The Kiln Exhaust Sniffer: A Do-it-Yourself Oxygen Probe.

I have a self-employed friend who makes exquisite detailed castings in silver, gold and bronze. He is a qualified metallurgist and I am just a lowly potter, but we share a common interest in furnaces and kilns. He has a problem, that the graphite crucibles used for melting the precious metals gradually burn away in his gas-fired furnace. One would expect that they'd last longer if the furnace atmosphere was reducing rather than oxidizing. How can he tell when the furnace is adjusted to do this?

This is familiar ground to a potter. One idea would be for him to instal an oxygen probe in the metal-casting furnace, but these things are so expensive. The oxy-probe I use cost me $800, and it's a fragile delicate item. We wondered how practical it would be, to use an automotive exhaust gas oxygen sensor to sniff the furnace gases. Bought new, an EGO sensor costs about $80, but from an auto wrecker we obtained three used ones for $5 each. Not a lot to lose, if the idea didn't work out. After a few experimental runs the project already seems very promising. Not only for the metallurgist and his crucibles, but also for gas-firing potters who might like to sniff their exhausts. If this is new ground to you, a brief explanation is probably in order:

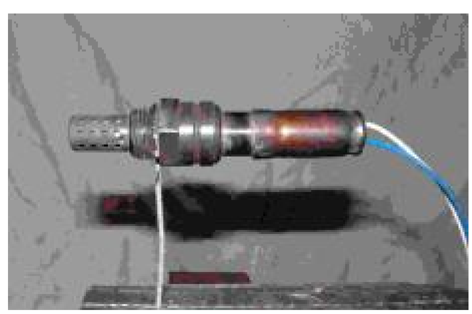
Oxy Probes and EGO Sensors.

Oxy probes and EGO sensors both work on the same principle. Both contain a small pellet of zirconium oxide, which has the useful property of absorbing oxygen atoms from hot gases. One side of the little pellet is exposed to the hot gas being measured. The other side is exposed to ordinary clean air. Both surfaces have a thin porous coating of platinum metal, so they can conduct electricity.

Oxygen atoms in very hot gas become "ionized". That is, they gain extra electrons and become electrically charged. So when the zirconium pellet attracts oxygen ions, it also acquires an electrical charge. If the concentration of oxygen is greater on one side of the pellet than it is on the other, there will be a small voltage difference between the two sides. The greater the difference in concentration, the bigger the voltage given out.

In a kiln oxy-probe, the little zirconium oxide pellet is fixed to the end of a long hollow alumina tube, so it can be poked down through the thick kiln wall into the hot interior.

In an automotive EGO sensor the little pellet is shaped like a tiny hollow thimble, and mounted inside a perforated shell on the end of what looks rather like a spark plug. The sensor screws into the exhaust manifold of the auto engine, with about 20 millimetres protruding inside. It's too short to poke through the thick wall of a kiln, but it works the same way as an oxy-probe.



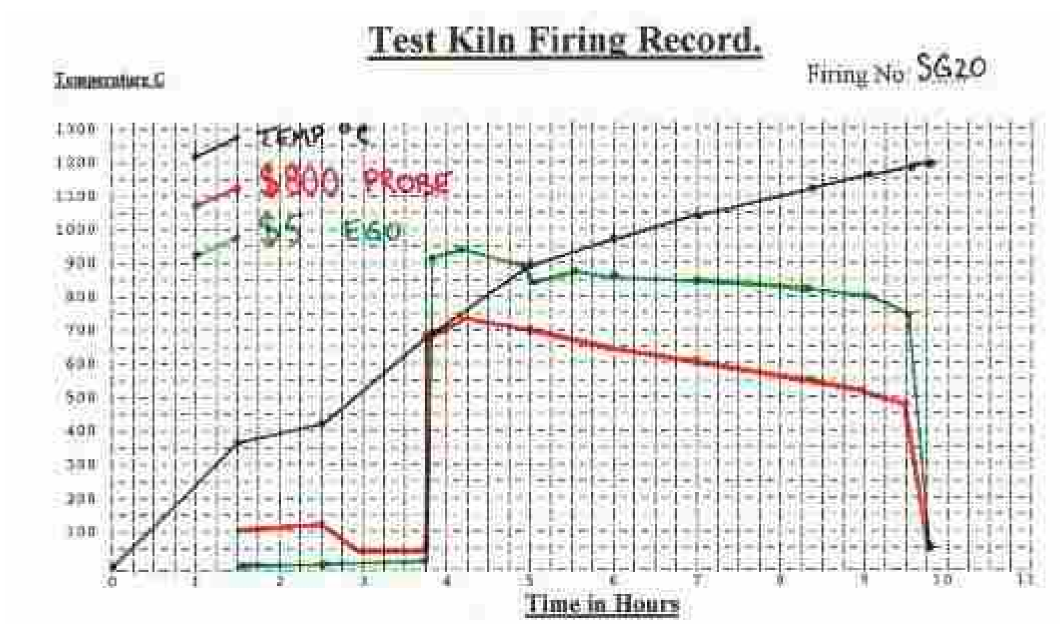
In both cases, one side of the pellet is exposed to the hot gases, and the other side is in contact with clean ordinary air. The voltage given out by the probe tells us what we want to know about the oxygen concentration in the hot gas.

Though both devices work in the same way, you obviously can’t just dangle an EGO sensor down inside a kiln. The EGO’s body is made of ordinary steel. Our problem was, how to expose the short end of the sensor to the hot kiln gases, without overheating the rest of the body?

Could one set up an EGO sensor at the exit flue of the kiln, with just the perforated thimble in the hot gases, and read millivolts on a digital meter attached to it? Would the sensor withstand the excessive heat there? These sensors only work when they’re sufficiently hot. But not TOO hot, surely. It's a bit more demanding than just having the sensor screwed into a metal exhaust manifold, with most of it out in the cool atmosphere. And, assuming the sensor was robust enough to survive, would the meter readings give worthwhile info about the atmosphere inside?

I made up a little bracket of stainless steel, to support an EGO sensor at the exit flue of our small test kiln. It seemed possible to expose the end of the sensor to the emerging hot gases, without having the stream diluted by ordinary air from the atmosphere. A thermocouple probe was fitted also, close beside the EGO, to monitor the temperature of the emerging gases. And of course, the $800 oxygen probe was fitted to the kiln in the usual way.

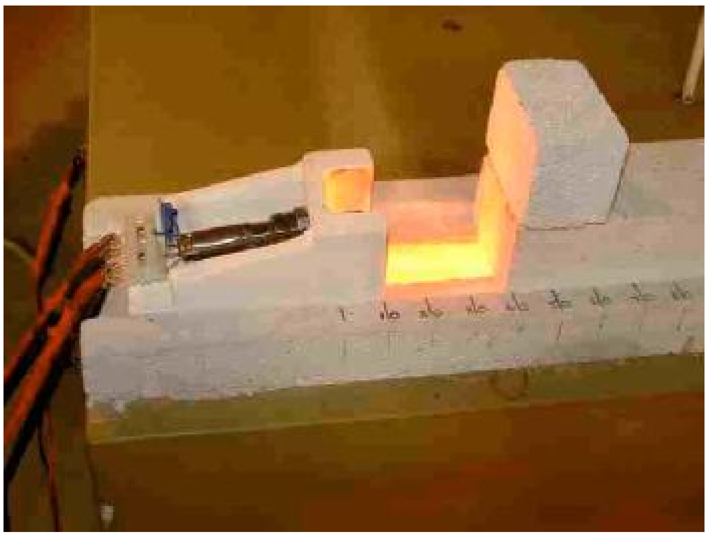
We ran the kiln to Cone 10, with a load of pots in copper red glaze, and plotted the usual graph of temperature versus time (in black, on the printout). Then from the kiln log sheet, plotted the millivolt readings of the $800 oxy probe, in red, and the $5 EGO sensor in green.



Reduction was commenced in this firing at about 700 degrees C, by closing the damper just enough. You’ll notice how both red and green lines on the graph shot up together abruptly as

soon as the kiln atmosphere became deficient in oxygen. Both traces stayed up, throughout the
firing. Near the end, with cone 10 down, the damper was opened a little for a few minutes of oxidation. And bingo... both traces dropped abruptly to low values again

All of this was very encouraging. The externally mounted EGO exhaust sniffer seemed capable of giving the same information as an internally mounted probe. But now let's face some practical considerations:. How to stop the steel body of the sensor from becoming overheated.? With the sensor on its original stainless steel bracket, temperatures as high as 870 degrees C were measured in the hot flue gas. How can we shield the body of the sensor from the hot gas, while still keeping the perforated end close to the flue?



After a bit of thought, I've settled on a bracket made entirely from clay rather than metal. It's a simple hand-building exercise to fashion a bracket which supports the sensor, while funneling the hot gas past it, and shielding it from clean outside air. What's more, any other potter could fashion an individual bracket to suit his/her particular kiln. The photograph shows our first attempt, made from paper clay. Fired to bisque temperature only, in the expectation that it will resist thermal shock better that way.

You'll notice that this method does not involve altering the kiln in any way. No need to drill any holes. The bracket just rests on top of the kiln, with the end of the sensor poking out into the path of the hot gases.

The threaded part of the sensor is about 10 mm long, so you'll need to make the clay wall about 10 mm thick. A plain smooth hole in the wall is OK. No need to try and make a thread inside for the sensor to screw in. It just lies there.

Would automotive EGO sensors of different makes give different millivolt readings in the same kiln? I made a test firing with two sensors mounted side by side at the kiln flue, to compare both with the $800 oxy probe inside the kiln. When the kiln was hot enough, the damper was inched shut until reduction seemed likely All three sensor readings rose immediately Not by the same millivolt amount, to be sure, but leaving no doubt that reduction was on the way.

<u>Choosing a Sensor from the Auto Wrecker.</u>

If you have a choice, ask for a sensor with two wires attached. The one-wire variety works just the same, but it's harder to make a reliable connection to the metal body. There's a three-wire variety, even a four-wire variety, in which two of the wires are for a heater down inside. Unless you plan to use the heater for sniffing cooler gases, the extra wires just make things confusing.

If you really have to use a one-wire sensor, a competent welder can attach a length of steel wire to the metal body with a quick dab of electric arc. This gives a reliable connection for the meter, at a distance from the heat of the flue.

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Testing a Used EGO Sensor.

If you choose to experiment with this exhaust sniffer using a brand-new EGO sensor, then you'll not need to test it. But if you use a salvaged one from an auto wrecker, testing it is no big deal. You already have a digital multimeter of course. Set it on a suitable range, likely to be 2000 millivolts. And you'll need a propane gas torch to heat the sensor while you read its output voltage.

Clamp the sensor in a vice, or use multi-grips. Clip the meter onto the leads (this is easiest with a 2-lead sensor. If there's only one lead, then the body of the sensor is the other side of the signal). Play the flame from the gas torch onto the perforated metal thimble of the sensor, and expect an instant rise in the meter reading. You can heat the thimble red hot with no risk of damage. An output signal of 700 or 800 millivolts is not unusual, but only if the gas flame is starved for oxygen.

If your propane torch has a fierce blue oxidising flame, the probe may just get red hot but the reading only rises a little (say 60 or 100 mV). But if you now cover some of the air inlets on the side of the burner, so the flame becomes reducing, the millivolt reading shoots up at once. That's good news. The sensor is working. When you remove the flame, the signal should drop within a second or two. That's all.

Will Kiln Gases Poison the Sensor?

Lead fumes certainly poison EGO sensors in auto engines. But you wouldn't be reducing a lead glaze, would you? Zinc oxide in glaze recipes might also cause a problem. In a reducing kiln, zinc oxide becomes zinc, which then evaporates as zinc vapour. Rising up the flue, the vapour encounters oxygen again at the flue opening and once more becomes zinc oxide. In one of our test firings the EGO sensor became so coated with white powdery zinc oxide that its readings were unreliable. The sensor reverted to normal once the zinc oxide was brushed away.