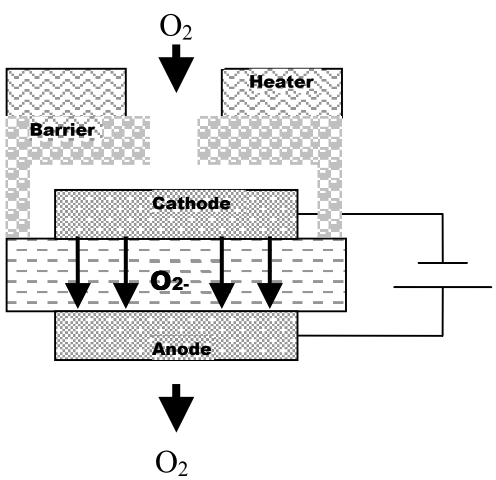
Delta F Solid State Coulometric Oxygen Sensor

This Technical Bulletin provides individuals who need to monitor oxygen an appreciation for the suitability of the Delta F Solid State Coulometric Sensor's capabilities. This new offering is Delta F's first departure from the non-depleting electrochemical sensor used in all of our traditional oxygen analyzers. Those familiar with the working principle of the Delta F non-depleting coulometric sensor will notice the similarities between the working principle of the solid state coulometric oxygen sensor and our electrochemical sensor. The flow of electrons, or current, from an electrochemical reaction is measured directly to provide the sample gas oxygen concentration. The nature of the solid state coulometric sensor provides advantages over our traditional sensor in some applications.

<u>Why Solid State Coulometric?</u>

As with any analytical application, It is important to understand the advantages and disadvantages of a particular oxygen sensing technology before you buy. Experienced users know that not every oxygen analyzer is suitable for every application. For example, non-depleting electrochemical oxygen analyzers are highly stable, have superior measurement sensitivity and are therefore unmatched for ppb-level oxygen measurement. However, they would be destroyed very quickly in applications having high concentrations of solvents in sample gases. Paramagnetic oxygen analyzers on the other hand can be made of chemical resistant materials and are therefore a good fit for making percent level measurements in solvent laden sample gases. However, they lack low end sensitivity to make low ppm measurements. The list of oxygen sensor technologies that work well in specific applications is extensive. Delta F is now offering a *<u>solid state coulometric</u>* oxygen sensor to satisfy a segment of ppm and percent-level oxygen monitoring needs. This sensor's attributes, detailed below, fulfill some application needs where other oxygen sensing technologies have left users dissatisfied with their performance.

<u>Principle of Operation</u>



<u>Sensor Diagram</u>

The solid state coulometric oxygen sensor is used to measure oxygen by counting the number of electrons flowing through its circuit. The circuit is connected between the sensor's cathode electrode and its anode electrode. A Polarizing DC voltage is used to facilitate the flow of electrons. Oxygen from the sample gas gets to the cathode electrode by diffusing through a very small hole in a barrier covering the cathode. Oxygen molecules in contact with the cathode are reduced according to the following electrochemical reaction:

$$O_2 + 4e^- \rightarrow 2O^{2-}.$$

The oxygen ions, O^{2-}, are attracted though a solid electrolyte that is heated to 400°C and are converted back to molecular oxygen at the anode electrode. The electrochemical oxidation reaction that takes place at the anode is:

$$2O^{2-} \rightarrow O_2 + 4e^-$$

The quantity of electrons ($4e^-$) that flow through the circuit between the cathode and anode is proportional to the concentration of oxygen in the sample gas. This flow of electrons, or current, is measured by the analyzer electronics and the oxygen concentration is displayed.

Attributes & Limitations of this Sensing Technology

Users of Delta F analyzers featuring the solid state coulometric sensor will realize the following benefits:

Calibration/Stability:

Systems with this sensor are factory calibrated, allowing them to be used immediately without anyone having to calibrate them in the field prior to use. The analyzer will maintain its accuracy over time. The sensor is not consumed when it is exposed to oxygen, it does not require a constant purge to protect the sensor when the analyzer is not being used and its lifetime is not dependant on how much oxygen it is exposed to.

Sensor Size/Packaging:

The sensor is very compact. It occupies a space less than 1" cube. Its small size allows it to be not only packaged as a traditional "flow-through" sensor, but also for in-situ measurement. The in-situ sensor is supplied mounted on a bulkhead fitting. The bulkhead fitting and sensor penetrate less than 2" from the wall it is mounted on. The in-situ design allows you measure the oxygen content of your process environment directly. There are no pumps or extractive sample systems required with an in-situ sensor. In-situ measurement also eliminates consumption and disposal of sample gas.

Ranges of Operation:

Three ranges of analyzers using the solid state coulometric sensor are available: 0-10,000ppm, 0-25% and 0-100%. One of these three ranges must be specified at the time of order. The 0-10,000ppm range sensor has resolution of 0.5ppm near zero. The 0-10,000ppm range analyzer is designed for those applications requiring accuracy at less than 1,000ppm, but greater than 0.5ppm. The 0-25% range sensor is designed for applications requiring accuracy between 0.1% (i.e. 1,000ppm) and 25%. The 0-100% range sensor is designed for applications requiring accuracy between 1% and 100%.

Speed of Response:

The sensor responds very quickly to changing oxygen concentrations. The 0-10,000ppm range sensor can be exposed to air and in less than a minute it will measure <10ppm on pure nitrogen. This makes the sensor attractive for users who have upset prone applications and need to make ppm-level measurements. In addition to being fast to respond to changing sample gas concentrations, the performance of the sensor is not affected by reasonable changes in flow rate.

Sensor Replacement/Durability:

The sensor does not get consumed when oxygen is being measured and has a long life expectancy. However, in the real world there may be applications or situations that can damage any sensor. Users can be assured that the replacement cost for a solid state coulometric sensor is low.

Operating Pressure:

Since both the cathode and anode electrodes are in direct contact with the sample gas, the sensor can operate from sub-atmospheric pressure up to 100psig.

Electrolyte Maintenance:

The sensor uses a solid ceramic electrolyte and, therefore, no periodic electrolyte maintenance required. The sample gas will not be humidified or adulterated in any way after it passes by the sensor. This is a key consideration for individuals wishing to make in-situ measurements or who wish to recycle sample gas from a "flow-through" analyzers exhaust back into the process.

No Dependence on O_2 Content in Air as Reference Gas:
The sensor does not need a reference gas to support the measurement. Changes in barometric pressure or elevation have traditionally affected analyzers relying on air as a reference gas.

As with any oxygen sensing technology, this sensor does have some limitations.

Background Gases:
The sensor cannot be used with sample gases containing hydrocarbons, combustibles, H_2, CO, NO_2, S, or Pb. If the analyzer were sampling any of these gases, it may give false low readings or the sensor may be damaged.

Low Level Sensitivity/Accuracy:
This sensor is not designed for ppb-level analysis. It is limited to those applications that require accuracy above 1ppm. It will work well in applications requiring measurements to be made at ppm and/or percent level, provided none of the above mentioned gases are present.

All things considered, the solid state coulometric sensor has many characteristics that make it attractive for a number of applications and is complementary to our standard sensor. Contact Delta F for more specific information on how this oxygen sensing technology can work in your application.