MAGNET SAFETY

Superconducting magnets, such as Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) equipment, pose unique safety concerns. These concerns include cryogen safety, strong magnetic fields and the potential for creation of oxygen deficient atmospheres. The highest potential for the most serious of 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.

1. Hazards Associated with Magnets

1.1 Magnetic Fields

1.1.1 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 pre-determined radius of the magnetic field.

1.1.2 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, 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.

1.1.3 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.

1.1.4 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.

1.1 Cryogen hazards (cryogens are extremely cold substances)

1.2.1 Liquid helium is used to maintain the magnetic field in NMR and MRI systems. Liquid nitrogen is also used. Both liquids are extremely cold (liquid helium -452°F, liquid nitrogen -320°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, and this can cause rapid asphyxiation and unconsciousness without warning.

1.2.2 Contact with liquid or cold vapors can cause severe frostbite.

1.2 Fire Hazards

1.2.1 The cryogenic gases 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.

1.2.2 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. Cooling the magnet with water helps prevent the rapid venting of cryogens.

2. General Guidelines for Magnets

2.1 Magnet Locations

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

2.1.2 No work stations shall be designed or placed within the 5 gauss field of a magnet. The 5 gauss line should not extend into public thoroughfares or building egress routes. Individuals should be able to enter and exit the room without passing through strong magnetic fields.

2.1.3 Magnetic fields must remain within the limits of the room or occupied area realizing that normal wall, ceilings and floor materials do not block static 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.

2.1.4 At least one magnetically compatible fire extinguisher should be mounted immediately external to magnet rooms

2.2 Room Size – For NMR magnets, the magnet room must be large and high enough to accommodate the helium cloud resulting from a quench (loss of superconducting field). 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 seek the highest point in the room as it warms and expands up to 700 times in volume. During the next few minutes the remaining helium will boil off. Nothing can be done to stop a magnet quench once it begins.

2.2.1 An NMR magnet room should always be sized so the space between the ceiling and the level of seven feet in the room is large enough to contain the initial volume of helium gas released from a quench. There must be adequate exhaust ventilation in the room of at least 10 air changes per hour.

2.2.2 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%.

2.2.3 For MRI units which utilize larger volumes of cryogens or for NMR magnets in smaller rooms or in rooms with inadequate ventilation, helium vent pipes hard-ducted to the helium quench valve or automated exhaust fans tied to oxygen monitors must be installed.

2.2.4 Supplemental ventilation, oxygen alarms and emergency procedures must be established when magnets are installed in below grade pits. These are particularly important for NMR magnets. 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.

2.3 Signage

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

2.3.2 A visible indicator demarcating the 5 gauss line should be installed after magnet start up. The indicator can be a temporary barrier or permanent floor marking.

2.4 Cryogen Safety – The following hazards are of primary concern especially during filling operations of NMR magnets.

2.4.1 The minimum personal protective equipment requirements are thermal gloves, face shield, lab coats, closed (covered) shoes, and long pants.

2.4.2 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.

2.4.3 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.

3. Emergency Procedures

3.1 Procedures for Staff

3.1.1 Magnetic Resonance (MR) 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 for "EMERGENCY RESPONDERS" in this document.

3.1.2 On-site personnel and visitors without training must follow the direction of MRI personnel regarding hazards.

3.2 Medical Emergency

3.2.1 If the individual is conscious and oxygen levels are safe for entry, assist the person to safety.

3.2.2 If the individual is not conscious or if assistance from an outside emergency medical team is requested or required, call Pitt Police at 412-624-2121.

3.2.3 Contact the designated personnel in charge of the area.

3.2.4 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.

3.3 Fire Emergency

3.3.1 All staff should review and familiarize themselves with the guidelines and procedures listed in the "Fire Safety and Life Safety" section of this manual.

3.3.2 Be aware of the compatible fire extinguisher locations adjacent to magnet rooms.

3.3.3 Follow the applicable Emergency Procedures as outlined above.

3.3.4 From a safe location, contact the designated personnel in charge of the magnet area and inform them of a fire emergency.

3.3.5 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.

4. Procedures for Emergency Responders

If knowledgeable magnetic resonance (MR) 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. These guidelines are intended to aid responders in specific scenarios.

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

4.1 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.

4.2 If oxygen levels are safe, and fire, sparks or emergency electrical conditions exist within the magnet room:

4.2.1 Confirm that a low oxygen level alarm is not active (refer to 4.1 above). 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.

4.2.2 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) can not enter the room. Allow entry to necessary personnel only.

4.2.3 Only MR-compatible fire extinguishers can be brought into the magnet room.

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

4.3.1 Confirm that a low oxygen level alarm is not active (refer to 4.1 above).

4.3.1 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) can not enter the room. Allow entry to necessary personnel only.

4.1.1 Resuscitation aided by metallic devices can not 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.

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

4.2.1 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) can not enter the room. Allow entry to necessary personnel only.

4.2.2 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.

4.2.3 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).

4.2.4 The magnet quench procedure will create a dangerous environment. Expect a loud noise from the escape of cryogens 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.

4.2.5 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.

4.2.6 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.

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

4.2.8 Initiate the quench after consultation with MR personnel.

4.2.9 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.