Tohoku Magnet Operating Procedures
November 7, 1984
Revision: March 6, 1985

Table of Contents

I. Establishing the System Insulating Vacuum

It is important to establish clean conditions in the system insulating vacuum. Normal residual contaminants will cryopump when the system is subsequently cooled, but poor performance of the insulating system can result; residual contaminants can also confuse subsequent diagnosis of the vacuum integrity of the system. Therefore, a pump-and-purge procedure, repeated as necessary, is specified to establish the cryostat insulating vacuum. The helium dewar, the nitrogen buffer dewar, and the coil cryostat all share a common vacuum, but are relieved in a redundant manner. An identical system is provided for each of the two magnet coils.

1. Verify that MV/RV-03-V, MV/RV-06-V, and MV-04-V are closed.

2. Attach a utility vacuum system capable of reaching 10 microns to MV/RV-03-V, and another to MV/RV-06-V if desired. An automatic solenoid valve or LN_2 trap shall be installed in between the vacuum space and the pump to prevent back migration of oil during power failures.

3. After the pump station vacuum has been established, MV/RV-03-V (and MV/RV-06-V if also pumped) are throttled open, and the magnet vacuum spaces are evacuated. Periodic backfilling with dry N_2 gas to ~2 psig and re-evacuation are recommended for the removal of moisture. The parallel plate reliefs (PP-01-V and PP-02-V) protect against overpressurization. Pumping and purging should continue until significant amounts of moisture are no longer collected in the oil.

4. When ~50 micons are achieved as indicated by PT-03-V and PT-06-V, valves MV/RV-03-V and MV/RV-06-V are closed. Pump out operators shall be physically removed.

5. If the vacuum starts to degrade substantially (e.g. rises 100 microns overnight) leak checking should be performed.

6. The utility vacuum station is then attached to MV-04-V, and the above pump-and-purge procedure repeated for this dewar neck vacuum space. Monitor the vacuum with PT-05-V. Close MV-04-V and cap.

7. Record all final vacuum levels achieved.

II. LN_2 System Cleanup

1. Verify the cryostat system vacuum has been established according to Procedure I.

2. Open valves MV-08-N, MV-09-N, and MV-10-N.

3. Close valve MV-07-N. EV-01-N should also be normally closed at this time.

4. Hook a utility vacuum pump to MV-07-N and establish a good vacuum.

5. Throttle MV-07-N open to pump out the LN_2 system.

6. Continue pumping until ~100 microns is achieved. Note that MV-08-N, MV-09-N, and MV-10-N are not "vacuum" grade valves and may leak slightly. Record the vacuum level achieved.

7. Close MV-07-N, MV-09-N, and MV-10-N. Remove the vacuum pump.

8. Attach a source of clean dry N_2 to MV-07-N regulated to less than 15 psig. Open MV-07-N to establish flow through CV-02-N. Next open MV-09-N and MV-10-N to backfill the system.

9. Close MV-07-N and remove the temporary piping.

III. LHe System Cleanup

1. Verify procedures I and II have been completed.

2. Install the LHe transfer line. Pump out the vacuum space on this transfer line to 50 microns, if the vacuum is in doubt and remove the pump out operator. Record the vacuum level achieved.

3. Close valves MV-01-H, MV-02-H, MV-11-H, and MV-12-H. Make sure that all ports on the top LHe dewar flange are tightly sealed.

4. Connect a utility vacuum pump with an automatic solenoid or LN_2 trap protection to valve MV-12-H.

5. Open MV-12-H slowly. Pump and purge as required to reach at least 250 microns and water is no longer accumulating in the pump oil.

6. Close MV-12-H and pressurize with clean dry nitrogen gas to 2 psig through valve MV-11-H.

7. Close MV-11-H.

8. In the event that LN_2 of the cooldown of the shield proceeds with the iron open, it is permissible to install the transfer line after the iron is back together. Simply istall the line with valve MV-02-H under a positive purge of nitrogen or helium gas.

IV. LN_2 Shield/Support Cooldown Procedure

The following items are cooled directly by introducing LN_2 into the LN_2 supply dewar:

1. Magnet and LHe dewar radiation shield.

2. All magnet horizontal and axial support posts (Randolite posts).

3. The magnet stainless steel vertical support arms.

4. LHe dewar neck heat intercept.

The liquid nitrogen is carried through stainless steel tubing which is connected thermally to all of the above through flexible copper battery cables. The liquid nitrogen shields are free to contract about their standoffs. This rapid cooldown of the system should pose no thermal stress problems. A thermal syphon technique is employed. One LN_2 line runs to the bottom of the magnet insulated as well as possible. The second line or the return line "picks up" virtually the entire heat load inducing boiling which causes a natural circulation to be set up due to the buoyancy difference between the lines.

1. Verify procedures I to III are completed.

2. Connect a 160 liter LN_2 supply dewar to EV-01-N through an insulated line. This dewar should be located on the floor not on the platforms.

3. Verify that EV-01-N is closed and blow down the line by briefly cracking the fitting at EV-01-N.

4. Close MV-10-N and MV-08-N. Open MV-09-N. This valve arrangement creates a forced flow situation which will be necessary to overcome the vapor locking of the system.

5. Turn on EV-01-N and continue filling until liquid has accumulated as indicated by liquid level probe LLT-03-N.

6. Return the LN_2 valves to their normal position; MV-08-N and MV-10-N open. MV-09-N closed.

7. Monitor and record the cooldown vs time. This should include the following.

   a) All ten chromel constantan T.C. wires.
   b) Axial position dial indicators.
   c) Coil resistance.
   d) LN_2 usage rate. A flow meter attached to MV-07-H may or may not work depending on the closure of the normal valve. CV-02-N.
   e) Vacuum levels, PT-03-V, PT-04-V, PT-06-V, PT-05-V.

8. This procedure may be carried out with the iron separated or together.

V. LN_2 Cooldown of the LHe System

As the system is presently configured there is no refrigerator provided for the magnet system. The system is designed to be precooled with LN_2 to save money although a direct LHe cooldown presents no additional problem. The savings in precooling is $5,000 to $8,000.

1. Verify that Procedures I through IV have been completed. Make sure that the LN_2 continues to be filled into the LN_2 system.

2. Close all helium flow meters (FI/MV-01-H, FI/MV-02-H, FI/MV-03-H, FI/MV-04-H, and FI-05-H). Close FI-05-H by setting PCV-01-H to its maximum relief setting.

3. Connect the temporary flow meter FI-06-H between MV-12-H and the 6" vent line.

4. Open MV-02-H and connect a 160 liter dewar under positive pressure to the LHe transfer line. The connection is with a surgical rubber hose. If a heavier wall hose is used (e.g. vacuum) a relief valve must also be used to prevent trapped volumes between the dewar's valve and MV-02-H.

5. Blow down the pressure in the dewer if it is excessive (i.e. > ~ 15 psig).

6. Open MV-12-H to monitor the cooldown.

7. Cooldown shall proceed at a rate of no more than 30 liter/hr of LN_2. This equals ~ 750 SCFH on flow meter FI-06-H. Blow down the dewar or pressurize with N_2 to maintain this flow rate. Open the dewar valve slowly to establish the correct flow. It is very important that cooldown does not exceed this rate to avoid thermal stress.

8. Monitor coil resistance to determine when the coil has reached LN_2 temperature. To monitor coil resistance one of the four power leads must be removed. As a precaution always short both sets of leads with the attached 100 Ω Dale resistors. Use the 30 volt/3000 Ω series power supply to monitor resistance. This will provide a 10 mA constant current. Resistance Ω = 100 x volts across the coil. Coil resistance will essentially stop falling at approximately 4.5 Ω. This will occur after roughly 700 liters have been transferred. Continue filling with LN_2 until the liquid level is up into the storage dewar by several inches. Do not exceed 12 inches. A 160 liter dewar will fill up the helium dewar by ~ 9 inches. The liquid nitrogen flow rate can be increased during this step if desired. Liquid level can be found with a wooden rod inserted into the dewar through one of the helium level probe ports. Record the amount of LN_2 added after a constant resistance is obtained and the final LN_2 depth. This will possibly eliminate the future need to measure the LN_2 depth.

9. Record the following

   a) Coil resistance and LN_2 consumption.
   b) Axial position dial indicators.
   c) Vacuum levels.

10. Disconnect the last LN_2 fill dewar.

11. Close MV-12-H.

12. Disconnect the temporary flow meter FI-06-H from both MV-12-H and the 6" vent. It is very important that FI-06-H be disconnected at both ends. Its pressure rating is only 35 psig.

13. Connect the small vent line from the outlet of FI-06-H to the liquid helium transfer line. All LN_2 will, therefore, be vented outside through the 6" pipe.

14. Make sure that the transfer line is seated properly.

15. Pressurize the helium dewar with N_2 gas through valve MV-11-H to drive all the LN_2 out.

16. Disconnect the small vent line and plug the opening into the 6" pipe.

17. Connect a source of dry N_2 gas to the LHe transfer to vaporize any remaining LN_2 that can't be forced out from the bottom of the magnet.

18. Close MV-02-H.

19. Attach a vacuum pump with an automatic solenoid valve or cold trap and pump to MV-12-H out the LHe system. Pump out the system to at least 500 microns as read on the thermocouple gauge PT-07-H. LN_2 freezes at $63^{\circ}K$ and 93 torr. At $52^{\circ}K$ solid nitrogen still has a vapor pressure of 5700 microns. It is crucial that all LN_2 must be removed.

20. If 500 microns cannot be achieved within a couple hours, the system has leaks or nitrogen remains. Check for leaks and repeat the above procedures until adequate pump down is obtained.

21. Close MV-12-H and remove the vacuum pump.

VI. LHe Cooldown

1. Verify procedures I through V have been completed.

2. Pressurize the system to 1 psig with He gas through MV-11-H.

3. Open MV-02-H.

4. Under a positive purge insert the helium transfer line into a 1000 liter LHe dewar and then close MV-11-H.

5. Open all flow meters on the control panel, (FI/MV-01-H, FI/MV-02-H, FI/MV-03-H, FI/MV-04-H, and FI-05-H).

6. Transfer at a 4 psi difference between the fill dewar and the storage dewar. This rate is approximately 250 liter/hr. Open MV-01-H if required to reduce the pressure.

7. Continue filling with additional dewars until the storage dewar is full. To change dewars close MV-02-H. Remove supply dewar. Crack MV-02-H for a positive purge and insert transfer line into new dewar. Fully open MV-02-H. Make sure that the supply dewar pressure is 4 psig greater than the storage dewar pressure. Use this procedure for any fixture filling.

8. Install the braces for the helium transfer lines. This will ensure that the transfer lines have been lifted and do not block the magnet LHe flow.

9. Monitor and record the following

   a) Helium usage.
   b) Flow rates.
   c) Coil resistance.
   d) Vacuum.
   e) Thermocouple wires.
   f) Unusual conditions, cold spots, pressure oscillations, etc.

VII Coil Energization

(Note that steps enclosed in double brackets pertain to initial charge up).

1. Verify that procedures I through VI have been completed.

2. Verify that the ground strap from the magnet and from the center tap of the dump resistor are in place and properly connected.

3. Open the dump resistor, disconnect the center tap ground at the dump resistor, and check the resistance to ground first with a VOM and then with a Hipot tester. Connect the tester to a magnet lead and to the adjacent helium storage dewar. Charge the system to 700 V and record the leakage current. It should not exceed 2 μ amperes; in the event that it does, take steps to correct the condition. Likely sources of ground current frost around current leads or instrumentation connectors, etc.

   When the hipot test is satisfied, reconnect the center tap ground.

4. Inspect the high current cable connection at the magnet terminals for proper polarity, and at the dump resistor terminals for integrity.

5. Verify that the instrumentation connectors on each coil are properly made up.

6. Power up the "Auxiliary Power Supplies" chassis at the magnet control console. Put the control in "local", and power up the system power supply.

7. Verify that the system storage dewar pressures are stabilized at 3 psig or less, and establish the lead flow at 40 scfm or greater.

8. Make up any interlocks that remain in trip status as indicated on the "Magnet Control Unit chassis" press "Reset" to clear the respective red LED after an interlock has been satisfied.

9. Operate the "emergency off" button and verify the trip status.

10. Throttle each lead flow in turn to 30 scfm and verify that each causes the proper trip. Note it takes a few minutes for each low flow condition to cause a trip since the time response of the flow meter interlock circuit is not immediate. After each flow trip is checked, reset to 40 scfm or greater.

11. Verify that the four magnet lead voltage analogue/trip meters are set at the specified trip levels: $\pm$ 40 mV for the upper and $\pm$ 20 mV for the lower lead voltages.

12. Verify that the magnet current trip point is set to $\pm$ 700 amperes.

13. Dial the magnet current ("P.S. Set Current") to 100 amperes and press the "on" button on the control unit.

14. While the magnet is charging, observe the lead voltages and magnet current on the analogue/trip meters.

    Monitor and log all the system parameters on the Magnet Control Unit rotary switch.

    When the set current is reached, make an inspection of the dump resistor and the system helium dewars on the magnet platform.

    ((Log the cold mass support strain gauges and the axial position dial indicators. Measure and log the central magnetic field.))

    Press the "emergency off" button and allow the magnet to discharge. Record the dump resistor temperature after the coil is discharged.

    ((During the discharge record on a chart recorder the discharge voltage, the voltage from the center tap to ground, the coil unbalance voltages,

and the coil current vs time. Inspect the dump switch and the magnet platform area after the magnet is discharged.))

15. ((Increment the magnet current 100 amperes and repeat step 14. Repeat this cycle until 700 amperes is reached, and the final magnet discharge is completed.))

16. Set the magnet current to 700 amperes and allow the magnet to charge to operating current. During the charge up period, log the system parameters indicated in step 14.

VIII System Warm Up and/or Iron Movement

1. The magnet system is designed to be moved cold. However, LHe should be removed and replaced with LN_2. Do not exceed the 12" depth rule required in the LN_2 cooldown section.

2. Before separating the iron by any amount, disconnect the interconnecting power cable. This will prevent accidental charging of the magnet and crushing anything in between. Always short both sets of power leads through the 100 Ω Dale resistors mounted on each dewar current lead flag pair before disconnecting any power cable. This protects against electrical shock from residual current of the exponential discharge.

IX Emergency Procedures

1. LN2 System

   For any unusual problem such as a pressure greater than 20 psig or LN2 spraying out of a valve, shut off the LN2 source at the supply dewar. With current in the magnet discharge the coil if the problem cannot be solved in 5 minutes. This serves as a precaution. The high flow interlock will normally cause a trip. Investigate before proceeding.

2. LHe System

   For any unusual problem such as a rapid pressure rise, press the magnet dump switch. Investigate before proceeding. In case of a massive quench immediately leave the area surrounding the magnet especially the upper platform. Evacuate all remaining Lab F and Lab E personnel if required.

3. Vacuum System

   If the pressure rises to > 50 microns when the system is at LHe temperature, press the magnet dump switch. Investigate before proceeding. If the pressure rises to 1 atm such that cold gas is escaping from the parallel plate reliefs or pump outs, immediately leave the building. Evacuate all remaining Lab E and Lab F personnel by

communicating through downstream doors. Do not reenter the building. Call the Fire Department.