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# AMI LIQUID HELIUM LEVEL SENSOR

## INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

## I. INTRODUCTION

The AMI liquid helium (LHe) level sensor uses a small niobium-titanium (NbTi) wire as the detector element. A heater creates and helps maintain a normal zone in that portion of the wire above the LHe level while that portion of the wire below the liquid helium level remains superconducting. The output voltage of the sensor varies linearly with a change in liquid level.

The AMI LHe level sensor is designed to operate with an AMI LHe level meter. Operation of the sensor with other level instruments or operation of different length sensor with an instrument calibrated for a different length may void the sensor warranty.

Standard rigid 4.2K LHe level sensors are typically painted a gold color. The 2K LHe level sensors are painted red. The 2K LHe level sensors have been constructed for operation with an AMI Model 1700 instrument configured at the factory for 2K operation or a Model 1740 Dual channel LHe level instrument that can be set for 2K operation by the customer. AMI cannot guarantee the accuracy or operation of a 2K sensor used with a standard (non-2K) LHe level instrument.

AMI manufactures a radiation-resistant level sensor for use in areas with high level of ionizing radiation. These special LHe level sensors will have phosphor-bronze (PhBr) leads since the radiation will break down the Teflon wire insulation over time.

The PhBr lead wire also provides for the lowest level of standby LHe loss since the PhBr wire has a high thermal conductivity compared to copper (Cu).

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## II. SPECIFICATIONS

| Specification | | Value | | | | |
|---|---|---|---|---|---|---|
| Sensor Tube Diameter (inches) | | 3/32 | 3/16 | 1/4 | 5/16 | 3/8 |
| Sensor Tube Type | | flexible | rigid | rigid | flexible | rigid |
| Sensor Tube Color | | blue | gold[a], red[b] | | blue | gold[a], red[b] |
| Lemo Connector Option Available? | | No | Yes | | No | Yes |
| Sensor Wiring | | PhBr | Teflon insulated Cu or Formvar insulated PhBr | | | |
| Radiation Resistant Option[c] | | N/A | Available | | | |
| Active Length ($L_A$) (inches) | Minimum | 1 | | | | |
| | Maximum 2K | N/A | 40 | 97 | N/A | 97 |
| | Maximum 4.2K | 60 | 40 | 80 | | |
| Overall Length (OAL) (inches) | Minimum | $L_A$ + 1[d] | $L_A$ + (1[d] or ≥4) | | $L_A$ + (1[d] to 6) | $L_A$ + 1[d] |
| | Maximum with flying leads | 61 | 46 | 108 | 82 | 125 |
| | Maximum with Lemo Connector | N/A | $L_A$ + 5 or $L_A$ + ≥8 | | N/A | $L_A$ + 5 or $L_A$ + ≥8 |
| LHe Temperature (K) | | 4.2 | 2 or 4.2 | | | |
| Sensor Nominal Excitation Current (mA) | 2K Sensor | 57 | | | | |
| | 4.2K Sensor | 75 | | | | |
| Sensor Nominal Maximum Voltage (V) | 2K Sensor | N/A | 27 | 64 | N/A | 64 |
| | 4.2K Sensor | 52 | 35 | 70 | | |
| Sensor Nominal Resistance (ohms/inch) | Sensor at 20K | 11.5 | | | | |
| | Sensor at 300K | 13.5 | | | | |
| Maximum magnetic field strength (tesla) | | 10 | | | | |

a. Standard AMI 4.2K LHe Level Sensor
b. AMI 2K LHe Level Sensor
c. These sensors do not contain any Teflon material
d. 0.5 inch above and below sensor active length

Caution symbol: necessary instructions in this document in order to protect against damage to the product.

## III. INSTALLATION

A. Carefully remove the sensor from the shipping tube and remove all packaging material.

*NOTE: If there is any shipping damage, save all packaging material and contact the shipping representative to a file a damage claim. Do not return the instrument to AMI unless prior authorization has been received (refer to Section VIII).*

B. The sensor must be mounted with the electrical leads (or connector) at the top.

C. For minimum losses, mount the liquid helium sensor so that warm helium gas rising from the sensor can pass directly out of the dewar without contacting surfaces at LHe temperature.

Do not mount the sensor in restricted areas (tubes, etc.) where the liquid level around the sensor might be depressed by pressure differences in the gas. Do not cover the holes in the sensor.

D. The sensor may be mounted by taping or clipping it to an appropriate support structure. Do not exert excess pressure on the sensor with the mounting device to avoid crushing the tube. Avoid constraining both ends of the sensor and allow for contraction of the sensor during cooldown.

*NOTE: Avoid bending the sensor or lead wires when cold to avoid the possibility of cracking or breaking the sensor or wire insulation.*

***CAUTION**: Do not operate the sensor in a vacuum. Operating the sensor in a vacuum may cause thermal damage and/or destruction of the superconducting filament sensor. Do not inadvertently turn the instrument on with the sensor in an evacuated chamber. Operation in pumped liquid helium environments is acceptable to 1K as long as liquid helium is present.*

E. Avoid installing in a location where icing (frozen water or gas) may occur since ice formations may cause erratic operation. Ice formation on the NbTi level sensing filament may stop the propagation of the normal (resistive) zone before it actually reaches the liquid/gas interface. This will give an indication of a higher helium level than actually exists.

F. Ensure the level instrument is de-energized (unplugged) and connect the sensor to the meter. The liquid helium level sensor leads are color coded:

**Table 1: LHe Sensor Wiring**

| Lead Wire Function | Cu Leads Teflon Insulation Color | PhBr Leads Formvar Insulation Color |
|---|---|---|
| I+ | Red | Red |
| V+ | Blue | Green |
| V- | Yellow | Natural Copper |
| I- | Black | Navy / Black |

## IV. OPERATION

The liquid helium level sensor is designed to work with all AMI liquid helium level instruments. The level meter will be calibrated for a specific length level sensor (calibrated length will be marked on the calibration label of the level instrument) or yje instrument set to the sensor active length.

*NOTE: All standard straight level sensors have a nominal one-half inch non-active portion at the top and bottom of the sensor.*

Further information on the helium level instrument is contained in the Installation, Operations and Maintenance Instructions for the particular model instrument to be used.

Helium consumption is a function of the power input to the sensor and will vary with the current, temperature (resistance) and the length of the sensor. AMI has, under ideal laboratory conditions, measured the helium consumption for a typical sensor to be as low as 20 milliliters per hour. This was measured in an open dewar when the hot gas did not contact the dewar walls. However, in typical installations the helium consumption will be somewhat higher. The maximum helium consumption (at 75 mA and 4.5 ohms/cm) would be 35 ml/hr/cm of active length. To minimize helium consumption it is recommended the sensor be installed in accordance with the installation instructions and the power to the sensor turned off at the level instrument between measurements.

Liquid helium losses due to superconductive helium level sensors can be quite variable. These losses, due to current in the sensor, are generally a function of physics and not the manufacturer.

The sensor element is a very small diameter NbTi wire held in a vertical position. The top of the wire has a small heater attached to initiate a resistive zone in the superconducting wire filament. Once initiated, the resistive zone will propagate from the heater area down to the liquid helium level and will stop without penetrating below the liquid. It takes a rather large amount of heat to maintain the filament in the resistive state in opposition to the cooling effects of the surrounding helium gas. In the best case, the heated gas leaves the system without transferring heat to the liquid helium. In the worst case such as in a completely closed dewar, all of the heat from the sensor eventually finds its way to the liquid and causes evaporation.

If the current in a sensor is left on continuously large losses can occur. It is usually only necessary to turn the electronics on when it is desired to know the level and then turn it off. This procedure will minimize the helium losses. For those who want this process automated, AMI has developed patented "Sample and Hold" line of liquid helium level instruments. These instruments include the Model 1700 and 1740.

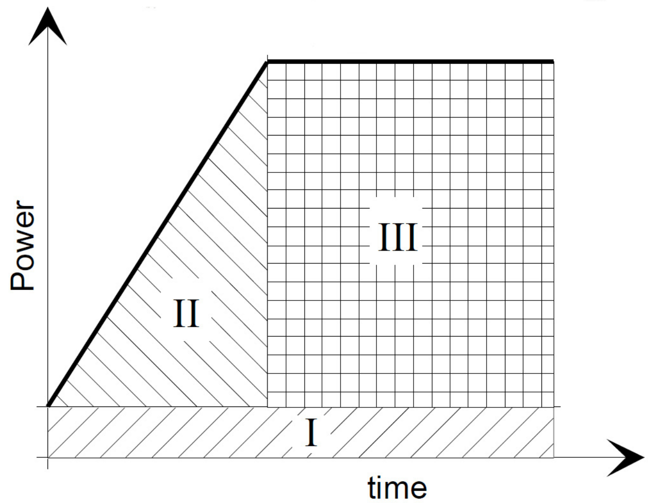
These instruments combine analog and digital electronics to measure the level on a periodic basis. The measurement is made by turning on the sensor current and monitoring the progress of the resistive zone. The instant the resistive zone is determined to have reached the liquid helium level, the current is turned off and the liquid level is saved and displayed. The whole process is repeated at intervals selected by the customer. The liquid losses increase as the sample frequency increases.

The losses for worst case conditions can be estimated if all the parameters are known.

Parameters are defined as follows:

| | | |
|---|---|---|
| $Q_h$ | = | Power produced in watts by the heater at the top. |
| $Q_v$ | = | Power produced in watts during the growth of resistive zone towards liquid level. |
| $Q_s$ | = | Power produced in watts after static conditions are reached, i.e. after the resistive zone reaches the liquid surface. |
| $I$ | = | Sensor current (0.075 amperes). |
| $R_h$ | = | Heater resistance (approximately 5 ohms). |
| $R_s$ | = | Normal state resistance/length of NbTi filament (approximately 4.55 ohm/cm @ 20K). |
| $v$ | = | Velocity of propagation of resistive zone (approximately 20 cm/second @ 75 mA sensor current). |
| $L_G$ | = | Length in cm of sensor active region not submerged in liquid helium. |
| $t$ | = | Amount of time the current is on in seconds. |
| $t_0$ | = | Time at which normal zone starts propagating in seconds. |
| $t_1$ | = | Time at which resistive zone stops at liquid level in seconds. |

There are three regions where heat is produced:




Region I. *The heater region*

Heat is produced as long as the current is on.

$$Q_h = I^2 \cdot R_h \cdot t$$

Region II. *The transition region*

The normal zone is assumed to propagate at a constant velocity (20 cm/second). The heat produced in the NbTi filament during the time required for the resistive region to reach the liquid surface is:

$$\begin{aligned} Q_v &= I^2 \cdot R_s \cdot L_G \cdot (t_1 - t_0) / 2 \\ &= I^2 \cdot R_s \cdot L_G^2 / (2 \cdot v) \text{ since } (t_1 - t_0) = L_G / v \end{aligned}$$

Region III. *The steady state region*

After the resistive zone reaches the liquid surface, the filament becomes a simple resistor with constant resistance. The power produced in this steady state is:

$$Q_s = I^2 \cdot R_s \cdot L_G \cdot t$$

EXAMPLE:

Let's estimate the loss for an extreme case of a 60 inch (152.4 cm) long sensor in an MRI system with all of the sensor length above the liquid helium level ($L_G$ = active length).

All other cases are better than this and can be easily calculated. The results are:

$$Q_h = 0.028 \text{ watts} \cdot t$$

$$Q_v = 14.86 \text{ joules}$$
$$Q_s = 3.9 \text{ watts} \cdot t$$

Since the heat produced in region III (steady state) is wasted and not required for level sensing, AMI has developed and patented a sample-and-hold system which reduces the third term ($Q_s$) to zero because it automatically turns the current off when the resistive zone reaches the liquid helium.

The sample time for this example of a 60 inch sensor is approximately 7.6 seconds. The total energy input for this sample is thus:

$$\begin{aligned} Q_h &= 0.028 \text{ watts} \cdot t \\ & \quad \text{where } t = 7.6 \text{ seconds} \\ &= 0.21 \text{ joules} \\ Q_v &= 14.86 \text{ joules} \end{aligned}$$

Consequently, total heat input ($Q_h + Q_v$) is approximately 15.1 joules. The latent heat of evaporation of liquid helium is approximately 21 joules/g. So in this case we have evaporated 0.72 grams of liquid helium (about 5.7 ml) for one sample.

If only 10 inches (25.4 cm) of the sensor is above the liquid helium level then:

$$\begin{aligned} Q_h &= 0.028 \text{ watts} \cdot t \\ Q_v &= 0.431 \text{ joules} \\ Q_s &= 0.143 \text{ watts} \cdot t \end{aligned}$$

The third term, $Q_s$, is again reduced to zero (due to sample-and-hold functionality) and the sample time is approximately 1.27 seconds, thus the total heat input for a sample is $Q = 0.45$ joules

The helium loss is 0.45 joules/(21 joules/g) = 0.021 grams or approximately 0.166 ml.

The velocity of propagation is the most uncertain term in the calculation. These calculations are intended to give you an idea of what the worst case helium losses are and to demonstrate helium loss variability.

## V. TROUBLESHOOTING

A. No level reading:

1. Ensure level meter is plugged in.
2. Ensure the leads are connected to the proper instrument terminals.
3. Ensure all lead wires are secure and are not broken.

4. Ensure the vessel is cold and capable of collecting helium.

B. Erratic or erroneous level reading:

1. Ensure there is no ice formations around sensor.

2. Ensure sensor is not installed in a restricted area.

*NOTE: Anomalous behavior of the sensor may be seen, under some conditions, at the lambda point of helium.*

If the cause of the problem cannot be located please call an AMI technical support representative at +1 (865) 482-1056 or support@americanmagnetics.com.

## VI. MAINTENANCE

The helium level sensor will provide years of useful service and require no maintenance if installed and operated in accordance with these instructions. The sensor is a sealed unit and internal repair or service is not feasible.

## VII. WARRANTY

All products manufactured by AMI are warranted to be free of defects in materials and workmanship and to perform as specified for a period of eighteen months from date of shipment. In the event of a failure occurring during normal use, AMI, at its option, will repair or replace all products or components that fail under warranty, and such repair or replacement shall constitute a fulfillment of all AMI liabilities with respect to its products. All warranty repairs are F.O.B. Oak Ridge, Tennessee, USA.

## VIII. RETURN AUTHORIZATION

Items to be returned to AMI for repair (warranty or otherwise) require a return authorization number to ensure your order will receive the proper attention. Please call an AMI representative at +1 (865) 482-1056 or contact technical support at support@americanmagnetics.com for a return authorization before shipping any item back to AMI.