NORECS AS
Haslevollen 3E
NO-0579 Oslo
Norway

1 MOSE introduction

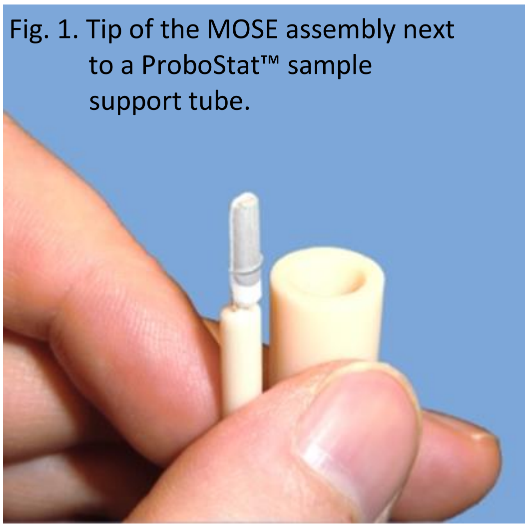
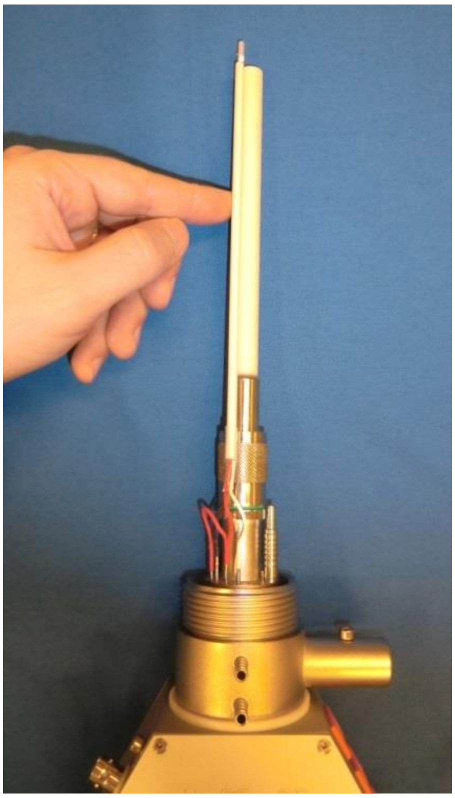


Fig. 1. Tip of the MOSE assembly next to a ProboStat™ sample support tube.

Miniature Oxygen Sensor Electrode (MOSE) is a combined oxygen sensor and S-type thermocouple mounted ready for use in any standard ProboStat™ configuration. The sensor has a built-in metallic reference: made of a metal and its oxide, it is placed and sealed inside a zirconia sheath. The sensor requires no reference gas and is very small; sensor tip of the electrode is 10 mm long and 3 mm diameter (Fig.1).

By default the MOSE sensor is made to fit 60 cm long ProboStat™ system in the outer chamber, with the center of the sensor tip at the sample height. At special request the MOSE can be manufactured to any length, and can be made to fit also the inner chamber of ProboStat™.

The default model can be used for temperature range from 600°C to 1050°C. Optional “low temperature” version from 500°C to 900°C.



The whole sensor assembly can be seen in Fig. 2. The default length for the sensor is ~54 cm. The sensor on Fig. 2 is made shorter so that it fits into a single image. The sensor can be made to a custom length on request.

Fig. 2. Overview.

2 Connecting to ProboStat™

The S-type MOSE needs to be used with ProboStat™ that has S-type thermocouple wiring.

It is very important not to bend the tip of the sensor nor apply any sort of force onto it. The thin Pt and Pt/Rh wires can easily get cut by the sharp alumina tube.

The wires of S-type MOSE have the following colors and functions, and recommended connection feedthroughs on ProboStat:

MOSE wire color	MOSE wire function	ProboStat feedthrough code for outer chamber	ProboStat feedthrough code for inner chamber	Instrument voltage terminal
Black	Thermocouple +	9 (TCT+)	1 TCB+)	Positive
Red	Thermocouple -	10 (TCT-)	2 (TCB-)	Negative
White	O_2 Reference	8 (LV)	3 (ILC)	Positive
Red	Common	7 (LVS)	4 (ILV)	Negative

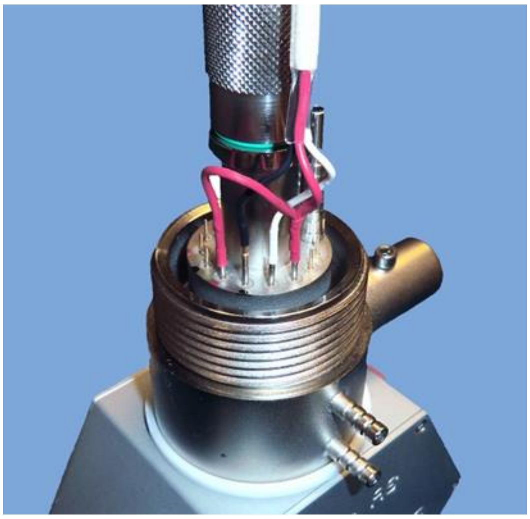


Fig. 3. Suggested connection scheme for S-type MOSE.

Suggested connection scheme for S-type MOSE:

From left to right:
Feedthrough 10 Red (TCT-) = Thermocouple -
Feedthrough 9 Black (TCT+) = Thermocouple +
Feedthrough 8 White (LV) = O_2 sensor reference
Feedthrough 7 Red (LVS) = Common

For the recommended connections MOSE thermocouple voltage would be measured on TCT (feedthroughs 9 and 10), and the sensor voltage - between the LVS and LV (feedthroughs 7 and 8). Utilize a BNC-banana adapter that is shipped with ProboStat™ systems for these measurements in case needed to connect to a measuring instrument.

We advise against using combinations of shield feedthroughs (5, 7, 14, 16) or LC (6) for carrying sensor voltage. The O_2 sensor voltage electrode must never short circuit with common electrode or connect with the ground potential while the sensor is above room temperature. Using more than one shield pin will allow this possibility (a switch on ProboStat™ base unit may connect all shield pins together).

Other configurations can also be used as long as the thermocouple voltage is carried in the correctly compensated feedthrough.

3 Background

Zirconia is a solid electrolyte conducting oxygen ions at high temperatures. An electrochemical voltage appears between the two platinum plated surfaces of the zirconia when they are in contact with two gaseous atmospheres at different oxygen partial pressures. This voltage follows the Nernst equation:

$$E = \frac{RT}{4F} ln \frac{P_{meas}}{P_{ref}}$$

where:

R and F are the constants,
E is the voltage,
T is the temperature,
P_{ref} is the reference oxygen partial pressure,
P_{meas} is the measured oxygen partial pressure.

Knowing the reference oxygen partial pressure, and measuring voltage and temperature, you can calculate the oxygen partial pressure you need to measure.

MOSE, unlike common zirconia sensors called "air reference" sensors, gets its own O_2 reference from a mixture of metal/metal oxide placed and sealed inside it. This avoids using any reference gas.

3.1 Calculation of oxygen partial pressure

The calculation of oxygen partial pressure follows the Nernst equation, as below:

$$E = E_0 + \frac{RT}{4F} \ln \frac{pO_2}{0{,}2095}$$

$$pO_2 = 0{,}2095 \times 10^{\left(20{,}158 \times \frac{E-E_0}{T}\right)}$$

where E_0 is the MOSE voltage (when placed in air).

To calibrate the sensor this measurement is done in several temperatures with known pO_{2ref} so the E_0 can be solved for. The E_0 versus temperature is a linear dependency y=cx+d where line coefficient c is used for calibration factors for the specific sensor.

Final calibration factors are:

B_x=c×(4×96.487/8.315) and A_x=E_0-(c×T0)×(4×96.487/8.315). This calibration is already done, and the factors A_x and B_x are given with each sensor included in a calibration and calculation excel sheet.

With these any pO_2 can be calculated using the following formula:

$$\mathrm{p}_{O2meas} = \mathrm{p}_{O2ref} \times \exp((46.416 \times \frac{E}{T}) - \frac{\mathrm{A}_x}{T} - \mathrm{B}_x)$$

The provided excel sheet uses mV, and % O_2 (1013.25 mbar).

3.2 Examples

For example when A_x=26619.55069 and B_x=-25.06457246

Sensor voltage of 48 mV at 700°C should result in 0.209 O_2/atm
Sensor voltage of 20 mV at 700°C should result in 0.055 O_2/atm
Sensor voltage of -20 mV at 700°C should result in 0.00816 O_2/atm
Sensor voltage of -200 mV at 700°C should result in 0.00000152 O_2/atm

4 Operation

In order to get the pO_2, the user needs to know the sensor voltage, and the sensor temperature.

4.1 Sensor voltage

Using voltmeter with internal impedance/resistance higher than 1 Giga Ohm, measure between red and white sensor leads.

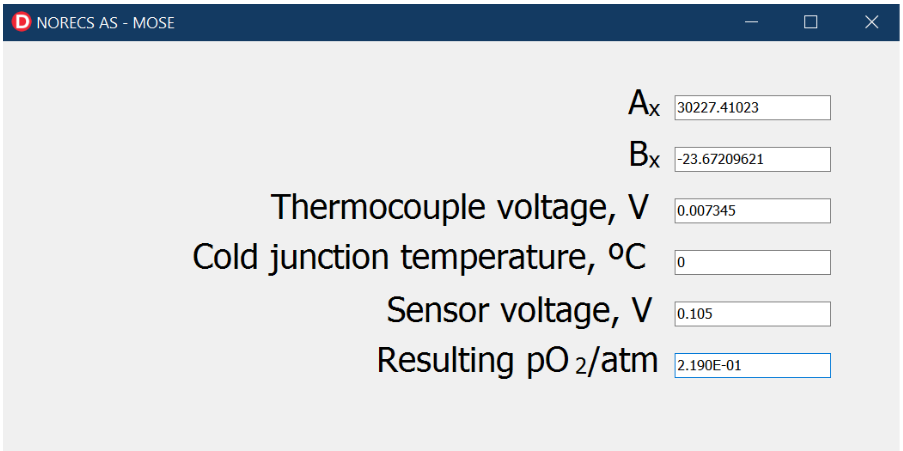
4.2 Thermocouple voltage

Measure voltage between the black and red sensor leads.

4.3 Calculations with MOSE calculator

The easiest way to get the sensor pO_2 is to use the NORECS AS - MOSE Calculator software that can be downloaded for free from:

http://www.norecs.com/work/_files/__PUBLIC_FILES__/software/MOSE%20calculator/



Input	Notes
Ax	Calibration factor A_x, provided in Excel file or email
Bx	Calibration factor B_x, provided in Excel file or email
Thermocouple voltage, V	Voltage measured between black and red sensor leads
Thermocouple cold junction temperature, °C	Temperature at the spot where the black and red sensor leads (thermocouple wires or thermocouple compensation wires) end, and the instrument probes (or other identical wires) start
Sensor voltage, V	Voltage measured between red and white sensor leads
pO_2/atm	Oxygen pressure in atmospheres, 1013 mbar

The software takes care of the tedious process of converting cold junction temperature into voltage and using that voltage in conjunction with the measured sensor thermocouple voltage to get the absolute temperature of the sensor. Be advised, that the pO_2 calculation is very sensitive to temperature. The ambient room temperature e.g. the cold junction compensation, in this arrangement is not typically well controlled. For example, someone opening a door to the lab may show as a change in pO_2, but was actually a change in the cold junction temperature. Remedy for this is to insulate the junction between thermocouple wires and wires of similar material, so they do not change their temperature quickly.

The Omega software can also be used to measure a thermistor located at the cold junction, to obtain the exact cold junction temperature for each data point.

Mind the polarity of the wires and instrument terminals. The software will inform if the voltage entered is outside of the range of an S-type thermocouple, but it has no way of knowing if the measured sensor voltage is correct or not.

4.4 Calculations with EXCEL sheet

Various versions of the calculator/Excel file exist.

In case more than one sensor was delivered, select correct tab on the accompanying excel file. The name of the tab needs to match the serial number of the sensor. The Excel file is emailed, ask NORECS for it if you do not have the file.

Note that the voltage is to be entered in mV, and the resulting pO2 is in $\%pO_2$/atm.

Enter the temperature of the sensor to the accompanying Excel file at the bottom to cell F48 or F52. Enter the sensor voltage as millivolts to field E48 or E52. Some file versions require user to click calculate to get P1. The Excel file cell addresses given here may vary.

Note that the sensor temperature must be known; measured with device capable of reading S-type thermocouple, or by using the MOSE calculator software.

4.5 Calculations with OMEGA software

NORECS Omega software (not included) and with a suitable multichannel multimeter, the whole process can be automated. The pO_2 will be measured continuously and plotted on the screen of a computer as well.