Tech/App Note 14

Oxygen Sensors: Lead-Free vs Standard Lead Type

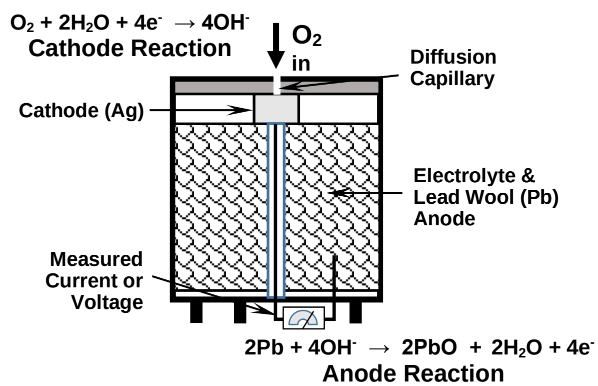
Why Use a Lead-Free Oxygen Sensor?

Compared to standard oxygen sensors, lead-free sensors:

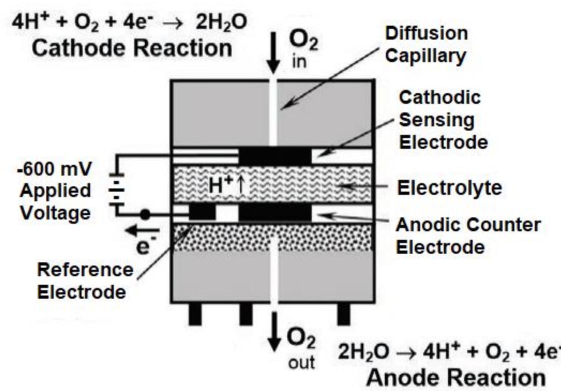
- Are higher cost but longer-lived, not prone to leakage, lighter weight, contain no toxic materials, but use more power.

Sensor Design

The **Conventional "standard" Oxygen Sensor** is a galvanic cell, which uses a sacrificial anode of lead wool and an inert cathode. The cell is low-cost and the reaction proceeds without external power by the net oxidation of lead to lead oxides: $2Pb + O_2 \rightarrow 2PbO$. Once the lead is consumed, or the solid $PbO/Pb(OH)_2$ completely coats the Pb surface, the sensor stops working. The resulting lead oxyhydroxides have higher volume than the original lead wool, and therefore the contents expand and build pressure, causing a tendency to leak. The life of the sensor depends on the rate at which oxygen diffuses in, which is controlled by the diameter of the inlet capillary. A narrow capillary allows sensor lives of up to 3 years, but can result in transient pressure effects and false alarms.



Galvanic Oxygen Sensor with Lead



Catalytic Lead-Free Oxygen Sensor

The **Lead-Free Oxygen Sensor** uses catalysts and an applied voltage to reduce oxygen at the cathode and regenerate it at the anode. Because there is no consumable material, the sensor can last a long time, typically 5 or more years, until somehow the catalyst becomes deactivated, the inlet capillary becomes plugged, or the electrolyte dries out. There is also no significant volume change and thus these sensors are not prone to leakage. The need for an applied voltage causes lead-free sensors to use more power and therefore they are most commonly employed in instruments with rechargeable batteries such as the POLI or MUNI. However, by using a narrow inlet capillary the power draw has been reduced enough that lead-free oxygen sensors can be used in the UNI, albeit with more frequent battery replacements. Note also that the outlet pore must not be blocked, so that the regenerated oxygen can escape out the bottom of the sensor.

Further Comparison and Summary

The table below summarizes the advantages and disadvantages of both types of sensors. Although the lead-free sensor has a higher initial purchase cost, its longer life means that the cost is usually lower for long-term use. Both sensors have a fast response time of about 10 seconds or less, although direct comparisons show the lead-free sensor to be a bit faster, and the galvanic sensor slows a bit with age as the lead wool gets coated. A significant advantage for the lead-free sensor is of course the absence of toxic lead, which may need to be treated as hazardous waste upon disposal of the standard galvanic sensor. Another difference is that the conventional leaded sensor uses an alkaline electrolyte, which absorbs acid gases like CO_2 and SO_2. Under typical atmospheric conditions this is not an issue, but when the measured gas contains percent levels of acid

Comparison of Oxygen Sensors

Factor	Standard Lead-Containing Galvanic Cell	Lead-Free Electrochemical Cell
Cost	Lower purchase price; higher long-term	Higher purchase price; lower long-term
Life	1-3 years, ends when Pb is used up	5 years or more; indefinite end
Power	Low power: OK for non-rechargeable monitors	Moderate power: Better for rechargeable monitors, but non-rechargeable work OK with more frequent battery changes
Range	0 - 30% Vol	0 - 30% Vol
Resolution	0.1% Vol	0.1% Vol
Response time	t_{90} ~ 10 s (slows with age)	$t_{90} \leq 10$ s (slightly faster)
Leakage	Prone to leakage	No leakage
Weight	High	Low
Electrolyte	Alkaline: Acid gases at % levels cause high readings; cannot use above 25% CO_2	Non-alkaline
Waste	Lead (Pb) may be hazardous waste	Non-hazardous
Pressure Effects	Low on short-lived cells; high on long-lived cells	Moderate

components, they are sucked into the sensor along with additional oxygen, causing high readings. Therefore corrections are needed for elevated acid gas levels, and the lead-galvanic cells cannot be used with CO_2 levels above 25%. Small inlet capillaries used in either sensor (to extend sensor or battery life) can result in transient low or high readings with rapid pressure changes, such as when going quickly up or down an elevator or mine shaft. Such transients can cause the sensors to go into alarm, but they tend to settle back down to normal readings within several seconds to a few minutes.

Shipping and Storage of UNI with Lead-Free Oxygen Sensors

To save battery life, UNI monitors equipped with lead-free-oxygen sensors are shipped in air-tight bags containing packets of oxygen scavenger. Upon removal, the UNI will read low oxygen levels until it has equilibrated with the ambient air, and it may need re-calibration. If desired, the bag can be resealed after expelling as much air as possible, for later storage of the UNI during a subsequent period of non-use.

Turning the unit off does not save much power if stored in ambient air, because this only turns off the display, which uses much less power than the oxygen cell, which remains on even with the power off. Therefore, storing at reduced oxygen levels is a more effective way to save battery life.

UNI lead-free oxygen monitor in air-tight shipping package with oxygen scavenger packets