EC250 ELECTROCHEMICAL SENSOR

TECHNICAL BULLETIN 014

Percent oxygen measurement, 0 to 100%
For gas blending, ambient air monitoring, and process control applications

Introduction

The Neutronics EC250 (CAG250) oxygen sensor is designed to measure oxygen in the range of 0 to 100% by volume. The sensor output is linear with respect to the partial pressure of oxygen. Although it is similar to conventional galvanic oxygen sensors (lead anode / KOH electrolyte) in operation, the chemistry of the EC250 sensor is quite unique. By using a weak-acid electrolyte, this sensor can withstand high levels of CO_2, CO, and other acidic gases. This results in a sensor with a superior technical advantage over KOH type sensors in applications where these gases are present.

Operation

The EC250 sensor housing holds a lead anode, oxygen cathode (gold), and weak-acid electrolyte. A non-porous Teflon FEP membrane is bonded to the gold electrode. Oxygen permeating the membrane is electrochemically reduced at the gold electrode. The current generated is directly proportional to the partial pressure of oxygen at the sensing surface of the cell.

The reaction equations are:

Cathode	$O_2 + 4H^+ + 4e \rightarrow 2H_2O$
Anode	$2Pb \rightarrow 2Pb^{++} + 4e$
Overall	$O_2 + 4H^+ + 2Pb \rightarrow 2H2O + 2Pb^{++}$

In both the KOH and weak-acid type cells, the net reaction generates PbO. The PbO is normally dissolved into the electrolyte, however, there is a point at which the electrolyte becomes saturated with PbO. At that point, PbO precipitates onto the lead anode, which can cause eventual cell failure.

The weak-acid electrolyte has a higher capacity to dissolve the PbO than the conventional KOH electrolyte. This gives the EC250 sensor a more stable signal and an exceptional service life characteristic.

Features

- Wide measurement range – 0 to 100% oxygen
- Rapid response time – T_{90} < 15 seconds
- Long service life – expected sensor service life is > 2 years
- Patented weak-acid based technology – withstands high levels of CO_2, CO, and other acidic gases
- Low output drift – less than 1% drift over an 8 hour operation period at constant temperature and pressure

Applications

Industrial safety	Emissions monitoring
Oxygen deficiency monitoring	Glove box systems
Contact lens manufacturing	Hazardous material storage areas
Controlled environments	Inert gas purity / nitrogen purity systems
Cryogenic gas storage areas	Laboratory and research facilities

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Description

The EC250 sensor is designed with an integral temperature compensation circuit (see Figure 1). The circuit compensates the cell output from 5° to 40°C.

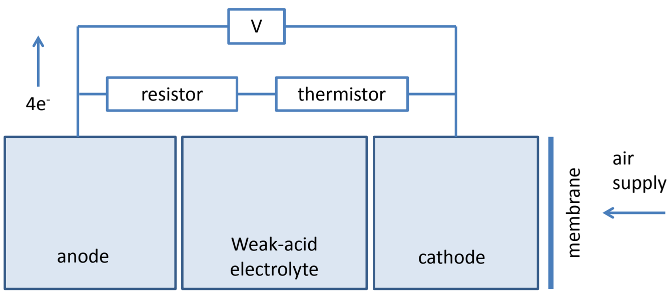

Fig. 1, sensor schematic

The use of acetic acid electrolyte results in two exceptional characteristics. The sensors exhibit low or non-existent cross sensitivity to gas species common in the end products of combustion, and they show excellent signal stability to changes in position and to motion.

The sensors show little effect by other gases including refrigerants and hydrocarbons. However, since the electrolyte is acidic, the sensors show some sensitivity to high concentrations of caustic vapors (see Figure 2).

Effect	Type of gas
Minimal effect	CO_2, CO, H_2S, NO_x, N_2, Ar, H_2, CH_4
Minor effect	Cl_2, CFCs, SO_2, NH_3, HCl
Moderate effect	IPA, Hexane, CCl_4
Severe effect in high concentrations	Sodium hydroxide, Acetone*, MEK* (*strong degradation to CPVC housing)

Fig. 2, cross sensitivity

Signal output

The EC250 sensor is linear with respect to the partial pressure of oxygen and compensated for the effect of temperature in the range of 5° to 40°C. Each new sensor has a unique signal output which will fall within the area defined between the HI and LO curves as depicted in Figure 3. The accuracy in full scale (100% oxygen) is ± 2% or better over the operating temperature range. At constant temperature and pressure, the accuracy in full scale is ± 1% or better.

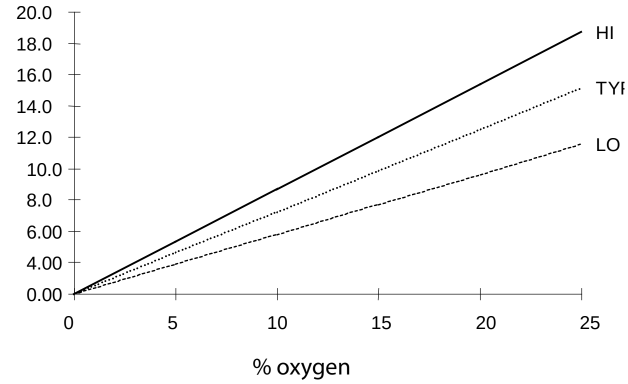

Fig. 3, mV signal output @ 0-25%

Response time

The EC250 sensor responds to step changes in oxygen concentration on the order of 97% of the final value within 25 seconds or better. For example, if the sensor is exposed to 100% nitrogen from a starting concentration of 20.9% oxygen (air), the sensor output will correctly decrease to an equivalent t of 0.6% oxygen in 25 seconds or less.

The sensor responds to a 90% step change in oxygen concentration within 15 seconds or better. For example, if the sensor is exposed to 100% nitrogen from a starting concentration of 20.9% oxygen (air), the sensor output will correctly decrease to an equivalent of 2.1% oxygen in15 seconds or less.

Zero offset

The housing material for the EC250 sensor is CPVC plastic. Theoretically, some oxygen from the surrounding air can permeate the housing wall into the sensor resulting in an extremely small baseline voltage. However, equilibrium with the surrounding air is quickly reached after the sensor is manufactured. The resulting baseline voltage of the typical sensor is very stable. When a gas stream consisting of 100% nitrogen in exposed to the sample port of the sensor, the baseline voltage (zero voltage) will be 500µV or less.

Humidity effects

The concentration of oxygen varies directly with changes in the relative humidity (RH) of the sample gas. That means that the output of the EC250 sensor is directly proportional to changes in the RH of a sampled gas. Figure 4 shows the change in concentration of oxygen in ambient air for the range of 0-100% RH at different temperatures. The change in the oxygen concentration is directly related to the dilution effect of water vapor.

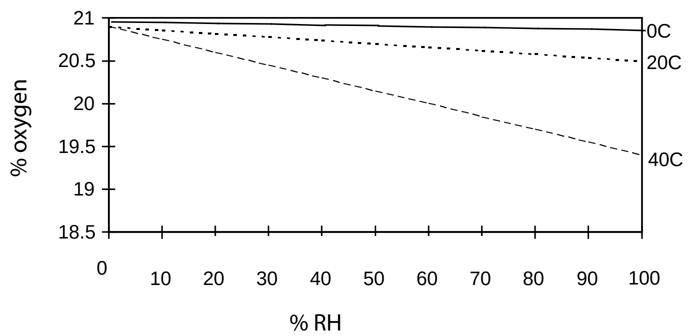

Fig. 4, humidity effects

Stability

Under normal operating conditions, the EC250 sensor exhibits less than 1% (full scale) drift over an 8 hour operation period at constant temperature and pressure. Factors that determine long-term stability and drift include:

- Operating temperature
- Sample pressure
- Shock/vibration
- Chemical exposure

Signal drift during sudden temperature changes is due to the response of the temperature compensation circuit, included in the EC250 sensor. The thermal mass of the sensor typically slows down any transient temperature effects. However, the EC250 may exhibit a slight increase in signal output when exposed to rapidly changing ambient temperatures. The drift is temporary as the sensor body normalizes with the surrounding ambient temperature. As a result, the sensor signal will not exhibit drift to changes in temperature of less than 1°C per hour.

Pressure effect and sample flow

The partial pressure EC250 is affected by changes in barometric pressures. The signal output is proportional and linear with respect to changes in the resulting partial pressure of oxygen. The relationship of signal output to changes in the barometric pressure may be expressed by the formula:

$$S_t = S_{measured} \times P/1013$$

Where:
St = theoretical signal output
Sm = measured signal output @ 1013 mbar
P = barometric pressure (mbar)

The sensor output is not directly affected by sample flow, however, a minimum flow of 3 sccm should be maintained to ensure sample exchange at the sample port. A sample flow of 100 sccm is typical for most applications.

Expected service life

Since the EC250 is a galvanic type cell, service life is calculated based on the theoretical consumption of cell components (lead anode and electrolyte). Life is stated in oxygen-percent hours:

[oxygen concentration (%)] x [exposure time (hours)]

For the EC250, service life is estimated at approximately 1,500,000 oxygen % hours. That indicates an expected lifetime of more than 5 years in ambient air (20.9% oxygen). It is important to note that several factors affect the actual service life of the sensor. These include storage temperature, operating temperature and pressure, and exposure to chemicals.

Installation guidelines

The EC250 sensors (see Figure 5) are designed for industrial applications. Guidelines for use include:

- Do not expose the sensor to gas sample streams that exceed the recommended operating temperatures
- For optimal performance and service life, mount the sensor with the sensing surface pointed down or in a horizontal position. Do not install the sensor with the sensing surface pointing in an upward position. Follow these recommendations for sensor storage.
- Take precautions to prevent condensation on the surface of the sensing surface
- Do not expose the sensor to biased voltage

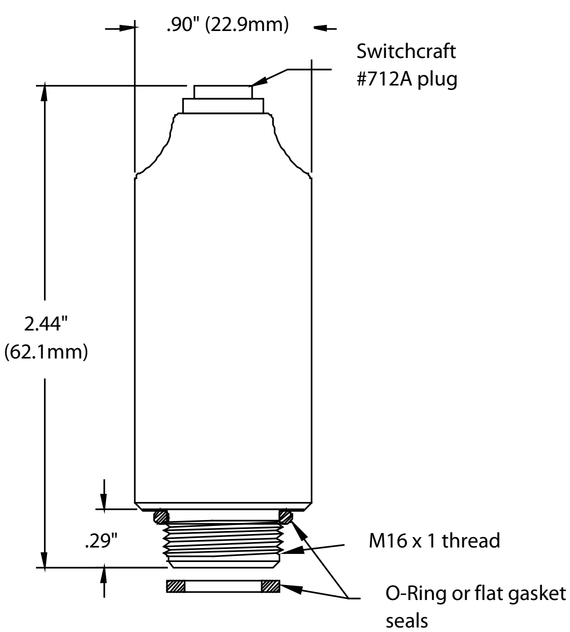

Fig. 5, sensor configuration

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Technical specifications

Measurement technology	Electrochemical
Measured gas	Oxygen
Measurement range	0 to 100%
Output	10.0 to 15.5mV in air at 1013 mbar and a temperature range of 23 ±2°C
Zero offset	≤ 0.50mV when exposed to 99.9% to 100% nitrogen at STP
Response time (T_{90})	≤ 15 seconds at 23 ±2°C
Linearity	Within ±1% of full scale
Stability	< 1% of full scale over an 8 hour period at constant temperature, pressure, and humidity
Operating service life	> 24 months (> 1,500,000% oxygen hours under normal operating conditions)
Operating temperature range	5°C to 40°C (41°F to 104°F)
Zero offset	≤ 0.5 mV when exposed to 99.9% to 100% nitrogen
Humidity range	5 to 95% RH non-condensing
Storage life	6 months
Optimal storage temperature	5°C to 25°C (41°F to 77°F)
Maximum storage temperature	-15°C to 50°C (5°F to 122°F)
Interference	< 2% of full scale in presence of 10% carbon dioxide < 2% of full scale in presence of 70% helium < 2% of full scale in presence of 75% nitrous oxide < 2% of full scale in presence of 5% halothane
Pressure effect	Continuous use in pressure range from 0.5 to 1.5 atm
Electrical connector	Switchcraft 712A power connector
Process connection	M16 x 1 thread
Mounting	For optimal performance, install the sensor with the sensing surface pointing down or horizontal
Warranty	12 months from date of shipment
Part number	C1-16-1000-01-0

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