TATE

OPERATING INSTRUCTION MANUAL
FOR
SUPERCONDUCTING MAGNET SYSTEM

DESIGNED AND MANUFACTURED
FOR
OREGON STATE UNIVERSITY

Serial # C294M

BY
CRYOMAGNETICS, INCORPORATED
P. O. BOX 548
739 EMORY VALLEY ROAD
OAK RIDGE, TENNESSEE 37831-0548
(~~615~~ 865) 482-9551

1006 Alwyn Dr.

WARNING: DO NOT ATTEMPT TO OPERATE THIS EQUIPMENT BEFORE THOROUGHLY READING THESE OPERATING INSTRUCTIONS.

TABLE OF CONTENTS

LIST OF OPERATING MANUALS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The purpose of this operating instruction manual is to familiarize the equipment user with the following:

a) System Design Specifications

b) System Description

c) System Operating Procedures

d) System Safety Precautions

UNDER NO CIRCUMSTANCE SHOULD THIS SUPERCONDUCTING MAGNET/CRYOSTAT SYSTEM BE OPERATED BY PERSONNEL WHO HAVE NOT FIRST READ THIS INSTRUCTION MANUAL IN ITS ENTIRETY.

2.0 SYSTEM DESIGN SPECIFICATIONS

This superconducting magnet system was specifically designed in accordance with the following requirements. Any use of applications of this equipment outside of these design parameters is neither intended nor recommended.

TABLE 2-1 SYSTEM DESIGN SPECIFICATIONS

A. Superconducting Magnet	Custom Solenoid
Manufacturer	Cryomagnetics, Inc.
Model	Custom
Rated Central Field	90 kilogauss at 4.2K
Homogeneity	+/-0.1% over a 1 cm DSV
Rated Operating Current (9.0 tesla)	76.44 amperes
Total Inductance	9.9 henries
Superconductor	Twisted Multi-filamentary NbTi/Cu
Fabrication	Epoxy impregnated to prevent training
Quench Protection	Adiabatic protection using Cu matrix and diodes
Persistence	Persistent switch installed on magnet. Switch heater operating current: 55 mA

→ defeats operation at LN_2 temp

→ quench protection diodes inhibit possibility of operating magnet at LN_2 temp. Diodes turn on at 3-6V + if $R \sim 1\,k\Omega \Rightarrow I < \frac{6}{1500} \approx 0.004\,A$

B. Magnet Power Supply	1 each
Manufacturer	Cryomagnetics, Inc.
Model	IPS-100
C. Magnet Support Assembly	1 each
Manufacturer	Cryomagnetics, Inc.
Model	Custom
D. Cryostat	1 each
Manufacturer	Janis Research Co.
Model	7RD
E. Variable Temperature Insert	1 each
Manufacturer	Cryoindustries
Model	Custom

F. Helium Level Sensor	1 each
Manufacturer	Cryomagnetics, Inc.
Model	3D-080
G. Temperature Controller	1 each
Manufacturer	Lakeshore Cryotronics
Model	DRC-91C

3.0 SYSTEM DESCRIPTION

This superconducting magnet system consists of the following elements which will be discussed individually:

a) Superconducting Magnet
b) Cryostat
c) IPS-100 Power Supply
d) Persistent Switch and Heater Supply System
e) Helium Level Sensor
f) Magnet Support Assembly
g) Electrical Connections

3.1 Superconducting Magnet

The custom designed 9.0 tesla at 4.2K superconducting magnet is optimized for 0.1% homogeneity over a 1 cm diameter spherical volume. The magnet has been thoroughly tested by Cryomagnetics. The final test results are indicated in Table 3-1.

The superconducting magnet was built using twisted multifilamentary NbTi wire in a copper matrix. The coil is completely epoxy impregnated to prevent training. The copper matrix used in the wire acts as a form of quench protection along with diodes.

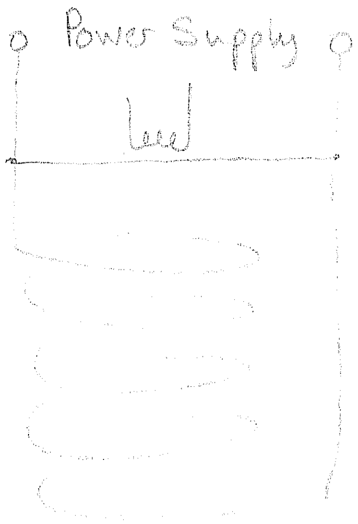
TABLE 3-1

Magnet Specifications

Oregon State University
December 21,1990

Rated Central Field	90 kilogauss at 4.2K
Maximum Test Field	93.1 kilogauss at 4.2K
Rated Current (90 kilogauss)	76.44 amperes
Inductance	9.9 henries
Homogeneity	+/-.1% over 1 cm DSV
Field to Current Ratio	1177.4 gauss/ampere
Charging Voltage	1 volts
Persistent Switch Heater Currents	55 milliamperes

2" - bore? 2.5"?



3.2 Cryostat

The liquid helium cryostat is a nitrogen shielded bucket style. It is of all stainless steel construction manufactured by Janis Reseach Company.

3.3 Magnet Power System

The magnet power supply consists of a Cryomagnetics' Model IPS-100 power supply and all required protection devices, cables, and interconnecting hardware.

The IPS-100 power supply is capable of providing +5 to -5 volts at 0-100 amperes. Detailed instructions can be found in the IPS-100 manual.

3.4 Persistent Switch and Heater Supply System

The superconducting magnet has a persistent switch installed. The persistent switch heater supply is located in the IPS-100 power supply. See the IPS-100 manual for more instructions.

3.5 Helium Level Sensor

A helium level sensor is mounted on the magnet support assemby to monitor the helium level. The sensor active length is 80 cm long. This sensor can be used with any Cryomagnetics helium level readouts.

3.6 Magnet Support Assembly

The magnet support assembly consists of all hardware required to suspend the superconducting magnet from the top of the cryostat. It houses all interconnects required for proper operation of the magnet system.

Helium vapor-cooled current leads are required to introduce the fairly high currents used by the magnet to the cryogenic environment. The leads are used to provide an efficient means of traversing the roughly 300 degree temperature differential from room temperature to 4.2K. Vapor cooling of the current leads minimizes the heat loss of the input power cables to the LHe bath. Your system will usually be provided with leads that have a rating of 25 to 100 amps depending on the superconducting magnet and the control system power supply. The maximum rating of the current leads is stamped on the top of the leads. A manifold with a pressure relief valve is located on top of the current leads. This is needed when a variable temperature insert is used. Another relief valve is located on the top plate. These two valves should have helium gas flow when operating the system. If not see Figure 3-2 on how to adjust them. They should be set for approximately 1-2 psi.

Copper radiation baffles are mounted on the fiberglass support tubes and are necessary to reduce the radiative heat load on the LHe bath. The baffles form a fairly tight fit along the inner wall of the cryostat in order to force the helium gas to utilize its maximum cooling capabilities on them.

Helium fill and vent ports are provided on the top plate of the support assembly. A large quench relief valve is also located on the top plate. This will usually blow off if the magnet is quenched causing a rapid boil-off of liquid helium. This is a safety device and should NEVER be "tied down".

A 19 pin electrical connector can be used for feed through of electrical signals such as are required for liquid helium level sensing or magnet charging voltage sensing. Table 3-2 contains any pin assignments which may have been installed by Cryomagnetics during system construction. Note that several pins are available for use applications. See Figure 3-1 on magnet installation on the support assembly.

3.7 Electrical Connections

The pin designations for the 19 pin connector are found in Table 3-2. This connector contains all electrical contacts to the magnet and system monitoring components within the liquid helium vessel.

TABLE 3-2

WIRING DIAGRAM

19 PIN CONNECTOR	CONTROL CABLE WIRING	ELECTRICAL CONNECTIONS
A	TAN	PERSISTENT SWITCH HEATER blck @mag
B	PINK	PERSISTENT SWITCH HEATER red @mag
C	ORANGE	MAGNET VOLTAGE TAPS blue @ magnet
D	VIOLET	MAGNET VOLTAGE TAPS yellow @magne
E	WHITE/YELLOW	I+ HELIUM LEVEL SENSOR
F	WHITE/BLUE	I-, V- HELIUM LEVEL SENSOR
G	RED	V+ HELIUM LEVEL SENSOR
H	WHITE/GREEN	
J	WHITE/BLACK	
K	BLUE	
L	RED/BLACK	
M	RED/YELLOW	
N	RED/GREEN	
P	GREEN	
R	GREY	
S	YELLOW	
T	BROWN	
U		

TABLE 3-3
WIRING DIAGRAM
VARIABLE TEMPERATURE INSERT

10 PIN CONNECTOR	CONTROL CABLE WIRING	ELECTRICAL CONNECTIONS
A	RED	I+ TEMPERATURE SENSOR
B	BROWM	I- TEMPERATURE SENSOR
C	GREEN	V+ TEMPERATURE SENSOR
D	BLUE	V- TEMPERATURE SENSOR
E		
F		
G	WHITE	HEATER
H	BLACK	HEATER

TEMPERATURE SENSOR ON SAMPLE MOUNT - SERIAL # C10465

TEMPERATURE SENSOR ON VAPORIZER - SERIAL # C10468

Cable 1 : T_A

5-pin amph. →	10-pin.
A	A
B	B
E	~~Z~~C
D	D
H	—
heater red	G
blk	H

Cable 2 : T_B

5-pin amp →	10 pin
A	A
B	B
E	C
D	D
H	
heater red	G
blk	H

4.0 MAGNET SYSTEM OPERATING PROCEDURES

The Cryomagnetics, Inc. superconducting magnet/cryostat system will give many years of trouble free rewarding service, if the proper operating instructions as contained in this manual are followed.

4.1 Preparation for Cooldown

Most dewars are shipped with the vacuum space evacuated and should not need evacuating. This is a result of the final testing at the factory, and it helps ensure a clean vacuum space. If the system needs evacuating the following procedure should be followed. This is best done with a good pumping station (e.g. a cold - trapped rotary/diffusion pumping station) capable of bringing the ultimate pressure down to approximately 10^{-5} Torr. Any inserts with independent vacuum jackets must also be evacuated at this time. An engineering drawing showing the details of your system is enclosed for your reference.

Every vacuum jacket is protected against cold leaks with a pressure relief valve which will vent any pressure that exceeds 2 to 4 psig. This pressure relief is usually located on the evacuation valve or the side of the dewar.

The evacuation valves supplied for the dewar and insert vacuums (optional) are mostly of the bellows sealed type. After evacuating the jacket, the valve should be firmly closed, but care should be exercised to avoid damaging the seat with too much pressure.

When evacuation of the (dewar or insert) jacket is initiated, always be sure that the pressure on the pump side of the evacuation valve is lower than the jacket pressure. This is done to avoid drawing oil vapor from the pump into the vacuum jacket. Thus, one should not pump the vacuum jacket while liquid helium is in the dewar, since liquid helium will usually cryopump to a lower pressure (10^{-5} Torr or less) than the pumping station in use.

CAUTION: NEVER PUMP ON THE HELIUM RESERVOIR UNLESS THE DEWAR IS UNDER VACUUM. THIS COULD RESULT IN MAJOR DAMAGE (COLLAPSE) TO THE DEWAR AND THE ENCLOSED MAGNET.

4.2 Cooldown Procedure

1) General

Before introducing any liquid cryogens into the dewar, check carefully for water in both the nitrogen and helium reservoirs. This is particularly important for dewars with an open nitrogen reservoir, due to condensation on the walls during warm up from a previous run. If not removed, this water will freeze upon cooling, and could cause severe damage to the dewar, magnet and any cryostat insert.

If possible, one should evacuate the helium reservoir (with the dewar jacket under vacuum - see last caution) in order to remove all the air, and then back fill with helium gas. Similar procedures will also be necessary for any cryostat inserts present in the system. Such procedures will be described in the enclosed description for the insert (e.g. "SuperVaritemp" System Operation). In either case, one should at least purge the helium space thoroughly with helium gas, and isolate it with one-way valves (e.g. pressure relief) to prevent air from entering back into this space.

2) Liquid_Nitrogen_Transfer

(a) Nitrogen Reservoir

The nitrogen reservoir should now be filled with liquid nitrogen. If an automatic device is supplied, check the instructions for this device. Otherwise, maintain a steady flow of liquid into the reservoir, but not so fast that a large spattering occurs. It is always advisable to maintain the liquid nitrogen level as high as possible, since the efficiency of some dewars will decrease rapidly when the nitrogen level drops far below the top of the reservoir. Open nitrogen reservoirs should always have a cover flange (usually an aluminum/styrofoam flange is supplied) on top of the reservoir. This will reduce consumption of liquid nitrogen as well as the amount of condensation build-up around the top of the dewar.

(b) Helium Reservoir

It is very important to cool the helium reservoir, the magnet and any cryostat insert to as close to liquid nitrogen temperature as possible. This must be done to conserve the amount of liquid helium necessary for final cooldown to 4.2K. This can be done in one of two ways.

The first method involves direct transfer of liquid nitrogen into the helium reservoir. This is the faster method, and could take from one to several hours to cool the magnet/cryostat assembly to 77K. The temperature may be monitored by a thermometer inside the reservoir, or judged by the amount, or lack of boiling, of the liquid nitrogen. When cooled, the helium reservoir must be emptied completely by either blowing or siphoning the liquid nitrogen out.

CAUTION: REMOVE ALL LIQUID NITROGEN FROM THE HELIUM RESERVOIR PRIOR TO TRANSFERRING HELIUM.

The helium reservoir should be evacuated and back filled with gaseous helium. The pressure inside the helium reservoir must drop to about one Torr. Should the pressure remain higher (about 90 Torr), this may indicate the presence of liquid (or frozen) nitrogen in the helium reservoir. The blowing (or siphoning) and pumping procedure should be repeated to ensure that all the nitrogen has been replaced by helium (gas).

The second method of cooling the helium reservoir (and its contents) to nitrogen temperature is to fill the nitrogen reservoir with liquid nitrogen, while maintaining an overpressure of helium gas in the helium reservoir. A combination of radiational and conductive cooling will eventually cool the helium reservoir close to nitrogen temperatures. This process will take at least overnight, and possibly up to several days (in bigger units) for the helium reservoir/magnet/insert to cool down. If an over pressure of helium gas is not used, one should seal the reservoir (after purging it with helium gas) with a one way valve to prevent air from entering when the temperature (and the pressure) of the helium reservoir drops.

For either of the two methods above, any cryostat insert in the helium reservoir must be at least thoroughly purged with helium gas.

3) Liquid_Helium_Transfer

In many cases, a liquid helium transfer line is supplied with the system, with a built-in "initial fill" adapter in the helium reservoir. The purpose of such an adapter is to bring the liquid helium entry point below_the_magnet during the initial helium fill or your system may have a straight access to the bottom of the dewar. On the cool-down the transfer line should go to the bottom for a efficient transfer. The transfer should start at a steady slow rate in order to make full use of the cooling power of the cold helium vapor as it rises and escapes through the helium vent tube(s). This rate should be maintained for at least 5-10 minutes, and the temperature inside the reservoir monitored carefully (if this option is included). When the temperature inside the reservoir drops to approximately 10K, the liquid helium transfer rate should be increased, and the helium level monitored through any supplied level probe. The amount of liquid helium needed will be a function of the size of the reservoir, the coil, as well as the efficiency of the transfer. About five liquid helium liters, plus one liter per five pounds of magnet is required to cool the reservoir and magnet from 77 to 4.2K. This, along with the overall capacity of the helium reservoir, should offer a rough figure for the amount of liquid helium required for initial cooldown.

When the helium reservoir is full, all entrances into the reservoir should be sealed, except for the vapor cooled high current magnet leads. This will cause the dewar boil-off to vent through the leads, thereby intercepting most of the heat load that such leads bring into the helium reservoir. This is particularly important when large currents are passing through the leads. Also a small relief on the top plate should be venting at the same time as the current leads, this cools the neck of the dewar. These relief valves are adjustable so that both valves can be set to vent at the same time (see adjustment instructions amended to manual).

It is good procedure to maintain the liquid helium level above the coil at all times. This is absolutely necessary when a current is passing through the superconducting coil in order to prevent a magnet quench and possible damage to the coil. With this in mind, any subsequent liquid helium transfers should be made above the level of the remaining liquid in the helium reservoir. This can be done without the initial fill line (if supplied), or simply by keeping the tip of the transfer line above the remaining liquid.

4.3 Superconducting Magnet Operation

1) General Precautions

During the operation of any superconducting magnet system, certain hazards to the operator and the equipment exist, and should be noted. The following precautions should therefore be taken before any attempt is made to charge the magnet:

Remove (or tie down) any objects (tools, screws, etc.) that could be magnetized and attracted to the magnet when the field is turned on. Also remove any personal articles such as watches or credit cards that could be affected by intense magnetic fields. This is particularly important in large coils and units with a room temperature bore.

Make absolutely sure that the liquid helium level is above the superconducting coil before the field is turned on, and throughout the whole time that current is passing through the coil. Failure to do so may result in a magnet quench (sudden loss of field associated with the coils going "normal") that could damage the coil. Also, any quench relief (usually located at the helium reservoir pumping arm or on the top plate) should be checked for proper operation, in order to protect the dewar and operator in the unlikely event of a magnet quench.

Exercise extreme care when handling the power circuit for the magnet. In particular, never disconnect the power supply from the circuit while it is providing a current to the magnet. A lethal voltage can immediately develop at the terminal being disconnected. This is due to the large change in flux and associated large emf that can develop when a sudden interruption of the current (and magnetic field) occurs. The proper procedure for handling the magnet power circuit will be detailed below.

$$y(T) = \frac{8T}{67.91(A)}(xA)$$ 11

2) Charging the Magnet

The following procedure assumes that only a magnet power supply is provided with the system, and that a low resistance standard shunt (e.g. 100 ampere, 100 millivolt) is connected in series with the power supply/magnet circuit. The shunt enables accurate monitoring of the current in the circuit by monitoring the voltage across this shunt. When a programmer (or a programmable power supply) is also provided, check the enclosed manual for any modification in the charging procedure.

1) Check the enclosed magnet specifications and note the rated field, 9T the rated current 76.44A at that field and the recommended charging voltage. ~~[illegible]~~ [illegible] 1V Also check whether a persistent current switch is supplied at the coil. Yes Never exceed the rated current indicated in these specifications. In rare cases one current may be rated at 4.2K, and a higher one at lower temperatures.

2) Make all the necessary electrical connections according to the enclosed pin wiring diagrams. These could include the persistent switch heater, ✓ magnet voltage taps, ✓ magnet current, etc., in addition to the main magnet leads and any other sweep or secondary coils supplied. Particular importance should be given to the higher current magnet circuit, where any loose contacts could result in dangerous overheating during the current flow.

3) Make certain that the liquid helium level is above the 60% superconducting coil, and preferably up to its highest recommended level.

4) Make certain that the helium reservoir is vented through the vapor cooled high current magnet leads. This flow should be

periodically checked throughout the experiment to ensure proper cooling of these leads.

5) Turn the persistent switch heater power supply on, to change the persistent switch to its "normal" mode (if the system includes such a switch).

6) Close the line switch for the magnet power supply, with both the current and voltage limits set at zero.

7) Set the current limit to a value equal or less than the rated magnet current. This is best done by initially shorting the high current cables before attaching them to the magnet leads on top of the cryostat. The current limit can now be set to any desired value, and the position of the (current) indicator noted for later reference. Thus, the same current limit can be set after the power supply is connected to the magnet leads.

8) Start charging the superconducting coil b~~e~~y setting the voltage limit to the recommended charging voltage. The current will now start to increase at a rate determined by the charging voltage, in inductance of the coil, the lead resistance, the (protective) diode (across the output terminals of the power supply) voltage, and any additional diodes' voltage that might be supplied as part of an (optional) energy absorber. Systems with a programmable power supply, or an electronic programmer will have an accompanying manual that describes the charging procedure to be followed.

9) Once the current limit is reached, the voltage across the magnet will approach zero. Fine adjustments of the current may then be slowly made to obtain a precise magnet current (and

field).

10) For magnets with a persistent current switch, the switch heater power supply may now be turned off to bring the switch to its superconducting mode. The current in the coil will now flow in a closed (superconducting) loop, and the current passing through the magnet leads may now be reduced to zero in order to eliminate Joule heating in those leads. This is done by ramping the supply's output current down to zero and switching the power supply off. The current in the leads will drop to zero. *Do not change the setting on the current limit and do not disconnect the power supply from the circuit unless removable current leads were provided with the system (see section 4-4)*.

If the persistent switch needs to be turned back to its "normal" state (e.g. for changing the field), the magnet power supply should first be turned back on (if it was turned off), and the power supply's output current should be set back to its original value (if it was ramped down). With the current limit unchanged, the last current that flowed through the circuit should once again pass through the leads. Only at this point should the persistent switch heater power supply be switched on to change the persistent switch back to its "normal" mode. This interrupts the closed superconducting loop in the coil, and brings back the power supply and magnet leads into the same circuit as the coil.

11) To reduce the field to any level below the operating level, one can *very slowly* reduce the current limit in order to avoid a magnet quench. The voltage across the coil will reverse

its polarity due to the back emf of the coil.

An alternate method is to switch the power supply to ramp down and observe the current decay in the circuit. This can be followed by a slow decrease in the current limit to the approximate value desired, then a resetting of the ramp to UP. The power supply will then ramp UP to the new current limit and stop.

12) To discharge the coil, the power supply should be ramped down to zero. The voltage across the coil will once again reverse polarity during the discharge, and the current will decay to zero.

CAUTION: DO NOT DISCONNECT THE POWER SUPPLY FROM THE CIRCUIT AS LONG AS ANY CURRENT IS FLOWING. A LETHAL VOLTAGE CAN OTHERWISE DEVELOP AT THE TERMINAL BEING DISCONNECTED.

13) Once the current drops to zero, all power supplies can be turned off (not disconnected), and the system allowed to warm up gradually to room temperature. Should the power supply have to be disconnected from the circuit while the coil is superconducting (with the current apparently zero), a low resistance shunt should be connected across the magnet high current terminals before disconnecting the leads. This shunt must be kept in place until the coil turns "normal". Once the coil is "normal", it is then quite safe to disconnect the power supply or cables from the circuit. Any safety pressure relief valves should be kept in position to allow venting of the cryogen gases as the dewar warms up, and prevent any air or moisture from condensing inside the dewar.

4.4 Troubleshooting

All power supplies and other electronic components supplied as part of your superconducting magnet/cryostat system have their accompanying manuals. The operator should always refer to these manuals for proper operating procedures, and in case of any difficulties with these parts.

Should any difficulty arise with the dewar or superconducting coil supplied, it is recommended that you contact Cryomagnetics before any repair work is undertaken. In addition to the description of the difficulty, it is always helpful to obtain the model and serial number of the system in question.

5.0 VARIABLE TEMPERATURE OPERATION

5.1 Evacuate Dewar and Insert

A recommended practice is to evacuate the dewar and insert assembly, with a high vacuum type pumping system, prior to use. Since high vacuum systems are not always available, a mechanical (roughing) pump may be used.

5.2 Evacuate Sample Tube

Attach a mechanical (roughing) vacuum pump to the vapor pumping port located at the top of the cryostat. Continue to evacuate the sample tube until variable temperature operation commences.

5.3 Check Flow Conductance

Open the helium throttle valve by turning counter-clockwise the flow valve operator. Your roughing pump should indicate a flow of air to the sample chamber. The sound made by the pump is commonly referred to as a "gurgle". The gurgle indicates a non-contaminated flow system is present before cooling. CLOSE THE THROTTLE VALVE "FINGER" TIGHT, IMMEDIATELY AFTER OBSERVING AN OPEN CONDITION (DO NOT OVERTIGHTEN).

5.4 Precool Cryostat

Make sure that the pressure regulator vent manifold assembly is installed on the high current leads. Fill the helium reservoir with liquid nitrogen to a level between 6 - 12 inches above the magnet. Fill the outer reservoir with liquid nitrogen. Wait for a period greater than 30 minutes for maximum cooling of the magnet and liquid helium reservoir to occur. Efficient precooling will minimize liquid helium consumption during transfer.

Helpful notes: 1) For convenience, many customers prefer to remove one-half of the foam backed nitrogen cover from the dewar while filling; this greatly increases the access for filling and the observability of the liquid level. Replace the cover after filling to reduce condensation in the reservoir section.

2) A small diameter (.09 - .125 inch) clear plastic (lucite) rod makes a handy economical liquid nitrogen level indicator. Insert the rod into the helium reservoir through an access port. Upon reaching the bottom, pause for approximately 5 seconds. Remove the rod and wave it back and forth in the air. The initial frost formed on the rod will indicate the level of liquid nitrogen in the dewar.

5.5 Check Flow Conductance

Open the helium throttle valve by turning counter-clockwise the flow valve operator. Your roughing pump should indicate a flow of liquid nitrogen to the sample chamber. The gurgle indicates an open flow system is present cold, i.e. nothing has frozen in the valve, helium capillary, and heat exchanger. CLOSE THE THROTTLE VALVE AFTER OBSERVING AN OPEN CONDITION.

5.6 "Blow Out" the Liquid Helium Reservoir

Remove the liquid nitrogen from the liquid helium reservoir. Insert a tube through the fill port to the bottom of the reservoir and seal it so that a small pressure (approximately 2-3 psi) can be applied above the liquid in the reservoir. Pressurize the reservoir with helium gas. The liquid nitrogen will be "blown out" of the tube. In order to remove all of the nitrogen from the reservoir, it may be necessary to hold the vapor-cooled current leads off-gas manifold pop-off shut to obtain sufficient pressure in the reservoir. Try to assure that all liquid nitrogen is removed. Leave the reservoir back filled with helium gas.

5.7 Check Flow Conductance

Open the helium throttle valve. Your roughing pump should indicate a flow of helium gas to the sample chamber. The gurgle indicates an open flow system is still present; further, the entire sample tube will be purged with helium gas which should prevent any non-desirable freezing from occurring. CLOSE THE THROTTLE VALVE AFTER HEARING THE "GURGLE".

5.8 Fill the Helium Reservoir

Assure that the liquid nitrogen is full. If the dewar does not yet contain liquid helium, the transfer line should reach to the bottom of the magnet so that the enthalpy of the helium gas can assist in cooling the magnet. Fill the helium reservoir to the desired volume of liquid helium. At least _____ cm of liquid helium is required in the system to cover the helium inlet valve. During the transfer, it is recommended that the flow conductance to the sample tube be re-checked. This assures that the entire variable temperature system remains open to the proper helium flow.

Helpful notes: 1) The pumping arm is an ideal vent path for the gas during transfer. Loosen the relief flange on the pumping arm during transfer.

2) During a refill, WHEN THE SYSTEM ALREADY CONTAINS LIQUID

HELIUM, position the transfer line above the liquid so that the initial warm gas will not consume liquid helium. If possible, allow the liquid helium to begin exiting the transfer line before it is inserted into the dewar.

5.9 Initiate Pressure Regulation

After the completion of the liquid helium transfer, seal all helium access ports. The pop-off valve located on top of the high current leads will maintain the positive pressure needed to drive the liquid helium into the heat exchanger and sample tube and assure venting through the high current leads. All other helium ports should be stoppered or sealed so that no venting can occur elsewhere.

Helpful note: A heat gun is handy for removing any frost that has formed on any of the ports during transfer.

5.10 Maintain Liquid Nitrogen Level

For maximum efficiency, maintain the liquid nitrogen level above the thermal anchor flange inside the nitrogen reservoir.

5.11 Sample Cool Down

Valve off the mechanical pump which is pumping on the sample tube. Open the helium flow valve operator approximately two-four turns. When the pressure in the sample tube is equal to atmospheric pressure vent the sample tube to the air or a helium recovery system. The heat exchanger and sample tube will cool down. Liquid helium will collect in the sample tube in a short time (approximately 5 minutes).

5.12 Variable Temperature Operation

After sample cool down, the flow valve operator should be rotated to approximately one-half turn open. Attached a temperature controller or power supply to the electrical feedthru wired to the heat exchanger and located on the insert assembly. In general, the power to the heat exchanger should be set to 200 mw which will result in a sample temperature of approximately 8 - 10 K; the flow control valve should be fine adjusted until the sample temperature is between 8 - 10 K. Henceforth, the temperature can be varied from 5 - 300 K by adjusting only the power input to the heat exchanger! ONCE SET, IT IS NOT NECESSARY TO ADJUST THE FLOW VALVE OPERATOR.

Helpful note: Unfortunately, system parameters, such as sample tube size, radiative and experimental heat inputs, mass of sample, and window mounts, etc., vary thus, the exact setting of the most efficient helium flow should be experimentally determined for your condition.

5.13 Operation Below 4.2K

Two modes of operation are possible below 4.2K - (a) sample in vapor and (b) sample in liquid.

(a) Re-attach the mechanical pump to the sample tube. Close the helium flow valve operator. After evacuating the sample tube, open the flow control valve approximately one-quarter turn. Continue to pump on the sample tube. Fine adjust the flow requirement so that your lowest desired temperature is reached. The temperature of the sample zone can be adjusted from this minimum to approximately 20K by heat input to the heat exchanger alone. This method does limit the lowest achievable temperature of the system.

(b) Turn off any heat exchanger power. Open the flow valve operator two - three turns. The sample tube will fill with liquid helium, AFTER WHICH THE FLOW VALVE SHOULD BE CLOSED. Pump on the sample tube. The roughing pump will bring the system to the lowest possible temperature.

5.14 Sample Change

Quick change of samples are a standard feature of your system. No warming of the dewar is required. Simply remove the sample positioner from the top of the cryostat. When ready, re-insert the sample positioner with the new sample. Do not remove the sample while the temperature is less than 4.2K. During the time the sample positioner is removed from the system, the flow of helium to the sample tube should be maintained; this will prevent any freezing of air in the sample tube. Alternately, when the sample positioner will be removed for long periods, install a sealable blank cap on top of the sample zone; close the flow valve operator; evacuate the sample tube. REMEMBER to return the sample zone to a positive pressure before removing the blank cap.

5.15 Shut Down

1) Turn off all power to the heat exchanger. 2) Shut the flow valve operator. 3) Continuously evacuate the sample zone until the dewar returns to room temperature. If it is not possible to continue operating the mechanical pump; seal off the sample zone. The system will vent, as it warms, through the positive relief valve which protects the sample tube.

6.0 SYSTEM SAFETY PRECAUTIONS

CAUTION

6.1 NEVER DISCONNECT THE CURRENT LEADS WHEN THE MAGNET IS CHARGED A POTENTIAL FATAL VOLTAGE (KILOVOLTS) WILL OCCUR THAT CAN CAUSE SEVERE INJURY OR DEATH.

6.2 NEVER TOUCH THE CURRENT LEADS WHILE THE MAGNET IS ENERGIZED. ALWAYS USE A 30 KV INSULATED TOOL.

6.3 NEVER OPERATE THE MAGNET WITH INSUFFICIENT LIQUID HELIUM LEVEL.

6.4 NEVER OPERATE THE VAPOR COOLED CURRENT LEADS WITHOUT HELIUM GAS FLOWING.

7.0 LIMITED WARRANTY POLICY

Cryomagnetics warrants its products to be free from defects in materials and workmanship. This warranty shall be effective for one year after the date of shipment from Cryomagnetics. Cryomagnetics reserves the right to elect to repair, replace, or give credit for the purchase price of any product subject to warranty adjustment. Return of all products for warranty adjustment shall be FOB Oak Ridge, Tennessee, and must have prior authorization for such return from an authorized Cryomagnetics' representative.

This warranty shall not apply to any product which has been determined by Cryomagnetics' inspection to have become defective due to abuse, mishandling, accident, alteration, improper installation or other causes. Cryomagnetics products are designed for use by knowledgeable, competent technical personnel.

In any event, the liability of Cryomagnetics, Incorporated is strictly limited to the purchase price of the equipment supplied by Cryomagnetics, Inc. Cryomagnetics, Inc. shall not assume liability for any consequential damages associated with use or misuse of its equipment.

INSTALLING A MAGNET ON CRYOMAGNETICS' SUPPORT ASSEMBLY

1) The magnet will be attached to the support assembly using 10-32 threaded rods.

2) Rotate the magnet until the magnet current leads align with the current bus bars on the support assembly.

3) Attach the magnet to the support assembly with brass threaded rods using two nuts on both sides of the support assembly's lower plate. The overall length and straightness should be checked and adjusted at this time.

4) Clamp the current bus bar on the support assembly to the magnet's current leads and solder with 60-40 solder. A one inch minimum length solder joint should be made. If the voltage taps are not already connected they can be attached at this point.

5) If the magnet has a persistent switch the heater wires and the magnet's voltage taps should be connected to the feed thru connector on the support assembly's top plate.

RELIEF VALVE PRESSURE ADJUSTMENT

"CA" & "CPA" Series Relief Valves

Cracking Pressure Adjustment Instructions

1. Insert standard hex key wrench into **locking screw.** ("CA" and "4CPA" use 5/32" wrench; "8CPA" uses 5/16" wrench.)
2. Break **locking screw** by turning counterclockwise until wrench slides into **adjusting screw.**
3. Turn both screws to reach desired cracking pressure. (Turning clockwise increases opening pressure.)
4. **Retract wrench** into **locking screw.**
5. **Lock against adjusting screw** by turning clockwise.