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Strong Magnetic Fields

STANDARD OPERATING PROCEDURE (SOP)

Type of SOP: ☒Process/Equipment ☐ Hazardous Chemical ☐Hazardous Class

All personnel who are subject to these SOP requirements must review a completed SOP and sign the associated training record. Completed SOPs must be kept with the UC Davis Laboratory Safety Manual or be otherwise readily accessible to laboratory personnel. Electronic access is acceptable. SOPs must be reviewed, and revised where needed, as described in the UC Davis Laboratory Safety Manual. The unique properties of each chemical must be considered when preparing a SOP.

Date SOP Written: **10/29/19** Approval Date: **9/5/22**

SOP Prepared by: **Jeff Walton**
CLSC SOP Task Force

SOP Reviewed and Approved by (name/signature): **James Ames**

Department: **NMR Facility**

Principal Investigator/ Laboratory Supervisor:	**Derrick Kaseman**	**530-752-7794**
Lab Manager/ Safety Coordinator:	**Derrick Kaseman**	**530-752-7794**
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Location(s) covered by SOP: Building: **Chemistry 93,MS1D 15 18A 18D 19 25**
Room #(s): **See Above** Lab Phone: **530 752-7794**

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1. HAZARD OVERVIEW

This SOP provides a summary of basic magnetic field safety and hazards specific to the operation and maintenance of instrumentation that produce magnetic fields. The primary hazard associated with magnetic fields is its attraction of magnetic objects. Secondary hazards associated with most, but not all, magnetic fields include cryogenic and electrical hazards. Electrical hazards such as exposed leads are present with most magnetic field instrumentation. Superconducting magnets present a unique hazard from quenching. For the purposes of this SOP, a magnetic field will be considered potentially hazardous if it exceeds 600 gauss (60 mT) or the field produced maintains strength greater than 5 gauss over a distance of 6 inches.

2. DETAILED HAZARD DESCRIPTION

A. Magnetic Field Hazard.

Magnets come in three different varieties: permanent, electromagnetic, and superconducting.

i. By far the most important hazard is the attraction of magnetic objects in close proximity to the magnetic field. Magnetic force on an object is proportional to the magnetic field gradient. The highest magnetic field gradients are at the mouth of the bore on superconducting magnets and at the sharp corners of permanent and electromagnets. Particular care should be taken in these areas. A 5 gauss line shall be used as a physical indication of where a magnet's magnetic field has a strength of 5 gauss. Objects such as gas cylinders, carts, surgical clips and metal surgical implants, clipboards, tools, jewelry, watches, mops, buckets, scissors, screws, electronics with transformers or batteries, etc. have all been documented as being potential hazards. Even low mass items can become hazardous projectiles 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 torqueing may cause serious injury.

ii. Another important hazard is the functioning of bioelectric devices (e.g., pacemakers (17 Gauss) or insulin pumps), which can be compromised potentially affecting the health of the owner.

iii. A third effect is that some devices may be damaged. Cameras, cell phones, credit cards, and other magnetic media will lose functionality in a magnetic field of sufficient strength (300 to 4000 Gauss for credit cards).

B. Cryogenic Liquids.

Cryogenic liquids are defined as liquids with a normal boiling point below -150 ^{o}C (-240 ^{o}F). Some examples include: liquefied N_2, O_2, and He, which have typical gas to liquid expansion volumes of 650-1500:1. Refer to SafetyNet #58 - Safety Precautions for Cryogenic Liquids and Cryogens SOP for more on cryogenics safety.

C. Quenching.

Superconducting magnets present a unique hazard known as quenching. The most noticeable result of a quench will be the accelerated venting of cryogens from the magnet (quench example, further quench examples). A quench is the (normally unexpected) loss of superconductivity in a magnet resulting in rapid heating through increased resistance to the high current. This loss of superconductivity vaporizes the magnet cryogens, which may displace air, resulting in an oxygen deficient atmosphere and possible asphyxiation. You cannot smell cryogenic gases and will not know until it is too late that the air has been displaced. YOU CANNOT STOP A QUENCH! If gas is visibly coming out of the magnet, **EVACUATE IMMEDIATELY!**

D. Electrical Hazards.

Electromagnets have high current power supplies as do superconducting magnets during installation. Appropriate precautions should be taken. Refer to SafetyNet# 512: Electrical Safety.

3. ENGINEERING/VENTILATION CONTROLS

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Whenever possible magnets should be secured or anchored to minimize the risk of falling (*e.g.* due to seismic activity). Refer to manufacturer recommendations for instillation and anchoring. A thorough risk assessment should be completed to determine if seismic bracing is also appropriate. Taller magnets, such as superconducting magnets, should be secured to walls or ceilings. Small magnets often rest on carts or structures with wheels to allow them to be moved and should be secured to their carts with the wheels locked whenever the magnet is in place and not in transit.

Superconducting magnets make use of cryogens; thus, the magnets and the cryogens should only be used in well-ventilated areas. Use within rooms without forced ventilation (*e.g.*, cold rooms) may cause a buildup of gas as the cryogen evaporates or sublimes, displacing oxygen creating an asphyxiation hazard. Quench lines that exhaust the cryogenic gas into the atmosphere in an area well away from trafficked areas, should be considered when installing new equipment in order to help mitigate the release of gas into laboratory space. If the use of cryogens is required in a small or unventilated room contact the Chemical Hygiene Officer or chem-safety@ucdavis.edu for alternative respiratory and/or ventilation options available, including oxygen monitors. Superconducting magnets are sometimes placed in recessed areas to contain the field within a room. In these cases, personnel are not allowed in the recessed area during a nitrogen fill, as the area may fill with cold, denser-than-air nitrogen gas.

The 5 gauss line must be denoted with a physical barrier, such as non-metallic stanchions, or a visible warning, such as tape on the floor around the magnet. Small magnets or magnets with heavy shielding may have internal 5 gauss lines and do not need to be marked in such a way. Contact the Chemical Hygiene Officer or chem-safety@ucdavis.edu for help measuring and marking a 5 gauss line.

REQUIRED - Insert descriptions of lab-specific engineering used to reduce magnetic field and/or chemical exposures or specific equipment safety features.

Rooms with magnets have card key systems. Safety training in Magnetic fields is required to obtain card access. Doors have signs warning of magnetic fields. The 5 Gauss line is marked on the floor with tape. Plastic chains on plastic post may also be used to denote the 5 Gauss Line.

4. ADMINISTRATIVE CONTROLS

The following elements are required:

1. Complete the UC Laboratory Safety Fundamentals (or approved equivalent) training prior to working in the laboratory;
2. Complete laboratory-specific safety orientation and training on laboratory-specific safety equipment, procedures, and techniques to be used, including any applicable laboratory-specific Laboratory Safety Plan(s), prior to receiving unescorted access to the laboratory;
3. Demonstrate competency to perform the procedures to the Principal Investigator (PI), Laboratory Supervisor, laboratory-specific Safety Officer, and/or trainer;
4. Be familiar with the location and content of any applicable Safety Data Sheets (SDSs) for the chemicals to be used (online SDSs can be accessed from UC SDS);
5. Implement good laboratory practices, including good workspace hygiene;
6. Inspect all equipment and experimental setups prior to use;
7. Follow best practices for the movement, handling, and storage of hazardous chemicals (see Chapters 5 and 6 of Prudent Practices in the Laboratory for more detail). An appropriate spill cleanup kit must be located in the laboratory. Chemical and hazardous waste storage must

follow an appropriate segregation scheme and include appropriate labeling. Hazardous chemical waste must be properly labelled, stored in closed containers, in secondary containment, and in a designated location;
8. Do not deviate from the instructions described in this SOP without prior discussion and approval from the PI and/or Laboratory Supervisor;
9. Notify the PI or Laboratory Supervisor of any accidents, incidents, near-misses, or upset condition (*e.g.,* unexpected rise or drop in temperature, color or phase change, evolution of gas) involving the process, hazardous chemical(s), or hazardous chemical class described in this SOP; and
10. Abide by the laboratory-specific working alone SOP, if applicable.

For Magnetic Fields, the following are also required:

11. Read and understand any lab specific safety plans, manuals or guides relevant to magnetic fields;
12. Any individual filling or maintaining a superconducting magnet must be trained on all information contained within Safety Net# 58: Cryogenic Liquids;
13. Cryogen handling insulated gloves shall be inspected annually at the minimum. If any surface holes or non-uniform insulation materials are observed, the gloves must be replaced and the compromised gloves discarded;
14. If applicable, implement and maintain a documented filling schedule for any cryogenics needed for superconducting magnets. Consult manufacturer for frequency of fills required. To avoid a quench situation, maintain a schedule for filling magnets with their respective cryogenic liquid (fill scheduling and cryogenics are dependent on size and design of the magnets—consult with manufacturer). Use cryogen level sensors where applicable and always refill or de-energize the magnet if low cryogen levels are indicated on the sensors;
15. Any individual using magnets must be trained on all information contained within SafetyNet# 512: Electrical Safety, for exposed leads;
16. Install proper signage on all entrances and exits of rooms containing magnetic fields. See Section 8. Designated Area for examples of signage; and
17. A small hand-held permanent magnet should be available to test any object for magnetic properties.

INSERT - Laboratory specific SOP for filling magnets with Liquid Helium and Liquid Nitrogen. Note usually LN2 is filled during a LHe fill, but LN2 must be filled more often and so is frequently done by itself.

LN_2- A non-magnetic Dewar of Liquid Nitrogen is wheeled up to the magnet (do not use Dewars without wheels that require a steel cart). Operating Data (Cryogen levels and boil-off rates) are recorded. Put on PPE per Cryogenic SOP. Remove two heat sinks from two LN2 ports on the magnet. A steel braided hose is connected to the storage Dewar on one end and to a magnet LN2 port on the other. A rubber hose is put on the other LN2 port so that when full LN2 is directed away from personnel. Turn on the LN2 valve slowly so as to not build up excess pressure in the magnet. When full shut the valve. Remove transfer line and return magnet to normal operating state. Do Not leave during a fill.

LHe – Liquid nitrogen and Liquid Helium Dewars are wheeled up to the magnet. Operating Data (Cryogen levels and boil-off rates) are recorded. Put on PPE. The liquid nitrogen is connected as a above. The LN2 valve is cracked so that a minimal amount of LN2 is flowing. The fill port of the magnet is loosened so that the plug can be removed quickly.

Before the fill begins, ensure the helium recovery system bladder(s) are empty.

High purity helium gas (cylinder) is connected to the vent of the Dewar through a flow apparatus, which consists of a flow gauge and a valve. Open the valve to allow the high purity He to flow through the tubing to purge the tubing connecting the cylinder to the dewar. Purging should last at least 5 min to ensure no air is introduced into the dewar. Purging pressure should be ~1 PSI and can be measured by closing the needle valve on the regulator.

Slowly open the valve on the He recovery system to route the He gas flow around the He flow meters. In chemistry, make sure the He path flow through the heat exchangers. In the case there are no He level sensors open the valve partially to so the He flow through the meter is reduced but not 0. This may need to be adjusted once the fill begins. In Chemistry 93, the gas totalizer needs to be by-passed before the fill begins.

Slowly insert the long end of the transfer tube is inserted into the LHe Dewar slowly but stopped before the transfer line contacts the liquid. The valve on the He gas flow apparatus is closed and the valve on the He vent is opened. Close the 1 PSI pressure relief valve on the He dewar. Allow the transfer line to purge , while slowly inserting the long end of the transfer line into the dewar. Helium will come through and when it finally comes through as liquid (white plume), the plug above He transfer port on the magnet is removed and the short end on the transfer tube is inserted into the magnet.

Ensure that the compressor on the He recovery system is running. If a He sensor is not available for the fill, check that the valve bypassing the He flow meter is adjusted to a flow rate can be observed, but it should not exceed 50% of the dynamic range of the meter. In Chemistry 93, the totalizer bypass valve should be adjusted such that He passes through the totalizer at a rate <3 cu ft/ min.

After ~5 min, the fill backpressure can be increased to 2 PSI. The transfer ends when one of the 3 conditions is met

1) He meter indicates the He dewar is full
2) He flow meter or totalizer (Chem 93) suddenly jumps in flow rate, indicating liquid is flowing out of the top of the magnet
3) The bladder of the helium recovery system is full and the backpressure of the system exceeds 100 Pa.

in the LHe storage Dewar is released to stop the transfer. The transfer line is removed and all hardware replaced. Once thawed, all valves need to be moved into their original positions before the fill.

REQUIRED - Insert descriptions of any additional administrative controls (e.g., restrictions on procedure/quantity/work equipment/work locations/unattended operations/etc.), including controls that may be chemical-specific (e.g., cryogens).

Personnel should remain in the room during transfers. For the magnet in the pit in room 25, personnel should stay out of the pit during transfers.

INSERT IF APPLICABLE- Descriptions of any special handling or storage requirements.**NA**

5. PERSONAL PROTECTIVE EQUIPMENT (PPE)

At a minimum, long pants (covered legs) and closed toe/closed heel shoes (covered feet) are required to enter a laboratory or technical area where hazardous chemicals are used or stored.

In addition to the minimum attire required upon entering a laboratory, the following PPE is recommended for all work with Magnetic Fields:

A. Eye Protection:
   i. Eye protection, if required, must be ANSI Z87.1-compliant.
   ii. Splash goggles may be substituted for safety glasses, and are required for processes where splashes are foreseeable (i.e. cryogen fills) or when generating aerosols.
   iii. In addition to safety glasses/goggles, a face shield is required for transferring cryogens from any pressurized container and should be considered for large volume transfers.
   iv. Ordinary prescription glasses will NOT provide adequate protection unless they also meet the Z87.1 standard and have compliant side shields.

B. Body Protection: At a minimum a chemically-compatible laboratory coat that fully extends to the wrist is necessary.
   i. It is important pant legs cover the tops of footwear so cryogens do not enter the shoes and cause damage before the footwear can be removed. Clothing should never have outer cuffs or be of a design that may trap cryogens against the body.

C. Hand Protection:
   i. Loose-fitting, thermal-insulated gloves (not intended for full immersion purposes) that are meant for incidental contact **must** be available to all personnel using Cryogens. These gloves shall be inspected at least annually, and replaced as directed in the Administrative Controls. No metal jewelry, watches, or rings should be worn while handing Cryogens. Consult Cryogens SOP and SafetyNet#58 for additional information on proper PPE when handling cryogens in a magnetic fields environment.

Metallic objects should be tested for magnetic properties before being brought into a magnetic field area. Only non-magnetic metals should be brought into the vicinity of strong magnetic fields. A simple test magnet should be available to test metallic objects. In cases where metallic items cannot be tested, they must be considered magnetic. Magnetic jewelry, watches, rings, and wearable electronics (e.g. fitness trackers) must **NOT** be worn while near a magnetic field environment (i.e. inside the 5 gauss line). Do not carry wallets, credit cards and other magnetic media, keys, cellphones and other electronics while near a magnetic field environment (check your pockets).

REQUIRED - Insert descriptions of any lab-specific PPE and hygiene practices used, including any specialized PPE needed for a procedural step/task.

NA

6. SPILL AND EMERGENCY PROCEDURES

Follow the guidance for chemical spill cleanup from SafetyNet #13 and/or the UC Davis Laboratory Safety Manual, unless specialized cleanup procedures are described below. Emergency procedure instructions for the UC Davis campus and UCD Medical Center are contained in the UC Davis Laboratory Safety Manual, campus Emergency Response Guide (ERG), and UCD Health System ERG. The applicable ERG must be posted in the laboratory. All other locations must describe detailed emergency procedure instructions below.

Quenches can occur spontaneously! In the event of a quench of a superconducting magnet **EVACUATE IMMEDIATELY! Get out!**

The most noticeable result of a quench will be the accelerated venting of cryogens from the magnet. A quench is the (normally unexpected) loss of superconductivity in a magnet resulting in rapid heating through increased resistance to the high current. This loss of superconductivity vaporizes the magnet cryogens, which may displace air, resulting in an oxygen deficient atmosphere and possible asphyxiation. You cannot smell cryogenic gases and will not know until it is too late that the air has been displaced. YOU CANNOT STOP A QUENCH! If gas is visibly coming out of the magnet, **EVACUATE IMMEDIATELY!**

Seismic event – In the event of an earthquake EVACUATE IMMEDIATELY!

If a magnet does not have a quench line, after evacuating the room pull the nearest fire alarm to evacuate the building. Helium gas is lighter than air and can seep into higher floors through ceilings.

If a leak is suspected from a dewar or delivery line/system, discontinue use. If it is safe and feasible to do so, move the leaking dewar to a safe location. Contact the vendor immediately. Please note that dewars have built in venting controls to avoid over pressurization and will vent sporadically for a short amount of time to maintain safe pressures.

Should any metallic object strike the magnet, notify the PI or Lab Manager immediately. Do NOT attempt to pull the object off yourself. You risk damage to the magnet and yourself!

Consult the Cryogens SOP for additional information on cryogen-specific spill and emergency procedures.

INSERT - Descriptions of any specialized spill clean up procedures for the hazardous chemicals used in this SOP (e.g., Cryogens). Additional details of lab-specific spill cleanup should be provided if applicable.

If a Dewar tips over, do not try to pick it up. Open vent, and evacuate. Leave door open.

INSERT IF APPLICABLE - Descriptions of any specialized emergency procedures for locations outside of the UC Davis main campus and the UCD Medical Center campus.

NA

7. WASTE MANAGEMENT AND DECONTAMINATION

Hazardous waste must be managed according to Safety Net #8, and must be properly labeled. In general, hazardous waste must be removed from your laboratory within 9 months of the accumulation start date; refer to the accumulation time for waste disposal to ensure compliance. Hazardous waste pick up requests must be completed using WASTe.

Note: See the WASTe Factsheet for instructions on how to complete a label.

REQUIRED - Insert descriptions of laboratory-specific information on the waste streams generated, storage location, and any special handling/storage requirements.

NA

8. DESIGNATED AREA

Where a magnetic field produces a field strength greater than 5 gauss over a distance of 6 inches, a 5 gauss line must be used to designate said area. The 5 gauss line is a physical indication of where a magnet's magnetic field has a strength of 5 gauss. This line can be denoted with a barrier, such as non-metallic stanchions, or a visible warning, such as tape on the floor around the magnet. Small magnets or magnets with heavy shielding may have internal 5 gauss lines and do not need to be marked in such a way. Contact the Chemical Hygiene Officer or chem-safety@ucdavis.edu for help measuring and marking a 5 gauss line.

To highlight the designated area within a workspace, it is advised to create a floorplan highlighting the location of all magnetic field producing devices and the location and existence of all 5 gauss lines within a work area and to post the floorplan at the entrance of said area.

Hazard warning signs are required to be posted at all access points to the room containing magnetic fields. Below are examples of signage for magnetic fields.

INSERT - Description(s) of designated area(s) for your laboratory. Designated areas are required for "Particularly Hazardous Substances". The entire laboratory, fume hood, or a portion of the laboratory may be used, and must be labeled with the hazards.

Entire Laboratory.

9. DETAILED PROTOCOL

REQUIRED - Insert or attach detailed laboratory-specific procedures magnetic fields. You may also include any relevant supporting resources such as SafetyNets, journal citations, etc. that are applicable.

Described above

TEMPLATE REVISION HISTORY

Version	Date Approved	Author	Revision Notes:
1.0	**06/25/2018**	**CLSC Task Force**	**New template**

LAB-SPECIFIC REVISION HISTORY

Version	Date Approved	Author	Revision Notes:
1	10/29/19	**Jeffrey Walton**	Initial SOP generation
2	9/5/22	**Derrick Kaseman**	Revised for He recovery system and contact information

Documentation of Standard Operating Procedure Training

(Signature of all users is required)

- ✓ Prior to using **Strong Magnetic Fields**, laboratory personnel must be trained on the hazards involved in working with this SOP, how to protect themselves from the hazards, and emergency procedures.

- ✓ Ready access to this SOP and to a Safety Data Sheet for each hazardous material described in the SOP must be made available.

- ✓ The Principal Investigator (PI), or the Laboratory Supervisor if the activity does not involve a PI, must ensure that their laboratory personnel have attended appropriate laboratory safety training or refresher training within the last three years.

- ✓ Training must be repeated following **any** revision to the content of this SOP. Training <u>must be documented</u>. This training sheet is provided as one option; other forms of training documentation (including electronic) are acceptable but records must be accessible and immediately available upon request.

Designated Trainer: *(signature is required)*

I have read and acknowledge the contents, requirements, and responsibilities outlined in this SOP:

Name	Signature	Trainer Initials	Date