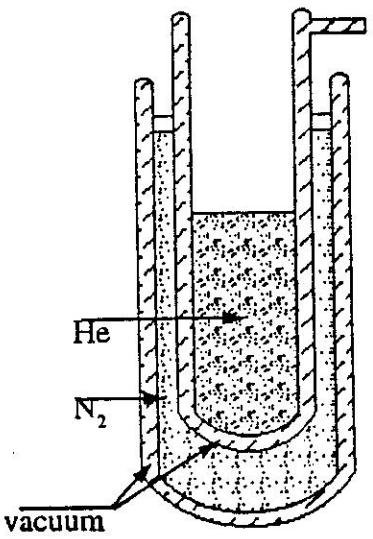
file [451]lowt.tex, v4: 18 Nov 1994

The Low-Temperature System for Second Sound

The low-temperature system is based upon a dewar with four chambers. Starting from the outside these are:

(1) outer vacuum chamber
(2) liquid nitrogen (LN) chamber
(3) inner vacuum chamber
(4) experiment chamber with the measurement cell



The outer vacuum chamber is permanently sealed off and is not accessible. The LN chamber cools the environment of the experiment chamber into which liquid helium is transferred. The inner vacuum chamber is accessible for pumping by a small pump. The experiment chamber is connected to a heavy-duty pump to pump off helium gas, reducing the temperature of the liquid helium bath from 4.2 K at atmospheric pressure to about 1.5 K.

Before liquid helium is added to the experiment chamber, the system must be prepared by precooling it. The steps are as follows:

(1) Helium gas diffuses through the glass from the experiment chamber to the inner vacuum chamber. We can expect to find some helium gas in the inner vacuum chamber, and if it is left there it will conduct significant heat to the experiment chamber. We get rid of it by successive dilution with air. A little air in this chamber is not a problem because it will freeze on the walls and not conduct heat. Helium, by contrast, will not freeze out. Procedure: Connect a small pump to the glass tube on the rear of the rack leading to the inner vacuum chamber. Open the glass stop-cock and pump out. Then disconnect the pump and let air in. Then pump out again. Repeat three or four times. Each repetition dilutes the residual helium gas by a factor of about 1000.

(2) To precool the experiment chamber we need some gas in the inner vacuum chamber to provide thermal contact with the walls of the LN bath. Therefore, we allow a small amount of air into the inner vacuum chamber. Procedure: Close the stop-cock and disconnect the pumping hose. Put your finger over the opening on the glass tube and open the stop-cock briefly. This will allow a volume of air equal to the volume of the small entry tube into the inner vacuum chamber. Close the stop cock, which will hopefully allow you to remove your finger.

(3) As we precool, we do not want water vapor to freeze in the experiment chamber. We therefore pump out the experiment chamber with the large pump as normally connected. Procedure: Open the valve between the experiment chamber and the pumping line, plug in the pump fans, and turn on the pump at the electrical box on the wall. The pressure gauge on the left should drop to about 2 mm of Hg.

(4) We use LN to precool the system. There is a long window on the dewar so that we can see the liquid nitrogen in the LN chamber and the liquid helium in the experiment chamber. Procedure: First check to see that there is no water condensed at the bottom of these chambers. If there is water, it will freeze, expand, and crack the dewar. Next, fill the LN chamber with LN, right to the top.

(5) We use helium gas to cool the measurement cell by thermal convection. Procedure: After the LN has been in place for about 20 minutes we can add the gas. Open the main valve on a tank of helium gas and watch the pressure rise on the tank inner gauge. Open the large control valve (clockwise!) on the tank pressure reducer and set the tank outer gauge to about 10 psi. (Attach a line from the tank to the connection to the experiment chamber, but don't open the small Veeco valve yet.

Close the large valve to the large pump and turn off the pump, but leave the pumping line connected to the experiment chamber. Now open the small Veeco valve slowly to admit helium gas. If you open this valve carefully you can fill the experiment chamber with helium without pulling too hard on the pressure reducer on the helium gas tank. Allow the experiment chamber to fill to atmospheric pressure. You'll know when you get there because the right-hand pressure gauge will read 4.2 degrees. Close the small Veeco valve, but leave the hose connected to the helium gas tank. Turn off the gas at the tank.

(6) After the helium gas is added to the experiment chamber, a good deal of LN will boil away. As the system cools, the pressure of helium gas in the experiment chamber will fall. Procedure: Top up the LN chamber, and add helium gas as needed to maintain the pressure near atmospheric.

This is the end of the precooling procedure. Now wait.

(7) Liquid helium (LH) is expensive, so we keep track of its use. Procedure: Open the top valve on the LH vessel and insert a dipstick. You can feel the taconis vibrations. Touch the bottom of the vessel and mark the location on the dipstick with an alligator clip. Raise the dipstick, and note the point where the vibrations change from slow to fast. This is the top level of the LH. You can find that location to a precision of 1/4 inch. Mark the location on the dipstick with a second alligator clip. Measure the distance between the two alligator clips in inches and use the conversion chart for your LH vessel to determine the number of liters remaining. If your initial level reading is less than the most recent level recorded on the vessel clip board, indicate the difference on the clip board and attribute it to "boil off." Make sure that the level of helium in the vessel is high enough that the transfer tube will extend below the surface. If there is doubt, raise the level of the entire vessel.

(8) We transfer LH by pressurizing the LH vessel with helium gas. We regulate the pressure with a valve on the gauge board. (The gauge is useless, but the control valve and the pressure release toggle valve are useful.) Procedure: Position the LH vessel for transfer, and make sure that the helium gas in the experiment chamber pressure is at 1 atm. pressure. Attach a line from the helium gas tank to the gauge board input and attach the output to a hose large enough to fit the large connection on the LH vessel. Establish a slow flow of helium gas to flush these lines. Attach to the large vessel input, but don't open the valve to the vessel. Make sure you have a flashlight handy.

(9) We precool the transfer tube. Procedure: Slowly lower the long end of the transfer tube into the top of the vessel, below the LH surface. If the LH level is high, frost will soon form on the free end of the tube and very cold helium gas will escape. If the level is low, you may need to open the valve to the helium gas on the vessel and allow some helium gas to enter in order to get adequate cooling of the transfer tube. When admitting helium gas, close the valve to the small safety pressure release.

(10) We transfer helium from the storage vessel into the experiment chamber of the dewar. Procedure: Remove both corks at the top of the experiment chamber. Slowly lower the transfer tube into both vessel and dewar. The short end of the tube will go down into the dewar as far as the transfer tube itself will allow. The long end must extend below the helium surface in the storage vessel. Secure the O-ring with the brass fitting around the transfer tube at the vessel. Some helium liquid may flow immediately due to boiling in the vessel. When the initial flow has stopped, pressurize the vessel with helium gas (1 to 2 psi) by closing the valve to the safety pressure release and opening the valve to the helium gas line. Watch the liquid condense at the bottom of the experiment chamber by illuminating with the flashlight.

(11) We don't want to continue to transfer helium if the experiment is not going to work because the dewar has failed. Procedure: As liquid helium fills the experiment chamber, watch the bottom of the LN chamber to be sure that boiling continues. If the LH cools the LN below its boiling temperature we know that the dewar has "gone soft." If LN boiling stops then stop the transfer; otherwise, continue. When the level of liquid helium reaches the START mark on the side of the dewar then stop the transfer by turning off the helium gas flow and releasing pressure with the toggle valve. Remove the transfer tube, and replace the corks on the access holes on the top of the dewar. You should feel gas escaping from the pop valve.

(12) Wrapping up the transfer: Procedure: Measure the level of LH in the vessel as before, and record the liquid used on the clipboard. Charge the amount to the Advanced Lab. Make sure that the O-ring and brass fitting have not inadvertently got transferred from the LH vessel to the transfer tube. Close the top valve and the gas-line valve on the vessel, and open the valve to the safety pressure release. Remove the helium gas line and return the LH vessel so that others may use the LH.

(13) Enjoy your low-temperature experiment. Procedure: You can reduce the temperature of the helium bath by pumping on it with the large pump. Be sure that the fans are on to cool the pump. The temperature can be controlled rather precisely by regulating the large valve to the pump. At low temperature, the temperature is measured by the pressure gauge and using the 1958 helium tables to convert from (mmHg) to (degrees K). The lambda point occurs at 38 mmHg. The pressure gauge gives an accurate reading of temperature above and below the lambda point, but it does not give a correct reading after the temperature has risen through the lambda point from below. [Note that whereas we measure temperature by reading a pressure gauge, we previously measured the pressure of helium gas by reading a temperature gauge. The low-temperature world is strange.]