OXFORD

HELIUM LEVEL METER; HLM2

INSTRUCTION MANUAL

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IMPORTANT

This operating manual is intended to help the user set up and operate an Oxford Instruments Helium Level Meter.

Before attempting to operate the meter, PLEASE READ THE INSTRUCTIONS.

This product is guaranteed for 1 year against defective materials and workmanship under the general conditions of sale as detailed in the Company's order acceptance.

The guarantee does not apply to damage caused by failure of the operator to follow the recommended operating instructions. This point should particularly be remembered when dealing with the wiring.

CONTENTS

SPECIFICATION

Probe length	100mm to 500mm (Other lengths to special order)
Sensing System	Superconductive Wire
Probe Diameter	4.75mm, 3/16 inch standard and 9.5mm, 3/8 inch as an option.
Indication	3 inch moving coil meter
Recorder Output	Approx 500 mV into 50 K ohms
Control Outputs	Two changeover contacts operating at preset levels, with optional hysterisis. Contact Rating 250 V, 3A AC or DC Maximum Load 80 W DC or 200 VA AC
Accuracy	2% of FSD

*Helium Consumption

Static	4 ml/hour
On LOW rate	5 ml/hour
On High rate	25 ml/hour
Continuous	150 ml/hour

Sampling Rate

On LOW rate	1 sample per 100 seconds approx
On HIGH rate	1 sample per 10 seconds approx

Continuous operation possible by internal adjustment

Magnetic Field	Unaffected by Magnetic fields up to 4 Tesla
Sensor Temperature	4.2K ± 1K Operation down to 1.6K by internal adjustment
Power Requirements	110/240 V AC, 50-60 Hz, 8VA

* Since much of the heat conducted down the sensor support tube and generated in the wire is dissipated into the gas rather than the liquid, the helium consumption will vary both with the level of the liquid and the boil-off rate of the cryostat itself. The figures quoted correspond to the increase in helium consumption due to a 250mm long probe in a half full, low-loss NMR magnet cryostat having a static boil off of 8 cc/hour of liquid. (These being the conditions under which the increase in boil off due to the level indicator is a maximum).

MOUNTING OPTIONS	Freestanding Case Rack Mounting (2 units together in 19 inch rack)
ACCESSORIES SUPPLIED	Mains Lead 3m, 10ft Probe Lead 3m, 10 ft Test Link (Mounted Internally) Instruction Manual

CALIBRATION RECORD

Serial Number ....

Probe Length ....

Supply Voltage ....

Mounting Option ....

Relay 1 Level ....

Relay 1 Hysteresis ....

Relay 2 Level ....

Relay 2 Hysteresis ....

Modifications:

1 OPERATING INSTRUCTIONS

1.1 GENERAL

The instrument monitors the liquid helium level in a cryostat by means of a vertical superconductive wire dipping into the liquid. With a suitable current flowing, the portion of the wire above the liquid remains in the resistive (non-superconducting) state, whilst the wire immersed in the liquid is in the superconducting state. Under these conditions a measurement of the voltage developed across the wire will indicate what fraction of the wire is above the liquid surface.

To reduce the power dissipated in the cryostat, the current is not passed through the wire continuously. Instead the current is switched on for about one second and a reading stored within the instrument. This is then displayed on the meter until the next current pulse. The time between measurements may be varied by the user, by means of internal adjustment, should this be required. A high measurement rate allows a rapidly changing level to be followed whilst a low rate reduces the dissipation within the cryostat to a minimum for normal operation. At the low rate the helium boil off due to dissipation is negligible even in a low loss storage vessel.

A chart recorder output is provided to enable the helium level to be recorded and two change-over relay contacts allow alarms or an automatic top-up system to be operated at preset levels.

1.2 INSTALLATION

The equipment comprises the following items:-

1) Indicator Unit
2) Sensor Probe
3) Sensor Interconnecting Cable
4) Power Supply Cable

These should be carefully unpacked and checked for mechanical damage.

WARNING The sensing element consists of a very fine wire. The probe should not be subjected to any unnecessary knocks or vibration.

Install the sensor probe in the cryostat through the appropriate mounting port.

Ensure that the supply voltage corresponds to that for which the instrument was calibrated.

Interconnect the probe and indicator unit and connect the latter to the supply. The green lamp should light indicating that the unit is operating.

1.3 SAMPLING RATE

The red SAMPLE lamp indicates when a current is being passed through the wire. Between current pulses the meter retains a steady reading corresponding to the liquid helium level at the time of the previous pulse. The interval between sampling pulses may be changed by the SAMPLE RATE switch.

In the HIGH RATE position the interval between pulses is approximately 10 seconds. This is sufficiently short to enable the rise in liquid level to be followed whilst filling a cryostat.

For normal operation where the liquid level is not changing rapidly the LOW RATE may be used to reduce the power dissipation within the cryostat. The interval between sampling pulses is then approximately 100 seconds.

For special applications where the liquid is changing very rapidly and dissipation is not a problem, it is possible to modify the instrument for continuous operation. (See section 4.7)

1.4 RECORDER OUTPUT

An analogue output signal is provided at the rear of the instrument for use with a chart recorder in order that the helium consumption may be continuously monitored. An output voltage of zero corresponds to a full cryostat (Helium Level = 100%) whilst a voltage of approximately 500 mV is obtained when all the helium is exhausted (Helium Level = 0%). If the recorder has an input impedance of less than 50K ohms it will affect the calibration of the instrument by a small amount. This may be corrected for by performing the span calibration described in section 4.5 with the recorder connected.

1.5 CONTROL OUTPUT

Two independent change-over relay contacts are provided at the rear of the instrument for the operation of alarms or an automatic filling system. The relays may be set to operate at any two chosen levels by means of an internal adjustment. In addition it is possible to introduce hysteresis on either of the relays by addition of a single resistor. In this way a single relay may be used to control an automatic filling system. Thus a relay centred to operate at 50% but with 60% of hysteresis incorporated will switch to the low state when the level in the cryostat falls to 20%, initiating the filling operation. It will remain in the low state and filling will continue until the level reaches 80% when it will switch back to the high state and the filling process will be terminated. The second relay is then free for use as an alarm, set for example to 10% to indicate that the automatic filling process has failed for some reason.

As supplied the relay contacts are normally set to operate at 10% and 20% respectively with no hysteresis. Sections 4.8 and 4.9 describe the adjustment of the level setting and the addition of hysteresis.

1.6 OPERATION BELOW 4.2K

The instrument is normally supplied set for optimum operation on liquid helium at 4.2K. However, it is possible to use it at temperatures down to 1.6K. The diagram below shows the behaviour of the sensor wire as a function of current and temperature.

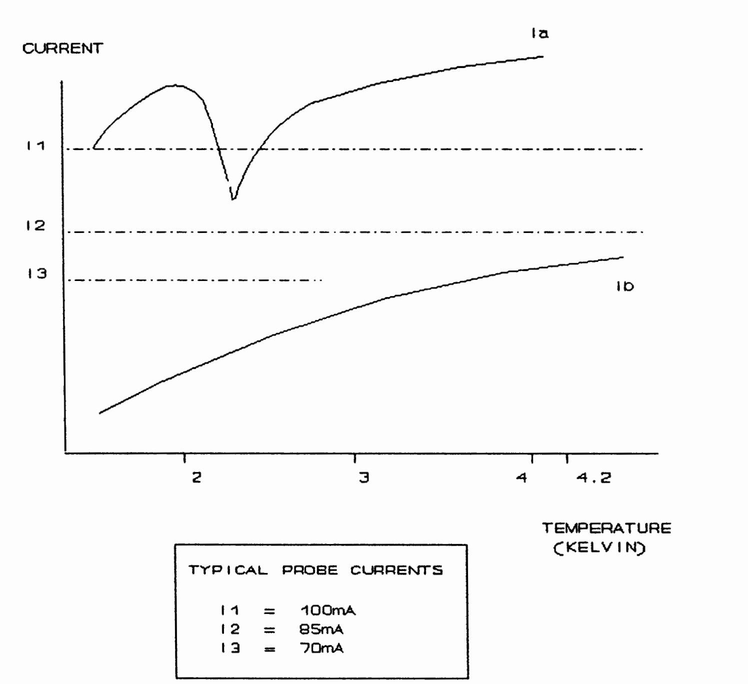


Figure 2 Sensor wire current vs temperature curves

Successful operation of the sensor is possible provided the current through the wire is between the limits I_a and I_b both of which are a function of temperature. For normal 4.2K operation the current is set to I_1 giving a wide margin of error at this temperature.

There is a current I_2 which allows operation over the entire 1.6K to 4.2K range. However, the margin of error is small and it will be necessary to set the current with care with the probe in situ in the cryostat if operation over the full temperature range is required. If operation is required over a small range e.g. around 2.2K a current such as I_3 will give a greater margin of error.

Measurement and adjustment of the wire operating current is described in section 4.4. For a typical probe I_1 = 100 mA, I_2 = 85 mA and I_3 = 70 mA.

1.7 OPERATION IN A MAGNETIC FIELD

The effect of a magnetic field is to very slightly reduce the current required in the probe at a given temperature, In practice the probe will be mounted in the helium reservoir of a magnet rather than in the central core and will not experience the full field of the magnet. It has been found that in fields up to 4 Tesla no adjustment of the operating current is neccessary.

The current pulse through the probe produces no significant magnetic field and no effect is observed on the homogeneity of a high resolution NMR magnet when the probe is installed in its helium reservoir.

2 MOUNTING

2.1 GENERAL

The instrument is built on a single printed circuit board, mounted in an integral frame and case assembly. The main frame consists of the front and back panels and four rails joining these together. The sideplates and the top and bottom covers bolt to the rails and may be removed to allow easy access for servicing. For most operations it is only necessary to remove the top cover.

2.2 FREESTANDING VERSION

The normal version of the instrument is designed for freestanding operation and is fitted with four rubber feet attached to the bottom cover.

2.3 RACK MOUNTING VERSION

The freestanding version my be adapted for mounting in a half-width rack by the addition of two mounting ears which bolt through the front pair of holes in the sideplates. The top and bottom covers are left in position as dust covers though the feet must be removed.

The sideplates have symmetrical mounting holes so that when the instrument is rack mounted these may either be left with the handles showing, as in the freestanding version, or reversed front to back so that the handles are hidden inside the rack. The choice will largely depend on the appearance of the other instruments in the rack.

For mounting in a full-width (19 inch) rack two similar instruments may be mounted side by side. In this case one side plate of each is discarded and the two units are bolted together by their rails. The front and back panels and the top and bottom covers butt together giving a neat unbroken appearance to the complete assembly. As in the half rack mounting version a pair of ears are used to support the assembly in the rack and the remaining two sideplates may be mounted with their handles hidden or visible as preferred.

Where it is required to mount a single instrument in a full-width rack a dummy unit is available to mount alongside it.

3 PRINCIPLES OF OPERATION

3.1 GENERAL

The sensor relies on the wire in the liquid being more efficiently cooled than the wire in the gas. Thus the Joule heating of the resistive section of the wire is sufficient to keep this above its critical temperature where it is in gas but not where it is in liquid. To maintain this situation requires the correct value of current in the wire as described in section 1.6. With no current in the wire the entire length will become superconducting. It is therefore necessary to incorporate a small heater resistor in thermal contact with the top of the wire to drive the end of the wire into its resistive state. Provided the current in the wire is sufficient this resistive region will then propagate down the wire to the liquid surface. The probe is shown diagrammatically on page 12.

In operation a constant current is passed through the wire and heater resistor from I+ to I-. When the voltage between V+ and V- is monitored it will be found to follow one of the family of curves for different liquid levels shown on page 13. Here the voltage is seen to increase as the resistive region propagates down the wire until the liquid surface is reached, at which point a steady value is obtained proportional to the length of wire above the surface of the liquid.

After a time long enough to ensure that the resistive region has reached the liquid surface a sampling pulse stores the final value of the voltage across the wire for display on the meter. Immediately after the sampling pulse the current through the wire is switched off. After a quiescent period of duration determined by the RATE switch, this cycle of events is repeated.

3.2 CIRCUIT DESCRIPTION

The circuit of the instrument is shown on page 14. Q1, Q2 form an asymmetrical multivibrator. Q2 is on for a time determined by C1 and R2 (about 1 second) and off for a time determined by C2, R3 and R4, the former being shorted out in the HIGH position of the RATE switch. When Q2 is on the SAMPLE lamp LED 1 is illuminated and Q3 is switched on. This generates a reference voltage determined by the zener diode D4 at the base of the current source transistor Q4. This transistor causes a constant current to pass through the sensor wire and the 10 ohm resistor R9. The current flowing in the wire may be monitored by the voltage developed across R9 (TP3 to TP4) and may be preset to the required value by RV1. To facilitate this adjustment the current may be caused to flow continuously by linking TP1 and TP2 with the test plug provided. When this plug is not in use it is normally stored linking TP3 and TP4 thus shorting out the current monitor resistor and making the full supply voltage available across the wire.

The voltage developed across the wire is applied via the sampling gate Q5, to the storage capacitor C5. The gate driver transistor Q6 is normally on so that Q5 is off isolating C5 from the sensor wire.

At the end of the current pulse, the negative going edge on the collector of Q1 is differentiated by C4 and R13 producing a short positive pulse on the collector of Q6. During this pulse the sampling gate is open and C5 charges to its new value. D3 and C3 ensure that the current source remains on for a short time after Q2 has switched off, thus ensuring that the correct current is still passing through the sensor wire during the sampling pulse.

The voltage stored on C5 is displayed on the meter via the high input impedance buffer amplifier IC1. Since the voltage developed across the wire is zero when it is totally immersed, the meter is scaled to read backwards. RV2 enables the meter sensitivity to be adjusted to suit the sensor in use.

R14 limits the maximum sensitivity available and also generates an output voltage in the range zero to 500 mV to drive an external recorder.

The control level amplifiers IC2 and IC3 compare the voltage from the buffer amplifier with a reference voltage from the level setting potentiometers RV3 and RV4 respectively. When the liquid helium level falls below the set level the amplifier output goes negative energising the appropriate relay via its driver transistor.

Test points TP7, TP8 and TP9 enable the set point voltage for either of the relays to be applied directly to the buffer amplifier input, overriding the voltage on the storage capacitor. This allows the set point of the appropriate relay to be observed on the meter for ease of adjustment. The test plug enables TP8 to be linked to either TP7 or TP9 as required.

A controlled amount of positive feedback may be introduced around either of the control level amplifiers by means of the resistors R20 and R21. This provides for the hysteresis in the operation of the relays referred to in section 1.5

The supply rails required in the instrument are -20 volts and +10 volts. D11, D12 and Q7 stabilize the -20 volt rail, whilst the +10 volt rail is stabilised by D10.

4 CALIBRATION

4.1 GENERAL

The instrument is normally supplied correctly calibrated for the sensor which accompanies it and with the relay levels set to approximately 10% and 50% respectively. If the sensor is replaced or different level settings are required the appropriate recalibration may be readily accomplished. The only test equipment is a voltmeter.

In addition it is possible to modify the operation of the instrument for specific applications by means of minor circuit changes.

A shorting plug is provided for test and calibration purposes which enables adjacent test points to be temporarily linked together. When the plug is not in use it may be stored linking TP3 and TP4.

4.2 ACCESS

Removal of the top cover by means of its four securing screws allows access to all the calibration adjustments. The relevant potentiometers are clearly labelled on the printed circuit board.

4.3 METER ZERO

With the instrument disconnected from the supply the meter should read 100%. This may be set by means of the screw on the front of the meter. Since the resistance of a totally immersed probe is zero whatever its length this automatically ensures that the 100% calibration is correct for all probes.

4.4 PROBE CURRENT

The amplitude of the measuring current is set by RV1, in accordance with the principles outlined in section 1.6. The current may be monitored with a voltmeter connected between TP3 and TP4. A reading of 1 volt corresponds to a sensor current of 100 mA. To simplify setting the current the wire may be energised continuously by linking TP1 and TP2 with the test plug. The plug is removed after the current has been set to the required value. For operation at 4.2K the sensor current will normally be in the range 100-120 mA. If the sensor current is changed for any reason it will be necessary to reset the meter sensitivity as described below.

4.5 METER SENSITIVITY

With the probe in the cryostat but lifted just above the surface of the liquid, RV2 should be set so that the meter reads 0%. To determine the correct height for the probe it may be dipped below the surface and slowly withdrawn. When the meter reading stops decreasing the sensor is just clear of the surface. This adjustment is best made with the cryostat nearly empty so that the sensor wire is surrounded by cold gas. After the adjustment has been made the sensor should be returned to its correct position in the cryostat. With the probe in room temperature gas the meter will read slightly below zero due to the temperature coefficient of resistance of the wire.

4.6 PULSE WIDTH

The pulse width is normally fixed at about 1 second. However for an abnormally long sensor, or for operation over a wide temperature range it may be desirable to lengthen the current pulse. This allows more time to be sure that the resistive region has reached the liquid surface, but does so at the expense of increasing the dissipation in the cryostat. The pulse width may be varied by changing the value of R2. It may be monitored with an oscilloscope or a timer at TP1, or simply by noting the length of time for which the sample lamp is lit.

4.7 SAMPLE RATE

If the standard sample rates are not convenient for a particular application these may readily be changed by altering the value of R3 and R4. The former only affects the rate in the low position of the sample rate switch. Reducing the value of these resistors reduces the time between samples. It is not advisable to reduce either resistor below 100K ohms, corresponding to a time between samples of around 1 second.

It is possible to operate the unit continuously, at the expense of increased dissipation. Permanently linking TP1 and TP2 with the test plug ensures that current passes through the wire continuously. In addition it is necessary to short out the sampling gate Q5 so that the wire voltage is continuously monitored. This may be done by linking the two outer leads of this transistor.

During continuous operation the wire current may be reduced since the propagation time of the current down the wire is not critical. This will give a small reduction is dissipation. However the helium boil off could still be around 150 ml per hour, so that continuous operation should only be attempted where really rapid level changes are expected.

4.8 RELAY LEVELS

The operating point of the control relays may be preset anywhere in the range 0 to 100% by means of the present potentiometers RV3 and RV4, the former controlling relay 1 and the latter relay 2. The test plug may be used to set these controls. With the test plug linking TP7 and TP8 the meter will indicate the operating level of relay 1, whilst if TP8 and TP9 are linked the meter will indicate the operating level of relay 2.
NB: It is necessary that the probe is connected during this operation but it is not necessary for it to be immersed in helium.

4.9 RELAY HYSTERESIS

It is possible to apply hysteresis to either of the relays as described in section 1.5. To do this a resistor must be inserted in the printed circuit board in the position labelled R20 or R21. The former affects relay 1 and the latter relay 2. The value required is best determined empirically since it will depend on the sensor length and operating current however a value of 1 M ohm will typically give around 30% of hysteresis. Smaller values of resistance will give larger amounts of hysteresis. If the setting method described above is used for a relay to which hysteresis has been applied the level shown on the meter will be a mean level around the centre of the hysteresis band. A useful method of checking the exact operating point of the relay is to employ the setting control for the other relay to swing the meter through the range of the instrument. Thus if relay 1 has had hysteresis applied the test plug should be inserted between TP8 and TP9 and RV4 operated to swing the meter pointer through the full range of the meter scale. Relay 1 will respond to the meter just as if it were being driven by the probe and thus the exact scale values at which it pulls in and drops out can be noted. These may be adjusted by changing the value of R20 and the correct setting as described above.

4.10 MAINS SUPPLY

The instrument is normally supplied set for 230 volt operation. To convert it to 115 volt operation it is only necessary to change the links on the mains transformer primary. For 230 volt operation the two halves of the primary are connected in series whilst for 115 volt operation they are connected in parallel. The appropriate positions for the links are shown below.

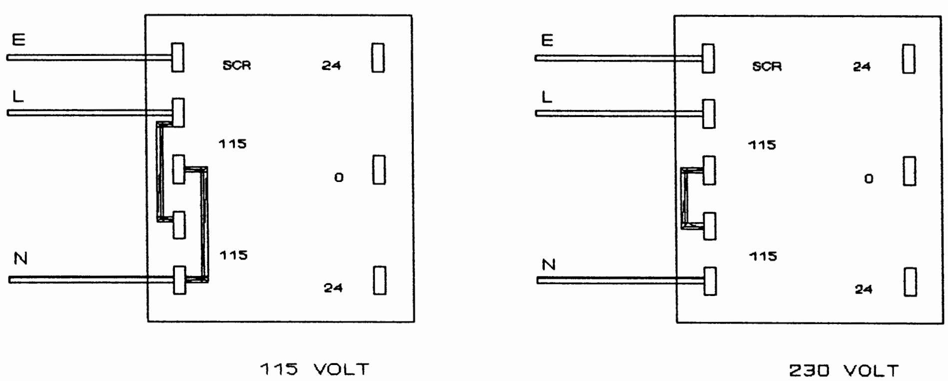


Figure 3 Mains voltage selection

5 SERVICING

5.1 PROBE

The most likely cause of failure is a damaged sensor probe. This of necessity employs a very fine wire which can be broken by rough handling. The symptom of an open circuit sensor is a meter reading below zero, irrespective of the liquid level. The sensing element can be checked on the resistance range of a multimeter. The resistance of the element varies according to its length but is typically 50-100 ohms. The sensor is shown schematically together with its pin connections on page 12.

5.2 ELECTRONICS

Failures in the electronics can be readily located by a few simple tests.

The supply lines can be measured at TP 10 (+10 v) and TP 2 (-20 v) relative to TP3 (O v)

An erratic reading can indicate that the operating current is incorrect for the sensor so that the resistive region is not propagating correctly. Alternatively a bad connection between the sensor and the indicator may be responsible.

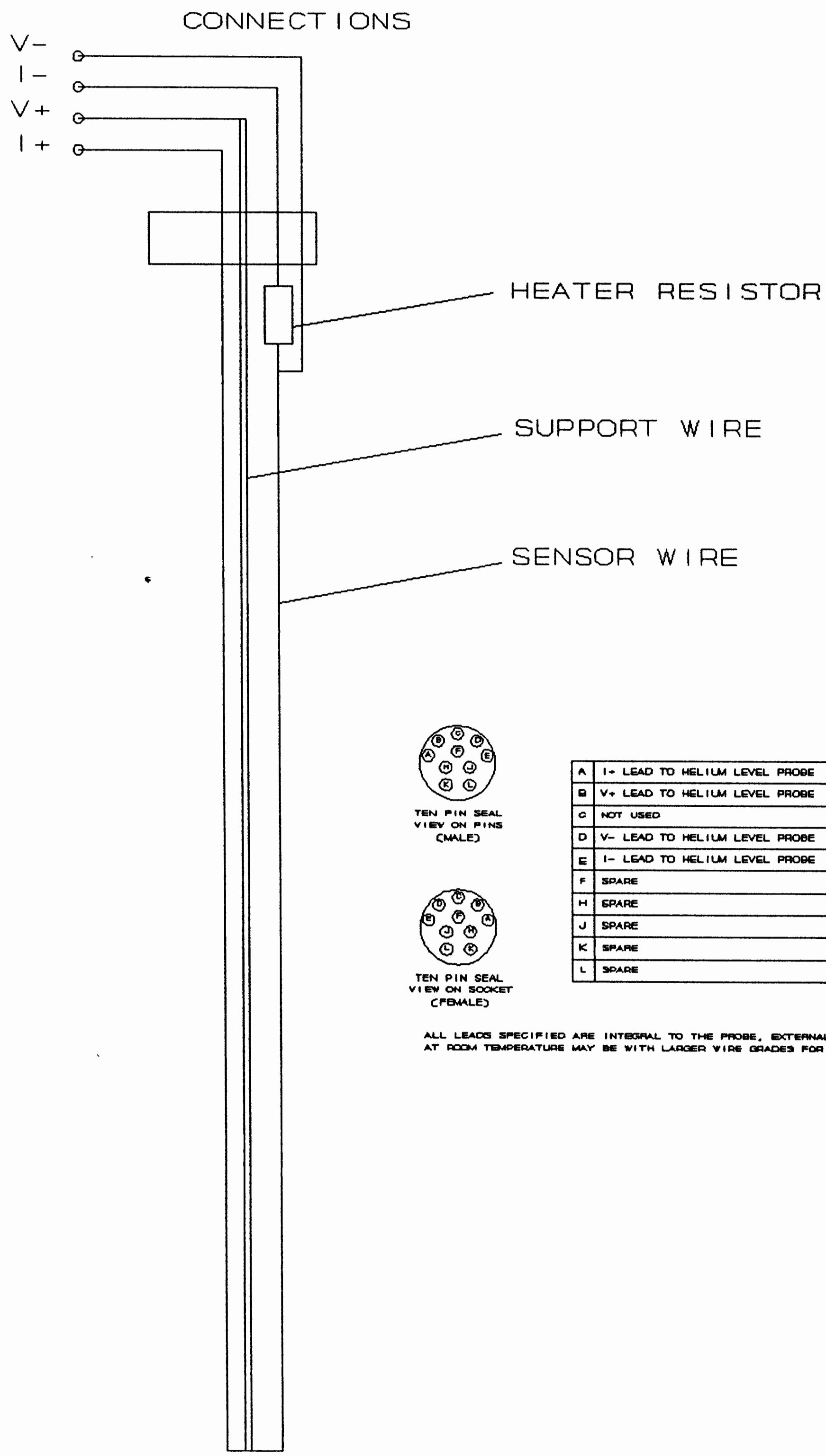
Operation of the sample light indicates that Q1 and Q2 are functioning correctly.

Monitoring the voltage between TP4 and TP3 enables the current source Q4 to be checked. The voltage here should be about 1 volt during the current pulse and about 30 mV at other times. If an increase in voltage is not observed during the pulse, repeat the test with the four connections to the sensor shorted together. If the correct voltage is now observed the fault lies in the sensor or its connections. If there is still no voltage Q4 or its associated circuitry is at fault.

The voltage across the wire itself may be monitored at TP5 and if displayed on an oscilloscope should follow a curve similar to the one shown on page 13.

The gating pulse for the sampling gate should be visible on an oscilloscope connected to TP6 and if present confirms the correct operation of Q6. This point should normally be at -20 volts but should rise to 0 volt for 10 milliseconds at the end of the current pulse.

The voltage across C5 can be measured with a voltmeter but will fall rapidly after the pulse due to the shunting effect of the meter. Provided IC1 is functioning correctly the same voltage should be observed at its output.
Failure of either of the level relays indicates a fault in either the relay itself or its associated driver transistor or amplifier.



		WIRE GAUGE	WIRE TYPE	
A	I+ LEAD TO HELIUM LEVEL PROBE	41	COPPER	R
B	V+ LEAD TO HELIUM LEVEL PROBE	44	COPPER	W
C	NOT USED			
D	V− LEAD TO HELIUM LEVEL PROBE	44	COPPER	Gr
E	I− LEAD TO HELIUM LEVEL PROBE	41	COPPER	O
F	SPARE			
H	SPARE			
J	SPARE			
K	SPARE			
L	SPARE			

ALL LEADS SPECIFIED ARE INTEGRAL TO THE PROBE, EXTERNAL INTERFACING AT ROOM TEMPERATURE MAY BE WITH LARGER WIRE GRADES FOR MAXIMUM STRENGTH.

Figure 4 Probe schematic and wiring

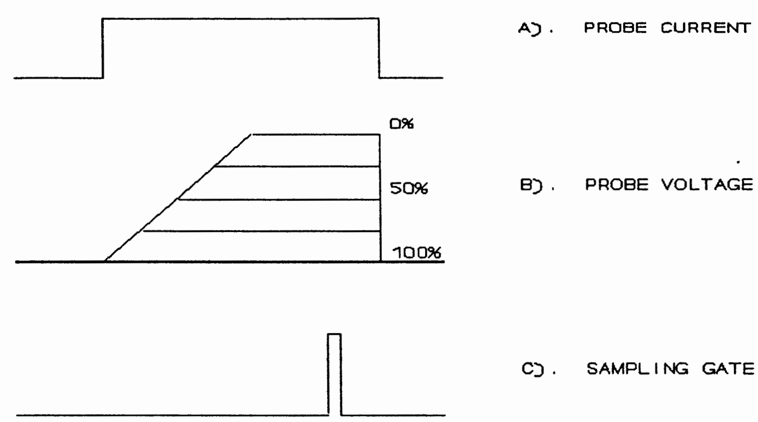
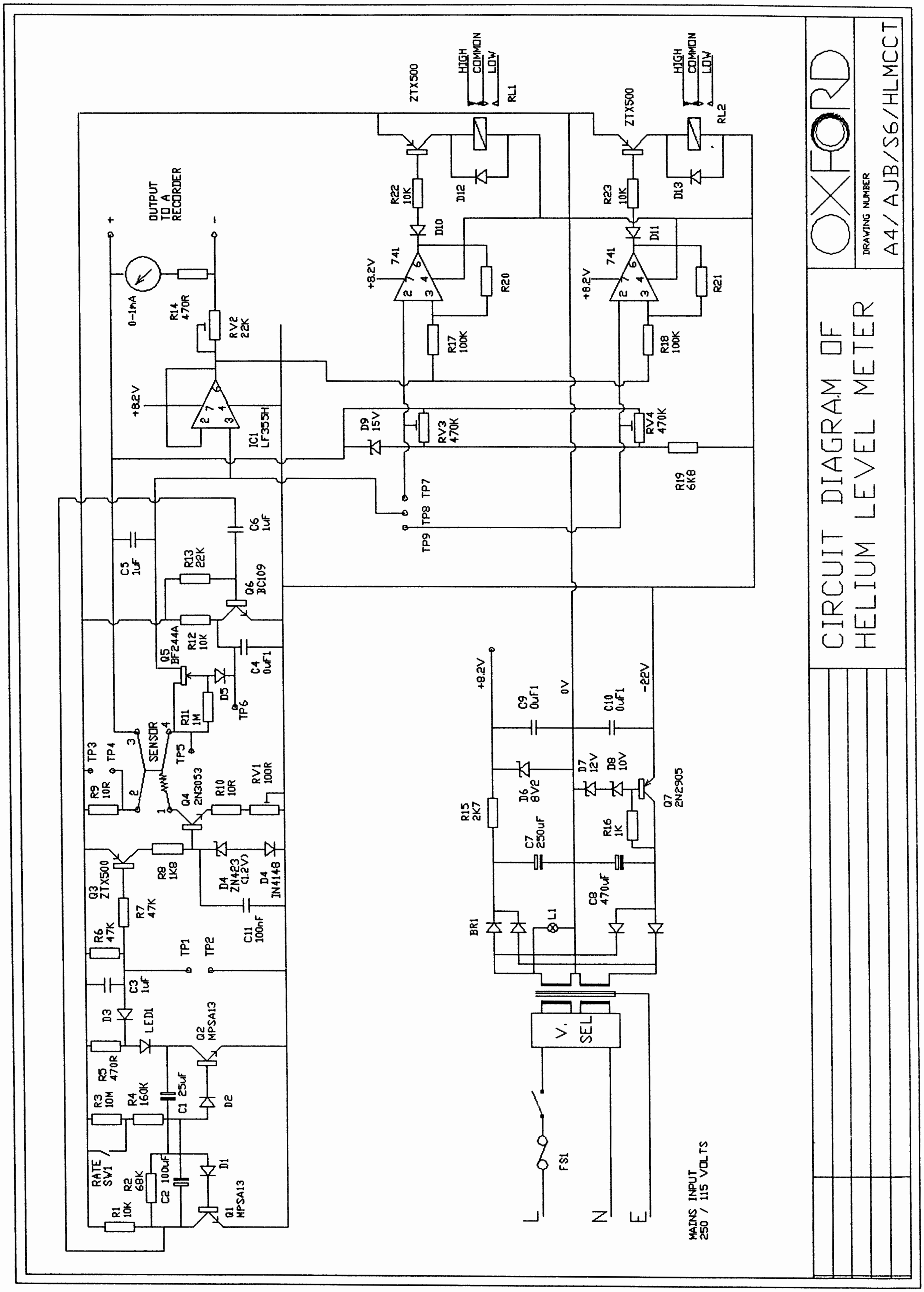


Figure 5 Probe current and voltage waveforms


OXFORD
DRAWING NUMBER
A4/AJB/S6/HLMCCT
CIRCUIT DIAGRAM OF
HELIUM LEVEL METER
OUTPUT TO A RECORDER
0-1mA
R14 470R
RV2 22K
IC1 LF355H
+8.2V
741
ZTX500
HIGH
COMMON
LOW
RL1
RL2
R22 10K
R23 10K
D10
D11
D12
D13
R17 100K
R18 100K
R20
R21
D9 15V
RV3 470K
RV4 470K
R19 6K8
TP7
TP8
TP9
C5 1uF
C6 1uF
R13 22K
Q6 BC109
R12 10K
Q5 BF244A
C4 0uF1
D5
TP6
R11 1M
SENSOR
TP3
TP4
TP5
R9 10R
R10 10R
RV1 100R
Q4 2N3053
Q3 ZTX500
R8 1K8
D4 ZN423 (1.2V)
D4 IN4148
R7 47K
R6 47K
C11 100nF
TP1
TP2
C3 1uF
D3
LED1
Q2 MPSA13
R5 470R
R3 10M
R4 160K
C1 25uF
D2
RATE SV1
R2 68K
C2 100uF
D1
R1 10K
Q1 MPSA13
0V
-22V
C9 0uF1
C10 0uF1
D6 8V2
D7 12V
D8 10V
Q7 2N2905
R15 2K7
R16 1K
C7 250uF
C8 470uF
BR1
L1
V. SEL
FS1
L
N
E
MAINS INPUT 250 / 115 VOLTS