Philips Medical Systems MR, Inc
Magnet Group
450 Old Niskayuna Road
Latham, NY 12110

Magnet Warm-up In the Field

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Philips Medical Systems MR, Inc.
Magnet Group
450 Old Niskayuna Road
Latham, New York, 12110, USA

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Organization	Approval By:	Date
Engineering Systems		
Technical Support/ Field Service		
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CONTENTS

PURPOSE AND SCOPE

This document prescribes procedures for warm-up of cryo-cooled MRI magnets in the field using a warm-gas recirculation process. This procedure is used to remove suspected nitrogen, oxygen, CO_2 and water ices that may have formed within the helium vessel as a result of atmospheric leaks.

Intended Use

This document and procedure is intended for use ONLY by personnel who are thoroughly trained and qualified in safe practices related to cryogenic MRI magnets, including:

- working around high voltages;
- dangers of strong magnetic fields;
- dangers and safe handling of cryogenic liquids and gases; and
- specialized factory training in thermal-cycling of magnets.

Applicable Documents

44171	De-icing Instructions for F2000 Magnets
46054	De-icing Instructions for Titan-Series Magnets
53021	De-icing Instructions for 4K-Coldhead Magnets

Safety Considerations

This section must be read and understood by everyone who works with or are exposed to any elements of the magnet system.
All operating and service personnel must be thoroughly trained and certified in safe practices related to working around high voltages and strong magnetic fields, and in the use and handling of cryogenic liquids and gases.
Four types of precautionary notices are used in this document: Danger; Warning, Caution, and Notes. The definitions of each, and their formats, are presented below.

DANGER **Notices call attention to actions or conditions which can result in serious injury or death.**

WARNING **Notices call attention to actions or conditions which may result in personal injury or in catastrophic damage to equipment.**

CAUTION ***Notices call attention to actions or conditions which can result in damage to equipment or in abnormal performance.***

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IMORTANT: Notices point out something of special interest or importance to the current step.

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MAGNET WARM-UP PROCEDURE

DANGER **These procedures must be performed only by trained and qualified personnel. Failure to perform these procedures properly may result in serious injury or death, and in damage to equipment.**

1. Required Equipment & Material

Equipment:

Thermal-Cycle Kit (p/n 430232-51, or higher), consisting of:

- Thermal Cycle Blower Assembly (p/n 430384-51); and
- Pre-Cool Kit Assembly (p/n 430231-51).

Additional Requirements for complete Thermal-cycle:

- 4-6 Cylinders Dry Helium Gas (4 to de-ice bottom fill- 2 for make up gas)
- Compressed Gas Regulator(10 PSI)
- Yellow Jacket® hose with valve

2. Preliminary Set-up

1) Ensure the magnet's bottom-fill line is clear of ice. If blockage exists, follow de-icing procedures from document 44171, 46054, or 53021 before proceeding.

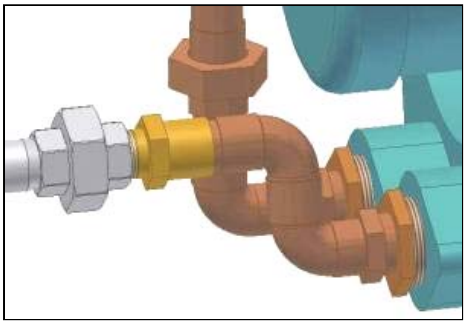
2) Open the yellow-handled vent ball-valve on the magnet (turn handle ¼-turn).

3) ***IF DIRECTED***, *recover* Liquid Helium from magnet, per appendix A. If *not* directed to recover, *remove* LHe following procedure in Appendix A section 4.

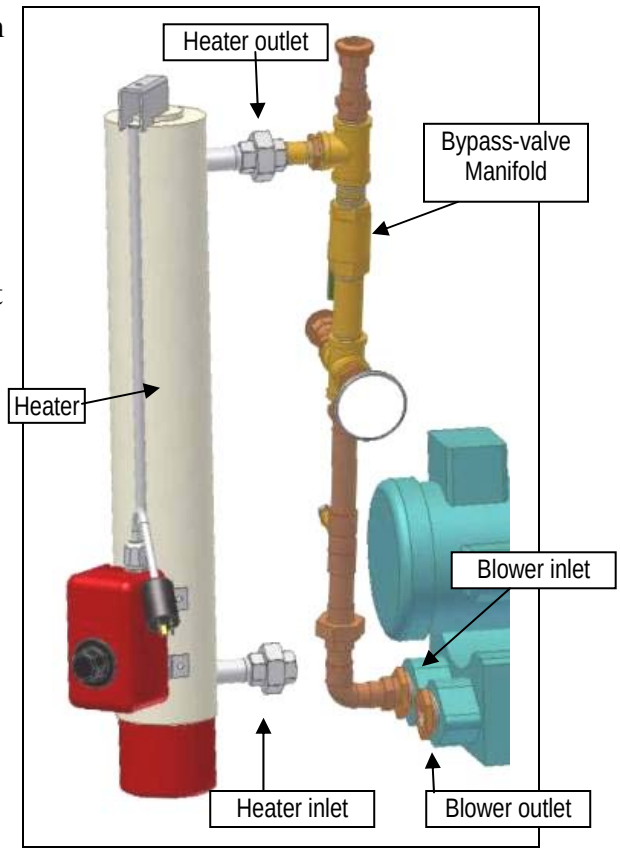
4) Connect the bypass valve manifold between the blower motor suction inlet and the heater outlet. (see right) Do not tighten couplings at this time.

IMPORTANT: Be sure to install the silicone O-rings at both the heater inlet and outlet couplings, to reduce He-gas loss.

5) Connect the blower outlet to the heater inlet and check for proper alignment (below).



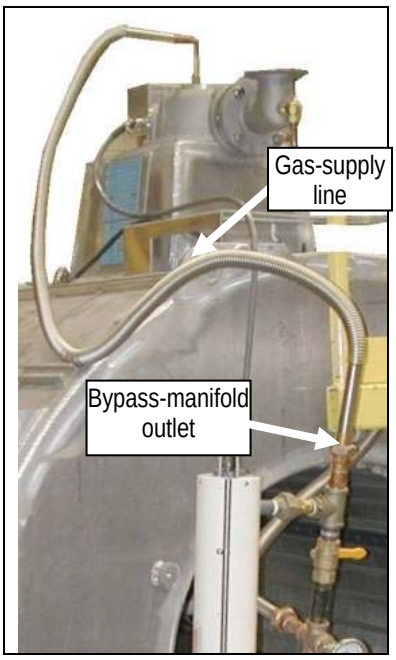
6) Tighten all three couplings using supplied wrenches.



7) Purge and connect the helium-gas make-up line to the fitting located on the bypass valve manifold. Set regulator to approximately 1psi and purge blower and heater with He gas to remove air.

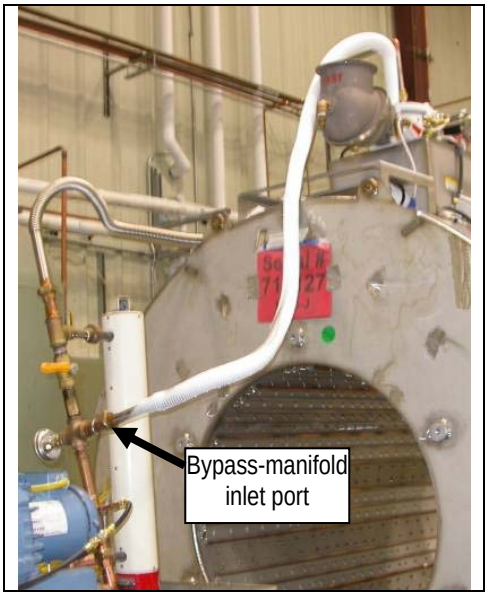
8) Connect the *gas <u>supply</u> line* (the flexible metallic hose with the attached bottom-fill stinger) to the output end of the bypass manifold as shown at right, and purge the line using the He-gas makeup bottle

9) After purging air from the metallic line and stinger, install the stinger into the magnet's LHe-fill port, as seen at right and on next page. Ensure stinger is properly seated in the bottom-fill funnel. Tighten fitting to make a gas-tight seal.



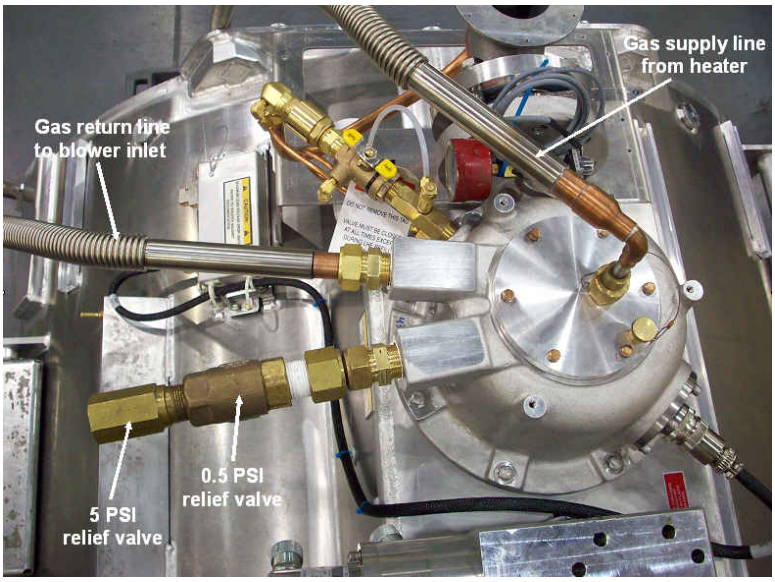
10) Connect the end of the *gas-<u>return</u> line (the other* flexible metallic hose) to a lead port on the magnet (see right).

11) Allow escaping helium gas from the magnet to purge air from the gas-return line, and then install the free end of the line to the bypass valve manifold inlet port (opposite the return gas thermometer).

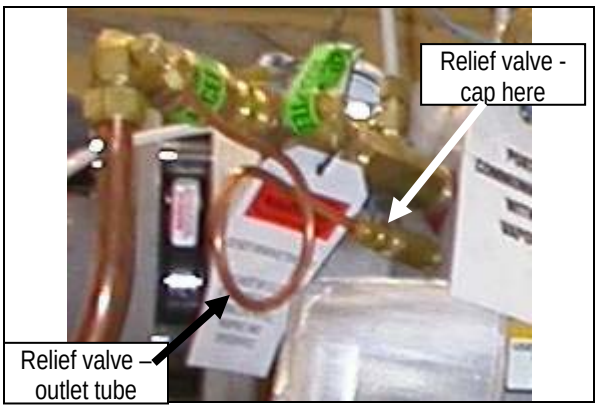


12) Install the relief-valve assembly (as shown below) to the other lead port.

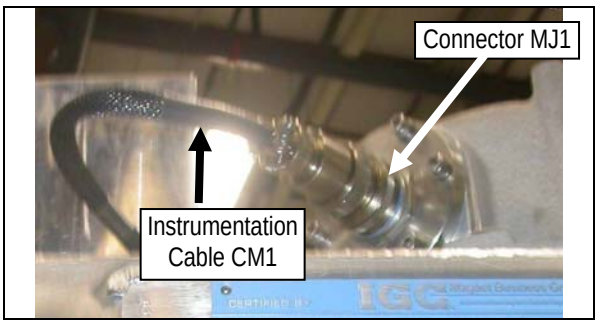
(Below) Magnet top-works showing gas lines and relief valve assembly.



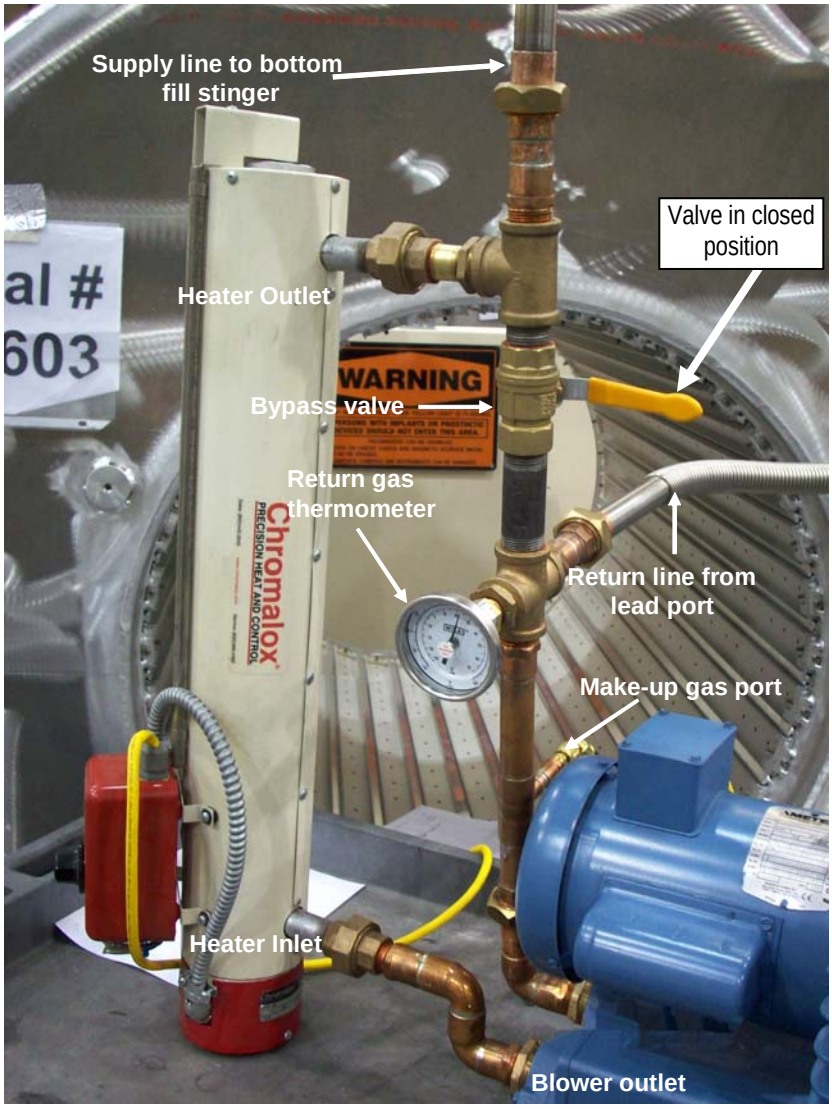
13) On F2000 and Titan magnets, disconnect the relief-valve outlet tube, and cap the valve with the ¼-inch cap from the pre-cool kit.



14) Disconnect the CM1 instrumentation cable from the MJ1 connector, and install the breakout box cable to MJ1. Connect the other end of the cable to the MJ1 breakout box.



(Below) Completed installation of the Thermal Cycle Blower w/o Wiring



3. Warm-up the Magnet

CAUTION ***Heater outlet temperatures greater than 300°F may result in damage to the magnet and/or the blower kit.***

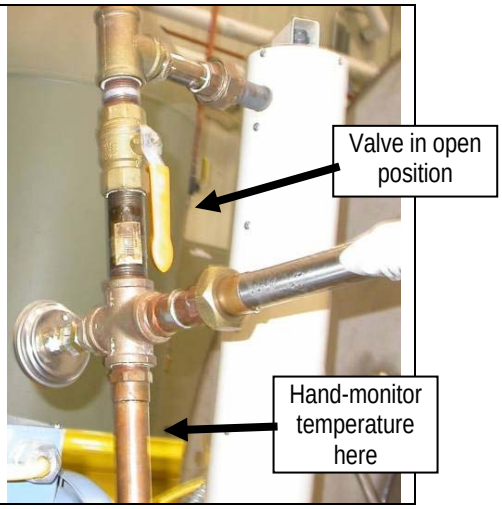
1) Set the heater temperature control to 0° F.

2) Connect the ramp tool power source "Y" adapter to the facility's ramp-tool-power outlet.

3) Connect heater and blower mains to ramp tool power source "Y" adapter to start the recirculation of Helium gas within the magnet.

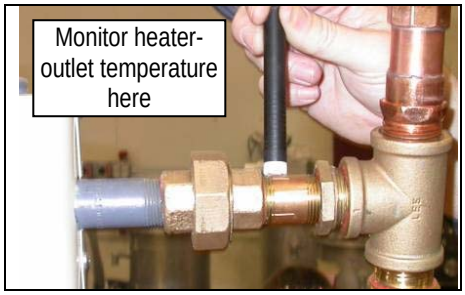
4) Re-set the heater temperature control to 250° F.

IMPORTANT: You must start the process with the bypass valve on the manifold wide open (in line with the pipe) to insure you do not freeze the seal on the blower. As the system pressure becomes more stable, (~100mB) start closing the bypass valve. Monitor the effect of closing the bypass valve as it decreases the blower inlet temperature and adjust the bypass valve as required to keep the pipe cool to the touch but free of frost, and the blower housing slightly warm to the touch.

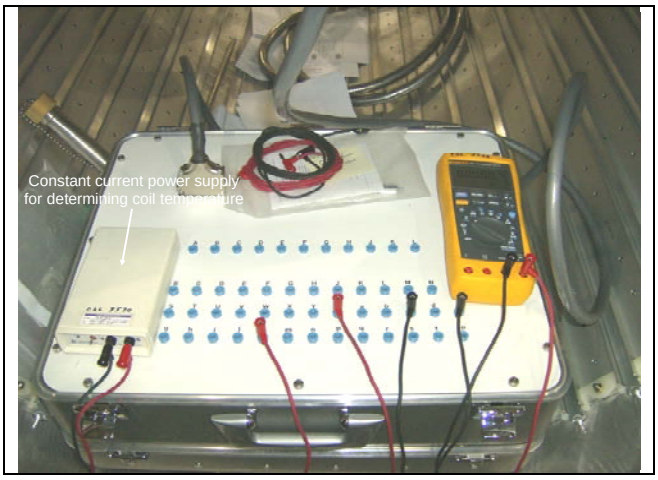


4) The yellow ball valve on the magnet vent can be closed once the pressure has stabilized around 60 - 70mB. Monitor the circulating pressure in the magnet and replenish as necessary with helium gas by opening the make-up gas valve to maintain ~60-120mB as indicated on the magnet pressure gauge.

5) Use the supplied surface contact probe and thermocouple module, (see right) to verify that the heater outlet temperature does not exceed 300°F. If the outlet temperature is too hot, adjust the heater thermostat.



6) Connect a Digital Multi-meter to the 41-pin breakout box (right) and monitor the Helium vessel temperature thermistors resistances, using pins U, V, W, X, and Y. See Table 1, below.



Pin Connections	F2000, Titan, Rex Sensor Location	HFO Sensor Location
U – V	4K Bottom	Lower Vessel Bottom
V – W	4K Bottom	Lower Vessel Mid-Point
X – Y	4K Mid-point	Upper Vessel Bottom

Table 1 *– Sensor Identification Chart*

(NOTE: resistance of V-W not available on some Rex magnets)

The resistance value will decrease as the helium-vessel temperature rises, with the final value reaching approximately 23Ω.

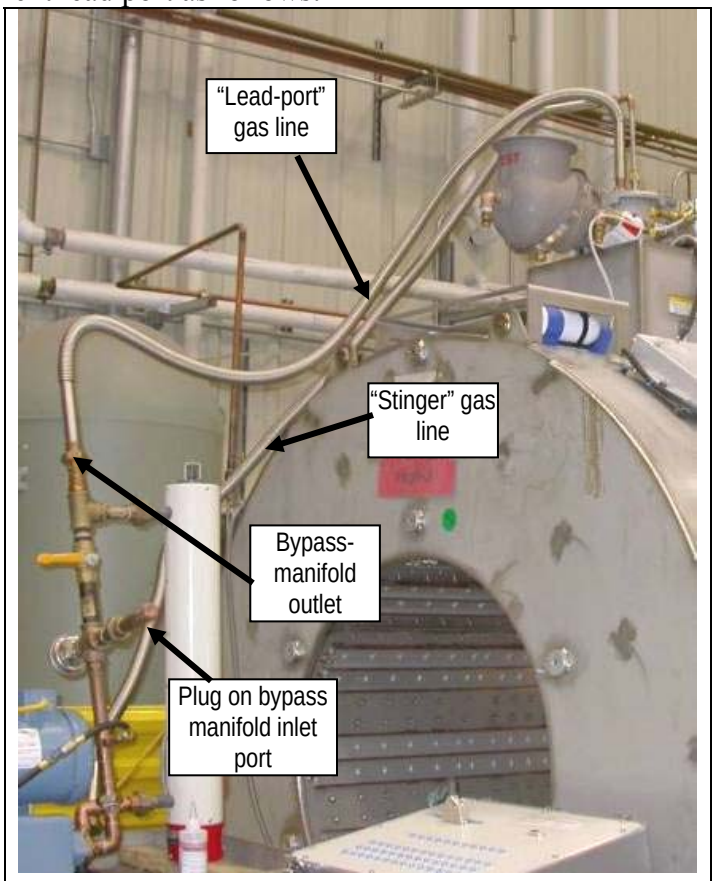
7) Monitor the flexible metallic hose from the high current lead port; when the line is no longer frosted, the return gas temperature thermometer may be used to reference the return gas temperature. Final temperature should be above 75°F (24°C), and should be viewed in conjunction with the Helium vessel thermistors' values.

8) Turn off the heater and blower by disconnecting their power mains when the return gas temperature reaches 75°F (24°C), Proceed to Section 4, "Purging the Magnet".

4. Purging the Magnet

After warming the magnet to temperatures above 274K (approximately 28 ohms on the thermistors), the Helium vessel must be flushed using warm, dry Helium gas. Reconfigure the heater to allow the supplied Helium gas to be heated prior to entering the magnet through the high current lead port as follows:

1) Disconnect the return gas "lead port" line from the bypass-manifold inlet port.
2) Plug the bypass-manifold inlet port using cap fitting.
3) Disconnect the gas supply "stinger" line from the bypass-manifold outlet port. Leave this line open to atmosphere.
4) Re-connect the "lead port" gas line to the bypass manifold outlet port.
5) Set He-gas regulator outlet to ~2 - 4 PSIG and open make-up gas valve. Verify gas flow from open end of "stinger" gas-line.



6) Set heater temperature to 225° F and reconnect the heater mains.
7) Using the portable hygrometer, (right) monitor the temperature and relative humidity (RH) of the exhaust gas flow by placing the hygrometer probe into the open end of the "stinger" gas line, at least 7.0cm deep. The exhaust gas temperature should be above 75° F.

(Continued next page)

8) After flushing the helium vessel with four (4) bottles of helium gas, check the relative humidity and temperature of the exhaust flow as previously done in step 7. RH should be very near 0.0% and the temperature should be above 75° F (see right). If these conditions have been met, the magnet may be considered dry and the warming process completed.

   a. If the RH is above 2.0% continue the flushing with two (2) additional cylinders of helium gas and recheck reading. If RH is still high, contact PMS Helpdesk for further instruction.
   b. If temperature of exit gas exceeds 140° F, turn off heater and allow exhaust gas flow to cool below 140°F before taking readings.

Procedure Complete

APPENDIX A

Removal and Recovery of Liquid Helium (LHe) from the Magnet Space

DANGER Cryogens in liquid form. Use extreme care when handling cryogens. Boiling and splashing may occur when filling a warm container, or when inserting warm objects into the liquid. Contact with cryogens, or their cold vapor, can cause cold-contact burns and damage to the eyes and skin.

DANGER When inserting open-ended pipes into cryogens, never direct the open end of the pipe or piping toward any person. Contact with the liquid, or cold vapor from the liquid, can cause burns and damage to the eyes and skin.

Protective Clothing

Eyes and skin must be protected when handling or working around cryogens. Accidental contact of skin or eyes with cryogens, or cold cryogen vapor, may cause a severe freezing injury similar to a burn. A face shield, or safety goggles, and loose fitting gloves which can readily be removed if any liquid spills or splashes on them must be worn when handling or working around cryogens. Wear cuff-less trousers outside of boots to shed liquid.

NOTE

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FIRST AID NOTICE

IN THE EVENT OF CONTACT WITH CRYOGENS OR COLD VAPOR, MOVE EXPOSED PERSON TO A WELL VENTILATED AREA AND TREAT FOR FROSTBITE. CONSULT A PHYSICIAN IMMEDIATELY.

EYES: FLUSH WITH WARM WATER [NEAR BODY TEMPERATURE - 95±5°F (35±3°C)] TO THAW THE TISSUE. PROTECT THE EYE WITH A RIGID EYE SHIELD OR PLASTIC OR PAPER CUP, DO NOT PATCH THE EYE.

SKIN: FLUSH THE AFFECTED AREA WITH WARM WATER [NEAR BODY TEMPERATURE - 95±5°F (35±3°C)] TO THAW THE TISSUE. CAREFULLY REMOVE CLOTHING; IF CLOTHING STICKS TO UNDERLYING SKIN LEAVE CLOTHING ON UNTIL ARRIVAL AT A MEDICAL FACILITY. CONTINUE RE-WARMING. DO NOT APPLY DIRECT HEAT TO THE AFFECTED AREA. LOOSELY APPLY DRY, STERILE, BULKY DRESSINGS TO PROTECT THE EXPOSED AREA.

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1. **Equipment Needed:**
   - LHe Transfer Line (IGC P/N K0007) or equivalent
   - Bottom-fill tube extensions, ½-inch
   - 300mb reference pressure gauge with high current port adapter (installed pressure gauge may be used if it is correct range)

- 5 PSIG lead port relief valve
- Hoses, Yellow Jacket®
- Regulator, He Gas
- Gas bottle, He
- LHe Dewars, Empty
- Helium vent adapter
- LN2 transfer line
- LN2 bottom-fill tube adapter

2. Preliminary Set-up

1) Determine the amount of LHe in the magnet, using the Remote Magnet Monitoring Unit.
   a. If there is no LHe in the Magnet, go directly to Magnet Warm-up Procedure.
   b. If LHe level is low and/or recovery of LHe is deemed to be disadvantageous, the alternate LHe removal procedure in Section 4 may be used.
2) Remove the ¼" Swagelok fitting cap at the Taconis bottle tee on the magnet vent-assembly.
3) Disconnect the ¼" vent tubing at the 70mb magnet vent-assembly valve. Cap off the 70mb magnet vent valve with the ¼" Swagelok cap removed previously.
4) Purge the Yellow Jacket hose from the He gas regulator and connect to the uncapped Taconis bottle tee opening.
5) Install the 5 PSIG lead port relief valve if magnet does not have integral valve.
6) Install the 300mb reference pressure gauge to the high current port (if required).
7) Remove the vent tube from the helium vent elbow and install the Helium vent adapter.
8) Connect one end of the LN2 transfer line to the Helium vent adapter and prepare the other end to connect to the LHe Dewar vent.

3. Remove the Liquid Helium

1) Vent-down the storage Dewar; open the vent valve.
2) Insert the magnet-end of the transfer line into the bottom-fill port of the magnet through the A&N compression nut, and into the bottom-fill funnel. Press the line into the funnel to make a "snug fit" into the funnel.
3) Tighten the A&N compression nuts to prevent He gas from escaping around the A&N fittings.

CAUTION **Monitor the magnet pressure during the removal to avoid over-pressurizing the magnet. Over-pressurizing the magnet may result in bursting the rupture disk.**

4) Open the LHe charge/discharge valve of the Dewar.
5) Insert the Dewar-end of the line into the storage Dewar through that A&N compression nut, and push the Line to a point ½-inch above the bottom of the Dewar.
6) Place the empty LHe-storage Dewar next to the magnet.
7) Connect the LN2 transfer line to the LHe Dewar vent outlet.
8) Open the Dewar vent valve. Ensure adequate room ventilation is maintained during transfer process.
9) Slowly pressurize the Magnet through the Taconis bottle tee with He gas to start the transfer of LHe. Do not exceed 275mb pressure on the magnet to prevent burst disk rupture. If integral valve is installed on magnet, do not exceed integral valve cracking pressure.
10) Transfer the LHe out of the magnet.
11) Change Dewars as necessary to remove all the LHe from the magnet.
12) Monitor the LHe level as the LHe is transferred, using a Helium-level indicator.
13) After removing as much of the LHe from the magnet that can be recovered:
    - Remove the magnet-end of the line from the magnet.
    - Cap off the A&N port.
    - Remove the Dewar end of the line from the Dewar.
    - Close the vent and charge/discharge valves opened earlier for the transfer.
    - At the Dewar, verify the 0.5 psi. relief valve is **OPEN**.

4. Alternate LHe Removal Procedure

1) Perform steps for setting up the thermal cycle blower in section 2, omitting Step 13.
2) Lift the bottom fill stinger approximately 2-3cm.
3) Tighten the A&N compression nuts to prevent He gas from escaping around the A&N fittings.
4) Proceed with section 3, Warm up Magnet. Ensure that the blower bypass valve is completely open. Large amounts of He gas will be generated during this process as the liquid helium is vaporized. Complete removal may take several hours depending upon the amount of LHe in the magnet.
5) Monitor the LHe level of the magnet using the Helium-level indicator during this process. When LHe level reaches 0% and pressure in the magnet stops rising, LHe removal is complete.
6) Disconnect CM1 cable from MJ1 and install breakout box cable to MJ1. Connect other end of cable to MJ1 breakout box connector on face of panel.
7) Continue with Magnet Warm-up Procedure by first loosening the A&N fitting on the LHe fill port and reinserting bottom fill stinger into bottom fill cup. Retighten fittings to prevent gas loss. Proceed to Section 3 step 3.


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