Helium Monitoring System

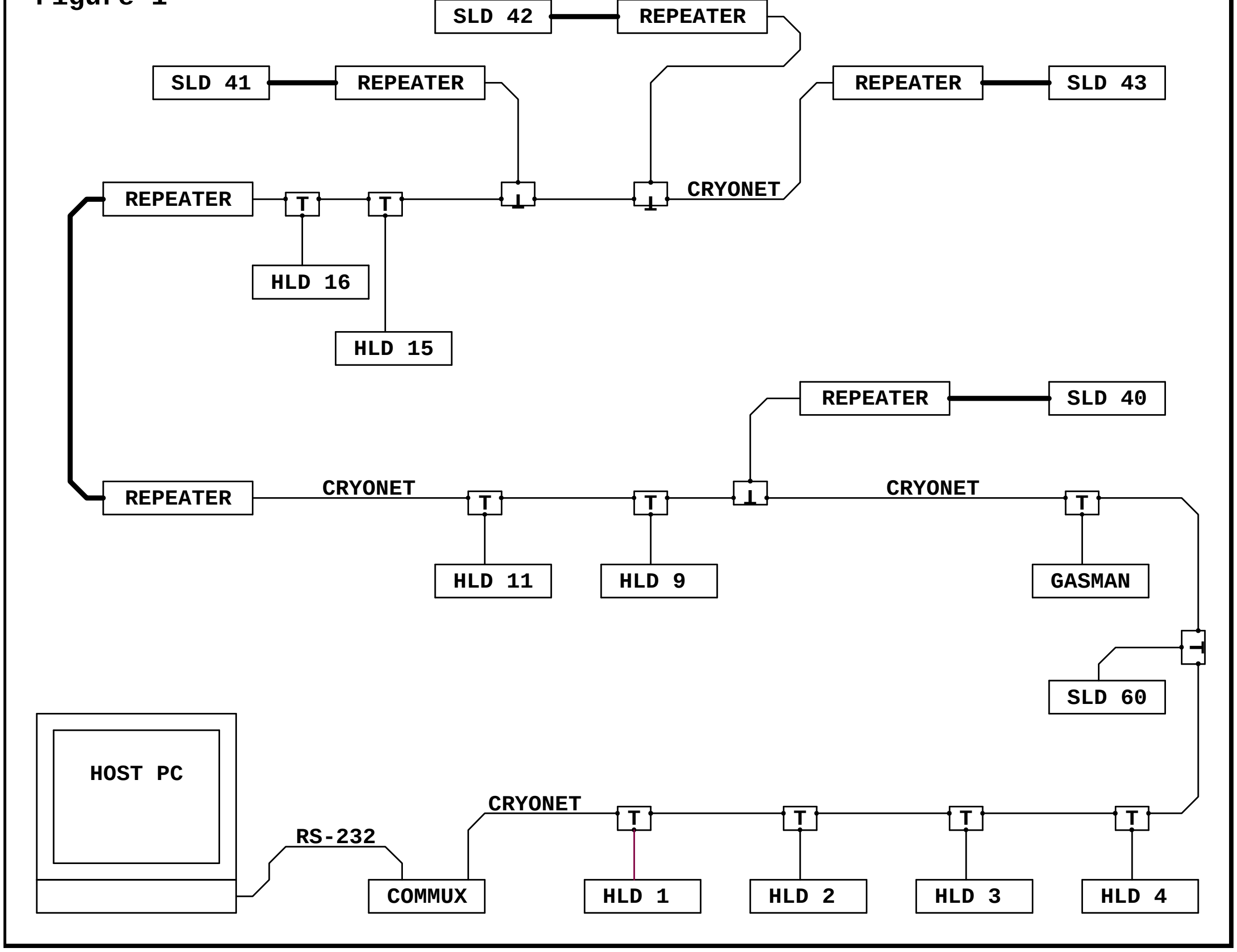
TABLE OF CONTENTS

1. OVERVIEW

The Helium Monitoring System described in this document consists of seven components. In Figure 1 all of these components are shown connected in schematic form.

- **HOST** - A personal computer with terminal software and a RS-232 serial port.
- **COMMUX** - A device used to interface between the HOST RS-232 serial line and a RS-485 multidrop network.
- **CRYONET** - The name applied to the RS-485 multi-drop network used for communication between the different elements of the helium monitoring system.
- **HLD #** - The Helium Level Detector used to measure the liquid level in a helium transport dewar.
- **SLD** # - The Helium Level Detector used to measure the liquid level in a research cryostat dewar.
- **GASMAN** - A device used to read the helium gas flow meters. This one device can read up to 24 gas meters.
- **REPEATER** - Optical fiber repeater, RS-485 communications on one side and optical fiber on the other side. This device is used to isolate the electrical communications between different parts of the CRYONET.

Figure 1



3 COMMUX

3.1 Introduction

The COMMUX (Communications Multiplex) is a device used to interface between the HOST-PC, RS-232 serial port and the CRYONET (Cryogenic Network), a RS-485 multi-drop network. We made the choice to construct our own RS-485 interface for the HOST-PC so that future changes in desktop computers would not require major changes in our network. Only the RS-232 serial port of the HOST-PC is used and only at 4800 baud. The low communications speed is sufficient considering the relative small amount of data and infrequent use of the CRYONET. The RS-485 side of the communications is also done at 4800 baud. Again this low speed is sufficient and adds to the communications distance. At present there is just under 2000 feet of CRYONET cable in use.

3.2 Operating Criteria

The COMMUX operating criteria is really quite simple. The COMMUX monitors the HOST serial line for activity. When a valid command is received from the HOST the COMMUX interprets the command. The command structure is such that all commands contain a device name, device number, and command. The COMMUX translates the simple text command from the HOST into the command structure used by the devices attached to the CRYONET. This command is then transmitted over the CRYONET. The COMMUX then waits for a response from addressed device. If a message is received it is translated from the CRYONET command structure to simple text and then transmitted to the HOST. If no message is received or if the original message was in error this information is also transmitted to the HOST.

3.2.1 HOST Commands

At present there are two different types of devices attached to the CRYONET.

There are helium level detectors and helium gas meter reading devices. There are two slightly different types of level detectors, the HLD (Helium Level Detectors) and SLD (Stationary Helium Level Detectors). The HLD uses in entire set of COMMUX commands while the SLD only uses a subset of those commands. There are also service and calibration commands for each of these level detectors.

The GASMAN (Helium Gas Meter Reader) is the second type of device attached to the CRYONET. It is used to monitor the flow of evolved helium gas from both transport/storage dewars and experimental cryostats. Space has been allocated for new devices to be added to the CRYONET. In particular a pressure monitoring device may be the next device added to the system. The COMMUX help screen is shown in Figure_3.2.1.

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FIGURE 3.2.1

Cryogenic Engineering Communications Multiplexer
(COMMUX):
<CTRL>X RESTART         ?       HELP
<CTRL>T ECHO ON
<CTRL>S ECHO OFF

Helium Level Detector (HLD) Commands:
ALLDATA        BATTERY
DATE           LABLIST
LEVEL          LULVER
NEWDATA        SETDATE MM-DD-YR HH:MM:SS
STATUS

GASMAN (GAS) Commands:
CRYOCNT        DATE
LABCNT         RSTCRYO
RSTLAB         SETDATE MM-DD-YY HH:MM:SS
STATUS

COMMAND  FORMAT:      [HLD,GAS]  [##]  [command]
[DATA]
```

3.2.2 COMMUX / CRYONET Commands

The message structure for commands on the CRYONET have the following parameters.

- Messages vary in length from 5 to 255 bytes. To transfer more data than 255 bytes multiple messages are required.
- Each message has the following format.
  - Byte #1 = Target node, with mark bit set.
  - Byte #2 = Message length (5 - 255 0 bytes.
  - Byte #3 = Checksum.
  - Byte #4 = Source node.
  - Byte #5 = Command / Response opcode.
  - Byte #6 - #255 = Command parameters and / or data.
- Only the master device (COMMUX) can initiate communications.
- Slave devices can only communication after being addressed.
- If a slave devices detects an error in the command it ignores the message and makes no response.
- The master devices waits for a fixed length of time to receive a response. If no response from the addressed slave device the master device tries to communicate twice more. If no response from the slave device the COMMUX reports the error to the HOST.

3.2.2.1 COMMUX Commands

source	opcode	description
	$00	reserved
	$FF	end of table marker
	$FE	reserved for RESET all nodes
C	$01	report status
C,H,G	$02	ready / continue
C,H,G	$03	retransmit
C,H	$04	EOT (End of Text)
C	$05	send battery status
H	$06	receive battery status, ‘##.#’
C	$07	send new level data
C	$08	send all level data
H	$09	receive level record, ‘MM/DD hh:mm ### end lab user’
C	$0A	send LUL (Lab User List) version #
C	$0B	receive LUL
H	$0C	receive LUL version #, ‘##’
C	$0D	receive LUL record, ‘1-ADAM 1-NEW 2-XIA 3-EDA 4-JDR’
C	$0E	send date and time
C	$0F	set data and time, ‘MM-DD-YR hh:mm:ss’
H,G	$10	receive date and time ‘MM-DD-YR hh:mm:ss’
C	$11	read level and send
H	$12	receive level, ‘hh:mm ###’
C	$20	send CRYO_COUNTER
G	$21	receive CRYO_COUNTER, ‘######’
C	$22	send LAB_COUNTER

G	$23	receive LAB_COUNTER, '######'
C	$24	reset CRYO_COUNT
C	$25	reset LAB_COUNT

end:

3.3Description of hardware

4 HLD

4.1 Introduction

4.2 Description of level measurement

4.3 Description of hardware

4.4 Description of communications

5 SLD

5.1 Introduction

5.2 Description of level measurement

5.3 Description of hardware

5.4 Description of communications

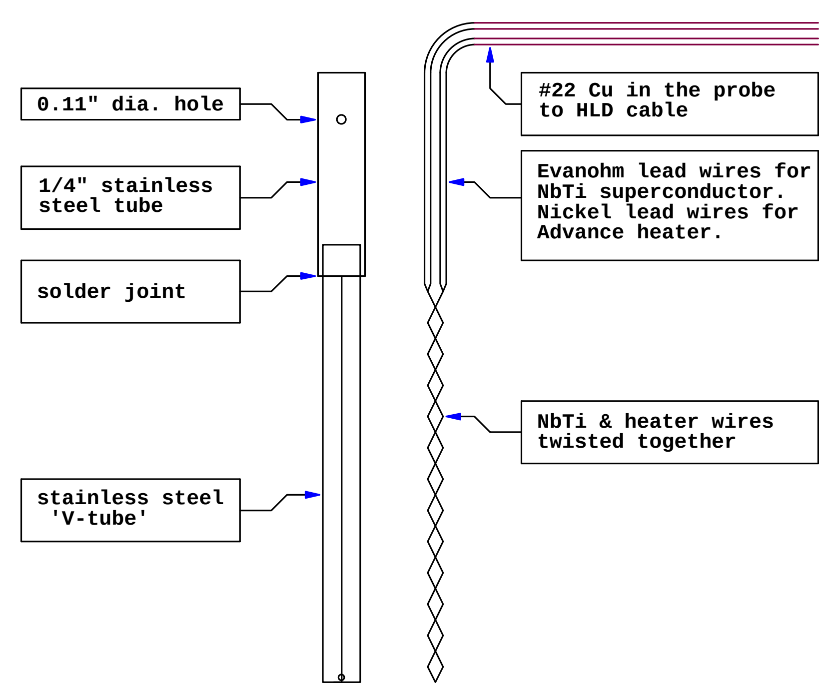
6 PROBE

6. 1 Description

The active components of the liquid helium depth measuring probe consists of a sensor made of NbTi superconducting wire twisted together with a heater made of Advance wire. The lead wires for the superconductor are made of Evanohm so that changes in temperature do not affect the level measurement. Nickel lead wires were chosen for use with the heater, because of their low resistance and small change in resistance with change in temperature. The heater is driven with a constant current, during measurement, from a 12 volt battery. A low heater lead resistance was necessary for compliance with this limited power source.

The lead wires are housed in a 0.25” stainless steel tube. The bifilar sensor and heater wires are suspended inside a ‘V-tube’ which is soldered to the end of the stainless steel tube. We found it important that the active section of the probe be as open as possible and the ‘V-tube’ format worked well given the construction techniques at our disposal, Figure 6.1.

Figure 6.1



As the probe is submerged in liquid helium the sensor becomes superconducting. The current in the heater wire is sufficient to heat the sensor in the cold helium gas, above the superconducting temperature, but not enough heat to change the temperature of the submerged wire. The resistance of the sensor is then measured and is inversely proportional to the depth of the helium liquid.

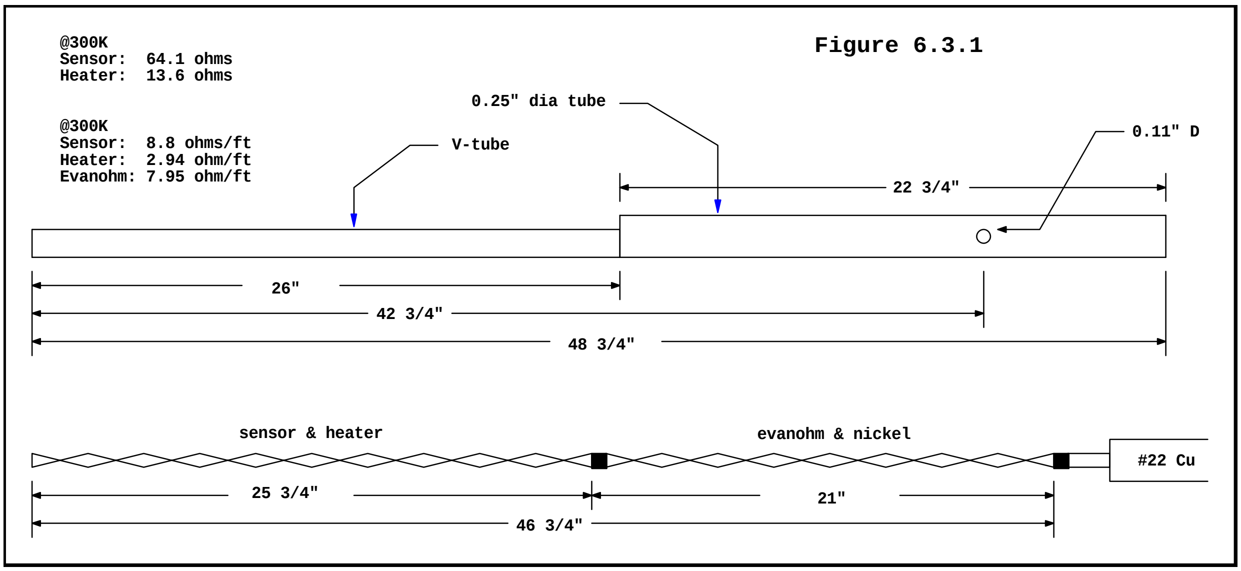
6.2 Level measurement procedure

A Motorola MC68HC11 microcontroller is used to control the duration of the current in the heater wire, the sense current in the sensor (superconducting wire), and the ADC (analog to digital converter). The heater current is such that the power dissipation per unit length in the heater is in the range of 100mW to 200mW per inch, a typical heater current might be 0.5A. The typical duration of the heater current is 125msec, but can be controlled via software with a range of (1 to 255msec). When the heater current is switched on the sense current in the sensor is also switched on, with a typical value of 10mA. At the end of the heater current cycle the ADC is used to take 100 readings of the voltage drop across the sensor and then both the heater current and sense current are switched off. This raw value from the ADC is averaged and then compared with a value in the LCT (Level Conversion Table). That lookup table is generated by the user and is a volume vs. liquid depth table for the dewar. When the volume matching the raw ADC value is found it is then displayed on a LCD (Liquid Crystal Display) located on the front panel of the HLD (Helium Level Detector. When the <READ> command is activated the liquid level is displayed in less than one second. The accuracy of this level measurement is typically 1% of the volume of a (100 to 250 liter) transport dewar.

6.3 Probe construction

6.3.1 Constructing the probe shell

The probe shell length is determined from the dewar dimensions. In Figure 6.3.1 the dimensions for a typical 100 liter storage dewar are shown. Note that the length of the ‘V-tube’ is approximately 2” longer than the depth of the liquid storage volume for the dewar. This is done to insure that the active length of the sensor is slightly longer than the working depth of the dewar. Also note the small hole near the top of the 0.25” tube. This is necessary to prevent Taconis oscillation inside the tube. The stainless steel ‘V-tube’ is silver soldered to the 0.25” diameter stainless steel tube. Not shown in Figure 6.3.1 is the small hole at the bottom of the ‘V-tube’ used to tie the sensor to the bottom of the ‘V-tube’. Cotton sewing thread is used to tie the sensor in place along the length of the ‘V-tube’.



6.3.2 Constructing the sensor

The sensor length is determined by doubling the depth of the dewar and adding at least 4”. The extra length is to allow for shortening during twisting as well a trimming of the sensor as it is constructed. After the NbTi superconducting and Advance heater wires have been cut to length they are folded in half. The loop end of the sensor and heater is fastened to a battery powered screwdriver via a hook. Note: the slow rotational speed of the battery powered screwdriver simplifies twisting the sensor and heater wires. Tie a piece of string around the loop near the hook to help keep the wire on the hook. The four loose ends of the wires are held between two pieces of cork which are secured in a tool vise. While twisting it may be necessary to ‘milk’ the wires by running your fingers along its length to help work out small irregularities that may arise during this operation. The sensor should take on the appearance of a piece of cord. To remove the sensor from the vise tie a couple of pieces of string around the sensor near the vise. This is ensure the sensor does not unravel when removed from the vise. After the sensor has settled remove the hook form the sensor.

At this point the length of the sensor should be measured again to ensure sufficient length for the intended probe. The sensor needs to be trimmed so that the connections are made near the confluence of the ‘V-tube’ and round tube. The heater (Advance - gold colored) wires should be cut so that they are the longest. The superconducting (NbTi - dark brown color) wires should be cut shorter than the heater wires. This will insure that the heater is in contact with the full length of the superconductor. The cuts should be staggered with the distance between the shortest wire and the longest wire being about 1.5”.

To strip the insulation from these wires a heat sink is placed about 0.25" from the end of the wire and the insulation is burned off with a match or candle. Note: Of the many methods used to remove the insulation from the sensor wires, burning worked best for us. The carbon is then removed with 600 grit sandpaper and a small amount of flux remover. The cleaned ends of the Advance heater wire needs to be silver soldered so that it may be soldered to the nickel lead wires with electrical solder.

6.3.3 NbTi to Evanohm & Advance to Nickel Connections

A D-pin connector is used to crimp the NbTi superconductor and Evanohm wire together, see Figure 6.3.3A. Use a hand wire wrap tool to form a small coil of #30 copper wire around a small rod or resistor lead. The length of the coil should match the length of the of the crimp section of the connector. Snap the pin from the connector so that the crimp section of the connector is all that remains. Press fit the coil into the connector. Remove the insulation from the Evanohm lead wire.

Figure 6.3.3A

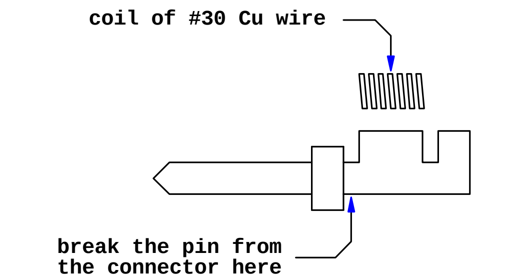
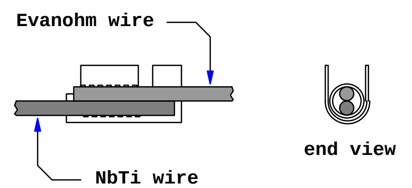


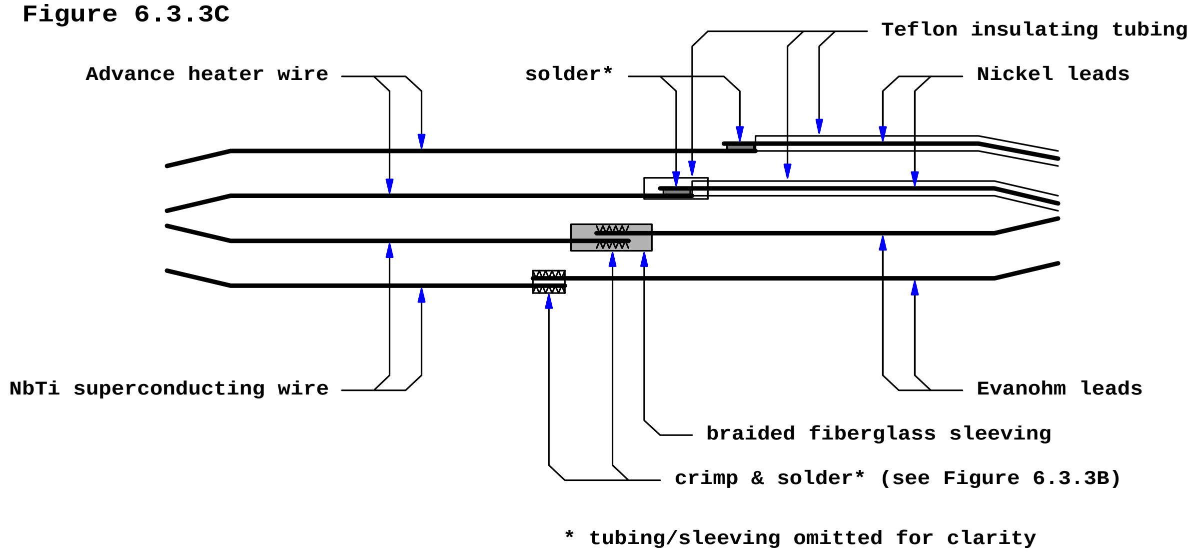
Figure 6.3.3B



Slide one NbTi wire in from one end of the crimp connector and the Evanohm lead wire in from the opposite end of the connector, see Figure 6.3.3B. Note the NbTi wire is a dark brown color and the Advance wire is a gold color. Once the wires are inserted, crimp the connector and solder until there is solder flow around the coil. Note: Do not leave a 'glob' of solder on the joint as space is at a premium. Also, the solder will not bond to the NbTi wire, but the solder strengthens the crimp and does bond to the Evanohm, copper, and crimp connector. After the crimp has cooled, cut a piece of braided fiberglass sleeving to slide over the crimp.

The heater wire is soldered to the nickel lead wire. It is a good idea to tin these wires before you attempt to solder them. Once both wires are tinned and clean solder them together. After soldering slide a piece of Teflon tubing over the nickel wire, see Figure 6.3.3C. The nickel wire that we used was uninsulated, so the complete length of the nickel wire had to be covered with the Teflon tubing. A second larger diameter short piece of Teflon tubing is used to cover the solder joint.

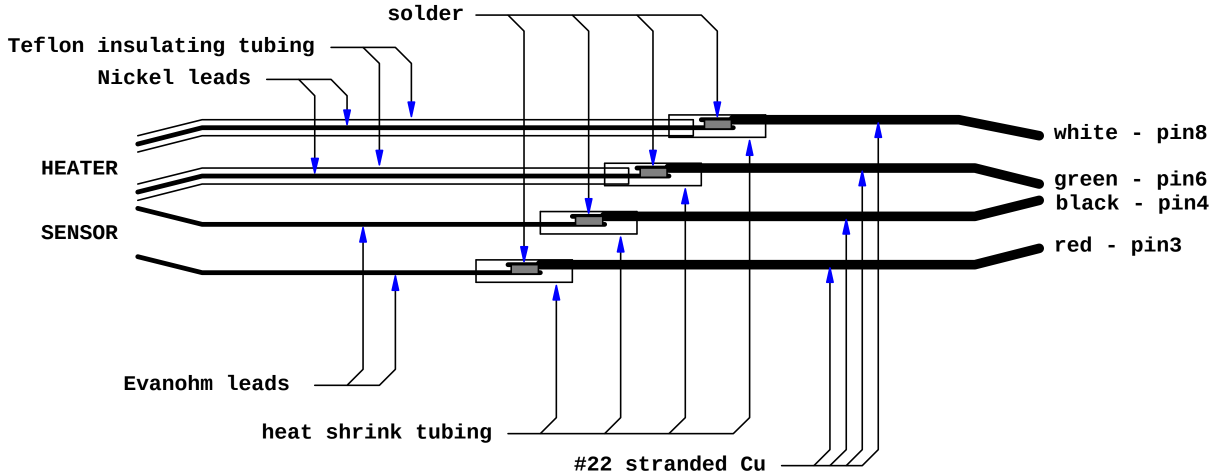
Figure 6.3.3C



6.3.4 Lead Wire to HLD Cable Connections

The lead wires for the heater and NbTi sensor are connected to a four conductor cable that attaches to the HLD (Helium Level Detector) via the nine pin CPC probe connector, see Figure 6.3.4. The red and black wires of the cable are soldered to the Evanohm wires (which lead to the super-conducting wire). Each of these connections are then insulated with heat shrink tubing. The red wire becomes pin 3 and the black wire becomes pin 4 of the CPC connector. The green and white cable wires are soldered to the Teflon covered nickel heater lead wires and insulated with heat shrink tubing. The green wire becomes pin 6 and the white wire becomes pin 8 of the CPC connector.

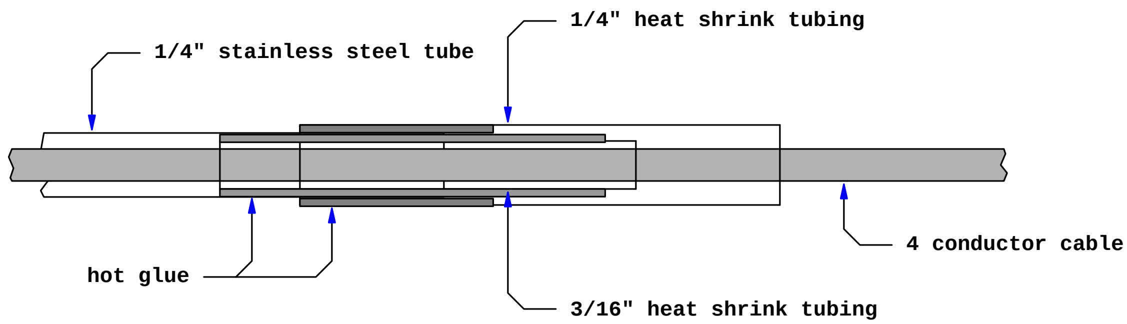
Figure 6.3.4



6.3.5 Final Assembly of the Probe

Slide the probe wires down the inside of the stainless steel tube. Align the end of the probe with the hole at the base of the ‘V-tube’. Mark the probe cable to indicate how far down inside the tube the cable is to slide. Apply a layer of hot glue for about 0.5” between the mark and the stainless steel tubing. Slide a section of 3/16” heat-shrink tubing approximately 3” long to a point 0.5” below the scribe mark on the network cable. Use the heat gun to shrink the heat-shrink tubing. This just helped create a seal to prevent helium from escaping, see Figure 6.3.5.

Figure 6.3.5



Place a mark 0.5” from the top of the stainless steel tube, see Figure 6.3.5. Use the heatgun to heat the stainless steel tube (This is to prep the tube for the hot glue). Slide a 1/4” diameter piece of heat-shrink tubing approximately 2.5” long to a point **near** the installed 3/16” diameter heatshrink tubing. Go completely around the steel tube and the 3/16” heatshrink. Don’t worry about it becoming hard. Use the heatgun to melt the glue and keep it molten. This should also help drive off air bubbles that may have become trapped in the glue when it was applied. Once the glue is fairly molten and flowing, quickly slide the 1/4” heatshrink up to the scribe mark on the stainless steel tube. This should be done in one motion as the glue will tend to harden and you won’t get the chance to apply more heat as that would shrink the 1/4” heatshrink prematurely. Once the 1/4” heatshrink is in place use the heatgun to shrink it down. Start applying heat from the top of the stainless steel tube and slowly work toward the of the probe cable. This will help clear out any remaining air bubbles and help equally distribute the hot glue. When the probe is installed in the dewar this joint may be heated again and bent to a convenient angle.

6.3.6 Attach Probe Connector to Cable

7 GASMAN

8 REPEATER

END: