INDIANA UNIVERSITY

Laboratory Safety Guideline

Superconducting Magnets and NMR Safety

Introduction

Superconducting magnets are used to generate strong magnetic fields in Nuclear Magnetic Resonance (NMR) and other scientific instruments. The wire coils of the superconducting electromagnet inside the instrument are cooled to liquid helium temperature using two cryogenic liquids, liquid nitrogen (-196° C) and liquid helium (-269° C). This is accomplished by insulating the coils with a three layer system consisting of an outer vacuum, an intermediate layer of liquid nitrogen, and an inner container of liquid helium. At this low temperature the electrical resistance of the wires approaches zero, and the magnet once charged can run continuously without losing power.

The power continues to cycle as long as the wires are kept cold. More liquid helium must be added periodically as the helium slowly boils off. Liquid nitrogen is used to keep the liquid helium from rapidly boiling off.

Magnetic Field Strength

NMR magnets have very strong, static magnetic fields. Magnet strength is normally described in terms of Gauss or Tesla units (1 T = 10,000 G).

Earth's magnetic field:	0.6 Gauss at the equator
Refrigerator magnet:	100 - 150 Gauss
MRI medical scanners:	0.3 - 1.5 Tesla (3 - 15,000 G)

High magnetic field NMR spectrometers, FTMS, and other superconducting magnets:

200 MHz:	4.7 Tesla (47,000 G)
300 MHz:	7.0 Tesla (70,000 G)
500 MHz:	11.7 Tesla (117,000 G)
800 MHz:	18.8 Tesla (181,000 G)

Damage to the instrument by ferromagnetic materials within the 5-gauss perimeter may cause a purge of the liquid cryogenic gases. The 5 gauss perimeter is marked on the floor of the facility or by chain barriers.

WARNING

Exposure to strong magnetic fields can cause serious injury or death and significant damage to personal property, equipment and data.

NMR Safety

1. **Individuals with medical devices (e.g. cardiac pacemakers and metal prostheses) must remain outside the 5-gauss perimeter**. The NMR spectrometers generate strong magnetic fields that can affect the operation of some pacemakers and harm implanted or attached devices, such as prosthetic parts and metal blood vessel clips. Persons with these types of medical concerns should contact their physicians about the possible health risks before entering the Facility.
2. **Floppy disks, tapes, cards with magnetic strips, cellular phones, laptops and mechanical watches should remain outside the 5-gauss perimeter.** Strong magnetic fields surrounding the NMR spectrometers can damage the strip of magnetic media found

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on credit cards, ATM cards, driver's licenses, and other kinds of cards. Floppy disks, tapes, cellular phones, and laptop computers are also susceptible to damage inside this perimeter. Mechanical wrist and pocket watches will also malfunction and be permanently damaged when exposed to a strong magnetic field.

3. **Metal objects must remain outside the 5-gauss perimeter.** Strong magnetic fields surrounding the NMR spectrometers attract objects containing steel, iron, and other ferromagnetic materials. This includes most ordinary tools, electronic equipment, compressed gas cylinders, steel chairs, and steel carts. Unless restrained, such objects can suddenly fly toward the magnet which can cause personal injury and extensive damage to the probe, dewar, and superconducting solenoid. The greater the mass of the object, the more strongly it is attracted by the magnet. Only non-ferromagnetic materials should be used near the instruments.
4. **The magnet/dewar has a high center of gravity and could tip over in an earthquake or if struck by a large object.** In addition to serious injuries to persons near the magnet, the sudden release of nitrogen and helium gases from the dewar will displace breathable oxygen in the room. The instruments are supported by anti-vibration legs that are bolted to the floor.
5. **In the event of a "magnet quench," leave the room immediately and contact the NMR Facility Staff**. A quench refers to the sudden release of gases from the dewar. Rapid expansion of liquid helium or nitrogen to gas can displace breathable oxygen in an enclosed space creating the possibility of asphyxiation. Do not re-enter the room until the oxygen level has returned to normal. See specific Cryogenic Purge instructions below.
6. **Only individuals who have had special training should transfer liquid helium and nitrogen to the instruments.** Handling cryogens is dangerous and can cause serious burns. Safety glasses, gloves and closed toed shoes should be worn during the transfer of all cryogens.
7. **Do not exceed the boiling or freezing points of your sample**. A sample subjected to a temperature change can build up excessive pressure which can break the tube. Broken glass, projectiles and hot or toxic chemicals can cause injury. To avoid this hazard, establish the freezing and boiling points of a sample before doing a variable temperature experiment, and never rapidly heat or cool a sample. Always wear safety glasses near the magnet when performing variable temperature experiments.
8. **Be very careful with sample tubes as they are fragile and break easily.** The top of the sample tube can break off when the probe is removed. The sample should be ejected before removing the probe from the magnet. Use extreme caution when removing the probe if the sample cannot be ejected.
9. **Do not operate the NMR spectrometers in the presence of flammable gases or fumes**. Flammable gases or fumes create the risk of injury or death from inhalation, fire and explosion.
10. **Do not look down the barrel of an NMR spectrometer if a probe is in place**. Pneumatic ejection of a sample from the probe could cause injury.

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Cryogenic Purge

A cryogenic liquid purge within the NMR facility may create an oxygen deficient atmosphere due to rapid evaporation of liquid cryogenic gases from the NMR instruments. Rapid evaporation and the high expansion ratios (N_2=1:696, He=1:754) of liquid cryogens can quickly displace all the breathable air in the facility and create an asphyxiation hazard.

In the event of a purge, the liquid nitrogen (density=1.153 kg/m^3 @ 21.1^o C) will settle in low areas relative to air (density = 1.200 kg/m^3) and the liquid helium will rise (density = 0.165 kg/m^3).

A purge of liquid cryogens will be very fast and may only take a few seconds. A loud hissing sound will occur and gaseous nitrogen and/or helium will be observed exiting the top of the equipment. The visible cloud is condensed water vapor from humidity in the air due to the cold gasses escaping the instrument.

PERSONNEL MUST LEAVE THE AREA IMMEDIATELY!

Assist any injured personnel to the exit. Close the door. Dial 911 for emergency medical assistance.

The emergency assembly area is outside the NMR laboratory in the hallway. All laboratory personnel should reassemble at that point and account for all personnel:

- Make sure all lab personnel are present at the assembly area in the hallway outside the laboratory.
- **Do Not** re-enter the lab or allow anyone else to enter the laboratory until the purge has ceased and fresh air has been introduced to the lab.

Under no circumstances are personnel to re-enter the laboratory until the purge is complete and fresh air has been provided. The continued presence of an oxygen deficient atmosphere in the laboratory is a life-threatening condition.

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