Differences and correlations between instrumental minimum detection limit and electrochemical sensor resolution

The resolution of sensor measurements or readings is often mistaken for the minimum detection limit. Sensor resolution and instrumental minimum detection limit are the value that is desired to be minimized. Actually, these two concepts are correlated but not entirely equivalent, which should be clearly differentiated.

Definition of instrumental minimum detection limit

Generally, minimum detection limit is defined as the gas concentration of the substance being measured that corresponds to the minimum detectable signal, which can be distinguished from the instrument noise with a certain level of confidence (Normally refer to 99% confidence level) often based on statistical methods.

Function of instrumental minimum detection limit

Detection limits are crucial performance indicators that demonstrate capabilities of an instrument and also serve as a valuable tool in assessing instrument's suitability for a particular application. In a stable instrument state, internal noise contributes to drift and fluctuations which may affect measurement readings.

Higher noise levels raise the minimum detection limit by increasing the likelihood of interference, which results in more challenges to differentiate between the signal and background noise. Detection limit acts as a benchmark for comparing signal-to-noise ratios among similar instruments, determining detection sensitivity, and establishing boundary between signal and noise, which is intended for the gas detection instrument.

Factors affecting the minimum detection limit

Signal noise, design of instrument, environmental factors and measurement systems can all have a significantly impact on performance of gas detection instrument.

For example:

- Increased background noise can hinder the detection of low concentrations of target gas. A higher signal-to-noise ratio leads to improved detection of lower concentration, thereby enhancing the minimum detection limit.

- Interference from gases other than target ones, as well as environmental factors like temperature and humidity will impact the ability to detect certain specific target gas.

When an electrochemical gas sensor is integrated into a gas detection instrument, the minimum detection limit typically varies from its resolution (Value of instrumental minimum detection limit is greater than sensor resolution). A great number of instruments claiming to provide readings do not use sensors that offer the required signal stability to provide a reading at the specified level while maintaining accuracy. In cases where instruments claim a certain resolution without specifying the minimum detection limit, the initial non-zero reading may appear greater than expected value. Therefore, the minimum detection limit and resolution cannot be equated directly.

In conclusion, minimum detection limit of a gas detection instrument refers to the lowest concentration of a gas that the instrument can reliably detect and measure or the instrument's ability to detect a specific gas at very low levels.

Definition of sensor resolution:

Resolution of electrochemical gas sensors indicates the minimum detectable and distinguishable change in target gas concentration and can also be described as measure of the smallest separation between two adjacent target gas concentration points that can be detected by the gas sensor.

Typically, resolution is quantified as the smallest incremental alteration in amount of chemical that sensors can consistently and accurately measure. The higher resolution indicates that sensors can detect smaller changes in gas concentration, meaning that they’ re more sensitive to changes in the environment.

Correlation between instrumental minimum detection limit and sensor resolution

It is important to notice that electrochemical gas sensor is a sensitive component but not a gas detection instrument. Gas detection instruments require the installation of a electrochemical gas sensor for proper operation. The minimum detection limit is usually a parameter that measures the performance of the instrument. The term "resolution" refers to the precision of sensors in the field of electrochemical gas sensors. Higher resolution depends on the instrument's application circuitry, including aspects such as signal-to-noise ratio and algorithmic processing to achieve a lower minimum detection limit.

The minimum detection limit is closely linked to the sensor's resolution but is not entirely equivalent. It represents an approximate instrument reading determined by the sum of deadband and the sensor's resolution, which indicates the lowest concentration of a substance that can be reliably detected and distinguished from background noise. The resolution is specifically related to electrochemical sensors’ ability to detect small changes in concentration.

Why minimum detection limit is not mentioned in most electrochemical sensor datasheet?

Most electrochemical gas sensor datasheet only mention resolution but not minimum detection limit.

Here are the following reasons:

- Gas sensors are not independent instruments, but only sensitive components and they must be installed into gas detection instruments for operation and then there’s actual detection limit.

- Some gas sensor manufacturers don’t actually have detection limits in the true sense of the word while labelling their product specifications with detection limits, but rather an approximation of the lowest detection limit based on the resolution of the sensor as measured by the sensor's inner test system.

Electrochemical gas instrument’s minimum detection limit can be approximately calculated by the following formula below:

Minimum detection limit≈ [Max. Baseline (Zero Signal) – Min. Baseline (Zero Signal)]

/ (2 * Sensitivity) + Resolution

Using the SemeaTech 4-Series CO-100 sensor as an example:

Baseline (Zero signal) : < ±0.2 μA

Sensitivity: 0.4 ± 0.1 μA/ppm

Resolution: 0.5 ppm

The minimum detection is approximately equal to [0.2-(-0.2)]/(2*0.4)+0.5 =1 ppm

It follows that the approximate value is of 4CO-100 is 1 ppm.

Methods to improve instrumental minimum detection limit:

- To get lower minimum detection, some measures can be taken to reduce signal noise like improving measurement system, enhancing instrument performance and avoiding environmental distraction.
- The merit of the minimum detection limit is also influenced by the amount of data collected per reading. If real-time response is not imperative and a delayed response is acceptable, collecting more data points for each readout becomes viable. This practice tends to align the average data more closely with the baseline and improve the signal-to-noise ratio, thereby aiding in the reduction of background noise and lowering the minimum detection level.