ATMOSPHERIC MONITORS

INTRODUCTION

Emergency incidents pose potential hazards to the health, welfare, and safety of firefighters and other rescue workers alike. Hazards may be identified while approaching the scene, or after the completion of a thorough scene size up. Conversely, the presence of toxic or flammable atmospheres may complicate or hinder the recognition of hazardous environments. Though warning signs or clues may point to the existence of these dangers, the only practical means for detecting and measuring the presence of these hazardous conditions is through the use of atmospheric monitoring, or metering devices.

Atmospheric monitoring provides a means of early warning and detection for those personnel entering an existing, or potentially hazardous environment. These devices aid not only in the detection of noxious or deadly gases, but also assist in measuring (e.g., as a percentage or in parts per million) various gas concentrations in ambient air. Once an atmospheric environment is deemed unsafe, various interventions may be initiated (e.g., ventilation or securing utilities) to mitigate the problem(s).

HOW ATMOSPHERIC DEVICES WORK

Monitors (or meters) are designed to provide a responder with early warning and detection of potential atmospheric dangers. Today's meters are portable, easy to operate, and safe for use in numerous types of atmospheres. Furthermore, they are designed to measure in concentrations as low as parts per million (ppm); these concentrations represent very small amounts of a given contaminate or gas.

In order to operate an atmospheric monitoring device properly, personnel must be capable of interpreting various meter readings, as well as understanding why and how a given device responds in a given atmosphere. Without this knowledge, responders may walk into toxic or oxygen deficient atmospheres without warning.

Each sensor housed within a given atmospheric monitoring device is calibrated to alarm at a specific point or concentration. Single-gas meters, or "Gas-Tracs," are designed to alarm when detecting specific gases or toxins for which they are calibrated. With multi-gas meters, one, or all of the sensors could alarm at the same time. The most popular sensors in use today are those which detect combustible gases, oxygen, and various toxic gases (e.g., Carbon Monoxide and Hydrogen Sulfide).

Combustible Gas Sensors(CGI) measure the amount of flammable vapor in ambient air. Most meters are set up to measure flammable vapor concentrations as a percentage (0%-100%). An alarm will activate at a level well below the Lower Explosive Limit (LEL) of the vapor being measured. LEL refers to the lowest concentration of a flammable gas, when mixed with ambient air, forms an ignitable mixture. Hopefully, you will never encounter atmosphere that is at 100% of LEL. At 100%, an explosion is imminent and you are in serious danger!!

Oxygen Sensors measure the amount of oxygen present in ambient air. These sensors are set to alarm in an oxygen deficient atmosphere (19.5% or less) or in oxygen enriched atmosphere (23.5% or more). You may recall that ambient air normally has an oxygen concentration of 20.9% to 21.0%.

Oxygen sensors are important for various reasons. First and foremost, oxygen deficient atmospheres pose a life safety hazard and the potential for asphyxiation. Secondly, and equally important, is the pertinence of oxygen concentrations as it relates to flammability issues. In the presence of fire, lower oxygen concentrations may result in slower fire growth or eventual extinguishment. On the other hand, low oxygen concentrations in a confined space subject to fire poses a potential for backdraft. Similarly, oxygen enriched air poses the potential for rapid or explosive fire spread. Thirdly, oxygen needs to be present to acquire a proper “LEL” reading. In an oxygen deficient atmosphere, you will observe a reading that is actually below the correct “LEL” percentage. As a rule of thumb, correct “LEL” readings require a minimum of 10% oxygen to be reliable without the use of some type of dilution appliance.

Toxic Sensors are more commonly designed to aid in the detection and measurement of Carbon Monoxide (CO) and Hydrogen Sulfide (H2S). CO is a by-product of the combustion process and is usually associated with malfunctioning furnaces or appliances. H2S is a common toxic often found in manholes, sewers, or other confined spaces. It is also found in atmospheres where materials are rotting or decaying. Only 10 ppm is needed to affect the well being of responders. The unit of measurement utilized by toxic sensors is parts per million (ppm). As discussed earlier, ppm represents a small fraction of the overall concentration of a given gas or toxin.

Put in perspective, consider the fact that Hydrogen Sulfide possesses a danger level of a mere 5 ppm. For every million parts (or units) of this gas, only five parts (or units) is required to produce an inhalation hazard to humans. This is an extremely low level concentration and poses potential health hazards for responders. Self-Contained Breathing Apparatus (SCBA) is required when mitigating incidents involving this product.

TYPES OF METERS

There are two basic types of meters in use by the fire service: direct reading and visual and audio alarms. Direct reading meters display digital readings on the meter screen at the time of sampling. Direct meter reading meters may display a myriad of readings depending on the types of sensors installed in the device. Nevertheless, personnel must be capable of identifying and interpreting the values displayed. For example, most combustible gas or oxygen sensors display concentration values in terms of percentages. Toxic sensors, on the other hand, display concentrations in ppm. In general, direct reading meters will flash an LED light and or possess an alarm which activates when a sensor detects an unsafe atmospheric level.

Visual and audio type meters include “Gas-Tracs” and other single-gas sensing meters. “Gas-Tracs” are calibrated to alarm at 50% of the LEL of a flammable gas. When this type of meter alarms, a series of lights (green, yellow or red) activate; each light represents a different level of concentration. As a secondary means for warning its user, an audible alarm is also activated at higher atmospheric concentrations.

It is imperative that users of any atmospheric monitoring device familiarize themselves with the individual capabilities of each device in their workplace. Instruction manuals are the best source for acquiring this information.

An important issue all personnel must consider about these metering devices is a phenomenon referred to as “relative response.” Atmospheric metering devices are designed to detect the presence of one or more specific gases. If a meter detects a specific gas, it will show a “direct” reading for that gas. If, however, one utilizes a meter calibrated for Methane to detect gasoline vapors, the meter will provide a “relative response” reading. Another words, the meter is registering the presence of a gas to which it is not calibrated and is thus providing a relative reading of its concentration.

Should one utilize a meter to detect and determine atmospheric concentrations outside that which the meter is actually calibrated, a relative response rating should be obtained. The simplest way to accomplish this means is to multiply an acquired reading by a factor of two (2). This represents a “street wise” method for determining the concentration of flammable vapor in air.

HOW SENSORS WORK

The mechanics behind how sensors work is complicated. Despite this fact, the evolution of meter technology has produced improved reliability and ease of operation.

In practice, sensors operate on a simple process. Essentially, air passes over a sensor(s). The sensor absorbs the sample, converts it to an electrical signal, and transmits a reading to the display screen. In some instances, the electrical signal activates an alarm.

Combustible Gas Indicators (CGI) utilize a system of Catalytic Beads connected by a balanced resistor which measures the electrical resistance between the “Sensing Bead” (actually burns the flammable gas) and the “Reference Bead” (stays at a neutral temperature). This electrical resistance between the tow beads is converted into an electrical signal sent to the display screen to be read as a percentage of the “LEL”. Even though there is actual burning going on inside the sensor, a Flame Arrestor is employed to make the meter intrinsically safe.

CGI sensors are also susceptible to being “Poisoned” or “Inhibited”. Poisons are substances that will adhere to the Catalytic Bead and cause permanent damage to a portion and/or the entire Sensing Bead. A sensor that has been exposed to a poison becomes desensitized and cannot recover. Such poisons include TRV Silicone, Armor-All, and Tetraethyl Lead (found as a gasoline additive). Inhibitors are also substances that adhere to the Catalytic Bead and decrease the “life of a sensor. These substances include Sulfur Compounds, and Halogenated Compounds.

If you think your meter has been exposed to a poison or an inhibitor, calibration is the only way to identify if there has been any loss of sensitivity to that sensor or if the sensor needs to be replaced.

Toxic and Oxygen sensors utilize and Electrochemical Sensor which consists of two electrodes (the Working electrode and the Counter electrode) suspended in a liquid electrolyte. When the toxic gas or oxygen reaches the Working Electrode, an electrochemical reaction occurs. The electrical resistance between the Working Electrode and the Counter Electrode is measured and converted into an electrical signal that is sent to the display screen as a parts per million (ppm) or percentage (%)reading depending on what you are measuring. Remember that since there is always Oxygen present, the Oxygen Sensor is always sensing oxygen whether the meter is turned on or not. This will decrease an oxygen sensors’ life from the normal 24-36 months in a toxic sensor to 12-18 months in an oxygen sensor.

Any sensor is susceptible to adverse conditions. Humidity, extreme high or low temperatures and corrosive atmospheres can have an adverse effect on a sensor. These effects can be seen by a “stray” in a sensors reading. You may see a 1 or a 2 reading when first turning on a meter or you may see a -1 or -2 reading. This does not mean that your meter is not working properly. To acclimate your meter to its surroundings, do a “Zeroing” function to the meter. If the problem persists, have the meter calibrated.

There are chemicals that may have a “cross-sensitivity” with a specific sensor. You may see a reading on the display screen that is not the gas the sensor normally looks for. An example of this is Hydrogen. Hydrogen is a byproduct of a charging battery. As the battery charges, Hydrogen gas is produced and off-gased. If entering an area with a meter containing a CO sensor, the CO sensor will react to the Hydrogen present in the room. It will appear that you have a reading for CO, but you may actually be detecting the cross-sensitivity to Hydrogen. Along with Hydrogen, the CO sensor will also show a cross-sensitivity to any chemical in the “ENE” family such as Acetylene and Ethylene. This does not mean that the CO sensor can be used as a substitute metering device for these materials, but it may explain why you see a CO reading when CO is not present.

RANGES OF DANGEROUS ATMOSPHERES

The Environmental Protection Agency and OSHA has established "action levels" designed for use by hazardous waste sites. These levels are designed to ensure safe operating environments for affected employees. Since fire/rescue personnel are often faced with incidents requiring interior operations or confined spaces, it is important to consider all environmental and physical characteristics of an incident. Serious consideration must be granted to the existence of, or potential for, leaks (gas or liquid) within, or outside, the confines of a given structure. Meter readings are certain to be different on the interior, versus the exterior of a structure.

When working in the presence of combustible gases, one must consider the following operating guidelines:

- Atmosphere less than 10% of the LEL – continue work with caution;
- Atmosphere is 10% - 25% of the LEL – continue work with extreme caution; and
- Atmosphere is greater than 25% of the LEL – withdraw immediately!

Personnel should remember that most multi-gas meters will alarm at 10% of the LEL. This low alarm parameter is likely to keep personnel out of harm's way while compensating for relative responses.

When working in the presence of potentially hazardous oxygen-rich or oxygen-deficient atmospheres, one must consider the following operating guidelines:

- Atmosphere is in range of 21% - normal range – safe to operate;
- Atmosphere is below 19.5% - utilize SCBA - combustible gas values will be skewed;
- Atmosphere is between 19.5%-23.57%; continue work and monitor with caution; and
- Atmosphere is greater than 23.57% - explosion hazard! - withdraw immediately!

When working in the presence of Carbon Monoxide (CO), one must consider the following:

- Atmosphere is greater than 35 ppm – utilize SCBA; and
- Atmosphere is greater than 2,000 ppm – atmosphere is extremely combustible!

When working in the presence of Hydrogen Sulfide (H2S), one must consider the following:

- Atmosphere is greater than 5 ppm – utilize SCBA…..consider withdrawing due to inadequate Personal Protective Envelope (PPE).

Conversion Formula of Percentage to parts per million (ppm): 1% = 10,000 ppm

CALIBRATION, ZEROING and BUMP TESTING

Calibrating a metering device ensures it will respond appropriately in a given atmosphere for which it is designed to operate. Calibration is accomplished by exposing the sensor(s) to a known concentration of gas. These known concentrations are then set so when the sensor is exposed to that gas in the future, it can determine how much of the gas is present. Since improper calibration techniques may lead to equipment failure, only trained personnel should perform this function. Furthermore, trained personnel should follow all manufacturer guidelines and recommendations. Lastly, to ensure equipment readiness, calibrations should be performed on a MONTHLY basis.

Bump Testing is a field operation that should be done to all meters at the beginning of every shift or prior to placing any air monitoring meter into service. A bump test is a functionality test to ensure that all sensors in the meter are working. This is done by exposing all the sensors to the gases that they are designed to meter. You should see a rise in the readings on the display screen. Continue to let them rise until they reach their alarm settings (or in the case of oxygen, to its lower alarm setting). This will ensure that the meter is detecting and that the alarms activate when they reach their alarm settings. At the completion of the bump test, you will have a functioning meter.

Zeroing a meter ensures that all of its sensors are aligned in accordance with normal atmospheric measurement parameters. Most multi-gas meters display a menu-driven guide on their displays explaining the process to the user. Zeroing should always be performed outside a potentially hazardous environment. In other words, this process should be performed in a “clean” air environment – not in a potentially contaminated area such as next to the tailpipe of the apparatus. If performed properly, the user should observe the following results:

- Combustible Gas Sensors = 0% LEL
- Oxygen Sensors = 20.9% to 21.0%
- Toxic Gas Sensors = 0 ppm

Once the meter has been zeroed out, it should be ready for use. If the meter’s sensors do not respond appropriately (i.e., to the proper values), the meter may require a complete calibration or manufacturer servicing.

CARE AND MAINTENANCE

Without a doubt, the most important factors impacting the readiness and serviceability of any piece of machinery is proper maintenance and upkeep. As such, always follow manufacturer guidelines regarding the use and care of their products. Battery life is dependent on regular charging and maintenance. Meters stored in chargers on fire/rescuer apparatus may require the availability of trickle chargers and shore lines. Battery packs may require replacement on a daily, or fairly regular, basis. Some meters even possess a low battery alarm.

Meter sensors require the same, if not more thorough, care and maintenance as batteries. In general, meters are delicate instruments and are highly susceptible to damage. Sensors can be easily replaced or interchanged. Nevertheless, sensors must be treated delicately. Various chemicals may damage sensors. In some instances, a meter may then produce unreliable readings or lose its sensitivity. A malfunctioning meter could lead its users to disaster!! Finally, sensor life will largely depend on the relative use or disuse of the meter. Remember, for example, that oxygen sensors are always functioning, even if the meter is turned off. Sensors also have a specific shelf life. Outdated sensors will tend to drift during use, offering its user wide variances in actual measurements.

PRACTICAL USE

Most incidents will present the responder with various clues as to the potential hazards posed. Occupancy types, tank or container shapes, placarding, and color markings are several indicators for fire/rescue personnel to utilize when evaluating the presence of potentially hazardous atmospheres. Toxic and flammable atmospheres, on the other hand, are not as easily detected.

To reduce the likelihood of disaster, ensure all meters are properly calibrated and zeroed, prior to use. Utilize two meters at each incident and compare each meter's results. Consistent readings amongst the two are indicative the sampling results are accurate. Results which differ may require further investigation, perhaps with the assistance of another meter. When approaching a building in which a leak is suspected, hold the meter in front of you. As you approach, the meter will hopefully provide a warning if appropriate. If the meter alarms, walk towards the side of the structure and note any subsequent alarming of the atmospheric device. In this manner, a perimeter (i.e., hot zone) may be established. Prior to entering a structure, place the meter in the crack of the door. Perhaps, the meter may alarm, thus providing an early warning prior to entry. As a matter of practice, ensure all sensor readings are considered and evaluated. If, for example, the oxygen sensor is reading low oxygen levels, it is obvious an atmospheric contaminant is displacing the "good" air. If necessary, utilize SCBA and withdraw!

Atmospheric monitoring is a critical element in evaluating site or scene safety, establishing safety zones, and determining the need for proper protective clothing. Always utilize a meter's readings to formulate strategic planning and carry out sound tactical decisions. It could mean your life or the lives of your co-workers!