INSTRUCTIONS FOR USE

CarboProbe ZI Pro

CarboProbe ZS Standard

CarboProbe ZS Pro

ECONOX SA
Route de Miécourt 16
2942 Alle – Switzerland
T: ++41 32 465 10 00
F: ++41 32 465 10 01
www.econox.ch
info@econox.ch

CONTENTS

1. Operational principles

The purpose of ECONOX *CarboProbe* oxygen sensors is to measure and regulate atmospheres in heat treatment furnaces.

General points

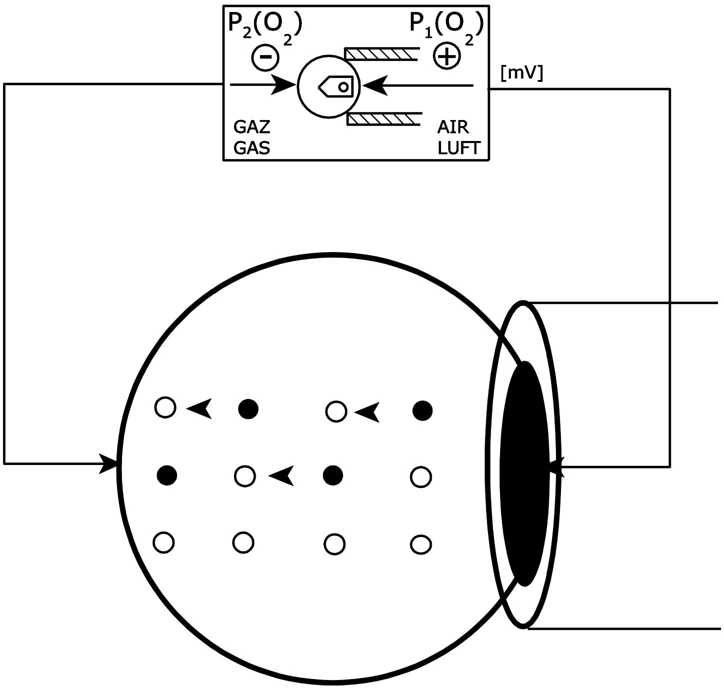
ECONOX uses two different types of electrolyte made of ZrO_2 (zirconium oxide) for its oxygen sensors:

1. A ball made of ZrO_2, an ECONOX-patented system, which may only be obtained from ECONOX. The ball is used in the *CarboProbe ZI pro* sensor.

2. A C-700 ZrO_2 electrolyte.
This is used in the *CarboProbe ZS* and *HT* sensors.

These elements made of zirconium oxide (ZrO_2) placed at work temperature and separating two gaseous areas with differing partial oxygen pressure (pO_2), behave like electrochemical batteries by transferring oxygen ions. At the terminals of both electrodes on the ball, the value of the voltage delivered is linked to the absolute temperature and the difference in partial oxygen pressures, according to the Nernst equation.

The diagram shown below represents the operation of the ZrO_2 ball; the principle is the same for the C-700 ZrO_2 electrolyte.



$$E = 0.0215 \cdot T \cdot \ln \frac{P1 \cdot O_2(référence)}{P2 \cdot O_2(four)}$$

E =	voltage [mV] at terminals
T =	temperature [°K] in the furnace
P1O2 =	partial oxygen pressure of ambient air (20.9%)
P2O2 =	partial oxygen pressure of the atmosphere in the oven

The measuring element in the oxygen sensor is a ceramic composed of zirconium oxide doped with yttrium. The latter presents defects in the crystal lattice. Most parts of the lattice which could be occupied by oxygen ions are incomplete.
The main property of the ceramic is to allow the movement of oxygen ions at temperatures over 700°C. Above that temperature, the zirconium becomes a conductor through the movement of oxygen ions rather than that of electrons. The voltage thus generated is an expression of the relations between the relative difference in oxygen concentrations (ambient air and atmosphere in the furnace) and the temperature of the sensor.
The voltage is expressed in the following equation:

$$E = 0.0215 \cdot T \cdot \ln \frac{P1 \cdot O_2(\textit{référence})}{P2 \cdot O_2(\textit{four})}$$

By interpreting the voltage measured on exiting the sensor, using the NERNST formula, the oxygen concentration of the atmosphere in the furnace can be read instantly and precisely. By knowing the oxygen concentration, the CO content and the temperature, the carbon potential can be determined using the fixed stoichiometric relations that exist between O_2 – CO – CO_2 concentrations. In this way, the mVs measured on exiting the sensor are a function of the carbon potential for a given temperature and CO level.
The sensor voltage depends solely on the composition of the gas and the temperature.

The carbon potential is then calculated using the following formula:

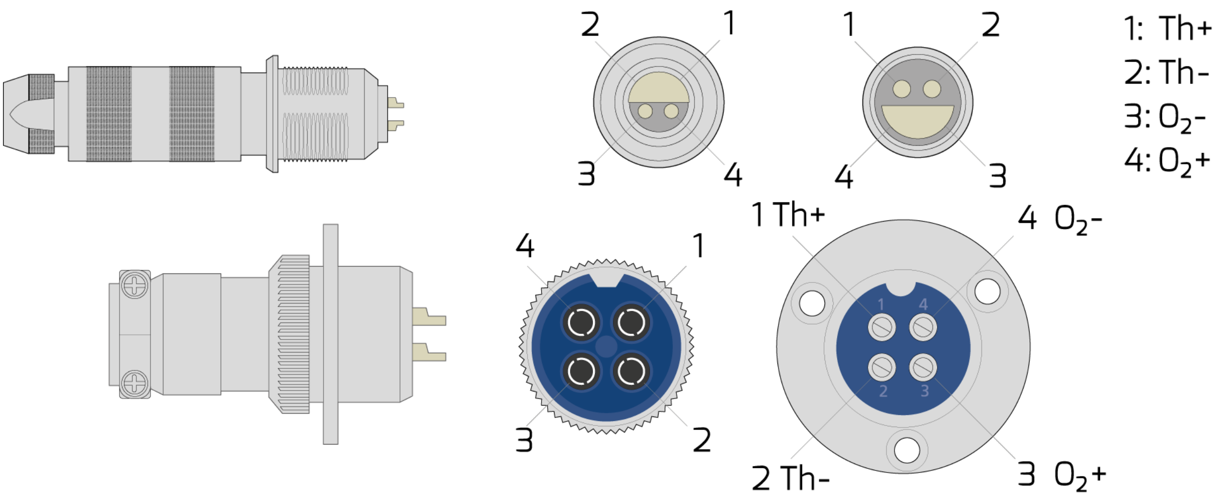
$$\%C = F(E[mV] \cdot \textit{température}[°C] \cdot P_{CO})$$

2. Technical specifications for CarboProbe sensors

Output	0 to 1200 mV
Reading	Oxygen sensors must be used with control devices with input impedance of 10 megohms or over.
Insertion depth	10 cm minimum
Precision	±0.05% C
Response time	Under one second
Standard air	Clean, dry standard air with an output of 30 to 50l/hr for *CarboProbe ZI* sensors and 0.5 - 1l/hr for *CarboProbe ZS* and *HT* sensors.
Cleaning air	An output of 150l/hr ought to be sufficient; in any event, the air flow must be fast enough to keep the mV value for the sensor under 250mV for 1 minute.
External electrode	Special steel resistant to high temperatures
Temperature range	700°C to 1150°C
Thermocouple	K-, R- and S-type or no thermocouple
Thermal and mechanical shock	*CarboProbe ZS* sensors must be brought up to temperature gradually (over a 10-minute period). This precaution does not apply to *CarboProbe ZI* sensors, in which the ball is highly resistant to thermal shock.

Electrical plug

Here are the connections for the electrical plug:



3. Installing the sensor

All our oxygen sensors are tested after assembly. No offset is set when the sensors are shipped.

Points to be followed when installing a sensor:

1. The sensor must never obstruct the loading of the furnace.

2. The sensor must be placed as close as possible to the load in order to measure the temperature and atmosphere precisely, as these have a direct impact on the load. Placing the sensor close to a turbine will improve readings.

3. If the sensor is installed too close to the heating elements or the furnace door, the temperature cannot be measured correctly. Any difference in temperature between the sensor and the regulation thermocouples ought to be avoided.

4. Thermal and mechanical shocks must be avoided when installing the sensor, or during the heat treatment cycle (this causes the deterioration of the zirconium oxide measuring element).

5. No methanol projections should come into contact with the oxygen sensor (significant thermal shock). Consequences include cracks, deterioration of the measuring element or even the distortion of the external electrode. In such cases, the lifespan of the sensor may be considerably reduced. If methanol projections cannot be avoided, consider selecting our *CarboProbe ZI pro* sensor with its protective external ceramic casing.

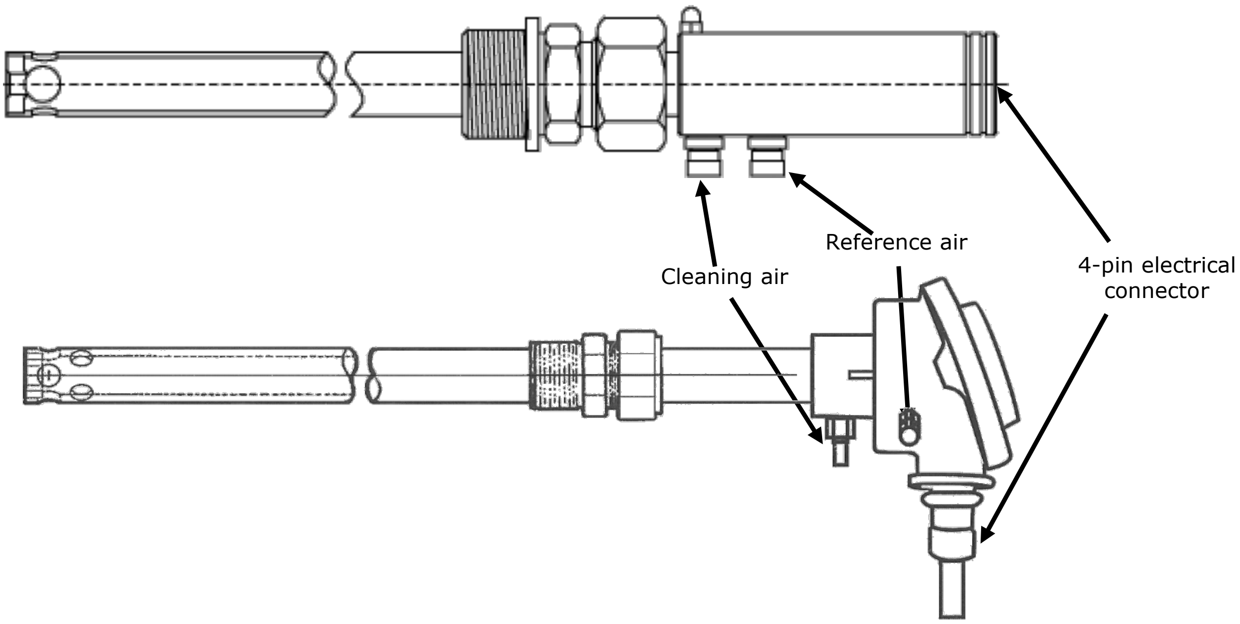
6. The temperature of the measuring element must be between 700 and 1,150°C (maximum of 1,700°C for the *CarboProbe HT* sensor).

7. The sensor is supplied with a 1'', 1 ½'' or 1 ¼'' connector depending on your order and the type of *CarboProbe*. When fitting it to the furnace, ensure that the core temperature of the sensor does not exceed 60°C.

8. The connector linking the sensor to the furnace must be airtight. If necessary, you may check its airtightness using a lighter: when moving it around the connector, no flame should flare up from the connector.

9. *CarboProbe ZS* sensors must be brought up to temperature gradually; otherwise the measuring element may suffer irreversible damage. In order to avoid this problem, the sensor must be inserted slowly into a furnace that is up to temperature. **The sensor must be inserted gradually over a period of 10 minutes**. This precaution does not apply to *CarboProbe ZI* sensors, in which the ball is highly resistant to thermal shocks.

4. Reference air



5. Starting the furnace

Turn on the reference air and connect it to the sensor. If the sensor is placed or replaced on a hot furnace, turn on the air as soon as you can.

The *CarboProbe ZI pro* sensor is resistant to thermal shocks and can, therefore, quickly be placed in a hot furnace. For *CarboProbe ZS pro* sensors, please take the precaution of introducing the sensor into the furnace over a period of **10 minutes** (only when the furnace is at high temperatures).

WARNING!

When exchanging or removing a sensor from a furnace that is up to temperature and contains gases, please follow the instructions below:

- Turn off the air-stirring turbine
- Do not allow air to enter the furnace. Depending on the gases within the furnace (e.g. hydrogen), there may be an explosion.
- Carefully remove the sensor, avoiding mechanical and thermal shocks (for *CarboProbe ZS pro* and *standard* sensors) and place it either on a brick or on a concrete surface.
- **NEVER ATTEMPT TO SPEED THE COOLING OF A SENSOR**

Sensors ought to be changed only when the furnace does not contain dangerous gases.

6. Furnace atmosphere

The work conditions for the sensor (i.e. high temperatures) and the atmosphere within the furnace when in operation have a direct influence on the lifespan of the sensor.

The following points are very important and require your full attention in order to benefit from a long-lasting sensor.

1. The items to be treated must be free of grease or zinc-based components.
2. There must be no residues from quenching oil or salt.
3. Do not use a zinc-based basket to hold small items. Zinc accelerates the deterioration of the measuring element in oxygen sensors.
4. The lifespan of the sensor may also be reduced if the furnace is operating close to the soot threshold over a long period and if the soot is not burned at regular intervals.
5. Mercury and other heavy metals are also damaging to the measuring element in the oxygen sensor. They must therefore be avoided as far as possible.

7. Maintenance

The few steps shown below must be performed in accordance with the suggested schedule in order to guarantee the proper operation and long lifespan of the sensor. Please refer to section 8 "Troubleshooting" for further information.

Description	**Frequency**
Check standard air and output - *CarboProbe ZS pro*: 0.5 - 1l/hr - *CarboProbe ZI pro:* 30 – 50 l/hr	Once a week
Launch a cleaning cycle and burn soot to clear the measuring element of any impurities. - Cleaning output: 150l/hr - Furnace turbine off	Every 4 hours
If burning the soot is not effective, dismantle the sensor, **allow it to cool** and clean the soot away with compressed air.	Once a week
Check the proper operation of the machines used to clean the items to be treated	Twice a month

8. Troubleshooting

Introduction

When there are doubts as to the validity of sensor reading, a few simple tests conducted while the sensor is in operation can assist in diagnosing the problem. The majority of carbon potential controller indicate the temperature and the mV signal emitted by the sensor. Using the controller, check whether these indications are plausible, in order to establish whether the issue is the temperature or the mV signal.

Checking the impedance of the sensor

Place a 50kohm resistance through the mV signal pins (3 and 4). The mV signal should drop; if the decrease is less than 20% of the original value, there is no problem. If, on the other hand, the decrease is greater than 50%, then the sensor probably requires repairs, as the measuring element is most likely contaminated.

Checking the standard air and airtightness

Prior to anything else, disconnect the standard-air supply from the head of the sensor and check that air is indeed flowing into it. Reconnect the standard air. Check whether the air supply tube is connected to the corresponding connector. Then perform the following procedures depending on the type of sensor you use:

CarboProbe ZS pro

While the sensor is in operation, suddenly cut the standard-air supply (by pinching the tube with your fingers). The exit signal from the sensor should gradually drop by a few mVs in one minute. After releasing the tube, the voltage displayed should immediately return to its initial value. If the change was greater than 25 mV, the sensor is probably cracked and therefore gives incorrect readings, in which case it must be repaired.

CarboProbe ZI pro

While the sensor is in operation, suddenly cut the standard-air supply (by pinching the tube with your fingers). The mV value should drop slowly by a maximum of 20mV in 5 seconds. After releasing the tube, the voltage displayed should immediately return to its initial value. If the sensor voltage drops suddenly (over 20 mV in 10 seconds), the sensor is no longer airtight; in which case it must be repaired.

Checking the thermocouple

Disconnect the connection cable and use a voltmeter to check the exit signal from the thermocouple. Start at the controller and gradually work back to the sensor terminals, then towards the thermocouple wires inside the sensor head. Take a number of readings along the way to pinpoint the defect. If the thermocouple defect is inside the sensor itself, it must be repaired.
ECONOX can, on request, provide millivolt-temperature conversion tables for S-, R- and K-type thermocouples.

Checking the oxygen signal

If the sensor emits an oxygen signal but the signal seems to be incorrect, perform the following checks. All of these may be performed while the sensor is in the furnace. They do not constitute any kind of calibration, but they do give an indication of the condition of the sensor.

1. Measure the oxygen mV signal. Leave the mV-meter connected to the terminals and **(20 sec maximum)** short-circuit the oxygen mV pins on the sensor; then

remove the short-circuit. The mV signal should return immediately to initial value(<30s). If the signal slowly returns (>3 min.), it means that the sensor is defective and should be replaced.

2. Now disconnect the connection cable and use a mV-meter to check the mV signal. Start at the regulator and gradually work back to the sensor terminals. Take a number of readings along the way to pinpoint the defect. If the defect lays within the sensor itself, it must be repaired.

Checking the effectiveness of a purge

Check the oxygen signal during a purge (burning) cycle. It is not possible to make a general recommendation regarding air output for purges. The crucial parameter is not the quantity of purging air, but rather the response to it. The correct output is that necessary to bring the mV signal under 250 mV for one minute.
The air output for purges must not be such that it brings about excessive temperature changes. Soot burning must be controlled using a thermocouple so as to avoid excessive overheating of the measuring element. It may be necessary to remove the sensor from the furnace and clean off any soot residues using compressed air (after the sensor has cooled and returned to the ambient temperature).

Burning soot completely is effective when the voltage is close to 0mV.

9. Repairing the sensor

CarboProbe sensors are highly technical measuring instruments subjected to potentially difficult work conditions. The lifespan of a given sensor depends, to a large extent, on the conditions in which it is used. If you suspect that the sensor is malfunctioning, and the troubleshooting section has not helped you in solving the problem encountered, then the sensor probably requires repair.

When sending a sensor for repair, pack it carefully in its original packaging, mark it "Fragile Instrument", and return it to:

ECONOX
Rue de l'église 25
2942 Alle – Switzerland
T: ++41 32 465 10 00
F: ++41 32 465 10 01
www.econox.ch
info@econox.ch