RAE SYSTEMS by Honeywell

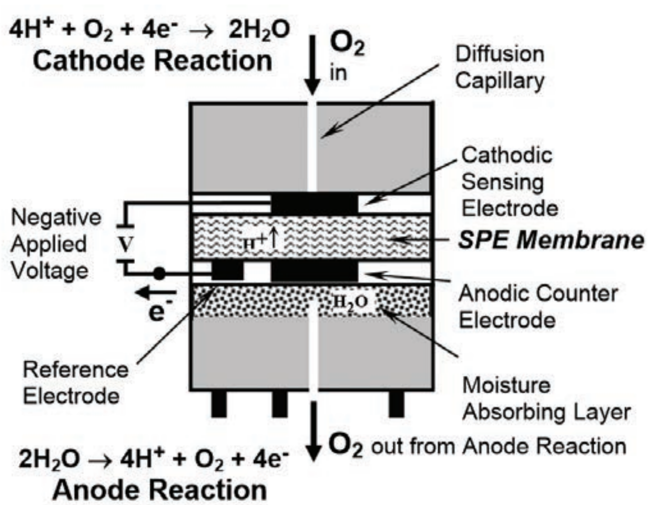
SPE (SOLID POLYMER ELECTROLYTE) OXYGEN SENSOR

INTRODUCTION

This Technical Note describes the characteristics and use of the SPE oxygen sensors. These sensors offer longer life and avoid the leakage problems associated with traditional O2 sensors containing lead wool and liquid electrolyte. RAE SPE sensors come in two variants: a low power version for the ToxiRAE II (p/n 022-0100-000) and a higher power version (p/n 022-0103-000) for selected gas meters with rechargeable batteries including the VRAE, QRAE Plus, and EntryRAE. The SPE O_2 sensors are not compatible with the MultiRAE or AreaRAE series monitors.

SPE Sensor Design

The figure below shows the main components of the SPE oxygen sensor. A negative (cathodic) bias voltage is applied between the platinum sensing electrode and the reference electrode. Oxygen enters through a capillary and is reduced to water at the sensing electrode. The capillary limits the amount of oxygen reaching the electrode by diffusion. In the other half-cell, water is oxidized to oxygen, and protons are released. The protons travel across the SPE membrane, and O_2 is vented through a second opening on the bottom side of the sensor. Humidity is absorbed from the ambient air and is stored in a water-absorbing layer. This layer and the SPE membrane are moist, but not wet, and therefore the sensor cannot leak.



The amount of current necessary to reduce the incoming oxygen at the sensing electrode is proportional to the concentration of oxygen in the atmosphere being sampled. The net reaction of oxygen entering the top and leaving the bottom gives rise to the common name of "oxygen pump" for this type of sensor.

Comparison to Lead Wool O_2 Sensors

Both SPE and lead wool sensors have similar size and operate in the range 0-30 Vol.% O_2 with a resolution of 0.1 Vol.%. The chief advantage of the SPE sensor is that the reagents (O_2 and H_2O) are continually supplied from the ambient air, whereas the lead wool sensors have a limited supply of reagent (Pb) that is gradually consumed. Therefore, SPE sensors are theoretically capable of operational lifespans of two to five years, whereas lead wool sensors last at most two years. In addition, SPE sensors contain no toxic lead metal or liquid electrolyte. During normal use, Pb wool sensors convert lead to lead oxide (PbO_2) which has a larger volume than the original wool. This causes the cell to expand, creating a risk of cracking and leaking the liquid electrolyte.

The main drawback to the SPE sensors is that they tend to have higher power consumption. To address this issue, RAE Systems has developed special, low-power-consuming SPE sensors for that can operate in the ToxiRAE II for up to 1 year on a single, non-rechargeable lithium battery. This was accomplished without significantly compromising the resolution, while the response time increased somewhat from about t_{90} = 15 seconds to t_{90} = 30 seconds.

In summary, the SPE compared to the lead wool sensor has:

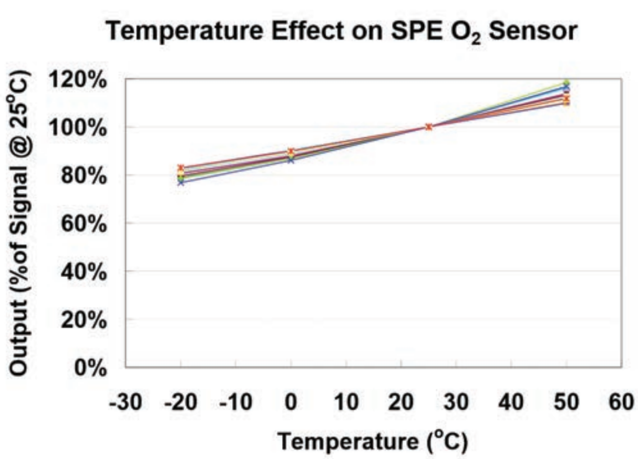
1. Longer inherent life because the reagents are constantly replenished
2. No liquid electrolyte to leak out
3. No toxic metals
4. Lighter weight
5. Less pressure effect when used in rechargeable monitors
6. Higher power consumption
7. Similar matrix gas effects
8. Both require some ambient humidity to function long term and prevent the electrolyte or membrane from drying out
9. Slightly greater temperature effects, but lower thermal mass for more accurate temperature compensation (see below)

Pressure and Humidity Effects

The SPE oxygen sensor shows no significant effects of humidity or pressure. However, during a sudden change in either of these factors, there may be a transient response that soon equilibrates. For example, when going up or down an elevator of a high-rise building or mine shaft, or when moving from an air-conditioned building to humid outdoors, allow a few minutes for the response to equilibrate. Pressure equilibrations takes longer on the ToxiRAE II than the rechargeable instruments because of the smaller pore inlet diameter on the former. The normal operating pressure is ±10% of ambient and the humidity must be greater than 5% to provide the water needed for reaction and prevent the SPE membrane from drying out.

Temperature Effects

The figure below shows that the sensor response increased with increasing temperature. In some instruments such as the ToxiRAE II and QRAE Plus, this effect is canceled through firmware compensation, allowing calibration at room temperature while measuring at other temperatures. For some instruments, this effect may need to be compensated by calibrating as close as possible to the use temperature. Check the instrument manual to determine if the oxygen sensor has temperature compensation.



Matrix Gas Effects

Because both lead wool and SPE oxygen sensors rely on capillary diffusion to limit the rate of oxygen entering the cell, the matrix gas effects are the same. The effect of the matrix gas can be estimated using Graham's law of diffusion:

$$\text{Response(Matrix 2)} = \text{Response(Matrix 1)} \times (MW_1/MW_2)^{1/2}$$

Where MW_1 and MW_2 are the molecular weights of the matrix gases. Air can be considered a mixture of 20.9% oxygen in a matrix gas of 70.1% nitrogen, which has $MW_1 = 28$. Thus, if an oxygen sensor is calibrated in air and then used to measure 20.9% oxygen in argon (MW2 = 39.95), the sensor would read:

$$20.9\% \times (28/39.95)^{1/2} = 17.5\%$$

Similarly if used to measure 20.9% O2 in a light gas such as helium ($MW_2 = 4$), the response would be:

$$20.9\% \times (28/4)^{1/2} = 55.3\%$$

If a mixed matrix gas is used, then MW_2 is the average molecular weight calculated from the mole fraction. For example, in a mixture of 80% argon and 20% helium, the average MW_2 is

$$(0.8 \times 39.95) + (0.2 \times 4) = 32.76$$

and the response of 20.9% O_2 would be

$$20.9\% \times (28/32.76)^{1/2} = 19.3\%$$