UC Irvine
Environmental Health & Safety

Magnetic Field Safety Program

Responsible Administrator: Radiation Safety Officer
Revised: July 2025

Summary:

1. Program Description

The University of California, Irvine Magnetic Field Safety Program (MFSP) develops and implements operating procedures and standards of conduct to guide individuals using or having responsibility for the use of static magnetic fields in complying with national radiation protection standards set forth by the American Conference of Governmental Industrial Hygienists (ACGIH) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

2. Scope

This manual details elements of the MFSP to:

- Establish policies and procedures for safely working with strong static magnetic fields.
- Comply with radiation exposure guidelines established by ACGIH and ICNIRP.

3. Definitions

- **Bioelectronics device –** Any type of electrically powered medical device that assists in maintaining metabolic processes or is worn for diagnostic purposes. These may be surgically implanted or worn externally. Examples include cardiac pacemakers, implanted defibrillators, and insulin pumps.
- **Cryogenic liquids** – Gases condensed to liquid form at extremely low temperatures. One such example is Liquid Nitrogen. It condenses at –196°Celsius (– 320°Fahrenheit). The term “cryogenics” applies to all temperatures less than –150°C (–238°F).
- **Designated static magnetic field area –** A work area in which the occupational guidelines for exposure to magnetic fields have the potential to be exceeded.
- **Ferromagnetic materials –** Materials that are attracted by a magnet. A few materials, e.g., iron, cobalt, nickel, and alloys of these metals, have strong attraction.
- **Gauss (G) –** Unit of measurement for magnetic flux: 10,000 G = 1 Tesla (T).
- **Magnet –** A body/device that attracts certain materials, such as iron, by virtue of a surrounding field of force created by the motion of its electrons and alignment of its atoms.
- **Magnetic field –** Region near a magnet, electric current, or moving charged particle in which a magnetic force acts on any other magnet, current, or moving charged particle.
- **Magnetic flux (B) –** The flow of magnetic force, represented as lines of force.
- **Magnetic flux density (β) –** The number of flux lines passing through a unit area of surface.

$$\beta = \frac{\phi}{Area}$$

- **Oxygen deficiency** – A condition that occurs when a breathable atmosphere contains less than 19.5% oxygen. Note: normal air contains 20.8% oxygen.
- **Superconductivity –** Describes the property shown by some materials to conduct electricity without electrical resistance and energy loss.
- **Surgical implant –** For the purpose of this manual, any surgically installed metallic device. Examples include, but are not limited to, orthopedic plates, screws, pins, and artificial joint components, metallic or metal containing stents, catheters, and aneurysm clamps.
- **Tesla –** Equal to one Weber per square meter. $1\ \mathrm{T}{=}1\ \mathrm{Wb/m^2} = 10{,}000\ Gauss$
- **Weber (Wb) –** The International System of Units (SI) unit of magnetic flux density (or field strength).

4. Responsibilities

4.1 Principal Investigator

The principal investigator (PI) is responsible for compliance with the guidelines and procedures set forth in this manual. The PI may delegate aspects of the magnet safety program to laboratory personnel, but the PI assumes ultimate responsibility and accountability for all operations within their lab.

Responsibilities include:

- Registering magnets capable of producing ≥ 2 T fields with Environmental Health and Safety.
- Contacting the Radiation Safety Division or the manufacturer for a consultation prior to purchasing the magnet.
- Developing, with the assistance of the Radiation Safety Division, emergency plans for handling a quench.
- Ensuring that all laboratory personnel, maintenance personnel, and visitors who may be exposed to static magnetic fields are informed in advance of their potential risk and of the actions required to minimize that risk.
- Ensuring that all research personnel are appropriately trained in strong magnet safety.
- Encouraging open discussion of magnet safety issues, problems, and violations.
- Wearing personal protective equipment (PPE) and enforcing PPE when handling cryogens.
- Reporting injury or illness to EHS.
- Reporting gas detection and ventilation systems.

4.2 Laboratory Personnel

All laboratory personnel must do their part in maintaining a safe working environment for themselves and their co-workers. It is their responsibility to:

- Follow the practices and guidelines for operating strong magnets set forth in this manual.
- Wear the appropriate PPE.
- Report unsafe conditions to their supervisor or to the Radiation Safety Division.

4.3 Environmental Health & Safety

The Radiation Safety Division at EHS will perform hazard evaluations of magnet labs every two years and ensure compliance with safety procedures outlined in this manual.

5. Program Components

5.1 Magnet Registration

Magnets capable of producing a field greater than or equal to 2 T must be registered with EHS.

5.2 Strong Static Magnetic Field Hazards

The hazards from static magnetic fields are limited to a few work areas; however, since there are no visual cues associated with a magnetic field, it is important to understand and mitigate these hazards. Potential hazards include effects on surgical implants and bioelectronics devices, effects of fringe fields, quench hazards, electrical hazards, and damage to electronic equipment.

5.2.1 Effect on Surgical Implants and Bioelectronic Devices

Potentially fatal medical outcomes may result from exposure to magnetic fields in people who have ferromagnetic objects in their bodies. These objects are often obvious; cardiac pacemakers, for example. However, some ferromagnetic objects such as surgical clips and tiny metal fragments in eyes, may be far from obvious and require a high "index of suspicion" on the part of the individual. A magnetic flux density exceeding 0.5 mT (5 G) across the torso region of the body may interfere with the operation of bioelectronics devices. Those with such devices must be particularly alert.

5.2.2 Hazards to Otherwise Healthy Workers

There are no known adverse bioeffects for flux densities within ACGIH exposure limits. The occupational guidelines for exposure to static magnetic fields are based on the avoidance of electrical potentials that are magnetically induced in the major arteries of the central circulatory system. The body extremities contain smaller blood vessels and experience smaller induced electrical potentials in strong magnetic fields than do major arteries such as the aorta in the central circulatory system. On this basis, the ICNIRP has set a higher exposure limit for the extremities.

5.2.3 Fringe Field Effects and Kinetic Hazards

Energized super-conducting and conventional resistive electromagnets produce strong magnetic fields. Depending on the specific design of the electromagnet, these fields can extend out a significant distance with sufficient strength to accelerate objects toward the magnet with enough energy to seriously injure persons and/or damage the magnet. Such common items include, but are not limited to iron/steel cuttings, bolts, screwdrivers, most tools, and some survey equipment.

There are two potential hazards associated with these "flying" objects. The first would be if the object were to directly strike an individual. The second would be if the object were to strike a fragile piece of equipment. Although most equipment is relatively robust and likely to survive unscathed, there is the notable exception of thin vacuum windows. While many electromagnets have no exposed vacuum windows, some do require thin vacuum windows as an integral part of their function. These windows pose a significant hazard if ruptured for any reason. Therefore, it is essential to remove all loose ferrous objects from the area near any electromagnet and avoid bringing such objects with you when working in the vicinity of an energized electromagnet.

5.2.4 Electrical Hazards

Two significant electrical hazards that can be encountered with magnets and magnetic fields are the production of eddy currents and failure to protect exposed leads.

a. Eddy currents

    - Non-magnetic electrically conductive materials may experience a force or resistance to motion due to induced eddy currents.
    - Electrical supply circuits and magnetic cores must be grounded to prevent voltages induced by eddy currents from appearing in dangerous locations.

b. Exposed leads
    - If metal tools accidentally come into contact with exposed leads and short them out, the likely outcome will be vaporization of the metal tool and an arc flash.
    - If terminal voltages exceed 50 V and significant inductive energy (>0.5 Joules) can be released due to loss of conductor continuity and an employee accidentally touches an exposed, energized lead, electrocution may result.

5.2.5 Effects on Electronic Equipment

Electronic equipment and magnetic carriers may be affected by static magnetic fields:
- At 2 mT (20 G) fields, cathode-ray devices and tubes may malfunction.
- At fields above 1.0 mT (10 G), magnetic storage media, credit cards, and analog watches may be permanently damaged.

5.3 Cryogenic Magnet Hazards

Superconductivity is achieved when superconducting wire is cooled to cryogenic temperature using cryogens such as liquid nitrogen (N2) and liquid helium (He). Potential hazards include quenching of the magnet and injuries while handling cryogens.

5.3.1 Quenching

A quench is the (normally unexpected) loss of superconductivity in an NMR magnet resulting in rapid heating through increased resistance to the high current. This can violently damage the magnet and cause rapid venting of large volumes of He/N2 gas into the room, quickly resulting in an oxygen-deficient atmosphere and/or cryogenic burns. Consequently, the electromagnet or superconducting magnet must have an appropriate emergency shutdown system designed to allow for the safe dissipation of stored energy and disconnection from the source.

Appropriate discharge must be made to direct cryogenic gasses from a quenched superconducting magnet to a safe, unoccupied location to avoid exposing individuals to an oxygen deficient atmosphere. To avoid a quench situation, use cryogen level sensors and refill or de-energize the magnet if low cryogen levels are indicated on the sensors. Keep an oxygen monitor in the magnet room at all times and check it for proper functioning according to manufacturer specifications. Quenching may result in room pressurization; therefore, doors to the magnet room must open outwards.

An oxygen deficiency hazard (ODH) environment is defined as having less than 19.5% oxygen. Oxygen levels of less than 12% can cause sudden unconsciousness. Levels of less than 8% can cause permanent brain damage, and levels of less than 6% can cause death within 5-8 minutes.

Note: Quench conditions can result from ferrous objects being drawn into the magnet bore. It is therefore imperative to follow the precautions outlined in section 5.2.3.

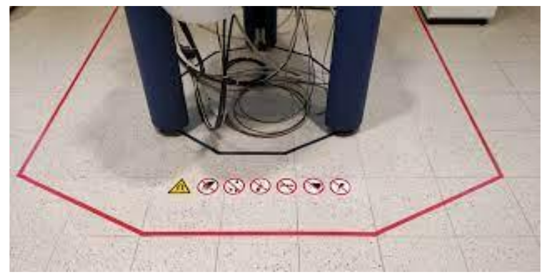
5.3.2 Protective Equipment

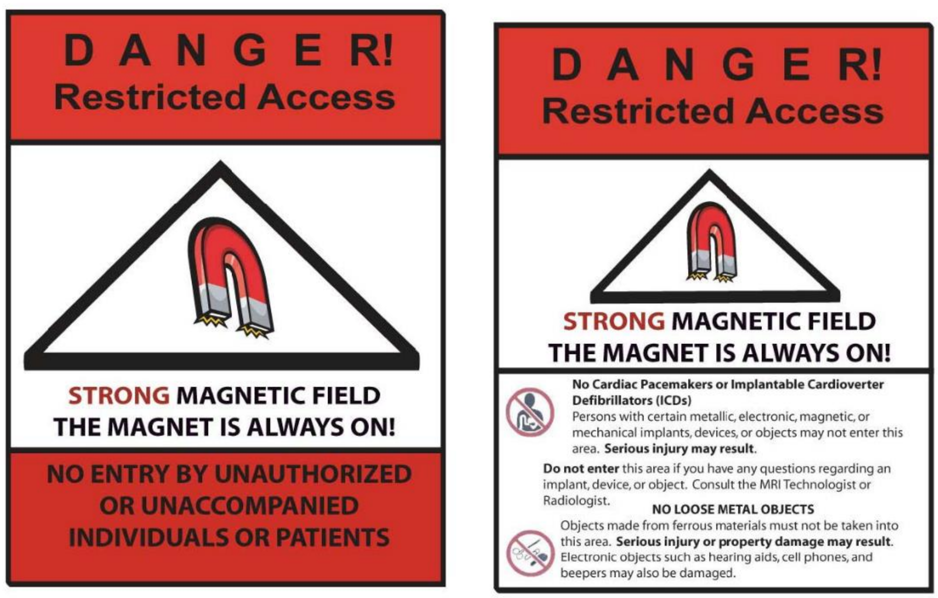
When working with cryogens, be sure to use PPE:
- Face Shield
- Cryogen protective gloves
- Pants or trousers
- Closed-toe shoes

5.4 Facilities Design Criteria

5.4.1 Posting of magnetic field hazards

- Develop a field strength map of the area surrounding the magnet, specifically marking where pacemaker hazards (>5 G) and kinetic energy hazards (>300 G) will exist. Post the map in a prominent place for use by staff and visiting researchers.
- Hazard Warning Signs are required to be posted at all access points to the magnetic fields.
    1. Basic sign:
        - Print and post basic signs on anteroom and corridor doors.
    2. Complex sign: (includes specific hazard warnings)
        - Print and post a complex sign on the entrance to the magnet room.
- Indicate 5 G zones:
    - Print and post complex signs on doors to rooms containing magnetic fields in excess of 5 G.
    - Mark the 5 G threshold line with floor tape or equivalent markings where appropriate.
- Place warning labels and signs on other equipment and entries to indicate specific hazards such as ultraviolet light or radiofrequency fields.





Basic hazard sign (left) and complex hazard sign (right)

5.4.2 Requirements for superconducting magnets

- Keep a calibrated oxygen monitor and alarm in the magnet room at all times and check it for proper functioning according to manufacturer specifications. Set the monitor alarm at 19.5% oxygen.
- Doors to the magnet room must open outwards.
- Rooms containing a magnet must have adequate ventilation.
    - Generally, five complete room air changes per hour are considered adequate for managing small spills or releases of cryogens. In the event of a major release, the staff

must immediately leave the room and the doors should be left open. If the risk of a catastrophic release exists, auxiliary ventilation should be considered to prevent the formation of an oxygen-deficient atmosphere.

5.5 Hazard Avoidance

- When purchasing a strong magnet, contact the Radiation Safety Division or manufacturer for a consultation to ensure the magnet room meets the instrument's specifications.
- Obey posted signs. Restrictions for visitors and individuals with bioelectronic devices and/or surgical implants must be strictly adhered to.
- Remove jewelry and other personal items that are ferromagnetic before entering the area. Do not bring ferromagnetic tools, instruments, or other objects into areas that have a ferromagnetic hazard.
- When handling cryogens, use insulated gloves, face shields (or other splash eye/face protection), closed-toe shoes, pants, and lab coats.
- Follow the guidelines established by the ACGIH and ICNIRP:

	Routine 8-hour average	**Maximum allowable**
Visitors, ferromagnetic implant and electronic medical device wearers	Routine exposure not recommended	0.5 mT (5 G) or as determined by physician
Trained employees/users	Whole body: 60 mT (600 G) Limbs: 600 mT (6000 G)	Whole body: 2 T (20,000 G) Limbs: 5 T (50,000 G)

5.6 Site Planning for New Machines

Before the installation of any new equipment that generates strong static magnetic fields (e.g., MRI, NMR, or other superconducting magnets), site planning must be conducted to ensure safety and compliance with institutional and regulatory standards.

Site planning must include:

- Hazard Assessment: Evaluate fringe field extent, kinetic hazards, and quench risks. Develop a field strength map to delineate 5 G and 300 G zones.
- Structural Evaluation: Confirm room layout, wall materials, ceiling clearance, and flooring can support the equipment's weight and environmental needs.
- Ventilation: Ensure adequate air exchange (minimum five room air changes per hour) to mitigate potential oxygen-deficiency scenarios, especially with cryogen use.
- Emergency Provisions:
    - Outward-opening doors
    - Oxygen monitoring with alarm set to 19.5%
    - Emergency shutdown/quench venting system directing cryogenic gases to a safe location
- Signage and Labeling: Pre-plan placement of required complex and basic warning signs. Mark thresholds of magnetic field strength zones with floor tape or appropriate visual indicators.
- Stakeholder Involvement: Coordinate with Environmental Health & Safety, Facilities Management, and the equipment vendor prior to delivery and installation.
- Training and Access Control: Update training records and restrict access to the room until the setup has been reviewed and cleared by Radiation Safety.

All equipment installations must be reviewed and approved by the Radiation Safety Division prior to operation.

6. Reporting Requirements

Employees are encouraged to report any safety concerns to their supervisor or to EHS via safety@uci.edu, (949) 824-6200, or anonymously via https://www.ehs.uci.edu/forms/report-injury/index.php.

Work-related injuries must be reported at https://www.ehs.uci.edu/forms/report-injury/index.php.

7. References

ICNIRP | Static Magnetic Fields (0 Hz)

ICNIRP guidelines on limits of exposure to static magnetic fields: ICNIRPstatgdl.pdf