Medical Oxygen Sensors – Technical Training

Why do we measure oxygen?

Oxygen is essential to human life. The atmosphere consists of 20.95% oxygen, often approximated to 21%.

Too little oxygen results in hypoxia, which is fatal if prolonged. In high concentrations (i.e. when inhaled under pressure) it can be fatal.

Oxygen in medical applications in the UK is classed as a controlled drug* and needs to be monitored when administered to ensure that the patient is breathing a safe gas mixture.

What are oxygen sensors?

Oxygen sensors (sometimes called **fuel cells**) are similar to batteries in that they give out a voltage. However, unlike a battery, the voltage from an oxygen sensor is directly proportional to the amount of oxygen that the sensor is being exposed to.

They are used to measure the level of oxygen in various applications, such as medical devices, industrial processes and automotive vehicle emissions testing.

Medical oxygen sensors come in various different shapes and sizes, with different specifications and a range of connectors.

R-22MED Oxygen sensor

R-30V Oxygen Sensor

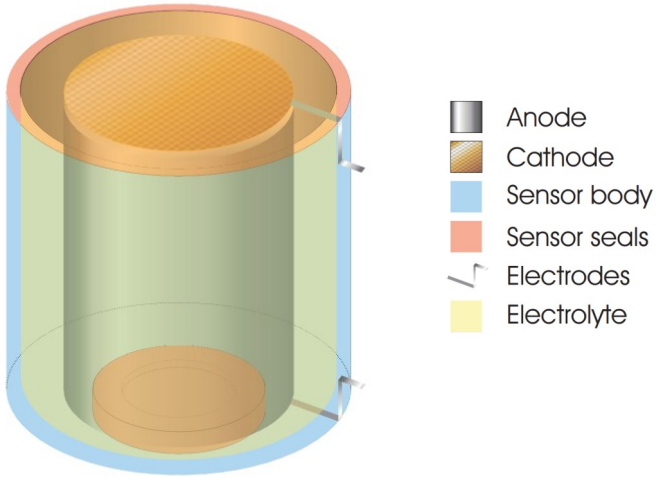
UFO 130-2 Oxygen Sensor

*British National Formulary (BNF), a joint publication of British Medical Journal and the Royal Pharmaceutical Society - https://bnf.nice.org.uk/treatment-summaries/oxygen/

How do they work?

Oxygen sensors contain an **anode***, a **cathode**** and a liquid **electrolyte***** solution, housed in a sensor body with a thin membrane that prevents the liquid electrolyte from escaping but allows oxygen to pass into the sensor at a molecular level.

The sensor has electrical connections to allow connection to the monitoring device.



Schematic of a typical oxygen sensor

Oxygen sensor with 3-pin Molex

Oxygen sensor with 3.5mm jack plug

***anode** – the electronically positive component of a sensor: most commonly lead, although lead-free alternatives are available.
****cathode** – the electronically negative component of a sensor: made from a noble metal, e.g. platinum, rhodium.
*****electrolyte** – the fluid between the anode and cathode. Oxygen dissolved in the electrolyte allows a chemical reaction to take place that generates electricity.

Where are medical oxygen sensors used?

Oxygen sensors are used in a range of applications, from hand-held devices to complex, multi-parameter monitoring equipment.

Envitec hand-held oxygen monitor

Stephan Stephanie ventilator and sensor

Philips MP50 patient monitor

GE Giraffe incubator

Mindray anaesthetic machine

Viamed supplies medical oxygen sensors from various different manufacturers, compatible with a wide range of manufacturer's devices.

- **Viamed** – Manufactured for Viamed by Envitec, branded as Viamed.
- **Envitec** – Originally a German company, now owned by Honeywell, a large American corporation with a diverse portfolio.
- **Teledyne** – Large American corporation with many different divisions, medical is just one sector they work in.
- **ITG** – German company, full name IT Dr. Gambert GmbH, specialising in gas detection and monitoring.
- **Maxell / Figaro** – Originally certified for medical use but no longer carry the correct accreditations.

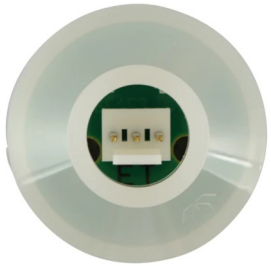
Each oxygen sensor has a specification to match the original sensors that they are designed to replace.

The full specification can be found on the sensor datasheet that is linked to the stock page for each sensor under the **Technical Document** section.

The main specifications that will be of interest to the customer are detailed on the Viamed webpage and the oxygen monitoring leaflets and catalogue:

Output connector – various types, e.g. jack connectors, Molex connectors, phone socket, slip rings etc.

Jack plug



Molex connector

Phone socket

Slip rings

Molex plug

DIL (dual in-line) connector

Sensor output – output is most commonly specified using the voltage in millivolts (mV), but sometimes as current in microamps (µA).

Examples: R-22MED 7.0 – 13.0mV in air

R-23V 24.0 – 32.0 µA in air

Sensor life – sometimes specified in months, but more commonly in % oxygen hours, e.g. 1,000,000 % oxygen hours.

To calculate the life of a sensor, divide the % oxygen hours by the percentage of oxygen that you want to know the lifespan for, which will give you the approximate life in hours.

Divide this by 24 to get the life in days.

at 100% oxygen: 1,000,000 / 100 = 10,000 hours
10,000 hours / 24 = 416 days

at 21% oxygen (air): 1,000,000 / 21 = 47,619 hours
47,619 hours / 24 = 1,984 days

Note: this calculation is a **theoretical optimum lifespan**.

Sensors all deteriorate differently, some may exceed this specification, some will fail to reach it.

Using sensors in high oxygen concentrations will shorten the lifespan.

Sensors are best stored in air when not in use to prolong lifespan.

Sensor depletion due to heavy use is not usually covered by warranty (this is at the manufacturer's discretion).

Response time – measured in seconds, with the exception of the UFO series, which is an **ultra-fast oxygen** sensor and the response time is measured in milliseconds.

The response time of a sensor is dependent upon the thickness of the sensor membrane used in the design.

As a sensor has a limited capacity, faster sensors use up their fuel supply sooner than slower ones.

Some applications, such as anaesthetic ventilators, require relatively fast sensors so that changes in the oxygen levels are registered quickly.

Other applications, such as enclosed incubators and oxygen hoods, can work with a slower sensor as it takes some time for the whole volume of gas in these devices to change noticeably.

Some applications, such as exercise stress-testing on treadmills, require ultra fast sensors to allow for breath-by-breath analysis. It is this type of application where UFO sensors are used.

Accuracy – Sensors are most accurate when calibrated in 100% oxygen.

This is because any error in the calibration when performed in air at 21% O2 will be multiplied around 5 times when the sensor is then subject to oxygen due to the linear output response of the sensor.

Teledyne recommends that for sensors being used to measure concentrations above 40%, oxygen calibration should be performed; for monitoring at lower concentrations, air calibration should be sufficient.

Calibration is best performed in a low gas flow of 2 – 5 litres per minute.

Warranty – Warranties vary from sensor to sensor.

The warranty period can be found on the stock page for the sensor or you can use the warranty checker in Intrastats if you know the serial number of a particular sensor and want to check the warranty status.

Effects of pressure

Oxygen sensors measure the **partial pressure** of oxygen present in the gas.

If the gas pressure is reduced, the output of the sensor is reduced, leading to a lower reading. Likewise, higher pressures lead to a higher reading.

The effect is directly proportional to the gas pressure, so an oxygen monitor that is calibrated to 21% at sea level will read 10.5% at around 5,700 m where the atmospheric pressure is halved.

Conversely, an oxygen monitor that is calibrated to 21% at sea level will read 42% if taken into a barometric chamber that is pressurised to 2 atmospheres.

In practical terms, this means that oxygen monitoring devices should be calibrated regularly to account for changes in barometric pressure due to fluctuating weather patterns. Maxtec does not specify a calibration interval but Teledyne has always recommended every 8 hours, which is a good rule of thumb based on legacy knowledge.

Effects of temperature

Oxygen sensors rely on a chemical reaction that speeds up when the sensor is warmer.

Without temperature compensation, a sensor would not read accurately if the temperature of the gas being measured increases or decreases.

Most oxygen sensors incorporate a temperature compensation circuit, which balances the effects of temperature fluctuations.

When a sensor is subject to a large change in temperature, it needs to reach thermal equilibrium in order to nullify the effects of the temperature change. In extreme temperature changes, this can take 1 – 2 hours.

Shelf life

In order to prolong the shelf life of oxygen sensors, most manufacturers take steps to reduce the amount of oxygen reaching the sensor membrane, which slows down the chemical reaction and prolongs the life of the sensor.

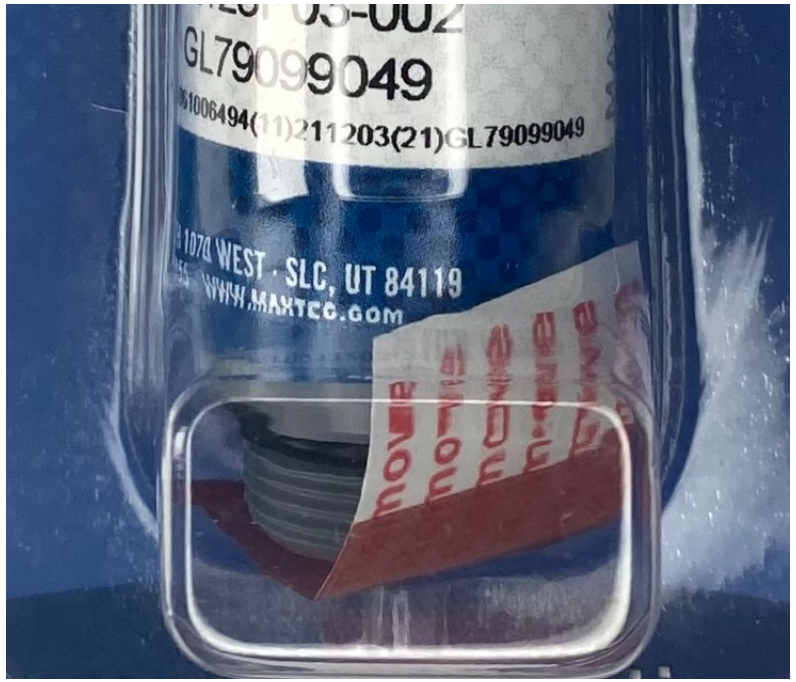
Some sensors are sealed into gas barrier bags shortly after manufacture.

These bags restrict the transit of oxygen molecules from the outside to the inside of the bag, whilst the sensor consumes the available oxygen inside it.

Once the oxygen is consumed, the sensor output drops significantly and the sensor effectively ‘goes to sleep’.

The reaction does not stop entirely as some oxygen molecules still find their way through the gas barrier, but the effect is such that after 12 months inside the bag, a sensor will still retain approximately 90% of its original lifespan.

Other manufacturers, such as Maxtec, instead use a gas barrier tape over the sensing surface, which works in a similar way to the bags, causing the sensor to slow down once the oxygen is consumed.



Viamed recommends that oxygen sensors be stored in unopened bags or with the tape in place until required and are put into service before the warranty period expires.

Occasionally, sensors will take some time to ‘wake up’ when the gas barrier is removed, and may respond slowly or with reduced output. This usually disappears within 20 minutes of exposure to air.

In rare cases, this may take up to 24 hours, but longer than that would indicate a problem with the sensor.

Lead-free sensors

Medical oxygen sensors are not yet required to be lead-free, although lead-free alternatives are now available in preparation for more stringent legislation being introduced in the future.

Safety

Always wear gloves if handling suspected leaking sensors.

Even small amounts of electrolyte on skin can cause the skin to melt, typically first noticed as a soapy feeling. Wash hands immediately if contact is suspected and notify the person responsible for first aid.

Do not dismantle sensors! Lead and lead oxide in the anode are toxic and dangerous to the environment.

Full safety advice is available on the material safety datasheets in Intrastats.

Sensor disposal service

Viamed offers a free sensor disposal service **for any manufacturer's sensors,** all the customer has to pay is the return carriage.

Maintenance/Service

Oxygen sensors do not contain user serviceable components.

Viamed can test sensors that are under warranty and replace them if found to be faulty.

Latex

All sensors and packaging are latex-free.

Where to find additional information

- Viamed website
- Product leaflets – linked to stock pages
- Technical datasheets – linked to stock pages
- FAQs on the stock page
- Memos on the stock page