looking after the air you breathe®

Oxygen depletion monitors

- Choice of sensor type

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1. Introduction

Analox manufacture a range of oxygen depletion monitors. This paper aims to clarify the differences between the sensors used in the various models available.

Having read this document, any users still unsure which type of sensor should be used in their application, should contact Analox for further advice.

2. Instruments available from Analox

Instrument Name	Application	Sensor Type
Analox O_2NE™	Fixed instrument configured as standard with two depletion alarms, representing warning (19.5%) and danger (18%) levels of oxygen.	Capillary
Analox O_2He™	Fixed instrument configured as standard with two depletion alarms, representing warning (19.5%) and danger (18%) levels of oxygen, specifically for use in areas where oxygen depletion is due to the use of helium (eg saturation diving)	Diffusion
Analox Safe-Ox™	Fixed instrument configured as standard with one depletion alarm (19.5%) and one enrichment alarm (23%) for levels of oxygen.	Capillary
Analox Safe-Ox He™	Fixed instrument configured as standard with one depletion alarm (19.5%) and one enrichment alarm (23%) for levels of oxygen specifically for use in areas where oxygen depletion is due to the use of helium (eg saturation diving)	Diffusion
Analox O_2 Buddy™	Portable instrument configured as standard with two depletion alarms, representing warning (19.5%) and danger (18%) levels of oxygen.	Capillary

Table 1: List of Analox depletion monitors

3. Sensor types

From the list of instruments in Table 1, there are clearly two types of sensor that are used in Analox oxygen depletion monitors.

3.1. Capillary sensor

The capillary type of sensor measures the percentage of oxygen in the atmosphere where the instrument is located. It is essentially immune to fluctuations in atmospheric pressure. It is however affected by the presence of background helium, which makes it questionable for use in an environment subject to oxygen depletion by helium. Please refer to Section 4.

3.2. Diffusion sensor

The diffusion type of sensor measures the partial pressure of oxygen in the atmosphere where the instrument is located. Therefore it is directly affected by fluctuations in atmospheric pressure, and can in extreme conditions generate nuisance alarms due to the lack of oxygen in the atmosphere caused simply by, for instance, a very low pressure weather front. Unlike the capillary sensor though, the diffusion sensor will work correctly in helium environments. The reading is presented to the user as an assumed percentage value, simply by saying that a partial pressure of 209 mBar ppO_2 is equivalent to 20.9% oxygen. This is of course only true at an atmospheric pressure of 1000 mBar. Please refer to Section 5.

4. Effect of helium on a capillary sensor

Helium is used widely in industrial applications, for example in magnetic resonance imaging equipment in hospitals and for offshore saturation diving. When a capillary sensor is exposed to helium, for instance caused by a spill or leak, the helium will cause the capillary sensor to give a higher than expected reading. Although not toxic, if helium is spilled or released in high levels into a confined space it can result in oxygen depletion. If capillary oxygen sensors are being used to monitor the levels of oxygen they can give readings that are high – this is potentially dangerous when monitoring oxygen depletion.

The reason for this phenomenon is down to the small size of the helium molecule. When present in high concentration, the helium molecules diffuse rapidly through the capillary into the oxygen sensor and at the same time allow more rapid diffusion of the much larger oxygen molecules. The result of this process is more oxygen molecules enter the sensor which results in artificially high readings.

It is preferable to use a partial pressure sensor when measuring oxygen in ambient environments where helium leaks and spills could occur. These sensors have a solid membrane diffusion barrier in place of the capillary and do not suffer the same effects as the capillary sensors.

Let us now investigate the issue further and show the extent of the effect caused by helium. This will allow an informed decision on whether the issue is relevant in a particular application.

Firstly let us look at the effect of pure helium leaking into a given atmosphere. As the concentration of helium increases, it will displace air from that atmosphere. As the air is displaced, the concentration of oxygen will fall, as shown in Figure 1.

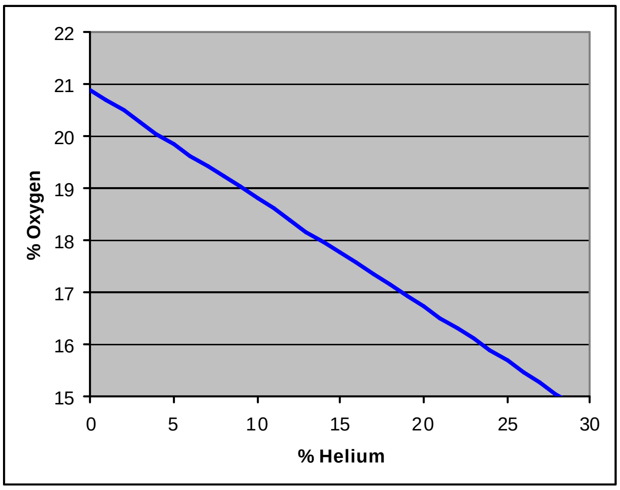

Figure 1: Depletion of oxygen by helium in an atmosphere

This graph shows us that the alarm limits of 19.5% and 18% oxygen relate to helium concentrations of approximately 7% and 14%.

Figure 2 shows us the sensitivity factor of the capillary sensor in the presence of varying levels of helium. With zero helium, we are saying that the sensitivity factor is 1.0. That is to say that the sensor will give a correct oxygen reading. As the helium increases, so too does the sensitivity factor.

At 7% helium, the sensitivity factor is approximately 1.055. This means that with say a sample of 19.5% oxygen, the sensor will indicate 1.055 x 19.5% (=20.6% oxygen). Also an alarm setpoint of 19.5% will require a level of oxygen less than 19.5/1.055 (=18.5% oxygen) to successfully trigger.

At 14% helium, the sensitivity factor is approximately 1.1075. This means that with say a sample of 18.0% oxygen, the sensor will indicate 1.1075 x 18.0% (=19.9% oxygen). Also an alarm setpoint of 18.0% will require a level of oxygen less than 18.0/1.1075 (=16.3% oxygen) to successfully trigger

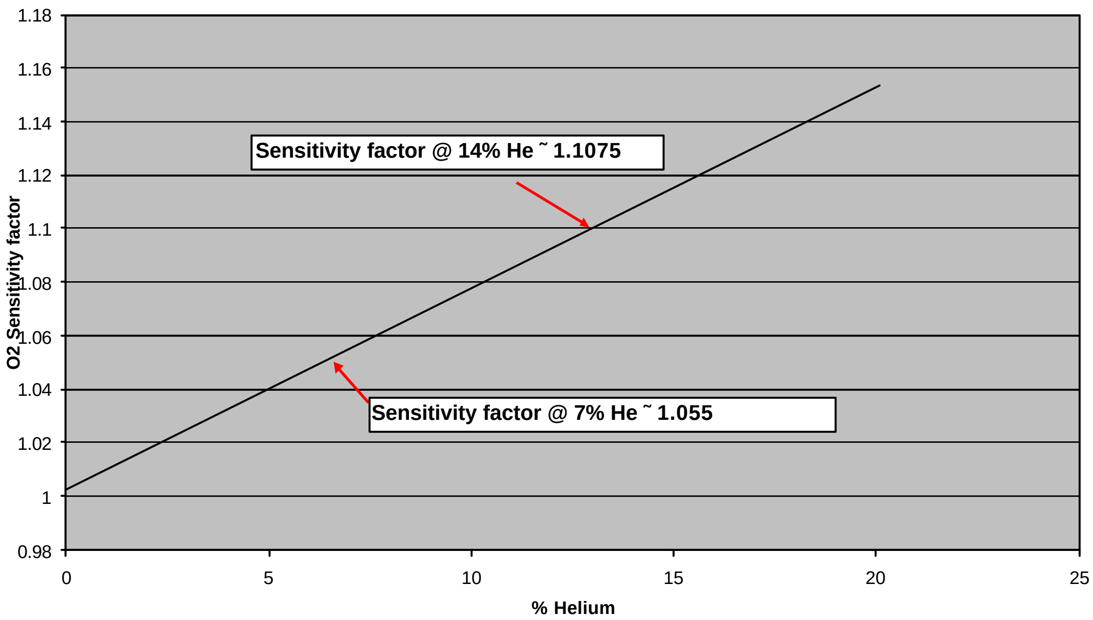

Figure 2: Sensitivity factor of oxygen sensor in presence of helium

Whilst these numbers are not dramatically incorrect, and are probably unlikely to cause harm to personnel (refer Section 7), they are still sufficiently erroneous that Analox would advise considering use of the diffusion type of sensor in such applications.

5. Effect of atmospheric pressure on a diffusion sensor

We will assume that the instrument has been calibrated to read 20.9% when it is measuring 209mBar ppO_2 at an atmospheric pressure of 1000 mBar.

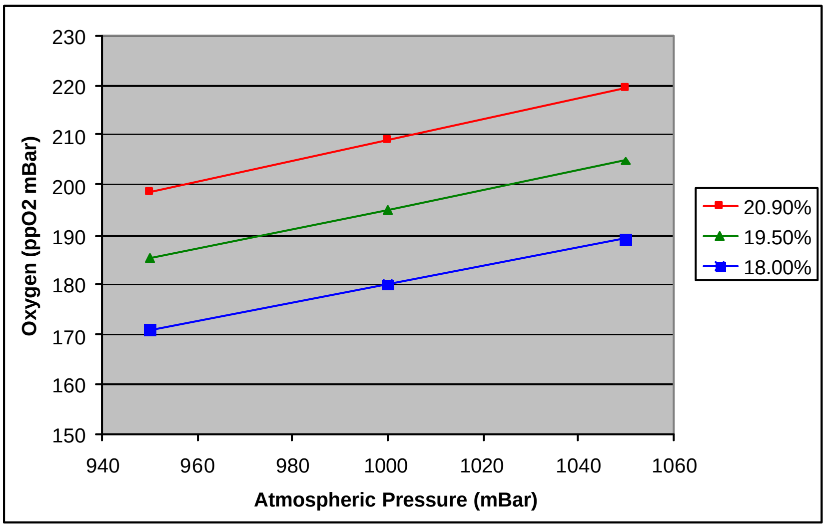

Figure 3: Variation of oxygen with atmospheric pressure

Figure 3 demonstrates the readings obtained from sensors at different atmospheric pressures when subjected to three samples of oxygen – 20.9% which is taken as normal air, and then levels corresponding to the two typical alarms – 19.5% and 18.0%. You can see that a sample of 20.9% oxygen will measure just under 198.5mBar (ie display 19.85% oxygen) at 950mBar atmospheric pressure. In theory that is satisfactory in that it will not lead to a nuisance alarm. The nuisance alarm would occur if the reading fell to 195mBar oxygen, which is equivalent to 20.9% oxygen at an atmospheric pressure of 933mBar.

Also a genuine 19.5% sample of oxygen will measure 204.75mBar at 1050mBar atmospheric pressure. This means that under these conditions, the sensor will not go into alarm. It would actually require a gas of 18.5% oxygen to trip an alarm set at 195mBar when the atmospheric pressure is 1050mBar. Likewise, at 1050mBar atmospheric pressure, the test gas to achieve the second alarm (normally 18%, or 180mBar), would be 17.1%.

To summarise, low atmospheric pressures increase the likelihood of a nuisance depletion alarm, and high atmospheric pressures lead to reducing the effective alarm setpoint.

The examples shown here are fairly severe. Atmospheric pressure in many locations will very rarely reach the figures quoted here.

6. Ageing of sensors

6.1. Capillary sensor ageing

Typically the output of a capillary type of sensor may reduce from an indicated 20.9% oxygen down to around 20.0% in a 1 year period. The sensor will continue to operate over its lifetime of about 2 years. As the sensor output falls, it becomes more likely that a nuisance alarm is generated. For this reason, we recommend that customers calibrate the instruments every 4 to 6 months and replace sensors at 18 month intervals.

6.2. Diffusion sensor ageing

Typical the output of a diffusion type of sensor may reduce from an indicated 20.9% down to around 19.5% in a 1 year period. The sensor will continue to operate over its lifetime of between 2 and 3 years. As the sensor output falls, it becomes more likely that a nuisance alarm is generated, particularly in the event of low atmospheric pressure conditions. For this reason, we recommend that customers calibrate the instruments at around 4 to 6 month intervals, and replace the sensor every 2 years.

7. Effect of oxygen depletion on humans

The table below shows the typical effect of oxygen depletion on humans. This table should be taken as guidance only. Analox do not claim to be medical experts! If in doubt, consult relevant medical practitioners.

Oxygen Content of Air	Signs and symptoms
19.5%-15%	Decreased ability to work strenuously. May impair co-ordination and may induce symptoms in persons with coronary, pulmonary, or circulatory problems.
15%-12%	Respiration deeper, increased pulse rate and impaired coordination, perception and judgement.
12%-10%	Further increase in rate and depth of respiration, further increase in pulse rate, performance failure, giddiness, poor judgement and blue lips.
10%-8%	Mental failure, nausea, vomiting, fainting, unconsciousness, ashen face, blue lips.
8%-6%	8 minutes may be fatal in 50-100% of exposures; 6 minutes may be fatal in 25-50% of exposures; 4-5 minutes, recovery with treatment.
6%-4%	Coma in 40 seconds, convulsions, respiration ceases, death.

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