Accurate measurement of gaseous oxygen at very low oxygen levels

Introduction

There are many oxygen gas analysers available that can measure oxygen concentrations down to percentage levels or a few ppm. A few instruments can even sense oxygen levels well below 1ppm, such as Cambridge Sensotec's Rapidox 3100 which can detect oxygen down to 10 -20 ppm. Since calibration gases are commonly available only down to 10ppm or 15ppm how can one be sure that such very low oxygen measurements are accurate?

Low oxygen sensor technology

Many ppm oxygen analysers such as the Rapidox range contain a solid-state oxygen sensor known as a zirconia sensor. Sensors of this type are commonly used in car exhausts to ensure optimum fuel ef ciency and minimum emissions. The zirconia sensor consists of a zirconium dioxide ceramic electrolyte with gas permeable platinum electrodes. It is open to the atmosphere at one end and exposed to the gas at the other.

When the sensor is heated to temperatures of 350 deg C and above the ceramic material conducts oxygen ions. Disparities in oxygen levels on the two sides of the sensor will result in the generation of an electrical voltage and this voltage serves as a measure

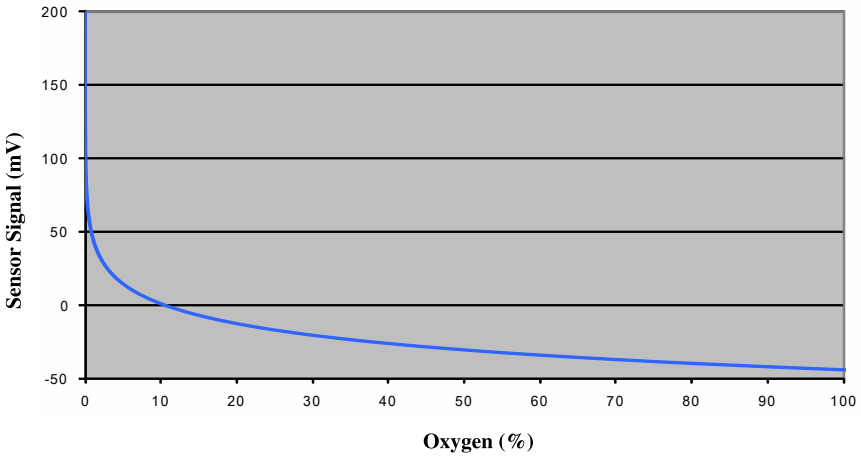

Diagram 1: Nernstian sensor signal from zirconia sensor LINEAR PLOT

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of how much oxygen the gas contains relative to the atmosphere. The signal voltage follows the Nernst equation and gives a logarithmic response to oxygen levels so that the sensor signal increases logarithmically as oxygen levels reduce.

Diagram 1 shows a graph of the sensor signal in mV against oxygen concentration. The graph illustrates that at oxygen levels of a few ppm and below the sensor signal response to changing oxygen levels is very great. At very low oxygen levels the sensor has a large response to any change so that it can very accurately detect changes in very low levels of oxygen.

If the sensor response is redrawn on a logarithmic scale as shown in Diagram 2 it becomes clear that the sensor response is perfectly linear through each decade of oxygen concentration. This means that the accuracy of the sensor is maintained over each decade of oxygen concentration and does not diminish as zero oxygen concentration is approached.

Measuring oxygen levels at 5ppm O2

Let us assume we wish to measure 5ppm oxygen but have only air and 10ppm calibration gas available. The graph in Diagram 2 shows the points where the oxygen partial pressure is 21% (air), 10ppm and 5ppm. With the zirconia sensor calibrated in air and at 10ppm the 5ppm operating point will fall outside the calibration points. However, the sensor gives a logarithmic response and in logarithmic terms 5ppm is very close to 10ppm. This logarithmic nature of the zirconia sensor means that high accuracy is maintained as oxygen levels fall below the lower calibration point, and this response continues down to extremely low oxygen.

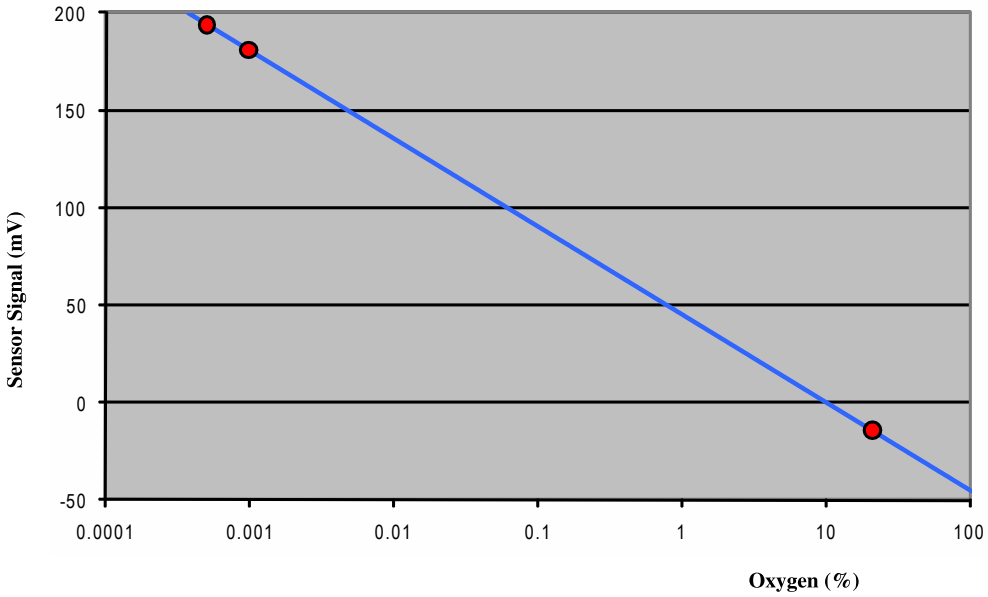

Diagram 2: Nernstian sensor signal from zirconia sensor LOGARITHMIC PLOT

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