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Testo Tech Notes:

CO Sensor - H_2 Cross Sensitivity

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 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, without engineered solutions, 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.

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Applications where H_2 is high

Reciprocation Internal Combustion Engines - Rich Burn Type

Rich burn engines are designed to operate with low O2 levels in the exhaust. As a result the exhaust typically has high concentrations of CO (pre catalyst thousands of PPM CO) and normally less than 1 percent oxygen (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 H_2 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.

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Sensor life: The cost of hydrogen compensation

To measure the H2 for compensation 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 completely 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's solution to H_2 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.

The good news is that Testo 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 an ideal 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 concentrations or sources with high concentrations of interferent gases (H2) and not 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. This system calibration is stable for relatively long periods of time and is very 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. This pre-configured setup is selected prior to testing. 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 equally in both accuracy and reproducibility to a non-diluted test system, however it provides much greater protection and durability.

CO Sensor
H2 Cross Sensitivity
White Paper

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Summary

H2 is an 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. Testo has essentially eliminated H2 cross-sensitivity through several technology advancements listed below:

Electrode selection:

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

Cross compensation:

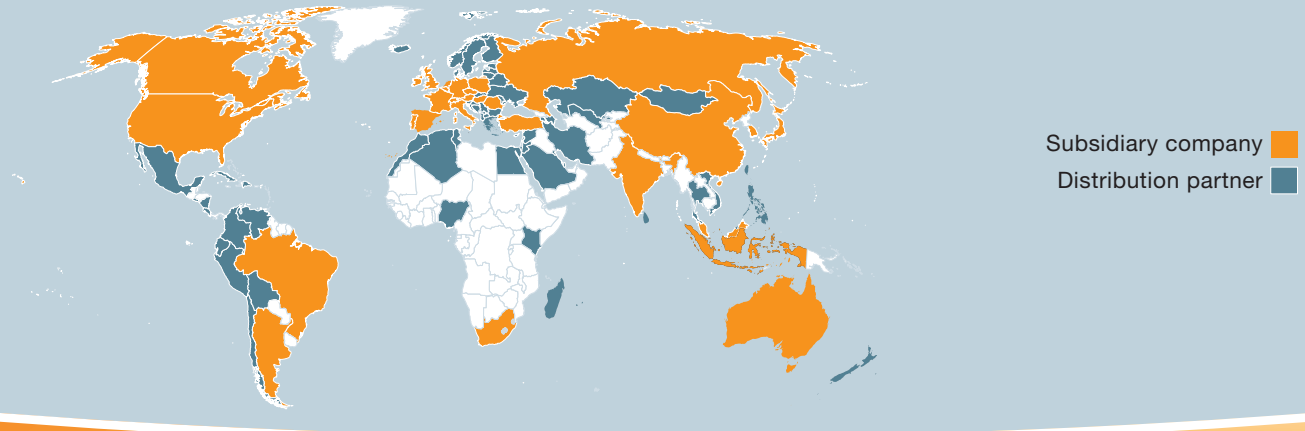
- Electronically compensate output response by measuring the H2 interference gas and applying the interference to the sensor output
- The testo easyEmission software provides a means to calibrate and compensate for cross interference

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.
- Dilution air also plays a role in converting some cross interferent gases whereby they no longer behave as an interferent due to reduced concentration
- The measurement are mathematically corrected back to stack conditions so the measurements displayed are correct

Testo: Precision Instruments, Global Reach.

Testo is a world leader in the design, development, and manufacture of portable test and measurement instrumentation. Backed by 60 years of measuring engineering experience, our mission is to provide the best quality, service, and value in the industry. Testo portable emission analyzer are world renown for their accuracy, ease-of-use and rugged construction. These are just some of the reasons why they are used by more regulatory agencies and fortune 500 companies than any other analyzer. They are perfect for testing natural gas engines, diesels, turbines, process heaters, and boilers, the oil and natural gas markets.



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