Multigas Detectors

for the Fire Service…know the basics

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The Need

Emergency response crews face two basic challenges when entering dangerous environments. They need to know if the air is acceptable for normal, unprotected breathing and safe from potential explosions. Portable multigas detectors can help meet this challenge.

A wide variety of gas detection equipment is available on the market today. Technology exists to meet almost any detection need from simple, single toxic gas detectors to portable analytical laboratories. However, one flexible product at the right price is the best choice for both daily use and emergencies. That product is the "multigas" detector: one unit that can sense several gases at the same time.

Gas detection needs are expanding. Increasingly, fire services are being called on to handle situations where hazardous substances may be present and proper detection equipment is necessary.

The Basics

Portable multigas detectors come in many styles and configurations. In most cases, they can simultaneously detect three to five gases and alert the user when the gas exposure level becomes a concern.

These detectors consist of multiple sensors in a single case. The electronics then change the sensor output into a numerical display showing the level of gas exposure. There are four basic types of portable gas sensors:

- Catalytic
- Electrochemical
- Infrared
- Photoionization Detectors

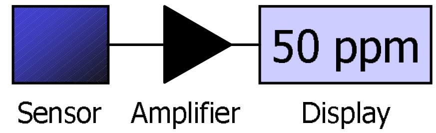

Figure 1
Basic detector operation

These sensors operate in different ways to enable them to detect certain gases. The two most common sensors are the catalytic and electrochemical sensors. Catalytic sensors detect flammable gases and electrochemical sensors detect many toxic gases. Infrared sensors and PID sensors are designed to detect either special gases or especially low gas levels, which cannot be detected by the other two technologies.

How Catalytic Combustible Sensors Work

To detect flammable gases, a heated wire is used. Basically, a special wire coil is heated by applying power to it.

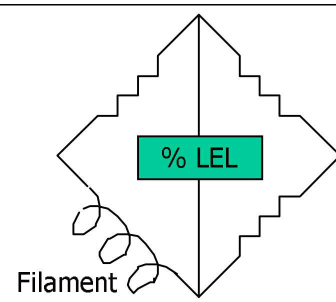

Figure 2
Combustible gas circuit

The wire filament is selected or specially treated so that the surface will react and will readily burn (oxidize) gases that come in contact with it. If this coil is exposed to combustible (oxidizable) gases, the gas molecules react on the wire surface. This reaction releases heat and increases the temperature of the wire. As the wire temperature increases, the electrical resistance of the wire increases and is measured by a simple "Wheatstone Bridge" circuit which accurately measures this change. The result is then converted to a display reading on the face of the instrument (see Figure 2).

Since the catalytic combustible gas sensors act like small heaters, they use a lot of power and regularly require fresh or recharged batteries for the combustible gas detector. To increase sensitivity and reduce power consumed by these sensors, many manufacturers form a ceramic bead around the wire coil. This bead is also treated with special chemicals to make it more reactive. The bead increases sensitivity by providing more surface area for the reaction to occur.

What Catalytic Combustible Sensors Detect

In order for a flame to exist, three conditions must be met. You must have:

1. A source of fuel such as methane or gasoline vapors.
2. Enough oxygen to oxidize or burn the fuel.
3. A source of heat to start the process.

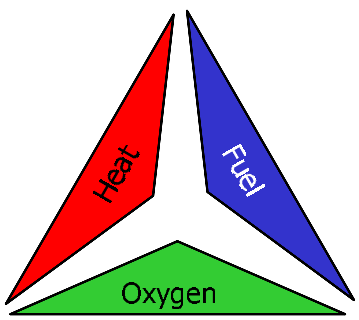

Figure 3
The Fire Triangle: Oxygen, Fuel and a Heat Source

Explosive Limits

Generally, for flame to occur, the fuel must be in a gas form to mix with air (the oxygen source). For instance, with gasoline, the liquid does not burn but the vapor given off by the liquid creates a dangerous situation. If a liquid does not give off enough vapors, it will not burn easily under normal conditions.

In general, any flammable substance with a flashpoint (the minimum temperature at which a liquid gives off vapor in sufficient concentration to ignite) of less than 100°F may be detected. (NFPA 325 lists the flashpoint of many common substances). Liquids such as diesel and jet fuels, have high flashpoints and cannot be readily detected by catalytic sensors since they do not give off enough vapors at normal temperatures to support combustion.

Too much gas can also displace the oxygen in an area and fail to support combustion. Because of this, there are limits at both low-end and high-end gas concentrations where combustion can occur. These limits are known as the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL). They are also referred to as the Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL). Figure 4 graphically demonstrates these limits relative to gas concentration.

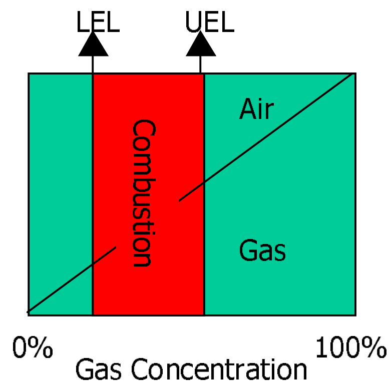

Figure 4
Lower and Upper Explosive Limits

To sustain combustion, the correct mix of fuel and oxygen (air) must be availaible. The LEL indicates the lowest quantity of gas which must be present for combustion and the UEL indicates the maximum quantity of gas. The actual LEL level for different gases may vary widely and are measured as a percent by volume in air. These LEL numbers are also published in NFPA 325.

Gas Type	**LEL** (% gas by volume)	**UEL** (% gas by volume)
Methane	5.0%	15.0%
Hydrogen	4.0%	75.0%
Propane	2.1%	9.5%
Acytelene	2.5%	100%

Table 1
Explosive limits for some common gases

Most combustible gas instruments measure in the LEL range and gas readings are shown as a percentage of the LEL. For example: a 50% LEL reading means the sampled gas mixture contains half the gas necessary to support combustion.

Combustible Gas Response Factors

Catalytic combustible gas sensors can detect a wide variety of potentially flammable gases. From natural gas leaks to gasoline spills, this sensor is very good at helping to determine if there is danger.

However, it should be noted that different combustible gases react at different rates with the sensor. For instance, the same "%LEL" levels of two common flammable gases such as methane and pentane will yield different sensor outputs and different readings on the instrument display. To ensure an appropriate response on average, a mid-range response gas such as pentane is often used for calibrating the instruments.

Gas Type	Actual % LEL	Actual Gas Concentration	Typical Display Reading (%LEL)
Pentane	50%	0.70%	50%
Methane	50%	2.50%	100%
Propane	50%	1.05%	63%
Styrene	50%	0.55%	26%

Table 2
Comparison of actual LEL and gas concentrations with typical instrument readings

Table 2 shows four typical flammable gases and the resulting displays of a combustible gas detector calibrated to read pentane. There is a wide variation in the typical catalytic sensor response to these gases. Since you do not know what you will be called on to detect, the most common approach is to select a "middle-of-the-road" gas, such as pentane, as your calibration gas.

Catalytic combustible gas sensors have met the needs of many industries for many years. In supporting the fire service's requirements for proven, reliable and cost-effective hazard analysis, this workhorse technology will continue to be a key factor for years to come.

Electrochemical Toxic Gas Sensors

In addition to detecting combustible gases, multigas instruments can help determine if the atmosphere is acceptable for breathing. These instruments can answer two basic questions:

1. Is there enough oxygen present for me to breathe? and
2. Are there any other toxic gases present which can harm me?

Once again, portable gas detectors can handle the majority of common air-monitoring situations. Many can be ordered with a combustible sensor, an oxygen sensor and up to two or three toxic gas sensors, depending on your application.

How Electrochemical Toxic Gas Sensors Work

Toxic gas sensors measure one type of gas at a time. The two toxic gases most commonly encountered on the job are carbon monoxide (CO) from furnace leaks or car exhaust and hydrogen sulfide (H_2S) from sewer gas.

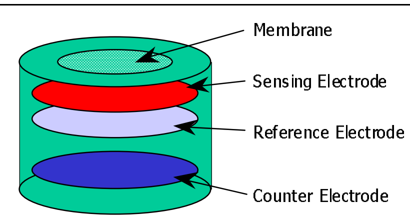

Figure 5
Electrochemical Toxic Gas Sensors Basic Construction

An electrochemical sensor is similar to a small battery. One chemical component required to produce the electric current is not present in the sensor cell. The target gas, such as CO, diffuses into the membrane at the top of the sensor. The CO then reacts with the chemicals on the sensing electrode and generates an electrical current to be measured and displayed as in Figure 1. If no CO is present, no reaction occurs and no current is generated.

Electrochemical sensors are typically available for a wide variety of gases, from carbon monoxide to chlorine. Check with your safety products supplier to see what is available to meet your specific needs.

Cross-Sensitivity

Since sensor output is driven by chemical reactions, there are many circumstances where gases other than the ones we are interested in will cause a reading on the instrument display. This is known as "cross-sensitivity" and chemical engineers designing the sensors do their best to limit this phenomenon. They attempt to make the reaction very specific or install filters to screen out common "interferants" when possible.

As an example, most electrochemical CO sensors also respond to alcohol vapors and unsaturated hydrocarbons, such as ethylene or acetylene. When exposed to these substances, the instrument displays an upscale reading and can produce a "false alarm" for CO. Fortunately, these compounds are present only in limited quantities in fire service situations.

It pays to know what types of gases you are likely to encounter on your calls. If you are calling mostly on homes, oxygen, CO and H_2S may be all you need to monitor. Calls to industrial facilities, however, present the possibility of a much wider range of deadly gases, so you must be careful to fully understand the risks of each response situation.

Oxygen Sensors

Oxygen sensors operate on the same basic principles as other electrochemical sensors. Oxygen from the air diffuses into the sensor and reacts to produce an electrical current. Typically, oxygen sensors use the oxidation of lead as the basis for their detection. As lead is consumed (oxidized), sensor life diminishes.

Our surrounding atmosphere contains an average of 20.8% oxygen. Since oxygen is present in the air at all times, oxygen sensors are slowly being consumed, even as they sit "unused." Manufacturers are responding by slowing the reactions in the sensors. Just a few years ago, these sensors typically lasted a year; some now last well over two years.

Although you may want to place your oxygen sensor in a box containing no oxygen to increase the life of the sensor, this may damage your sensor permanently. Be sure to follow the manufacturer's instructions on proper storage for your instruments.

Infrared Sensors

Some gases are not very reactive and require detection by other means. Carbon dioxide (CO_2) is an example of an important gas that cannot be detected using typical electrochemical cells.

Infrared (IR) sensors, which are commonly used to detect CO_2, approach gas detection in a completely different way. With IR sensors, the amount of gas is determined by how much the gas absorbs light, not by some type of chemical reaction to detect the gas. No chemical reaction occurs.

Gases absorb certain wavelengths of light and certain gases absorb certain frequencies. For instance, astronomers determine the composition of distant stars and galaxies by noting which wavelengths of light are missing from the spectrum of light coming from the object.

Figure 6 shows the basic layout of a portable instrument IR sensor. A special "source" emits light that passes through a filter. This filter screens out all but a very specific set of light wavelengths, typically in the infrared part of the spectrum (just slightly longer wavelengths than the eye can detect).

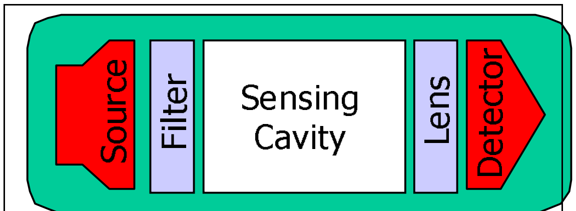

Figure 6
Infrared Sensor Basics

The wavelength of light allowed to pass through must match the wavelength that is easily absorbed by the gas you want to detect. The amount of light energy received at the detector decreases as more of the "target" gas passes into the sensing cavity.

For CO_2, (common in fermentation processes such as brewing), this is the best means of detection available in portable instruments today. The industry is also experimenting with the use of infrared sensors for combustible gas sensing as a replacement for catalytic technology.

The main issues here are cost. IR sensors are more complex and costly; yet, they have the potential to last longer. As the technology matures, it is possible that IR sensing technology may overtake catalytic technology as the choice for combustible gas detection.

Volatile Organic Compounds and Photoionization Detectors

One last large group of compounds relevant to portable gas detection is volatile organic compounds (VOCs). This class of typically industrial compounds (which includes toluene and isobutylene) is sometimes present during emergency spill response actions.

VOCs can be toxic at relatively low concentrations over the long term; this has caused significant concerns in industries where worker exposure must be limited.

While many VOCs are also flammable and can be detected with a catalytic sensor, the levels of concern are typically at the parts-per-million (ppm) level. For example, toluene has an LEL of 1.2% and a permissible 8-hour exposure of 50 ppm. Exposures to LEL levels are 240 times higher than the shift exposure level (1.2% is 12,000 ppm). Clearly, a different technology is needed to protect workers and determine if there are hazards present.

Enter photoionization detectors (PIDs). PIDs rely on specific chemical properties of the VOCs. Instead of absorbing light, a PID uses a light source (in this case in the ultraviolet [UV] spectrum – wavelengths just shorter than we can see) to "ionize" or bump electrons off gas molecules (see Figure 7).

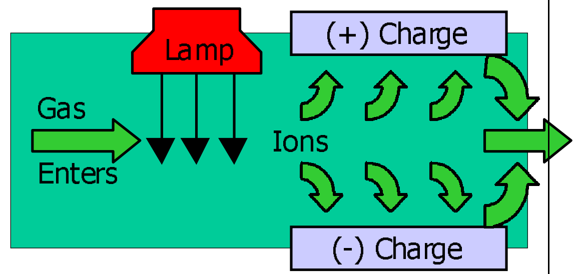

Figure 7
Photoionization Detector Basics

Once the gas is ionized, it passes through two charged plates, which separate the gas ions and the now "free" electrons. As the gas ions flow towards the plates, a current (which can be measured) is generated between the two plates. This current is sensitive to the amount of ionized molecules (the more gas present, the more gas is ionized and the higher the current). The instrument then converts this output into a reading that is displayed on the face of the instrument.

PID sensors, however, are not at all specific; they will indicate that some VOCs are present, but not what type. Many instruments with PID sensors have built-in conversion factors; if you know what type of VOC you are measuring, you can obtain a direct ppm reading on your display.

While PID sensors are excellent tools for the specific requirement, they are not necessarily the best choice for everyone. They add cost and complexity to the gas detector and require more complex maintenance. Be sure to carefully weigh your applications when considering what type of detector to purchase; often, a standard unit will meet the majority of your gas detection needs.

Calibration and Calibration Checks

No gas detection presentation is complete without some discussion of the required sensor maintenance. While most digital instruments come equipped with electronic self-diagnostics, sensors must be checked directly.

It is usually obvious when an oxygen sensor is inoperative since it should read near 20.8% under normal circumstances. If it is malfunctioning, it will likely not be able to read properly in clean, ambient air.

Other sensors, however, normally have no output (instrument display will read "zero"). To verify proper operation, it is important that you institute a program where each gas sensor is exposed to a known level of gas before each day's use. Without this check, you could falsely assume the atmosphere is safe when it actually contains deadly gases.

This does not mean that you must fully calibrate your instruments each day. You must, however, be sure they are operating within the manufacturer's specified limits.

Tying it all Together: Packaging and Software

The sensors form the heart of any gas detection instrument, but their operation should be as easy as possible.

Portable multigas detectors come in many shapes and sizes, from small handheld instruments to larger units which may be placed on the ground. In general, though, emergency response teams have more than enough gear to carry, making instrument size very important.

Figure 8
Typical, Compact Portable Gas Detector

The ability to rapidly assess gas readings in emergency situations is key to the safe operation of any instrument. Physical features such as an easily seen display and alarm lights should be carefully considered when making your decision.

Software Keeps it Simple

In addition to the physical features, instrument operation can be critical to its proper use and maintenance. Today's advancements in processing power allow sophisticated software to operate in even the smallest instruments. Be sure to trial-run any instrument before you buy; it may look easy enough when the salesman is in your station, but will you and your team be able to operate it effectively when the support isn't there?

Fire Service Applications

There are many applications for multigas detectors in the fire service, many of which you will be called on to perform on a regular basis – so it pays to be prepared. Some of these applications include:

- Confined space entry
- Home CO alarm calls
- Natural gas leaks
- Gasoline spills
- Odor calls
- Overhaul

Confined Space Entry

There are many situations when emergency response teams may be called in to perform emergency services or rescues in confined spaces. While mainly industrial in nature, a confined space is usually defined as any enclosed area not typically meant for human habitation.

A multigas detector can provide the appropriate measures to help ensure the confined space atmosphere is safe *before* your team enters and *while* working in the area.

Home Calls

With the advent of carbon monoxide monitoring in the home, the number of calls to fire departments regarding CO alarms in the home has risen dramatically.

You need to be prepared to verify the complaint upon arrival and determine if the premises are safe for habitation. You may even be called upon to help locate the source of the gas (often a car in the garage or a leaky furnace vent).

A multigas detector can help determine if the premises are safe. In addition, they often provide the leak detection necessary to locate the source of the problem.

You may also be called in for natural gas leaks or "bad smells". Having the capability to measure several gases at once becomes a distinct advantage in these situations.

Overhaul

During overhaul operations, you can never be certain of the conditions when you enter a damaged structure. A gas detector can let you know when it is necessary to don your breathing apparatus.

Conclusion

Multigas detectors are available to meet most of your gas detection needs. From standard catalytic and electrochemical sensors to advanced IR and PID sensors, they can detect a great variety of gases and vapors which can pose a threat to your team as they perform their duties.

In general, a standard four-gas unit with a combustible, oxygen, carbon monoxide and hydrogen sulfide sensor is adequate for many needs. These units, readily available from most safety products or fire service distributors nationwide, can help ensure everyone goes home safely at the end of the shift.

Gas detection is fundamental to emergency response; make sure you "know before you go."

Ted Hardenbergh is the portable instrument product line manager for the MSA Instrument Division. If you have any questions about multigas detectors or would like information on products available from MSA, please call us at 1-800-MSA-2222.

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