HPD MODEL CP-525
VOLTAGE STANDARD CRYOPROBE

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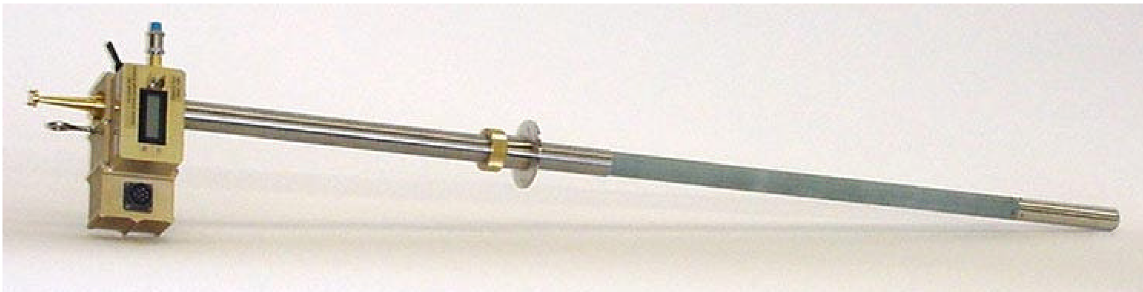

1.0 GENERAL DESCRIPTION

The model CP-525 cryoprobe is the interface between a Josephson voltage standard (JVS) chip and its microwave and bias electronics system. The cryoprobe, shown in Fig. 1, is made to insert into a variety of liquid helium Dewars and provide a gas tight and RF-tight seal at the top of the Dewar. The Josephson array chip (1) mounts onto the lower WR-12 flange (2) of a tube waveguide (3) inside a magnetic shield (4) at the bottom of the cryoprobe. The waveguide is an internally silver plated 12.5 mm diameter stainless steel tube with launching horns on each end. The magnetic shield and waveguide are supported by a 28 mm diameter fiberglass tube (5). A second 32 mm diameter stainless steel tube (6) and sliding flange (7) attach the cryoprobe to the top of the Dewar. Helium vapor vents through a gas recovery and safety valve (8) at the top of the support tube. This allows an easy connection for helium gas recycling and lowers liquid helium consumption. Six #32 copper wires provide the bias and potential connections to the chip mount (9). An RF-tight box (10) at the top of the cryoprobe encloses a printed circuit board (11) with 6 RFI filters that protect the chip from noise picked up in the bias cable. The bias leads terminate in an 8-pin twist lock connector (12) (Amphenol PT02A-16-8S). The electrical circuit diagram is shown in Fig. 2. The 75 GHz microwave input is connected to the WR-12 flange (13) at the upper end of the tube waveguide. A liquid helium level sensor (14) is mounted in the support tube and extends to the bottom of the magnetic shield. It is connected to a battery operated readout module (15). A screw eye (16) at the top of the cryoprobe provides a convenient support point for lowering the cryoprobe into a Dewar. A fiber glass support bracket (not shown) attaches to the back of the filter box to support and protect a 75 GHz microwave assembly.

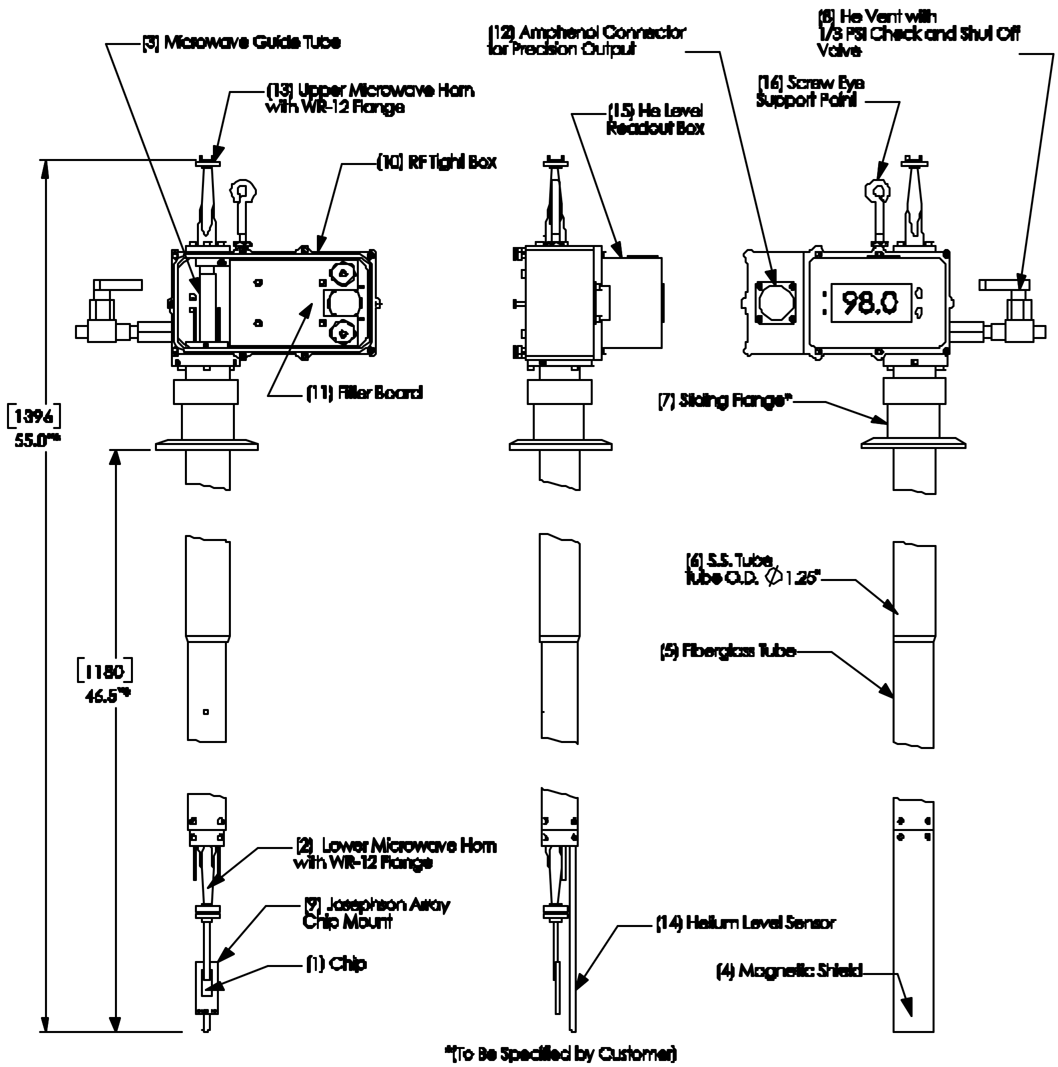

Fig. 1 Mechanical drawing of the CP-525 Cryoprobe

1.1 RFI Filters

The stability of the constant voltage steps produced by a Josephson array requires that the array be protected from radio frequency interference (RFI) that may be generated by equipment in the system or picked up on the system cables. Each of the 6 lines that connect to the Josephson chip passes through a filter network in the box at the top of the cryoprobe. The filters use several stages of discrete components to intercept frequencies below 100 MHz. Higher frequencies are blocked by lossy transmission lines created by pressing conductive foam against a meander line on the printed circuit board. The foam also attenuates RFI that may be transmitted through the air between the input and output sides of the box enclosing the filters.

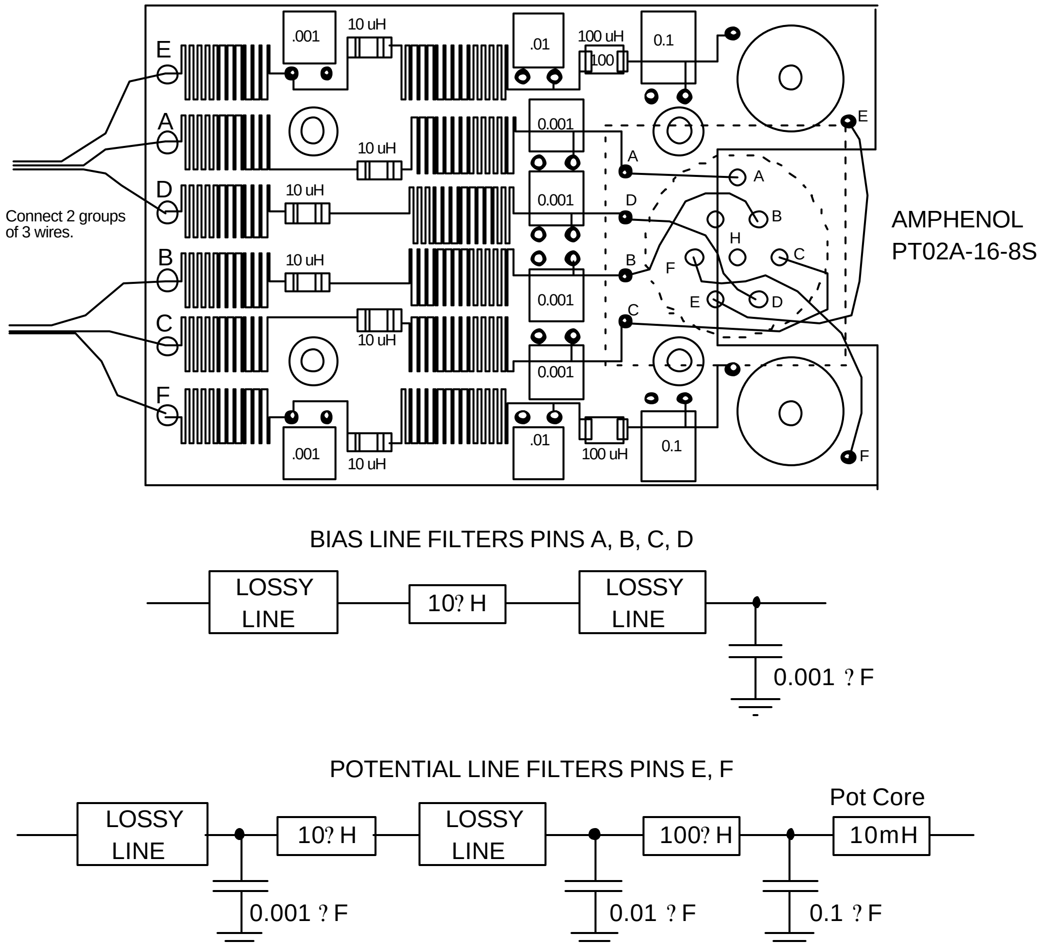

Fig. 2 Filter printed circuit board layout and schematic diagram.

2.0 SPECIFICATIONS AND FEATURES

? Milled aluminum connector/filter box.

? Six #32 pure copper array leads (4 bias, 2 potential) wired through 5 stages of RFI filtering to Bendix connector PT02A-16-8S. Thermal EMF in potential leads is less than 1.0 µV.

? G-10 support tube with internal wiring, helium level sensor, and waveguide.

? Sliding flange assembly with 70 - 110 cm depth adjustment range (Specify Dewar flange type).

? Low loss, internally silver plated stainless steel tube waveguide with WR-12 input and output flanges. Typical attenuation at 75 GHz of 0.8 dB with periodic resonant peaks to 1.5 dB.

? Helium level sensor and integral fully shielded battery driven display.

? 15 cm long AD-MU-80 magnetic shield (CP-EXP-1184 optional, $1500 extra).

? Heat leak equivalent to less than 0.6 liter of liquid helium/day.

? Helium vent system with relief and shutoff valves.

3.0 MOUNTING A JOSEPHSON ARRAY CHIP TO THE CRYOPROBE

The CP-525 cryoprobe is designed to accommodate the JVS chip mount developed at NIST and now sold commercially by Hypres, Inc. Attach the chip mount to the cryoprobe as follows:

1. Remove the magnetic shield to expose the waveguide and bias wires.
2. Attach the chip mount flange to the cryoprobe flange with brass (nonmagnetic) screws.
3. Prepare the ends of the 6 bias wires so that each is freshly tinned. The insulation on this wire is removed by the heat of soldering so there is no need to scrape the insulation off. Trim the tinned portion of the wires to 2 mm.
4. Rotate the cryoprobe so that the JVS chip is facing down. If necessary, tin the 6 solder pads on the chip mount with clean solder. Solder each of the 3 wires exiting either one of the bias shield tubes to the 3 solder pads on the left side of the chip mount. Use only electronic grade 63/37 rosin core solder. Solder the 3 wires from the other bias tube shield to the 3 solder pads on the right side of the chip mount. The order of the wires among the three pads is unimportant.
5. The solder joints should be shinny. Gently pull on each wire to test for a good joint.
6. Replace the magnetic shield and secure it with 4 screws.
7. Use an ohmmeter to verify the following approximate resistances between the designated pins of the bias connector at the top of the cryoprobe:

A to D	2-8 O
A to E	5-20 O
A to F	20 – 200 kO (depends on chip, see spec. sheet)
B to C	2-8 O
B to F	5-20 O
A to Case	open circuit

8. Resistances outside these ranges indicate a problem with the chip or the cryoprobe wiring.

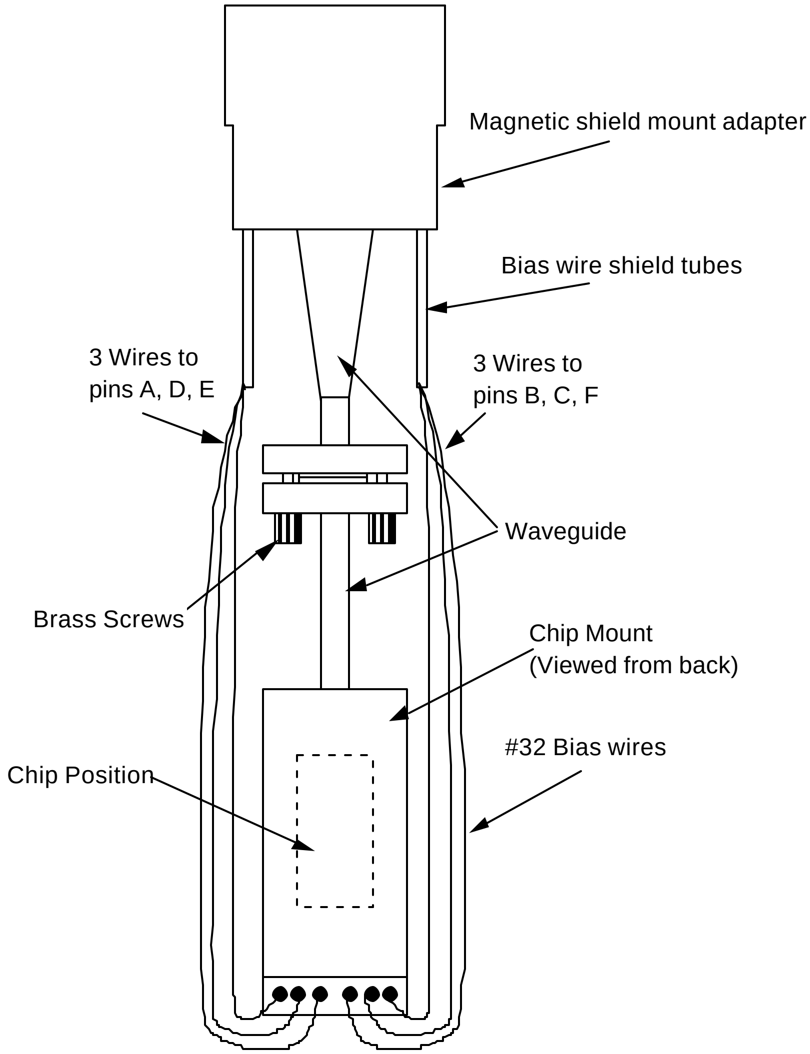

Fig. 3 Detail of chip mount wiring.

4.0 LIQUID HELIUM SAFETY

A liquid helium Dewar is essentially a large thermos bottle with a long and narrow neck. In a typical 100 liter Dewar the neck is about 45 cm long and the inner cylindrical container is about 60 cm deep. This makes a total depth from the top flange of about 105 cm. It is very important to prevent air from entering the liquid helium storage Dewar because it condenses to a solid in the neck of the Dewar and can eventually plug the neck. Without an escape path for the helium vapor, the pressure in the Dewar will rise until the Dewar ruptures. This can be explosive. Keeping the top of the Dewar covered at all times will prevent this problem.

If an ice block should develop in the neck of a liquid helium storage Dewar, there are a number of procedures which can be used to resolve this problem. First determine if the container is equipped with a redundant relief passage (as are most storage Dewars) and if one or both are blocked. If only the center one is blocked, the liquid access port assembly may be removed from the Dewar (after depressurizing) and defrosted separately outside. During this process the dewar must be sealed from the atmosphere until the access port is once again ready to use. A piece of Plexiglas can be used to cover the top of the liquid access port. Once the helium gas settles in the dewar, the extent of the blockage can be viewed easily through the Plexiglas using a flashlight.

4.1 Procedure for Ice Block Removal

Warning
Use only a blunt object inside the neck of the dewar. The neck material of the dewar is very thin and is easily damaged or punctured.

If both passages are blocked or if only one is present, use the following procedure:

1. Using a piece of tubing positioned just above the blockage, direct a flow of room temperature (or heated) helium gas onto the blockage until an opening is formed to relieve the helium space.
2. Once an opening is formed, the rest of the blockage may be carefully chipped away if it is accessible, or melted away with additional gas if it is not.

If the blockage has just formed or it is determined that very little pressure buildup is present in the helium space, the following alternate procedure may be used:

1. Obtain a suitable length of copper or aluminum rod and affix a stop at a point such that the rod cannot accidentally drop into the helium reservoir when the blockage is pierced.
2. Warm the rod somewhat, if convenient.
3. Lower the rod into the neck tube to contact the blockage and allow it to remain there until its heat capacity has been completely transferred. Repeat until an opening is formed.
4. Carefully chip away the remaining ice.

After an ice block has been cleared and the liquid helium is consumed, the remains (ice or water) of the blockage at the bottom of the helium reservoir should be removed before the dewar is refilled.

During storage, a liquid helium Dewar should always vent through a low pressure relief valve, never through an open neck or vent tube. Always wear a safety face shield and cryogenic gloves when opening the top of the Dewar, cleaning the neck, inserting or removing the cryoprobe, or measuring the liquid helium level with a thumper tube.

Warning
When working with liquid helium Dewars, always insure the work area is well ventilated. Liquid helium is a potential asphyxiate when used in poorly ventilated areas. Avoid skin contact with liquid helium or its boil-off gas. Always wear loose fitting gloves of impermeable material rated for cryogenic temperatures and chemical goggles or safety glasses when handling liquid helium.

Keep hands and face away from the Dewar opening while performing any of the procedures listed below. A sudden release of vapor could cause severe burning or propel particles or objects out of the dewar neck.

5.0 COOLING THE CRYOPROBE

Typically liquid helium storage Dewars have four tubes exiting horizontally from the neck. They attach to:

(a) A pressure gauge.
(b) A high pressure relief valve.
(c) A vent gate valve.
(d) A vent gate valve in series with a low pressure relief valve.

Dewars are usually shipped with helium gas venting through only valve (b)**. To maintain the Dewar in a safe condition, be sure that gate valve (c) is closed and open the gate valve that is in series with the low pressure relief valve (d).** If there is substantial pressure (for example 5-10 psi) in the Dewar, it is desirable to control the vent rate before finally opening valve (d) all the way. This could take several hours**. When the Dewar is in your laboratory, either valve (d) or the low pressure relief valve (8) Fig. 1 on the cryoprobe must be open.** Venting helium boil off gas through the cryoprobe intercepts heat conducted down the waveguide and wires and reduces helium consumption.

Confirm that the cryoprobe flange is a match for the helium Dewar. If not, replace the cryoprobe flange as required. It is essential that the flange make a gas tight and electrically continuous seal. Select an area with a minimum ceiling height of 3 m and attach a pulley securely to the ceiling. Thread a cord and hook through the pulley. The cord should be at least twice as long as the distance from floor to ceiling. The bias shorting connector should be attached to the cryoprobe bias input. Use the hook to attach the cryoprobe at the eye bolt to the cord and pulley and suspend the cryoprobe above the helium Dewar. Wrap the cord at least once around the protective ring at the top of the Dewar to minimize the chance of accidentally dropping the cryoprobe. Vent the Dewar to ambient pressure by opening the gate valve in the vertical tube exiting the neck insert. Cracking the valve to slow the vent rate will conserve expensive liquid helium. When the venting stops, remove the Dewar neck insert. Be sure that the rubber gasket stays with the Dewar. There should be a clear path of at least 3.2 cm diameter to the bottom of the Dewar**. Always minimize exposure of the Dewar opening to room air by covering it or plugging it with a cloth.** Air that is allowed to enter the neck will freeze and may plug the neck or bond the cryoprobe to the neck. See Section 4.0 "Liquid Helium Safety" for further information on liquid helium.

Before cooling the cryoprobe, attach the bias shorting plug to the Bias connector (12). This reduces the probability that magnetic flux will be trapped in the Josephson array.

The cryoprobe should be inserted into the Dewar and lowered slowly over a time of about 15 minutes. Helium gas venting will begin when the cryoprobe has been lowered about 30 cm. The probe is normally lowered in steps of 5-10 cm, stopping each time the Dewar begins to vent. Take care to minimize the exposure of the Dewar opening to the room air by wrapping a cloth or paper towel around the Cryoprobe tube where it enters the Dewar. When the probe is fully immersed secure the probe flange to the Dewar with the flange clamp. It may be necessary to adjust the position of the cryoprobe flange to set the cryoprobe to the right depth - about 1 cm off the bottom of the Dewar.

When the cryoprobe is set to within 1 cm of the Dewar bottom, press the helium level readout button to activate the readout. The reading will stabilize in about 15 seconds. Record the value on a chart for helium level versus time. Refer to liquid helium use charts to estimate when it is necessary to order more liquid helium. A typical use chart for a 100-liter Dewar is shown in Fig. 4.

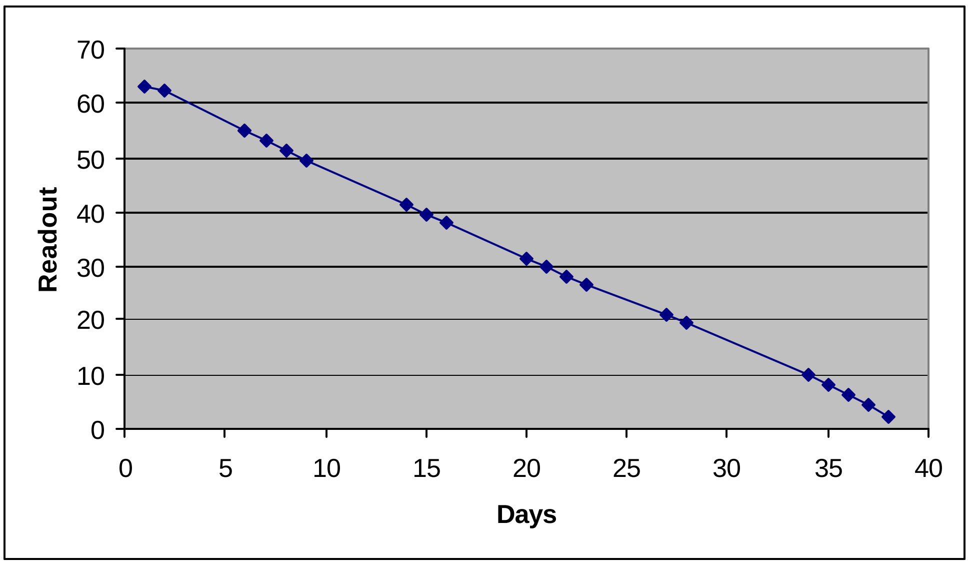

Fig. 4 Typical liquid helium usage for a CP-525 Cryoprobe in a CMSH 100 liter Dewar. The calibration can be adjusted (as above) to approximate liters remaining in the Dewar.

When the cryoprobe is secured into the Dewar, valves (c) and (d) can be closed and valve (8) opened allowing helium gas to vent through the 0.3 psi relief valve on the cryoprobe. This helps to conserve helium by using the cold vent gas to cool the waveguide and wires to the array. If the vent valve (c) is left open, air may enter the Dewar causing an ice block that can damage the Dewar and/or the cryoprobe. The cryoprobe is intended to remain fully immersed in a 100-liter Dewar for the approximately 6-week holding time of the Dewar.

When the cryoprobe is all the way down and the flange clamp secured, remove the bias shorting plug from the cryoprobe. Connect the bias cable to the cryoprobe array bias input (12).

5.1 Changing Dewars

(1) Vent the new Dewar and remove the neck insert. Temporarily plug the neck with a paper towel. NEVER LEAVE A DEWAR WITH AN OPEN NECK!

(2) Turn off all system power (any order) and disconnect all cables from the cryoprobe.

(3) Raise the probe about 50 cm and wait for the shield boil-off to stop venting (about 20 s).

(4) Attach the bias shorting plug.

(5) Quickly transfer the probe to the new Dewar and lower it about half way. This step should be done in 5 seconds or less.

(6) Slowly lower the probe, secure the flange, close valves (c) and (d) and open valve (8). The Dewar will vent through valve (8).

(7) Put the neck insert into the empty Dewar and be sure its vent valve (c) is closed and (d) is open.

The Josephson array chip should never be left in an empty Dewar that is warming up. As ice in the Dewar melts, water will condense on the chip and destroy it. This is a frequent failure mechanism for Josephson array chips.

5.2 Topping off a Partially Filled Dewar

To top off the volt-standard Dewar from another Dewar, position the Dewars so that the transfer tube will reach the bottom of both Dewars. This may require raising one or the other Dewar. The transfer tube should then be slowly inserted all the way into the source Dewar and pre-cooled by blowing liquid helium through it. The tube is fully cooled when the "puffing" stops and the plume coming out of the tube changes to a very dense plume. The output end of the tube should then be RAPIDLY inserted into the volt standard Dewar. It may be necessary to pull the tube partially out of the source Dewar to accomplish this. The transfer is completed by pressurizing the source Dewar with helium gas (3 psi max) to force the liquid through the tube. When the volt standard Dewar is full as indicated by a thumper tube or a rapid increase in venting, the transfer tube should be quickly removed from both Dewars. Normal fill time is about 15 minutes. If a warm transfer tube is inserted into a partially filled volt-standard Dewar, the flow of warm gas may vaporize most or all of the helium in the Dewar.

5.3 Filling a Warm Dewar

If the volt-standard Dewar is not at liquid helium temperature, it must first be pre-cooled by filling it with liquid nitrogen (LN_2) for 16-24 hours. After this cooling is complete, EVERY LAST DROP of LN_2 must be removed. This can be done by tipping the Dewar upside down and pouring out the LN_2. (If even a tiny amount of LN_2 remains, its heat of fusion will evaporate a large quantity of liquid helium.) Once the Dewar has been cooled in this way it can be filled as described above except that the initial transfer rate should be low to reduce the helium loss as the Dewar is cooled from 77 K to 4.2 K.

5.4 Measuring the Liquid Helium Level

Typically, liquid He Dewars consist of a cylindrical inner tank with hemispherical ends. This tank is suspended inside a super insulated vacuum vessel by a 50 cm neck tube. Because of the hemispherical ends, the volume of liquid helium is a nonlinear function of the depth. A conversion chart is usually attached to the outside of the Dewar. There are several ways to determine the level of liquid helium in a Dewar.

5.4.1 Using the Liquid Helium Level Sensor

The liquid helium level sensor is a 4 mm diameter x 60 cm long tube mounted inside the cryoprobe tube. The sensor contains a length of fine superconducting wire. The normal state resistance of this wire is about 330 O. When the He liquid level button is pushed, a current of about 70 mA is driven through this wire. At this level of current there is a sharp transition from superconductive to normal conductivity at the surface of the liquid helium. Thus the voltage across the wire is an indication of liquid helium level. This voltage is offset and scaled so that the meter indication is approximately a 0-100% reading for a liquid level of 0-60 cm. Two trimpot adjustments are provided to set the zero and 100% levels. These are factory set to read 100% when the sensor is fully immersed, and 0% when the sensor is near liquid helium temperature but not immersed in liquid. The user may want to change the calibration to be appropriate for a particular Dewar. To do this, use a nearly full Dewar and determine the liquid level independently, for example with a thumper tube (see below). Suppose that you determined that the Dewar is 85% full and that the liquid level is 50 cm below the top flange. To calibrate the sensor readout, lower the cryoprobe 50 cm into the Dewar so that the end of the sensor is at the liquid surface. Set the “0 adjust” to get a 0% reading on the display. Now lower the cryoprobe until the end hits the bottom of the Dewar and adjust the “full scale” to read 85%. The same procedure can be used to make the display read in cm or inches rather than %.

Power for the liquid helium sensor is supplied by four 9 V batteries wired in series. The 36 V is regulated down to 30 V to drive the sensor and 5V to drive the display. Pushing the button will cause the LED indicator to light if the combined battery voltage is greater than 32 V. When the LED fails to light, it is time to replace the batteries. Assuming five seconds/reading, the batteries are sufficient for about 700 readings.

To replace the batteries, remove the screws that attach the helium sensor module to the main cryoprobe filter box and disconnect the two pin sockets that connect through RFI filters to the sensor. Snap in four new batteries and replace the module.

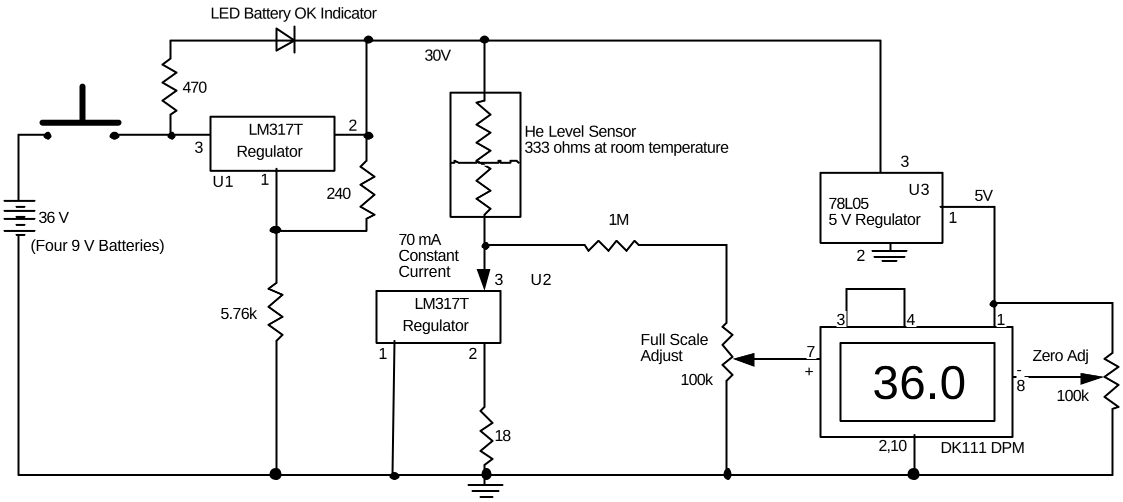

Fig. 5. Schematic of the He level sensor readout circuit.

In NISTVolt® software version 9.0 and above, Main Menu function (p) provides an easy way to keep track of liquid helium consumption. It starts by asking the operator to input the current liquid helium level as indicated by the sensor in the cryoprobe or measured manually. This value is stored along with the date and time in a file Helium.sys. The most recent 70 days of the file are then plotted.

5.4.2 Measuring liquid helium by Weight

Liquid helium weighs about 0.14 kg/liter. Thus a platform scale can be used to determine the quantity of helium in a Dewar. If you have the scale (typically costing about $3500), this method is very convenient and reliable.

5.4.3 Using a Thumper Tube

A thumper tube consists of about 1.3 m of thin wall 4 mm diameter stainless steel tubing, open at one end, and terminated with a 4 mm diameter to 12 mm diameter copper adapter at the other end. It is used as follows: Seal the copper adapter with your thumb and then slowly lower the tube into the Dewar all the way to the bottom. Mark the bottom position with an alligator clip on the tube. You should feel vibrations on your thumb. As you raise the tube, the vibrations will make a fairly sharp transition to a higher frequency as the tube passes through the surface of the helium. Mark this position with a second clip. The separation of the two clips, together with the depth/volume table attached to the Dewar gives the number of liters remaining. REMEMBER TO MINIMIZE THE EXPOSURE OF THE OPEN NECK TO THE ATMOSPHERE AND TO CLOSE THE DEWAR IMMEDIATELY WHEN FINISHED.

5.4.4 Liquid Helium Level Effect on the Array I-V Curve

The I-V curve of the array is temperature dependent and can be used to give a warning of low liquid helium level about one week before the array fails due to rising temperature. To do this, turn off the Gunn diode and display the I-V curve on an oscilloscope with a voltage scale of 1V/div., DC coupled, and a current scale of 50µA/div. Use the position controls to center the I-V curve exactly at the center of the screen. With the sweep switch in the high position, adjust the sweep amplitude to +/-5 V (full screen width). The trace should sweep from the origin up the critical current to about 100 µA (2 divisions), then almost horizontally out to 5V, then down to about 10 µA and back to the origin. The pattern will repeat in the third quadrant. Accurately measure the point at which the trace crosses the 4V grid line on its way back to the origin. (Increase the current sensitivity to 10 µA/div to get the most accurate value.) This is called the 4 V return current and has a typical value of 7 µA for a full Dewar. As the helium level approaches the chip, it will rise 1 or 2 µA per day with chip failure occurring when it has approximately doubled.

In some versions of NISTVolt® software, running the SelfTest automatically measures the 4 V return current.

6.0 LEAKAGE ERROR AND UNCERTAINTY

Significant errors may occur if there is leakage current between the array voltage leads or from these leads to ground. This leakage current causes a voltage drop across the resistance of the cryoprobe RFI filters, R_p *? 8* ? , and results in an error that is not corrected by the reversal process. There are two kinds of leakage that must be considered, resistive leakage and dielectric absorption. Resistive leakage can result from fingerprints on the filter components, solder flux, or faulty capacitor dielectric. Dielectric absorption is a time-dependent process caused by a slow change in the orientation of electric dipoles in the filter components.

The error owing to both resistive leakage and dielectric absorption can be estimated by making the measurement illustrated in Fig. 6. (VMetrix makes a leakage tester box that implements the circuit of Fig. 6.) The circuit of Fig 6(a) converts a DVM to an ammeter with a gain of 1 V/ ? A. A hand held DVM with a resolution of 10^{-4} V is often sufficient because, when used with the circuit of Fig. 6, it can resolve $10^{?10}$ A. For even better resolution, use a 5 or 6 digit DVM. The applied voltage V_1 should approximate the maximum array voltage, for example V_a = 10 V (a 9 V battery is a convenient source). To measure leakage current, disconnect the potential wires that are normally soldered to the array mount and connect them as shown in Fig. 6 (a). Any leakage current I_L that flows in the probe wiring or filter elements will induce a voltage $V_{DVM} = 10^6\ I_L$ at the DVM terminals. Take care to reduce motion around the apparatus since this induces capacitive currents that can make an accurate measurement impossible. Because I_L depends on the elapsed time since the last reversal, I_L should be measured at a time that approximates the situation in a normal calibration – typically 30 s after the last reversal. The procedure is:

1. Short the leads of the leakage measuring circuit to read V_1 on the DVM.
2. Connect the leakage measuring circuit across the leakage path to be tested.
3. Reverse the applied voltage, wait 30 s and record V_{DMV1}.
4. Reverse the applied voltage, wait 30 s and record V_{DVM2}.
5. Use the average of the two readings to compute $I_L = (V_{DVM1}+V_{DVM2}) / (2 \times 10^6)$.

The effective leakage resistance is given by $R_L = V_1 / I_L$. The error, E_L, resulting from cryoprobe leakage is $0 < E_L < V_a R_p / R_L$ depending on how much of R_p lies in the leakage current path. The path of leakage current can be determined by measuring leakage as the filter elements are disconnected one by one. This procedure is justified only if the leakage error E_L becomes excessive, that is, greater than a few nV.

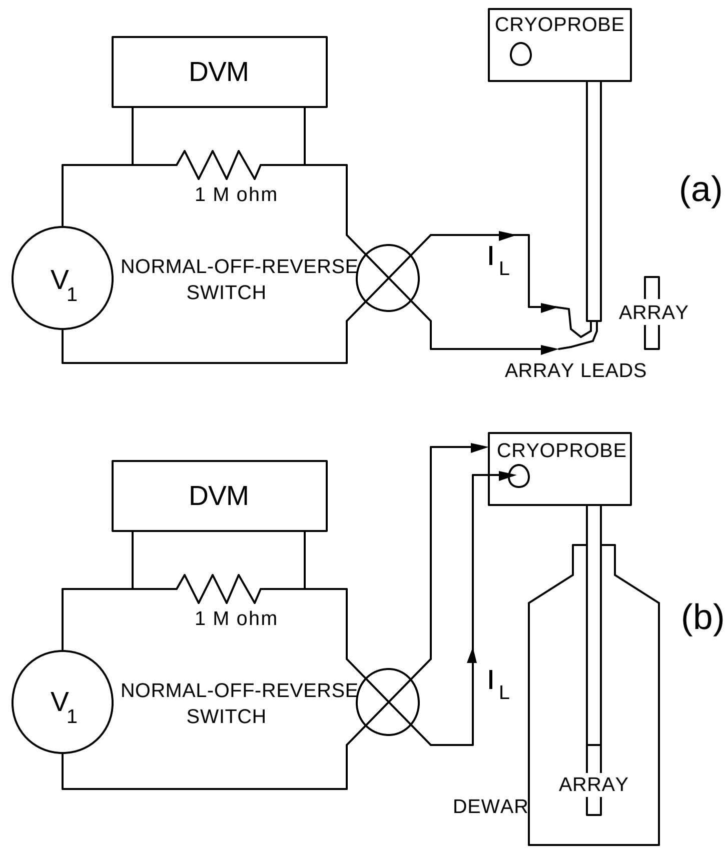

Fig. 6 Circuits for measuring leakage current.

Measuring leakage as described above is somewhat inconvenient because it requires warming and disconnecting the Josephson array chip. Since the most probable sources of leakage are the capacitors to ground in the cryoprobe RFI filters, a quick check for leakage can be made by removing all of the array bias and potential leads and measuring between either array terminal and ground (see Fig 6(b)). This can be done with the array immersed in liquid helium. The measurement generally produces a leakage current about 4 times greater than the method shown in Fig 6(a) because the capacitor leakage paths are effectively in parallel rather than in series. Thus one should use $R_L = 4\ V_1/I_L$ with the leakage to ground method.

For systems using NISTVolt® software, the setup screen provides the opportunity to enter both a leakage error correction and a leakage uncertainty. These values are expressed as *fractional errors* $E_L^?$. The worst case *fractional error* in system measurements caused by the leakage current occurs if we assume that this current flows through 100% of R_p. In this case, the fractional error is

$$E_L^{?} = R_p/R_L\ .$$

Without additional knowledge of the leakage path it is appropriate to enter a value for the leakage error correction of $E_L^{?}/2$ and the same value for the leakage uncertainty. In a NISTVolt® calibration, the effect of leakage error is to increase the value assigned to the DUT. Therefore, the correction decreases the assigned value by the estimated magnitude of the error. The computed value V_{DUT} in every calibration is thus multiplied by (1-leakage error correction) to compensate for leakage. Since an uncertainty of $\pm\ E_L^{?}/2$ spans the worst case range of leakage uncertainty, we assume a rectangular distribution and assign a default value of 99 degrees of freedom (see the *Guide to the Expression of Uncertainty in Measurement*, G.4.3 and Table G.2). Uncertainties in NISTVolt® are expressed in nV so the value reported on the calibration report (u_L) is the value entered for leakage uncertainty in the setup screen multiplied by the voltage being measured and divided by root 3 to account for the rectangular distribution, that is,

$$u_L \ ?\ \frac{V_{DUT} R_p}{2 R_L \sqrt{3}} .$$

Leakage error can be highly dependent on environmental conditions such as humidity and should therefore be measured regularly and whenever any change is made in the wiring or cryoprobe filters. In calibrations of typical Zener reference standards, both the leakage correction and its uncertainty are normally insignificant relative to the total uncertainty. In a direct comparison of two Josephson standards, leakage may be an important factor and should be very carefully evaluated and minimized. The leakage measurement should be repeated about twice a year (more frequently in humid or corrosive environments) to ensure that new leakage paths have not developed.

7.0 THERMAL VOLTAGES IN THE POTENTIAL WIRES

The cryoprobe is designed to minimize thermal voltages across the 270 K temperature difference between the Josephson array terminals and the cryoprobe output connector. This is accomplished by using selected pure copper wire between the array and the first stage RFI filters and enclosing the filters in a thick aluminum isothermal box. This reduces the total thermal voltage to less than 1 µV. In a typical measurement, reversals of the array voltage allow the constant and linearly drifting part of this thermal voltage to be measured and eliminated from the final result. Residual uncertainty from nonlinear thermal voltage drift is normally below 10 nV depending on your laboratory conditions. However, if the thermal voltage is large and has a nonlinear drift, a significant measurement error may occur. It is therefore advisable to monitor the thermal voltage and take corrective action if it becomes larger than 1 µV.

The best way to measure the cryoprobe thermal voltage is to disconnect the Josephson array and short the potential wires at the cold end of the probe. Then, connect a nanovoltmeter to pins E and F of the bias connector. Start a plot of voltage versus time using a voltage range of about 10 µV. NISTVolt® software provides a convenient way to do this. Then, with the plot running, slowly insert the cryoprobe all the way into a liquid helium Dewar. After the voltage settles, remove the cryoprobe. The voltage difference between room temperature and liquid helium temperature should be less than 1 µV.

8.0 TROUBLE SHOOTING RELATED TO THE CRYOPROBE

8.1 Low Critical Current or Small Josephson Steps

Magnetic flux trapped in the Josephson array is the most common cause of low critical current. A low critical current or small Josephson steps may be caused by excess noise coupled into the array from the room. This can happen if the electrostatic shield around the Josephson chip is incomplete for example from:

(1) Cryoprobe flange not matched to and/or not electrically connected to Dewar flange.
(2) Any added wiring to the cryoprobe that can act as an antenna around the RFI filters.
(3) Paint on the Dewar flange that prevents a solid electrical connection.

8.2 Array Instability

Instability of the Josephson steps may be caused by:

(1) All of the items of 8.1 above.
(2) Poor system grounding especially between the frame of the cryoprobe and the bias source.
(3) A defective DC block in the waveguide between the microwave source and the cryoprobe.
(4) Insufficient microwave power. The waveguide may develop a high loss from absorption of moisture or physical damage. Remove the cryoprobe from the Dewar and warm it with the standard procedure (section 5). Remove the magnetic shield and check for loose screws or wires. If there is no obvious problem, remove the array chip from the cryoprobe and dry the waveguide by blowing warm, dry gas through it. Use a microwave power meter to measure the waveguide loss. It should be less than 1.5 dB.

8.3 Incorrect I-V Curve

A distorted or incorrect Josephson array I-V curve may be caused by:

(1) An open lead to the array or a defective array. Use an ohmmeter to verify that the resistances between the receptacles of the 8-pin cryoprobe Bendix connector are as listed in section 3.

(2) If the Josephson chip is exposed to moisture during a transfer between Dewars, that moisture can get under the chip contacts. When it freezes, it will lift the contacts resulting in an open circuit. The fix is to remove the cryoprobe from the Dewar, carefully warm and dry the chip, and then re-cool.

(3) An open ground between the cryoprobe and the bias source. This allows capacitive currents from the RFI filters to reach the current measuring circuit.
(4) Any added capacitance across the array terminals.
(5) Any load that can draw current across the array potential leads.

(6) Static discharge damage to amplifiers in the bias source - a common problem of the JBS500 that is fixed in later models.

(7) A defective bias source, a defective bias cable, or improper oscilloscope settings. Connect a 10 kO bias test resistor to the bias cable to determine if the problem is before or after the cryoprobe bias connector. With settings of 1 V/div. DC coupled on both axes, the I-V curve of the bias resistor should be a 45º line.

9.0 OPTIONAL ACCESSORIES

Thumper Tube
Insulated WR-12 Waveguide Clamp
Polyethylene WR-12 flange isolation membrane
Hook and Pulley System
Bendix Bias Shorting Plug
Spare Bendix Mating Connector Type PT06A-16-8P
Leakage and Thermal EMF Measurement Cable Kit