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SWISS QUALITY SINCE 1984
Measuring & control systems Carbon & Oxygen

Operating Manual

CarboProbe™ CP
Simple potter's probe

CarboProbe™ DS
Gas-tight oxygen probe

CarboProbe™ HT
Industrial oxygen probe with ceramic sheath

CarboProbe™ HT-PRO
Industrial oxygen probe with enhanced protective ceramic sheath

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1 Operational principles

The purpose of the ECONOX *CarboProbe™ CP, DS*, *HT* and HT-PRO oxygen probes is to measure the oxygen content at high temperature (from 600°C to 1700°C).

1.1 Functional principle

ECONOX uses the **C3M/C700 ZrO_2** electrolyte made of ZrO_2 (zirconium oxide) for its oxygen sensors:

Fig 1: C3M/C700 ZrO_2 sensor

The *CarboProbe™* acts like a galvanic element.

It consists of a solid-state electrolyte made of zirconium oxide (ZrO_2) as an oxygen ion conductor and 2 platinum electrodes, one of which (inside the probe) is in contact with a reference gas - usually air - and the other (on the outer part) with the gas to be analyzed.

In addition, a thermocouple can be installed to record the temperature at the measuring point.

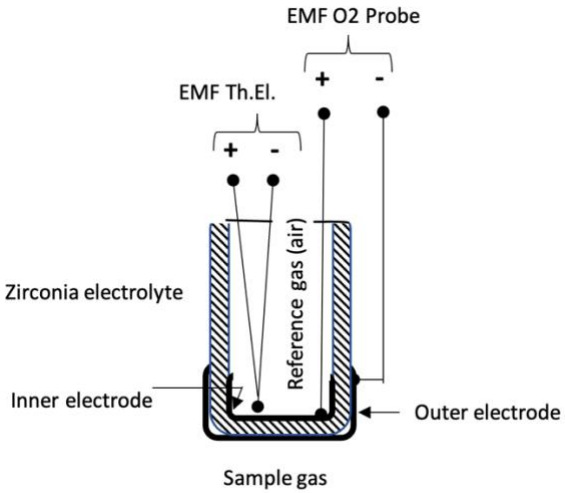

Fig 2: Example ZrO_2 cell

An emf can be measured at the electrodes, which corresponds to the oxygen potential difference between the reference gas and sample gas according to the Nernst equation:

$$\mathbf{EMF = 0.0496.T.\ lg\ \frac{pO2(1)}{pO2(2)}}$$

pO2 (1)= Oxygen partial pressure of the reference gas in bar -For air pO2(1) = 0.209 bar
pO2 (2)= Oxygen partial pressure of the sample gas in bar

E = EMF in mV
T = absolute temperature.

The EMF is not only dependent on the oxygen partial pressure ratio, but also on the temperature.

1.2 Probe assembly

In principle, an oxygen probe consists of the following elements:

- 1 support pipe with the C3M/C700 sensor at one end. The pipe is available in various lengths (see point 5)
- 1 Platinum outer electrode
- 1 Platinum inner electrode
- 1 Input for the reference air
- 1 Connection head with a plug for transmitting the temperature and probe voltage values to the transmitter or PLC inputs
- A thread for fixing to the furnace wall. (see points 5-7)

The HT and HT-PRO probes are supplied with an additional outer protective tube made of aluminum oxide.

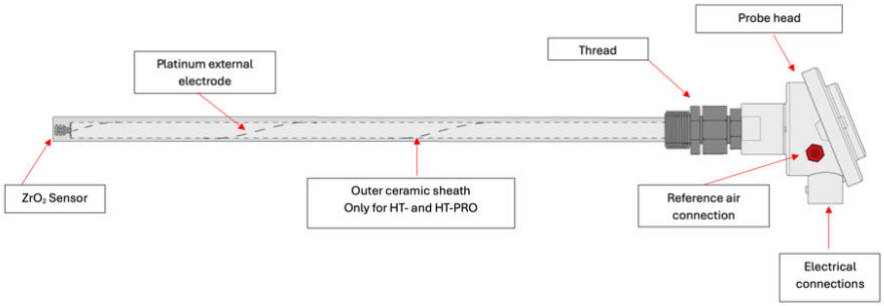

Fig 3: Probe features

2 Econox Online Services (ECOS)

ECOS gives you a way to connect to Econox and learn more about your product. Here is the information you have access to:

- Product technical specifications
- Manufacturing date
- Repair dates
- User manual
- Conformance certificate
- Ask for help
- Report a problem with your product
- Recycling certificate

2.1 Login with NFC or QR code

If your Econox product is supplied with an NFC tag or QR code, you can

simply scan it with your Iphone or Android device to get access to the ECOS webpage.

2.2 Login with your product serial number

If you do not have a QR code or an NFC tag you can still login to ECOS by entering the probe serial number on https://www.econox.com/ecos

If you encounter problems connecting to ECOS, please contact us at info@econox.ch

3 Packaging

The Econox *CarboProbe*^{TM}, 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. Returning a probe in packaging other than the original may affect warranty conditions.

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

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4 Application

Oxygen probes can be used in a vast range of industries. *CarboProbe™ CP, DS, HT and HT-PRO* **cannot be used** in carburizing mixtures. If you are operating a heat treatment furnace and measuring the %C, please consider using our *CarboProbe™* ZI or ZS suitable for heat treatment*.

CarboProbe™ CP, DS, HT and HT-PRO are mostly used for :

- Control of glaze color and firing ceramics
- Control of air supply in industrial incinerators
- Measurement of fuel/air ratios in combustion
- Fuel combustion efficiency control
- Furnace gas analysis
- Waste management systems
- Potters' kilns
- Annealing furnaces
- Flue gas analysis
- O_2 levels at high temperatures
- CO_2 harsh environments
- Technical ceramic kiln systems
- Universities and laboratories

*See www.econox.com for more information.

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5 *CarboProbe™* technical datas

The *CarboProbe™* CP, DS, HT and HT-PRO are all based on the C3M/C700 ZrO_2 oxygen sensor. They consist of a ZrO_2 oxygen sensor, mounted in an industrial thermocouple head with all electrical and reference air connections. Probes are normally supplied with an internal R-type or S-type thermocouple. They are suitable for measurement of oxygen concentration at temperatures from 600°C to 1700°C.

- *CarboProbe™* HT and DS are very accurate for research laboratory use. *CarboProbe™* DS has a gas tight thread for laboratory use.
- *CarboProbe™* HT and HT-PRO are robust for industrial use and are protected by an alumina ceramic sheath of 15 or 25mm outside diameter.
- *CarboProbe™* CP is aimed at potters and is not to be used in industrial environment.

	CP	DS	HT	HT-PRO
Sensor	ZrO_2	ZrO_2	ZrO_2	ZrO_2
Head	Grey	Grey	White	White
Thread	-	M16 fine pitch	¾''	1''
Outer diameter	8.5mm	8.5mm	15mm	25mm
Electrical Connector	4-pin standard	4-pin standard	4-pin standard	4-pin standard
Protective sheath	-	-	Yes	Yes enhanced
Max length	500mm 19.7''	1100mm 43.3''	1100mm 43.3''	1000mm 39.4"
Reference air	1 to 6 l/h	1 to 6 l/h	1 to 6 l/h	1 to 6 l/h

CarboProbe™ CP shall not be used in an industrial environment
CarboProbe™ DS is supplied with a gas tight M16 fine pitch thread
CarboProbe™ HT is a robust probe with an outer ceramic sheath
CarboProbe™ HT-PRO is a robust probe designed for harsh environment

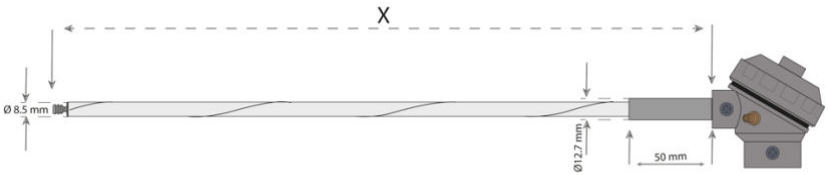

Fig 4: CarboProbe™ CP

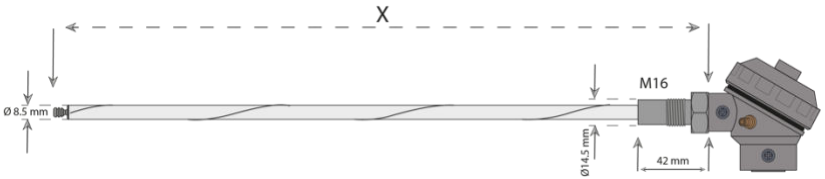

Fig 5: CarboProbe™ DS with M16 fine pitch thread

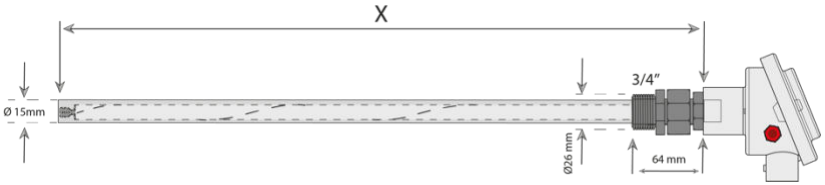

Fig 6: CarboProbe™ HT with ¾'' thread and ceramic sheath

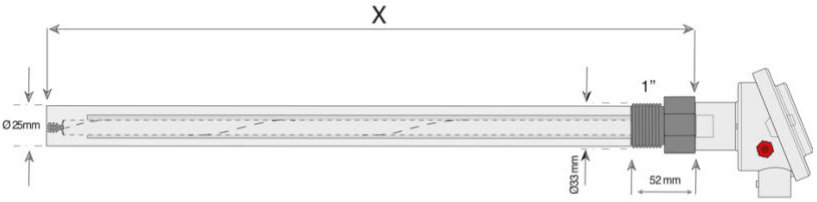

Fig 7: CarboProbe™ HT PRO with 1'' thread and double ceramic sheath

Check www.econox.com for more information.

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More technical specifications:

Output	0 to 1200 mV
O2 measuring range	*Maxi 100%* *Mini* pO_2 10^{-24}/700°C - pO_2 10^{-12}/1300°C
Readout impedance of the instrument	*CarboProbe™* should be used with controlling, recording and indicating instruments having input impedance of 10 megaohms or higher
Insertion depth	5 cm minimum (15cm for HT-PRO)
Thermocouples	Type R, S or without
Operating Temperatures	600°C (1112°F) to 1700°C (3092°F)
Mechanical shock	Resists mild mechanical shock; handle carefully
Thermal shock	They should be introduced/removed from furnace slowly (25mm per minute intervals)
Reference air	Uncontaminated dry air at maximum rate of 1 to 6 l/h
Cleaning air	No cleaning air is required

All wiring and electrodes are platinum, for outstanding corrosion resistance and high temperature application. Probes are supplied with a 4-pin electrical connector ready for connection to any suitable 4-conductor cable.

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6 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

AA: Type of Thermocouple

00: No TC
10: S-type
13: R-type

BB: Probe type

10: *CarboProbe™ HT*
11: *CarboProbe™ CP*
15: *CarboProbe™ DS*
19: *CarboProbe™ HT-PRO*

CC: Probe length from tip of ZrO_2 sensor to bottom of head

10: 100mm
20: 200mm
30: 300mm
40: 400mm
50: 500mm
60: 600mm
70: 700mm
80: 800mm
90: 900mm
100: 100mm
110: 1100mm

DDDDD: Unique ID number

E: Represent the type of bearing size of probe

3/4: 3/4'' thread
1: 1" thread

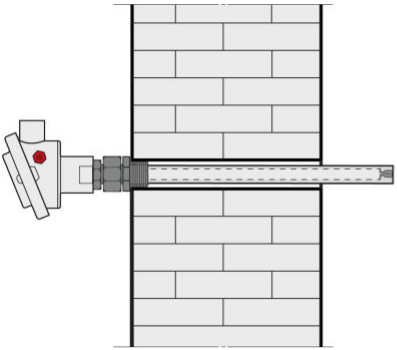
7 Installing the *CarboProbe™*

Please follow the following recommendations when installing your CarboProbe™.

1. The *CarboProbe™ CP, DS,* HT and *HT-PRO* must be brought up to temperature gradually; otherwise, the measuring element and support tube 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 or removed gradually over a period of 10 minutes**.

2. Place the *CarboProbe™* where it will not touch the load and will not be in struck when loading. The sensor should be inserted so that its tip is approximately **5 centimeters into the kiln/furnace** (15cm for HT-PRO).

   Special case: for the glass industry, the sensor must be set back a few centimeters in the insulation/bricks to prevent crystallization and deposits on the protective tube (see below).



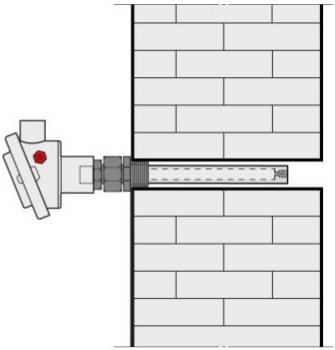


Fig. 8: standard installation Glass industry

3. If the *CarboProbe™* is installed too close to the heating elements or the kiln/furnace door, the temperature cannot be measured correctly. Any difference in temperature between the *CarboProbe™* and the thermocouples should be avoided.

4. Thermal and mechanical shocks should be avoided when installing the *CarboProbe™* or during the measure (this causes the deterioration of the zirconium oxide measuring element).

5. The temperature of the measuring element must be between 600°C and 1700°C

6. The *CarboProbe™* HT is supplied with a ¾''thread. The *CarboProbe™* DS with an M16 fine pitch thread, and the CP with a stainless-steel tube. When fitting them to the kiln/furnace, ensure that the temperature of the probe head does not exceed 80°C.

It is very important that the *CarboProbe™* be fitted correctly to your kiln/furnace. The *CarboProbe™* HT requires a ¾'' thread (1'' for HT-PRO) while the *CarboProbe™* DS requires an M16 thread.

As an alternative, a larger hole can be closed up with ceramic fiber. This will prevent back pressure flames from coming out onto the head of the probe and will help to prevent damage.

7. Install the probe anywhere in the kiln or furnace where a thermocouple probe could be installed. If the probe is used at temperatures over 1100°C, the probe should hang vertically, to avoid bends caused by high temperature. The probe will measure the oxygen concentration at the probe tip, provided that the operating temperature is between 600°C and 1700°C.

8. In order to get a representative sample of the atmosphere the *CarboProbe™* should not be placed directly over a burner port or where the gasses move rapidly. Since the *CarboProbe™* is extremely sensitive, the readings may fluctuate rapidly reflecting the non-homogeneous gas environment.

9. Likewise, a corner placement for the sensor is not advised because the gasses might not be well mixed, unless your kiln/furnace has a turbine. The three best placements are in the **center of the door**, **roof** or **back wall**.

10. If you are a potter, connect the cable to the supplied voltmeter and turn it on by moving the knob to the "ON" position. Don't worry about the intermediate positions you might feel while turning the knob; they are not of interest. If the probe is at a correct temperature you should immediately get a mV reading. Report it on the diagram in chapter 7.3 to determine if you are reducing or oxidizing

Do not forget to connect the probe to a clean/dry source of reference air with a maximum air flow of 6 l/h
(See chapter 8.1 for more information)

A small pump is supplied in the box only with the *CarboProbe CP*

7.1 Electrical connection

Specific 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™ , and* are called "**compensated cables**." You should always use shielded, compensated cables between the *CarboProbe™* and the controller, up to a maximum length of 30 meters.
Shields should be connected to ground at the instrument end only.

S or 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 needs 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 $\%O_2$.

Never wire thermocouples using ordinary copper wire.

Econox recommends using the following shielded, compensated cable:

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

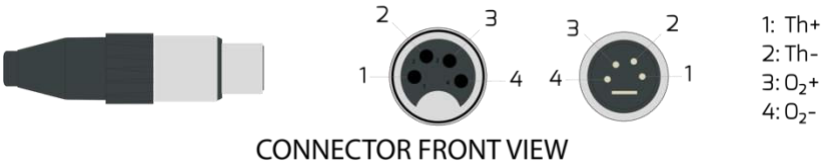


Fig 9: *CarboProbe™* electrical connector

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.

The cable should not touch any hot surface of the kiln/furnace.

7.2 Electrical wire color coding

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

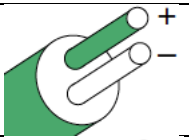
K		–270 to 1372°C –454 to 2501°F
S		–50 to 1768°C –58 to 3214°
R		–50 to 1768°C –58 to 3214°
N		–270 to 1300°C –450 to 2372°F
O_2	Econox standard for O_2 signal is BLUE for (+) and BLACK for (–)	

Fig 10: *Wire color coding*

7.3 Working with an O_2 probe (oxidation/reduction)

Working with an oxygen probe is easy if you understand the value it gives. When it comes to oxidation or reduction, roughly speaking, a reading less than 100mV represents oxidizing conditions and a reading over 300mV represents reduction. Heavy reduction might give a reading of 500mV or even more. In between 100mV and 300mV the temperature must be known for accurate interpretation.

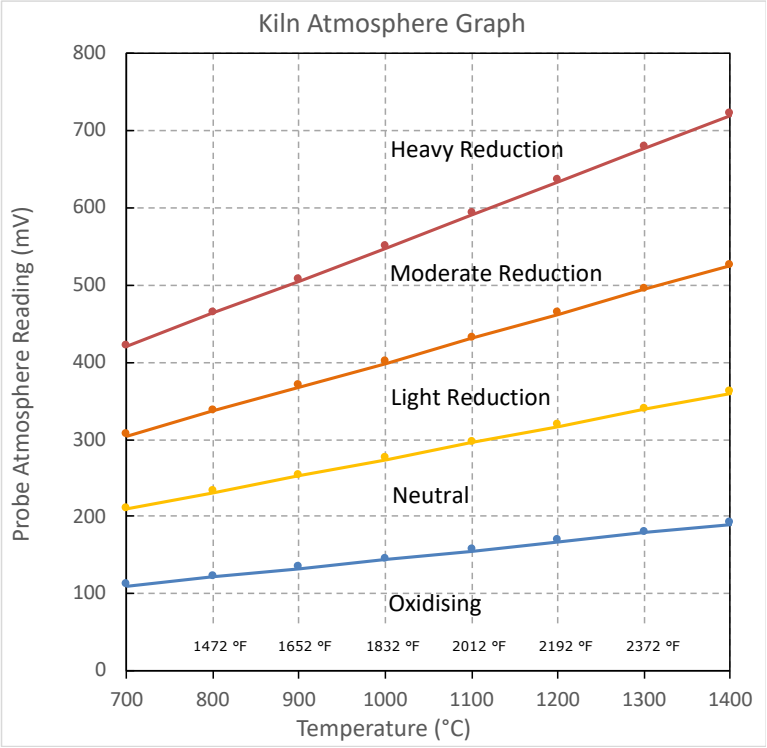


Fig 11: *Kiln atmosphere graph (mV vs temp)*

In any flame, the air and fuel never mix perfectly. As burning fuel blows past the tip of the oxygen probe, some of the flame will have excess air and some will be gas rich. This means that the oxygen reading will jump around as the flame flickers past. This is most noticeable when there is just the right amount of air to give a neutral flame.

Air consists of 20.9% oxygen, about 78% nitrogen and some trace gases. In a flame, the fuel combines with the oxygen in the air and burns, forming carbon dioxide and water vapor (steam). Inside a kiln, there is a mixture of fuel, oxygen, carbon dioxide, steam and nitrogen. The amount of each of these depends on the amount of fuel and air in the flame.

7.3.1 Oxidizing flame*

With excess air, there is typically over 2% oxygen in the exhaust gas, but it can be almost up to the limit of 20.9%. This is called an "oxidizing" flame.

7.3.2 Neutral flame*

With exactly the right amount of air for the fuel, there is a "neutral" flame. Even in ideal conditions, there will be some fuel and some air that cannot find each other to burn completely. A little unused fuel and air will be in the exhaust gas leaving the kiln. There is typically anything from 0.02% to 2% unused oxygen in the exhaust.

7.3.3 Reducing flame*

With too little air, there will be unburnt fuel in the exhaust gas. This is called a "reducing" flame. Many people say that there is no oxygen under these conditions, but there will always be some unused oxygen in the exhaust. It might be less than 0.02%. The oxygen present might be less than 0.000001%, but it can be measured.

*There is no sharp distinction between oxidizing, neutral and reducing. There is a smooth variation from one to the next, so the above figures are only guidelines.

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7.4 Calculating the O_2 concentration

The table below shows the relation between the mV from the probe and the temperature, used to calculate the $\%O_2$.

°C	800	900	1000	1100	1200	1300	1400
mV							
25	7.1	7.8	8.4	9.0	9.5	10.0	10.4
50	2.4	2.9	3.4	3.9	4.3	4.8	5.2
75	0.8	1.1	1.4	1.7	2.0	2.3	2.6
100	0.28	0.40	0.55	0.71	0.89	1.09	1.30
125	0.09	0.15	0.22	0.31	0.41	0.52	0.65
150	0.03	0.06	0.09	0.13	0.18	0.25	0.33
175	0.01	0.02	0.04	0.06	0.08	0.12	0.16
200	0.004	0.008	0.014	0.024	0.038	0.057	0.081
225	0.001	0.003	0.006	0.010	0.017	0.027	0.041
250	0.000	0.001	0.002	0.004	0.008	0.013	0.020
275	0.00014	0.00039	0.00092	0.00192	0.00360	0.00625	0.01015
300	0.00005	0.00015	0.00037	0.00082	0.00164	0.00299	0.00507
325	0.000016	0.000054	0.000149	0.000353	0.000745	0.001428	0.002534
350	0.000006	0.000020	0.000060	0.000152	0.000339	0.000683	0.001266
375	0.0000019	0.0000075	0.0000241	0.0000651	0.0001541	0.0003266	0.0006327
400	0.00000063771	0.00000278827	0.00000966903	0.00002797462	0.00007006485	0.00015614883	0.00031620647

Fig 12: Example of calculated value in $\%O_2$

7.4.1 Manual calculation

If you wish to do your own manual O_2 calculation you can download our Excel file from www.econox.com/documentation . This file allows you to input the temperature as well as the mV coming from the probe and returns a calculated value of the O_2 in %, ppm, and log.

7.4.2 Automatic calculation

Automatic management of the *CarboProbe™* including automatic O_2 calculation can be achieved using our ContrOx box.

ContrOx includes an O_2 calculator and display, temperature display, data recording and USB export, 4-20 mA output (for O_2 and temperature), as well as a pump to supply a constant flow of reference air to the probe (see chapter 8.1)

More information can be found on www.econox.com.

7.5 Special note for Potters

The *CarboProbe*™ CP is able to identify precise combustion atmospherics no matter what the weather conditions are. For instance, when the weather is clear, and the barometer indicates high pressure, there is more oxygen available to the burners.

If you set the available air to a fixed flow each time, you may be varying the oxygen/fuel ratio by 15% or more relative to the air available when it is stormy, and the barometric pressure is low.

Many potters note that they get "better reduction" in stormy weather. What actually is happening is they are simply using the same settings for their burners and getting less oxygen.

With our *CarboProbe*™ CP you adjust the burners to the atmospheric indication according to the mV coming from the *CarboProbe*™.

Noting the time of the firing, plot the atmospheric reading and the temperature. Each firing should be charted, and adjustments noted. At some point your particular glazes will fire efficiently and beautifully.

Once you have the readings charted (and no matter what the weather conditions are) you can repeat the results.

As a potter, here are your advantages:

Fuel savings - an economical firing depends on supplying the right ratio air/fuel, without waste of energy from heating excess air.

Reliable glaze colors - Knowing the right level of reduction every firing gives you the colors you want, firing after firing.

Reduced air pollution - Use the CP Probe as a guide for stoking wood-fired kilns to reduce wood consumption and unnecessary ash and smoke.

8 Probe operation and maintenance

The Econox *CarboProbe™* requires no mechanical maintenance and any attempt to dismantle it within the warranty period will invalidate the warranty.

CarboProbe™ need an adequate flow of reference air to work (see chapter 8.1).

No purging/cleaning air is available on these probes. The blue connector on the *CarboProbe™* HT-PRO **IS NOT** a purge connector, please contact us for more information about how to use that blue connector for calibration purpose.

Using the blue calibration connector of the *CarboProbe™* HT-PRO probe as a purge connector may damage your product and void the warranty.

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8.1 Reference air

A constant flow of Reference Air 1 to 6l/h is needed to maintain the accuracy of the *CarboProbe™*. Small pump is supplied with the *CarboProbe™ CP* only. 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.

CarboProbe™ DS, HT and HT-PRO must be constantly supplied with clean, dry and* free from contamination *reference air.
Please note the following color-coded reference air inlet.

Reference air
CarboProbe™ CP, DS, HT and HT-PRO

Calibration connector*
CarboProbe™ HT-PRO only

Fig 13: Color-coded reference air inlet and calibration inlet (HT-PRO only)

Note for potters:

Some potters using the *CarboProbe™* CP and working in strong oxidation can do without reference air (or only switch on the pump for a few seconds per hour), whereas during strong reduction phases, it is necessary. If the small pump with AA batteries is not suitable, you can easily replace it with an aquarium pump or contact us for a continuous air supply. Each case is different.

*Do not use the blue connector on CarboProbe™ HT-PRO as a purge/cleaning connector as it might damage your product and void warranty (see chapter 8 for more info or contact us)

8.2 Inserting removing from kiln/furnace

The *CarboProbe™ CP, DS*, *HT* and *HT-PRO* must be brought up to temperature gradually; otherwise, the measuring element and support tube may suffer irreversible damage. In order to avoid this problem, the sensor must be inserted slowly into a furnace that is up to temperature.

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

9 Troubleshooting

9.1 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 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.

9.2 Probe location

If your probe is placed near or directly above your burner, you may experience significant fluctuation on your readings. This is not due to a probe problem but rather it accurately reflects how the atmosphere is rapidly changing in some areas of the kiln. It is best to place the probe in other parts of the kiln.

9.3 Checking the impedance of the sensor

The impedance of an oxygen probe is a function of the electrode contact area, materials of construction, the working temperature and the age of the ZrO_2 cell. 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 controllers have built-in probe impedance testing.

9.4 Checking the reference air

Start by disconnecting the reference air tube from the *CarboProbe™* head and check that air is actually flowing through the tube.

Dip the end of the hose lightly into a glass filled with water.

An air flow should produce bubbles.

Reconnect the reference air hose to the red (or gold) connector on the probe head.

9.5 Checking the thermocouple

If your *CarboProbe™* is fitted with a thermocouple, you can perform the following checks, depending on the type of fault

Case 1: the PLC indicates the maximum temperature of the measuring range. (Depending on measuring instrument)
In this case, the thermocouple is broken or the measuring line is interrupted (cable broken or cut). Check the thermocouple and the measuring line and replace the probe or cable if necessary.

Case 2: Temperature displayed differs from usual values under the same conditions.
Using a temperature voltmeter, check the measuring instrument and the measuring line.
If the measuring instrument and the measuring line are ok, the error probably lies in the thermocouple inside the probe. It must be replaced.

Econox can supply temperature conversion tables in millivolts for type S-R and K thermocouples on request.

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

9.6 Checking the oxygen signal (fault or deviation)

If the *CarboProbe™* displays an oxygen signal, but the signal appears to be inaccurate, perform the following checks with the *CarboProbe™* in function and at temperature.
First, disconnect the connection cable from the probe head and measure the voltage (mV) directly on the probe head using a voltmeter.

Case 1: **Voltage on probe = voltage on instrumentation.**
If the voltage (mV) measured directly in the probe head is **the same** as the one displayed on **the instrumentation**, the problem probably lies in the probe.

Case 2: The voltage on the probe seems correct but is far from the value displayed on the instrumentation.
In this case, the problem lies with the measuring line or the measuring instrument.
Use a voltmeter to check the line step by step to find where the fault is.

10 Factory service

The Econox *CarboProbe™* is a highly technical measuring instrument subject to potentially difficult working conditions. The lifetime of the *CarboProbe™* depends, to a large extent, on the conditions in which it is used. If you suspect that your *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 you 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
Route de Porrentruy 1
2942 Alle – Switzerland

ECONOX SA
Route de Porrentruy 1
2942 Alle - Suisse

Tel/WhatsApp: +41 32 465 10 00

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