

Gas Detection Technology in Confined Spaces

**Andrew Saunders
Applications and Training Specialist
BW Technologies by Honeywell**

Introduction

The danger of toxic gas hazards is a very real and daily threat that people face in numerous occupations. In the state of Kentucky, one police officer and two sewer workers died in an attempt to rescue a third sewer worker who had been overcome by H₂S gas at the bottom of an underground pumping station. All four were pronounced dead upon their removal from the station.

In the state of Georgia, a plumbing contractor and two co-workers were laying out a new sewer line for an industrial building under construction when a fatal accident occurred. The contractor entered the manhole and descended 15 feet into the sewer to measure a stub out location for the new line. Co-workers were unsuccessful in their rescue attempts and the contractor was removed by the fire rescue squad. He was pronounced dead on arrival at a local hospital. Atmospheric tests revealed the oxygen level in the sewer to be six percent.

Deaths of workers in confined spaces are a recurring occupational tragedy. According to NIOSH (National Institute for Occupational Safety and Health), approximately 60% of deaths involve would-be rescuers. With the proper equipment and training, the vast majority of these fatalities can be prevented. When working in a confined space, atmospheric monitoring is a vital.

What is a Confined Space?



Exhibit 1.

Generally speaking, a confined space is any space that is large enough for an employee to enter and perform work. The space has limited means of entry or exit, and is not designed for continuous occupancy. A permit-required confined space has one or more of the following characteristics:

- A hazardous atmosphere (oxygen deficiency, toxic gases or explosive gases) is present or has the potential to be present.
- Material with the potential for engulfment is present.
- The space has inwardly sloping walls or dangerously sloping floors.
- The space contains any other serious safety hazard.

OSHA Weighs in

The Occupational Safety and Health Administration (OSHA) put the Permit-Required Confined Spaces Final Rule (29 CFR 1910.146) into effect on April 15th, 1993. OSHA also specifies the requirements of a non-permit required confined space. Procedures for atmospheric testing can be found on their website at www.osha.gov and is as follows:

Atmospheric testing is required for two distinct purposes:

Evaluation of the hazards of the permit space and verification that acceptable entry conditions for entry into that space exist.

(1) Evaluation testing. The atmosphere of a confined space should be analyzed using equipment of sufficient sensitivity and specificity to identify and evaluate any hazardous atmospheres that may exist or arise, so that appropriate permit entry procedures can be developed and acceptable entry conditions stipulated for that space. Evaluation and interpretation of these data, and development of the entry procedure, should be done by, or reviewed by, a technically qualified professional (e.g., OSHA consultation service, or certified industrial hygienist, registered safety

engineer, certified safety professional, certified marine chemist, etc.) based on evaluation of all serious hazards.

(2) Verification testing. The atmosphere of a permit space which may contain a hazardous atmosphere should be tested for residues of all contaminants identified by evaluation testing using permit specified equipment to determine that residual concentrations at the time of testing and entry are within the range of acceptable entry conditions. Results of testing (i.e., actual concentration, etc.) should be recorded on the permit in the space provided adjacent to the stipulated acceptable entry condition.

(3) Duration of testing. Measurement of values for each atmospheric parameter should be made for at least the minimum response time of the test instrument specified by the manufacturer.

(4) Testing stratified atmospheres. When monitoring for entries involving a descent into atmospheres that may be stratified, the atmospheric envelope should be tested a distance of approximately 4 feet (1.22 m) in the direction of travel and to each side. If a sampling probe is used, the entrant's rate of progress should be slowed to accommodate the sampling speed and detector response.

(5) Order of testing. A test for oxygen is performed first because most combustible gas meters are oxygen dependent and will not provide reliable readings in an oxygen deficient atmosphere. Combustible gases are tested for next because the threat of fire or explosion is both more immediate and more life threatening, in most cases, than exposure to toxic gases and vapors. If tests for toxic gases and vapors are necessary, they are performed last.

[58 FR 4549, Jan. 14, 1993; 58 FR 34846, June 29, 1993]

Gas Detection Evolution



Exhibit 2.

The first gas monitors were low tech and provided by Mother Nature. Miners have been using canaries and mice to alert them in potentially hazardous atmospheres for centuries. The canary or mouse would be the first to react in this altered atmosphere thereby warning the miner to evacuate the mine shaft.



Exhibit 3.

On MSHA's website www.msha.gov; "Carbon monoxide, a potentially deadly gas devoid of color, taste or smell, can form underground during a mine fire or after a mine explosion. Today's coal miners must rely on carbon monoxide detectors and monitors to recognize its presence underground. However, before the availability of modern detection devices, miners turned to Mother Nature for assistance. Canaries -- and sometimes mice -- were used to alert miners to the presence of the poisonous gas. Following a mine fire or explosion, mine rescuers would descend into the mine carrying a canary in a small wooden or metal cage. Any sign of distress from the canary was a clear signal that the conditions underground were unsafe, prompting a hasty return to the surface. Miners who survive the initial effects of a mine fire or explosion may experience carbon monoxide asphyxia.

According to tests conducted by the Bureau of Mines, canaries were preferred over mice to alert coal miners to the presence of carbon monoxide underground, because canaries more visibly demonstrated signs of distress in the presence of small quantities of the noxious gas. For instance, when consumed by the effects of carbon monoxide, a canary would sway noticeably on his perch before falling, a much better indicator of danger than the limited struggle and squatting, extended posture a mouse might assume."



Exhibit 4.

The Flame safety Lamp designed by scientist Humphry Davy was one of the first gas measurement devices. An internal flame was surrounded by iron gauze that had small holes so that a flame could not pass through yet it could receive the methane gas. The intensity of the flame gave a measure of the methane gas concentration in the atmosphere.



Exhibit 5.

Today's gas monitoring equipment has come a long way from the miner's canary. Workers need to have a personal multi-gas monitor to perform the required atmospheric pre-testing and continuous monitoring. The monitor needs to be rugged and reliable to work in some of the adverse conditions that can exist in these environments. At a minimum, the detector should provide protection from:

Gas Hazards

Oxygen Deficiency - An atmosphere containing oxygen at a concentration of less than 19.5 percent by volume.

<u>LEVEL</u>	<u>SYMPTOMS AND EFFECT</u>
20.9 %	Oxygen content in fresh air
19.5 % – 12 %	Impaired judgment, increased pulse and respiration, fatigue, loss of coordination
12 % – 10 %	Disturbed respiration, poor circulation, worsening fatigue and loss of critical faculties, symptoms within seconds to minutes.
10 % – 6 %	Nausea, vomiting, inability to move, loss of consciousness, and death.
6 % – 0 %	Convulsions, gasping respiration, cessation of breathing, cardiac arrest, symptoms immediate, death within minutes.

Oxygen Enrichment - An atmosphere containing more than 23.5 percent oxygen by volume. An oxygen enriched atmosphere, even by a few percent, considerably increases the risk of fire.

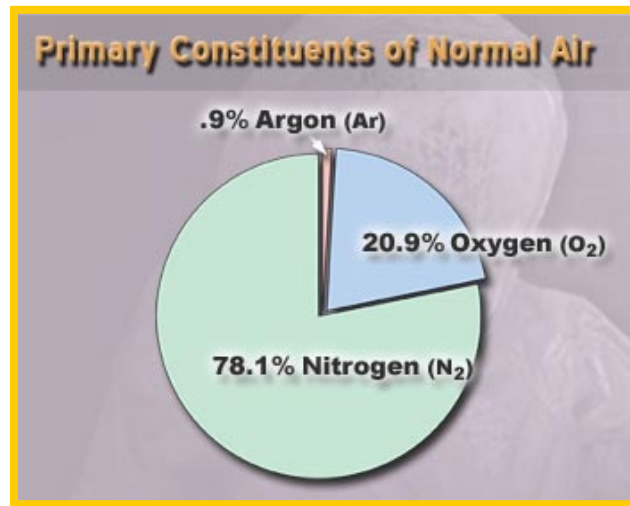


Exhibit 6.

The LEL (Lower Explosive Limit) of an explosive gas; typically Methane with the alarm set at 10% LEL. The Fire Tetrahedron below shows the 3 components (Fuel, Oxygen, and Source of ignition) that result in an explosion or fire.

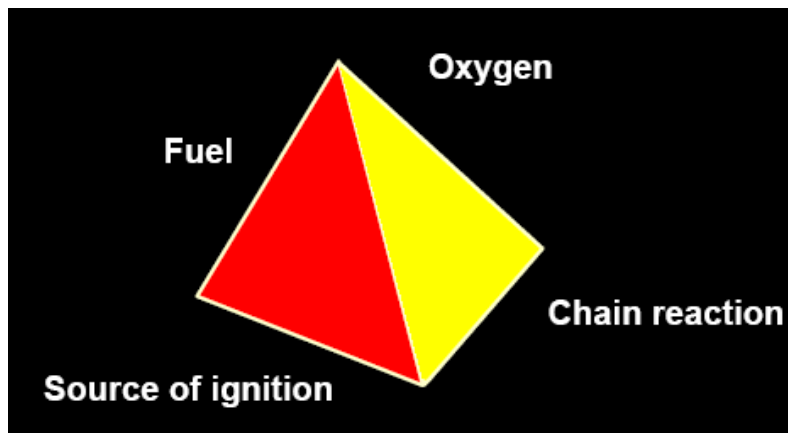


Exhibit 7.

Hydrogen Sulfide (H_2S), a toxic gas with a distinct odor of “rotten eggs”. Although a person can smell less than 1 part per million (ppm), the nose quickly becomes anesthetized and can no longer detect the smell. The alarm is typically set at the “time weighted average” (TWA) of 10ppm.

PPM	TIME	SYMPTOMS AND EFFECT
10	8 Hrs.	Permissible exposure limit (FED. OSHA)
15	15 Min.	Short term exposure limit.
50-100	1 Hr.	Mild eye irritation, mild respiratory irritation, loss of sense of smell.
200-300	1 Hr.	Marked eye irritation, marked respiratory irritation.
500-700	1 Hr.	Unconsciousness, death.
>1000	< 1Min.	Death.

Carbon Monoxide (CO) also known as the “silent killer”. CO is an odorless, colorless and toxic gas. The alarm is usually set at the TWA of 25-35ppm.

PPM	TIME	SYMPTOMS AND EFFECT
35	8 Hrs.	Permissible exposure limit (FED. OSHA)
200	3 Hrs.	Slight headache, discomfort.
600	1 Hr.	Severe headache, sick feeling, discomfort.
2000	2 Hrs.	Confusion, headache, nausea.
2000	30 Min.	All of the above with slight palpitation of the heart.
2500	30 Min.	All of above with unconsciousness.
4000	<1 Hr.	Death.

Sensor Response Time

Oxygen, combustible gases, hydrogen sulfide and carbon monoxide are simultaneously monitored in a multi-gas detector that provides a relatively quick response of typically 30 seconds or less (T90 response time). As the gas passes over the sensors, the full response is not immediate. T90 response time is a common measurement in regard to gas detection, which is defined as the time it takes the sensor to reach 90% of full response. Although the T90 of each sensor varies – oxygen 15 seconds, LEL 20 seconds, CO less than 30 seconds and H2S less than or equal to 30 seconds – waiting a minimum of 30 seconds will cover all 4 sensors at each sampling point.

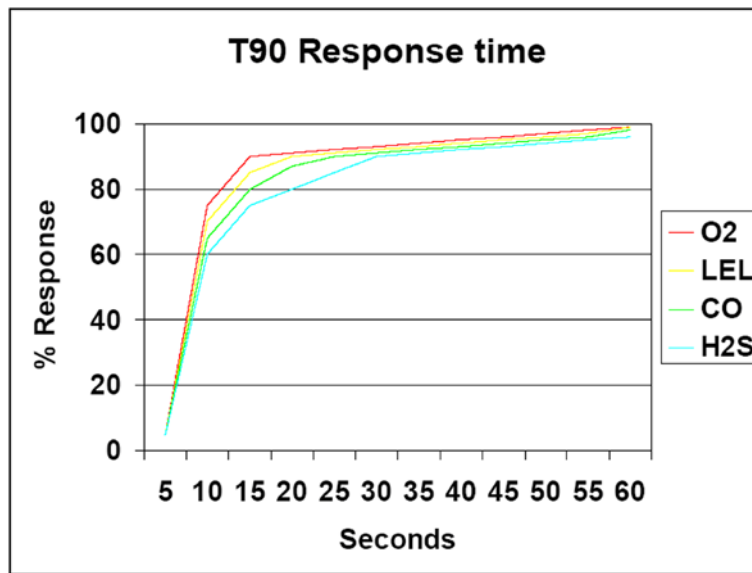


Exhibit 8.

Pre-Testing the Confined Space

Gas detection procedures have changed as a result of innovative monitor design. Through the 1980s, most gas monitors operated in diffusion mode only. The monitor had to be exposed to the ambient atmosphere in question, thereby making pre-testing difficult. Many workers would lower the monitor into the confined space with a drop line and quickly retrieve it to check alarm status. Hand aspirators and attachable or “piggyback” pumps were the next development and were an improvement, but less than ideal. The few monitors equipped with internal pumps suffered from poor reliability and if the pump failed, the monitor was rendered inoperable.

Through the 1990s, the reliability issue of the pump was addressed. Today, the best performance comes from a gas monitor equipped with an internal pump and external hose with a hydrophobic filter. The internal pump allows for easy pre-testing of the confined space and limits the amount of accessories involved in the process. Diffusion monitors are still very popular for their small size and cost. Hand motorized pumps are now a commonly available option.

Although pre-testing is easier, proper procedures must be followed. Two important factors that need to be considered are gas stratification and response time. Gas stratification occurs in a static environment where a particular gas will “hang out” based on its vapor density.

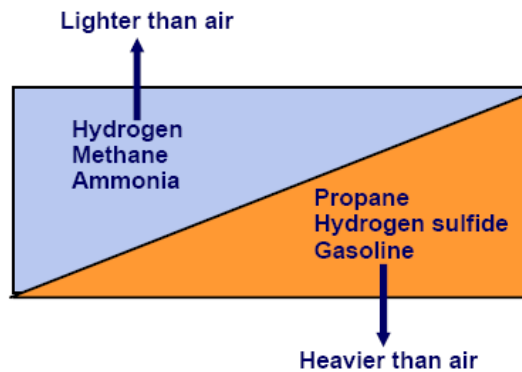


Exhibit 9.

Because of stratification, pre-testing involves taking readings at the top, middle and bottom of the confined space.

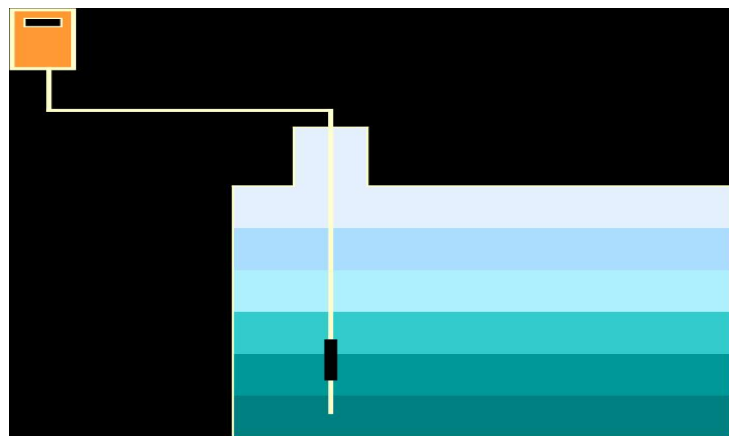


Exhibit 10.

The second factor is once again related to response time. When using a typical 10 foot length of hose, there will be a delay before the gas reaches the monitor depending on the flow rate. For example, if the flow rate in the hose is 3 seconds per foot, it will take an additional 30 seconds added to the T90 response time of 30 seconds equaling 60 seconds. Simply speaking, drop and hold the end of the sampling hose at the top of the confined space for 1 minute. Slowly lower the hose to the middle and hold for 1 minute and again at the bottom. Total pre-testing time would be approximately 4 minutes.

Continued Use in the Confined Space

After a successful pre-test, operating the monitor in the confined space is essential to ensure no changes have taken place in since the initial pre-test. All alarms must be responded to with an extreme sense of urgency. Evaluation of any alarm can be viewed in today's monitor after safely evacuating the confined space. Immediate, TWA, and STEL alarms are stored in the monitor's memory and can be called up on the display.

Sewer workers are typically very knowledgeable when entering and working in confined spaces. Unlike other occupations where confined space entry is a rare event, sewer workers' typical work environment is a permit required space. They must understand that the atmosphere may suddenly become lethally hazardous from causes beyond their control.

Well equipped workers often carry a confined space gas detector kit. A common kit could include a multi-gas monitor with pump and 10 foot sampling hose for pre-testing (longer lengths available), spare batteries (rechargeable or alkaline), quad-gas cylinder for bump testing and calibration with gas regulator.

Monitor Testing and Verification

Completing a functional test of the instrument prior to each day's use, also referred to as bump testing, is common practice. Advancement in sensor technology has allowed for longer intervals between calibrations of the monitor (up to 180 days). Bump testing ensures that the sensors provide an adequate response to gas and generate the appropriate alarms throughout this interval. A confined space gas detector kit allows the worker to quickly check the monitor by applying gas and looking for the proper response. This test typically takes less than 20 seconds. If the monitor fails the bump test, it cannot be used until it is successfully calibrated.

Sensor technologies used in today's gas monitors have improved significantly over the last decade. Advances such as electrochemical over solid state, enhanced poison resistance, and less cross-interference have resulted in more reliable performance. This evolution is one reason why calibration intervals have lengthened. Still, gas monitors must operate in harsh conditions and are not impervious to damage. Along with physical shock to the instrument, sensors can be damaged by gas concentrations that exceed the detectable limit. Filters and sensor ports can become obstructed by liquid, dirt and dust producing no change in readings even though the atmospheric conditions may have fluctuated. Proper bump testing and verification of accuracy between calibrations can prevent a false sense of security. Following this protocol will ensure confidence in the workers as well as everyone responsible for keeping them safe.



Exhibit 11.

Increasing in popularity is the use of a docking station that will do the bump test, calibrate, record data and charge the monitors. In case of an event where evidence of proper maintenance and care of a gas detector must be given, docking stations provide objective proof that procedures are being followed.

Always remember these monitors exist to save lives. Unfortunately, it is estimated that 20% of workers fail to use them properly, if at all. Training is crucial; most manufacturers offer classes on a regular basis and strive to make portable gas detectors easy to use, reliable and affordable. Proper instrument use saves lives.