Operating Manual

CarboProbe™ ZI

Industrial oxygen probe for heat treatment

CarboProbe™ ZS

Industrial oxygen probe for heat treatment

CarboProbe™ ST

OEM Industrial oxygen probe for heat treatment

ECONOX SA
Rue de l'église 25
2942 Alle – Switzerland

T: ++41 32 465 10 00
F: ++41 32 465 10 01

www.econox.ch
www.econox.com
info@econox.ch

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Measuring & control systems

Table of Content

1 Operational principles

The principle of operating an oxygen probe is dependent on two electrodes making contact with either a platinum coated zirconium element at the tip of the sensor or a Zirconia oxide ball, one side is called the outer electrode and the other one the inner electrode.

The special alloy protection tube is one conductor for the oxygen probe signal. The protection tube has excellent resistance to corrosion and oxidation at high temperature and has good mechanical strength.

The purpose of the ECONOX *CarboProbe™ ZS, ZI* and *ST* oxygen probes is to measure and regulate atmospheres in heat treatment furnaces.

1.1 General informations

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

1. A **ZrO_2 ball**, which may only be obtained from ECONOX.
The ball is used in the *CarboProbe™ ZI* probe.

2. A **C3M* ZrO_2** electrolyte.
This is used in the *CarboProbe™ ZS and ST* probe.

These elements are made of zirconium oxide (ZrO_2). When they are placed at working temperature and separate two gaseous areas with differing partial oxygen pressure (pO_2) their behaviour is like an electrochemical battery by transferring oxygen ions.

At the terminals of both electrodes on the **C3M ZrO_2** electrolyte or the **ZrO_2 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 C3M sensor is an updated version of the C-700 sensor

1.2 Functional principles

The functional principles of a *CarboProbe™* is based upon the comparison of the two oxygen partial pressures in two separate gaseous mediums. The zirconium oxide which represents the measuring element has faults in its crystal structure, i.e. some of the sites which could be occupied by oxygen ions are free. At a temperature above 600°C the oxygen ions start to migrate, which is a typical feature of this ceramic material. This results in the measuring element becomes conductive. The voltage generated represents a relation between the relative difference of the oxygen concentrations and the **ZrO_2** cell temperature.

In order to compare the partial pressure, the oxygen probe must be supplied with a gas of a known content of oxygen (ambient air: $\%O_2$ = 20.9 %). **This is what we call reference air**. Moreover, some of the Econox *CarboProbe™* are equipped with a thermocouple allowing measurement of the actual treatment temperature.

Thus, the user who knows the CO content either by analysis or by theoretical calculation and who takes into account the values measured by the Econox *CarboProbe™*, is able to determine the carbon potential, %C (and the oxygen concentration) in the heat treatment atmosphere.

The measuring element of a *CarboProbe™* has a limited lifetime. Its surface layer changes depending on the impurities (soot or dust residues) which are found in the heat treatment atmosphere. Therefore, the measuring element should be replaced when its impedance exceeds the tolerances admitted.

2 Unpacking

2.1 CarboProbe™ comparison chart

	***CarboProbe™* ZI**	***CarboProbe™* ZS***	***CarboProbe™* ST****
Sensor	ZrO_2 Ball	C3M sensor***	C3M sensor***
Head	Red	Black	White
Patent	No	Yes	Yes
Thermal-shock resistant	**YES**	**No**	**No**
Connector	Gold coated LEMO	Gold coated LEMO	Standard Amphenol
Max length	1000mm	1350mm	1350mm
Reference air	20-30l/h	1-6l/h	1-6l/h

* *The CarboProbe™* ZS standard is a discontinued product replaced by the CarboProbe™ ZS pro
***CarboProbe™* ST is supplied in batch of 10 pieces as OEM probe only (with no Econox name)
*** The C3M ZrO_2 sensor is an updated version of the C-700 sensor.
Check www.econox.com for more information.

2.2 Packaging

The Econox *CarboProbe™*, although a robust unit must be unpacked and handled with care. Each probe is dispatched in a secure package.

This package should be kept in a secure place at all times, should the need arise to return the probe to Econox. Any probe not being returned in its original packaging may affect warranty conditions.

The package consists of an outer box and an inner layer of polyurethane which houses the carbon probe.

Each pack includes the probe together with the operating manual, warranty card, test certificate of the *CarboProbe™* and an access card to the Econox Online Services (www.econox.com/ecos).

Make sure you remove the "plastic plugs" holding the sensor and the sticker before inserting the CarboProbe™ ZS and ST into a hot furnace.

FAILURE TO DO SO WILL PERMANENTLY DAMAGE THE *CARBOPROBE™* AND VOID WARRANTY !

Note: CarboProbe™ ZI Pro does not have plastic plug.

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3 Serial number

Econox serial numbers are easy to understand and give you all the details about the characteristic of the probe.

AA-BB-CCC-DDDD-E-FFF

AA: Type of Thermocouple

00: No TC	20: K-type
10: S-type	30: B-type
13: R-type	40: N-type

B: Probe type

7	*CarboProbe™ ZI* without ceramic protection
8	*CarboProbe™ ZI* with ceramic protection
14	*CarboProbe™ ZS*
16	*CarboProbe™ ST*

CC: Probe length from tip of electrode to bottom of head

50:	500mm	**100:**	1000mm
65:	650mm	**120:**	1200mm
75:	750mm	**135:**	1350mm
85:	850mm		

DDDDD: Unique ID number

E: Represent the type of bearing size of probe

1: 1'' thread **2**:1½'' thread

FFF: Length of the outer ceramic tube

4 Specification

Output	0 to 1200 mV
Readout impedance	*CarboProbe™* should be used with controlling, recording and indicating instruments having input impedance of 10 megaohms or higher
Accuracy	±0.05 weight percent carbon in normal operating range
Response time	Less than 1.0 second at 700°C and above
Thermocouples	Type K, S, N or without
Operating Temperatures	600°C to 1150°C
Mechanical shock	Resists mild mechanical shock. Handle carefully
Thermal shock	*CarboProbe™ ZI* resists thermal shock *CarboProbe™ ZS & ST* are less resistant and should be introduced/removed from furnace slowly (25mm per minute intervals)
Available length ZI	500mm, 650mm, 750mm, 850mm, 1000mm
Available length ZS & ST	500mm, 650mm, 750mm, 850mm, 1000mm, 1200mm, 1350mm
Reference air	Uncontaminated dry air at maximum rate of 20-30l/h (ZI) and 1-6l/h (ZS and ST)
Cleaning air	Uncontaminated dry air at maximum rate of 300 l/h, **See chapter 7.2 for more information**

5 Installation

The following points are important for the correct installation and operation of your *CarboProbe™*.

5.1 Mechanical

Econox *CarboProbe™* can be mounted vertically or horizontally. Longer probes (over 1000mm) should be installed vertically for longer lifetime.

Please also note the following :

- The *CarboProbe™* must never obstruct the loading of the furnace.
- Locate the *CarboProbe™* near a furnace control thermocouple, if possible.
- The *CarboProbe™* 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 probe close to a turbine will improve readings.
- If the *CarboProbe™* is installed too close to the heating elements or the furnace door, the temperature cannot be measured correctly. Any difference in temperature between the *CarboProbe™* and the control thermocouples should be avoided.
- No methanol drops should come into contact with the oxygen probe.

  Consequences include cracks, deterioration of the measuring element or even the distortion of the external electrode. In such cases, the lifetime of the probe may be considerably reduced. If methanol drops cannot be avoided, consider selecting our protective outer ceramic tube (Econox Item: **008491** – Outer ceramic tube 35/27x500mm)
- Locate the probe away from atmosphere inlets.
- Ensure that the fixing to the furnace casing is gas tight.

Our *CarboProbe™* is supplied as standard with a "burn-off" or "cleaning" port. If this port is not to be used ensure that it is closed, and is fully tight. Make sure thread sealant is used to obtain a gas tight seal.

The Econox *CarboProbe™ ZI Pro*, unlike the *CarboProbe™ ZS or ST*, has a high resistance to thermal shock and can be inserted or withdrawn from a hot furnace quickly without problems or precaution.

As a precaution introduce (or remove) the *CarboProbe™ ZS* or *ST* probe into a hot furnace in stages of 25mm per minute intervals.

When screwing the *CarboProbe™* in or out of the pipe fitting, use the adjusting thread nut on the *CarboProbe™* sheath.

Do not under any circumstances use the *CarboProbe™* head for tightening or loosening the probe.

Make sure you are using a high-temp silicone tubing or metallic tube for connecting **the red reference air fitting** on the probe head and ensure that the *CarboProbe™* is fed with a constant supply of reference air 1l/h (ZS or ST) or 20-30l/h (ZI).

It is essential that the *CarboProbe™* is fitted with a certain supply of probe cleaning air. Econox can supply a probe air supply cabinet, which is a self-contained source of reference air and probe clean air. It can be positioned in close proximity to the probe eliminating long tubing for air piping.

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

5.2 Electrical connection

Specifics cables need to be used for connecting the *CarboProbe™* to the controller. These cables are different depending on the type of thermocouples used in the *CarboProbe™* , they are called "**compensated cables**". You should always use screened compensated cables between the *CarboProbe™* and the controller, up to a maximum length of 30 meters.
Screens should be connected to ground at the instrument end only.

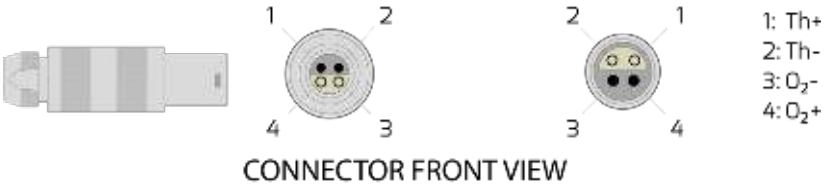
S,R compensated cable OR ordinary copper wire should be used to connect pin 3 and 4 (O_2 signal) to the Controller (**only Pin 1 and 2 cable need to be compensated**) K compensated cable should not be used to connect the O_2 signal as it will generate a small error that will induce a small variation of %C.

Never wire thermocouples using ordinary copper wire.

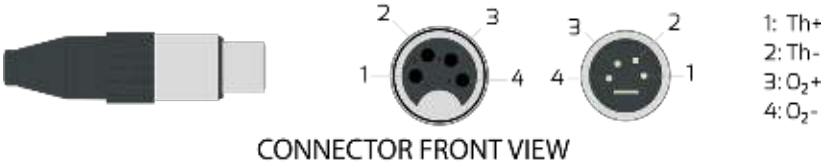
Econox recommends using the following screened compensated cable:

Econox item **008686** - Compensated cable 4 x 0.5 TYPE S, R
Econox item **800547** - Compensated cable 4 x 0.5 TYPE K

5.2.1 CarboProbe™ ZI and ZS wiring



5.2.2 CarboProbe™ ST wiring



Do not place power wiring and probe wiring in the same conduit. The wires from several oxygen probes may be placed in the same conduit.

5.2.3 Electrical wire color coding

All Econox thermocouple wire are available with IEC 584-3 colors codes.

K		–270 to 1372°C –454 to 2501°F
S		–50 to 1768°C –58 to 3214°
R		–50 to 1768°C –58 to 3214°
N		–270 to 1300°C –450 to 2372°F
O_2	Econox standard for O_2 signal is BLUE for (+) and BLACK for (–)	

6 Furnace atmosphere

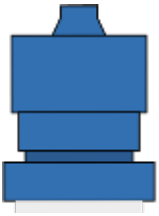
The working conditions for the *CarboProbe™* (i.e. high temperatures) and the atmosphere within the furnace when in operation have a direct influence on the lifetime of the probe.

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

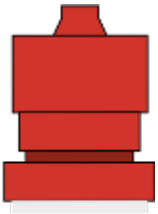
- The parts to be treated must be free of grease or zinc-based components.
- There must be no residues from quenching oil or salt.
- Do not use a zinc-based loading fixtures to hold parts. Zinc accelerates the deterioration of the measuring element in oxygen sensors.
- The lifetime of the *CarboProbe™* may also be reduced if the furnace is operating close to the soot threshold over a long period or if the soot is not burned at regular intervals.
- 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.
- The furnace must be in excellent condition, with no leaks and door seals. If air migrates into the furnace, the carbon atmosphere will not be consistent in the chamber, causing erratic load results. Furnace leaks can cause out of tolerance %C results.
- The flow rate of N_2 and methanol must be consistent. Variation of either gas flow will cause incorrect carbon readings. Controllers/flowmeters are usually calibrated to a known gas composition.

7 Probe maintenance

The Econox *CarboProbe™* requires no mechanical maintenance and any attempt to dismantle it within the warranty period (see warranty card) will invalidate the warranty. The integrity of any atmosphere control system depends on the sensor/measurement device. In case of oxygen probes this is certainly the case as the probe is most often in situ and subject to many different types of factors.
CarboProbe™ need an adequate flow of reference air to work (see chapter 7.1) and some cleraning air for a longer lifetime (see chapter 7.2). Please note the following color coded 8mm air inlet



Blue = Cleaning air



Red= Reference air

7.1 Reference air

A constant flow of Reference Air 1l/h (ZS and ST) or 20-30l/h (ZI) is used to maintain the accuracy of the *CarboProbe™*.

Reference air should be **dry**, **clean** and **free** from any contamination.

Compressed air should not be used. Econox can provide a probe air supply cabinet, which provides separate air pumps for reference air and probe cleaning air.

CHECK AND ADJUST reference air flow as necessary
at least ONCE PER DAY

7.2 Probe cleaning

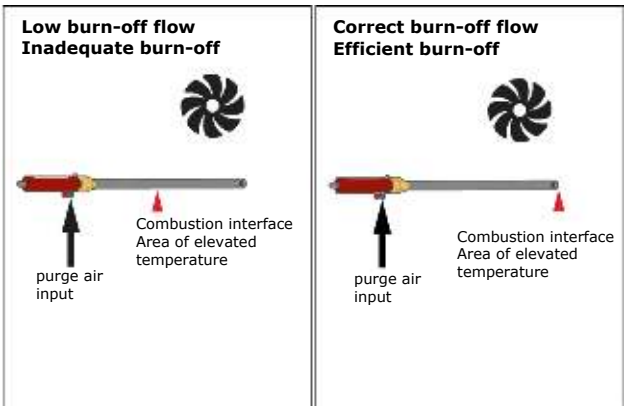
Over 85% of probe failures in service are due to excessive carbon build up on the probe, this is more commonly described as soot build-up. This can, however, be reduced or prevented by regular probe cleaning, or "burn off", using air.

The important factors affecting efficient probe burn-off are:

- Furnace atmosphere pressure/velocity around the probe
- The flow of burn-off air
- The duration of the cleaning or burn-off process
- Temperature increase at the probe tip

When air is forced down ***inside the probe sheath*** a combustion reaction takes place with the furnace atmosphere, this is an exothermic reaction causing a local rise in temperature.

As the flow of burn-off air is increased the air flow will naturally move down ***inside the probe sheath*** until it reaches the tip of the probe. Carbon will only be removed from the probe tip if the air reaches the tip of the probe to react with the soot, hence burning the carbon away.



Care should be taken to avoid the combustion interface centering exactly on the probe tip, if this is the case the probe temperature may rise by as much as 200°C. It is important to note that the probe tip must be kept below 1150°C to avoid permanently damaging the sensor. Therefore, it is important that the burn off flow is adequate when probe cleaning takes place above 900°C.

The condition of the furnace atmosphere near the probe is of great importance when establishing the correct flow rate. For example, in one installation a flow of 300l/h was required to overcome the atmosphere but only 60l/h was required when the furnace fan was switched off. (In most cases no more than 300l/h is required).

Probe cleaning normally takes between 2 and 4 minutes. It is best carried out at the start of a cycle to ensure correct operation during the process and may be repeated during long cycles (or periodically in a continuous furnace) to maintain the level of atmosphere control.

Econox can provide a probe air supply cabinet which provides separate air pumps for reference air and probe clean air.

Most carbon controllers have inbuilt facilities to activate the probe cleaning air automatically.

The cleaning cycle may be initiated by:

- a timer
- an event, like a door limit switch
- a combination of the two above

In a continuous belt furnace a timer is normally used whereas a batch furnace might use a signal from a door limit switch. If the batch furnace is put into stand by, the cleaning might then be time controlled as no door signal will appear during the stand by period.
In most cases manual activation is available for maintenance purpose.

If the control system is missing this option, the function can be provided in the probe air supply cabinet as an alternative.

WARNING:

Inadequate or incorrect probe air cleaning may lead to soot contamination of the probe tip and invalidate the warranty.

CHECK AND ADJUST burn-off flow as necessary at least ONCE PER DAY.

7.3 Suggested maintenance schedule

The following table is a recommended maintenance schedule. Each situation, furnace is different and customer needs to fine tune it according to their protocol or process results.

Description	Frequency
Check reference air (red connector): - CarboProbeTM ZS, ST: 1-6l/h - CarboProbeTM ZI : 20-30l/h	Once a day
Launch a cleaning cycle and burn soot to clear the measuring element of any impurities (blue connector): - Cleaning output: 150 to 300l/h (see chapter 7.2) - Furnace turbine off	Every 4 hours
If burning the soot is not effective, dismantle the *CarboProbe™*, **allow it to cool** and clean the soot away with compressed air.	Once a week

8 Troubleshooting

8.1 Introduction

Unfortunately, there is no definitive method for determining the accuracy of an oxygen probe. The only way to establish that the *CarboProbe™* is reading accurately is to compare the reading with a reference oxygen probe, foil test, or a gas analyzer.

When there are doubts as to the validity of *CarboProbe™* readings, a few simple tests conducted while the *CarboProbe™* 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 correct, in order to establish whether the issue is the temperature or the mV signal.

8.2 Checking the impedance of the sensor

The output impedance of an oxygen probe is a function of the electrode contact area, materials of construction, and temperature. The lower the impedance, the more surface area is in contact with the electrode assembly. A value below 25K ohms at temperature above 800°C is acceptable, once the value rises above 50K ohms it is necessary to change the probe.
Some carbon controllers have inbuilt probe impedance testing.

8.3 Checking the reference air and air tightness

Prior to anything else, disconnect the standard-air supply from the head of the *CarboProbe™* and check that air is indeed flowing into it. Reconnect the standard air. Check whether the air supply tube is connected to the red connector. Then perform the following procedures depending on the type of probes you are using:

8.3.1 CarboProbe™ ZS and ST

While the *CarboProbe™ ZS* or *ST* is in operation, suddenly cut the reference air supply (by pinching the tube with your fingers). The output signal from the *CarboProbe™* should not drop by more than a few mV 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 *CarboProbe™* sensor is probably cracked and therefore gives incorrect readings, in which case it must be repaired.

8.3.2 CarboProbe™ ZI

While the *CarboProbe™ ZI* is in operation, suddenly cut the reference air supply (by pinching the tube with your fingers). The mV value should drop slowly by a maximum of 10mV in 5 seconds.

After releasing the tube, the voltage displayed should immediately return to its initial value. If the *CarboProbe™* voltage drops suddenly (over 50 mV in 10 seconds), the *CarboProbe™* is no longer airtight; in which case it must be repaired.

8.4 Checking the thermocouple

Disconnect the connection cable and use a voltmeter to check the output* signal from the thermocouple. Start at the controller and gradually work back to the *CarboProbe™* terminals, then towards the thermocouple wires inside the *CarboProbe™* head. Take a number of readings along the way to pinpoint the defect.

ECONOX can, upon request, provide millivolt-temperature conversion tables for S-, R- and K-type thermocouples.

*Check www.econox.com/documentation for more information

8.5 Checking the oxygen signal

If the *CarboProbe™* gives an oxygen signal but the signal seems to be incorrect, perform the following checks. All of these may be performed while the *CarboProbe™* 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 *CarboProbe™* is defective and should be replaced.

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

8.6 Checking the effectiveness of a purge

Check the oxygen signal during a cleaning (burn-off) 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 air output for cleaning must not be such that it brings 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 *CarboProbe™* from the furnace and clean off any soot residues using compressed air (**after the *CarboProbe™* has cooled down to ambient temperature**).

See chapter 7.2 for more information on probe cleaning.

8.7 Visual Observation

(Observe warnings concerning removal of probe from the furnace.)

Probe/sheath shows significant accumulation of soot or other deposits (this may mean that the burn off procedure is incorrect and may invalidate warranty).

Probe sheath is not bent nor corroded.

CarboProbe™ tip as viewed through the sheath holes, shows no obvious fracture and it appears physically intact.

Probe sheath/head shows no signs of mechanical damage.

9 Factory service

CarboProbe™ probes are highly technical measuring instruments subject to potentially difficult working conditions. The lifetime of the *CarboProbe™* depends, to a large extent, to the conditions in which it is used. If you suspect that the *CarboProbe™* is malfunctioning, and the troubleshooting section (chapter 8) has not helped you in solving the problem encountered, then it probably requires repair.

When sending a *CarboProbe™* for repair, pack it carefully in its original packaging, mark it "**Fragile Instrument**" and send it back to us.

If your are shipping from outside of Switzerland please enclose a pro-forma invoice (http://www.econox.com/send-defective-probe) with a maximum value of 300 euros per unit.

Then return it to:

ECONOX SA
Rue de l'église 25
2942 Alle – Switzerland

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Notes :

ECONOX SA
Rue de l'église 25
2942 Alle – Switzerland
T: ++41 32 465 10 00
F: ++41 32 465 10 01

www.econox.ch
www.econox.com
info@econox.ch

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