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1 ZOSHBI

ZOSHBI is a zirconia oxide oxygen sensor for high temperatures in ProboStat. The sensor is used in the mounted on the inner chamber gas in line. ZOSHBI has higher temperature range (500-1400°C) than our MOSE (500-1050°C) oxygen sensors.

The yttria stabilized zirconia ceramic tube is (nearly) pure oxide ion conductor at elevated temperatures. A voltmeter connected to the electrodes on both the inside and the outside surfaces of the tube can be used to measure the potential across the tube. The potential of oxygen ions across the tube can be measured from the proportional potential of electrons via the connected electrodes with a voltmeter.

This oxygen sensor construct requires a reference gas which is both supplied and evacuated from the same "Inner In" gas connection by utilizing 1/32" gas lines threaded into the 1/8" default gas line. This is a non-standard approach that requires replacing the quick connect with a bulkhead and threading a thin gas tube inside another gas tube. At this time, this product and this manual must be considered experimental without the normal assumptions of ease of use, ease of setup, warranty etc.

For oxygen sensors without the need for reference gas ask us about "MOSE".

2 Mounting a reference flush gas line

2.1 New ProboStat

In case a new ProboStat is purchased same time as ZOSHBI the reference gas (RG) flush line can be preinstalled, even to ProboStat units with Base unit heating (BUH). Overall, the BUH unit has steeper bends on gas lines, and the interior of the ProboStat hexagon is inaccessible, so retrofitting A steel RG line may be impossible or at least much harder than retrofitting a standard ProboStat.

2.2 Existing ProboStat without base unit heating

Remove the side plate of the base unit hexagon and remove the Bulkhead quick connect for the Inner In gas line, replace with bulkhead such as Swagelok SS-200-61. The gas line bend is roughly 60° and threading a 1/32" gas line all the way to "inside" the ProboStat can be achieved by utilizing these approaches.

- After cutting the 1/32" to legnth, use sandpaper to ensure the ends are open for unrestricted flow
- Remove sharp edges will help threading the line
- Rotating the 1/32" gas line while pushing it in
- Using PTFE, PEEK or other suitable material instead of SS as material of the 1/32" gas line. These materials are more malleable and have lower friction

2.3 Existing ProboStat with base unit heating

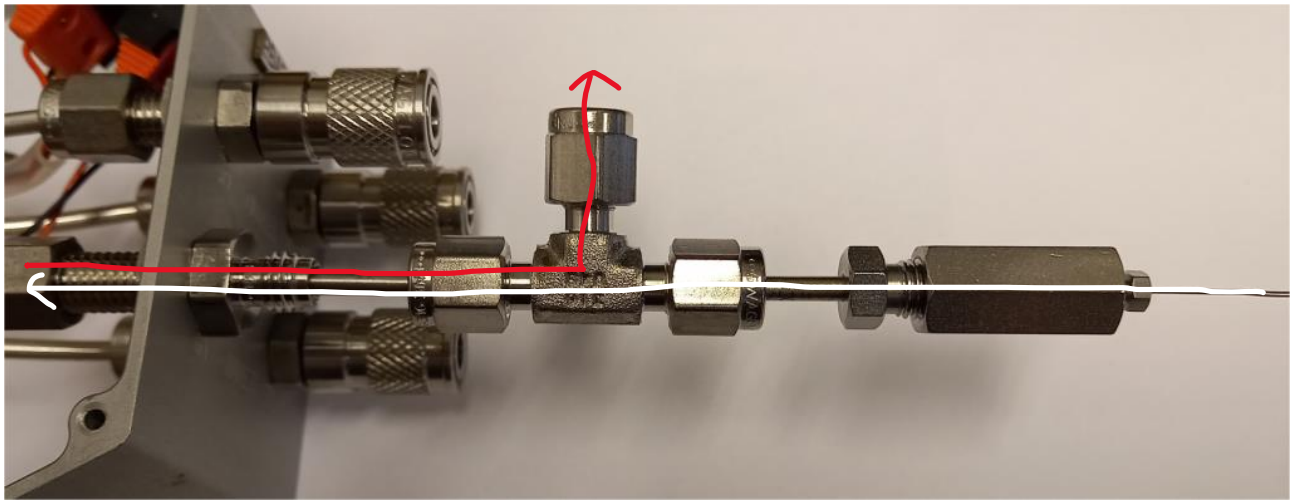
Retrofitting base unit with base unit heating is challenging. The bend on the gas line is 120°. The above methods can be tried but success is not guaranteed. Try mounting the line before ordering ZOSHBI.

2.4 Gas line measurements

The distance of the 1/32" gas line protruding into ProboStat should be about 5 cm. Some length makes it easier to mount the ZOSHBI. Any potential extra length above 5 cm can only be in a material that tolerates temperatures above 200°C.

At the outside end of the 1/32" gas line, the length is up to the user. The reference gas used for the oxygen sensor is typically air. An adapter from 1/32" gas line to the reference supply is needed, and the outcoming

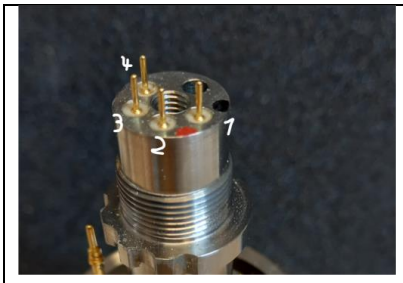
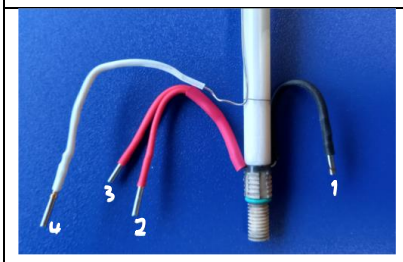
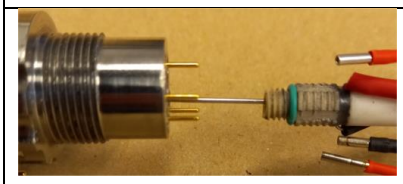
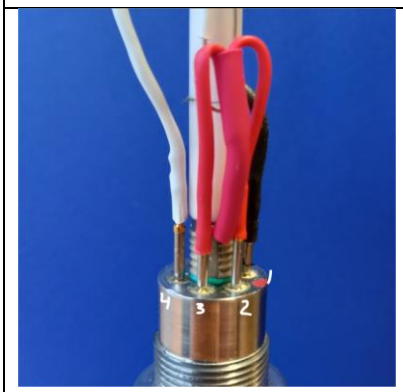
reference gas flows out, potentially into the room or to a vent in case the experiment uses dangerous gases. A hermetic seal may be needed to ensure the ingoing and outcoming gases have no possibility to escape the gas system. Such arrangement can be a 1/8” T-type joint, where the 1/32” goes through the straight part, and the size reduction is done with 1/8” to 1/32” adapter. Be advised this adapter is permanent and cannot be removed without removing the full length of the 1/32” line. For normal base units this is not a problem as new line can be added when needed, but for base units with heating the line cannot be easily added back. The “permanent” adapter block does not prevent normal use of ProboStat, as the extra gas entry can be blocked with a plug.



The 1/8” to 1/32” adapter must be bored through to allow the 1/32” line to continuously run all the way through.

3 Mounting the sensor

The first step of mounting any measurement setup on ProboStat that utilizes the ZOSHBI sensor, is to mount the sensor itself.

	The ZOSHBI mounts on the Inner In gas line and the four electrode contacts of the inner chamber.
	The sensor has three leads one of which has double purpose. Red and Black form an S-type thermocouple, whereas Red and White measure electrolyte potential. For that reason, the red lead has two ends. The threads on the PEEK adapter may be shorter, this is to avoid excessive rotation when mounting.
	The inside of the oxygen sensor has alumina spacer tube with four holes, only two of which are occupied. It takes a number of tries until the 1/32” gas delivery line enters one of the free holes.
	It may be necessary to add some high temperature vacuum grease on the 1/32” gas delivery line to discourage the gas from taking a shortcut and pass less via the sensor tip. Silicone etc. contaminations should be considered.
	Mounting the electrode contacts: Pin 1: Sensor Black, Thermocouple + Pin 2: Sensor Red, Thermocouple - Pin 3: Sensor Red, Electrolyte reference side Pin 4: Sensor White, Electrolyte experiment side The nomenclature here is of particular concern, the the immediate visual outside of the sensor tube is also the experiment side, and in that sense the “inside” while what is hidden from the view, the “inside” the sensor tube itself, is flushed with reference gas, and thus the “outside”. To avoid this contradiction, it is best to think of the sides and electrodes from these sides as “experiment side” and “reference side”. The pins are numbered clockwise from the inner out gas.

Bend the three connections aside, ensure the threaded adapter of the sensor has an O-ring. Inside the sensor is an insulation tube with four holes. Two are filled with the electrode lines, and two empty ones. The empty ones can carry the reference gas up and down from the sensor tip.

When mounting the sensor, the first phase is to gentry and carefully move the sensor around until the 1/32" reference gas line enters one of the two free holes. Gently slide the sensor down all the way and screw it to the threads. There is enough space, flexibility and play for the 1/32" gas line to bend to accommodate for the <1 mm radius it rotates along. It is good idea to be gentle and alert for any feedback of potential elevated resistance.

The gap between the inside of the alumina hole and the outside of the 1/32" gas line allows some of the gas to return without going to the tip of the sensor. To prevent this shortcut as potential pathway for the gas, the gap can be filled with high temperature vacuum grease or small piece of thin PTFE tape. Good flow of the reference gas to the tip of the sensor can be verified by altering the flush gas contents or the flow rate. Unfortunately, this validation requires the setup to be heated to several hundred °C, so it is not an easy or quick process.

4 Usage

4.1 Measurements

Both properties to be measured are voltages. The thermocouple voltage between Pin 1 and Pin 2 can be measured from the ProboStat TCBI miniature thermocouple connector. The internal wiring of these contacts inside the ProboStat are appropriate S-type thermocouple compensation wires.

The sensor voltage can be measured between the Pin 3 and Pin 4 designated on ProboStat ILV and ILC accordingly. These are standard BNC panel mounts.

Measurement and calculations can be automated with Omega software (and suitable multimeter). Omega software has functionality for conveniently (measuring and) calculating cold junction compensation, thermocouple voltage to temperature conversion and solving the Nernst equation.

4.2 Thermocouple calculations

Thermocouple voltage to temperature calculations including cold junction compensation are outside the scope of this manual.

4.3 Oxygen partial pressure

In case of oxygen partial pressure measurements with YSZ ceramic the Nernst equation

$$E = \frac{\mathrm{RT}}{4\mathrm{F}} \ln\left(\frac{\mathrm{p}O_2\mathrm{Experiment}}{\mathrm{p}O_2\mathrm{Reference}}\right)$$

Can be conveniently rearranged for calculation of pO_2 in the experiment

$$pO_2\mathrm{Experiment} = \mathrm{p}O_2\mathrm{Reference} \cdot 2.71828^{\left(-46421\frac{E}{T}\right)}$$

Or for verifying operation from known gases

$$E = -0.0000496\ \mathrm{T}\ log_{10}(pO_2\mathrm{Experiment}/\mathrm{p}O_2\mathrm{Reference})$$

Where
E is the sensor electromotive force in Volts
T is the sensor temperature in Kelvins

Or, for conveniency; use E in millivolts, and constants of -46.421 and -0.0496 in the formulas accordingly.