Instructions, Rox™ Ruthenium Oxide RTD Installation, Model RX-102B-RS

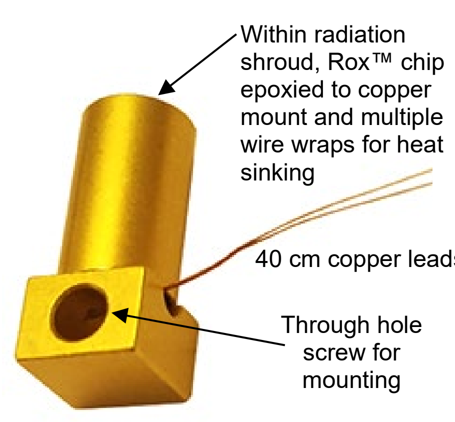
Proper temperature measurement at ultra-low temperature range is made difficult by several factors. Most importantly the thermal conductivity of materials decreases rapidly below 1 K. This limits the ability to thermally connect the thermometer to the experiment, heat sink electrical lead wires connecting the thermometer, and dissipate joule heat created in the thermometer's resistive element via joule heating. This, in turn, limits the power available for performing resistive measurements at these temperatures with typical excitations on the order of 1 fW for temperatures below 20 mK. High resistance devices can also be prone to self-heating due to RF noise pick-up or DC leakage current in the measurement instrumentation. The RX-102B-RS temperature sensor is uniquely designed for ultra-low temperature measurements, as low as 5 mK.

NOTE: DO NOT heat the sensor above room temperature.

The sensor has been thermally cycled multiple times. Microcracks form in the material during initial cycling, causing an initial shift in resistance that is stable through future thermal cycles. Upon heating above room temperature, these microcracks anneal, and the thermal conditioning process must be repeated to return the sensor to stable operation.

The RX-102B-RS incorporates many features to yield maximum compatibility for ultra-low temperature thermometry. This thermometer is based upon a ruthenium oxide sensing element designed to have lower temperature response than commercially available chips. At 10 mK, the typical resistance is 10,000 Ω, making the device less prone to self-heating due to noise pick-up or DC leakage current in the measurement instrumentation.

To maximize thermal connection, the ruthenium oxide chip is directly epoxied to the mounting adapter which is machined from a single piece of high thermal conductivity copper. Additionally, a thermal radiation blocking shroud is assembled over the sensing element to block heat from being transferred from the surroundings. The exterior of the thermometer is gold plated, further improving its resistance to errors caused by radiative heat transfer. The mounting position of the sensing chip is away from the mounting screw of the adapter to minimize stress on the chip. Two 36 AWG copper leads connect directly to the ruthenium oxide sensor and are heat sunk with multiple wraps around the copper mounting adapter. Minimal epoxy is used to minimize the heat capacity of the sensor. The through hole in the copper block is sized to allow mounting with either an English 6-32 screw or a metric size M3 screw.



There are three aspects of temperature sensor use critical to optimum performance: mounting the sensor package, joining sensor lead wires to connecting wires, and thermally anchoring wires. Adhere to the instructions below for maximum sensor performance.

SENSOR MOUNTING

1. The RX-102B-RS sensor is designed for screw mounting. The through hole will accommodate either an English #6 screw or a metric M3 screw. An existing threaded hole may be used or a new one created using the appropriate.
2. Clean the surface area with a solvent such as acetone followed by an isopropyl alcohol rinse. Allow the solvents to evaporate before sensor positioning.
3. Apply a small amount of Apiezon® N grease on the flat surface around the mounting hole. Greases have very poor thermal conductivity so a minimum amount should be used. The goal is to fill voids with the grease, not to create a boundary layer of grease.
4. Screw the adapter to the experiment using the proper screw for the hole. Brass screws are the best choice as they will contract slightly more than the copper mounting adapter thus tightening the mount as the temperature is lowered. Avoid over tightening (torque of 30 to 50 in-oz [0.21 to 0.35 Nm] should be sufficient). Stainless steel screws should be avoided as they will contract slightly less than the copper mounting adapter allowing the mount to loosen with decreasing temperature.

LEAD CONFIGURATION

The sensor is wired in a two-lead configuration, each wire being 36 AWG (0.127 mm diameter) copper wire, insulated with heavy build polyimide to an overall diameter of 0.152 mm (0.006 in), 40 cm (16 in) long. This length of wire is provided to allow thermal anchoring with a bobbin or something similar before transitioning to system wiring. See the section below on heat sinking and thermal anchoring for more details.

There is no polarity for the device. While the device is built as a 2-lead device, it is calibrated with these leads attached, to account for the wire. Transition to a 4-lead configuration at the end of the copper leads with your own wire.

WIRING ATTACHMENT

To attach long leads, use a 4-lead measurement scheme by attaching two connecting wires to each sensor lead. A 4-lead configuration is required to avoid measurement errors caused by lead resistance. The one exception to this rule would be the case where super-conducting wire is to be used and the sensor isn't expected to measure correctly when the wire is not superconducting and ohmic.

1. Prepare the sensor leads and connecting lead wires with an RMA (rosin mildly active) soldering flux, tin them with a minimal amount of 60% Sn 40% Pb solder. Use a low wattage soldering iron that will not exceed 200 °C. Clean off residual flux with rosin residue remover. Place a heat sink clip over the package to protect the sensing element inside the package from excessive heat.
2. Strip connecting wires' insulation by delicately scraping with a razor blade, fine sandpaper, or steel wool. Phosphor-bronze or Manganin wire, in sizes 32 or 36 AWG, is commonly used as the connecting lead wire. These wires have low thermal conductivity to help minimize heat flow through the leads. Typical wire insulation is Polyvinyl Formal (Formvar™) or Polyimide (ML). Formvar™ insulation has better mechanical properties such as abrasion resistance and flexibility. Polyimide insulation has better resistance to chemical solvents and burnout.
3. Prepare the connecting wire ends with an RMA (rosin mildly active) soldering flux, tin them with a minimal amount of 60% Sn 40% Pb solder. Use a low wattage soldering iron so that the temperature does not exceed 200 °C.
4. Clean off residual flux with rosin residue remover. Prepare the sensor lead in the same manner.
5. If using the sensor lead, place heat shrink tubing over it to provide both insulation and mechanical strength to the joint.
6. Attach one sensor lead with the connector wire and apply the soldering iron above the joint area until the solders melt, then remove the iron immediately. Repeat for the other set of connector wire and the other sensor lead.
7. Avoid putting stress on the device leads and leave enough slack to allow for thermal contractions that occur during cooling which may fracture a solder joint or lead.

HEAT SINKING/THERMAL ANCHORING

1. Heat flow through the connecting leads can create an offset between the sensor and the true sample temperature. Thermally anchor the connecting wires to assure that the sensor and the leads are at the same temperature as the sample.
2. Thermally anchor connecting wires at several temperatures between room temperature and cryogenic temperatures to guarantee minimal heat conduction through the leads to the sensing element.
3. If the connecting leads have a thin insulation such as Formvar™ or Polyimide, thermally anchor them by winding them around a copper post, bobbin or other thermal mass. A minimum of five wraps around the thermal mass should provide a sufficient anchor. However, if space permits, additional wraps are recommended. To maintain good electrical isolation over many thermal cycles, first varnish a single layer of cigarette paper to the anchored area, then wrap the wire around the paper and bond in place with a thin layer of IMI 7031 Varnish. Formvar™ wiring insulation has a tendency to craze with the application of IMI varnish. Once IMI varnish is applied, the wires cannot be disturbed until all solvents evaporate and the varnish fully cures (typically 12 to 24 hours).
4. A final thermal anchor at the sample itself is a good practice to ensure thermal equilibrium between the sample and temperature sensor.

TEMPERATURE CONTROL

The ability for this sensor to accurately report the temperature of the surface it is attached to extends beyond the sensor itself. Additional concerns such as wiring, grounding and instrumentation play a role in making a successful measurement. **This application note details what is required outside the dilution refrigerator for a successful measurement.**

RECOMMENDED CRYOGENIC ACCESSORIES FOR PROPER INSTALLATION AND USE OF ROX™ SENSORS

- **Stycast® Epoxy 2850FT**: Permanent attachment, excellent low temperature properties, poor electrical conductor, low cure shrinkage.
- **Apiezon® N Grease**: Low viscosity, easy to use, solidifies at cryogenic temperatures, excellent lubricant.
- **IMI 7031 Varnish**: Non-permanent attachment, excellent thermal conductor, easy to apply and remove.
- **Indium Solder**: 99.99% pure, excellent electroplating material, foil form.
- **RMA Soldering Flux**: Variety of types; refer to Lake Shore Product Catalog for details.
- **Phosphor-bronze Wire**: Available in single, duo, and quad strands, no magnetic attraction, low thermal conduction.
- **Manganin Wire**: Low thermal conductivity, high resistivity, no magnetic attraction.
- **Heat Sink Bobbin**: Gold-plated oxygen-free high-conductivity (OFHC) copper bobbins.
- **Instruments:** For ultra-low temperature measurement, the Model 372 AC resistance bridge is the only instrument capable of reading measurements.

For complete product description and detailed specifications on the above accessories and instruments, consult the Lake Shore Temperature Measurement and Control Catalog, call (614) 891-2244, E-mail sales@lakeshore.com, or visit our web site at www.lakeshore.com.