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Excavation Safety News

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It's a GAS!

Using Atmospheric Monitors for Confined Space Work

Editor's Note: *Make sure that you read and follow all governmental regulations and manufacturers' instructions regarding the proper use of all safety and construction equipment on all your job sites.*

OSHA requires use of a direct-reading instrument for confined space work, meaning that the gas detector must display current readings in "real time." This instrument indicates a normal level of oxygen (20.9%) and no other gases. Also, the battery is fully charged (bar graph in lower right corner of the display). The unit is operating in the peak-hold mode (mountain peak in upper right corner).

Proper use of atmospheric gas detectors is probably the single most important step in most confined space safety programs. Why? Because it is impossible to smell, taste, or see most hazardous atmospheres. As a result, workers in confined spaces are likely to be seriously injured or killed, if the atmosphere is hazardous, or becomes hazardous. Gas detectors are used to check the quality of the air before entry, and monitor changes that might take place during the entry.

Composition of Fresh Air

The primary components of normal air are:

Nitrogen	78.1%
Oxygen	20.9%
Argon	.9%
Other gases (water vapor, carbon dioxide, and other trace gases)	.1%

See "Using Gas Monitors" on page 2…

"Using Gas Monitors" from page 1

Our bodies depend upon a sufficient concentration of oxygen. Further, the atmosphere must be free of toxic contaminants. Problems occur when there is a change in these levels – specifically too little oxygen, too much oxygen, or the presence of toxic or flammable gases or vapors.

The Spring 1996 issue of **Excavation Safety News** focused on the "Ins and Outs of Confined Spaces." Because of its importance, the issue was re-published nine years later, in January 2005. Each of those newsletters discuss "how and why" that confined spaces may contain different atmospheres, and how those atmospheres might change as work progresses. Go to ***www.trenchsafety.com/usefulinfo/excavationsafety*** to download a free copy.

How Gas Detectors Work

Gas detectors use sensors to measure the contents of atmospheres. Those sensors respond to the atmosphere and provide information to the processors in the gas detector. In turn, numerical displays — along with visual and audio alarms — provide information to entrants, attendants and entry supervisors about air quality.

This gas detector utilizes four different sensors to monitor various gases.

Different types of sensors, using different detection principles, monitor different types of gases.

Oxygen

Oxygen levels are typically monitored with "fuel-cell" type sensors. These sensors generate an electrical current, based upon the amount of oxygen consumed by the sensor (applying Faraday's Law). The processors in the gas detector then monitor the current, and adjust the displays and alarms accordingly.

Fuel-cell type sensors get "used up" over time. As oxygen enters the sensor, a metallic (lead) anode is oxidized. When all the lead (Pb) in the sensor is converted to lead oxide (PbO_2), the sensor must be replaced. Even if the gas detector is in the "off" position, the sensor is still being used. Life expectancy of an oxygen sensor is generally one to two years, or, in the case of one brand, three years. Be sure to check the manufacturer's warranty to determine the life expectancy of the oxygen sensor.

The person is holding the oxygen sensor. On the detector you can see where this sensor plugs into the circuit board.

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Excavation Safety News

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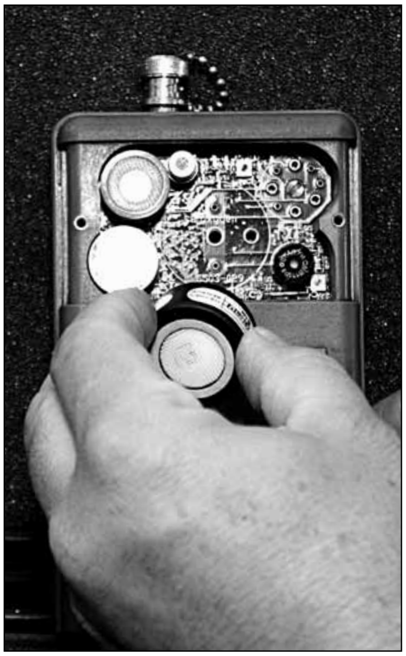
This newsletter provides a brief overview of safety regulations and systems. It is not intended to provide specific legal or engineering advice. Please refer to OSHA CFR29, Part 1926, Subpart P, "Excavation and Trenches," and to other governmental regulations, and to manufacturers' instructions for specific information.

Construction techniques and equipment usage must be in accordance with all governmental regulations and manufacturers' instruction. All orders placed with TrenchSafety are subject to the terms, conditions, and warranty limitations contained in TrenchSafety's Rental and Sales Agreements.

"Using Gas Monitors" from page 2

Toxic Gases

Toxic sensors monitor gases such as carbon monoxide and hydrogen sulfide. While it might seem they should last forever, in practice, life expectancy is two to four years. Multiple factors can affect life expectancy, including desiccation (drying out), leakage, contamination, etc.



The person is installing the oxygen sensor. Once the new sensor is in place, the unit will need to be re-calibrated.

Combustible Gases

Combustible gas sensors, which monitor methane gas and other flammable gases, are catalytic. Typically, these monitors contain porous platinum coils with ceramic beads in the sensor, which are heated to a very high temperature. The beads actually oxidize (burn) a sample of any combustible gases or vapors that might be present. The detector responds accordingly.

Life expectancy of combustible gas sensors is generally two to four years. A strong mechanical shock can actually break the beads, which results in immediate and permanent failure. Tetra-ethyl lead (found in gasoline), various silicone products, and prolonged exposure, or excessive exposure to hydrogen sulfide, can "poison" combustible gas sensors, resulting in premature failure.

Silicone poisoning is of particular concern because it initially only effects the sensor's ability to detect methane, while not exhibiting any inhibition to other gases. For this reason, catalytic-combustible gas sensors should always be calibrated to, or challenged with, a gas mixture containing methane.

Choosing a Gas Detector

There are two key questions to ask:

- What potential gases might be present (or, the case of oxygen, not present)?
- Will the atmosphere in the space "get to" or damage the monitor?

Answering these questions will require a thorough analysis of the areas in and around the confined space, as well as the type of work to be performed. Welding, painting, cleaning, or decontamination-type work might change the atmosphere as work progresses, might introduce additional contaminants, or might result in a chemical reaction with existing contaminants. Under such conditions, you should compare the results of your analysis with the gas monitor's technical specifications and other materials to make certain there is a match.

An example is chlorine. If there is potential for chlorine exposure, the gas detector you chose will need to be able to respond to chlorine. The detector itself will also need to be able to withstand the corrosiveness of chlorine gas.

Some gas detectors may be configured to check for as many as six different gases simultaneously. As a minimum, you are almost always concerned with too little or too much oxygen, and the presence of toxic gases (carbon monoxide and hydrogen sulfide), or flammable gases and vapors (methane, etc.).

This detector is in alarm mode, showing 18% of the lower explosive limits (LEL) and 19 parts per million (PPM) of hydrogen sulfide. Oxygen is low at 20.2%, but is within OSHA's acceptable range. The high levels of combustible and toxic gases <u>may</u> be displacing the oxygen.

See "Using Gas Monitors" on next page…

"Using Gas Monitors" from page 3

The Challenges of Sewer Systems

One of the challenges with sewer systems centers on the fact that they are a part of a continuous system of piping. That makes it near-impossible to isolate the area where workers will be located. As a result, the atmosphere in a sewer may suddenly and unpredictably change, from causes beyond anyone's control. OSHA 1910.146, Appendix E, Sewer System Entry, specifically recommends use of a gas detector with a broad range sensor in sewer-type work where the specific hazards have not been identified. Appendix E states:

> *"The oxygen sensor/broad range sensor is best suited for initial use in situations where the actual or potential contaminants have not been identified, because broad range sensors, unlike substance-specific sensors, enable employers to obtain an overall reading of the hydrocarbons (flammables) present in the space. However, such sensors only indicate that a hazardous threshold of a class of chemicals has been exceeded. They do not measure the levels of contamination of specific substances. Therefore, substance-specific devices, which measure the actual levels of specific substances, are best suited for use where actual and potential contaminants have been identified. The measurements obtained with substance-specific devices are of vital importance to the employer when decisions are made concerning the measures necessary to protect entrants (such as ventilation or personal protective equipment) and the setting and attainment of appropriate entry conditions. However, the sewer environment may suddenly and unpredictably change, and the substance-specific devices may not detect the potentially lethal atmospheric hazards which may enter the sewer environment."*

See "Using Gas Monitors" on next page…

Broad-range sensors: An example

Below is a partial list of the gases that are measured by one particular manufacturer's broad-range sensor:

- *Acetic Acid*
- *Acetone*
- *Acrylonitrile*
- *Ammonia*
- *Benzene*
- *Butanone (MEK)*
- *Butyl Acetate*
- *Butyl Alcohol*
- *Carbon Monoxide*
- *Carbon*
- *Tetrachloride*
- *Chlorobenzene*
- *Cyclohexene*
- *Dichlorobenzene*
- *Dichloroethylene*
- *Dimethylamine*
- *Diisobutyl Ketone*
- *Ethanolamine*
- *Ethyl Acetate*
- *Ethylamine*
- *Ethanol*
- *Ethyl Chloride*
- *Ethyl Ether*
- *Ethyl Mercaptan*
- *Flourotrichloromethane*
- *Formaldehyde*
- *Heptane*
- *Hexane*
- *Hexone*
- *Hydrogen Chloride*
- *Hydrogen Cyanide*
- *Hydrogen Peroxide*
- *Hydrogen Sulfide*
- *Isoamyl Acetate*
- *Isobutyl Alcohol*
- *Isopropyl Alcohol*
- *Isopropylamine*
- *LPG*
- *Methanol*
- *Methyl Acetate*
- *Methyl Alcohol*
- *Methyl Chloride*
- *Methyl Chloroform*
- *Methylene Chloride*
- *Methyl Ketone*
- *Methyl Mercaptan*
- *Methyl Styrene*
- *Naphthalene*
- *Nitropropane*
- *Nitrotoluene*
- *Propyl Alcohol*
- *Styrene*
- *Sulfur Dioxide*
- *Tetrachloroethylene*
- *Toluene*
- *Trichloroethylene*
- *Turpentine*
- *Vinyl Chloride*
- *Xylene*
- *Xylidine*

…and dozens more

While the gas detector will not identify the gas that is present, it will warn there's something dangerous in the atmosphere. Further investigation will be required.

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It is important to emphasize that Appendix E of the OSHA confined space entry standard is non-compulsory, and the use of a broad-band sensor provides neither the specific identification of the actual contaminant present nor a quantifiable readout. The benefit of a broad-band sensor is that it may provide an alarm in a hazardous condition where few other sensors can detect the substance. The drawback of a broad-band sensor is that it may also provide a positive response to conditions that may not be of concern.

Certain "legacy" instruments are available from select manufactures or, as an alternative, a photo-ionization detector (PID) may be considered. Note: Neither PID sensors nor broad-band sensors will respond to all potential hazards.

It is critical to check the atmosphere in every confined space, even after ventilation, to make certain it is safe.

Using a Gas Detector

Proper use of gas detectors vary between manufacturers. Everyone involved in atmospheric monitoring will need to be trained, and must follow the manufacturer's instructions. Gas detectors, over the years, have also gotten a lot simpler to operate. Most manufacturers require that you turn on the unit in clean air, and let the detector complete a warm-up cycle.

Some manufacturers — and the International Safety Equipment Association (ISEA) — recommend verifying sensor accuracy before each day's use. They suggest a "bump" test or full calibration before each use. If the instrument fails the bump test, it must be adjusted through a full calibration before use.

In April 2004, OSHA issued a Safety and Health Information Bulletin (SHIB 05-04-2004) in which the ISEA recommendation was recognized as a suggested and prudent practice. Though OSHA does state that the Bulletin is not a standard or a regulation, and it creates no new legal obligations, it is stated in the same paragraph that states that employers may be cited for violating the General Duty Clause. See ***www.goodforgas.com/documents/appnotes/OSHA_SHIB_05-04-2004.pdf***, and ***www.goodforgas.com/documents/appnotes/ISEA_Statement.pdf***

There are a couple of different techniques for testing, depending upon the specific gas detector.

Some instruments use "peak-hold" or "latching-circuits," which allow the gas detectors to be lowered into the confined space. The peak-hold feature allows the gas detector to "latch on," or "remember" the worse-case measurement.

Other instruments use remote sampling methods. An aspirator, which is connected to the gas detector with tubing, is lowered into the confined space. A hand-powered or motorized pump draws a sample of the atmosphere to the gas detector for analysis.

This next point cannot be overstressed: ***It is critical that you follow the manufacturer's instructions.*** It is also important to allow any sensor enough time (20-30 seconds) to respond to the atmosphere it is in. When an aspirated system is used it is also critical to allow for enough air to move through the sampling system before the gas will reach the sensors. Again, the manufacturer will specify that time.

Gases Form into Layers

Gases have different weights compared to normal air, and they will form layers — stratify — in confined spaces, so it is important to check at

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Periodic "bump" tests and calibrations —ALWAYS completed according the manufacturer's instructions — are absolutely necessary to ensure the accuracy of all your detectors.

different levels above the lowest level. Methane gas, for example, is lighter than normal air and tends to rise. Hydrogen sulfide is heavier than normal air and tends to settle in low places in confined spaces. Most safety professionals recommend testing at levels of every four (4) feet.

OSHA's Monitoring Rules

OSHA requires that atmospheres in confined spaces be tested prior to entry, and as "often as necessary" thereafter. Most safety professionals recommend continuous monitoring of a confined-space atmosphere. In many cases, the entrants will carry the gas detector into the confined space.

OSHA also specifies an order of testing. First, test the oxygen levels. Next, check for combustible gases. Third, check for toxic gases. As a practical matter, most gas detectors check all three types of gases simultaneously.

Alarms

Alarm levels will vary with the gas.

As we saw in the chart on page 1, oxygen makes up 20.9% of normal air. OSHA says that atmospheres with less than 19.5% or more than 23.5% oxygen are hazardous. Most gas detectors will sound and show an alarm when the level of oxygen falls outside the range of those numbers.

For combustible gases, OSHA refers to lower explosive limits, or LEL. With sufficient oxygen and a source of ignition, combustible gases will explode at a 100% concentration of the lower explosive level. OSHA says that an atmosphere is hazardous when the level of combustible gases reaches 10% or more of the LEL. Consequently, most gas detectors produce an alarm at 10%.

There are three different methods of expressing levels of toxic gases.

- **Time-Weighted Average, or TWA** — This measurement is based upon an eight-hour exposure. Many gas detectors automatically compute it. It's important to remember that if the monitoring session is either less or more than eight hours, the TWA is calculated based on the equivalent of an eight-hour exposure.
- **Ceiling** — This is a maximum exposure. It should not be exceeded for even one second.
- **Short-Term Exposure Limit, or STEL** – Some gases or vapors have a maximum Short-Term Exposure Limit that is higher than the

See "Using Gas Monitors" on next page…

What is PPM?

The concept of PPM can be a bit difficult to grasp. Just how small is 1 part per million? To help you, below are some comparisons.

1 PPM is equivalent to:

- *One automobile in a line of cars bumper-to-bumper from Cleveland, Ohio, to San Francisco, Calif., or*
- *One inch in 16 miles, or*
- *One minute in two years, or*
- *One ounce in 32 tons, or*
- *One penny in $10,000.*

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Time-Weighted Average. STEL measurements are based on a five-minute, a ten-minute, or a 15-minute time weighted average.

Though today's instruments are sophisticated enough to calculate the various exposures, confusion can still result. A commonly adopted (and safer) strategy is to set the ceiling alarm to the lowest numeric value of any of the three types of alarm. By doing so, there is only one "take-action" point, and no need to understand the different calculations.

OSHA Regulations

OSHA addresses toxic gases in several places in their Standard, including 1910.146 Appendix E, and Subpart Z. Some states have requirements that are more restrictive. You should also check Material Safety Data Sheets (MSDS) for requirements.

For example, OSHA's 1910.146 Appendix E specifies the following limits:

- Hydrogen Sulfide – 10 parts per million (PPM) based upon an 8-hour TWA
- Carbon Monoxide – 35 PPM based upon an 8-hour TWA

Depending upon the gas detector, the unit will go into alarm whenever any of these limits are reached. The visual display will indicate the actual percent of oxygen, the percent of the LEL for combustible gases, or the PPM of toxic gases. There will also be one or more visual and/or audible alarms.

When the unit produces an alarm, workers must immediately exit the confined space. The space will then need to be re-analyzed to determine the source of the hazardous atmosphere, and steps will need to taken to eliminate or control that source.

A bottle of calibration gases, showing the various concentrations.

Gas Monitor Maintenance

There are two common types of maintenance — calibration and changing the sensors.

Gas detectors use sensors to measure the concentration of gas in an air sample. Over time, "sensor drift" can occur, resulting in inaccurate readings. This occurs in all gas detectors, and with all sensors. Causes of sensor drift include:

- Chemical degradation of sensors
- Drift in electronic components
- Use in extreme environmental conditions
- Exposures to high (over-range) concentrations of gases and vapors
- Poisoning of LEL sensors
- Chronic or acute exposure of toxic gas sensors to solvent vapors and corrosive gases
- Harsh storage and operating conditions
- Dropping the gas detector onto a hard surface or submerging in liquid

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A sensor that is damaged or consumed will fail to respond to the very gas for which it is designed. Such sensors will display "zero," even when the gas is present. For combustible and toxic-gas sensors that means the detector will always read zero or a much lower than actual concentration.

A "bump" test is performed simply by exposing the sensors to a known concentration of gas and checking the numerical readings on the gas detector. If the readings are within ±10% of the known concentration, the gas detector passes the test.

Calibrations are similar to bump tests, but with one significant difference. The gas detector resets itself, based upon that concentration. For example, if the known concentration of the lower explosive limit (LEL) is 50%, the gas detector will adjust itself to display 50% LEL, when exposed to that concentration.

Over time, sensor drift will occur again and the gas detector will need to re-calibrated.

Most manufacturers strongly suggest that gas detectors be calibrated at least once every 30 days. If there are any concerns about accuracy, a bump test should be performed or the unit should be re-calibrated.

The gas used for bump tests and calibrations should be supplied, or approved by, the manufacturer. OSHA also says that gas detectors must be calibrated according to the manufacturer's instructions.

Changing sensors is simply a fact of life with gas detectors. When a sensor needs to be changed — (for example, an unsuccessful attempt is made to calibrate it, or the user realizes it based on a bump test — the gas detector will display an error message. The bad sensor is removed and the new sensor is installed in a socket. The gas detector must then be re-calibrated.

Conclusion

Understanding the potential atmospheric hazards, choosing the right atmospheric monitor, properly using the monitor, and performing regular bump tests and calibrations will help to ensure worker safety.

More Information Is Available…

Two previous issues of **Excavation Safety News** covered other aspects of confined space work. The August 2005 issue discussed *"The Ins & Outs of Confined Spaces,"* and the October 2006 issue provided information on *"Proper Use of Ventilation in Confined Spaces."* Both issues are available as FREE downloads from ***www.trenchsafety.com/usefulinfo/excavationsafety***