INSTRUCTIONS FOR USE

CarboProbe CP

CarboProbe CP PLUS

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1. Operational principles

The purpose of ECONOX *CarboProbe* oxygen sensors is to measure and regulate atmospheres. 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*, *HT, CP* and LTsensors.

An oxygen probe works by comparing the oxygen level in the kiln with the oxygen level inside the alumina tube. This is why the air inside the tube must always be renewed. If the temperature of the zirconia tip is over about 700 °C, it produces an electrical voltage. The less oxygen in the kiln, the bigger the electrical voltage, so the voltage can be used as a guide to the oxygen level.

There is no safety hazard - the maximum a probe can produce is less than a battery!

Introduction

The CP probe is a very simple, low cost oxygen probe with an easy-to-read digital meter displaying oxidation/reduction. The CP Probe saves you money by omitting the thermocouple pyrometer, so that you can continue to use cones. This probe is ideal to control both gas and wood-fired kilns.

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ECONOX supplies 2 different kinds of CP probes

CarboProbe CP	For the measure of oxygen concentration only
CarboProbe CP PLUS	For measure of oxygen concentration AND temperature (includes an R-type thermocouple for temperature up to 1700°C)

Applications

The advantages of measurement of oxidation/reduction include:

- **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.

How does the air supply affect the firing?

The right amount of air
will give the hottest flame and the fastest temperature rise. This is the most economical heating.

Too much air
makes the flame cooler. The flow of excess air can help distribute the heat more uniformly.

Not enough air
can still give a hot flame and can give interesting special effects in glaze colors.

The benefits of an oxygen probe

Efficient fuel use
To reach the highest temperature with the least fuel, use a neutral flame. The oxygen probe will tell you if you have a good balance of fuel and air, because the reading will be in the range of 100mV to 200mV.

Glaze control
Some glaze colors are affected by how heavily reducing the flame is. Sometimes there is a difference in color between a slightly reducing flame with an oxygen reading of 0.35 and a heavy reduction of 0.6. In a reducing flame, the oxygen reading is usually much more stable and it is easy to measure the degree of reduction quite accurately. The potter can record the reduction conditions, then obtain the same glaze colors on later burns.

How to install the oxygen probe

Fit the probe anywhere in the kiln or furnace where a pyrometer could be fitted. If the probe is used at temperatures over 1100 degrees C / 2000 degrees F, put it through the top, so the ceramic tube hangs vertically. If the probe is used horizontally at high temperatures, it will gradually sag.

Seal the hole for the probe well enough to prevent air from flowing inwards and affecting the oxygen reading.

When fitting or removing a probe into or out of a hot furnace, move the probe slowly to prevent thermal shock.

Once the kiln is over 700 °C and the reference air is available, the probe is ready to use.

Understanding an oxygen probe

Roughly speaking, a reading less than 0.1 represents oxidizing conditions and a reading over 0.3 represents reduction. Heavy reduction might give a reading of 0.5 or even more. In between 0.1 and 0.3 the temperature must be known for accurate interpretation.

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.

Chart of oxygen concentration from probe reading

mV	700°C	800°C	900°C	1000°C	1100°C	1200°C	1300°C
50	1.9 %	2.4 %	2.9 %	3.4 %	3.9 %	4.3 %	4.8 %
100	0.2 %	0.3 %	0.4 %	0.5 %	0.7 %	0.9 %	1.1 %
150	0.02 %	0.03 %	0.06 %	0.09 %	0.13 %	0.18 %	0.25 %
200	0.002 %	0.004 %	0.01 %	0.01 %	0.02 %	0.04 %	0.06 %
250	0.001 %	0.0004 %	0.001 %	0.002 %	0.004 %	0.01 %	0.01 %
300	0.00001%	0.00005%	0.0001%	0.0004%	0.001 %	0.002 %	0.003 %

Red= OXIDISING **Green= NEUTRAL** **Blue= REDUCING**

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.

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.

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.

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%. It might be less than 0.000001%, but it is there and 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.

Checking temperature using the CarboProbe CP plus

When the probe is ready to use, connect the probe to the meter. Select the "temperature" position. The meter will display the thermocouple signal from the thermocouple in mV.

There is no cold junction ambient temperature compensation in the meter, so the reading must be corrected for room temperature. This can be approximated by measuring room temperature separately then adding the thermocouple voltage corresponding to the room temperature.

Example, for an R-type thermocouple:
Ambient temperature is 25°C and meter indicates probe thermocouple signal 8.5 mV
Thermocouple chart (see section 4) shows 25°C corresponds to 0.14 mV
8.5 mV + 0.14 mV = 8.64 mV, which corresponds to 856°C from chart
Hence probe temperature = 856°C

Thermocouple test
Prolonged exposure (hundreds of hours) to high temperature (over 1500°C) causes evaporation of platinum. The thermocouple can be tested for open circuit or thinning that may lead to failure.

Swap the positions of the yellow and green wires in the meter. Select "TEST" position. The reading should be less than 0.005. A reading of 1 indicates that the thermocouple is either broken or may soon do so. This test should be done at room temperature.

3. 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.

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

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