Teledyne Oxygen Sensors Seminar background Information

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V3.1

INDEX

TELEDYNE OXYGEN SEMINAR

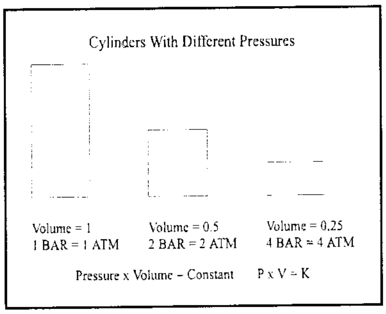
1. The Gas Laws

1.1 Boyles Law.

For gases such as Air, Oxygen, Nitrogen & Helium under ordinary conditions of pressure and temperature.

> *"The absolute pressure is inversely proportional to the volume provided that the temperature is constant."*

In other words if the pressure is doubled the volume the gas takes up is exactly halved if the temperature is kept constant.



This can also be expressed mathematically as $P \times V = K$

Pressure x Volume = Constant

If P1 V1 are the starting conditions and P2 V2 are the end conditions $P1 \times V1 = P2 \times V2$

The critical factor for this equation to work is temperature as temperature is assumed to be constant.

1.2 Daltons Law.

More correctly this is Daltons 1st Law2/5/01

If a closed vessel contains a mixture of two different gases which have no chemical action on each other then

"The total pressure is the sum of the pressures which the quantity present of each gas would exert if it alone occupied the vessel"

When the gas is air **P**total = **PO**xygen + **PN**itrogen

where Pt is the total pressure
PO is the partial pressure of Oxygen and
PN is the partial pressure of Nitrogen.
At the Standard pressure of 1 Bar in air **1 bar = 0.21 + 0.80**

If a gas contains 32% O2 and 68% Nitrogen the equation becomes **1 Bar = 0.32 + 0.68**

Gas is basically a large empty space populated by molecules moving around. The molecules exert a force against other molecules so that they repel each other . The speed the molecules move is governed by temperature and the molecules always try to spread out to share equally the available space.
For instance if a balloon of 100% Oxygen was burst in a sealed room it would disperse within seconds. .It does not leave pocket or a bolus of Oxygen hanging in space

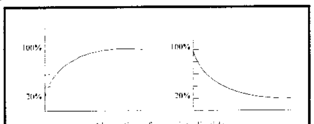
1.3 Henry's Law.

Liquids are similar to gases but have more closely packed molecules. Molecules of gas can move into liquids . Water contains dissolved Oxygen which allows fish to breathe by using their gills to separate the oxygen molecules from the water.

> *The amount of gas which dissolves in the liquid is directly proportional to the partial pressure of the gas adjoining it.*

By increasing the pressure of the gas on the surface of a liquid we increase the partial pressure and allow more molecules to dissolve into the liquid.
In addition to pressure, different gases have different solubility coefficients. i.e. Different gases will dissolve different quantities of their molecules into different liquids at STP.
Temperature effects the ability of a liquid to dissolve the gas.

If a gas is suddenly introduced into contact with a the liquid e.g. the Oxygen level is raised from 20.9% to 100% the Oxygen will begin to pass into the liquid. The liquid takes time to reach a new equilibrium. It starts quickly to take up the Oxygen but then becomes slower and slower as the liquid reaches saturation. If the gas is then suddenly removed e.g. 100% to Air 20.9% then the liquid soon contains more gas than the surrounding atmosphere and molecules transfer out of the liquid back into the air. The same time delay is evident.



Absorption of gases into liquids

Each of these gas laws plays a vital part in the mechanism of electrochemical galvanic fuel cells and the measurement of Oxygen.

The volume of the sensor is fixed so any increases in pressure directly increases the partial pressure of Oxygen in any gas mixture inside the sensor. Increasing the partial pressure of oxygen increases the number of molecules meeting the sensor electrolyte allowing more oxygen to enter the sensor giving a higher output. Temperature of the gas increases the speed the gas molecule move and therefore ensures more molecules come into contact with the surface of the liquid. Temperature of the sensor body increases the solubility of the electrolyte making it easier for the Oxygen molecules to pass into the electrolyte. More Oxygen dissolved into the electrolyte. the larger the sensor output.

All electrochemical sensors produce an output current directly proportional to the Partial Pressure of Oxygen

At STP the partial pressure of O2 is .209
At STP the percentage O2 present in air is 20.9%

It is important to ensure all Oxygen measurements are made at 1 Bar. Any container e.g. plastic bags or occluded Tee pieces must allow the gas to vent naturally into the atmosphere. Only when the restricted gas has reached equilibrium with the surrounding atmosphere of 1 Bar will the measurement be accurate.

2 Polarographic sensors

The Oxygen diffuses through a permeable membrane and reacts with an electrolyte between two electrodes. The resistance between anode and cathode is dependent upon the molecules of Oxygen present. A small highly stabilised voltage is applied across the electrodes and an external circuit measures this current and displays it as a percentage oxygen reading.

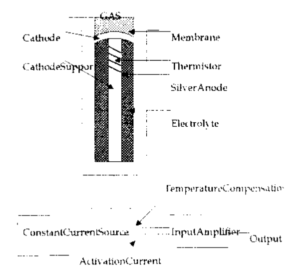
The electrolyte in the sensors dries out quickly and both it and the membrane must be replaced regularly. The electrodes also oxidises and must also be cleaned regularly.

Historically the Polarographic had two advantages. Fast response to Oxygen concentration changes and the ability to be switched off when not in use.

To overcome these problems a new type of self contained Polarographic sensor the T-4 was developed. This sensor lasts for approximately 6 months and is then discarded no cleaning or electrolyte changes are required as electronic circuits are used to cleanse the sensor electrodes.

This type of sensor is stable, accurate, and has a fast response. It requires a polarising time prior to use however the sensor is not being used up while it is switched off.

For instantaneous use a continuous polarising voltage is applied even while the instrument is not being used. This unfortunately also means the sensor is being used even with the instrument off reducing its useful life. A thermistor is used for temperature compensation and is usually used as part of the electronic circuitry. Stable electronic circuits are required as the typical output of a T-4 sensor is 4 micro Amps in Air.

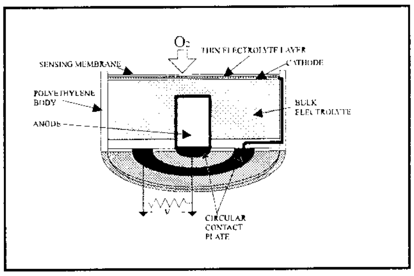


Polargraphicschematic

3 The Galvanic Oxygen sensor

This was originally designed and patented by Teledyne and is today the easiest and most common method of measuring oxygen.

The sensor is packaged as a complete self contained and expendable transducer so that when the chemicals are exhausted the sensor is discarded and replaced.-



The basic constituents of a sensor consists of a lead anode a gold plated cathode with a solution of Potassium Hydroxide as an electrolyte.

The cathode is a convex metal disk plated with a noble metal e.g. gold, silver, platinum etc. with numerous perforations. It is designed to facilitate the continuous wetting of the upper surface and therefore contains a small amount of electrolyte between the membrane and the cathode. This is to assure minimum internal resistance during the oxygen sensing reaction. It is essential that this portion of the electrolyte does not dry out or the membrane be allowed to contact the cathode directly.

When Oxygen is diffused into the sensor through the membrane the lead is oxidised into lead oxide and the reaction produces a small current between anode and cathode. The lead anode is specially designed to maximise the amount of metal available for the reaction .For this reason it is not solid but small particles bonded together. This increases the surface area in contact with the electrolyte and encourages even oxidisation throughout the complete electrode.

The rear of the sensor has another flexible membrane which is designed to accommodate internal volume changes that occur throughout the life of the sensor. Without this membrane the upper membrane would move to accommodate the internal volume changes and a variation in electrical output unrelated to oxygen concentration would be the result.

The sensing membrane is made of Teflon whose thickness is very accurately controlled. The entire space between the two membranes is filled with an solution of potassium hydroxide .
The main sensor body is manufactured from high density polyethylene.

Galvanic oxygen sensors require no external battery to work. They consume Oxygen and produce a small electrical current.

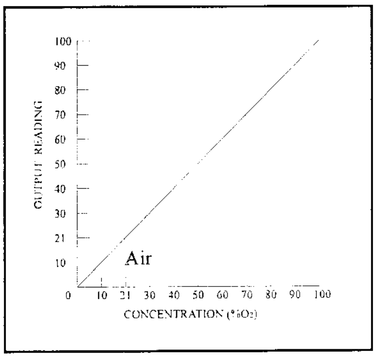
The earliest micro fuel cell sensors produced a large current output of 1 milliamp at 100% oxygen and can drive an analogue meter direct.

The simplest Oxygen analyser employs no electronics but is simply a sensor and a 100 micro Amps moving coil meter.

The sensor is made from several small parts each controlled to high standards . However no two sensors can be absolutely identical and therefore there will inevitably be small differences in outputs. These are cancelled out in the monitor by using a calibration control
The T-1 sensor generates about 1.0 mA in 100% oxygen . This is used to drive a 100 micro Amp moving coil meter with a 1 Kohm coil impedance. If the meter is replaced with a fixed 1 Kohm resistor the output can be measured with a digital millivolt meter . The calibration control to compensate for small output variations between sensors is a linear 2 Kohm resistor.

3.1 Sensor Linearity

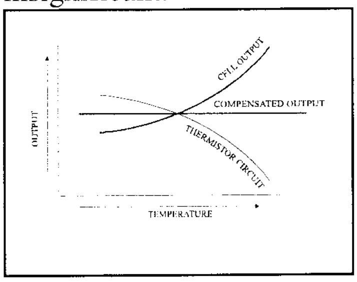
The sensor output is linear over its range



In the absence of oxygen there is virtually no output from the micro fuel cell and so no zero or special calibration gases are required. It is specific to oxygen
Strong inorganic oxidising gases e.g. Chlorine, fluorine. triflouride. can have an adverse effect on the sensor.
The micro fuel cell has a very stable output and it is not uncommon for a cell to run in a constant oxygen concentration at STP for weeks and maintain a reading within +/- 1 %.

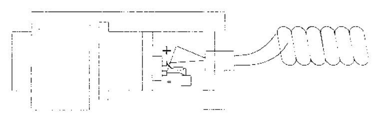
3.2 Temperature

The micro fuel cell sensor is temperature sensitive and increases its output by approximately 2.5% per degree Celsius. It therefore requires temperature compensation to keep it linear. This is achieved by using a thermistor resistor network across the sensor. With careful choice of components it is possible to get the match the tracking within 5% over the measuring range which makes the error to a final reading insignificant.

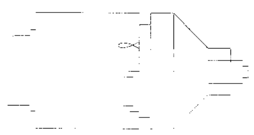


Temperature compensation can either be built into the sensor, into a sensor holder. or a combination of sensor and measuring circuit. Any of these methods produces the same effect
The response of the temperature compensation circuit is designed to be exactly the opposite of the sensors response to temperature. With careful design the two effects cancel out.
It is assumed that the sensor and the temperature compensation components are always at the same temperature. For most medical applications and the accuracy required the assumption is correct.

However if the gas is cold or hot a temperature gradient will exist across the sensor. Sensors should be allowed about 1 hour to temperature stabilise
This is important if the sensor is fitted to an Oxygen hood , or placed under an overhead heater whilst in a ventilator circuit.
The sensor has a thermal inertia and time is required for it to heat up evenly. It is therefore possible for the gas being measured to be at a different temperature to the compensation circuit . This is particularly true in high flow rates.
In sensors like the R-17 the temperature compensation circuit is located in the sensor immediately behind the socket.



Sensor Holder



Temperature compensation in sensor

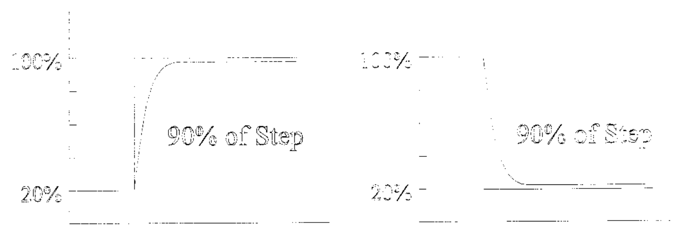
3.3 Response time

The response time of sensors is defined as the time taken for the output of the sensor to reach 90% of the final reading on a step change.

This rate of oxygen infusion into the sensor is primarily controlled by varying the thickness of the membranes during manufacture. The thicker the membrane the slower the response.
Once the oxygen is through the membrane the rate of absorption depends on the partial pressure and the solubility of the electrolyte. The chemical reaction is also temperature dependant. The shape of the curve is exponential and after a rapid rise the rate of change progressively slows down. This is due to the equalisation of pressures between the gas and the electrolyte. Once the electrolyte is saturated a constant output is achieved.

The last 10 % of reading can take several minutes particularly if the gas is stationary. By making the gas turbulent on the membrane as the molecules are absorbed into the sensor they are replaced by new gas keeping the partial pressure constant and the sensor reaches equilibrium faster.

The effect should be exactly the opposite if 100% oxygen is suddenly replaced by air 20.9%. In practice very often the air is stationary. This means gas is trapped particularly if a flow divertor is left attached. The trapped gas being almost stationary only slowly passes molecules of oxygen back from the sensor into the atmosphere leaving the mechanism of the sensor to use up the oxygen in solution. A moving gas is required to clear the sensor of the oxygen



The flow divertor should never be used in Head boxes, Oxygen Hoods). Oxygen Tents or Incubators

3.4 Accuracy

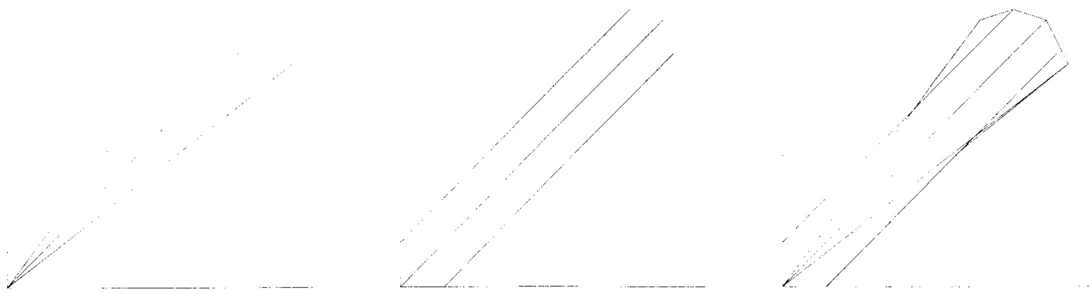
There are two main components affecting the accuracy of a monitoring system

Temperature:

The thermistor network can achieve an accuracy better than +/- 5% in tracking error which in practical terms means that a temperature change of 5-10 degrees Celsius will produce a maximum error of +/- 1% of reading. Measurements should be taken as soon as possible after a calibration and calibrations should be checked between measurements.

The method of display

When the micro fuel cell was originally introduced some 25 years ago electronics circuits to amplify dc voltages were not so stable as today so high output sensors and moving coil meters were the preferred method adopted. This method was adequate and for most purposes +/- 2% was acceptable. The accuracy limitation being almost entirely due to the moving coil meter. The specific limitation of accuracy with analogue meters is encountered in calibration technique. Setting a calibration of 20% instead of 20.9 is an error of 5% giving a reading of 95% when exposed to 100% oxygen. It is not uncommon with moving coil meters to only achieve maximum readings of 85% in 100% oxygen after a careless calibration at 21%. To lessen the inaccuracies all analogue systems should always be calibrated first at 100% particularly if mixtures over 50% are to be measured. As this is the most accurate method of calibration it is a good rule of thumb for all oxygen analysers. On top of user calibration inaccuracy the moving coil meter usually has an accuracy of +/-2% depending upon the type of movement and scale length.



A. Percent of Reading Errors   B. Percent of Full Scale Errors   C. Overall Accuracy

Digital readouts

Digital readouts can easily achieve a resolution +/- 0.1% and the errors can be contained well within the resolution of the final digit. It should be noted that the accuracy of the digital meter can never exceed the resolution and at very low oxygen levels e.g. at 10 % the 0.1% resolution is equal to +/- 1% accuracy.

The greatest measuring errors in the system will always be due to the operators .

These fall into three main categories the accidental movement of the calibration control during period between calibration and measurement , a severe change in environmental circumstances. method of measuring the gas.

Calibration can only be valid at the time unless there are no changes

3.5 Sensor life

Sensor life is a series of trade-offs. The basic formulae for the life of a sensor contains the amount of lead (physical size) the thickness of the membrane (speed of response) and the amount of energy taken from the sensor (type of readout)

The sensor life can be calculated as follows:

Life in months = Pb * K * 70% /I in 100% Oxygen (I = output current in Amps)
(Pb= Amount of lead)

K= 3.59 * 10 -4 (Proportionality constant)
70% = Anode efficiency.

Unfortunately it is impossible for the sensor to use up 100% of the lead. 70% is the worst case to be expected and is used to predicted expected life. Most sensors will be more efficient by using up more lead and therefore have a life longer than the predicted. No sensor should use less unless mistreated. As a rule sensors with an expected life in air of 48 months will have an expected life 1/5 of that in 100% oxygen i.e. 10 months
A sensor has a life expectancy measured in Oxygen % Hours.
e.g. an R-17 has a life expectancy of 700,000 O2% Hrs
This is 48 months in air

Other factors however play a part and one of the limiting factors is the electrolyte drying out. The thin layer of electrolyte between the membrane and the anode plays an important part in keeping the anode wet which in turn assures a minimum internal resistance during the oxygen sensing reaction. Membranes which are manufactured in Teflon are chosen carefully to match the sensor application. Thin membranes speed up the response but also allow water to diffuse more quickly out of the sensor. Thick membranes slow down the response and extend the working life of the sensor.
The ideal sensor has fast response yet long life. By using modern electronic circuitry it has been possible to combine these requirements and with reduced output create a sensor with a 7 second response time and an expected life of 48 months in air without greatly increasing the physical size. Such a sensor is the R-17 which has an output of 10.5mV in air nominally. The R-17 also has temperature compensation built into the sensor housing.

The R-17 and equivalent sensors have an expected life in air of 48 months. From the day they are manufactured they are consuming oxygen and converting lead into lead oxide. Eventually they fail. Failure of a sensor can be due to various factors.
the usable lead can be consumed.
The electrolyte can dry up.
The sensor can be physical damaged
The sensor can leak.

3.5 Extending Sensor Life

Theoretically the sensor could be starved of oxygen The theory being that the sensor uses up the oxygen in the volume of the cell saver cap and is left in Nitrogen which does not oxidise the lead. However due to the long life of the sensors , leakage or electrolyte drying out is as common as lead depletion and care has to taken concerning the environment surrounding the stored sensor..

Dry Gas

Great expense is expended by gas suppliers to produce dry air. Leaving the sensor in the resultant gas for any length of time will accelerate the drying out of the electrolyte.

Heat

Heat in the form of closed cars on hot days will encourage dry-out. Sensors should never be left in sunlight.

Sensor Exhaustion

When sensors near their exhaustion point they fail fairly quickly particularity in oxygen enriched atmospheres so should not pose the threat of inaccurate readings. As the lead is used up and/or the electrolyte dries out the internal resistance of the sensor increases reducing the output.
This can be checked by calibration in 100% and checking that the sensor returns to at least 22% on re-exposure to air. Where 100% Oxygen is not available sensors nearing exhaustion when calibrated in air may show drift either up or down either during calibration or when the sensor is returned to air after a reading.

Over pressure on membrane

Sometimes the electrolyte between the membrane and the cathode begins to dry out or has been squeezed by over pressure reducing the gap between the membrane and the cathode. In this instance the reduced volume of electrolyte can display itself as a slowly increasing baseline. If in doubt check calibration.

3.6 Sensor outputs

The output of a micro fuel cell although displayed as a percentage is actually proportional to the partial pressure of the oxygen in the gas mixture.

Applying Daltons law as the pressure increases the partial pressure increases. As the pressure decreases the partial pressure decreases.

Pressures in excess of 1Bar can be generated when the sensor is placed in a stream of gas e.g. the output of a CPAP flow generator .High flow rates can force gas onto the sensor faster than it can escape causing a back pressure on the membrane. This pressure is recognised by the sensor as an increase in partial pressure.

The sensor can be mounted in virtually any position without changing its sensitivity .

Gas Flow over sensors

Since the oxygen is diffused through a membrane the rate of flow across the sensor is not critical and can be 0.1-5 litres /min. without a substantial change in reading. This still depends on no back pressure being produced on the sensor face. Lower than 0.1L/min slows down the gas exchange on the sensor face and therefore slows down the response.

The sensor measuring position should always include an escape route for the gas to the atmosphere. Particularly at high flow rates any resistance to flow will generate a back pressure upon the membrane. High flow rates have difficulty in clearing the gas unless open to atmosphere and can cause a back pressure. This particularly relevant in CPAP circuits

Mechanical Shock

Although the sensors are rugged and can work in any position they are comprised of small internal components. Severe mechanical shocks can physically cause damage internally. The micro fuel cell was designed to be insensitive to shock, vibration and position. If the sensor is turned upside down quickly the baseline may show some movement due to the pressures generated inside the sensor case but should quickly return to its start point. The sensor can be accidentally dropped and usually has no ill effects. However the sensor is a mechanical device and can be weakened if regularly dropped or allowed to swing against solid objects

3.7 Humidity and water

Humidity does not directly affect the accuracy of the sensor however :-

Excessive moisture or condensation on the sensor surface will block diffusion of oxygen to the sensor and render it inoperative. In high humidity atmospheres hold the sensor facing down during calibration. Any droplets will have a chance to fall off the sensor membrane.

Using dry medical air for calibration will allow the flowing dry gas to evaporate any moisture on the sensor face.

Environments of 100% Humidity create a situation where the water vapour takes up a measurable volume of the gas and therefore reduces the partial pressure of the oxygen present in the air and reduces the reading

This effect can be calculated as follows.

Assuming STP Temperature = 25C pressure = 760mm and the gas is fully saturated 100% relative humidity

The Water vapour pressure from the standard tables is 23.756 mmHg

Vapour pressure tables exist which provide reference of water vapour pressure against temperature

%H2O =23.756 x100/ 760 = 3.13%

This is how much water vapour exists in the gas

In Air the original mixture dry contained 20.9% Oxygen the actual reading would be

20.9- (20.9 x 3,.13)/100 = 20.25 %

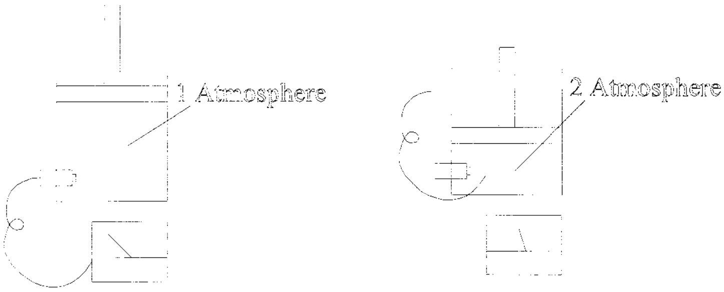
Error =0.65%

In order to obtain absolute accuracy the atmospheric pressure and temperature should be known. The relative Humidity should be 100%.

Sensors mounted in the inspiration side of ventilators also have moisture problems. The sensor holder is heavy and usually lies at the lowest part of the circuit where rain out moisture collects.

3.8 Pressure

Virtually all oxygen analysers measure the partial pressure and not the percentage of the gas they sense. The only time these instruments can accurately read percentages is when the pressure is atmospheric (1 Bar) and does not vary between calibration and measurement.
It is therefore important to calibrate the monitor at regular intervals (see manual).
Readings will be affected by Hyperbaric Chambers
Readings will be effected in closed circuits and systems under pressure



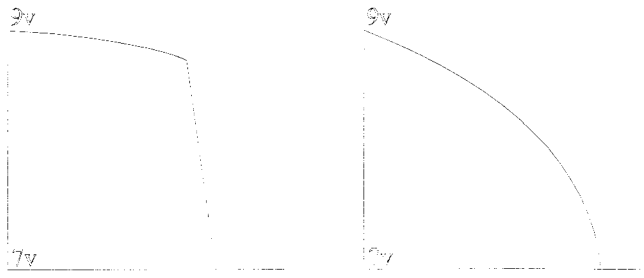
4.0 Using Oxygen Analysers

It is recommended that all Oxygen analysers employing galvanic oxygen sensors only be used a secondary measuring devices to verify the concentration of oxygen in gas mixtures

Setting Up An Oxygen Analyser

Battery Installation or replacement

Alkaline batteries are usually chosen because of their life and discharge characteristics. There can often be a point the internal stabilisation of the monitor electronics is critical upon the battery condition. The LCD readout will usually have a battery symbol of some kind to show the lowest condition in which the LCD is accurate. Unfortunately even slight deterioration after this point can cause inaccuracies in the reading. Alkaline batteries discharge very quickly at the end of there lives so if the battery warning symbol is ignored gross errors will be observed very quickly .



5.0 Sensor Installation

Gas Barrier bag

The gas barrier bags should not be punctured or have staples attached to them.

Sensor Leakage

Before removing the sensor from its protective bag visually inspect the sensor for damage or electrolyte leakage.

Sensor stabilisation

Allow the sensor a few minutes to stabilise after installation. Sensors are stored in special airtight gas barrier bags to slow down the electrochemical reaction during storage. During this period the sensor consumes the Oxygen in the container or bag leaving the sensor in Nitrogen.

Some sensors sometimes go into a "sleep" mode whilst being stored and occasionally may require 15 - 20 minutes exposed to air before they stabilise and can be used accurately. This is particularly true of sensors with no internal temperature compensation .

R-15 & R-23 may require 15 minutes before being able to calibrate.

T-1. T-2 can require much longer times.

If the sensor is left open to atmosphere for 1 hour it may require 1 hour to stabilise. These sensors require a maximum of 8 hours to stabilise

Care of Membrane

During installation and use do not touch or puncture the membrane. Oils from the skin can block the diffusion path.

Electrolyte

Sensor electrolyte is caustic.

Never let the electrolyte come into contact with skin eyes or mouth. If it does, flush the affected area with fresh water. See section on First Aid.

Never attempt to open or repair a sensor.

Check the sensor regularly for leaks. Leaking or exhausted sensors should be disposed of in accordance with local regulations which is usually similar to the disposal of batteries. For any problems with leakage or disposable consult the material safety data sheets.

Damage by Leakage

Sensors which become exhausted or leak whilst in sensor holders will cause damage to the sensor holder unless they are removed immediately and the sensor holder washed with water.

Care of Sensors

Never store sensors for long periods before use.

Never Subject sensors to High Temperatures i.e. (Car rear shelf)

Never Freeze sensors (left in cars overnight)

Never Subject sensors to physical shocks.

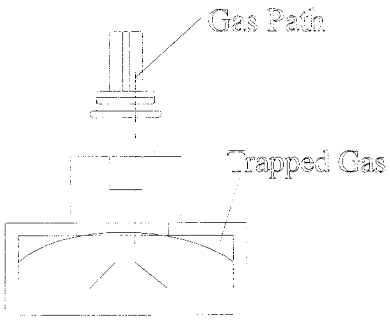
Never Subject sensors to vacuum

Never Submerge sensors in liquids

Never Attempt to open a sensor.

6.0 Flow Divertor

The flow divertor is designed to be used only in conjunction with the tee piece and only in flowing gases. Flowing gas is diverted onto the sensor face and decreases the time it takes the sensor to respond.



Failure to remove the divertor in static gas can cause the response time to be lengthened substantially and gas can become trapped in the area between the flow divertor bottom and the membrane.
It is essential that moving gas be present when the divertor is being used. Divertors must be removed in Incubators , oxygen tents , and Oxygen hoods.

7.0 Calibration

Ideally calibration should be set at 100% and then checked in air.
If the sensor is to be used in a flowing gas (CPAP) calibrate in a flowing gas. If the sensor is to be used in a stationary environment calibrate in a stationary gas.
As a rule of thumb calibration in air is usually sufficient for measurement up to 50%
All monitors should be regularly checked in 100% and Air to check linearity and air.
If a container or bag is used to contain the gas to be measured it must have pin size vent holes and the pressure must be allowed to return to ambient before a measurement is made.

Signs of end of life

Sensors deteriorate very slowly and near the end of their useful life may show a slow downward or upward drift in reading soon after calibration.

Tee method

The most accurate method of calibration is to use the Flow Divertor, Tee Piece and a two meter lengths of tubing
Flush with 100% Oxygen at a flow rate not exceeding 5 Litre/minute (a gentle stream of gas giving an audible hiss). When the reading is steady set 100% with the calibration control. Flush with Air. The reading should fall and reach a level between 20% and 22%
Always Calibrate prior to making a measurement

Room ventilation

Allow adequate ventilation in measuring area. In a confined space ambient Oxygen levels may build up beyond 21%. Check in fresh air. This can occur in neonatal units.

8.0 Storage of sensors.

8.1 Shelf Life

The useful life of the cell depends upon the concentration of oxygen . If it is left inside the sealed gas barrier bag its life expectancy should only deteriorate by 1/20 of its in air life per year. A shelf life of 1-3 years can be expected if sensors are stored correctly. The special barrier bag allows only a negligible amount of oxygen or moisture to pass through. It is not recommended that sensors be stored longer than absolutely necessary for warranty purposes. The sensor should retain 90% of its useful life after 24 months in the gas barrier bag.

8.2 Warranty
The Micro fuel cell has to viewed like a battery. Once manufactured its life depends almost entirely on the way it is used. Once the bag is broken the manufacturer has no control. The bags should be examined before opening for signs of leakage or damage. The manufacturer gives a two year limited warranty on the sensors from the date despatched. This is limited to faulty workmanship or materials but not exhaustion, i.e. exposure to air or oxygen. If possible examine the sensor in the bag and return unopened. If the sensor is removed from the bag and found to be faulty it should be returned immediately to the bag and submitted for examination.

8.9 Long storage times
Sensors stored for many months may not be covered by warranty when the bag is opened. Always purchase fresh sensors. All sensors have a serial number which can be traced to date of manufacture and quality control examinations. Never remove the label or deface the serial number

8.4 Testing Sensors
All sensors can be checked with a simple Digital multi-meter and a range of cables.
T1 , T-2 , T-5 & T5A.
The sensors require an equivalent to the temperature compensation circuit. i.e. approximately 200 ohms across the sensor. The current output can be measured.

R22, R23, R24 all have voltage outputs
Air 10.5 Mv +/-_ 3.0 Mv
100% Oxygen 50Mv +/- 15 Mv

The R-15 should have a load of 600 ohms and voltage can be measured
The R-23 has two outputs therefore half the R-15 output will be measured.

9.0 Types of Sensor .
How to find a Teledyne equivalent.
In most cases if it looks like a Teledyne sensor it has a Teledyne equivalent.

The exceptions are:
BPR sensor: small black sensor about 2cms in diameter with two pins for connection.
This sensor is very similar in output to a R-22
Critikon sensor: small green sensor
Sensors with replaceable electrolyte and membranes for which we do not have an equivalent.

T1 and T2 Galvanic sensors are usually used in sensor holders and originally had analogue readouts.
T2 is only to be used where Nitrous Oxide will be present. The T2 has a shorter life than the T-1
It has a reducing market as analogue readouts are being replaced with digital.
T5 and T5A were the first long life supercells from Telydyne and are only used in the Teledyne TED 140 and TED160 monitors.
Due to their output they require electronics to drive the display.
T5A is the Nitrous Oxide version.. However unlike the T2 the T5A has the same life as the T5 and can be interchanged.

The latest O.E.M monitors are starting to use R-17 sensors.

The Ohmeda Oxygen monitors , Draegar Oxygen monitor and HP Oxygen monitor module can be replaced safely by the R-15

Draegar sensors.
Draegar sensors are dual cathode sensors and are replaced by the R-23.

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The latest anaesthetic ventilators , and Intensive care ventilators from Draegar have been specifically designed to use both cathodes. These sensors can only be replaced with the R23.

Draegar incubators also use dual oxygen sensors and should be replaced with the R23.
It is important to be aware that the Draegar incubator appears to monitor the deterioration of the sensors and expects the sensors to track faithfully throughout there lives.

In line with Draegar they should be used in pairs . Never add only one sensor or the tracking system may prematurely reject it.

Draeger has a new mini sensor the S-1. There is no equivalent. This sensor has a very short life and in some areas it is replaced by the R-23 version. NB This requires special Draeger parts.

The R22, has been used for many years with Siemens ventilators.
The Servo 300 was specifically designed to take the smaller catalyst Research sensor.
Teledyne have now an equivalent in the R24. This sensor is 25% smaller and therefore has a shorter life expectancy.
It also has a higher output voltage and different temperature compensation circuits.

The R-13 is a direct replacement for the Ventronics sensor.

10.0 Problems with Sensors

Problems with sensors fall into three categories.

Electrical output failure,

No output the sensor is usually exhausted . These sensors are usually out of warranty or just inside warranty..
A proportion of sensors will leak. Sometimes the leakage is microscopic and cannot be easily observed.
Low output:: As with No output
A very small percentage of sensors fail within warranty due to exhaustion . Those that do usually fail early in there life cycle.
Erratic output: the erratic output can be caused by the sensor nearing the end of its life .
It can also be caused by mistreatment and physical abuse.

with T-1 & T-2 C1R & C2R the connections in the sensor holder can become dry joints .
A broken temperature compensation will generate a high output.

Mechanical failure,

Gross leakage is easily recognised
Anode disintegration can cause the sensor to rattle
Low levels of electrolyte can change the reading if the sensor is inverted.

User problems

Sensors are often returned with no fault found.
Usually the user has not tested the correctly.
Out of the bag new.
T-1 & T-2 type sensors have no thermal compensation acting as an electrical load. When the shorting clip is removed the sensor goes open circuit.

It can take up to 8 hours to stabilise. Sensors reading high should either have the shorting clip replaced or be left in a working sensor holder plugged into the instrument for several hours.
R-15 & R23 have a similar effect where they appear to go to sleep. This is due to all the Oxygen in the sealed bag being use up leaving the sensor in a Nitrogen atmosphere.

Humidity

Many sensor are returned reading low but on arrival no fault is found. In most ventilator circuits the sensor is heavier than the tubing and lies at the lowest point. Water collects in the sensor and gives a low reading or very slow response. By the time it reaches us the water has dried out.

Breakage of T-7 threads.

This will only happen if the sensor is dropped and hits the floor on the corner of the shoulder.

Pressure

CPAP circuits generate a lot of user problems initially until the user learns to calibrate in the same flow rate as the gas to be delivered

Response

The fast response of the sensors can show
Breath by breath variation in ventilators
Variations in oxygen Hoods and oxygen tents.
In this situation the sensor should be placed near the patients mouth.