Oxygen Sensor Output Varies with Temperature

Introduction

Oxygen gas sensors generate a current that is proportional to the oxygen concentration. This generated current also changes when the temperature of the sensor changes. The reason is as follows:

Partial pressure oxygen sensors depend on the partial pressure of oxygen to drive the oxygen through a solid membrane. The oxygen that has diffused through the membrane is then reduced on the cathode to generate a current. This type of sensor changes its output with temperature as the permeability of the solid membrane changes with temperature. Unfortunately these sensors use a polymeric membrane whose permeability is very dependent on temperature: about 3% change in output for each degree Celsius change in temperature. Adding a thermistor or other temperature detector can compensate for this error, although this increases the cost and size of the sensor and will require the sensor and the detector to be matched with respect to their thermal responses.

In contrast, Alphasense **mass flow oxygen sensors** use a very small capillary to restrict the flow of gas to the cathode. This type of sensor changes output with temperature due to the change of viscosity of the gas. Theoretically, Alphasense oxygen sensors should change by the square root of the Kelvin temperature which at 20°C is only 0.17%/K (about 20 times better than partial pressure oxygen sensors). This type of sensor is called a "mass flow control" sensor.

How Do Alphasense Sensors Perform?

Alphasense oxygen sensors show repeatable temperature dependence from sensor to sensor. The graph in Figure 1 shows the output for four sensors from -30 to 55°C. These results are repeatable from batch to batch.

Compensation

Temperature performance of Alphasense oxygen sensors can be improved by measuring the temperature of the sensor then correcting for ambient temperature changes. Ideally the temperature at the top of the sensor should be monitored. This is not a problem when instruments remain at constant temperatures, but with portable instruments the user will often see rapid and large temperature changes, so the position of the temperature compensation is important. The simplest compensation is a straight line with a slope of -0.17 (± 0.01)%/ K.

Batch-to batch repeatability

Figure 2 below shows the temperature dependence of eight O2-A1 oxygen sensors. This batch is typical and table 1 below lists the 95% confidence interval for twelve batches of sensors, manufactured over a one-year period. Use the results from this table when writing a correction algorithm for oxygen sensor temperature compensation.

Figure 1 Sensor output temperature dependence, with theoretical fit shown (-)--- line)

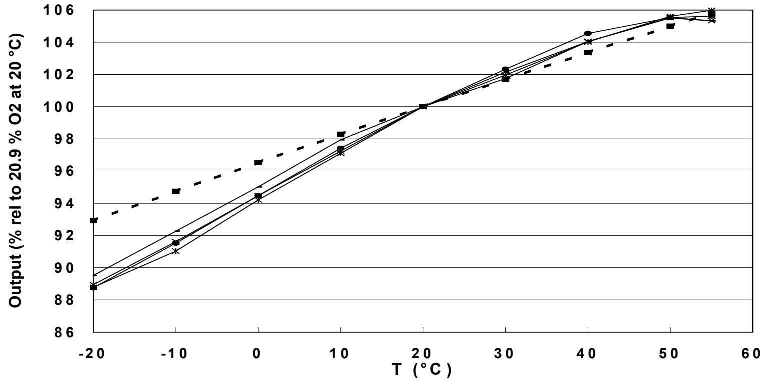

Figure 2 Typical temperature dependence for Alphasense oxygen sensors

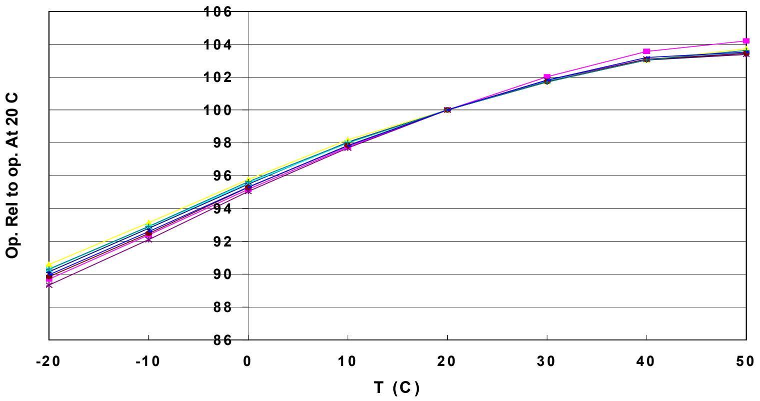

Table 1 Mean and +/0-95% confidence interval temperature correction, referenced to 20°C, for Alphasense oxygen sensors.

Temperature (°C)	-95% conf. interval	mean	+95% conf. interval
-20	87	**90**	93.5
-10	92.0	**92.5**	93.0
0	94.5	**95**	95.5
10	97.3	**97.5**	97.9
20	100 (reference)	**100**	100 (reference)
30	101.8	**102.2**	102.5
40	103.5	**104**	104.2
50	103	**105**	106

Very Low Temperature Use

Alphasense sensors have been tested down to -40°C (just below the freezing point of the electrolyte). Sensor-to-sensor variability and temperature dependence both increase below -20°C. If the sensor has been cooled below -37°, then on reheating, hysteresis will be observed and the sensor may require re-calibration. We warrant performance to -20°C, and warranted lower temperature limit of use is -30°C.

Transient Behaviour

Rapid changes in temperature can affect the sensor in the short term. Very fast temperature changes can create a transient current that will decay as the sensor comes to thermal equilibrium. The faster the temperature changes the greater the transient behaviour. The greatest transient performance is seen at temperatures between -5°C and 0°C. Although all oxygen sensors show this transient behaviour, Alphasense's programme of continuing improvement includes proprietary processing to minimise this problem so you will observe smaller transient currents with Alphasense oxygen sensors.

Summary

1. Alphasense oxygen sensors calibrated at 20°C change output <±1%(oxygen) from 0° to 40°C.
2. Alphasense oxygen sensor temperature dependence is repeatable: a universal software algorithm for compensation can be used.
3. When compensating for temperature changes, monitor the temperature near the top of the sensor.
4. Avoid usage near the electrolyte freezing point: stay above -30°C.
5. Use table 1 for temperature compensating Alphasense oxygen sensors.
6. Mass flow oxygen sensors from Alphasense show superior temperature performance to partial pressure sensors from other manufacturers.

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