2G Enterprises

SUPERCONDUCTING ROCK MAGNETOMETER
CRYOGENIC SYSTEM
MANUAL

March 2002

CONTENTS

A. INTRODUCTION :

A.1 Calibration data for:

CALIBRATION CONSTANTS:

SQUIDS:

X axis =	10^{-5} emu/ flux quanta
	div. DC offset per flux quanta
	div. DC bias
Y axis =	10^{-5} emu/ flux quanta
	div. DC offset per flux quanta
	div. DC bias
Z axis =	10^{-5} emu/ flux quanta
	div. DC offset per flux quanta
	div. DC bias

FIELD CONTROL COILS:

Sense region trim coils:

These coils are helmholtz pairs of 15 turns each coil of 0.016 inch insulated copper wire wrapped directly on the 21 inch OD dewar vacuum jacket.

The Axial trim coil	:	1 milliamp = 60 gamma
The SQUID direction trim coil	:	1 milliamp = 70 gamma
The Fill port direction trim coil	:	1 milliamp = 70 gamma

TEMPERATURE SENSORS:

The equilibrium diode voltages at temperatures shown are:

diode location	BNC	box	295K	77K	65K	15K	4.3K
shield	T1	1 or 2	0.4	1.0	1.05	N/A	
reservoir	T2	1 or 2	0.4	1.0	1.05	N/A	
cryocooler - inner	T1	3	0.4	1.0	1.05		N/A
cryocooler - outer	T2	3	0.4	1.0	1.05	N/A	N/A

(N/A = not applicable.)

FLOW GAUGE CALIBRATION:

The floating ball flow gauge was calibrated against an absolute displacement gauge at three points as given below:

Flow gauge reading	boil off
20 cc/m	0.07 liter per day
30 cc/m	0.10 liter per day
40 cc/m	0.15 liter per day

A.2. SUMMARY TRANSFER PROCEDURE - SRM DEWAR

1 Preparation : Collect all equipment near the SRM dewar (SRM).
- Supply dewar (SUPPLY).
- Helium gas supply
- Heat Gun
- Transfer line (LINE).
- Transfer adapter (ADAPTER) with stoppers and clamps.
- Record all health parameters (2-1-c). Numbers in (--) refer to detailed procedures. 4 temperatures, SQUID bias levels, safety pressure, cryocooler pressure

2 Bleed the pressure in the SUPPLY to atmospheric pressure (2-1-f) and measure liquid level.

3 Bleed the SRM to 2 psig (2-1-g). Close the needle valve at popoff valve from vent damper (2-1-h).

4 Attach the ADAPTER to the SRM side of the transfer LINE. Adjust clamps to snug fit on LINE
- (2-1-i).

5 Thoroughly flush LINE with helium gas (about 1 minute) , holding as an inverted "U", and make certain that the closed end extension is attached to SUPPLY side of line. Slowly insert the LINE into the SUPPLY (2-2-c), keep SUPPLY vent open and at one atmosphere.

6 Apply about 1/4 psig helium gas pressure to SUPPLY to get a small flow of gas out of the LINE. Open flip valve on ADAPTER. While exit gas is still warm quickly insert the LINE with ADAPTER into fill port. Tighten the hose clamp around the fill port and gently push LINE into fill port until it bottoms, then pull out 1/2 inch.(2-2-c).

7 Increase the transfer (SUPPLY) pressure to 2 psig (2-2-c).

8 When this exhaust gas get cold and ADAPTER is beginning to frost, close the flip valve (2-2-c) NOTE: the gauge on ADAPTER will oscillate by about +/- 1 psig when LINE is precooled. Push LINE to seat in fill port. Tighten hose clamp, ADAPTER to LINE, so no gas leaks.

9 Slowly increase the transfer pressure to 3 psig, monitoring the SRM safety pressure. When the SAFETY pressure reaches about 2 psig FULLY open the SRM vent valve (2-2-d). Turn vent valve back and forth when opened until it is cold, to help prevent valve stem seal from freezing.

10 THIS IS THE MOST CRITICAL TIME OF THE TRANSFER- EXTREME CAUTION MUST BE USED TO PREVENT BACK DRAFTING OF AIR INTO THE SRM VENT PORT (10-2-e).

11 If the safety pressure falls below 1 psig the VENT valve must be closed. Seal vent with red stopper & heat VALVE if necessary to close. Continue the transfer without changing transfer pressure, with the VENT valve closed. Hold the transfer pressure constant until safety pressure rises to 2 psig , open the vent valve (2-2-f).

12 Maintain the transfer pressure at 3 psig CONTINUOUSLY MONITORING THE SAFETY PRESSURE. If the safety pressure falls again to below 1 psig the vent valve must be closed again , then repeat step 11, (2-2-e).

13 Hold the transfer pressure constant and read the helium level gauge every minute - the level should increase at about 5 percent per minute (2-2-g).

14 When the SRM is full or the SUPPLY is empty the SAFETY pressure will abruptly rise about one psig. Also, the level gauge readings will stop increasing. At this time stop the transfer by opening the vent valve on the SUPPLY and start venting to one atmosphere (2-2-i). Leave the SRM VENT valve open at this time.

15 As soon as the SAFETY pressure falls to 2 psig close the VENT valve on the SRM (2-2-j).

16 The transfer may be continued from a second SUPPLY or it may be stopped.

17 To continue from a second SUPPLY, remove the transfer line and adapter from the SRM fill port and

immediately plug the fill port (2-3-b). Now remove the LINE from the depressurized SUPPLY and warm the inside of the line to room temperature by flowing helium gas thru the line. Do not try to conserve helium by starting the next transfer with the cold line, the probability of getting air and/or moisture into the fill port is much too great.

18 Follow steps 5 thru 14 above.

19 Additional SUPPLY dewars may be used as necessary.

20 Termination of the transfer from step 15 above, with the SUPPLY at one atmosphere, the safety pressure at 2 psig , and the LINE still in the SUPPLY and SRM

21 Loosen the hose clamp on the ADAPTER to FILL port and quickly remove the LINE and ADAPTER from the fill port. Plug the port immediately with the black rubber stopper (2-3-b).

22 Warm the FILL and VENT ports with a heat gun then remove the stopper from the FILL port and fit the brass cap with its pop off.

23 Check to make certain that the SRM vent valve is warm and closed. Open the valve at the flow gauge Pop-off valve. All vent gas will now flow through this pop-off valve and the flow gauge (2-5-b).

24 Remove the transfer line from the SUPPLY and close its transfer port (2-4-a). Measure the helium left in the SUPPLY and the final level in the SRM and record.

A.2. Suggested data recording for 755 and 760 2G magnetometers

DAILY:

1 Gas flow gauge. Should be between 0 and 40 divisions.
2 Pressure on safety gauge. Should be about 2.0 psig.(2/15 bar).
3 Atmospheric pressure, if convenient.
4 Measure and record standard sample. Dipole moment to be about
    - 1 X E-5 emu on each axis.
5 Wipe sample handler bars with clean cloth and use light spray of dry silicone or teflon lubricant.

WEEKLY:

1 SQUID signals with scope. Record peak to peak AC voltage, and value of I BIAS potentiometer.
2 Liquid helium level gauges, #1 and #2.
    - Should decrease about 2 % on one gauge per week. Each gaugemeasures 50 % of the total liquid volume, unless the system has a single level gauge sensor.
3 Temperatures T1 and T2 using boxes #2 and #3. DO NOT USE BOX #1 except for heating the shield, SQUIDS or pickup coils.
4 Cryocooler compressor pressure. This should be about 270/280, and should fluctuate by about 5 psig each cycle..

EACH YEAR:

1 Change the cryocooler adsorber. This takes about 30 minutes and is done with the magnetometer cold. New adsorbers are available through directly from CTI new adsorbers cost about US$550. Please refer to the CTI manual for addresses.

1. SYSTEM EVACUATION AND COOL DOWN:

The system is normally pumped out and cooled to liquid helium temperatures prior to delivery and whenever possible we deliver systems filled with liquid helium. This section of the manual is provided in the event that the system needs to be warmed to room temperature for any reason and then the customer needs to check the vacuum and conduct the complete cool down. In the following discussion, we assume that the SRM (Superconducting Rock Magnetometer) is at room temperature and under vacuum.

Figures 1-1, 1-2, 1-3, and 1-4 will assist in understanding the construction and connections of the magnetometer.

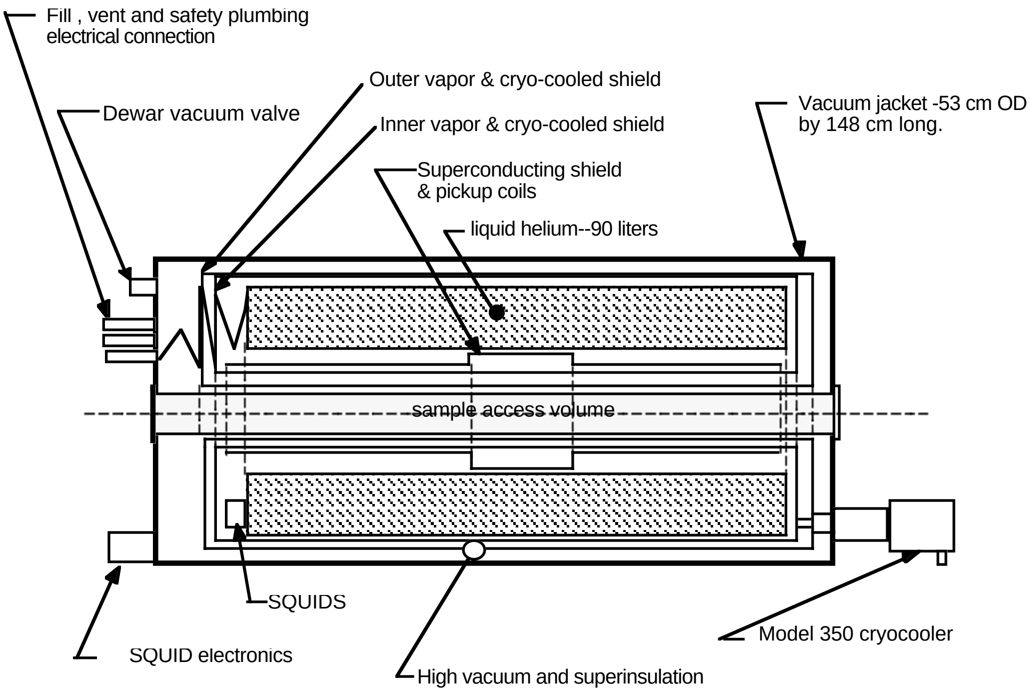
1.1 CHECKING VACUUM:

a) Remove the brass threaded plug from the vacuum valve on the SRM top plate (on the end of the SRM where the SQUID amplifiers are located), see 1-3. Using teflon thread seal, screw the brass hose barb fitting into the vacuum valve until it is tight. Do not over tighten. The brass fitting supplied with the SRM is for 1/2 inch inside diameter rubber vacuum hose. Other size fittings and hose may be used if desired.

b) Connect the hose to a vacuum pump that will reach a vacuum of at least 5 microns (5 millitorr) and install a vacuum gauge in the pumping line close to the SRM valve.

c) Pump the rubber hose and gauge down to 5 microns then open the vacuum valve on the SRM and record the pressure. If convenient close the pumping line between the gauge and the vacuum pump and record the initial pressure in the SRM. If the SRM has not been pumped since delivery and it has been allowed to warm to room temperature, then the initial pressure should be between 100 and 1000 microns.

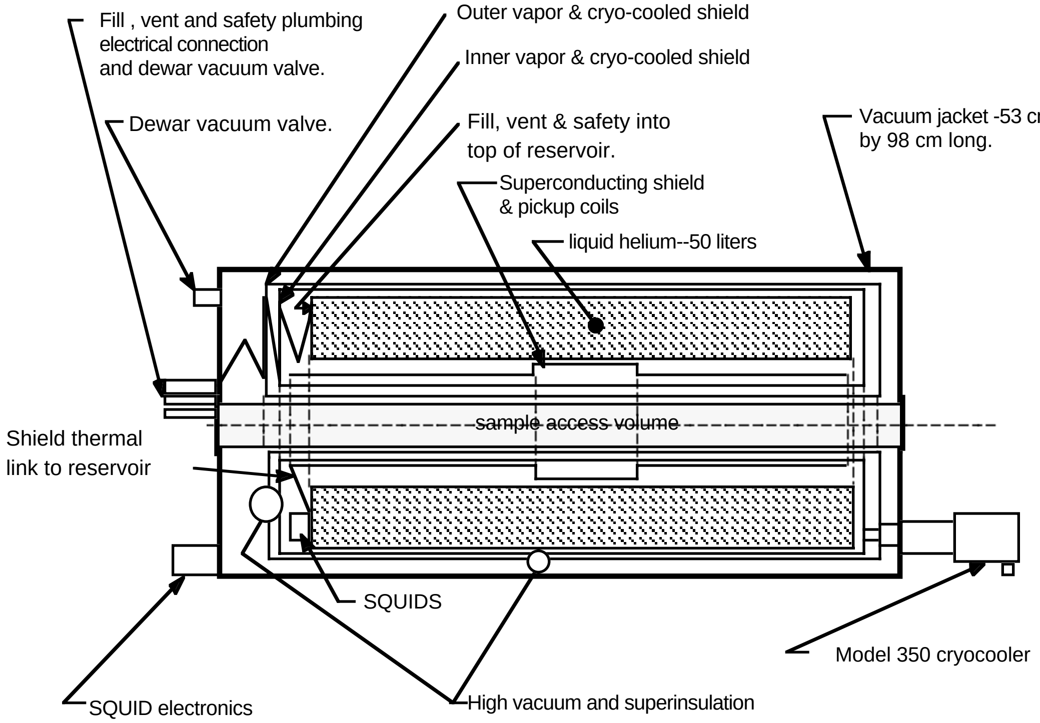
d) Close the SRM vacuum valve as soon as the pressure is determined. Proceed to the next section if additional pumping is required.



CUT AWAY SCHEMATIC OF MODEL 760-R SRM

Figure 1-1 2G SRM Manual

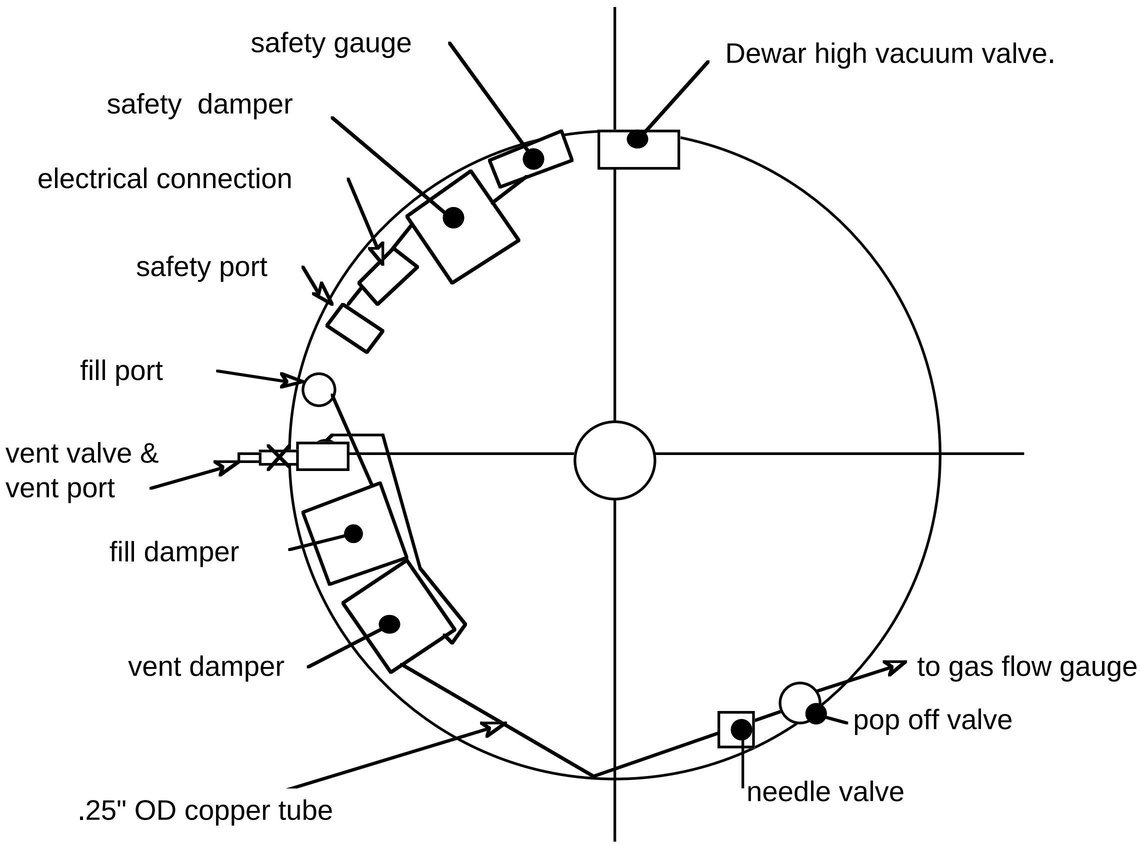
dwg # 727-AM
August 14,1993



CUT AWAY SCHEMATIC OF MODEL 755-R SRM

dwg # 727-AM-1
January 1993

Figure 1-2 2G SRM Manual



Magnetometer end plate - SQUID side.

Layout of plumbing on magnetometer
date: 3/18/93 By: WSG
scale: none
revisions:

2G Enterprises Dwg# 1267-AM

Figure 1-3
2G SRM Manual

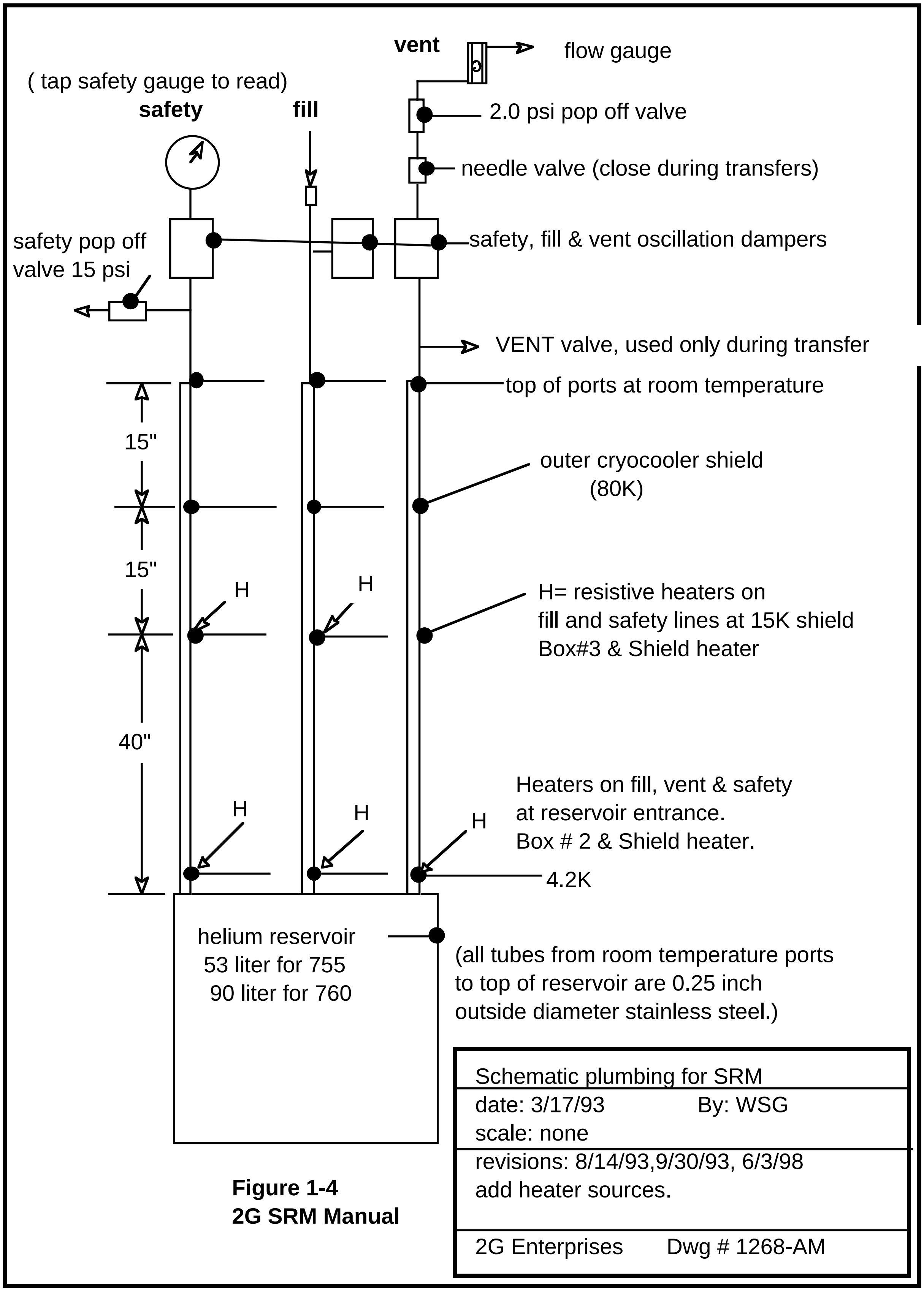


Figure 1-4
2G SRM Manual

1.2 PUMPING ON THE SRM VACUUM:

a) If the initial pressure is above 50 microns then it is desirable to pump on the vacuum space to remove the outgassing contaminants that have accumulated since the previous cool down.

b) A trap MUST be inserted between the vacuum pump and the SRM to prevent pump oil vapor from back streaming into the superinsulation space of the SRM. We strongly recommend a liquid nitrogen cooled trap although a good antiback streaming gauze type trap is adequate if it is clean. If a turbo molecular pump is used the trap is not needed.

c) With the pump, trap and gauge installed pump out the line to the SRM valve before opening the valve. Now open the valve to the SRM and pump until the vacuum reaches at least 30 microns and preferably 10 microns. This will take anywhere from 1 to 10 days depending on the time since the previous pump down. When the pump down is completed close the SRM valve and remove the vacuum pump. Replace the brass vacuum valve plug.

1.3 PUMPING ON THE HELIUM RESERVOIR:

When the system is warmed to room temperature it is a good opportunity to pump on the helium reservoir and all of its associated plumbing and oscillation dampers, and then to back fill this reservoir volume with ultra high purity helium gas. This will remove any contaminants that may have collected in the reservoir, which could cause plugging of the fill, vent or safety line when the system is cooled down. To pump, use the same vacuum system described in the previous section for pumping the dewar high vacuum. Remove the brass hex cap from the FILL port and install the brass hex cap with a vacuum valve in place of the pop off valve. Connect the pumping system to the output of this vacuum valve. Close the needle valve at the SRM VENT, and be certain that the SRM VENT valve is also closed. See figure 1-3 and 1-4 for the location of these fittings on the SRM top plate.

Pump down the line to the FILL vacuum valve then open this valve. The pressure will initially be one atmosphere and it will require several hours pumping to reach the 1000 micron level. Continue pumping until a pressure of below 200 microns is reached (about 6 hours). Now close the FILL port vacuum valve. Connect a hose from a cylinder of ultrahigh purity helium gas (99.999 %) to the VENT valve. Be certain to flush this hose with the helium gas first to avoid adding contaminants to the reservoir. Let helium gas into the reservoir until the SAFETY pressure reaches about 5 psig. Close the VENT valve and pump the reservoir back down to below 200 microns a second time. Repeat the filling with helium gas to 5 psig SAFETY pressure. The reservoir and all of the plumbing attached to it should now be filled with the ultrahigh purity helium gas.

1.4 LEAK TESTING:

If a vacuum leak is suspected it will be necessary to connect a helium mass spectrometer detector to the SRM vacuum valve. Pump down the connecting line in the manner described in 1-1-a through c and then open the vacuum valve and measure the background level of helium in the SRM vacuum space. External leaks can be located by normal leak detection techniques of applying small amounts of helium gas on any suspected regions and monitoring the internal helium background. The leak detector response can be very slow because of the large volume of the vacuum region in the SRM and the many layers of thermal insulation, so patience and care will be required in the leak testing process. It is advisable to contact the factory before leak testing the system and we will provide specific instructions depending on the nature of the suspected leak.

1.5 COOL DOWN WITH CRYOCOOLER PRECOOL:

a) Once it has been confirmed that the vacuum is satisfactory the SRM can be cooled to operating temperature. If time permits (about 7 days elapsed time required) it is more efficient to do the preliminary cooling with the cryocooler, then, when the reservoir and superconducting shield reach about 70 Kelvin the helium transfer and further cooling to 4.2 Kelvin will take only about 30 liters of liquid helium. An alternate procedure uses periodic helium transfers and the cryocooler to cool the SRM to helium temperature from room temperature in about two days. It is possible to do the precool with liquid nitrogen but this requires great care to avoid collecting any liquid in the reservoir and to remove ALL of the nitrogen gas prior to operating the cryocooler. We do not recommend this nitrogen precool. Please contact the factory BEFORE attempting a liquid nitrogen precool.

   The cool down using the cryocooler only is shown in Figure 1-5 for a 755 magnetometer. The same procedure applies to the larger 760 system but the time required to reach 50 Kelvin will be about 12 days. If the cooling reaches equilibrium at a higher temperature this indicates that either the magnetometer vacuum is not low enough or that the cryocooler is not performing properly. If the vacuum is not low enough there will be condensation in the sample access as well as a decrease in the cooling rate. The vacuum can be reduced by pumping while the system is cold. It is very important to use a liquid nitrogen trap in the pumping line to prevent back flow of oil vapor. Continue pumping until the cooling rate increases and the access tube warms to room temperature. This will normally take 8 or more hours of pumping.

   If the vacuum is OK, that is, if the cooling rate does not improve with pumping, then the cryocooler is probably not performing to specifications. Please contact the 2G factory for further advice.

b) If the system has warmed up from helium temperature and the fill, vent and safety ports have remained in the operating position so that no chance has occurred for air to enter the system , then close the needle valve between the vent pop off valve and the flow gauge and pressurize the helium reservoir to 6 psig on the safety pressure gauge. Use ultra high purity helium gas through the vent fitting, first flushing the external gas line from the helium supply cylinder to remove all air. Close the vent valve and turn on the cryocooler.
c) When cooling with the cryocooler, monitor the safety pressure every morning and evening and repressurize when needed to make certain that the SAFETY

d) pressure does not fall below 1 psig. As the helium reservoir cools the helium gas inside will be at a lower pressure and gas will need to be added about once per day for the first three days of cooling, then every other day for about four more days. It is also helpful to monitor the SQUID temperature (see section 3.2 for the thermometer description). It will require about 7 days for the reservoir and shield assembly to reach 70 Kelvin at which time it is efficient to complete the cool down with a liquid helium transfer.

e) All liquid helium transfers follow the procedures given in the following section 2. There are two very important aspects of this first transfer after a cryocooler cooldown that must be carefully reviewed to conserve helium and to prevent a solid air plug.

f) The first transfer of liquid helium is used to reduce the temperature from that produced by the cryocooler to below 10 Kelvin. It is much more efficient to use the heat capacity of the helium gas to provide this cooling rather than the heat of vaporization of the liquid, thus, we recommend that the first transfer be done slowly and stopped when the SQUID temperature reaches about 1.8 volts or about 10 Kelvin.

Starting the transfer: Record the temperatures and safety pressure readings and the helium level in the storage dewar. If the dewar pressure is below about 0.5 psig it will be necessary to increase it by adding UHP helium gas through the VENT valve. Be certain to completely flush the gas hose with helium gas before connecting it to the VENT. Add gas to reach a safety pressure of 1.0 psig and close the VENT valve.

Flush the helium transfer line with welding grade helium gas holding the line as an inverted U to keep air from counterflowing into the line. Slowly insert the line into the storage dewar keeping the storage pressure at one atmosphere. Tighten the seal around the line to storage dewar. Now apply a small helium gas pressure (about 1/2 psig) to the storage dewar and observe the gas flow out the end of the transfer line. Welding grade gas is adequate for the transfer. When the flow is steady but still warm, open the flip valve on the line adapter, remove the rubber stopper from the FILL PORT and quickly but smoothly insert the line into the PORT. The line will precool by gas flowing though the line and out the flip valve. When the flip valve starts to get cool (but before it gets frosty) close the flip valve. Now slowly increase the pressure on the STORAGE dewar to about 2.5 psig. When the safety pressure reaches 2.0 psig open the magnetometer VENT valve. Cold helium gas is now being transferred into the RESERVOIR.

Backdrafting is certain to occur during this transfer and the precautions given in section 2-2-e MUST be followed to prevent plugging of the vent port. The back drafting will occur when the SQUID diode reaches about 1.15 volts (55K) and the pressure will quickly decrease (in less than one minute so it is important to continuously monitor the safety pressure) to a negative value of 2 to 4 inches of mercury on the safety gauge. It is crucial that the vent valve be closed before this reservoir pressure becomes negative. By monitoring the SQUID temperature you can tell when the back drafting is about to start, i.e. when the SQUID temperature reaches 1.15 volts. This will leave just enough time to warm the vent valve and close it when the safety pressure begins to fall. If the transfer pressure is left constant at about 2 psig during the back drafting it will take about 5 minutes for the reservoir to reach equilibrium and for the safety pressure to rise to a positive 1 psig. During this time the SQUID temperature will fall rapidly to 1.6 to 1.8 volt and some liquid may collect in the reservoir.

The helium transfer can be stopped quickly by pulling the helium transfer line up in the storage dewar so that the line tip is abvove the liquid helium level of the storage dewar. It is important to keep the pressure on the storage dewar during this operation and until the safety pressure reaches about 1 psig. At this time the transfer pressure can be reduced and the line removed from the magnetometer fill port. as described below.

If the transfer line is left fully inserted into the stporage dewar then wait until the safety pressure has increased to about 1 psig, stop the transfer as follows:

a) Close the VENT valve on the SRM dewar when the safety pressure, Ps, reaches 1 psig.

b) Loosen the hose clamp on the large adapter hose at the FILL PORT and remove the transfer line and adapter from the fill port. Immediately plug the fill port with the solid black rubber stopper. It is most likely that some liquid helium was collected during the back drafting since the negative pressure produces a very rapid transfer of liquid. Check the lower helium level gauge (Section 3-1) and record its reading.

c) The SRM will now continue to cool for about 8 hours during which time the boil off rate will be in the 5 liter per day range. Open the needle valve between the pop off valve and the flow gauge so that this boiloff gas can vent through the pop off. Due to the high boil off rate the pressure will increase in the reservoir and it is important to monitor the safety pressure and keep it below about 6 psig by venting excess gas out the vent valve. This venting is to be done slowly and the SRM must NEVER be left unattended during this venting since the pressure may reduce to one atmosphere and then it would be possible for air to cryopump in the vent line and plug it.

d) When the superconducting shield temperature reaches the same temperature as the SQUIDS it is time to complete the helium fill. As noted above, this will require about 8 hours from the conclusion of this transfer. It is NOT critical when the next transfer is made since the cryocooler will hold the reservoir-shield assembly below 20 Kelvin continuously. The next transfer will proceed as a normal fill except it is much more likely that the back drafting will occur. Therefore, follow the instructions given in section 2 and fill the reservoir to whatever level is desired. After completing the transfer it will take about 6 hours for the SQUIDS and shield to reach equilibrium and for the SRM to be ready to operate. The helium loss rate and SQUID noise will continue to improve for several days before final operating conditions are reached. This is a good time to trap a low measurement field if desired.

1.6. COOLDOWN WITH HELIUM TRANSFER AND CRYOCOOLER:

The procedure to cool the magnetometer from room temperature starting with the helium transfer and the cryocooler operating is essentially as described in the above procedure except three separate helium transfers are required. A typical cooling time for this procedure is shown in Figure 1-6 for a 755 system. A 760 will require about 50% longer time at each step. These data show the minimum cool down time needed when time is very critical. It is more efficient and less stressful on the user to wait overnight between each helium transfer. This allows the superconducting shield temperature to reach equilibrium with the reservoir. For example, after the first transfer the reservoir is at 55 K and the shield is at 210 K. By waiting 9 or 10 hours before starting the second transfer, the shield will cool to about 60 K and this will save a few liters of helium on the second transfer. It is even more important to wait until the shield and reservoir reach the same temperature after the second transfer since any extra cooling of the shield will save on the final amount of helium collected after equilibrium is reached when the system is filled.

1.6.1 Beginning the cooldown:

The vacuum in the magnetometer should be checked to ensure that it is below about 25 microns, and if it is suspected that any air may have entered the reservoir, then the reservoir should be pumped and back filled with ultra high purity helium gas. (See section 1.3 for this pumping and back filling procedure.) Pressurize the reservoir to about 1 psig and remove the helium gas line from the magnetometer vent valve.

Flush the helium transfer line with helium gas holding the line as an inverted U to keep air from counterflowing into the line. Slowly insert the line into the storage dewar keeping the storage pressure at one atmosphere. Tighten the seal around the line to storage dewar. Now apply a small pressure (about 1/2 psig) to the storage dewar and observe the gas flow out the end of the transfer line. When the flow is steady but still warm, open the flip valve on the transfer line adapter, remove the rubber stopper from the FILL PORT and quickly but smoothly insert the line into the PORT. The line will precool by gas flowing through the line and out the flip valve. When the flip valve starts to get cool (but before it gets frosty) close the valve. Now slowly increase the pressure on the STORAGE dewar to about 2.5 psig. When the safety pressure reaches 2.0 psig open the magnetometer VENT valve. Cold helium gas is now being transferred into the RESERVOIR.

Turn on the cryocooler and measure the 4 temperatures (SQUIDS, superconducting shield, inner and outer cryocooled shields) using box 1 and 3 as described in section 3.2. The voltages should be about 0.4 volts for all diodes indicating room temperature.

Keep the transfer pressure steady at about 2.5 psig, but do not continually adjust the pressure regulator. The objective is to reach a steady transfer pressure since up and down changes will result in excess loss of liquid helium and make the transfer more difficult to monitor. Keep a record of the 4 temperatures, the safety pressure, and the transfer pressure taking readings every 10 to 15 minutes.

This first transfer will take about 4 hours during which time the SQUID temperature will decrease from room temperature to about 80 K (0.4 volt to 1.0 volt). The shield will cool much slower so when the SQUIDS reach about 1.0 volt the transfer is to be stopped to allow time for the shield and SQUIDS to reach equilibrium. The reservoir thermal mass is much larger than that of the shield so the shield will cool about 150 K while the reservoir warms only about 20 K. Also, the cryocooler is now continuing to cool the two thermal shields and after about 2 hours the inner shield will be colder than the superconducting shield so additional superconducting shield cooling will occur by radiation and conduction between these two shields. When the SQUID temperature reaches about 1.0 volt stop the transfer by slowly reducing the storage dewar pressure to 0.5 psig , then close the VENT VALVE on the magnetometer, remove the TRANSFER line from the FILL PORT and seal the PORT with the black rubber stopper. Continue to reduce the pressure on the storage to one atmosphere then remove the transfer line from the storage. Measure the helium level in the storage when convenient. It should require about 25 liter for a 755 SRM and 30 liter for a 760 to reach this 1.0 volt SQUID temperature.

Open the needle valve to the magnetometer flow gauge and continually monitor the safety pressure. The gas flow will be high and the normal magnetometer vent will not be able to maintain a stable pressure. When the safety pressure reaches about 5 psig, reduce it back to one psig by opening the VENT valve. This pressure reduction will need to be done about every 30 minutes for the next few hours.

After about 8 hours the superconducting shield and the reservoir will both be at temperature of about 100K and the second transfer can be started. At this time the reservoir and shield will both start to cool slowly because of the cryocooler, so if you are not ready to start the next transfer it will be important to monitor the safety pressure to be certain that it does not reduce below one atmosphere due to reservoir cooling. The cooling will be very slow so if the reservoir is at 1 psig it will require about 6 hours for the pressure to fall to zero.

Second and third transfers:

The second transfer is used to cool the reservoir to 10 K then to let the shield and reservoir reach equilibrium at about 30 K. This transfer is identical to the first one described in the previous section 1-5.e where the initial cooling to 80 K was done only with the cryocooler.

The third helium transfer will be done following the procedure given in the next section 2 for a normal helium fill. The one difference is that this third transfer will start with the helium reservoir slightly above 4.2 K so backdrafting is certain to occur very soon after the transfer begins. Use extreme caution and constantly monitor the SAFETY pressure and close the VENT valve as soon as the SAFETY pressure starts to fall near 1psig.

2. LIQUID HELIUM REFILLS:

The most crucial operation with the SRM DEWAR is the refilling of the reservoir with liquid helium. Before each refill this section should be thoroughly reviewed and understood. The attached summary chart lists the crucial step-by-step procedure with references given to the appropriate paragraphs in this manual for more detailed description.

Figures 1-1, 1-2, 1-3, and 1-4, given at the beginning of section 1, will assist in understanding the filling and safety procedures with the 2G magnetometer:

2.1 PREPARATION:

a) Measure the liquid helium remaining in the SRM reservoir.

b) Carefully check the 2G helium transfer LINE. Make certain that the LINE will reach the bottom of the SUPPLY dewar and that the SRM side is smooth and free of bends. Two LINE extensions are provided. Both extensions are closed at the bottom with the liquid pickup about one inch above the bottom to ensure that solids are not picked up from the bottom of the SUPPLY. One of the extensions must be used at all times. The SRM side must be at least 14 inches long to fit into the ADAPTER and seat in the fill port. If another LINE is used it must be of equal or greater length. Have a supply (about 1000 psig) of pure helium gas and a low pressure regulator available with a 30 psig maximum output pressure.

c) Record the following operating “health readings" of the dewar: Helium level, SQUID and shield temperature, cryocooler temperatures, pressure on the safety oscillation damper gauge (P_S), helium boil-off gas flow, and DC bias level of each SQUID (reading of the 10 turn bias potentiometer). Figure 1-3 shows the dewar system with the three oscillation dampers and the safety pressure gauge for measuring P_S.

d) Provide clear working space around the SRM dewar and the helium SUPPLY dewar.

e) Locate the helium SUPPLY dewar next to the SRM dewar so that the transfer line can easily reach the FILL PORT.

f) Bleed the pressure on the SUPPLY dewar down to atmospheric pressure. NOTE : this should be done very slowly to prevent large flash-off loss of liquid. A “rule of thumb" is to take about 5 minutes per one psi gauge pressure of positive pressure that is in the SUPPLY dewar. Also keep the rate slow enough so that the top plumbing of the SUPPLY dewar does not become excessively frosty.

g) Make certain that the SRM dewar pressure as read on the safety gauge is about two psig. The pressure should be increased, if necessary, before proceeding with the transfer by adding pure helium gas through the VENT port. If the SRM pressure is above two psig as read on the safety gauge then the pressure should be slowly reduced by bleeding gas off through the vent valve (see figure 1-3 and 1-4 for the location of this valve). CLOSE THE VENT VALVE.

h) Just prior to transferring it is advisable to close the needle valve , figure 1-4, in the vent popoff valve line. This will ensure that air will not be drawn into the vent damper if the SRM pressure falls below one atmosphere during the transfer (see back drafting comments in section 2-2-e below) We have found that these popoff valves will sometimes leak for very small negative pressures. This leaking can allow sufficient air to enter the damper volume and later to be cryopumped into the vent line and cause a solid air plug.

i) Unscrew the hex brass nut with popoff valve from the fill port and immediately close the port with a small black rubber stopper (size # 00). When the hex brass fitting is removed a large flow of helium gas will exit the port. It is important to seal this port as quickly as possible. Always bring the stopper to the port from the bottom side and rotate the stopper into the port. If the stopper is moved horizontally into the port the helium gas will very quickly freeze the stopper and your fingers. If the fill port top is cold the stopper may be blown off by the gas pressure. To prevent this hold the stopper in place and warm the port to room temperature with the heat gun.

j) Attach the transfer coupling adapter to the SRM end of the helium transfer line. Make certain that the rubber hoses are attached to each end of the adapter and that the hose clamps are in place to tighten around the fill port threads and around the transfer line on the small side of this assembly. NOTE: it is important to pre-adjust the clamp so that the hose is a snug fit around the transfer line. When the transfer line with the adapter is fitted over the threaded fill port connection almost no gas will escape and the danger of freezing the hose before the clamp can be tightened is greatly reduced. Close the flip valve on the adapter.

2.2 BEGIN HELIUM TRANSFER:

a) Inspect the fill adapter coupling that is now on the helium transfer line from step 2-1-i) above. Make certain that the adapter flip valve is open and that the clamp is pre-adjusted to be a snug fit to the transfer line. Check that a closed end transfer line extension is fitted to the storage dewar side of the line. This extension should have a hole cut in its side about one inch above the bottom. The purpose of this extension is to prevent the transfer of solid contaminants from the bottom of the storage dewar into the SRM.

b) Flush helium gas through the transfer line for about one minute to remove all traces of air. Keep the line as an inverted U during and after this flushing.

c) Slowly insert the helium transfer line into the SUPPLY dewar -keeping the SUPPLY dewar pressure at atmospheric - until the line is fully inserted. Now connect the helium gas supply to the SUPPLY and apply about 1/4 psig gas pressure. This will cause helium gas to flow through the transfer line and further purge it of any air. Before this exit gas starts to cool quickly remove the rubber stopper from the fill port and insert the line into the port until the large rubber hose of the adapter fits over the fill port threads. NOTE, it is very important that the line not be precooled further as in a more conventional helium transfer. This is because the frost that will accumulate on the outside tip of the line may get trapped in the fill port and be cryopumped down to the inner vapor cooled shield and cause a solid air plug. The LINE only needs to be inserted about 4 inches into the fill port at this stage. Now tighten the hose clamp on the large hose and push the line in until it is felt to hit bottom in the fill port. This will leave about 2 inches of the 3/8 inch diameter fill line exposed. Tighten the hose clamp around the LINE and then increase the helium gas pressure in the SUPPLY dewar to one psig. Pull the line back out about 1/4 inch to permit rapid precool.

The flip valve on the SRM dewar FILL ADAPTER was opened at the beginning of the transfer to precool the transfer line and thereby prevent warm helium gas from entering the SRM reservoir. Let helium gas vent out of this valve until the valve just gets frosty. Open and close the flip valve as it cools to prevent the valve stem from freezing open. Close the flip valve when the line is precooled. Notice that the adapter pressure gauge will oscillate by +/- 1 psig when the line is properly precooled. Push the LINE fully into the fill port, and make certain that helium gas is not leaking around the hose to adapter fitting.

d) The SRM dewar vent valve should be closed from step 2-1-g) above. Leave this vent valve closed and slowly increase the transfer gas pressure on the SUPPLY dewar to 3.0 psig (over about a one minute period) by using pressure from the helium gas cylinder.

   Monitor the safety gauge pressure, Ps, continuously during this step and as soon as it rises to 2.0 (two) psig open the vent valve. NOTE: connect a short rubber hose to the vent valve hose barb to direct the very cold helium gas away from the dewar top plate fittings and to above the instrument. If possible this gas should exhaust outside the room so it does not produce a large background concentration of helium in the atmosphere.

   The open end of the vent hose must be accessible since it may need to be sealed with a rubber stopper during the initial phase of the transfer. See the following step e).

e) Relatively warm helium gas will now be entering the cold reservoir and the boil off will increase until the transfer line has been cooled to liquid helium temperatures. This will require about 3 to 5 minutes if the transfer pressure is maintained at 3 psig.

   CAUTION: The most crucial part of the helium refill will occur at this time. As soon as liquid helium from the SUPPLY dewar starts to enter the SRM dewar reservoir it will abruptly cool the gas in the reservoir and in some cases can produce a pressure in the reservoir lower than ambient. This reduced pressure can result in air being drawn into the vent port (back drafting). This air will rapidly condense inside the vent line and can cause a solid air plug to form in the vent line in a few seconds. EXTREME CAUTION MUST BE EXERCISED TO PREVENT THIS. Continuously monitor the safety gauge pressure P_S , during this part of the transfer and if it begins to fall below 1.0 (one) psig close the vent valve. This valve may be frozen and very difficult to turn so insert a rubber stopper into the open end of the vent hose then warm the vent valve with the heat gun until it can be closed.

f) Maintain a constant transfer gas pressure of 3 psig until the safety pressure on the SRM dewar rises to about 2 psig, then open the vent valve again. This back drafting problem should not reoccur during the refill process. Now, slowly increase the transfer pressure to 3 to 4 psig. Maintain the pressure at 3 to 4 psig.

g) Read the helium level gauge every minute to monitor the transfer rate. Liquid should collect at a rate of 3 liters per minute or roughly 5% per minute on the level gauge. It is undesirable to read the level gauge more frequently than once a minute since it adds to the helium boil off.

h) Continue the transfer of liquid helium maintaining a constant transfer gas pressure. Much more efficient transfers are possible if all of these procedures are done slowly and smoothly.

i) If the transfer pressure is held constant it will be very easy to tell when the SUPPLY dewar is empty or the SRM dewar reservoir is full. The safety pressure will abruptly rise about one psig when either the SRM is full or when the SUPPLY dewar is empty-in either case it is time to stop the transfer. Also, you should watch the gas plume from the vent line - the gas flow will increase by about 2 to 1 when either the SUPPLY dewar is empty of the SRM is full. The helium level gauge readings will stop rising, then begin to fall but this is more difficult to observe quickly than the above two events. When these events occur release the transfer pressure by opening the SUPPLY dewar vent valve and let the SUPPLY dewar pressure reduce to one atmosphere.

j) Close the vent valve on the SRM dewar when the safety pressure , Ps , reaches 2 psig.

2.3 STOP HELIUM TRANSFER:

a) The SRM dewar reservoir pressure, Ps, should be allowed to reach about 2.0 psig as read on the safety gauge, with the gas transfer pressure released as described above in 2-2-i and -j and the vent valve should be closed.

b) Loosen the hose clamp on the large adapter hose and remove the transfer line and adapter from the fill port. Immediately plug the fill port with a solid rubber stopper.

2.4 USING A SECOND SUPPLY DEWAR (IF NEEDED):

a) Remove the transfer line from the first SUPPLY dewar when it is empty. Be certain to close the top valve on the SUPPLY dewar to prevent air from being cryopumped into the SUPPLY dewar reservoir. Hold the transfer line in an inverted “U” and flow room temperature helium gas through the line until in exits at room temperature. It is not advisable to try to move the cold line directly to a second supply dewar, to save a little helium. The danger of getting air or moisture into the fill line is too great.

b) Insert the transfer line into the next SUPPLY dewar to be used. Insert the line all the way to the bottom of the SUPPLY dewar, apply a 1/4 psig transfer pressure, watch the exit of the transfer line until helium gas flow is observed then quickly insert the line and adapter onto the fill port coupling being careful not to freeze the rubber hoses. NOTE: it is much safer and more efficient on the average to waste a little helium by not precooling the transfer line than to risk getting air into the fill port or freezing the hose couplings and having to restart the transfer. Follow the procedure described above in sections 2-2-c to 2-3 to partially precool the LINE.

c) When the transfer line is inserted, sealed and partially precooled, slowly increase the transfer pressure to 3 to 4 psig. Monitor the safety pressure and as soon as it starts to rise above two psig open the vent valve (note: this valve was closed in step 2-2-j above). Continuously monitor this safety pressure for the first 5 minutes of this second transfer process. It is very unlikely that the system will back-draft as described in section 2-2-e above, but caution is still a necessity.

d) Continue the transfer as described above until this SUPPLY is empty or the SRM is full.

e) Stop the transfer as described in section 2-2-i&j and section 2-3.

2.5 CONCLUDING THE TRANSFER :

a) Leave the line in the SUPPLY dewar and remove the transfer line and adapter assembly from the fill port and insert the rubber stopper in the fill port. Make certain that the stopper is snug, and warm the fill port to room temperature, REMOVE THE STOPPER , and quickly fit the hex head brass cap with its popoff to the fill port. The requirement when removing the transfer line from the fill port is to prevent the port from freezing thereby making it difficult to seal the port with the rubber stopper. Further, and most important, it is crucial that the line be removed and the port sealed without any opportunity for air to condense in the SRM dewar fill port.

b) As soon as the transfer line is removed from the fill port and the fill and vent ports are closed all vent gas will go through the oscillation damper and out the one way pop-off valve. This valve is now closed with the needle valve between the pop off and the oscillation damper (see section 2-1-h above). The reservoir pressure will usually decrease to about one atmosphere (zero on the gauge) within 10 minutes after the transfer is stopped. The pressure will then slowly rise, over the next few hours, until it reaches the setting of the pop-off valve. Continue to monitor the safety pressure until it reaches a positive pressure of about 1/2 psig then open the needle valve (section 2-1-h above).

c) Remove the transfer line from the SUPPLY dewar and close the SUPPLY dewar top valve. Store the transfer line in a safe place. Measure the helium level in the SUPPLY dewar if desired.

d) When the transfer is completed and all equipment has been put away it is advisable to repeat the system "health readings" taken in section 2-1-c above. These readings can be very helpful in analyzing any problem that may develop.

e) It will take one or two hours for the SRM to stabilize after a helium refill, and as long as one day to reach its optimum noise levels.

3. INSTRUMENTATION:

The SRM dewar system is fitted with one flexible helium level gauge for level when the system is horizontal, and one full length straight level gauge for use when the system is vertical, 4 diode thermometers, 4 resistive heaters and a 3 axis set of field nulling coils. The level gauges, diodes and heaters are connected through a 15 pin connector on the SQUID end top plate. The cable to the control electronics is fitted with a 9 pin connector and adapter interconnect boxes are supplied to fit between the 15 pin and 9 pin connectors. The box number and function is given in the table below:

Box#	function	9 pin#	15 pin #	switch
1	horizontal level gauge	5,3	5,3	LG 1
1	shield heater	5,4	5,4	shield htr.
1	SQUID heater	5,6	5,6	heater #1
1	Strip line heater	1,2	1,2	heater #2
1	Shield diode	1,7	1,7	T1
1	SQUID diode	1,8	1,8	T2
2	Horizontal level gauges	5,3	5,3	LG 1
2	Shield diode	1,7	1,7	T1
2	SQUID diode	1,8	1,8	T2
2	Reservoir heater	5,4	5,13	shield htr.
3	Vertical level gauge	5,3	5,9	LG
3	Cryocooler inner shield diode	1,7	1,10	T1
3	Cryocooler outer shield diode	1,8	1,11	T2
3	Fill&safety htr.at inner shield	5,4	5,12	shield htr.

3.1 HELIUM LEVEL GAUGES:

There is one superconducting wire helium level gauge in the helium reservoir on model 755 and 760 systems. This gauge functions as a variable resistor such that the part of the gauge that is below the liquid level is superconducting (zero resistance) and the part above the liquid is resistive. Thus, a measure of the voltage drop across the gauge at a constant current will determine the fraction of the gauge length that is below the liquid, i.e., the liquid depth. The gauge for horizontal operation is a flexible gauge that bends around the reservoir inner diameter. The gauge is connected to pins 3 and 5 of the 15 pin connector on the dewar with pin 5 being the common lead. The resistance of the gauge when the reservoir is FULL is about 50 ohms and about 300 ohms when empty. The helium reservoir is an annular volume (see figures 1-1 and 1-2). The reservoir is constructed of two concentric tubes, the outer one having an inside diameter of 15.25 inches and the inner tube having an outside diameter of 8.25 inches. When operated horizontally the actual helium volume is not a linear function of the level gauge reading. Figures 3-1 and 3-2 give the actual liquid versus level gauge reading for the 755 and 760 magnetometers when operated horizontally.

When the 755 or 760 is used for vertical operation a single level sensor is connected to pins 9 and 5. The output voltage is now a linear function of helium level over the volume of the reservoir. To read the vertical level gauge box 3 must be used to connect the pin 9 to pin 3 of the interconnect cable. When the gauge reads empty on all systems approximately 2 liters of liquid is still in the reservoir.

On systems built prior to Fall 1997 two horizontal helium level gauges were used. Level guage #1 measured one half of the volume and level gauge #2 measured the second half. These gauges were connected to pins 5 and 3 and 5 and 9 respectively.

3.2 THERMOMETERS:

There is a silicon diode thermometer mounted on the liquid helium reservoir (SQUID temperature) and one on the superconducting shield that is thermally linked to the helium reservoir. Two other diodes are mounted on the vapor cooled shields in the dewar vacuum space. Power to the diodes is supplied from the SQUID control/monitor electronics and its interconnect cable. Diode power is applied whenever the electronics is turned on and the cable is connected. The diode voltage is measured with an external DVM connected to either of two BNC outputs on the rear panel of the control electronics. The diode voltage at critical temperatures is given in the table at the front of this manual for each specific system. Figure 3-3 gives an approximate diode voltage versus temperature for our standard diodes. The voltage change with temperature is approximately 2.7 millivolts per Kelvin from room temperature to about 55K, and is about 0.060 volts per Kelvin from helium

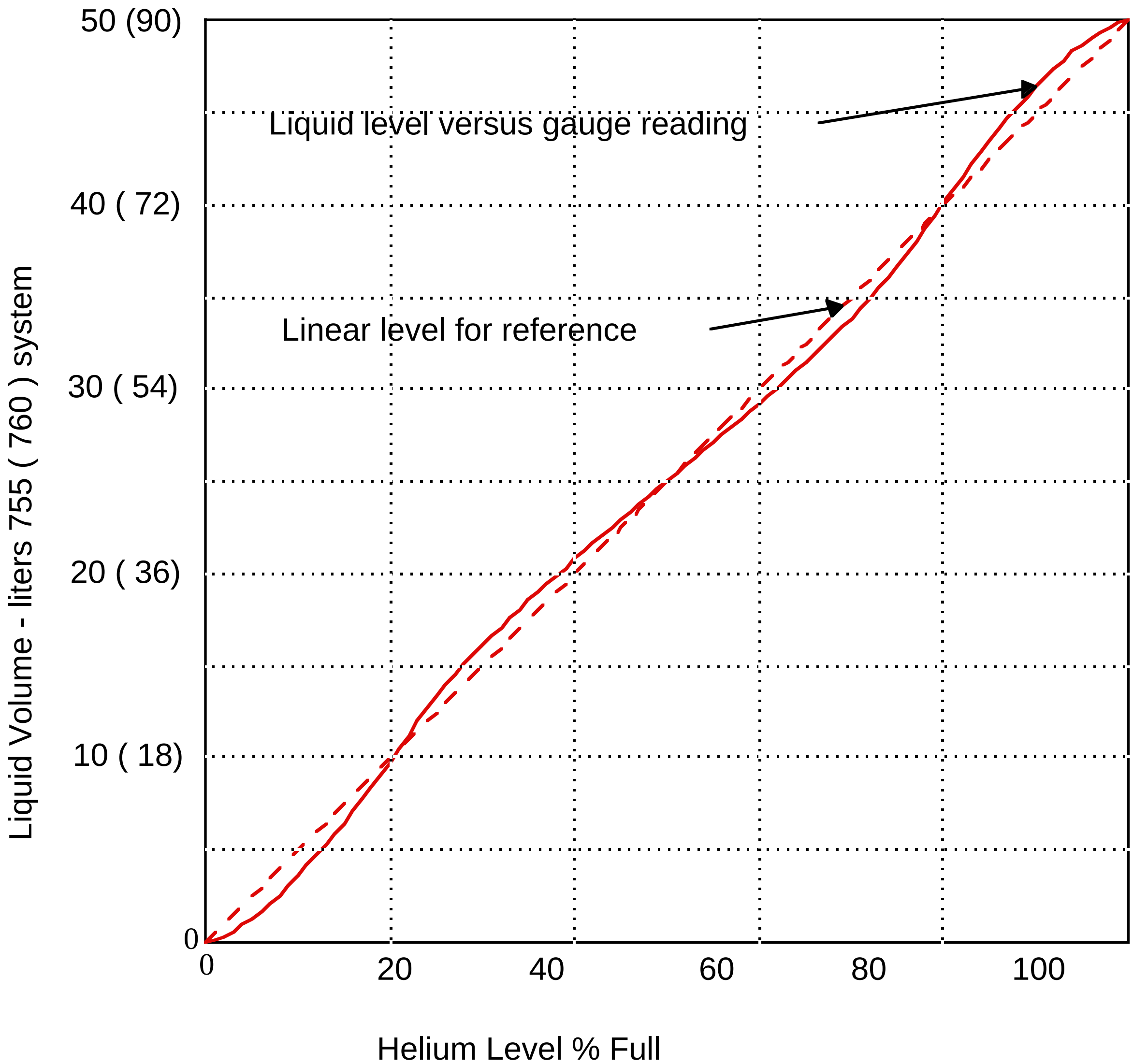
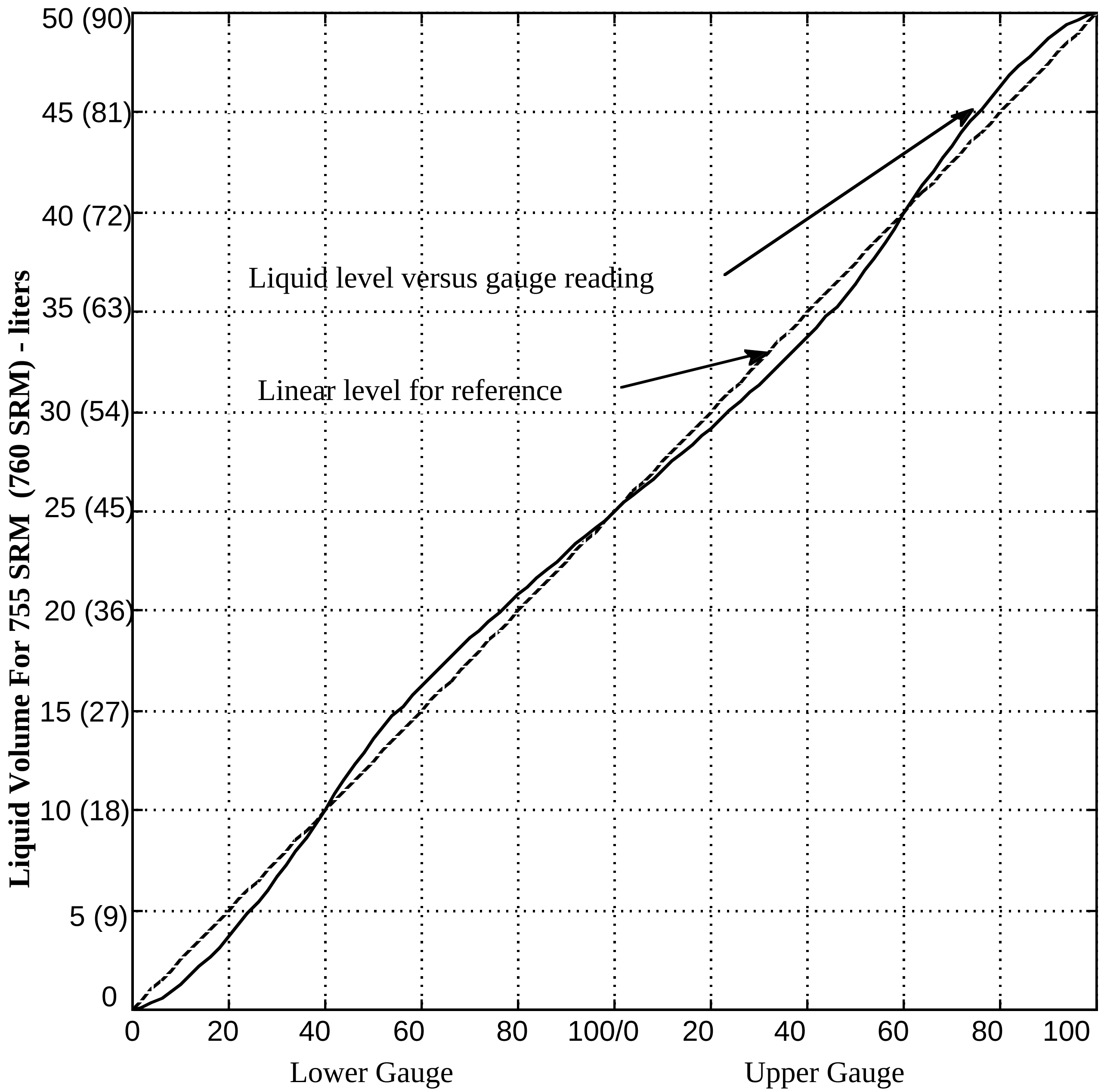


Figure 3-1 for 755 systems (760 systems) with single horizontal level gauge.



Level gauge reading in percent
for lower and upper gauge.

Figure 3-2 Liquid Volume versus Level Gauge
Reading for 755 SRM (760 SRM)
with dual horizontal level gauges

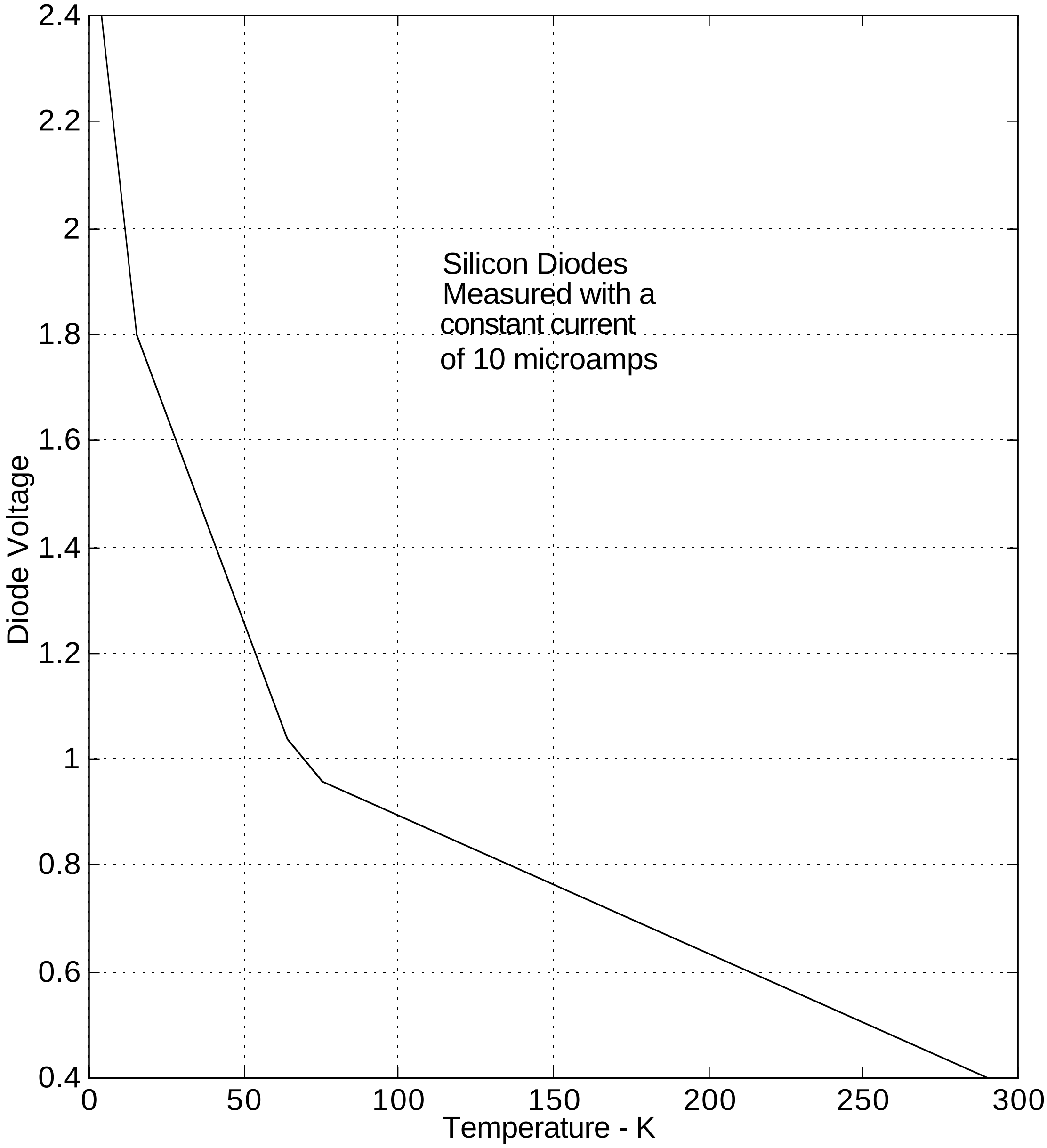


Figure 3-3. Diode Voltage versus Temperature

temperature to 20 K. We do not calibrate the diodes in the intermediate range of temperatures since this is not important to the SRM operation, and due to the nonlinearity it is difficult to calibrate. When the control/monitor cable is connected directly to the SRM top plate electrical feedthru 15 pin connector, using adapter number 2 the two BNC's monitor the reservoir top (SQUID) temperature and the superconducting shield temperature. The two cryocooler diodes can be read by connecting the control/monitor cable to the 15 pin connector on the SRM using adapter number 3 (see table above for pin connections).

3.3 HEATERS:

There are five heaters built into the system:

1. The superconducting shield heater on pins 4-5 of the electrical feedthru connector is a 500 ohm resistor attached to the superconducting shield. It is used to heat the shield above its transition temperature to change the trapped magnetic field.

2. The SQUID heater (#1) on pins 5 and 6 is a 500 ohm heater attached to the SQUID mounting block. It is used to heat the SQUIDS above their transition temperature to remove any trapped magnetic flux.

3. The strip line heater (#2) on pins 1 and 2 is a 500 ohm heater attached to the superconducting strip lines between the pickup coils and the SQUIDS. It is used to remove large circulating currents from the pickup coil structure without heating the SQUIDS or shield.

4. The fill-safety line heater on pins 5 and 12 is a 500 ohm heater attached to the fill and safety lines at the point where the two lines are thermally grounded to the inner cryocooled shield. This heater is used to heat these two lines up to assist in removing any solid air plug that may form. It is connected using adapter number 3 and powered with the SHIELD heater switch on the control electronics. Note, when this Box #3 is connected the diodes monitored by the electronics are the two cryocooler shield temperatures.

5. The fill, vent and safety reservoir heater is a 350 ohm heater connected to the three lines just before they enter the helium reservoir. This heater is on pins 5 and 13 of the SRM 15 pin connector and is powered by pins 4&5 of the control monitor with the shield heater switch using adapter number 2. The heater is used to assist in removal of a solid air blockage at the entrance to the reservoir.

3.4 FIELD NULLING COILS:

There are three coils mounted outside the dewar vacuum jacket to help establish a low field environment in the SRM measurement region. The calibration constants for these coils are given below and in the front of this manual. To use the coils to change the field it is first necessary to heat the superconducting shield to above its critical temperature as described in the following section. The coils are referred to as axial (to change the field in the sample access direction) and transverse - two orthogonal sets of saddle coils for changing the field in the directions transverse to the dewar axis. The axial coil is a helmholtz pair of coils wrapped on the dewar vacuum jacket. Each transverse coil is a pair of saddle shaped helmholtz coils 1/2 meter long and 1/2 meter circumferential length. The approximate field constants for these coils with 15 turns in each coil are given below:

transverse	= 70	gamma per milliamp.
transverse	= 70	gamma per milliamp.
axial	= 60	gamma per milliamp.

To null the SRM field it is advisable to use three independent current supplies for the coils (a simple 3 axis 9 volt battery powered supply is provided with the system) and a three axis flux gate in the access of the SRM. The 2G models 520 and 520A are ideal for this application. Heat the superconducting shield as described in the following section and adjust the coil currents to achieve the desired field. It requires about 45 seconds to heat the shield to its non-superconducting state and it can be maintained at this higher temperature (about 10 kelvin) by turning the heater on for about 10 seconds then off at 4 minute intervals and monitoring the diode voltage. When the desired internal field is achieved with the coils hold the coil currents constant and let the superconducting shield cool to trap the field. Wait until the superconducting shield temperature reaches 5 kelvin or less before turning off the coil currents. This temperature is measured with diode T-1 using box 1 or 2. Please check the actual equilibrium values for the specific SRM. It will require about 20 minutes for the shield to cool after it has been heated to 10 kelvin and another hour before the system lowest noise performance is achieved.

We have found that magnetometers used in steel shielded rooms without ferromagnetic shields around the magnetometer often have strong gradients, especially in the axial field. These gradients are caused, at least in part, by the fields from the cryocooler cold head. The axial gradient can be removed completely by wrapping about 6 turns of insulated copper wire around the cryocooler end of the magnetometer vacuum jacket. Connect these leads to a DC power supply with at least 0.5 amp adjustable output. Heat the superconducting shield and using this 6 turn coil adjust the current amplitude and polarity to provide gradients below 1 gamma/cm over about a 10 cm axial length centered at the sample measurement region. It normally will require 0.15 to 0.30 amp current. Leave this current on. Next use the 3 axis power supply and built in nulling coils to induce the field at the center of the measurement region to below a few gamma. If the room has other gradients these will also appear in the measurement region. It is best to carefully measure the field in the room at the magnetometer location, and if the field or gradient is too high, re-sweep the room and/or move the magnetometer to another part of the room for the field trapping. Once the field is trapped, the magnetometer can be moved back to its desired position, near a wall etc., and the trapped field will not change.

3.5 SWITCHING THE SUPERCONDUCTING SHIELD:

The superconducting shield is a crucial part of the SRM. Because of the unique properties of superconducting materials this shield provides very high attenuation of external magnetic field changes and permits the trapping of a specific field environment. Superconducting materials exhibit zero D.C. resistance so any change in magnetic field will produce an induced current that flows undiminished so long as the field change is applied. This means that the net magnetic flux linking a superconducting ring will remain constant. For a cylindrical shell structure of the type used on the SRM it can be shown that axial magnetic fields are attenuated by a factor of $31^{(l/r)}$, where l is the distance in from the open end of the shield measured on axis and r is the shield radius. Transverse fields are attenuated by a factor of $36^{(l/2r)}$. For the shield dimensions used in the 7.6 cm (3.0 in) 760 SRM and the 4.1 cm (1.65 inch) 755 this provides an attenuation of axial fields at the measurement center of 10^{11} and of transverse fields of 10^{6}.

The only operational procedure used with the superconducting shield in the SRM is its thermal switching. To trap a given magnetic field environment it is necessary to produce the desired field with coils, magnetic shields, etc. then turn on the shield heater for 1 (one) minute, then turn it off. The field at the SRM access can be measured with a fluxgate magnetometer during this process to determine the value to be trapped. As described in the previous section the field is usually adjusted with the built in nulling coils when the shield is normal. Maintain the desired field as constant as possible for the next 20 minutes. It is best to monitor the superconducting shield temperature (Diode T1, box 1 or 2) and wait until it cools to within 30 millivolts of its equilibrium value, (about 5 K at 2.3 to 2.0 volts for most of the diodes used), before removing the external field source. At this time the shield will be well below its superconducting transition temperature and the field will be trapped by the superconductor. It will take an additional hour or more for the SQUIDS to reach their lowest noise performance.

4. PLUGS IN FILL, VENT OR SAFETY:

It is possible to collect air or other contaminants in the fill, vent or safety lines between the room temperature ports on the SRM and the helium reservoir. As will be discussed in more detail in section 6 it is absolutely critical that the plumbing to the safety line be undisturbed since this line is the final pressure release if the fill and vent lines become blocked. Since the fill and vent lines must be opened for helium transfers these are the most likely lines to plug. Any air in these lines will be cryopumped down the line to a location where the temperature is below the freezing point of the contaminant involved. If a sufficient quantity of contaminant is cryopumped it will form a solid bridge across the bore of the line and seal it from gas flow. This can, of course be a very serious problem and great caution must be exercised at all times to prevent contaminants from entering the system.

The fill and safety lines are thermally grounded at the inner vapor cooled shield which operates at 80 kelvin without the cryocooler and at 16 kelvin with the cryocooler. The vent line is thermally grounded at both vapor cooled shields. The outer shield is at 120 kelvin without the cryocooler and at 80 kelvin with the cryocooler. Therefore, when the cryocooler is running, air will cryopump down any of the three lines to the inner vapor cooled shield thermal ground and could block the line at this location. Without the cryocooler the blockage would form at the top of the helium reservoir.

The most common problems we have experienced are plugs forming in the fill and vent lines with the cryocooler operating. The following discussion addresses the identification of this type of blockage and the techniques used to clear them.

4.1 Air plug in the fill line:

A solid air blockage in the fill line will become apparent during a liquid helium transfer. If the line is completely blocked then there will not be gas flow out of the line when the stopper is removed to insert the transfer line. In this event the blockage must be cleared before helium can be added to the system. First, connect the transfer adapter to the fill port being very careful to flush the adapter with helium gas and to prevent any additional air from entering this port and seal the small side of the adapter with a rubber stopper. Check very carefully to make certain that the adapter is tightly clamped to the port. Now pressurize the fill adapter and port to 6 psig with pure helium gas. Hold this pressure constant and turn on the fill-safety heater by connecting the control monitor cable to the 15 pin connector on the SRM top plate with box 3 and activating the shield heater switch. This heater is a 500 ohm resistor with 30 volts giving a power of about 2 watts at the thermal connection between the fill - safety lines and the inner vapor cooled shield. This power will heat the 16 kelvin portion of the fill - safety lines to 70 kelvin in 5 to 10 minutes. During this heating the air plug should melt and be blown into the helium reservoir by the 6 psig helium gas supply. The air will freeze to the reservoir walls and will not cause additional problems unless the SRM is warmed up to above 70 kelvin. If the heater does not melt the plug then the plug may be at the entrance to the helium reservoir. Connect box #2 to the magnetometer and plug in the control electronics. Turn on the SHIELD heater switch and this will apply heat to the fill, vent and safety lines where they enter the reservoir top. Keep the pressure applied to the fill port and the plug should clear.

If the above 2 steps do not clear the plug turn the heaters off, and leave the 6 psig gas pressure applied to the fill port and turn off the cryocooler. The inner vapor cooled shield will slowly warm to about 80 kelvin in 12 to 16 hours and during this warming the plug should clear as described above. If the plug still does not clear the next step will be to alternately pump on and pressurize the fill line as described below in section 4.4.

4.2 Air in the vent line:

Air can be drawn into the vent line during a transfer if the vent valve is not closed quickly enough during a fill when back drafting occurs or at the conclusion of the transfer. Also, if the vent popoff valve leaks and the system pressure is allowed to reach atmospheric it is possible that air will counter-flow around the popoff valve seal and collect in the vent oscillation damper where it can be slowly cryopumped into the vent line. In either case the plug will form at the entrance to the inner vapor cooled shield. This thermal connection is very massive and it is impractical to heat it to melt the air plug with the cryocooler running. Therefore, the cryocooler must be turned off to allow the shield and vent line to warm enough to melt the plug. Follow the steps outlined in 4.3 or 4.4 below to clear the plug.

4.3 Pumping on the plugged line to clear:

Connect a vacuum pump with liquid nitrogen trap onto the VENT port and evacuate the line up to the solid air plug. This pump and the SRM MUST be monitored continuously during the entire warming process so that the pump can be turned off and the lines sealed immediately after the plug melts. The plug will normally clear in the vent line in about 12 hours. In the fill line with its heater this can clear in several minutes.

4.4 Clearing a plug by alternately pumping and pressurizing a line:

A second technique we have used to clear solid air plugs is to connect a vacuum pump as described above with a tee to a pure helium gas supply. The lines from the tee to the SRM port should be as short as practical. A section of each line on the input side of the tee should be made of vacuum type rubber hose, or quick action lever valves should be used in each line. Now by pumping out the line, then closing the line to the pump and opening the line to the gas supply set at 10 psig you will alternately remove the helium gas above the plug and replace this gas with room temperature helium. This pumping and pressurizing should be done as quickly as about four seconds per cycle. It will take up to one hour of these cycles to clear a solid plug. If a pressure-vacuum gauge is used in the pumping-pressurizing manifold you will be able to tell when the plug is starting to clear because the vacuum will not decrease as much on each successive cycle. When the plug clears flow helium gas through the vent and out the fill port for 20 to 30 seconds to insure that the plug is completely removed. Now pressurize the SRM to one psig then close all ports and let the venting occur through the normal vent damper and popoff valve.

4.5 Venting the SRM through the fill port when the vent port is plugged:

There may be times when the vent port is plugged and it is advisable to operate the SRM without taking the time and risks to clear the vent as described above. It is possible to continue operation by venting the helium boil off gas through the fill port. Connect a vacuum needle valve into the fill port plumbing. This connection must be done so that air is not drawn into the fill port. This is extremely important since plugging of the fill port will leave only the safety port clear and it will then be mandatory to warm the SRM until both fill and vent are clear, venting the gas out the safety. If the safety line became plugged the system would not have a way for the helium gas to escape and the internal pressure would rise until the lines spontaneously clear due to the internal pressure and the increased temperature and/or until the reservoir and its plumbing rupture explosively. This situation must be avoided at all cost.

5. CRYOCOOLER MAINTENANCE AND PROBLEMS :

The CTI manual on the cryocooler should be read carefully. This is especially important regarding the tightening and removal of the quick connect fittings on the pressure lines.

5-1 Replacement of the Charcoal Adsorber:

It is very important to replace the charcoal adsorber in the cryocooler compressor every 1000 hours (once per year). New adsorbers are available directly from CTI. This is the only routine maintenance that is required on the cryocooler.

5-2. Cold head sticking noises.

A specific problem we have experienced is contamination in the cryocooler system that results in sticking of the displacer in the cold head component of the cryocooler. This sticking is evidenced by a stick-slip noise from the cold head and can be observed visually by inspecting the sight glass (if equipped) on the cold head. The rotating drive mechanism will be erratic in phase with the sticking noise. It is sometimes possible to remove the contaminant by purging the cold head with the SRM at helium temperatures. Please contact 2G before attempting to purge the cold head. The following procedure MUST be carefully performed in the exact sequence given. We have developed a procedure that uses the cold head as a heat engine, rather than a cooler, during the purge. To do a purge we connect the cryocooler electrical drive power so that the cold head runs in reverse direction. This causes the cold head to heat the cryocooler cylinder and to warm the frozen contaminant so that it is flushed out with the helium purge gas.

A special electrical adapter is available from 2G to change the cold head direction. This adapter connects to the compressor electrical connector marked “Cold Head Power” and the cold head drive cable connects to the adapter. With this adapter in line, the cold head will operate as a heat engine. To purge the cold head:

5-2-1. Turn off the cold head and compressor and immediately disconnect both pressure lines from the cold head. Cap the ends of the lines and the fittings on the cold head. Let the system sit for at least 10 hours to warm the cold head.

5-2-2. Have a standard 210 cubic foot cylinder of 99.9995% pure (ultra-high purity) helium available and charged to at least 1500 psi. Use a pressure regulator that has an output pressure of at least 270 psi. Normal purity helium, such as that used for welding, is not pure enough and will often cause further contamination during the purge procedure.

5-2-3. Install the cold head direction-reversing adapter. If the reversing adaptor is not available the cryocooler cable can be modified as described below to reverse the direction: First, unplug the cable from the compressor. Remove the 2 screws and small clamp plates that secure the cable to the connector. Put the connector back onto the compressor to hold it while unscrewing the back of the connector (the part that the clamp screws went through). This back part is a snug fit to the rubber sleeve around the wires so try to hold the rubber sleeve to keep it from turning while you unscrew the connector. With the back of the connector slipped down on the electrical cable you will see the wires that go to the cold head. Looking into the front of the connector these wires are labeled A,B,C,D,E,and F going clockwise from the alignment slot on the connector. To reverse the motor direction you need to swap the 2 wires that go to pins E and B (or D). That is:

1. Remove the wire from pin E and remove the wire from pin B (it may be on pin D)
2. Leave the jumper from pin B to D.
3. Connect the E wire to B and the B wire to E.
4. Leave the housing off for now, but protect the wires (and you) from electrical shock with tape.
5. NOTE: It would be helpful to have a spare cable that is modified for this reversed direction operation.

5-2-4 Have a 1/4 inch OD copper tube to connect the pressure regulator to the 1/4 inch “Gas Charge” FLARE fitting on the compressor. This fitting is located below the 220 volt power input box on the rear of the compressor.

5-2-5. Connect the pressure regulator to the gas cylinder. Care is required to prevent contamination of the gas in the cylinder since the volume of the pressure regulator is filled with air, which will mix with the helium gas in the cylinder unless it is flushed during the connection process. FIRST turn the regulator pressure control in, i.e., so that gas flow will occur when pressure is supplied to the input side. SECOND connect the regulator to the cylinder then SLOWLY open the cylinder valve. A substantial flow of helium gas must immediately pass through the regulator thereby flushing the trapped air out rather than having it mix in the cylinder. After about 10 seconds turn off the regulator control valve and open the cylinder valve fully.

5-2-6 Connect the 1/4 inch copper tube to the regulator with fittings adequate for the 270 psi charging pressure. Be certain that the tube is long enough to reach the compressor input and then flush the 1/4 inch tube with helium gas through the regulator for about 60 seconds. The gas input at the compressor is a 1/4 inch flare fitting just below the 220 V power connector box. It is about 5 cm from the CHARGE valve. Remove the 1/4 inch flare cap from this fitting and connect the 1/4 inch copper gas charging line. While gas is still flowing out the tube connect it to the compressor 1/4 inch flare fitting. Before fully tightening the flage nut at the compressor, but with helium gas still flowing through the charge line, open the compressor gas charge valve about 1/4 turn to let a small amount of helium from the compressor flush out the section of line between the charge valve and the flare fitting. Now tighten the connection and then increase the pressure on the regulator to 250 psig.

5-2-7 Attach the purge valve supplied with the cryocooler tool kit to the cold head SUPPLY fitting. Tighten only a few turns at this time, and be certain that gas does not flow out the purge valve.

5-2-8 Open the compressor charge valve and simultaneously turn on the compressor and connect the SUPPLY line to the cold head RETURN fitting AND turn on the cold head drive. These three operations are to be done in the order given and in rapid succession, but don't panic. Adjust the pressure regulator to keep the compressor pressure at 250 psig.

5-2-9 Now, carefully tighten the purge valve on the SUPPLY fitting, by hand, until gas flows out the valve. The objective is to get a good flow on the compression stroke, and still maintain some flow at all times. If the valve is tightened too much the compression stroke will give a burst of gas but then the flow will stop completely, making it possible for air to be drawn into the cold head. Continue to run the system as connected until about 1500 psi pressure drop occurs in the helium gas supply cylinder. Be certain to leave about 500 psig in the gas supply cylinder

5-2-10. The cold head should run smoothly without any stick-slip sounds.

5-2-11. To STOP PURGE, remove the purge valve and simultaneously turn off the compressor. Reconnect the supply line to the SUPPLY fitting on the cold head, and the return line to the RETURN fitting on the cold head. Remove the direction reversing adapter from the cold head drive circuit. Restart the compressor and after running for a few minutes add helium gas to achieve a compressor pressure of about 280 psig. Close the compressor charge input valve, reduce the pressure regulator pressure to zero and remove the charge line.

5-2-12. This should have cleared the cold head of contaminants. It will now require about 24 hours for the SRM to return to equilibrium temperature and operation.

5-3. CHANGING THE COLD HEAD:

The cold head may need to be changed if the above procedures do not solve the sticking problems. This may be done with the magnetometer at helium temperatures, or when the system is warmed to room temperature.

5-3-1: Cold exchange of the cold head:

This procedure requires special tools and fixtures and should be done by a certified Cryogenic Technology Inc. (CTI) engineer or by a 2G engineer. Please contact CTI and 2G before this is done. Note, that the cold head cylinder is a PERMANENT part of the 2G helium dewar and is not to be removed with the cold head. To do an exchange, only the displacer part of the cold head is removed. Any loosening of the 10-32 bolts that hold the CTI cylinder to the 2G vacuum jacket can result in loss of dewar high vacuum and create a very dangerous and damaging situation.

6. HAZARDS OF SYSTEM EXPLOSION :

The liquid helium reservoir of the SRM system is in danger of a high pressure rupture whenever there is a loss of vacuum in the superinsulation region if the reservoir is at helium temperatures. If the fill, vent and safety lines have become plugged at the same time the danger then becomes a certainty. The purpose of the safety line is to provide a venting path that is never opened during normal system operation and therefore should never become plugged. This points out the critical purpose of the safety line and the requirement that it must not be disturbed without specific instructions from 2G. We have never experienced a rupture of one of our 2G systems so it is difficult to predict the extent of the damage that would occur, but it is clear that if a rupture seems likely then the region within at least 100 feet of the SRM must be evacuated to protect life and property.

Figures 1-1 through 1-4 give a cross section layout of the 760-R SRM and show the relative locations of the reservoir, vapor cooled shields and the superinsulation volume. The 760 and 755 systems have the same basic layout. The fill, vent and safety lines are 0.25 inch OD stainless steel tubes that pass through the superinsulation region from the helium reservoir to the outside of the SRM. The long length (up to 180 inches for the vent line and 80 inches for the fill and safety), and the small diameter are very important in achieving the very low helium loss rates. The same length and diameter makes it very easy for a solid air plug to block the line. In the following section we will discuss the most likely ways that a hazardous condition can occur in the SRM, and the time that one might have to resolve the problem before any danger occurs.

The time that may be required to reach rupture conditions depends on the circumstances of the system failure. In the following two paragraphs we will discuss the two most likely situations:

6-1. Catastrophic vacuum failure:

The loss of dewar vacuum is the least likely but the most hazardous situation. If the vacuum is lost due to a major accident such as fire in the laboratory, an object falling on the SRM and rupturing the outer vacuum jacket, or failure of the sample access tube, then the pressure will build up in the reservoir to the rupture point in a few minutes so the only choice is to evacuate the area immediately.

6-2. Slow vacuum failure:

If the vacuum loss occurs due to a leak in a vacuum seal or rupture of one of the plumbing or electrical fittings, then the pressure build up in the reservoir will be much slower and can probably be released fast enough through the vent, safety and fill ports. As soon as it is realized that a vacuum failure has occurred the operator must open the vent valve. Rapid flow of very cold helium gas will exit these three ports so great care must be used to prevent any contact with the cold gas. Most of the helium gas will be vented in about 10 minutes and after this time the volume of cold gas remaining in the reservoir should not produce enough pressure in further warming to rupture the reservoir walls. Continue to let the reservoir vent until the flow almost stops and/or the reservoir has warmed to room temperature (0.4 volts on the reservoir and shield diodes). It will take from 30 minutes to more than 24 hours for the reservoir to reach room temperature. As soon as possible contact 2G for further advice.

6-3. Plugging of the plumbing lines without vacuum failure:

The liquid helium reservoir is connected to the top flange of the SRM with three 1/4 inch OD stainless steel tubes that are within the superinsulation of the instrument. If the room temperature end of any of these tubes is left open to the atmosphere without a strong exit flow of helium gas, then air will be cryopumped into the line and will quickly (in a matter of a few seconds to a minute) solidify in the line somewhere between the outer and inner vapor cooled shields. This is a distance of up to 80 inches down in the lines. A solid air plug of this nature will support very high pressures, well beyond that required to rupture the helium reservoir!

If any indication is observed that the lines may be plugged PLEASE contact 2G immediately.

We have discussed in section 4 several ways to clear a plug in the fill and vent lines The danger occurs if all three lines become plugged at the same time. This should not occur since the safety line should NEVER be opened, BUT IF FOR WHATEVER REASON ALL THREE LINES DO BECOME PLUGGED THE SYSTEM IS IN DANGER OF RUPTURING. If the cryocooler is left on and is operating properly, then the liquid helium will slowly evaporate and the reservoir pressure will rise to equilibrium with the cryocooler at about 20 Kelvin. The pressure will be about 40 psig at this point and the reservoir walls will support this pressure with no difficulty. It will take many days for the pressure to rise to even 10 psig so it should be possible, following the procedures given in section 4, to clear at least one line before a danger point is reached. Please contact 2G as soon as any evidence exists to show that the lines may be plugged.

7. TELEPHONE, E-MAIL AND FAX NUMBERS

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