveys.

5 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. Sign templates are available, contact EHS at radiation-safety@cornell.edu.

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 Cryogenic Safety

Superconducting magnets using liquid helium and/or nitrogen present an additional safety concern with the handling of cryogens. Safety glasses or goggles, cryogenic gloves and body protection are required when handling these substances. EHS offers a cryogen safety class which is required if you work with cryogens.

In some lab or space configurations, oxygen displacement is a serious concern. The gas to liquid volume ratio for helium is 700 to 1 and 695 to 1 for nitrogen. Breathing in a pure inert gas environment for 5 to 10 seconds is sufficient to lose consciousness, longer periods of time can cause asphyxiation and death. Oxygen monitoring may be required. Contact EHS at askEHS@cornell.edu for assistance.

7 References

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