

Testo Tech Notes:

CO Sensor – H₂ Cross Sensitivity

Introduction

Gas measurement is a sophisticated science, that done right, can provide very accurate results, or done wrong, can lead to costly misdirection. Sensors that are intended to measure single gases may respond erroneously if they are not controlled or conditioned properly. It is very possible that a sensor may respond to that target gas and additionally respond to other gases as well. This unintended response is known as sensor “cross-sensitivity.”

Electrochemical (EC) sensors are remarkably versatile and compact measuring devices that can be very accurate. EC analyzers offer low-cost precision, portability, and rugged stability that rival other measurement technologies when installed in a properly engineered and maintained analyzer. Like most other sensing technologies, however, EC sensors are not immune to cross-sensitivities which require engineered solutions to mitigate.

An example of a common cross-interference to EC sensors occurs with the often used carbon monoxide (CO) sensors. CO sensors respond to both CO and hydrogen (H₂). H₂ is a combustion by-product of fuel degradation and is often found in combustion sources with low levels of oxygen in the exhaust. H₂ is not a factor in ambient air, nor in many simple combustion sources, so it would therefore not pose a measurement problem. However, in some combustion applications, H₂ concentrations can be quite high and if not accounted for, can cause the CO reading to be artificially high. This is because standard CO sensors will react to the H₂ and add the output to the CO reading. This reaction to H₂ corresponds to up to 60 percent of the total H₂ ppm concentration in addition to whatever CO value was measured.

Application where H₂ is high

Reciprocation internal combustion engines - rich burn type

Rich burn engines are designed to operate with low oxygen (O₂) levels in the exhaust. As a result the exhaust typically has high concentrations of CO (pre-catalyst can be thousands of ppm CO) and normally less than 1 percent O₂. In this type of combustion environment, high levels of H₂ are generated via combustion degradation. The H₂ concentrations are erratic and the correlation to CO is not fully characterized. Field testing has shown H₂ is often equal to or greater than the CO concentration. Even in controlled engines, the H₂ concentration can be 3 to 5 times the CO concentration. Field testing has also shown CO levels can rise to well over 10,000 ppm with H₂ levels tracking similar concentrations before proper engine control is achieved.

Cross-compensating CO sensors to negate H₂ interference

An effective solution to this cross-interference has been engineered and is readily available. Sensor technology was developed that would measure H₂ and subsequently subtract that value from the combined CO + H₂ reading. This cross-compensation allows accurate CO readings in the presence of varying H₂ levels or with no H₂. The ability to sense H₂ has been incorporated into many CO sensors by designing additional electrodes into an existing CO sensor and incorporating signal conditioning and logic to carry out the compensation.

Consequence

CO sensor with no hydrogen compensation

It is understood that EC CO sensors that are not designed to compensate for the H₂ will provide readings that could greatly overstate CO. The consequence of trying to tune an engine with a CO analyzer that does not compensate for H₂ means the operator does not really know the CO readings and cannot setup the engine correctly. It may appear the engine controls are not working, when they are, or are not. Conclusions based upon this false information can prove very costly.

Sensor life

The cost of hydrogen compensation

To measure the H₂ requires an additional electrode in the sensor. This electrode has specific design ranges and restriction to provide optimal results. Rich burn engines can produce high levels of H₂ (especially pre-catalyst testing) that are beyond the sensors' capabilities. This could cause over-ranging the sensor which results in shortened sensor life or catastrophic failure. High level reactions cause the sensor's electrodes to oxidize, or erode rapidly. H₂ levels of 1000 ppm or higher can consume and destroy the electrodes which results in sensor drift or failure. For most testers H₂ is not required for tuning or compliance and so they have little interest to monitor it, however exceeding the H₂ sensor range can lead to costly sensor degradation and early sensor replacement.

Testo solution to H₂ in the exhaust gas

Integrated sample dilution system

As we have seen, H₂ is an unavoidable constituent in many combustion applications, and H₂ is a significant cross-interference for CO readings that must be accounted for. The problem is that very often combustion gas levels are much higher than the normal range for which sensors are designed.

An effective method to eliminate the effect of high H₂ concentrations is by diluting the sample gas. Testo's emission analyzers have a patented dilution system to accommodate high range gases in many testing applications. This system allows the H₂ compensated CO sensors to be used for all engine testing ranges and not risk the operational health and overall accuracy of the measurement.

The dilution system accurately dilutes the incoming combustion gas to lower the gas concentrations at the sensors. Conveniently, when the dilution system is activated, the same electronic circuitry also corrects the readings by the same factor. So if a dilution of 5:1 is activated it would reduce a 5000 ppm gas to 1000 ppm at the sensor thereby extending the life of the sensor and allowing it to operate in a more optimum sensing range. The reading on the display (and in software) is corrected to still read 5000 ppm. The operator does not need make additional corrections.

Dilution system use & calibration

The dilution system allows testing at suspect or unknown combustion sources simply by activating at a high dilution value (e.g. 20:1). The dilution system provides a reliable tool that allows the tester to accurately monitor sources with elevated pollutant concentrations or sources with high concentrations of interferent gases (H₂). The dilution system also relieves the worry about sensor over-range or failure.

Calibration can be done in the field using normal CO calibration gas. A menu driven process allows the tester to verify and calibrate in a matter of a few minutes. System calibration is stable for relatively long periods of time and is simple to maintain.

Pre-configured analyzer setup

In order to simplify field testing the testo 350 offers pre-configured testing applications in the start menu. Prior to any measurement, a testing application menu is displayed. For rich burn engine testing, for instance, the testo 350 automatically configures the system to operate at a 5X dilution factor. Years of field experience has shown the 5X factor performs extremely well in both accuracy and reproducibility to a non-diluted test system, and it provides greater sensor protection and durability.

Summary

H₂ is a cross-interfering gas that occurs during combustion process. H₂ can influence the accuracy of CO readings equal to or greater than the actual CO. Compensation technologies exist that measure H₂ and subtract the effects from the CO to provide accurate readings. The testo 350 incorporates the following techniques to address the effects of H₂ in the sample gas:

Electrode selection:

Additional electrodes and the selection of electrode materials to measure and compensate for H₂.

Cross compensation:

Electronically compensate output response by measuring the H₂ interference gas and applying the interference to the sensor output.

Sample dilution:

- The testo 350's dilution system incorporates dilution air to the gas path to reduce the gas concentrations at the sensor's face
- By reducing the concentration, sensor life is extended.
- The measurement are mathematically corrected back to stack conditions so the measurement s displayed are correct
- Expands the testing range by up to 40 times

Testo has incorporated decades of experience to provide pre-configured instrument setups that reduce testing time and provide accurate analyzer performance.

About Testo...

Be sure.

TESTO, INC. is a world leader in the design, development and manufacture of portable test and measurement instrumentation. Backed by over 50 years of measuring engineering experience our mission is to provide the best quality, service and value to markets as diverse as industry, chemical, food service and production, pharmaceutical and biotech.

Testo is recognized as the leading manufacturer of portable combustion efficiency analyzers and emission monitoring analyzers. Testo is a major supplier of emission analyzers for the oil and gas industry, central and decentralized electric generation, manufacturing and industrial raw material processing, and environmental monitoring for EPA, state, and local regulatory compliance.

Testo offers NIST calibrations (where applicable) on all their instruments as well as ISO 9001 quality standards.

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