Honeywell | Gas Detection

Common Combustible Gas Sensing Technologies in Portable Detectors

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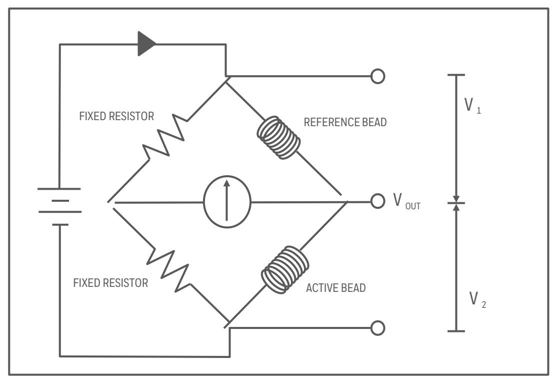
Catalytic Bead Combustible Gas Sensing Technology

The most common type of sensor used in a portable safety gas detector for the detection of combustible gases is the catalytic bead sensor. Catalytic bead combustible sensors have been used in portable safety gas detectors for more than 50 years and have a proven history of reliably keeping workers safe. This simple, inexpensive technology provides detection of a wide range of potential combustible gas hazards. Another, less familiar, combustible gas sensing technology that has been emerging relatively recently in a portable safety gas detector is Non-Dispersive Infrared (NDIR).

Workers around the world depend on portable safety gas detectors every day to alert them to potentially explosive atmospheres. This paper will look at the capabilities and limitations of these two combustible gas sensing technologies.

The Basics of Catalytic Bead Combustible Gas Sensor Operation

The catalytic bead combustible gas sensor works on the principle of catalytic oxidation, often referred to as catalytic combustion; i.e.: the sensor burns combustible gas molecules to determine the concentration of combustible gas present in the atmosphere being monitored. This type of combustible gas sensor contains two coils of very fine platinum wire coated with a ceramic or porous alumina material to form catalytic beads. The beads are connected to opposing arms of a Wheatstone bridge electrical circuit.



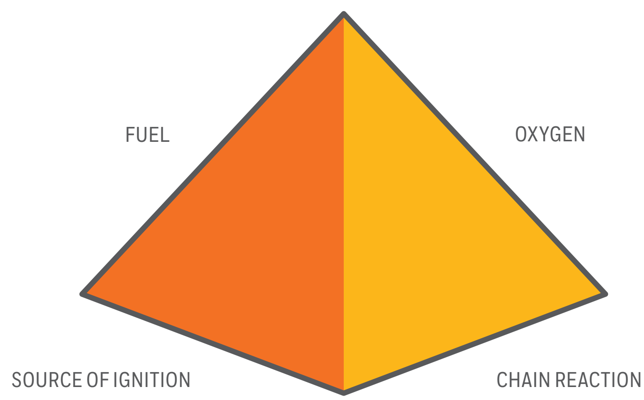
BALANCED WHEATSTONE BRIDGE CIRCUIT

The sensing bead is coated with a catalyst to promote catalytic oxidation (combustion) of gases at concentrations below the **Lower Explosive Level (LEL)**. The temperature compensation bead is sealed and cannot oxidize combustible gas molecules. A voltage is applied to the sensor which heats the platinum wire coil in both beads to a temperature of approximately 450°C. The catalytic bead sensor has a sintered filter flame arrestor to prevent the propagation of combustion outside of the sensor housing. In fresh air (20.9% v/v oxygen, 0 ppm toxic gases, 0% LEL combustible gases), the electrical output from both beads is balanced on the Wheatstone bridge circuit; what the gas detector displays as 0% LEL gas. If a combustible gas is present, catalytic oxidation (burning) will heat the sensing bead wire coil to a higher temperature than the opposing compensating bead, changing the voltage output of V_1 vs. V_2 thereby creating an unbalance in the Wheatstone bridge circuit. This difference between V_1 and V_2 is proportional to the concentration of combustible gas in the atmosphere.

The catalytic bead combustible gas sensing technology is relatively simple; however, there are a number of basic concepts that users of portable safety gas detectors need to be aware of when using this technology.

Catalytic Bead Combustible Gas Sensors Need Oxygen

This process of catalytic combustion requires oxygen. If you look at the fire tetrahedron, four basic elements must be present to initiate the combustion process:



There must be enough oxygen present to support catalytic oxidation. **DO NOT rely on the catalytic bead combustible sensor readings if the oxygen concentration is less than 10% v/v.** For that reason, it is recommended that portable safety gas detectors with a catalytic bead combustible sensor also include an oxygen sensor to ensure a sufficient concentration of oxygen is present.

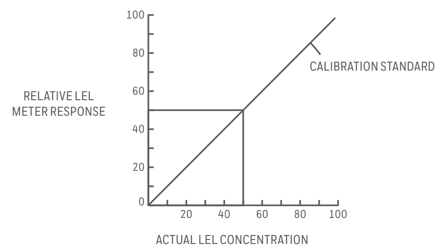
Catalytic Bead Sensor Technology Is Non-specific

A catalytic bead combustible sensor is capable of measuring the concentration of a combustible gas up to 100% of the LEL. This is a non-specific gas sensing technology and although the sensor is capable of detecting a wide range of combustible gases, the sensor has no idea what combustible gas is being detected. Since the sensor is capable of detecting various combustible gases and vapors, the sensor response is always relative to the gas the sensor was calibrated with. The following chart lists the LEL of some common hydrocarbons:

Hydrocarbon	Molecular Formula	LEL % v/v
Methane	CH_4	5.0
Ethane	C_2H_6	3.0
Propane	C_3H_8	2.1
Butane	C_4H_{10}	1.9
Pentane	C_5H_{12}	1.4
Heptane	C_6H_{14}	1.2
Hexane	C_7H_{16}	1.1
Octane	C_8H_{18}	1.0
Nonane	C_9H_{20}	0.8

Catalytic Bead Sensor Response Is Relative

The gas detector readings for the combustible gas measurement will be most accurate when the detector is used to monitor the same gas it has been calibrated with. When the sensor is calibrated, it is typically given two reference points: zero and a known concentration of combustible gas. Once the electrical output of the sensor is known at zero and at a second known reference point, the output of the sensor is linear over the detection range of the sensor, 0 to 100% LEL.



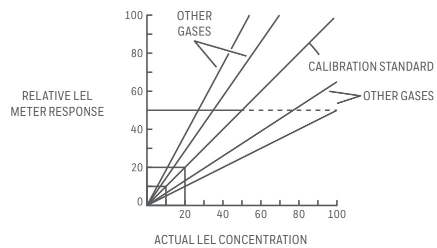
CALIBRATION STANDARD LINEAR RESPONSE

The catalytic bead sensor output is directly proportional to the rate of diffusion of combustible gas molecules. For a sensor calibrated to methane the detector readings will accurately reflect the actual concentration of methane gas in the atmosphere. But the sensor is capable of detecting other combustible gases and gases are not ideal; they have different properties, different lower explosive levels and different rates of diffusion. For heavier hydrocarbons the detector reading may be lower than the actual concentration due to a slower rate of diffusion. Diffusion barriers like the sintered filter flame arrestor can prevent the detection of more complex hydrocarbon compounds due to molecular size.

In the event a gas other than the calibration gas is being detected the reading produced by the catalytic bead combustible sensor will be relative to the calibration gas.

Correction Factors

A Correction Factor (CF) is sometimes used to determine the actual concentration of a detectable gas other than the gas used for calibration.



RELATIVE RESPONSE CURVES

The following table lists the Relative Response (RR) and correlating CF for a catalytic bead combustible gas sensor used in the GasAlertMicroClip XL product. RR data is determined through testing under laboratory conditions; CF is the inverse of the RR:

Gas / Vapor	Relative Response	Correction Factor[1]
Methane	100	1.0
Propane	60	1.7
Butane	70	1.4
Pentane	65	1.6

Gas / Vapor	Relative Response	Correction Factor[1]
Hydrogen	125	0.8
Ethylene	100	1.0
Acetylene	95	1.1
Heptane	50	2.0

Using the CF Table, we can determine that for a sensor calibrated to methane, but detecting pentane, we can multiply the detector reading by 1.6 for a better approximation of the actual concentration of pentane: 10% LEL methane reading = 16% LEL pentane. In this example the concentration of pentane is actually higher than the gas detector is indicating. Conversely, a detector calibrated to pentane but monitoring methane would indicate a higher concentration of methane than is actually present.

1. Correction Factors provided are based on a combustible sensor calibrated to methane and are provided for guidance only; actual sensor response may vary. This table is based on Relative Sensitivity data for the City Technology MICROpeL 75C combustible gas sensor. For the most accurate readings the detector should be calibrated to the known target gas. CFs have been rounded up.

If considering using a Correction Factor it is important to fully understand their use and implementation. Remember, that even if a CF is used, the catalytic bead combustible gas sensor is still a non-specific sensing technology. Also note that the higher the CF, the lower the relative sensitivity to that gas.

Regardless of actual combustible gas concentration, alarm set points for portable safety gas detectors are extremely conservative. Typically, the gas detector will provide two levels of alarm to alert workers to the presence of a combustible gas, first at 10% of the LEL and second at 20%; that affords a 90% to 80% buffer before a combustible atmosphere is encountered. The portable safety gas detector's job is to provide workers with early warning to keep workers safe.

It is important to be aware that the actual concentration of a combustible gas may be higher than what the portable safety gas detector is indicating! Be aware that atmospheric conditions can change quickly; take appropriate action when an alarm is activated.

Avoiding Catalytic Bead Sensor Poisoning

It is well known that certain airborne substances can have a detrimental effect on catalytic bead combustible gas sensors leading to partial or often complete loss of sensitivity. Permanent degradation of sensitivity is called "**poisoning**". Sensor poisoning can cause immediate, catastrophic failure; or, poisoning can be gradual and a sensor's catalytic oxidation efficiency will diminish over time. The most commonly encountered poisons are silicone based products. When airborne silicone vapors come into contact with the heated bead the end product is silica/glass, which can completely seal the sensing bead. Sensor poisoning is irreversible.

Products used daily that can have a detrimental effect on catalytic bead sensors include:

- Lubricants/Greases
- Rubber and plastic revival products such as "Armor All"
- Waxes and polishes
- Injection mould release compounds
- Caulking materials
- Personal care products – cosmetics, hand lotions, etc... containing ingredients such as polydimethylsiloxanes; cyclic methylsiloxanes; cyclomethicone
- Heat transfer fluids
- Silicone oils

Other potential poisons include volatile leads, especially tetraethyl lead which is still found in many aviation fuels; hydride gases such as phosphine, silane, germane, arsine; phosphates; and high concentrations of sulfur based gases such as hydrogen sulfide, carbon disulfide, dimethyl sulfide. Good news is, the catalytic bead sensors used in BW Technologies products have an internal filter designed to absorb sulfur based gases so that they do not cause permanent sensor damage. The filter provides 1000 ppm hour protection against H_2S poisoning, which means the sensor can withstand exposure to 1000 ppm H_2S for 1 hour; 10 ppm for 100 hours. Under normal operating conditions the combustible gas sensor should never experience loss of sensitivity due to H_2S exposure.

Some substances such as halogenated compounds, especially halogenated hydrocarbons (Freon, CFCs, HCFCs), chlorinated solvents (trichloroethylene and methylene chloride), and sulfur based gases, can also temporarily inhibit the sensor response; but typically the sensor can recover from an inhibition substance once removed from the contaminating environment and exposed to fresh air. Some substances may exhibit inhibition characteristics and then become a sensor poison if exposure time and/or concentration exceed sensor resistance.

Catalytic Bead Sensors with Enhanced Poison Resistance

BW Technologies by Honeywell portable safety gas detectors, by default, use a catalytic bead combustible gas sensor that offers superior silicone poison resistance. These sensors include a filter that helps to prevent potentially damaging molecules from entering the sensor cavity and coming into contact with the heated refractory beads.

FILTERED AND UNFILTERED CATALYTIC BEAD COMBUSTIBLE GAS SENSORS

There's a tradeoff, however, that impacts certain applications for the use of portable safety gas detectors. The silicone resistant filter prohibits the diffusion of larger, more complex molecules. As a result, the filtered combustible gas sensor is suitable for the detection of the smaller molecule hydrocarbons, such as: methane, ethane, propane, butane, pentane, hexane, and hydrogen. It is not suitable for detecting: complex, large molecule hydrocarbons, alcohols, ketones, and esters due to the physical size of the molecules.

If your application requires the detection of more complex hydrocarbons, or alcohols like ethanol and methanol, an unfiltered catalytic bead combustible sensor is recommended. Also be aware that even the unfiltered sensor has detection limitations as well; such as longer response time to larger molecules. A photoionization sensor (PID) may be a better choice for monitoring vapors of complex hydrocarbon products like diesel fuel and kerosene-based aviation fuel with Flash Points typically of 37.8°C (100°F) and higher.

The following chart illustrates the detection capabilities of an unfiltered and filtered catalytic bead sensor. GREEN indicates detectable; YELLOW indicates caution; RED indicates not detectable:

Gas/Vapor	Unfiltered	Filtered
Methane	✔	✔
Propane	✔	✔
n-Butane	✔	✔
n-Pentane	✔	✔
n-Hexane	✔	✔
n-Heptane	✔	!
n-Octane	✔	✖
n-Nonane	✔	✖
Methanol//Ethanol	✔	✖
Acetone	✔	✖
Toluene	✔	✖
Ethyl Acetate	✔	✖
Hydrogen	✔	✔
Cyclohexane	✔	✔
Methyl Ethyl Ketone (MEK)	✔	✖
Acetylene	✔	✔
Ethylene	✔	✔
Gasoline	✔	!

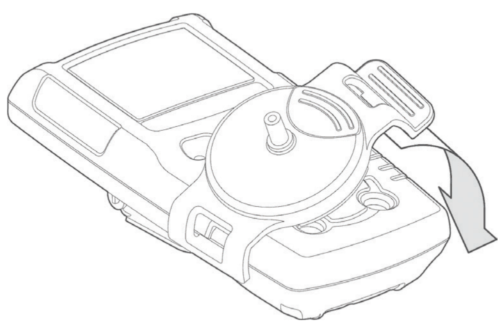
NOTE: For YELLOW be aware that although detectable by the filtered catalytic bead sensor response time is considerably slower than the unfiltered version.

Although the unfiltered catalytic bead sensor expands the detectable combustible gas capabilities over the filtered sensor, it is important to consider that the unfiltered sensor is more susceptible to poisoning and it is important to maintain a vigilant function testing (Bump Checking) protocol to confirm sensor response.

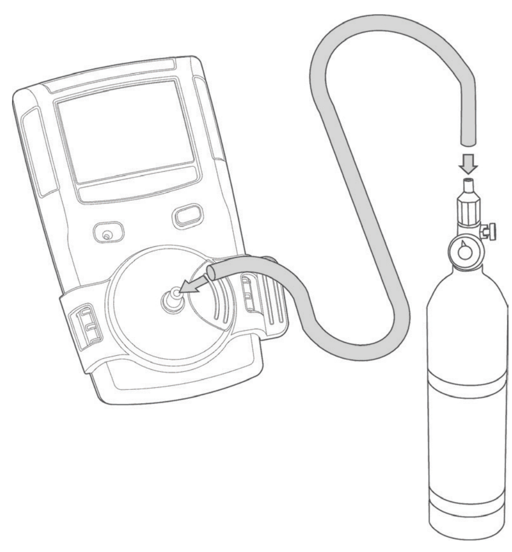
Bump Checking Direct Reading Portable Safety Gas Detectors

Unfortunately, sensor poisoning of catalytic bead combustible gas sensors presents a fail unsafe condition. It is not possible to determine with internal electronic diagnostics that the sensing bead is not capable of detecting combustible gas molecules, i.e.: that it has been poisoned. When the gas detector is turned on a voltage is applied to the combustible gas sensor and the platinum coil in the sensing and compensating catalytic beads is heated up to a specific temperature, the Wheatstone bridge circuit is balanced and the display indicates 0.

The only way to determine whether the catalytic bead combustible sensor is capable of detecting combustible gas is to perform a "Bump Check"; simply apply a concentration of target gas, capable of initiating an alarm condition, to the gas detector when it is in normal operating mode; visually observe that all sensors respond to the gas and that at a minimum a LOW alarm condition is activated ensuring that visual, audible and vibrating alarms function.



ONLY PERFORM A BUMP CHECK IN A FRESH AIR ENVIRONMENT (20.9% oxygen; 0 ppm toxic gases; 0% LEL combustible gases) *When detector is in standard operating MODE attach calibration cap*



Connect gas cylinder to calibration cap and open regulator valve – observe all sensors respond to target gas and alarms activate

Automated Instrument Management

Automated Bump, Calibration and Record Keeping Systems remove human subjectivity from the Bump Check equation; the system unequivocally indicates PASS or FAIL; and, **the system keeps Verifiable, Traceable and Complete (VTC) records.**

The most common configuration in a compliance confined space entry gas detector includes sensors for the detection of oxygen concentration, hydrogen sulfide, carbon monoxide and combustible gases. Although the catalytic bead combustible sensor is the only sensor that is susceptible to loss of sensitivity due to poisoning, other sensors may experience loss of function due to physical damage, liquid immersion, gas concentrations that exceed the detection limit or sensor ports may be obstructed by dirt and oils, etc... Manufacturers of portable safety gas detectors recommend Bump Checking all sensors to confirm the gas detector is capable of doing its job of alarming workers to the presence of a potentially life threatening atmospheric gas hazard.

INTELLIDOX AUTOMATED BUMP CHECK, CALIBRATION AND RECORD KEEPING SYSTEM

Perform a Bump Check to confirm sensor response and alarm activation prior to each day's use at a minimum. The only thing worse than a gas detector you know doesn't work, is a gas detector that you don't know doesn't work!

Choosing the Right Gas for Calibration and Bump Testing

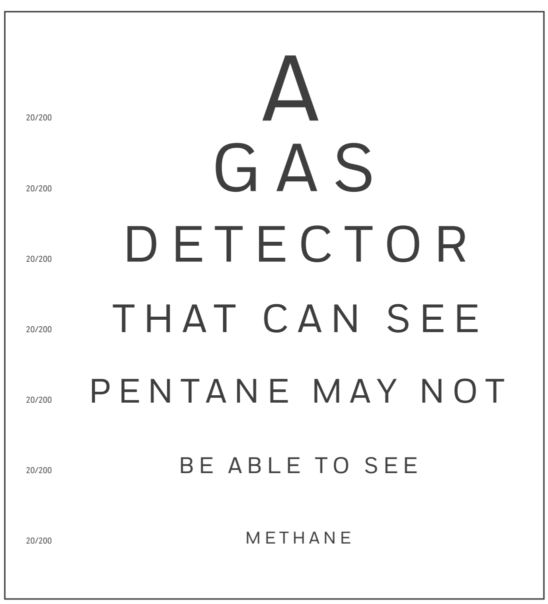
The gas used to calibrate a hydrogen sulfide sensor, for example, is self-evident: hydrogen sulfide; however, for a sensor that is non-specific the selection of a calibration gas may not be so evident. The question regarding what combustible gas should be used for calibration and Bump Testing is raised quite often.

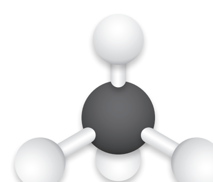
The catalytic bead combustible gas sensor readings will be most accurate if the sensor is calibrated to the same gas being detected. If you work at a propane plant and propane is the known potential gas hazard, it is logical to calibrate the combustible gas sensor to a known concentration of propane. Unfortunately, in many portable safety gas detector applications the combustible gas hazard may be unknown or more than a single combustible gas hazard may exist in the workplace.

In applications where the combustible gas hazard is unknown or can vary, calibration to methane is a common practice. But, given that pentane calibration overstates the actual concentration of methane some people feel that pentane provides the most prudent calibration strategy.

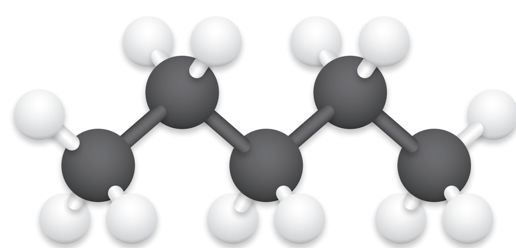
At BW Technologies by Honeywell we calibrate detector combustible gas sensors to methane taking the following into consideration:

- Methane is the most commonly encountered combustible gas in industrial safety applications.
- Portable safety gas detectors are used in a variety of workplace environments and sensors can be exposed to airborne substances that can compromise sensor response. A combustible sensor with lower sensitivity will first lose the ability to detect methane. Methane is the most difficult of the standard smaller alkane hydrocarbon molecules for the catalytic bead combustible sensor to detect. The methane molecule is a relatively stable structure and it requires more energy to catalytically oxidize, than say a long chain pentane molecule. It is possible that a catalytic bead combustible gas sensor with compromised response can detect pentane, and not be capable of detecting methane. Inversely, if we know the sensor can detect methane we can be assured the sensor is capable of detecting pentane.





METHANE



PENTANE

If the pentane safety factor response is an important consideration, there are other, safer ways, of achieving a similar result:

- Lower the detector alarm setpoints; instead of the standard 10 and 20% LEL warning, set the alarms for 5 and 10% LEL.
- Use a Correction Factor based on the Relative Response data for the specific catalytic bead sensor. Many gas detectors provide the ability to set a CF and the readings will reflect the corrected value automatically.
- BW Technologies by Honeywell can provide a “Pentane Equivalent”, methane calibration gas mixture. The cylinder contains 25% LEL concentration of methane, but we tell the gas detector it is being calibrated to 50% LEL, thereby adjusting the sensor to an equivalent pentane response. This provides the **“best of both worlds”** by ensuring the ability to detect methane while maintaining that pentane type response.

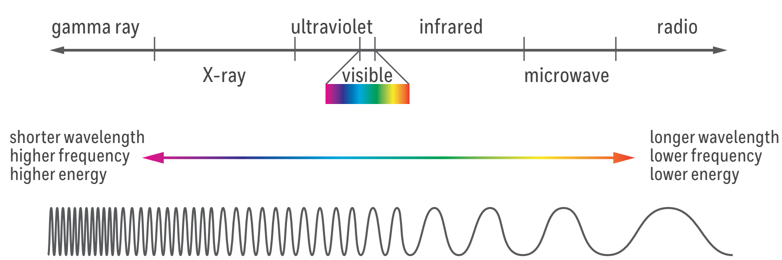
If the target combustible gas hazard is known, calibrate to a known concentration of that gas when possible. **If, as in many workplace environments the hazard on any given day is unknown, or, if methane is a potential hazard, ensuring methane response provides the safest approach.**

Non-dispersive Infrared Combustible Gas Sensing Technology

Another combustible gas sensor technology found in portable safety gas detectors, although far less common, is the Non-Dispersive Infrared (NDIR) type. NDIR has some distinct advantages compared to the catalytic bead type, like all technology it too has limitations.

The Basics of NDIR Sensor Operation

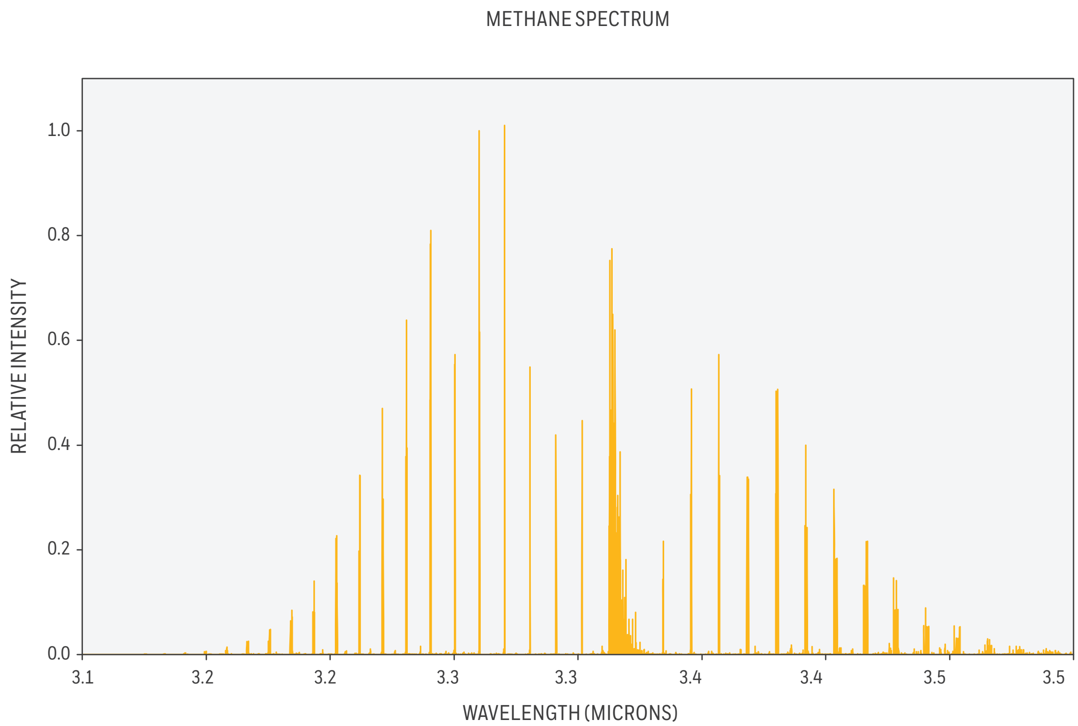
The non-dispersive infrared gas sensor technology is based on a gas molecules' absorption of infrared energy by the bonds of dissimilar atoms such as the carbon and hydrogen atoms in hydrocarbon gas molecules (C-H bond).



ELECTROMAGNETIC SPECTRUM

The typical NDIR combustible gas sensor includes an infrared energy source, a filter to allow the transmission of specific wavelengths of infrared energy, an optical cavity to allow the diffusion of gas molecules, a dual wavelength infrared detector, temperature sensor and electronics to process the response signal.

The active detector element transmits infrared energy at a wavelength that will be absorbed by the intended target gases; the fundamental absorption wavelength for C – H bonds is between 3.2 microns to 3.5 microns in the infrared spectrum which is the target band for hydrocarbon sensors.



INFRARED SPECTRA OF C-H BOND GROUPS. FROM DYNAMENT APPLICATION NOTE AN4

The amount of infrared energy received at the active detector decreases in relation to the reference wavelength as the concentration of target gas passing through the sensing cavity increases.

NDIR Sensor Application

The NDIR combustible gas sensor does not require the presence of oxygen to detect combustible gases. Typical applications for the NDIR combustible gas sensor would include monitoring detectable hydrocarbon gases in tanks under nitrogen storage blankets, or other inert atmospheres where oxygen concentration is insufficient to support catalytic bead sensor operation.

Besides being able to detect hydrocarbon gases in oxygen deficient atmospheres, other NDIR sensor technology benefits include:

- NDIR combustible sensors are not affected by the airborne contaminants, such as silicones that can poison catalytic bead sensors.
- NDIR sensors require less power to operate. Catalytic bead combustible gas sensors require constant power to maintain a consistent heat in the beads. Portable safety gas detectors with NDIR combustible sensor technology will provide longer battery run time.

NDIR Sensor Limitations

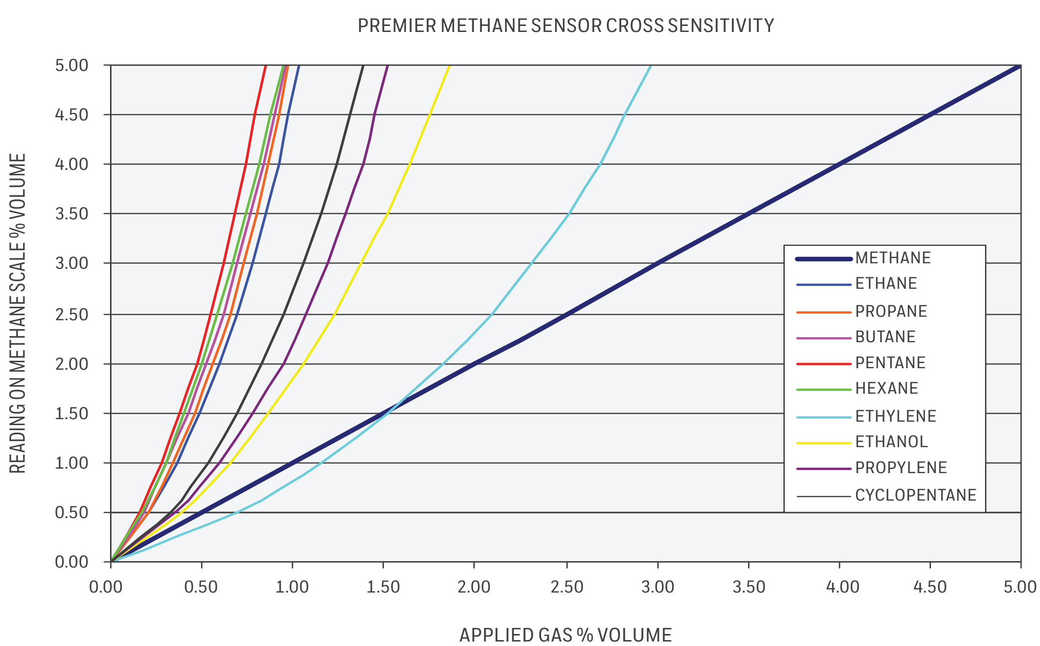
First and foremost, NDIR technology is not able to detect hydrogen (H_2), the most abundant element in the universe, and also a combustible gas threat in many portable safety gas detector applications. NDIR gas detection is dependent upon the energy absorption characteristics of dissimilar atoms in polynuclear molecules. Molecules such as hydrogen (H_2), oxygen (O_2) and nitrogen (N_2) are diatomic homonuclear molecules, i.e.: molecules consisting of two atoms of the same element. These molecules do not absorb infrared energy and are therefore not detectable by NDIR sensor technology. Another common combustible gas hazard that is not detectable by the NDIR combustible gas sensor is acetylene which absorbs infrared energy at wavelengths outside of the sensors target IR bandwidth.

The inability to detect hydrogen is a major limitation. One method recommended to overcome this significant shortcoming is to exploit the cross sensitivity of a carbon monoxide (CO) sensor to hydrogen and use readings on the CO sensor channel of the personal safety gas detector to indicate the presence of hydrogen. Using the CO sensor as a surrogate sensor for the detection of H_2 presents issues that users need to be aware of as well:

- Using a sensor as a surrogate sensor for the detection of a gas other than the intended target gas does not represent best practice.
- The CO sensor is intended to warn users of exposure to CO, a toxic gas hazard. Using the CO sensor as a H_2 indicator can create confusion. Remember that from a safety standpoint H_2 represents a combustion hazard – the LEL of H_2 is 4.0% v/v (4.0% v/v = 40,000 ppm).
- The low alarm setpoint for a CO sensor is typically 25-35 ppm. Many CO sensors exhibit approximately a 20-40% cross sensitivity to H_2. Given that information, it could take less than 100 ppm H_2 (0.25% LEL H_2) to create an alarm on the CO channel. This may result in what may be interpreted as nuisance alarms.
- Nuisance alarms cause users to lose confidence in their monitors and if H_2 is present, even in low concentrations, it may prove problematic. In the event users have experienced repeated false CO alarms due to low concentrations of H_2, they may become complacent about alarm conditions, and without adequate warning workers may find themselves in a dangerous situation.
- Another limiting factor is the detection range of the CO sensor, typically 500-1000 ppm. A concentration of less than 5% LEL H_2 could over range the CO channel. Over ranging can damage or cause premature sensor failure.
- It can be difficult to quantify the concentration of a gas other than the target gas by relying on cross sensitivity data which is intended to be used as a guideline only.
- In the case where the monitor's data is downloaded for objective evidence of alarm events, it is difficult to conclude whether it was a toxic or combustible exposure.

NDIR Sensor Responses to Hydrocarbons

Like the catalytic bead sensor technology, NDIR is also non-specific. The sensor will produce a reading from a gas molecule that is capable of absorbing infrared energy in the target bandwidth, but the sensor has no way to identify the species of gas that is being detected. The NDIR combustible sensors are factory calibrated to respond directly (linearly) to methane (CH_4). Hydrocarbons such as propane, butane, pentane etc. will generate a gas reading from the NDIR sensors, but the response is non-linear (the NDIR sensor output will increase more rapidly for heavy hydrocarbons than for methane as the gas concentration increases). This non-linearity of response can make it difficult to determine correction factors for other gases. Typically, the gas reading will be higher than that obtained from the same concentration of methane (ethylene is an exception). The following chart from a leading manufacturer of NDIR sensor technology illustrates the response to some other hydrocarbons based on calibration to methane. Note that the non-linearity is more pronounced in the higher concentrations.



BASED ON DYNAMENT PREMIER HYDROCARBON INFRARED GAS SENSOR

Although the response to other hydrocarbons is typically “fail-to-safe”, the gross non-linearity can also lead to nuisance alarms. It is possible that workers could be taking premature action to evacuate a work space. Nuisance alarms can be time consuming and expensive.

Other factors to take into consideration when determining whether NDIR technology is appropriate for an application:

- Warm up time – portable safety gas detectors with NDIR combustible gas sensors require a warm up period when the detector has been turned on. Depending on the manufacturer and sensor used, it can take from 60 seconds to 5 minutes before the sensor readings can be considered reliable.
- Cost – NDIR combustible gas sensors are typically 3 to 4 times the initial cost of a catalytic bead combustible gas sensor.

Calibrating and Testing Direct-reading Gas Detectors

Although the recommendation on calibration frequency can vary considerably between manufacturers, the recommendation to bump check direct-reading portable safety gas detectors prior to each day's use at a minimum is unanimous. Gas detectors are not typically calibrated every day, so it is important to perform a bump check to confirm sensor response and alarm activation between calibration cycles.

The U.S. Department of Labor Occupational Safety and Health Administration (OSHA) provide guidelines regarding calibration and bump checking in OSHA SHIB 09-30-2013 "Calibrating and Testing Direct-Reading Portable Gas Monitors" (see Appendix B).

The OSHA document references the International Safety Equipment Association (ISEA) "Statement on Validation of Operation for Direct Reading Portable Gas Monitors", (Appendix C). Honeywell Analytics has been an active member of the ISEA instruments group since 2006 along with other manufacturers of portable safety gas detectors.

Conclusion

Portable safety gas detectors are life safety devices designed to alert workers to the presence of potentially life threatening gas hazards. Workers around the world often rely on these devices with little, or no, understanding of the capabilities, let alone, the limitations of this important piece of PPE (Personal Protective Equipment). Users frequently believe the portable safety gas detector will provide warning of any, and all, combustible gas hazards that may be encountered in the workplace, when this may not be true.

The NDIR combustible sensor may provide a solution for the detection of hydrocarbons in some applications, but for everyday use, when combustible gas hazards can vary, or even be unknown, the catalytic bead combustible sensor remains the most common technology used in a portable safety gas detector.

Knowledge of the capabilities and limitations of different sensing technologies is important when determining what portable safety gas detector to select for an application. All instrumentation has limitations and being aware of that fact can make the workplace safer. Assuming that an NDIR combustible sensor will provide warning that combustible levels of hydrogen are present, could prove a fatal assumption.

APPENDIX A

Relative Response Data

NOTES: Relative Response Data shows the variation in response of several catalytic bead combustible sensors on exposure to a range of gases and vapors at the same % LEL concentration. The data is experimentally derived and expressed relative to the methane signal (=100). Testing was performed using sensors calibrated to 50% LEL CH_4 (based on 100% LEL = 5% v/v).

The results are intended for guidance only. All RR values have been rounded to the nearest 5%. For the most accurate measurements calibrate using the gas under investigation.

MICROpeL 75C (filtered, enhanced poison resistance) – BW P/N: SR-W-MP75C

Gas / Vapor	Relative Response	Gas / Vapor	Relative Response
Methane	100	Hydrogen	125
Propane	60	Ethylene	100
n-Butane	70	Acetylene	95
n-Pentane	65	n-Heptane	50

MICROpeL 75 – BW P/N: SR-W-MP75

Gas / Vapor	Relative Response	Gas / Vapor	Relative Response
Methane	100	Acetone	65
Propane	60	MEK	55
n-Butane	70	Toluene	55
n-Pentane	60	Ethyl Acetate	55
n-Heptane	50	Hydrogen	125
n-Octane	45	Cyclohexane	60
Methanol	105	Unleaded Gas	55
Ethanol	80	Ethylene	100
Isopropyl alcohol	60	Acetylene	95

4P-75C (filtered, enhanced poison resistance) – BW P/N: SR-W04-75C

Gas / Vapor	Relative Response
Methane	100
Propane	65
n-Butane	65
n-Pentane	55
n-Hexane	50
Acetylene	90

Gas / Vapor	Relative Response
Carbon Monoxide	120
Hydrogen	110
Ammonia	140
Cyclohexane	50
Ethylene	95
1,3 Butadiene	60

4P-75 – BW P/N: SR-W04-75

Gas / Vapor	Relative Response
Methane	100
Propane	65
n-Butane	65
n-Pentane	55
n-Hexane	55
n-Heptane	45
n-Octane	35
Methanol	85
Ethanol	85
Isopropyl alcohol	65
Acetylene	90
1,3 Butadiene	60

Gas / Vapor	Relative Response
Carbon Monoxide	120
Acetone	70
MEK	55
Toluene	40
Ethyl Acetate	55
Hydrogen	110
Ammonia	140
Cyclohexane	50
Leaded Gas	60
Unleaded Gas	60
Ethylene	90

4P-90C (filtered, enhanced poison resistance) – BW P/N: SR-W04

Gas / Vapor	Relative Response	Gas / Vapor	Relative Response
Methane	100	Carbon Monoxide	105
Propane	60	Hydrogen	100
n-Butane	60	Ammonia	125
n-Pentane	50	Cyclohexane	50
n-Hexane	40	Ethylene	85
Acetylene	80	1,3 Butadiene	55

4P-90 – BW P/N: SR-W04-UF

Gas / Vapor	Relative Response	Gas / Vapor	Relative Response
Methane	100	Carbon Monoxide	110
Propane	60	Acetone	65
n-Butane	60	MEK	50
n-Pentane	55	Toluene	45
n-Hexane	45	Ethyl Acetate	50
n-Heptane	45	Hydrogen	105
n-Octane	40	Ammonia	125
Methanol	90	Cyclohexane	55
Ethanol	70	Leaded Gas	55
Isopropyl alcohol	55	Unleaded Gas	55
Acetylene	80	Ethylene	90
1,3 Butadiene	55		

APPENDIX B

U.S. Department of Labor
OSHA SHIB 09-30-2013

Safety and Health Information Bulletins / Calibrating and Testing Direct-Reading Portable Gas Monitors (https://www.osha.gov/dts/shib/shib093013.html)

U.S. Department of Labor
Occupational Safety and Health Administration
Directorate of Technical Support and Emergency Management
Office of Science and Technology Assessment

Calibrating and Testing Direct-Reading Portable Gas Monitors

Safety and Health Information Bulletin SHIB 09-30-2013

*This Safety and Health Information Bulletin is **not** a standard or regulation, and it creates no new legal obligations. The Bulletin is advisory in nature, informational in content, and is intended to assist employers in providing a safe and healthful workplace. Pursuant to the Occupational Safety and Health Act, employers must comply with hazard-specific safety and health standards and regulations promulgated by OSHA or by a state with an OSHA-approved state plan. In addition, pursuant to Section 5(a)(1), the General Duty Clause of the Act, employers must provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm. Employers can be cited for violating the General Duty Clause if there is a recognized hazard and they do not take reasonable steps to prevent or abate the hazard. However, failure to implement any recommendations in this Safety and Health Information Bulletin is not, in itself, a violation of the General Duty Clause. Citations can only be based on standards, regulations, and the General Duty Clause.*

The information in this Safety and Health Information Bulletin (SHIB) provides workers and employers guidance on calibrating and testing direct-reading portable gas monitors (hereafter, "DRPGMs" or "instruments"). These instruments protect workers from unseen workplace gas hazards. Proper maintenance and calibration of the instruments ensures their accuracy in detecting worker exposure to harmful gases in the workplace. Follow the manufacturer's recommendations with regard to calibrating the instruments.

Introduction

DRPGMs are designed to alert workers to toxic gases, as well as oxygen-deficient and combustible atmospheres that may exist in their workplace environments, such as permit-required confined spaces, manholes, and other enclosed spaces. Several OSHA standards require the use of gas monitors. See paragraph (c)(5)(ii)(C) of 29 CFR 1910.146 (Permit-required confined spaces); paragraph (c)(6) of 29 CFR 1910.120 (Hazardous waste operations and emergency response); and section 5 (Entry into bins, silos, and tanks) of Appendix A of 29 CFR 1910.272 (Grain handling facilities). OSHA recommends developing standard procedures for calibrating and using DRPGMs that include documentation to verify the proper maintenance and calibration of the instruments.

Instrument inaccuracy due to improper or irregular maintenance and calibration can lead to exposure to hazardous levels of toxic gases or to an oxygen-deficient atmosphere. This exposure can cause workers to suffer serious injuries or illness, and even death. Flammable gas explosions are often catastrophic, resulting in worker injuries and death, or destruction of property.

The best way to verify that a DRPGM detects gas accurately and reliably is to test it with a known concentration of gas. This procedure will verify whether the sensors in the instrument respond accurately and whether the alarms function properly.

The International Safety Equipment Association (ISEA), founded in 1933, is a trade association for manufacturers of protective equipment, including DRPGMs. The ISEA recommends, at a minimum, verifying the operational capability of these instruments before each day's use, with additional testing conducted as necessary. This SHIB incorporates recommendations developed by the ISEA.[1]

1. See link to the "ISEA Statement on Validation of Operation for Direct Reading Portable Gas Monitors" at the end of this SHIB.

Calibration: The Key to Accurate Readings

Operators use DRPGMs to detect the presence and concentration of toxic and combustible gases, as well as oxygen deficiency or oxygen enrichment (which is a fire and explosion hazard). Workers must not rely solely on their sense of smell to alert them to these hazards. Employers should ensure that workers use these instruments when working in areas with potential hazardous atmospheres.

"Calibration" refers to an instrument's measuring accuracy relative to a known traceable concentration of test gas. DRPGMs compare the sensor's response to a known concentration of the test gas. To confirm the validity of this comparison, it is important to ensure the calibration gas has not expired (always check the expiration date of the gas before usage). The instrument's response to the calibration gas serves as the reference point.

The responsiveness of sensors will vary with workplace environmental conditions, such as temperature and humidity. Therefore, to the degree possible, operators should calibrate sensors in environmental conditions that are the same as (or similar to) the actual workplace conditions. Follow the manufacturer's guidelines for proper calibration.

Standard procedures for regular calibration that conform to the manufacturer's instructions, internal company policy, and/or the appropriate regulatory agency guidelines will help to ensure that calibration procedures are readily followed by the DRPGM operators, and that the instruments are operable and accurate when used. Employers should keep calibration records for the life of each instrument. This record enables operators to quickly identify a DRPGM that has a history of excessive maintenance/repair, or is prone to erratic readings, and to track drift of the sensors to determine when they need replacement.

Calibration Drift and Causes

When an instrument's reference point shifts, the reading will shift accordingly and be unreliable. This is called "calibration drift," and it happens to all sensors over time. An instrument that experiences calibration drift can still measure the quantity of gas present, but it cannot convert this information into an accurate numerical reading. Calibration checks or full calibration[2] with a traceable gas concentration will verify or update the instrument's reference point. Operators should conduct these procedures daily, or more frequently if needed, to ensure that the instrument will continue to produce accurate readings. Calibration drift occurs most often because of:

- Degradation caused by exposure to phosphates
- Degradation of phosphorus-containing components
- Degradation of lead-containing components
- Gradual chemical degradation of sensors and drift in electronic components that occur normally over time.
- Use in extreme environmental conditions, such as high/low temperature and humidity, and high levels of airborne particulates.
- Exposure to high concentrations of the target gases and vapors.
- Exposure of catalytic hot-bead LEL sensors in the instruments to volatile silicones, hydride gases, halogenated hydrocarbons, and sulfide gases.
- Exposure of electrochemical toxic gas sensors to solvent vapors and highly corrosive gases.
- Handling/jostling of the equipment causing enough vibration or shock over time to affect electronic components and circuitry.

2. See the discussion of calibration checks and full calibration later in this SHIB.

Operators should validate a DRPGM's operability when any of these conditions occurs, or is suspected, during use. When attempting to calibrate an instrument after exposure to these conditions, the sensor often will either display a failure message or will not allow the operator to fully adjust the display reading. Harsh operating and storage conditions can affect instrument performance, leading to inaccurate readings or even failure. While a DRPGM may appear undamaged during visual inspection, it actually could be damaged internally. At this point, the operator should replace the damaged sensor or have qualified personnel service the sensor. Be sure to follow the manufacturer's instructions regarding sensor replacement and servicing.

Worker Safety: The Number One Reason for Proper and Regular Calibration

The primary reason for proper, regular instrument calibration is to provide accurate gas-concentration readings that could prevent worker illness, injury, or death. Correctly calibrating an instrument helps to ensure that the DRPGM will respond accurately to the gases it is designed to detect, thereby warning users of hazardous conditions before the conditions reach dangerous levels. Some DRPGMs have two levels of alarms – warning and danger. The warning alarm alerts the operator and workers that the work environment has a detectable elevated concentration of toxic gas and is, therefore, potentially hazardous. The danger alarm indicates that the toxic-gas concentration exceeds the programmed hazard threshold, and that the toxic gas in the work area is above the warning level and approaching a hazardous level. Whether a DRPGM provides a warning or danger alarm at the proper concentration depends on its detection capabilities, its ability to translate its findings into an accurate reading, and the presence of interfering gases (see "Calibration Drift and Causes" above).

Bump Tests, Calibration Checks, and Full Calibration

Bump Test (or Function Check)

This is a qualitative function check in which a challenge gas is passed over the sensor(s) at a concentration and exposure time sufficient to activate all alarm settings. The purpose of this check is to confirm that gas can get to the sensor(s) and that all the instrument's alarms are functional. The bump test or function check does not provide a measure of the instrument's accuracy. When performing a bump test, the challenge gas concentration should trigger the DRPGM's alarm(s).

Calibration Check or Full Calibration

There are two methods for verifying DRPGM accuracy: a calibration check and a full calibration. Each method is appropriate under certain conditions.

A calibration check verifies that the sensor(s) and alarms respond within the manufacturer's acceptable limits by exposing the instrument to a test gas. The operator compares the reading to the test-gas concentration (as indicated on the cylinder containing the test gas). If the instrument's response is within the acceptable range of the test-gas concentration (typically ± 10-20% of the test-gas concentration), then the calibration check verified the instrument's accuracy. (Note: OSHA recommends that operators check with the instrument's manufacturer for the acceptable tolerance ranges.) An operator should "zero" an instrument (reset the reference point, in some cases "zero air" gas may be needed) before conducting the calibration check to ensure that the calibration check results are accurate. When performing a calibration check, the test-gas concentration should be high enough to trigger the instrument's alarm(s).

If the calibration-check results are not within the acceptable range, the operator should perform a full calibration. A full calibration adjusts the instrument's reading to coincide with a known concentration (i.e., certified standard) of test gas. Test gas used for calibration gas should always be certified using a standard traceable to the National Institute of Standards and Technology (NIST).[3]

3. The "Supplementary Materials for NIST Policy Review" page on NIST's website at http://www.nist.gov/traceability/suppl_matls_for_nist_policy_rev.cfm (accessed 08/15/2013) provides the following definition of "traceable to NIST": "According to the internationally recognized VIM definition, metrological traceability is a property of a measurement result by which that result is related to specified reference standards, not to institutions. Accordingly, the phrase 'traceable to NIST,' in its most proper sense, is shorthand for 'metrologically traceable to NIST's practical realization of the definition of a measurement unit' (see 2.43 in [JCGM 200:2008, International vocabulary of metrology - Basic and general concepts and associated terms (VIM Third Edition, 2008)]."

When to Perform a Bump Test and When to Perform a Full Calibration

In the past, there has been some confusion regarding proper calibration procedures and frequency. To clarify this issue, ISEA updated its position statement on instrument calibration in 2010, stating, "A bump test . . . or calibration check of portable gas monitors should be conducted before each day's use in accordance with the manufacturer's instructions." If an instrument fails a bump test or a calibration check, the operator should perform a full calibration on it before using it. If the instrument fails the full calibration, the employer should remove it from service. Contact the manufacturer for assistance or service.

Calibration Rules

The following are a few basic calibration rules for DRPGMs:

- Follow the manufacturer's guidelines for proper calibration. Operators cannot perform any job, including DRPGM calibration, properly or safely without the right tools. The type and concentration of calibration test gas, sample tubing, flow regulators, and calibration adapters are key links in the calibration chain. Operators should conduct any testing to verify the operation of the gas monitor in an environment that is the same as (or similar to) the working conditions (e.g., temperature, humidity, atmospheric pressure).

- Only use a certified traceable test gas, and do so before its expiration date. The instrument can only be as accurate as the test gas used to calibrate it. Be certain that the supplier can provide a certificate of analysis for every test-gas cylinder. The concentration of the test gas, particularly reactive gases such as hydrogen sulfide and chlorine, will only remain stable for a limited period. Never use a test gas after its expiration date.

- Train DRPGM operators on the proper methods of calibration. Most instruments are designed to be field calibrated with detailed instructions provided in the manufacturer's user manual, training videos, or computer-based training modules. Employers should train and test everyone responsible for performing DRPGM calibration.

Conclusion

Many workplaces have a risk of injury, illness, or death from respiratory hazards such as oxygen deficiency and the combustible or toxic gases. DRPGM technology and products exist to minimize such risks. Properly verifying the function and accuracy of instruments before each day's use will help to ensure that each worker finishes the job safely.

For more information contact OSHA at: 1-800-321-6742 (OSHA) – OSHA Main Number

www.osha.gov

Twenty-seven states and territories operate their own occupational safety and health programs approved by OSHA. States enforce similar standards that may have different or additional requirements. A list of state plans is available at http://www.osha.gov/dcsp/smallbusiness/index.html

OSHA's On-site Consultation Program offers free and confidential advice to small and medium-sized businesses in all states across the country, with priority given to high-hazard worksites. On-site Consultation Programs are separate from enforcement and do not result in penalties or citations. To locate the OSHA On-site Consultation Program nearest you, call 1-800-321-6742 (OSHA) or visit http://www.osha.gov/dcsp/smallbusiness/index.html.

On-Line Resources:

International Safety Equipment Association (ISEA)
1901 North Moore Street
Arlington, VA 22209-1762
(703) 525-1695
https://www.safetyequipment.org (OSHA Alliance 2003-2005)

ISEA Statement on Validation of Operation for Direct Reading Portable Gas Monitors:
http://www.safetyequipment.org/userfiles/file/calibration_statement-2010-mar4.pdf

APPENDIX C

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

The International Safety Equipment Association (ISEA) is the leading national organization of manufacturers of safety and health equipment including environmental monitoring instruments. ISEA is dedicated to protecting the health and safety of all workers through the development of workplace standards and the education of users on safe work practices and exposure prevention.

ISEA has developed this statement to ensure definition consistency in all documentation, and to emphasize the need to validate the operational capability of portable gas monitors. The statement reflects current instrumentation technologies and monitoring practices. Specifically, the statement intends to:

a) Define and clarify the differences between bump test (function check), calibration check, and full calibration;

b) Clarify when these validation methods are to be performed; and

c) Reemphasize to users, regulatory agencies and standards writing bodies the importance of validating the operational capabilities of portable gas monitors used to examine the atmosphere in potentially hazardous locations.

1. Definitions

a) **Bump Test (Function Check) –** A *qualitative* function check where a challenge gas is passed over the sensor(s) at a concentration and exposure time sufficient to activate all alarm indicators to present at least their lower alarm setting. The purpose of this check is to confirm that gas can get to the sensor(s) and that all the alarms present are functional. This is typically dependent on the response time of the sensors(s) or a minimum level of response achieved, such as 80% of gas concentration applied. Note, this check is not intended to provide a measure of calibration accuracy.

a) **Calibration Check -** a *quantitative* test utilizing a known traceable concentration of test gas to demonstrate that the sensor(s) and alarms respond to the gas within manufacturer's acceptable limits. This is typically±10 to 20% of the test gas concentration applied unless otherwise specified by the manufacturer, internal company policy, or a regulatory agency.

a) **Full Calibration –** The *adjustment* of the sensor(s) response to match the desired value compared to a known traceable concentration of test gas. This should be done in accordance with the manufacturer's instructions.

2. Recommended Frequency

a) A **bump test (function check)** or **calibration check** of portable gas monitors should be conducted before each day's use in accordance with the manufacturer's instructions. Any portable gas monitor which fails a bump test (function check) or calibration check must be adjusted by means of a full calibration procedure before further use, or removed from service.

a) A **full calibration** should be conducted at regular intervals in accordance with instructions specified by the instrument's manufacturer, internal company policy, or a regulatory agency.

b) Validation of an instrument's operability should be conducted if any of the following conditions or events occurs during use:

   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 a target gas and vapors.

   iii. Chronic or acute exposure of catalytic hot-bead LEL sensors to poisons and inhibitors. These include volatile silicones, hydride gases, halogenated hydrocarbons, and high concentrations of sulfide gases.

   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 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.

International Safety Equipment Association

March 5, 2010

References

A number of references were used for this note including articles from industry magazine publications and other web based materials. Some key resources:

- City Technology Ltd. – www.citytech.com – various data sheets and technical notes
- Honeywell Gas Book, 2013 Honeywell Analytics
- THE JOHN ZINK COMBUSTION HANDBOOK, Charles E. Baukal, Jr. EDITOR, 2001 CRC Press LLC
- Hazardous Gas Monitors - A Practical Guide to Selection, Operation and Applications, Jack Chou, 2000 McGraw-Hill
- A Discussion on Pellistor Gas Sensor Responses – article by Dr. Alan Doncaster, ClairAir Ltd. appearing in International Environmental Technology magazine 2009
- FUNDAMENTALS OF COMBUSTIBLE GAS DETECTION – A Guide to the Characteristics of Combustible Gases and Applicable Detection Technologies, Published by the Technical Staff of GENERAL MONITOR
- Dynament Ltd. – www.dynament.com – various data sheets and application notes
- Work Safe Alberta Workplace Health and Safety Bulletin CH038; Use of Combustible Gas Meters at the Work Site; Revised – July 2010.

Related Documents:

- Catalytic Bead Combustible Gas Sensing Technology in BW Portable Safety Gas Detectors – 2017.01.13
- NON-DISPERSIVE INFRARED COMBUSTIBLE GAS SENSORS – October 30, 2015 Rev. 2.0

Important Links:

- http://www.honeywellanalytics.com
- http://www.raesystems.com
- http://www.hautraining.com
- http://www.citytech.com
- https://www.cdc.gov/niosh/npg/
- https://www.osha.gov/dts/shib/shib093013.html
- https://www.osha.gov/dsg/annotated-pels/index.html
- https://safetyequipment.org

For more information

www.honeywellanalytics.com

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