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Case Study – Viability of Oxygen Depletion for Acute Leak Detection

Oxygen depletion has recently had a surge in been suggested to be the golden measure for gas leak detection, but for detection of acute gas leaks this is not possible. The key misunderstanding is that the gas leak to be measured doesn't just dilute the oxygen but the entire atmosphere, of which oxygen only represents a little over a 1/5th of, at 20.9% volume at Standard Ambient Temperature Pressure and (SATP – 25 ˚C @ 101325 Pa (sea level)). Equations **Equ 1, Equ 2** and **Equ 3** below show the relations for oxygen depletion and the gas detectors output:

Equ 1. $$O_{2\ Depleted\ Vol.\ (O)} = O_{2\ Atm.\ Vol.} \times \frac{(100 - Introduced\ Gas\ Volume)}{(100)}$$

Where: $O_{2\ Depleted\ Vol.\ (O)}$ = Depleted (or remaining) oxygen (% Volume) in an open (non-pressurising) space;

$O_{2\ Atm.\ Vol.}$ = Oxygen in atmosphere @ SATP (20.9 % Volume); and

$Introduced\ Gas\ Volume$ (% Volume).

Equ 2. $$O_{2\ Depleted\ Vol.} = O_{2\ Atm.\ Vol.} \times \frac{(100)}{(100 + Introduced\ Gas\ Volume)}$$

Where: $O_{2\ Depleted\ Vol.\ (E)}$ = Depleted (or remaining) oxygen (% Volume) in an enclosed (pressurising) space;

Equ 3. $$O_{2\ Detector\ Output\ Depletion} = \frac{(O_{2\ Atm.\ Vol.} - O_{2\ Depleted\ Vol.})}{(O_{2\ Detector\ Range})} \times 100$$

Where: $O_{2\ Detector\ Output\ Depletion}$ = Full-scale depletion of gas detector output (%);

$O_{2\ Detector\ Range}$ = 25 % Volume of Oxygen.

Equation **Equ 1** displaces the atmosphere and produces the greatest depletion. Equation **Equ 2** adds to the current volume and pressurises. It produces the smallest and a non-linear depletion. As an example a 1 % volume (10000 ppm) of a non-cross sensitive gas being introduced into a non-sealed atmosphere at SATP would cause the oxygen to be depleted to 20.691 % volume, using **Equ 1**. That is a change of only 0.209 % of oxygen.

The industry standard for oxygen sensors are electro-chemical cell which have a full scale measurement of either 25 % or 30 % volume of oxygen, 5 % annual loss of output and a resolution between 0.1 % and 1 % of full-scale, depending upon the combination of sensor and controller; and other environmental factors. Using equation **Equ 3** the 0.209 % depletion in oxygen represents a change in the output of oxygen gas detection of only 0.836 %. The reliability of a gas detection system to detect the 1% volume of introduced gas, would last lest then 2 months before the decay/drift in the output of the oxygen detector would give the same output as the 1 % volume of depleting gas. When other environmental factors like pressure variations, temperature changes, vibrations, large machinery or radio frequency equipment induced electrical noise; and the presence other gasses outside of the ones intended to be measured are also taken into consideration, the use of oxygen depletion to detect acute gas leaks is impractical to use safely.

Some specific cases and other examples where calculated using equations **Equ 1** and **Equ 2** to generate **Table 1** below:

Table 1. Examples of introduced gas volumes and resulting detection

Introduced Gas Volume (% Volume)	Output of Oxygen Detector (% Volume)	Depletion as change in Full-Scale Output (%) (25 % O_2 Sensor Range)
0.003 (30 ppm) CO TWA	20.8994	0.002508
0.04 (400 ppm) Refrigerant	20.8916	0.03344
1	20.691	0.863
6	19.646	5.016
12	18.392	10.032
24	15.884	20.064

*30 ppm (parts per million) CO (Carbon Monoxide) TWA (Time Weighted Average) Safe Work Australia Exposure Standards. And 400 ppm safety limit for toxic refrigerants.

From Table 1 the introduced gas volume would have to be considerably large to allow an oxygen detector to be used to detector other gasses reliably by oxygen depletion. The minimum introducible non-cross sensitive gas volume would be between 12 % volume, depending on how often the gas detection system is calibrated to reduce drift. As the controllers input resolution and overall system noise will limit the performance required to detect smaller output deviations reliably without producing false positives.

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