Appendix 4: Liquid Helium Transfer and Level Detection

Transfer Procedure

• Begin by locating the transfer line, usually hanging on its rack. Check the pressure with a thermocouple gauge. If the pressure is more than 60 microns, ask a staff member to pump down the line.

• The cryostat will have been precooled with liquid nitrogen one day in advance of your data run. (It is important to communicate with the staff about when you will and will not be taking data.) Cooling from room temperature to 77K with nitrogen conserves helium. Liquid nitrogen costs about $0.2/liter and liquid He, about $7/liter. We wish to conserve liquid helium, not only to minimize expense, but because it is a non-renewable resource, and we have no facilities for recycling it.

• For the quantum hall and superfluid helium experiments, the first step in the transfer process is to remove the liquid nitrogen. Each cryostat has a “blow-out tube,” a continuous stainless steel tube, which can rest on or near the bottom of the experimental area of the cryostat. To remove the liquid, connect the top of the blow-out tube to a storage vessel. Pressurize the Dewar with nitrogen gas. This will force the liquid to flow out through the tube. Pump the Dewar to make certain that the last millimeter or so of liquid is removed, then back-fill with nitrogen or helium gas.

• Next check the level of liquid helium in the storage Dewar. This is performed with the thermal-acoustic oscillation indicator, which is more commonly called the "thumper" in the lab. The change in frequency of the oscillations has to do with the resonant frequency of an open versus a closed tube. The reason why the oscillations, known as Taconis oscillations, occur in the first place is more complex and has been described in the literature.\(^1\) In any case, measure the liquid helium level in the storage Dewar before, as well as after, you transfer and record your measurements on the clipboard. This way you will know how efficient your transfer was and the staff can tell (at a glance) if and when it's time to order more helium.

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\(^1\) *Experimental Cryophysics*, Hoare, Jackson, and Kurti (eds), (Butterworths, London, 1961): Chapter 7 by A. Wexler, entitled "Transfer of liquefied gases"
• Insert the transfer tube into the storage Dewar and allow gas to flow out the other end until a white plume starts to form, indicating that the tube is sufficiently precooled. Then quickly insert the transfer tube into the FILL tube on the cryostat. The transfer tube should touch the bottom of the storage Dewar and then be raised 3-4 mm so that "dust" (solid air particles collected at the bottom of the storage Dewar) does not flow into and plug the transfer tube; the other end (in the cryostat) should be inserted as far as possible.

• Transfer slowly using about 0.25 PSI pushing pressure on the storage Dewar for about 1 minute, to precool. Then raise the pressure to about 1 PSI to increase the transfer rate. The economical transfer of liquid helium is particularly dependent upon the techniques used. Since the inside of the transfer tube and the cryostat must be cooled to 4.2K before any liquid will collect, too rapid a transfer will result in an excessive use or waste of liquid. Liquid helium has the smallest latent heat of vaporization of the cryogenic liquids and if only the latent heat were to be used in pre-cooling, about one liter of liquid would be needed for the transfer tube alone. However, with a slow transfer one can make use of the enthalpy of the evaporated gas to provide some cooling. The enthalpy of the gas between 4.2K and room temperature is about 75 times that due to the latent heat at 4.2 K. Thus, let the cooling power of the vapor provide the necessary pre-cooling effects rather than by just vaporizing liquid. The capacity of the helium reservoir in the cryostat is 2.8 liters. If you use 1 PSI pushing pressure, a rule-of-thumb for our particular transfer situation is that the number of liters transferred out of the storage Dewar is approximately equal to the number of minutes of transfer; how much greater that number is than the actual collected amount depends on the waste. As you cannot see the helium level above the windows, you will have to rely on the Level Monitor (described below) to know when the cryostat is full.

• Remove the transfer tube.

• Warm any frozen o-rings with a heat gun.

• The system is now ready to operate and cool down further.

The temperature of liquid He is 4.2 K at atmospheric pressure (760 mm Hg = 760 Torr). The temperature may be lowered by pumping on the liquid He to reduce the vapor pressure. This cools the helium by evaporation. Using the "1958 He\textsuperscript{4} Scale of Temperatures" (part of the Bench Notes), you can convert the pressure readings to
temperature. However, because of the location of the manometers, be aware of uncertainties; the relation between vapor pressure and temperature may not be accurate because of density stratification caused by cycling the pressure. The system is capable of pumping down to 4.8 mmHg, or about 1.56°C.

**Helium level detectors**

It is important to know how much helium is in a cryostat; a sufficient amount must be transferred so that an experiment can be executed in the available time, and the experimenter always wants to know how much more measuring time remains. The easiest method is by visual observation and this can be used when the helium level is in the vicinity of the windows in the cryostat. When the level is higher alternate methods are used. In this experiment we use a superconducting level detector and a capacitance level detector.

**SC level detector.** The level of liquid helium in the second sound, quantum hall and superconductivity experiments is monitored by a superconducting indicator (American Magnetics model 134 Liquid Helium Level Monitor) -- a piece of wire (typically a niobium alloy) with a superconducting transition temperature above 4.2 K. The portion of the wire in the liquid helium is superconducting (zero resistance) and the portion above the liquid is normal. The total resistance is related to the proportion of normal wire; a four-lead resistance measurement is necessary. Sufficient power must be dissipated in the SC wire so that the section in the vapor phase is normal while that in the liquid phase is superconducting. Additionally, there is a heater resistor built into the probe to ensure that a section of the wire above the liquid is warmed above the transition temperature; dissipation in wire then propagates the normal region down to the liquid-vapor interface. Dissipation in the wire is substantial. Therefore use the INTERVAL mode so as not to boil away your helium! Note that the bottom of the sensor is above the bottom of the cryostat; thus a 0% level indication does not mean you're out of helium -- but you can see the level through the window. Currently (1996) the commercial electronics box is not working. It has turned out that rather than repair, we can use the current supplied by this box, applied to the SC wire, and measure the voltage drop across the wire (about 22 V
when empty and 0 V when full). When not in use, turn off the current as it boils of a lot of helium due to ohmic heating.

**Capacitance level gauge.** Another way of detecting the level is to use a capacitance level gauge. This is used in the liquid helium heat capacity experiment. Two long concentric stainless steel tubes with a very small gap between them serves as the gauge. The tubes are separated by an insulating thread, which prevents shorting. The capacitance of a meter long section is of order 1000 picofarads. We take advantage of the fact that the dielectric constant of liquid helium is about 1.054 and that of gaseous helium is 1.00000+. Thus if the gap between tubes is filled with liquid helium the capacitance will be increased by 1.054, and intermediate levels will have a proportional increase of capacitance above that of the empty dewar. Our gauge is 24 inches long. It has an empty (cold) capacitance of about 742 pF and a change of 1.2 pF/inch for helium. The change for liquid nitrogen is 11 pF/inch. It is read with a simple hand held capacitance gauge.