Multigas Detectors

For the Fire Service

MSA

The Safety Company

An Increasing Need for Gas Detection

With emerging economies, which result in more intensive industry and manufacturing, and terrorist threats, first responders and fire service workers are increasingly being called on to handle situations where a wider range of hazardous substances may be present and proper detection equipment is essential.

Emergency response crews face two basic challenges when entering dangerous environments.

They need to know if the air is:

1.) acceptable for normal, unprotected breathing, and
2.) safe from potential contaminants.

Portable multigas detectors can help meet these challenges.

Optimization of existing technologies and development of low power components have enabled integration of new detection technologies into portable instruments. Today technology exists to meet almost any detection need from simple detector tubes to sophisticated portable analytical laboratories. However, when application needs are compared with cost, one flexible product emerges as the best solution at the right price for covering both daily use and emergency response needs. This product is the multigas detector: one unit that senses several gases at the same time.

The Basics

Portable multigas detectors come in many styles and configurations. In most cases, they can simultaneously detect four or five gases and alert the user when the gas exposure level becomes a concern. Other instruments, however, utilizing PID and IR sensors, are able to detect up to six gases at a time.

There are four basic types of portable gas sensors:

- Catalytic combustion
- Electrochemical (echem)
- Infrared (IR)
- Photoionization detectors (PID)

When any of these sensors sense gas, the electronics will change the sensor output into a reading on the display showing the level of gas exposure.

The operating principles of these detection technologies are very different. The two most commonly used and known sensing technologies are catalytic combustion and electrochemical detection. Catalytic sensors detect flammable gases and electro-chemical sensors detect oxygen or toxic gases. PID sensors are perfect for low-level gas detection, while infrared sensors monitor high gas levels in special applications that cannot be detected by other technologies.

Catalytic Combustion Sensors

In catalytic combusion sensors, a heated wire is used to detect flammable gases. Power is applied to a special wire coil, as with a traditional light bulb.

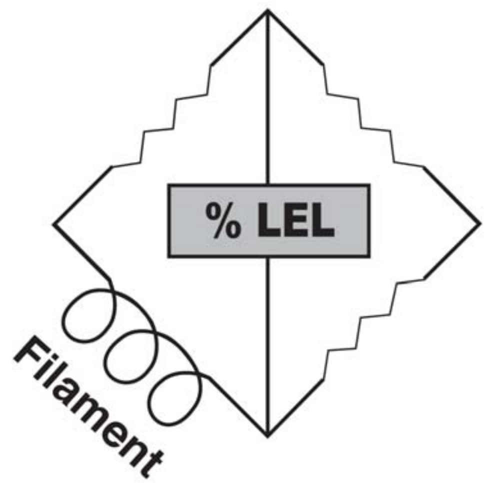

Figure 1
Combustible gas circuit

The wire filament is selected and specially treated so that the hot surface will react and will readily burn (oxidize) gases that come in contact with it. This reaction mechanism releases heat and will increase the temperature of the wire. As the wire temperature increases, the electrical resistance of the wire increases and is measured by an electrical "Wheatstone Bridge" circuit which accurately records this change. This change is then converted into a display reading on the face of the instrument. Any combustible gas exposed to the sensor will react on the wire surface and will provide a display reading.

Since the catalytic combustion gas sensors act like small heaters, they typically use a lot of power to operate and regularly require fresh or recharged batteries for the instrument. To increase sensitivity and reduce power consumption, many manufacturers form a ceramic bead around the wire coil. This bead is also treated with special chemicals to make it more reactive (a catalyst). The bead increases sensitivity by providing more surface area on which the reaction may occur.

What They Detect

For many years the concept of fire was symbolized by the 'Fire Triangle' or 'Triangle of Combustion' which consisted of fuel, heat, and oxygen. In order for a flame or combustion to occur, the following three elements had to be present:

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.

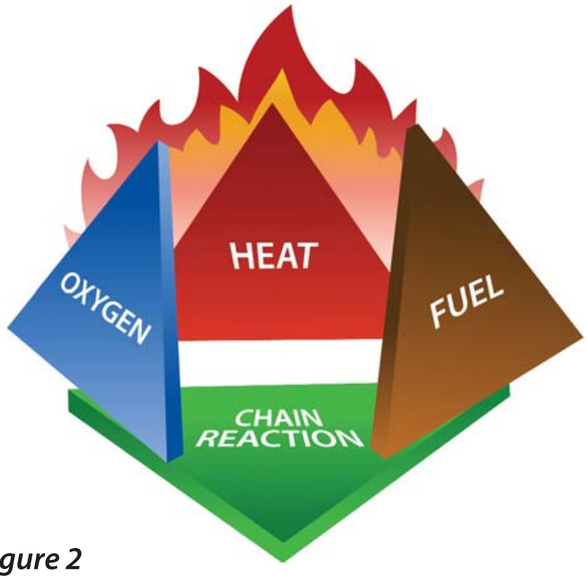

Figure 2
The Fire Tetrahedron

However, further fire research determined that a fourth element, a chemical chain reaction, was a necessary component of fire. This fourth element is the catalyst in the catalytic combustible gas sensor which enhances the combustion process. The fire triangle was subsequently changed to a "Fire Tetrahedron" to reflect this discovery.

Explosive Limits

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

Flammable substances with a flashpoint (the minimum temperature at which a liquid gives off sufficient vapor to ignite) of less than 100°F (38°C) may be detected. NFPA 325 lists the flashpoint of over 1,300 substances. High flashpoint liquids, such as diesel and jet fuels, cannot be readily detected by catalytic sensors since they do not give off enough vapors at normal temperatures to support combustion.

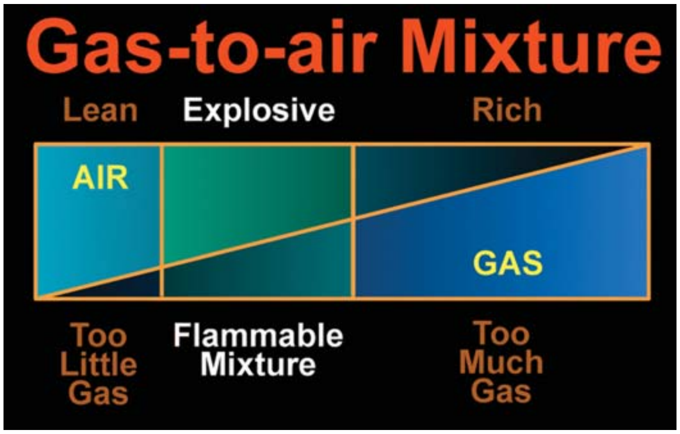

Figure 3
Lower and Upper Explosive Limits

If there is too much gas or vapor present in an area, the oxygen may be displaced and therefore combustion would not take place (too rich of a mixture). 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). The above figure graphically demonstrates these limits relative to gas concentration.

Explosive Limits for Common Gases

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%
Acetylene	2.5%	100%

The correct mix of fuel and oxygen (air) must be available to sustain combustion. 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 will vary widely and is measured as a percent by volume (%Vol) in air. These LEL numbers are also published in NFPA 325. LEL and UEL are heavily dependant on atmospheric conditions; an increasing temperature will typically lower the LEL as more vapor is likely to be present.

Readings are typically measured between 0-100% LEL. For example: a 50% LEL reading means the sampled gas mixture contains one half of the amount of gas necessary to support combustion.

Response Factors

Catalytic combustion sensors can detect a wide variety of flammable gases. From natural gas leaks to gasoline spills, this sensor technology is excellent at helping to determine the presence of a combustible hazard.

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 thus 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.

Comparison of Actual LEL and Gas Concentrations with Typical Instrument Readings

Gas Type	Actual % LEL	Actual Gas Concentration	Typical Display Reading (% LEL)
Pentane	50%	0.07%	50%
Methane	50%	2.50%	100%
Propane	50%	1.05%	63%
Styrene	50%	0.55%	26%

The above table 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 element for years to come.

Electrochemical Toxic Gas Sensors

In addition to detecting combustible gases, multigas instruments can be equipped to determine if the atmosphere contains toxic hazards. These instruments can answer two basic questions:

1. Is there enough oxygen present for me to breathe?
2. Are there specific toxic gases present?

How They 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.

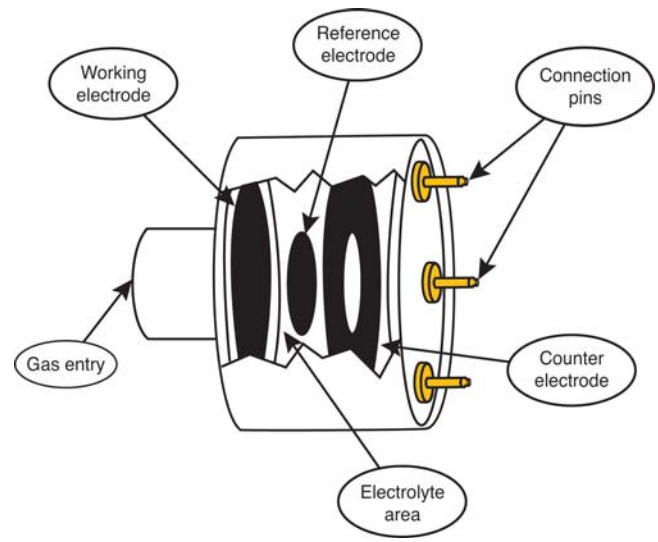

Figure 4
Electrochemical Toxic Gas Sensor

An electrochemical sensor is similar to a small battery, except that 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 and then reacts with the chemicals on the sensing electrode to generate an electrical current. This electron flow can be measured and displayed. If no CO molecules are 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

There are circumstances where gases other than the ones we are interested in will cause a chemical reaction in the sensor and therefore result in a reading on the instrument display. This is known as "cross-sensitivity". Engineers are designing sensors that limit this phenomenon by attempting to make the reaction very specific or installing filters to screen out common "interferents" when possible.

A well-known example that is often encountered is the response of electrochemical CO sensors to hydrogen, alcohol vapors and unsaturated hydrocarbons such as ethylene or acetylene. When exposed to these substances, the instrument displays an upscale reading and can alarm as if CO was present. Fortunately, most of these compounds are present in known areas, or only in limited quantities, in fire service situations.

Because of cross-sensitivity, a situation assessment of the types of gases you are likely to encounter on your calls is key to proper interpretation of the readings. If you are calling mostly on homes, then combustible gas, 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 gases, so you must be sure that you fully understand the risks of each.

Electrochemical Oxygen Sensors

An oxygen electrochemical sensor works in a similar manner to a toxic electrochemical sensor. As oxygen diffuses into the sensor and reacts, it produces an electrical current resulting in a reading. Oxygen sensors traditionally used the oxidation of lead as the basis for their detection. A drawback is that 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 (lead) are slowly being consumed, even as they sit "unused". Manufacturers are responding by slowing the reactions in the sensors. In years past, these sensors typically lasted a year; some now last well over two years. Lately, environmental regulations have driven newer technology that detects oxygen without the use of lead, creating opportunities to extend sensor lifetimes even more.

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 additional toxic gas sensors, depending on your application.

Infrared Sensors

Some gases are not very reactive and require other detection methods. 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 or hydrocarbons, approach gas detection in a completely different way. With IR sensors, the amount of gas is determined by how much light the gas absorbs, rather than by a chemical reaction.

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 coming from the object.

The following figure 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).

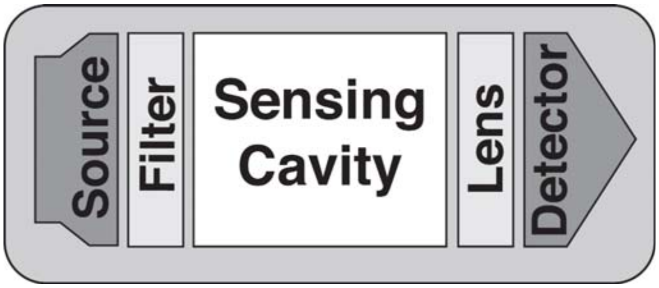

Figure 5
Infrared Sensor Basics

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

For CO_2, which is commonly found in fermentation processes such as brewing, this is the best means of detection available in portable instruments. Some manufacturers also offer infrared sensors for combustible gas detection.

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

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.

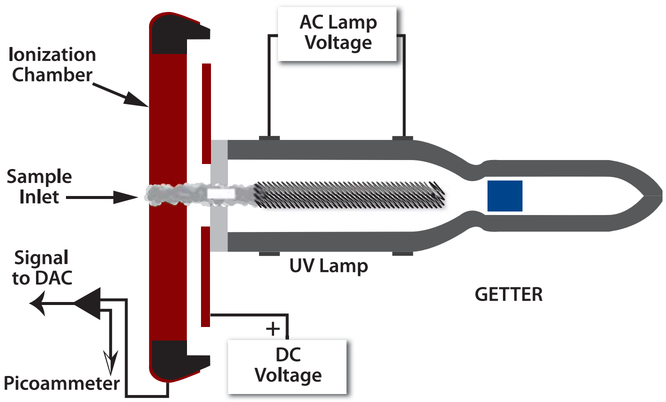

Figure 6
Typical Photoionization Sensor Design

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) or parts-per-billion (ppb) 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 provide adequate worker protection.

Photoionization detectors (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.

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, 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 the needs of 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 Bump Checks

A discussion of gas detection is incomplete without touching on sensor maintenance. Though most digital instruments are equipped with electronic self-diagnostics, sensors must still be checked directly with gas. It is usually obvious when an oxygen sensor is inoperative since it should read near 20.8% under normal circumstances. Simply breathing into the sensor should display a lower reading. If it is malfunctioning, it will likely not be able to read properly in clean, ambient air.

Other sensors, however, have no output (instrument display will read "zero") under normal conditions. To verify proper operation, it is important to institute a program where each sensor is exposed to a known level of gas before each day's use (this is called a "bump check"). If the reading is not within the expected limits, then your instrument needs to be adjusted with calibration gas to read correctly (this is called "calibration"). Without the bump check, the user could falsely assume that the atmosphere is safe when it actually contains deadly gases.

Tying it all Together: Packaging and Software

The sensors form the heart of any gas detection instrument, but it is also important for the unit's operation to 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, emergency response teams have more than enough gear to carry, making small instrument size an important attribute.

Figure 7
Typical Compact Portable Gas Detectors

Rapid instrument readings are another key consideration. Physical features such as an easily seen display, well-sized operating buttons and bright alarm lights should also be carefully considered when making your decision.

Software Keeps it Simple

In addition to physical features, an instrument's ease of use 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 buying; 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

Fire Service workers are regularly called on to perform in many applications where multigas detectors are beneficial – so it pays to be prepared. Some of these applications include:

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

Confined Space Entry

There are many situations where 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, both before your team enters and while they are working in the area.

Home Calls

With the advent of carbon monoxide monitoring in the home, the number of residential calls to fire departments regarding CO alarms has risen dramatically. You need to be prepared to verify the complaint upon arrival, and to 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". In such situations, having the capability of measuring several gases at once becomes a distinct advantage.

Overhaul

When entering a damaged structure during overhaul operations, you can never be certain of the conditions you will encounter. Invisible pipeline or carrier leaks can be easily traced with PID technology or electrochemical sensors. PIDs are often the right tool for setting a safety perimeter at traffic accidents with spills. The right gas detector can let you know when it is necessary to don your breathing apparatus.

Arson Investigation

PIDs are an excellent tool for arson investigation. Even after a fire has been extinguished, traces of accelerants can be detected with PID technology to indicate 'hot' areas from which a sample should be taken for lab analysis.

Conclusion

Gas detection is fundamental to emergency response. Multigas detectors are ideal for meeting the majority of fire service workers' 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- or five-gas unit with combustible, oxygen, carbon monoxide and hydrogen sulfide sensors is adequate for most needs. Readily available from most safety product or fire service distributors, these units can help ensure that everyone goes home safely at the end of their shift.

Rebecca Schulz is Product Line Manger of Portable Instruments at Mine Safety Appliances (MSA), and Kimberly Lewis is a technical writer. If you have any questions about multigas detectors or would like information on MSA products, please visit www.MSAnet.com or call 1-800-MSA-2222.

Note: This bulletin contains only a general description of the products shown. While uses and performance capabilities are described, under no circumstances shall the products be used by untrained or unqualified individuals and not until the product instructions including any warnings or cautions provided have been thoroughly read and understood. Only they contain the complete and detailed information concerning proper use and care of these products.

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Corporate Headquarters
P.O. Box 426, Pittsburgh, PA 15230 USA
Phone 412-967-3000
www.MSAnet.com

U.S. Customer Service Center
Phone 1-800-MSA-2222
Fax 1-800-967-0398

MSA Canada
Phone 416-620-4225
Fax 416-620-9697

MSA Mexico
Phone 52-55 21 22 5770
Fax 52-55 5359 4330

MSA International
Phone 412-967-3354
FAX 412-967-3451

Offices and representatives worldwide
For further information:

MSA
The Safety Company