INSTRUCTIONS FOR USE

CarboProbe ZI pro

CarboProbe ZS pro

ECONOX USA
600 Mogadore Road
Kent, OH 44240
T: +1 (330) 678-4328
www.econox.us
info@econox.us

Table of Contents

Operating principles

The purpose of ECONOX *CarboProbe* oxygen sensors is to measure and regulate atmospheres in heat treatment furnaces. ECONOX uses two different types of sensors made of ZrO2 (zirconium oxide) for its oxygen sensors:

1. ZrO2 Ball sensor
   The ZrO2 ball used in the *CarboProbe* ZI Pro sensor is an ECONOX-patented system and can only be obtained from ECONOX. The ball is more robust than other sensors and resistant to thermal shock.

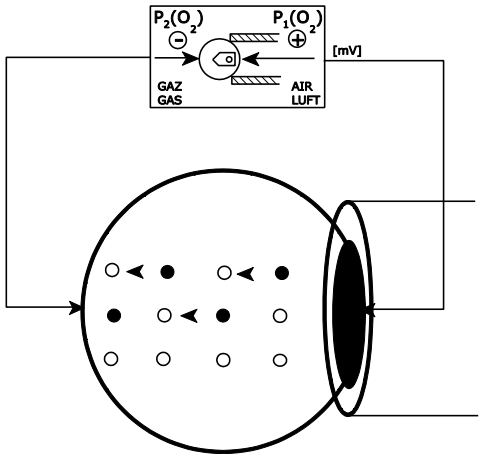
2. C-700 sensor
   The C-700 sensor is a rod shaped sensor and is used in *CarboProbe ZS* and *HT* sensors.

The ball sensor and C-700 sensor separate two gaseous atmospheres: the atmosphere of a furnace or oven and the atmosphere of ambient air outside of the furnace. They then act as electrochemical batteries by transferring oxygen ions. Both types of sensors are made of ZrO2 "doped" with yttrium. The yttrium creates defects in the crystal lattice of the ceramic. Portions of the lattice that could be occupied by oxygen atoms are incomplete. When the ceramic sensor is heated over 700C, it allows for the movement of oxygen ions. The zirconium becomes a conductor through the movement of the oxygen ions rather than electrons and the voltage generated is an expression of the relations between the relative difference in oxygen concentrations between the ambient air and atmosphere in the furnace as well as the temperature of the sensor. Therefore, the voltage in mV can be calculated with the Nernst equation:

$$E = \frac{RT}{nF} \ln\left(\frac{P_{O_2 reference}}{P_{O_2 furnace}}\right)$$

Simplified equation:

$$E = 0.0215\, T \ln\left(\frac{P_{O_2 reference}}{P_{O_2 furnace}}\right)$$



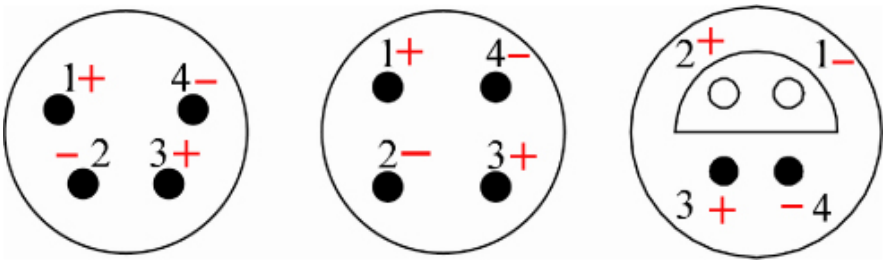
Where $E = voltage\ (mV) at\ terminals\ of\ sensor$
$T = \ temperature\ (°K)$
$P_{O_2 reference} = partial\ oxygen\ pressure\ of\ ambient\ air\ (20.9\%)$
$P_{O_2 furnace} = partial\ oxygen\ pressure\ of\ the\ atmosphere\ in\ the\ furnace/oven$

Sensor voltage depends solely on the composition of the furnace atmosphere and temperature of the furnace. The mVs measured across the sensor are a function of the carbon potential for a given temperature and CO level. The oxygen concentration of the furnace atmosphere can be

read instantly and precisely by interpreting the measured voltage across the sensor terminals. When the oxygen content, CO content, and temperature are known, the carbon potential can be determined using the fixed stoichiometric relations that exist between O_2, CO, and CO_2 concentrations.

Technical specifications

	CarboProbe ZI	CarboProbe ZS	CarboProbe HT
Output	0-1200 mV		
Reading	Oxygen sensors must be used with control devices with input impedance >= 10 megohms.		
Insertion depth	10 cm minimum		
Precision	.+/- 0.05% °C		
Response time	< 1 second		
Standard air	Clean, standard air with an output of 30-50 l/hr (1-1.75 CFH)	Clean, standard air with an output of 0.5-1 l/hr (.018-.035 CFH)	
Cleaning air	150 l/hr (the air flow must be fast enough to keep the mV value for the sensor under 250 mV for 1 min)		
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	Resistant to thermal shock.	Must be brought up to temperature gradually over a 10 minute period to resist thermal shock.	



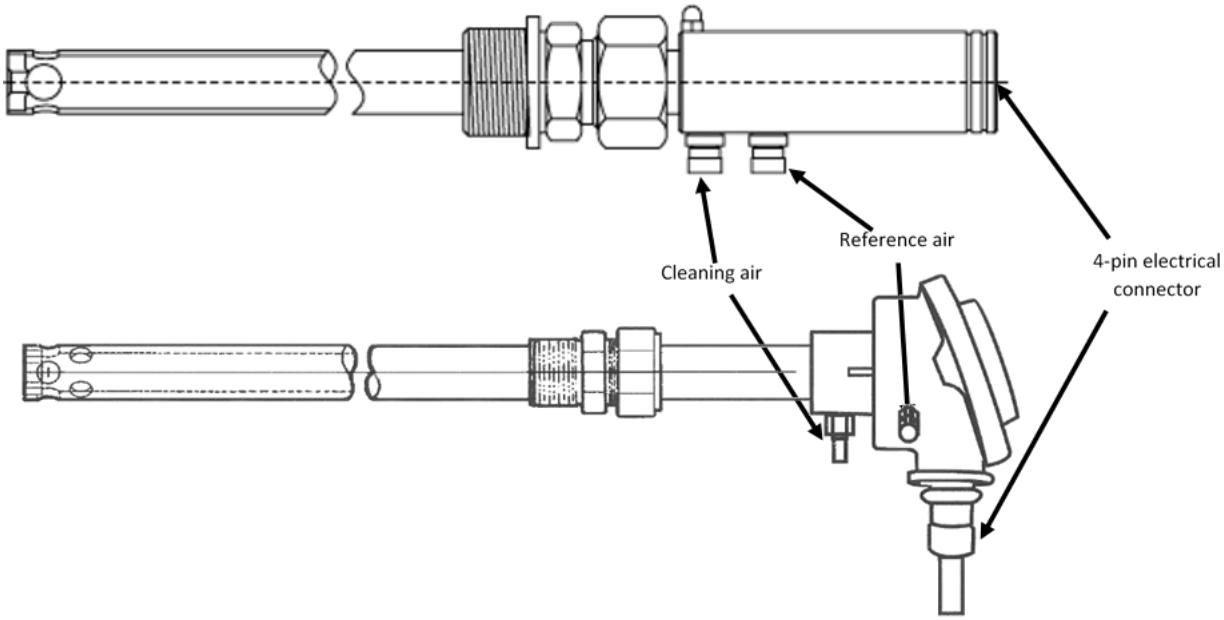
Installing the sensor

All ECONOX probes are tested after assembly. No offset is set when the sensors are shipped.

1. Sensor placement
    a. The sensor must be placed so that it does not obstruct loading of the furnace.
    b. Place the sensor as close to the load as possible 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.
    c. Do not place the sensor too close to heating elements or the furnace door. The temperature will not measure correctly. Placement that creates temperature differences between the sensor and the regulation thermocouples should be avoided.
2. Mechanical shocks must be avoided when installing the sensor and during the heat treatment cycle.
3. *Carboprobe* ZS and HT sensors must be brought up to temperature gradually during installation and heat treatment cycles to avoid thermal shock. Otherwise the measuring element may suffer irreversible damage. To avoid this problem, the probe must be inserted slowly into a furnace that is up to temperature over a period of 10 minutes. This precaution does not apply to *CarboProbe* ZI sensors, in which the ball sensor is highly resistant to thermal shocks.
4. No methanol projections should come into contact with the oxygen sensor (significant thermal shock will occur). 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 is protective external ceramic casing.
5. The temperature of the measuring element must be between 700 and 1,150°C (1292 – 2,102°F). The *CarboProbe* HT can operate with slightly higher temperatures, up to 1700°C (3092°F).
6. The sensor is supplied with a 1", 1-1/4", or 1-1/2" connection depending on your order and the type of *CarboProbe*. When installing the probe into the furnace wall, ensure that the core temperature of the probe does not exceed 60°C (140°F).
7. The connection between the probe and the furnace must be airtight. The airtightness can be checked using a lighter. Move a lighter around the connection point. If the flame flares up at the edges of the connection, the seal is not airtight.

Reference and cleaning air

Reference air is supplied to the probe through the red port. Cleaning air is supplied through the blue port and is used to burn off soot that may build up on the probe.



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**. (This is only necessary 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 should only be changed when the furnace does not contain dangerous gases.

Furnace atmosphere

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

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

1. The product to be treated must be free of grease or zinc-based components as well as quenching oil or salt tank residues.
2. Do not use a zinc-based basket to hold small items in the furnace. Zinc accelerates the deterioration of the measuring element in oxygen sensors.
3. Mercury and other heavy metals are also damaging to the measuring element in the oxygen sensor. They must therefore be avoided as much as possible.
4. The lifespan of the sensor may be reduced if the furnace is operating close to the soot threshold over a long period of time, and if the soot is not burned with cleaning air at regular intervals.

Maintenance

Maintenance must be performed in accordance with this provided schedule in order to guarantee the proper operation and long lifespan of the sensor. Please refer to the "Troubleshooting" section for further information.

Maintenance task description	Frequency
Check reference air and output - Carboprobe ZS pro: 0.5 - 1 l/hr - CarboProbe ZI pro : 30-50 l/hr	0-1200 mV
Launch a cleaning cycle to burn soot and clear the measuring element of any impurities. The furnace turbine should be off and the cleaning air output should be set to 150 l/hr	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 per week
Check the proper operation of the machines used to clean the items to be treated	Twice per month

Troubleshooting

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

Checking the impedance of the sensor

Place a 50 kohm 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 the decrease is greater than 50%, the sensor probably requires repairs, as the measuring element is most likely contaminated.

Checking the reference air and airtightness of the probe

Disconnect the reference air supply from the head of the sensor (red) and check that air is flowing. Reconnect the reference air. Check that 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, pinch the reference air tube with your fingers, stopping the flow of the reference air supply. The signal from the sensor should gradually drop by a few mVs in one minute. Release 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, pinch the reference air tube with your fingers, stopping the flow of the reference air. The mV value should drop slowly by a maximum of 20 mV 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 signal from the thermocouple. Start at the controller and gradual 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, a few checks can be completed. These checks may be performed while the sensor is in the furnace and do not constitute any kind of calibration. The checks give an indication of the condition of the sensor.

1. Measure the oxygen mV signal. Leave the mV meter connected to the terminals for less than 20 seconds and short-circuit the oxygen mV pins on the sensor. Remove the short-circuit. The mV signal should return immediately to the initial value (< 30 s). If the signal slowly returns (> 3 min.), the sensor is defective and should be replaced.
2. 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 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 purges. The crucial parameter is not the quantity of purging air, but rather the response to it. An output is acceptable if it keeps 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.

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 USA
600 Mogadore Road
Kent, OH 44240
T: +1 (330) 678-4328

www.econox.us
info@econox.us