AP 1007:
Calibration and Bump Test Requirements for Direct Reading Portable Gas Monitors

Manufacturers and regulatory agencies agree the safest and most conservative approach is to perform a functional test by exposing your gas detector to test gas before each day's use.

Oxygen deficiencies, explosive atmospheres, and exposure to toxic gases and vapors injure hundreds of workers every year. The atmospheric conditions that lead to these accidents and fatalities are usually invisible to the workers who are involved. The only way to ensure atmospheric conditions are safe is to use an atmospheric monitor. The only way to know whether an instrument is capable of proper performance is to expose it to test gas. Exposing the instrument to known concentration test gas verifies that gas is properly able to reach and be detected by the sensors. It verifies the proper performance of the instrument's alarms, and (if the instrument is equipped with a real-time display), that the readings are accurate. Failure to periodically test and document the performance of your atmospheric monitors can leave you open to regulatory citations or fines, as well as increased liability exposure in the event that a worker is injured in an accident.

There has never been a consensus among manufacturers regarding how frequently direct reading portable gas detectors need to be calibrated. However, manufacturers do agree that the safest and most conservative approach is to verify the performance of the instrument by exposing it to test gas before each day's use. Performing a functional "bump test" is very simple and takes only a few seconds to accomplish. It is not necessary to make a calibration adjustment unless the readings are found to be inaccurate. The regulatory standards that govern confined space entry and other activities that include the use of direct reading instruments are in agreement with this approach.

However, the definition of "bump test" has always been a little slippery. Some manufacturers differentiate between a "bump test" that provides a qualitative evaluation of the instrument's ability to detect gas and a "calibration check" that verifies that the response of the sensor(s) when exposed to known concentration test gas are within the manufacturer's requirements for accuracy. All manufacturers agree that instruments that fail either a "bump test" or "calibration check" should be put through a "full calibration" before further use.

ISEA Statement on Validation of Operation for Direct Reading Portable Gas Monitors

The International Safety Equipment Association (ISEA) is the leading international organization of manufacturers of safety equipment, including environmental monitoring instruments. The ISEA is dedicated to protecting the health and safety of workers through the development of workplace standards and the education of users on safe work practices and exposure prevention. In 2010 the ISEA updated their protocol for, *"Validation Procedures of Operation For Direct Reading Portable Gas Monitors"* to clarify the Association's recommendations for the procedures used to verify proper operation, and the accuracy of the readings.

The protocol was designed to reemphasize to OSHA and other standards writing bodies the importance of verifying the calibration of instruments used to monitor the atmosphere in potentially hazardous locations, to clarify the differences

Figure 1: Performing a functional "bump test" by exposing the instrument to test gas takes only a few moments perform.

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between a bump test (function check), a calibration check, and a full calibration. The protocol applies to all of the sensors installed in the direct reading gas detector, not just the combustible sensor. The latest version of the protocol also includes an expanded list of conditions and circumstances that should trigger a re-verification of the instrument's performance before further use.

In the United States a number of state and federal agencies, including the Occupational Safety and Health Administration, (OSHA), have now issued instructional best practice guidelines that are largely based on the ISEA protocol. In some jurisdictions performing a bump test (functional test) before each's days use is not yet mandatory, but in all jurisdictions according to both regulatory agency and manufacturer guidance, the safest course of action is to perform a bump test that includes exposure of the sensors in the instrument to test gas before each day's use.

What causes an instrument to lose accuracy?

Single-sensor instruments are designed to focus on a single toxic contaminant or hazardous condition (such as H_2S or O_2 deficiency), or the presence of a class of atmospheric hazard (such as the presence of combustible gas). "Zero maintenance" single-sensor instruments may or may not include a meter for the display or real time readings, and they may or may not be capable of calibration adjustment while exposed to test gas. Confined space and other types of multi-sensor instruments include several different types of sensors. The type of sensors installed depends on the specific monitoring application.

The atmosphere in which the instrument is used can have profound effect on the sensors. Each type of sensor uses a slightly different detection principle. Sensors may be poisoned or suffer degraded performance if exposed to certain substances. The kinds of conditions that affect the accuracy of sensors vary from one type of sensor to the next.

While the electrochemical sensors used to measure toxic gases like carbon monoxide and hydrogen sulfide are not worn out or consumed by exposure to CO or H_2S, they still eventually need to be replaced when they are no longer able to detect gas. Although CO and H_2S sensors may last for years without significant loss of sensitivity, the loss of sensitivity at the end of life may be sudden. Incidental exposure to other substances may also reduce sensitivity. For instance, many electrochemical sensors can be permanently affected by exposure to organic solvents and alcohols. Exposure to methanol is well known to potentially affect the performance of CO and H_2S sensors.

The most commonly used "fuel cell" oxygen sensors consume themselves over the use-life of the sensor, and will eventually need to be replaced. Defective or malfunctioning O_2 sensors

Figure 2: The only way to know whether an instrument is capable of proper performance is to expose it to test gas.

may need to be replaced sooner. Oxygen sensors near the end of their use-life may develop other types of performance problems, such as abnormally slow response. For these reasons performing a daily bump test on oxygen sensors is particularly important.

Combustible sensors are prone to damage due to exposure to poisons or substances that inhibit the sensor's response to combustible gas. Combustible sensors may be affected by exposure to volatile silicones, chlorinated solvents (such as methylene chloride), sulfides (including H_2S), hydrides (such as phosphine and arsine), or even exposure to high concentrations of combustible gas. Sensors may also suffer loss of sensitivity due to aging, mechanical damage due to dropping or immersion, or loss of sensitivity due to other causes.

Even if a sensor is internally healthy, if gas is not capable of reaching and diffusing into the sensor because of blockage or leakage in the pump or sampling system, or because the external filter has become clogged or contaminated, the sensor cannot properly respond. Thus even "zero maintenance" single-sensor instruments should be periodically exposed to gas to ensure that the instrument is capable of proper

response. Even if the sensor response and readings are correct, if the alarms are not properly activated, or if the instrument fails to operate properly in other ways when exposed to gas, the instrument must be serviced to restore proper function before it can be used.

What do the regulations say?

OSHA 1910.146 "permit-required confined spaces" paragraph (c)(5)(ii)(C) explicitly states (in part) that, "Before an employee enters the space, the internal atmosphere shall be tested, with a calibrated direct-reading instrument". OSHA Compliance Directive CPL 2.100, "Application of the Permit-Required Confined Spaces (PRCS) Standards, 29 CFR 1910.146" explains what is meant by "calibrated":

"A testing instrument calibrated in accordance with the manufacturer's recommendations meets this requirement. The best way for an employer to verify calibration is through documentation."

In other words, instrument users are held accountable to calibrating and / or testing the performance of their instruments in accordance with the manufacturer's instruction manual. OSHA expects instrument users to be able to document that their procedures match the requirements listed.

The instructions, cautions and warnings listed in the owner's manual are governed not by OSHA, but by the manufacturer's philosophy, the manufacturer's assessment of the characteristics of the product, and the external standards to which the instrument is Classified, Listed or Marked by Nationally Recognized Testing Laboratories such as Underwriters Laboratories® or the Canadian Standards Association® (CSA®).

Instruments used in environments characterized by the potential presence of flammable or explosive gases usually carry a certification for intrinsic safety. Devices certified as "Intrinsically Safe" prevent explosions in hazardous locations by employing electrical designs that eliminate the possibility of ignition. Certification for intrinsic safety is based on performance of the instrument when tested in a specific flammable atmosphere. The instrument should carry the logo of the testing laboratory that conducted the evaluation, as well as the specific hazardous location groups and or zones for which the classification applies.

Most manufacturers whose confined space instruments are sold in North America have submitted their designs for testing in accordance with both United States and Canadian performance criteria. A small "c" included in the classification mark indicates compliance with Canadian performance criteria.

Canadian Standards Association C22.2 NO. 152-M1984 (R2001), "Combustible Gas Detection" is the CSA standard that covers the details of construction, performance, and test procedures for portable instruments used to detect or measure combustible gases in hazardous locations characterized by the known or potential presence of combustible gas. Section 5.3, "Instruction Manual" lists the minimum information and warnings that must be included in the owner's manual of gas detectors that are compliant with this standard. Paragraph (k) requires that the manual include the following statement:

CAUTION: BEFORE EACH DAY'S USAGE SENSITIVITY MUST BE TESTED ON A KNOWN CONCENTRATION OF _____ (SPECIFY GAS) EQUIVALENT TO 25-50% OF FULL SCALE CONCENTRATION. ACCURACY MUST BE WITHIN -0-+20% OF ACTUAL.

In other words, to comply with Canadian requirements, the performance of the combustible sensor must be verified by exposure to known concentration combustible gas before each day's use. The manufacturer is free to specify the type and concentration of combustible gas to be used, and is free to specify a tighter performance tolerance if desired. The standard does not require that the instrument be adjusted before each day's use, only that it is found to be capable of

Figure 3: Automatic "Bump Test" stations are compact, automatic, cost effective, and very easy to use.

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detecting combustible gas according to the tolerances listed in the instruction manual. The standard is mute regarding the verification of performance of other types of sensors that may be included in the instrument. The only requirements are for the verification of performance of the combustible sensor.

Instrument users who operate and maintain their instruments in accordance with USA rather than Canadian requirements have more latitude in determining the interval between calibration checks.

Validation of operability

The complete text of the International Safety Equipment Association (ISEA) Statement on Validation of Operation for Direct Reading Portable Gas Monitors can be downloaded from the ISEA website at the following link:

https://safetyequipment.org/wp-content/uploads/2015/09/calibration_statement-2010-Mar4.pdf

The latest version of the ISEA statement applies to all types of direct reading portable gas detectors, not just confined space instruments. The ISEA protocol has been widely adopted by the gas detection equipment manufacturing community, even by manufacturers who are not members of the Association.

The ISEA protocol begins by clarifying the differences between a “bump test”, a “calibration check” and a “full calibration”:

A “bump test” (function check) is defined as a qualitative check in which the sensors are exposed to challenge gas for a time and at a concentration to activate all of the alarms to at least the lower alarm settings. It is important to understand what a qualitative test of this kind does not do. The test confirms that the gas is capable of reaching the sensors, that when they are exposed to gas the sensors respond, the response time (time to alarm) after gas is applied is within normal limits, and that the alarms are activated and function properly. However, a qualitative function test does not verify the accuracy of the readings or output of the sensors when exposed to gas.

A “calibration check” is a quantitative test using a traceable source of known concentration test gas to verify that the response of the sensors is within the manufacturer’s acceptable limits. For instance, a manufacturer might specify that readings in a properly calibrated instrument should be within ±10% of the value of the gas applied. If this is the pass / fail criterion, when 20 ppm H_2S is applied to the instrument, the readings must stabilize between 18 ppm and 22 ppm in order to pass the test. It should be stressed that these pass / fail criteria are manufacturer guidelines. Different manufacturers are free to publish different requirements.

A “full calibration” is defined as the adjustment of an instrument's response to match a desired value compared to a known traceable concentration of test gas. Once again, the calibration procedure, including the concentration of gas applied, method used to apply gas, and method used to adjust the readings are determined by the manufacturer.

The statement goes on to recommend the frequency for validation of the instrument’s operability:

A “bump test” (functional test) or “calibration check” of direct reading portable gas monitors should be made before each day's use in accordance with the manufacturer's instructions using an appropriate test gas.

Any instrument that fails the test must be adjusted by means of a “full calibration” procedure before further use, or taken out of service. If environmental conditions that could affect instrument performance are suspected to be present, such as sensor poisons, then verification of calibration should be made on a more frequent basis.

A “full calibration” should be conducted as required by the manufacturer. However, as discussed above, a “full calibration” should be conducted whenever testing indicates

Figure 4: Docking Stations are designed to automatically perform functional bump tests and calibrations, and automatically store test results.

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that adjustment is required. Even if the instrument is not yet "due" for a "full calibration", if the instrument fails a "bump test" or "calibration check" it must be calibration adjusted before further use.

According to the ISEA Protocol, even daily testing may sometimes not be enough

Certain conditions and events have the potential to adversely effect the performance of the sensors and/or the entire instrument. Sometimes the damage and effect on performance is immediate. Sometimes the underlying damage is chronic in nature, and occurs over time. However, when the instrument stops working properly, it can happen very quickly.

The ISEA Protocol provides a list of conditions that can adversely affect the sensors and trigger a need for more frequent validation:

i. Chronic exposures to, and use in, extreme environmental conditions, such as high/low temperature and humidity, and high levels of airborne particulates.

ii. Exposure to high (over range) concentrations of the target gases and vapors.

iii. Chronic or acute exposure of catalytic hot-bead LEL sensors to poisons and inhibitors.

iv. Chronic or acute exposure of electrochemical toxic gas sensors to solvent vapors and highly corrosive gases.

v. Harsh storage and operating conditions, such as when a portable gas monitor is dropped onto a hard surface or submerged in liquid. Normal handling/jostling of the monitors can create enough vibration or shock over time to affect electronic components and circuitry.

vi. Change in custody of the monitor.

vii. Change in work conditions that might have an adverse effect on sensors.

viii. Any other conditions that would potentially affect the performance of the monitor.

Lengthening the interval between bump test or calibration tests

Federal OSHA as well as a number of State Occupational Safety and Health administrations have in the past posted instructional letters to identify circumstances under which it may be appropriate to lengthen the interval between verification checks. The latest version of the ISEA Protocol no longer acknowledges or references these procedures to lengthen the interval between tests, and the most recent versions of the instructional letters posted on government websites have been updated to remove these procedures as well. If you decide to perform bump tests less frequently, remember that you, and your company, are making a decision to take on additional responsibility for ensuring that your procedures are valid. Make very sure you have comprehensive documentation to support the validity of your decisions and procedures. If the rules in your jurisdiction still permit testing the instrument less frequently, lengthening the interval between performing a bump test should only be considered if the following criteria are met.

i. During a period of initial use of at least 10 days in the intended atmosphere, calibration is verified daily to be sure there is nothing in the atmosphere which is poisoning the sensor(s). The period of initial use must be of sufficient duration to ensure that the sensors are exposed to all conditions that might have an adverse effect on the sensors.

ii. If the tests demonstrate that it is not necessary to make adjustments, then the time interval between checks may be lengthened but should not exceed 30 days.

iii. The history of the instrument since last verification can be determined by assigning one instrument to one worker, or by establishing a user tracking system such as an equipment use log.

iv. Any conditions, incidents, experiences, or exposure to contaminants that might adversely affect the calibration should trigger immediate verification of calibration before further use. Most importantly, if there is any doubt about the calibration of the sensors, expose them to known concentration test gas before further use.

Docking stations make CS instruments even easier to use and maintain

Given the requirement for documentation, the capability of instruments to log or automatically retain calibration information is highly desirable. Most data logging confined space instruments automatically update and store dates and other calibration information. Even non-data logging instruments usually include the date, or number of days since the last time the instrument was calibrated.

Most leading manufacturers of confined space gas detectors now offer automatic calibration or "docking" stations that can automatically calibrate and store instrument calibration records.

Docking stations that include fully automatic calibration are redefining the way that users with large numbers of direct reading instruments deal with maintenance and calibration issues. Instead of technicians or instrument specialists laboriously calibrating instruments one at a time, instrument users simply drop the gas detector into the docking station. The docking station automatically bump tests or calibrates the instrument, then updates and stores the test results. Use of automatic calibration stations makes it possible to verify the accuracy of confined space instruments on a much more frequent basis. Docking stations are also able to transparently improve the quality of bump test and calibration checks. Many docking station systems verify not only the final stable reading of the sensor, but the time it takes to reach the desired output level, as well as the shape of the sensor response curve, which can provide important diagnostic information on the health of the sensor.

The prices for automatic calibration stations are beginning to drop in the same way that prices for instruments have been dropping. In the past, it might take forty or more instruments to justify the expense of investing in a docking station. As prices continue to drop, customers with only a few instruments are finding that investing in an automatic calibration station makes very good sense.

Direct reading gas detectors are designed to help keep workers safe in potentially life threatening environments. Verifying the proper performance of your gas detectors is a mandatory part of every program that requires their use. But more importantly, it's an essential part of keeping your workers safe.

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