Analox O2EII® - Oxygen Analyser

Calibration: Choice of either air or calibration gas

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Introduction

The Analox O_2EII® analyser displays oxygen in the range 0.0-100.0 %. It is intended for use at atmospheric pressure, and its primary application is for the checking of nitrox gas mixes.

In the manual we recommend that the instrument is calibrated in air before use, but we have received enquiries about using other gas mixes for calibration.

This paper aims to set out the advantages and disadvantages of either method.

Any customers still unsure should contact Analox for further advice.

Atmospheric air or calibration gas?

The Earth's atmosphere contains a remarkably constant level of oxygen, which is widely assumed to be 20.9%.

Because of its accessibility and its price (it is free!), it is very attractive to use it as a calibration gas when air calibrating an O2EII®, or a multitude of other oxygen measuring systems used for personal protection.

Its main downside is that localised humidity levels can have an effect on the actual value. For that reason we provide a humidity compensation chart with each instrument, to show you whether to use 20.9% or some slightly lower value when calibrating.

Also take care that you are indeed calibrating in fresh-air. If you are in an enclosed space with restricted air circulation, you can't be sure that the air contains the expected amount of oxygen.

If you were to buy calibration gas, and for now let's assume that you bought an air mix, you will pay an amount of money directly proportional to the certified accuracy of the gas mix. A typical calibration gas might be specified as being accurate to +/-5% of value. In other words, a bottle certified to be 20.9% oxygen with +/-5% accuracy, would actually have a concentration somewhere in the region of 19.8% to 22.0%

Pay a bit more money, and you'll get a +/-2% accurate bottle (20.48 to 21.31%), and pay more still and you'll get a +/-1% accurate bottle (20.69 to 21.11%).

The advantage of the bottled gas is that it will be constant every time it is used – its humidity level will not vary. One disadvantage is cost, and indeed the increasing cost for meaningful accuracies. A second disadvantage is that it needs to be transported so it becomes far less convenient

Because of its cost, you may prefer to fit a calibration gas bottle with a flow regulator such that only the gas required for calibration is used, and none is wasted.

Typically, an ideal calibration flow rate would be in the range 0.2 to 1.0 litres per minute, and this could be passed over the O2EII® sensor using a flow adaptor available from Analox.

Which calibration gas?

If you opt to buy a calibration gas, an air mix is not your only choice. You could buy another mix containing a specified level of oxygen, or you could use pure oxygen.

Pure oxygen is actually not such a bad choice. It can generally be sourced with much better accuracies than that available for a gas mix (eg air). However there are also safety issues to be considered as pure oxygen can increase the risk of fire in many situations.

Cheap(ish!) medical oxygen may be better than 99.6% oxygen, and you can pay more and achieve 99.999% oxygen or even better. However that's getting more accurate than needed for an O_2EII®.

Before deciding which gas to buy, let's just think about what we actually want to measure. For instance in nitrox diving, you would generally never need to measure outside of the range 22% to 50% oxygen.

If you are going to buy a gas, the ideal gas would have a concentration greater than the gas mix to be measured. So for instance to measure 50% oxygen, ideally you would calibrate with something greater than 50% oxygen.

Why is this?

Let's discuss first a little about how an oxygen sensor works, and then come back to the choice of calibration gas.

How does the sensor work?

The intention here is not to go into the chemistry of precisely how the sensor works. All we aim to do is to provide a broad understanding of what's happening, and from that we can then discuss failure mechanisms.

The O2EII® oxygen sensor is commonly referred to as an electro-chemical fuel cell.

The most common electrochemical transducer is a battery which transforms chemical energy into electrical energy. Although less well known, a fuel cell performs the same transformation. The primary difference between a battery and a fuel cell is the place where the chemical energy is stored. In the instance of batteries, the chemical energy is stored inside the device itself. With fuel cells the chemical energy is stored externally; the rate at which the chemicals are fed into the fuel cell determines the amount of energy or power that is obtained.

The Analox oxygen sensor uses a lead anode and potassium hydroxide electrolyte. The cathode is a perforated metal disc which is plated with an inert metal. The fuel is the oxygen in the sample of gas being measured. This diffuses into the sensor and the chemical reaction taking place generates an electrical current measured in micro-amperes (units of one millionth of an ampere).

This tiny current is converted to a voltage by passing it through a resistance. The voltage generated is measured in millivolts (units of one thousandth of a volt).

The voltage generated is essentially linear. At zero oxygen, there will be zero volts, rising up to maximum millivolts at 100% oxygen.

Therefore by measuring the voltage created by the sensor, the analyser can display the oxygen concentration.

The major disadvantage of a fuel cell is that it has an expected lifetime. It will eventually fail, just as a battery would, as the chemical electrolyte is consumed.

We need to be aware of what happens when the Oxygen sensor fails to avoid the danger of un-knowingly analysing a gas mix with an exhausted or defective sensor.

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Oxygen sensor failure mechanisms

Table 1 refers to some of the commonest forms of oxygen sensor failure

Table 1: Oxygen Sensor - Failure Analysis

Failure Description	Failure Effect	Failure Recognition/Action
Electrolyte leaks out of sensor	Firstly beware of the safety information provided with the O2EII®. The electrolyte is caustic and can cause harm. Leakage path out of cell, also allows excess oxygen into cell. Initially, for a short period the sensor may give higher than expected outputs, but will quite quickly degrade to giving no output.	Observe any leakage of electrolyte from front of cell when inserting flow adaptor or Sensor Saver. Immediately discard any leaking cells in a safe manner. Do not use the O2EII® until a new sensor is fitted.
Broken Electrodes	Sensor output will fail towards zero output	Unable to obtain any readings - replace sensor
Failure of Internal connections	Either very high or very low output from sensor	Obvious erroneous value when attempting calibration – replace sensor.
End of Life Ceiling Mode	Sensor unable to maintain current output at correct level to drive load resistance. Output becomes non-linear at higher oxygen levels.	Regular replacement of cell will minimise likelihood of experiencing Ceiling Mode. Alternatively, calibrate in high concentration oxygen (eg pure oxygen), and then observe reading in atmospheric air afterwards. When Ceiling Mode evident, reading in air will be higher than expected (eg >22%) Replace sensor if Ceiling Mode detected.

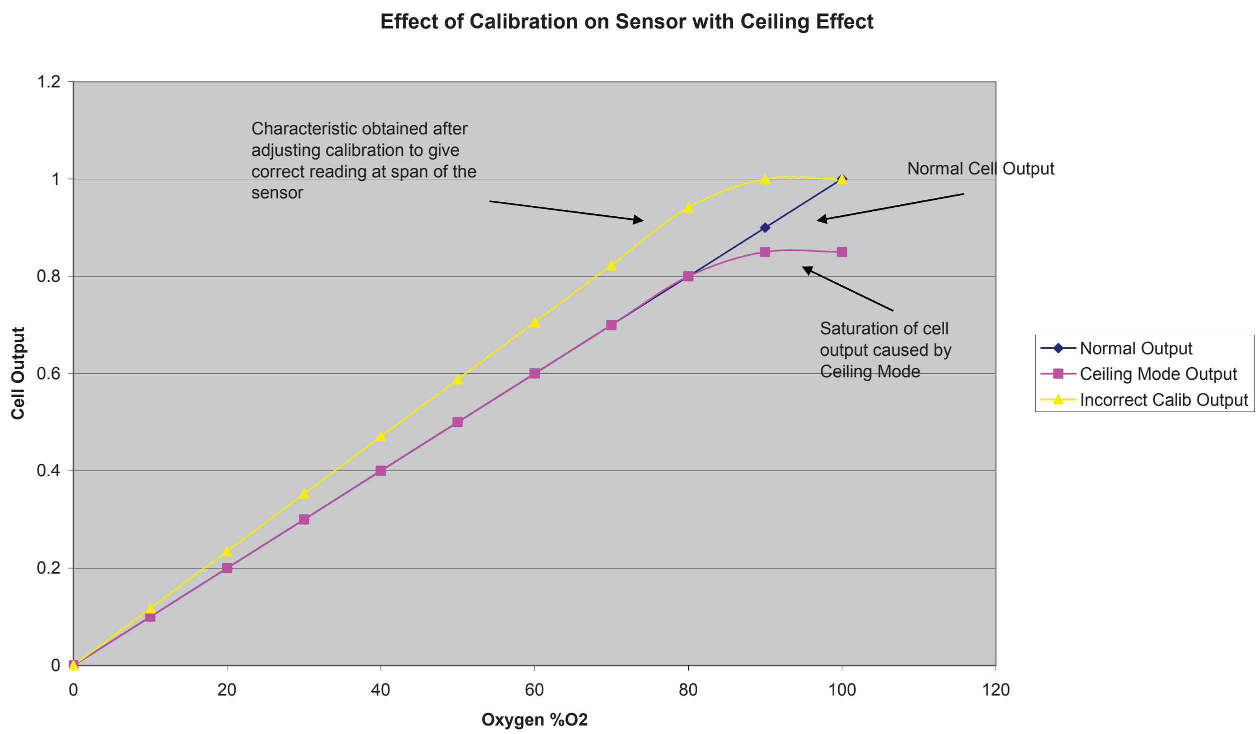
Ceiling Mode

In Table 1 we described several failure modes of the oxygen cell. The good point is that most failures will be readily recognised. However, Ceiling Mode is one failure that requires special consideration. The graph below should give a better insight of what will happen as a result. Note the blue line which is the ideal linear output obtained from the sensor. The pink line then shows that if Ceiling Mode is present, the cell is unable to generate the expected outputs for high oxygen concentrations.

The yellow line then shows the resultant analyser output having forced the reading to be correct at the span of the instrument (100%). This gives higher than expected readings all the way down the scale towards zero. Typically, you will note that after calibration in 100% oxygen, the subsequent in-air reading is abnormally high. Better still, you could use a second calibration gas (eg 50% oxygen), to check the linearity at the mid point, where it is more noticeable than further down the scale.

However, you'd now be carrying around two calibration gases and associated accessories, when all you really need to do is to change your oxygen sensor more frequently. Alternatively, you could ask a Dive Shop to test your O_2EII® on pure oxygen say at the start of a diving holiday.

As the sensor ages even further, the Ceiling Mode will occur at progressively lower concentrations of oxygen, and hence become much easier to detect.



So which calibration gas to use?

Before discussing the sensor and the failure modes, we stated that the best calibration gas to use is one with a higher concentration than the highest value expected to be measured.

With a view to being able to detect the occurrence of Ceiling Mode within the sensor, the best cal gas to use is 100% oxygen, which is also readily available. This will mean that you are proving the ability of the sensor to operate over the entire range.

Also 100% oxygen is generally cheaper to obtain with a better accuracy than say a gas mix in the range 40-90% oxygen.

Regular replacement of the oxygen sensor will minimise the likelihood of Ceiling Mode occurring. The use of pure oxygen to test/calibrate the sensor could be seen as a means of using the sensor until it fails, although generally this is not recommended – the sensor will sometimes fail at the most frustrating times. It's a bit like the oil-filter on your car. Replace it regularly, and it won't give you problems. Use it to the end of its useful life, and you risk the consequences of failure.

Conclusions/Recommendations

An air calibration is the easiest, the most convenient and certainly the cheapest way of calibrating your analyser.

If you regularly change your sensor, you ought not to experience the problems caused by the Ceiling Mode failure.

If you are concerned about Ceiling Mode, then perhaps change your sensor every 3 to 4 years rather than every 5 years, or better still, take your O_2EII® to a stockist or Dive Shop, and ask for it to be tested on pure oxygen.

If you really want the optimum safeguards at all times, and you are prepared for the inconvenience of carrying your own calibration gas, then consider buying pure oxygen for normal calibration. Detection of Ceiling Mode is possible by observing readings in air soon after calibration. Better still is to buy a second calibration gas (eg 50% oxygen) to check the linearity of the analyser.