

Magnet Safety Standard Operating Procedure

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Description [Provide additional information as it pertains to your research protocol]

Superconducting magnets, such as those used in Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) equipment, pose unique safety concerns. These concerns include cryogenic liquid safety, strong magnetic fields, and the potential for creation of oxygen deficient atmospheres. The highest potential for a serious incident involving these hazards exists during magnet start-up, cryogen filling and maintenance activities. Once magnets are operational and magnetic fields have been established, the hazards are minimal as long as operators, maintenance personnel, patients and/or visitors understand the proximity limits and procedures to follow when working near the magnet. All laboratory workers must read and understand the [Laboratory Emergencies SOP](#) prior to commencing any work in a laboratory.

Process [Write the steps for using chemicals in sample prep that cover your research protocol]

Potential Hazards [Provide additional information as it pertains to your research protocol]

Magnetic Fields

Ferromagnetic objects are strongly attracted to the magnet, and can become potentially lethal projectiles. Personnel can be severely injured and/or equipment can be damaged if hit by objects that are attracted to the magnet at a high rate of speed. In the case of MRI units, life threatening situations can occur if a person is pinned against the magnet by a large ferromagnetic object. Absolutely no ferromagnetic objects are allowed inside a magnet room or within the predetermined radius of the magnetic field.

Examples of items which must not enter the magnetic field or room include: regular fire extinguishers, air tanks, axes (fire fighters), guns, radios, flashlights, wheelchairs, stretchers, and defibrillators. Smaller metallic objects like badges, jewelry, watches, keys, dentures, glasses, hearing aids, and hair accessories must also be removed before entering the magnet room or magnetic field. Credit cards and magnetic storage media can be destroyed by the field.

Metallic implants and prostheses and foreign metallic bodies (even those which are not ferromagnetic) can move or dislodge, causing severe injury. Examples include aneurysm clips, implanted pins, shrapnel, insulin pumps, prosthetic limbs, cochlear implants, pacemakers, and cardiac or neural defibrillators.

Magnets generate strong electromagnetic fields and magnetic fields that can inhibit the operation of magnetically-sensitive equipment (certain implants or external devices), resulting in death or serious injury to

the user. The most common item in this category is the cardiac pacemaker. Persons with pacemakers should be restricted to areas where the magnetic field is less than (5) Gauss.

Cryogen Hazards (cryogens are extremely cold substances and cause oxygen deficient environment)

Liquid helium and nitrogen are used to maintain the magnetic field in NMR and MRI systems. Both liquids are extremely cold (liquid helium -452 degrees F, liquid nitrogen -320 degrees F), colorless, and odorless. A sudden boil-off of cryogens and accompanying loss of magnetic field (called a “quench”) poses a significant safety risk. During a system quench (deliberate or accidental), gases generated by the rapid boil-off of liquid helium and nitrogen should get vented outside, but there exists potential for gaseous helium and nitrogen to be released into the magnet room. These gases will appear as a dense white fog, and visibility may be obscured in the vapor cloud. The released gases displace oxygen in the air causing an oxygen deficient environment (below 19.5%). This can cause rapid asphyxiation and unconsciousness without warning.

Contact with liquid or cold vapors can cause severe frostbite.

Fire Hazards

The cryogenic helium and nitrogen are not flammable; however, the extreme cold that exists during and immediately after a quench may cause air to condense and create liquefied oxygen on surfaces. Any liquid dripping from cold surfaces should be presumed to be enriched oxygen and treated as a potential fire hazard.

Exposure of the magnet to intense heat (such as the conditions that exist during a serious structure fire) could cause the magnet to rupture violently if pressure relief devices fail.

Occupational Exposure Limits (OELs):

An oxygen level at or below 19.5% is an oxygen deficient environment.

Engineering Controls [Provide additional information as it pertains to your research protocol]

NMR and MRI magnets must be located in areas with restricted access to the public.

No workstations shall be designed or placed within the (5) gauss field of a magnet. The (5) gauss line of the magnetic field must not extend outside the room the magnet is located or into public areas or building egress routes. Note that normal wall, ceilings and floor materials do not block static magnetic fields. Individuals should be able to enter and exit the room without passing through strong magnetic fields.

In the case of an NMR type magnet, the strongest magnetic fields may occur at the bottom and top where shielding is less, which means that consideration must be given to occupied areas above and below the magnet.

Quench ducts

The best way to protect lab staff from a magnet quench (boil-off of cryogenic liquids) is to have manufacturer installed vent pipes hard ducted to the helium quench valve. This will vent helium directly to the outside and prevent displacement of oxygen in the room.



Room Size

Another option instead of quench ducts is to place the magnet in a room large and high enough to accommodate the helium cloud resulting from a quench. During a quench, one-half of the helium volume (between 40 and 100 liters for most NMR magnets) will boil off and be violently ejected from the helium vent on top of the magnet within one minute. This vapor cloud will warm and expand up to 700 times in volume and displace oxygen in the room. During the next few minutes the remaining helium will boil off. Nothing can be done to stop a magnet quench once it begins.

The magnet room should be sized so the space between the ceiling and the level of seven feet in the room is large enough to contain the volume of helium gas released from a quench. For units which utilize larger volumes of cryogenics or for magnets in smaller rooms or in rooms with inadequate ventilation, helium vent pipes hard ducted to the helium quench valve must be installed.

Air Changes

There must be adequate exhaust ventilation in super-conducting magnet rooms of at least 10 air changes per hour.

Oxygen Sensors

Oxygen sensors with associated local alarms must be installed in magnet rooms where there exists the potential for asphyxiation. Alarms for oxygen monitors installed in the magnet rooms should activate when levels of oxygen are below 19.5%.

Below grade pits

Supplemental ventilation, oxygen alarms and emergency procedures must be established when magnets are installed in below grade pits. Liquid nitrogen vapors will collect in low areas and expand to create an oxygen deficient environment. Because of this significant hazard only experienced personnel should be allowed in the room during start-up.

Signage

Approved signage must be posted at all entrances to magnet rooms prohibiting entry by unauthorized personnel and conspicuously warning of magnetic fields.

A visible indicator demarcating the (5) gauss line must be installed around the magnet. The indicator can be a temporary barrier or permanent floor marking.

Contact EHS for a review of all engineering controls 734-763-1143.

Work Practice Controls [Provide additional information as it pertains to your research protocol]

Cryogen Safety

The following hazards are of primary concern especially during cryogenic liquid filling operations of magnets.

Standard Operating Procedures are required for Dewar filling and transport, cryogen spills and clean-up, response to emergency alarms including oxygen sensor alarms and magnet quench.

Training is required regarding emergency procedures for magnet quench (catastrophic loss and discharge of coolant), causes and consequences of a quench, how to prevent quenching, actions and notifications in the event of a quench, and evacuation procedures.

Personal Protective Equipment [Provide additional information as it pertains to your research protocol]

The minimum personal protective equipment requirements for handling cryogenic liquids are thermal gloves, face shield, safety goggles, lab coat, closed (covered) shoes, and long pants.

Transportation and Storage [Provide additional information as it pertains to your research protocol]

Cryogenic liquids must be stored in designated locations. Cylinders must be transported on approved carts or dollies.

Waste Disposal [Provide additional information as it pertains to your research protocol]

Provide guidance on how waste products are disposed of. Be specific and describe the specific disposal procedure to be used, i.e., do not write “Dispose of in accordance with applicable regulations”.

Because most spent, unused and expired chemicals/materials are considered hazardous wastes, they must be properly disposed of. ***Do not dispose of chemical wastes by dumping them down a sink, flushing in a toilet or discarding in regular trash containers, unless authorized by EHS Hazardous Materials Management (HMM).*** Contact EHS-HMM at (734) 763-4568 for waste containers, labels, manifests, waste collection and for any questions regarding proper waste disposal. Also refer to [EHS’s Hazardous Waste webpage](#) for more information.

Exposures/Unintended Contact [Provide additional information as it pertains to your research protocol]

Description Of A Quench

A “quench” is an event that occurs only in superconducting magnets. It is a loss of superconductivity (i.e. a rapid increase in the resistance of the magnet coil windings). This process generates heat that results in the rapid evaporation, or boil-off, of the magnet coolant (liquid helium). This evaporated coolant is a hazard and must be immediately vented (through the quench pipe if available). NOTE: once initiated, a quench cannot be stopped and can potentially cause total magnet failure.

There are two (2) situations in which a quench may occur. Spontaneously due to some force or disruption to the magnet system or the emergency quench button is depressed during an emergency situation. Note: an emergency quench button does not apply to all labs.

Spontaneous Quench

In the event of a spontaneous quench, the operator should take the following steps:

1. Evacuate the magnet room.
2. Close the doors leading into the magnet room.
3. Notify UMPD by dialing from any university phone 911 or from an outside phone line (e.g., a cell) dial



(734)-763-1131. Then, call **Insert Name**, Facilities Manager at Cell: **Insert Number**, immediately following the incident.

Emergency Procedures for Staff

Personnel with access to the magnet rooms must be knowledgeable regarding magnetic fields, cryogen hazards, oxygen sensors and alarms, and the emergency response procedures listed in this document.

On-site personnel and visitors without training must follow the direction of the Lab Director, Lab Manager, or the lab research staff personnel regarding hazards. To minimize the chance of serious injury, this laboratory is equipped with an electronic oxygen sensor (O2 Sensor).

There are two different levels of alarm:

In the event of a **Visual Alarm**, meaning O2 levels are at 19.5% or less, all non-essential personnel must evacuate the room. Lab staff may quickly evaluate any potential leaks of liquid nitrogen or helium and attempt to correct the problem before evacuating the lab. Do not reenter the lab or allow anyone else to enter. Lab staff must contact **Insert Name**, Facilities Manager at Cell: **Insert Number** and provide any details about the O2 sensor going into the alarm. **Enter the lab only after the low oxygen alarm is inactive.**

In the event of a **Visual Alarm and Audible Alarm**, meaning O2 levels are less than 17%, all personnel must leave the room immediately. Do not reenter the lab or allow anyone else to enter. Contact UMPD by dialing from any university phone 911 or from an outside phone line (e.g., a cell) dial (734)-763-1131. Then, call **Insert Name**, Facilities Manager at Cell: **Insert Number** and provide any details about the O2 sensor going into the alarm. **Enter the lab only after the low oxygen alarm is inactive.** Note: Normal oxygen levels are 20.9%

See picture of alarm panel below showing visual, audible and digital oxygen level of room (sample picture below. Insert a picture if applicable).



Medical Emergency

1. If a low oxygen alarm is active, do not enter the lab.
2. If the individual is conscious and oxygen levels are safe for entry, assist the person to safety.
3. If the individual is not conscious or if assistance from an outside emergency medical team is requested or required, contact UMPD dialing from any university phone 911 or from an outside phone line (e.g., a cell) dial (734)-763-1131.

1. Contact the designated personnel in charge of the area.



2. Personnel must be posted at all direct entries to the magnet room(s) to greet emergency response personnel, provide this document to emergency responders and remind them of the existing hazards. Available personnel must be ready to direct and assist responders, and to ensure that only MR compatible equipment is brought into magnet rooms.

Fire Emergency

1. All staff should review and familiarize themselves with the guidelines and procedures in this SOP.
2. Be aware of the compatible fire extinguisher locations adjacent to magnet rooms.
3. Follow the applicable Emergency Procedures as outlined above.
4. From a safe location, contact UMPD by dialing from any university phone 911 or from an outside phone line (e.g., a cell) dial (734)-763-1131.
5. Call **Insert Name**, Facilities Manager at Cell: **Insert Number** and the designated personnel in charge of the magnet area and inform them of a fire emergency.
6. Personnel must be posted outside the building or at all direct entries to magnet room floors to provide this document to emergency responders and remind them of the existing hazards.

Procedures for Emergency Responders

If knowledgeable lab research personnel are on site, emergency responders are advised to consult them regarding hazards. A floor plan should be attached to this document to indicate locations of magnetic fields, oxygen detection equipment, MR-compatible fire extinguishers, flammable chemical storage, and manual magnet quench activator (as applicable) and electrical power shutdown controls. This SOP is intended to aid responders in specific scenarios.

If a low oxygen level alarm is active, no one should enter the magnet room.

1. If a recent quench displaced oxygen from the room, there may be dense white fog making it difficult to open the magnet room door due to increased pressure. Also, any liquid dripping from surfaces should be presumed to be enriched oxygen and treated as a fire hazard.
2. If oxygen levels are safe, and fire, sparks or emergency electrical conditions exist within the magnet room:
 - a. Confirm that a low oxygen level alarm is not active. Presence of dense white fog may be an indicator of a magnet quench and should not be assumed to be smoke or fire without verification.
 - b. Emergency responders planning to enter the magnet room must remove ALL metal without exception (see Hazard Description above). Anyone with non-removable metal (e.g. pacemakers or implanted devices) cannot enter the room. Allow entry to necessary personnel only.
 - c. Only MR-compatible fire extinguishers can be brought into the magnet room.

If oxygen levels are safe and it is necessary to enter the magnet room to assist an injured person:

1. Confirm that a low oxygen level alarm is not active.
2. Emergency responders planning to enter the magnet room must remove ALL metal without exception (see potential hazard section above). Anyone with non-removable metal (e.g. pacemakers or implanted devices) cannot enter the room. Allow entry to necessary personnel only.
3. Resuscitation aided by metallic devices cannot be administered inside the magnet room. Evacuate the victim to an area outside the magnet room and restrict entry into the magnet room by others.

If someone is pinned against the magnet by a ferromagnetic object:

Emergency responders planning to enter the magnet room must remove ALL metal without exception (see potential hazards section above). Anyone with non-removable metal (e.g. pacemakers or implanted devices) cannot enter the room. Allow entry to necessary personnel only.



Determine whether the object pinning the victim can be removed without causing further injury. If removal is successful, immediately evacuate the victim to an area outside the magnet room and restrict entry into the magnet room by others. Resuscitation aided by ferromagnetic devices can be administered once the victim is outside the magnet room.

If a life-threatening emergency exists and there is no other way to free the victim without eliminating the magnetic field, then it will be necessary to initiate a magnet quench (bring down the magnetic field).

The magnet quench procedure will create a dangerous environment. Expect a loud noise from the escape of cryogenics and a release of dense white fog. There is a high risk of asphyxiation and potential for frostbite. As the magnetic field decreases, the object pinning the victim may fall and could cause further damage. Also, any liquid dripping from surfaces should be presumed to be enriched oxygen and treated as a fire hazard.

Do not perform this procedure unless you are prepared to immediately evacuate yourselves and the victim if oxygen is displaced from the room. Follow these remaining steps **ONLY** if a quench is required.

Pressure generated by the quench may prevent doors from opening, so prop open the magnet room door. Allow no others to enter the room through the open door.

All personnel must know to leave the room and not return until the helium has dissipated and the room is safe to reoccupy.

Initiate the quench after consultation with the Lab Director.

Under no circumstances should ferromagnetic objects be brought into the magnet room unless magnetic resonance trained personnel verify that the magnetic field is no longer detectable.

Training of Personnel

All personnel shall read and fully adhere to this SOP when working with superconducting magnets.

[illegible]



Laboratory Director

Revision Date

Revision History (Do not print as part of SOP)

02/20/2023	Partial Revision	Removed emergency information sections, duplicate of new Laboratory Emergencies SOP. (DML)
05/18/2020	Partial Revision	Updated editing rights to headings (RSH)