Module 6:

Detection Devices

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Module Description

The purpose of this unit is to introduce participants to the detection devices commonly used by fire department hazardous materials technicians to monitor atmospheres in hazardous environments. The unit is also intended to provide hazardous materials team members with the opportunity for hands-on practice with the instruments used in their departments.

Prerequisites

- Students should have completed a hazardous materials operations level training program.
- Students should have completed Module 3: Health and Safety and Module 5: Practical Chemistry.

Objectives

Upon completion of this module, participants will be able to:

Objectives	NFPA Standards	OSHA Standards
Identify the type(s) of monitoring equipment, test strips and reagents used to determine the following hazards: • Corrosivity (pH) • Flammability • Oxidization potential • Oxygen deficiency • Radioactivity • Toxic levels	NFPA 472,4-2.1.3.3	1910.120 (q) (6) (iii) (B)
Identify the capabilities and limiting factors associated with the selection and use of the following monitoring equipment, test strips, and reagents: (to include but not limited to operation, calibration, response time, detection range, relative response, sensitivity, selectivity, inherent safety, environmental conditions and nature of hazard) • Carbon monoxide meters • Colorimetric tubes • Combustible gas meters • Oxygen meter • Passive dosimeter • Photoionization detector • pH indicator and/or pH meters • Radiation detection instruments • Reagents • Test strips	NFPA 472 4-2.1.3.4	1910.120 (q) (6) (iii) (B)
Given three hazardous materials, one of which is a solid, one a liquid, and one a gas, and the following monitoring equipment, test strips, and reagents, select the appropriate equipment and demonstrate the proper techniques to identify and quantify the materials. (For example, the techniques for the use of air monitoring equipment should include monitoring for lighter than air gases in a confined area, heavier than air gases and vapors in a confined area, and heavier than air gases and vapors in an unconfined area.)	NFPA 472 4-1.1.3.5	1910.120 (q) (6) (iii) (B)
Demonstrate the field maintenance and testing procedures for the monitoring	NFPA 472 4-2.1.3.6	1910.120 (q) (6) (iii) (B)

Instructor Preparation

Module 6
Prerequisite Quiz

1. Which of the following is the best definition of response time as it applies to detection devices?
   A. The period between beginning measurement and the initial reading
   B. The period between beginning measurement and obtaining a reading
   C. The length of time required to obtain a sample
   D. The length of time it takes a device to adjust for the calibration standard

2. Detector tubes are used to:
   A. Measure the concentration of known gases, vapors, and unknown hydrocarbons
   B. Identify specific gases in an atmosphere
   C. Distinguish between specific gases within a hazard class
   D. Detect flammable atmospheres

3. Alpha and beta radiation survey meters usually display readings in:
   A. Millroentgens per hour
   B. Millirems per hour
   C. Counts per minute
   D. Percentages of LEL

4. On a combustible gas indicator with a reading in % LEL, the reading indicates 0-100% of:
   A. The explosive gas in the atmosphere
   B. The non-explosive gas in the atmosphere
   C. The lower explosive limit
   D. The flammable range

5. The most common calibration gases for combustible gas indicators are:
   A. Methane, pentane
   B. Pentane, oxygen
   C. Methane, xylene
   D. Oxygen, methane

6. Which of the following is true of direct read-out instruments?
   A. Direct read-out instruments provide measurements in real time
   B. Measurements from direct read-out instruments do not need to be converted
   C. Measurements from direct read-out instruments are displayed digitally
   D. Direct read-out instruments detect specific chemicals

7. Which of the following instruments should you use in a flammable atmosphere?
   A. Instruments marked "UL"
   B. Instruments marked "FM"
   C. Instruments marked "intrinsically safe"
   D. Instruments marked "non-incendive"

8. Which of the following is the best definition of relative response as it applies to detection devices?
   A. The instrument's reading compared to the calibration gas
   B. The instrument's reading over the period of the response time
   C. The instrument's reading in response to a specific class of chemicals
   D. The instrument's reading in response to measurements from other devices

9. If you are monitoring a gas with an LEL of 2% and your combustible gas indicator reads 50% LEL, what is the actual percentage of gas in the atmosphere?
   A. 1%
   B. 2%
   C. 25%
   D. 50%

10. An atmosphere is assumed to be oxygen-enriched if concentrations of oxygen are greater than:
    A. 19.5%
    B. 20.9%
    C. 23.5%
    D. 25%

Introduction

Questions

For each of the following scenarios, what would be your initial actions? What type(s) of detection devices would you use?

1. *Your hazardous materials team responds to a leaking propane tank at 2:00 a.m. The one-ton tank is on top of a small construction building. It was being moved by a crane when it was accidentally smashed into a wall, breaking off an outlet pipe. You can hear propane leaking. The construction company wants to restart the crane to move the propane tank down to ground level.*

2. *Your hazardous materials team responds to a basement where unknown chemicals have leaked into the bottom of an elevator shaft.*

3. *Your hazardous materials team responds to a natural gas leak inside a large warehouse.*

4. *Your hazardous materials team responds to a leaking ammonia rail car outside on a warm day.*

5. *Your hazardous materials team responds to a vehicle accident involving a medical courier carrying radioactive isotopes for patient treatment.*

6. *Your hazardous materials team responds to a shopping mall for an unknown odor.*

7. *Your hazardous materials team responds to a 'green liquid' spill in a drainage ditch.*

When to Monitor

Detection equipment provides additional information about a product so you can take the safest approach when you respond to a release. Specifically, monitoring equipment helps you determine:

- Appropriate personal protective equipment
- Safe areas and evacuation zones
- Control tactics

Despite what some marketing information leads you to believe, there is no readily available cost effective instrument that will identify unknowns and tell you exactly how much is present.

Monitoring can be done to determine the level of a known hazard. For example, if a tank truck containing carbon disulfide is involved in an incident and begins leaking, responders must establish a safe area for the warm zone. Because the hazard is known, team members can use a detection device specific to carbon disulfide to rapidly and easily monitor the surrounding air.

In other situations, monitoring may be performed to identify an unknown hazard, to decide if a hazard is present, or to determine when it is no longer necessary to use personal protective equipment. Monitoring also provides information for assessing potential safety and health effects, and for documenting exposure for post-incident medical surveillance.

In an emergency situation, specific information about the type and level of the hazard must be readily obtainable. Most detection tools provide readout information in "real-time"— that is, a readout at the time the monitoring is being performed. These are also known as direct read-out instruments.

The information provided here about selected pieces of equipment is generic. Specific information should be obtained from equipment manufacturers. It is important to become thoroughly familiar with each unit prior to use in the field.

Detection Devices Limitations

In addition to knowing how to use monitoring equipment, it is important to keep in mind that this equipment cannot make decisions. Like all equipment, detection and monitoring devices perform specific functions and provide only limited information. Further, if the equipment is not properly maintained and operated, the information obtained may be incorrect. If you use detection equipment, you must be well-trained and ensure that the equipment is used within its limits.

Choose the right meter for the right chemical in the right situation. There is no one monitoring device for every incident. For an accurate picture of the atmosphere at an emergency, you must use a combination of instruments at a minimum, a combustible gas indicator and an oxygen meter.

Finally, detection and monitoring equipment, and the information generated by these devices, must be used within an Incident Command System. It is most effective when one person, the Incident Commander, can integrate various pieces of information into a whole picture and direct subsequent activities based on this information. Team members using detection and monitoring equipment should, however, continually question the information generated by the equipment and verify that the readouts make sense relative to other available information.

Activity

General Considerations in Monitoring

Purpose of Detection and Monitoring Equipment

The first step in using monitoring and detection equipment is to define the information needed. This will help determine the appropriate equipment and sampling strategies. Desired information may include:

- What hazard, if any, is present?
- Is it dispersing or concentrating?
- Do responders have adequate protection?
- Is the hazard affecting surrounding areas?

Factors Influencing the Quality of Information

Team members must be aware of various factors that can directly affect the instrument readings. Some of these factors are inherent to the instrument; others are determined by the environment in which the instrument is used.

- Instrument Factors:
  - Proper equipment operation
  - Instrument calibration and calibration checks
  - Equipment detection range
  - Device relative response (compared to the calibration gas)
  - Response time
  - Inherent safety
  - Reliability of power source

- Non-Instrument Factors:
  - Nature of the hazard
  - Location of monitoring
  - Interferences
  - Environmental conditions (e.g. temperature and humidity)

If these factors are not addressed, the readings may be improperly evaluated and result in poor decision-making.

Anyone responsible for evaluating information generated by monitoring equipment must have additional supporting data to justify subsequent actions. Supporting information must include each of the points listed above. These points, particularly those relating to non-instrument factors, should be documented along with the equipment readouts.

A more detailed discussion of each of these factors illustrates their influence on the data generated by the instruments.

Proper Equipment Operation

Most portable monitoring instruments are easy to operate, however, all require thorough knowledge of operating principles and procedures to ensure proper functioning. Never adjust settings on instruments without regard for the effect.

The most important initial check performed on an instrument is the battery check. Most analog display instruments have a battery check setting, and the needle should show adequate power available. Digital readout instruments often do not have a battery check option. These instruments display a low battery message when there is insufficient charge for instrument function. If there is inadequate battery power, turn off and recharge the instrument before you use it. To operate properly, an instrument must have sufficient battery power.

Other considerations regarding instrument operation include adequate warm-up time, meter zeroing, cleaning and decontamination, and maintenance procedures. Use only the attachments furnished with the instrument. Other attachments may give off or absorb contaminants that will affect the instrument reading.

Activity

Instrument Calibration and Calibration Checks

Monitoring instruments are calibrated at the factory to respond accurately to a particular vapor or gas within a specific concentration range.

Instrument response should be checked before and after each use against the calibration gas standard (or a check gas, if the calibration standard is not available or is dangerous to use). This check verifies that the instrument is responding accurately to its calibration standard. If the instrument responds the same each time, it is likely that the instrument is and has been operating properly. If the instrument calibration check is outside an acceptable response range (as given by the manufacturer), the information you obtain during use may not be valid for evaluating the situation. Send the instrument to a factory or an approved service center to be recalibrated.

The operating manual for the monitoring instrument should provide instructions for performing calibration checks. The appropriate check standards and regulators must be available in the field. All calibration checks must be documented.

Activities

Equipment Detection Range

A detection device is manufactured to detect a hazard within a certain range of concentrations. If the instrument is used to detect hazards outside that range, the instrument will not provide valid or reliable results. Meters can measure in % gas, % LEL, or ppm equivalents. For example, a % gas combustible gas indicator measures in the percent range. Other instruments, such as flame or photoionization detectors, are designed to detect gases and vapors in ppm equivalents.

Activities

Detection Relative Response

As discussed earlier, instruments are calibrated to a specific vapor or gas. Each instrument responds to any vapor or gas as if it is detecting its calibrant gas.

The reading an instrument displays may be higher or lower than the actual concentration when vapors or gases other than the calibration gas are present. This is known as the instrument's relative response—the instrument's response, or reading, relative to the calibration gas. The response is therefore expressed as calibration gas equivalents.

If operating properly, the instrument will respond consistently higher or lower to a given vapor or gas relative to the calibration standard. Conversion factors or relative response curves can be used to convert the instrument reading to a true concentration of the known vapor or gas. You should have this information before beginning monitoring. The use of these conversion factors will be discussed separately under each applicable piece of equipment.

Activity

Response Time

When monitoring at a hazardous materials incident, it is important to obtain information as early as possible. Data generated by monitoring instruments is not instantaneous. The time it takes the instrument to obtain the sample and produce a reading depends on the length of the sample hose, the flow rate of the pump, and the length of time the detector requires to generate a response.

For example, a combustible gas indicator with a 6 foot hose will respond more quickly than one with a 25 foot hose. In addition, the presence of a contaminant or other interference can slow response time.

No instrument is truly instantaneous—some respond in 5 to 10 seconds, others require 30 to 60 seconds. Consult the instrument operation manual and allow appropriate time for the instrument to respond completely before recording the reading. Continue sampling in the same location while waiting for the response.

Activity

Inherent Safety

Most monitoring instruments require electricity to operate. Electrical or electronic circuitry can be a source of ignition in a flammable atmosphere. If an instrument is going to be used in such an atmosphere, it must be manufactured and certified to be safe for such use. An instrument marked as "UL" or "FM" approved as "intrinsically safe" for Class 1/ Division 1/ Groups ABCD is safe for use in flammable atmospheres.

The National Electrical Code defines "Divisions" as follows:
Division 1: An area where a leak is, or may occur at any time.
Division 2: An area of sealed containers where a leak would occur only if a container ruptured or otherwise failed.

"Groups" refer to specific gases or vapors that may be encountered.
Group A: Acetylene
Group B: 1,3 butadiene, ethylene oxide, hydrogen
Group C: Acetaldehyde, carbon monoxide, cyclopropane, diethyl ether, ethylene, hydrogen sulfide, hydrazine, methyl ether

NEC markings should be found on combustible gas indicators because spills of flammable liquids or leaking flammable gases may result in flammable or explosive atmospheres. An "intrinsically safe" instrument should be used whenever the atmosphere is potentially flammable.

"Intrinsically safe" instruments are certified as such by the manufacturer or a third party. Instruments labeled "Explosion-proof" are generally stationary devices; any explosions are contained within enclosures.

Instruments approved as "non-incendive" for Class 1/ Division 2/ Groups ABCD are approved as safe for atmospheres that are not flammable. These instruments are considered safe in that they will not serve as sources of ignition for other combustible and flammable materials in the area. Limit the use of such instruments to clean-up activities or situations where it is certain that the atmosphere is not explosive or flammable.

Not all instruments have non-incendive ratings. Non-rated instruments should be used only with a combustible gas indicator so that you can be warned of potential flammable or explosive vapor concentrations.

Sampling Techniques

When entering an unknown atmosphere to conduct air monitoring, remember the fundamental physical properties of hazardous materials. Most gases and vapors will tend to sink in air, but some will rise. Good monitoring technique involves sampling enough locations to ensure that you have searched effectively for the hazard your instrument is designed to detect.

If the chemical you are monitoring for tends to rise in air, such as methane or anhydrous ammonia, begin sampling with the sensor held high, moving lower as you proceed. If the chemical tends to be heavier than air, hold the sensor low at first, then sample higher areas as you proceed.

Be sure to sample slowly enough so that the instrument has time to draw the sample in and produce a readout before you move to another location. Most instruments with integrated pumps require one to two seconds per foot of sample line. For example, if your instrument is equipped with a ten-foot sampling line, you may have to wait 20 seconds at a location to obtain a stable reading. Mechanical pumps usually sample more quickly and reliably than hand-aspirated pumps.

Non-Instrument Factors Likely to Influence Readout Data

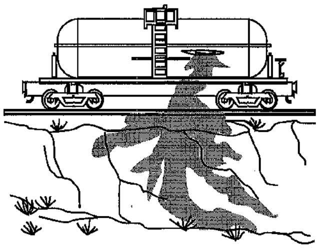
Any information you can gather about the material involved can assist you in choosing monitoring strategies. The team member preparing to sample the environment should consider the following questions.

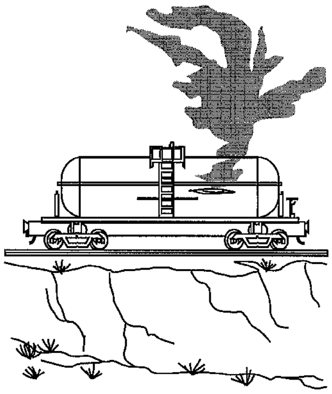
- Is the material organic or inorganic? Which instrument is most appropriate to use for detection and monitoring?
- What is the lower explosive limit/lower flammable limit of the material?
- Is there sufficient oxygen for the instrument to produce an accurate response?
- What is the vapor pressure of the material? Given the ambient temperature, is it likely that the liquid will generate enough vapors to support combustion?
- Will liquid present generate enough vapors to create a potential health hazard?
- What is the vapor density of the material—is the material lighter or heavier than air?
- What are the various exposure limits for the substance?
- How is the instrument likely to respond to the substance?

Location of Monitoring

Monitoring must be carefully planned so that time and resources are not wasted in gathering information. Choose monitoring locations based on environmental conditions and information you know about the hazard.

For example, in an incident involving a leaking cylinder of chlorine gas, reference materials can be used to determine that the vapor density of chlorine gas is 2.4. This means the material will “hug” low-lying areas and pool in areas where there are barriers blocking further dispersion. If the leak is outside, determine wind direction and speed so you can intelligently select sampling locations.





Documentation of monitoring locations is essential. Describe locations so other individuals can locate the same spot. Include information such as distance, direction, and elevation from the source. This allows the data to be more accurately evaluated. Also, take subsequent instrument readings at the same location so you can compare information as conditions change.

Interferences

Some hazardous vapors and gases interfere with proper operation of monitoring instruments. Such interferences can result in decreased instrument sensitivity or false readings. For example, the silicone sprays used on electrical contacts can damage CGI sensors over time. Water vapor and relatively low concentrations of methane can interfere with the readings of a photoionization detector. High levels of CO_2 will, over a period of time, degrade the oxygen sensor. The manufacturer of your meter should provide information on how the service life of your oxygen sensor is decreased by varying levels of CO_2. Also, certain vapors and gases can cause a detector tube to produce an inaccurate response. Manufacturers supply information about interferences for each specific tube; this information should be consulted before evaluating detector tube response. For example, directions for many types of detector tubes offer a 'humidity correction' chart used to modify the readings under different humidity conditions. Other types of interference include sunlight and radio waves.

Though calibration checks verify that an instrument is responding appropriately to its check gas, they may not reflect the action of some interferences. It is up to you to determine if interfering compounds are present, usually by comparing the response of one type of instrument to the response of another. Because temperature and humidity can affect the operation of the instrument, let the instrument equilibrate to outside temperature and humidity before using it. In some cases, taking the instrument from a climate controlled atmosphere to a warm humid atmosphere can cause the sensors to 'fog up'.

Questions

1. *What effect does the vapor density of a gas have on your sampling methods? Why?*

2. *In what situations might a non-intrinsically safe monitoring device be used?*

Environmental Conditions

Environmental conditions may affect the operation of monitoring instruments as well as the dispersion of hazardous materials. Humidity, temperature, barometric pressure, and direct sunlight are among the more common conditions known to affect instrument response. Some instruments lose sensitivity at high humidity. In particular, very high humidity decreases the sensitivity of photoionizers by preventing the detection of some gases and vapors. Some detector tubes also lose sensitivity because the humidity interferes with the chemical reaction that takes place in the tube.

High voltage power lines or hand-held radios may influence analog display instruments, causing the needle to fluctuate or drop below zero. This effect can be countered by removing the instrument from the area of high voltage lines, using a sample line to bring the test atmosphere to the instrument or limiting the use of hand-held radios in close proximity to meters.

Direct sunlight affects some digital readouts. LCD readouts tend to black out when exposed to direct sunlight for a period of time. It may take several minutes for the readout to return to normal.

Review the instrument operating manual for the effects of adverse environmental conditions on the device. Also, calibration checks help assess the effects of temperature, humidity, barometric pressure, and related environmental conditions. Perform instrument calibration checks under the same environmental conditions in which the instrument will be used, such as a safe area near the incident to be investigated. Finally, remember that high voltage and static can affect the needle display on some instruments.

All of these factors should be considered when operating any of the instruments discussed in this unit.

Validity of Measurements

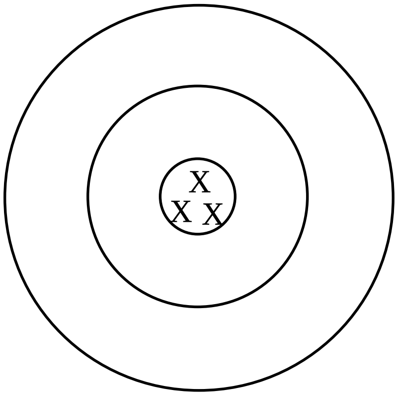
When evaluating detection devices, manufacturers may use a variety of terms to describe the instrument's ability to respond accurately and consistently to the materials it is designed to detect. Commonly used terms are accuracy, precision, and sensitivity and selectivity.

Accuracy is a measure of data quality and its relationship to some true value. An accurate reading results when the average of all measurements falls within an acceptable, predetermined interval from the true value (typically within 5% to 10%).

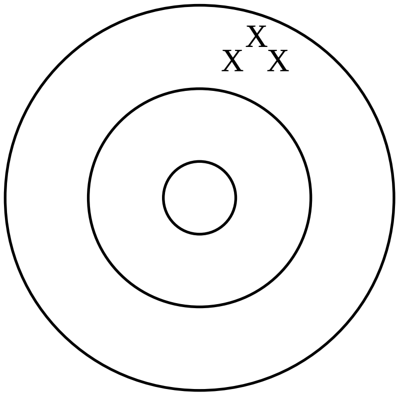
Precision is the grouping of separate readings around a calculated average. Instruments should respond in a consistent manner. Another term for this is reliability. Measurements can be inaccurate and still be reliable, so simply obtaining the same reading more than once does not guarantee that the reading is accurate.

Sensitivity is the ability of an instrument to detect a hazard. Highly sensitive instruments can detect minute amounts.

Selectivity is the ability of an instrument to detect a specific hazard by focusing on that hazard alone, through the use of selective membranes or chemistry.



Precise and Accurate Data



Precise but Inaccurate Data

Interpreting Readings

Accurately evaluating a meter reading is extremely important. It is all too easy to read a meter at face value and move on to the next objective. In addition to the considerations discussed above, consider the following when interpreting a meter reading.

- Is the appropriate instrument being used to assess the hazard?
- Was the instrument reading representative of a properly operating instrument? Was it fully charged, accurately calibrated, and free of contaminants?
- Does the instrument calibration still check out after readings are taken?
- Is the contaminant known or unknown?
- How sensitive is the instrument to the contaminant being monitored?

- Is there a conversion factor or relative response factor for the contaminant?
- Are there any interferences?
- Are environmental conditions affecting responses?
- Is the information required to evaluate the reading available?
- Are the meter scale units ppm, percent, or counts per minute?
- Is the range/scale factor x1, x10, or x100?
- Did the meter give a stable or erratic response?

Each of these factors can impact the instrument reading. The goal is to be sure that the reading is valid and represents the area that was monitored.

Combustible Gas Indicators

It is essential to be able to recognize flammable or explosive atmospheres. It is just as important to be able to anticipate the potential for such an atmosphere. This can be accomplished using a combustible gas indicator, or CGI.

CGIs, also referred to as “explosive meters” or “explosimeters,” are used to test atmospheres that may contain a sufficient level of combustible vapors to cause an explosion (lower explosive limit or LEL) or support combustion (lower flammable limit). The CGI is an essential piece of equipment for emergency response.

There are three different scales used on various CGI models: ppm, % LEL, or % gas. The most common is the % LEL meter. Its scale is 0-100% of LEL, not 0-100% of the flammable vapor or gas in air. For example, if a meter reading is 50% LEL, then it is indicating that 50% of the flammable vapor necessary to support combustion is present. If the LEL of the gas is 2%, then the CGI is indicating that there is one-half (50%) of LEL or 1% gas present. If vapor concentration increases, the reading will get closer to the LEL. Some CGIs also indicate when the concentration of combustible gas or vapor in air exceeds the upper explosive limit (UEL). The CGI operating instructions should be consulted prior to use for behavior at the UEL and above.

Instrument Operation

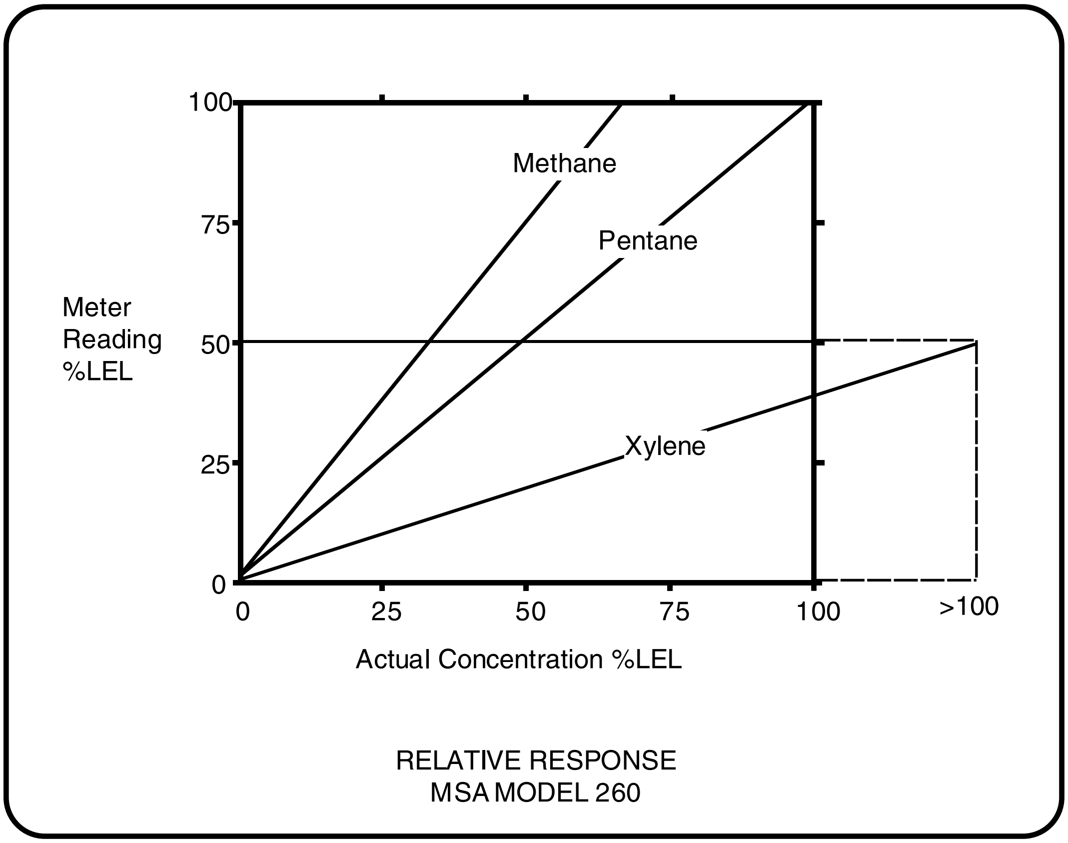
The CGI is able to detect gases or vapors by allowing air to diffuse into a sensor or by drawing a sample of air through its hose. A hand operated or battery-powered pump is used to draw the sample. Combustible gases enter the instrument, diffuse through a coarse metal filter, and come in contact with two hot filaments inside the sensor. Both filaments are heated to the same temperature and, therefore, have the same resistance. One filament is coated with a catalyst. Combustible gases burn on this catalytic filament; no combustion occurs on the uncoated filament. Combustion causes the filament with the catalyst to increase in temperature, causing an increase in resistance. This change in resistance causes an imbalance in the resister circuit. The change in resistance across the circuit is translated into a CGI meter reading.

All CGI readings are relative to a calibration gas. Readings correspond to the relative increase in resistance produced by the calibration gas when it burns on the catalytic filament. When measuring another gas or vapor, the instrument still responds to the increased temperature of the filament. However, some vapors and gases produce more heat when burned. These hot-burning gases cause the catalytic filament to become hotter at lower concentrations than the calibration gas. Conversely, some gases burn cooler than the calibration gas, and a higher concentration of such a gas is needed to cause the same increase in filament temperature.

Some combustible gas indicators are equipped with infrared (IR) capability. IR monitors are used on CGIs to detect the presence of higher levels of carbon dioxide and methane (in concentrations greater than 5,000 ppm).

Response curves or conversion factors indicate the gases that burn hotter or cooler than the calibration gas. Hot-burning gases will result in readings that indicate higher concentrations than actually exist. These gases appear on the left side of the calibration response curve and have conversion factors of less than 1. Cool-burning gases appear to the right side of the response curve and have conversion factors greater than 1.

The figure below demonstrates response curves for three materials. The calibration gas is pentane. Methane burns hotter than pentane, so the meter reading is at 100% LEL when the actual concentration is less than 70% LEL. Xylene burns cooler, so the meter reads less than 50% LEL when a 100% LEL condition exists.



Relative Response

A properly set low level alarm on a CGI meter is 10% of the LEL for the calibration gas. The reason this percentage is fairly low is that it serves as a safety factor to account for differences in the instrument's relative response.

Questions

1. *Based on the previous example for unknown spill situations, which would you rather have your meter calibrated to, methane or pentane?*

2. *If you select methane, what would the approximate actual concentration of pentane being monitored at a spill be when the meter reads 10% of the LEL?*

3. *Is this good?*

Oxygen is required for proper functioning of any CGI since oxygen is necessary for the combustion of the gas or vapor. Manufacturers' instructions should indicate the minimum concentration of oxygen required. Most instruments will not give an accurate reading at less than 10% oxygen. Oxygen-enriched atmospheres will enhance the catalytic combustion process and will result in false high readings.

The catalytic filament is vulnerable to contaminants such as sulfur compounds, heavy metals (especially organic lead), and silicon compounds. These materials form fumes that coat the wire filaments. Eventually, the filaments will no longer reach the proper temperature or the catalyst will become completely covered. Gases will no longer burn on the wire and the sensor will have to be replaced. The instrument may appear to work properly even when the sensor is no longer functional. Because of this vulnerability, it is extremely important to conduct a calibration check before and after each use.

Calibrating

Typical CGI calibration gases include methane, pentane, and hexane. Two meters from two different manufacturers may be calibrated to the same gas, yet respond differently to other gases because they use different catalysts. Response curves or conversion factors should be used only with the make and model for which they are supplied.

Questions

1. *What is the CGI calibration gas for your CGI?*

2. *If two CGIs from different manufacturers are calibrated to the same gas, yet respond differently to other gases, what should you do?*

3. *What can be done to simplify use of the meter with respect to response curves?*

Interpreting Results

Interpreting the readings from a CGI is easiest when the gas in the atmosphere being tested is the same as the gas to which the instrument was calibrated. An example of this is a CGI calibrated to methane used to test for a natural gas leak. If the meter reads 0.5 (or 50, depending on the type of readout), this means that 50% of the concentration of methane needed to reach an explosive environment is present. Since the LEL for methane is 5.3% methane in air, the meter indicates that a 2.65% (or 26,500 ppm) concentration of methane is present.

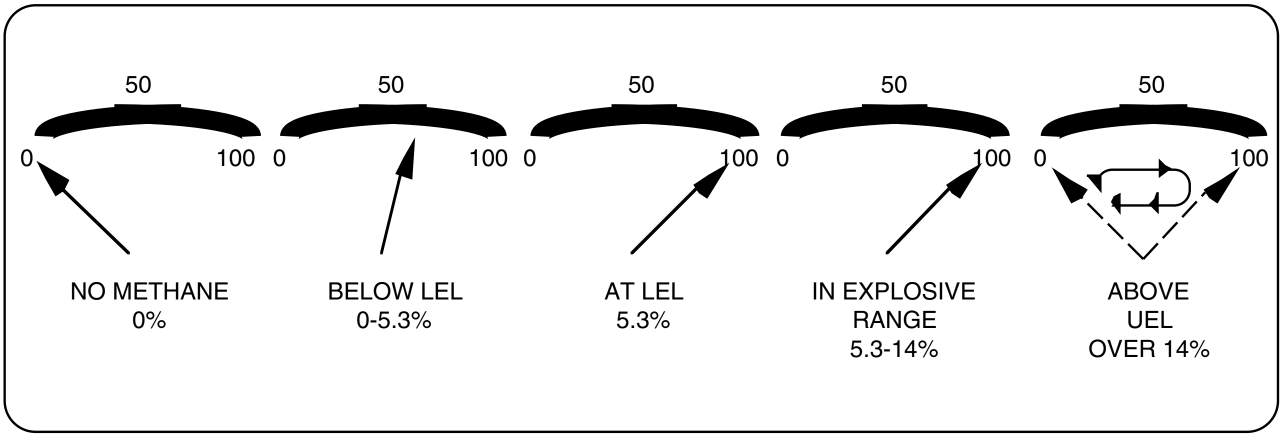
Response curves (such as the one shown below) and conversion factors can be used to determine the actual % LEL present if the identity of the material is known. When using response factors, multiply the readout in % LEL by the factor to obtain the actual % LEL present. For example, if a CGI calibrated to pentane is used to measure an environment containing methane, multiply the instrument reading by a response factor. If the response factor for methane is 0.6 for this instrument, the meter reading must be multiplied by 0.6. A meter reading of 50% LEL would correspond to an actual LEL for methane of 30%.

Questions

1. *If this same instrument had a reading of 40% LEL, what would the actual LEL be for methane?*

2. *If a different instrument calibrated to pentane had a response factor of 0.5 for methane and a reading of 70% LEL, what would the actual LEL be for methane?*

If a concentration greater than the LEL and lower than the UEL is present, the meter needle or digital readout will show a 1.0 (100%) level or greater. This indicates that the ambient atmosphere is readily combustible. When the atmosphere has a concentration of gas above the UEL, the instrument may react in one of several different ways. If it is an analog meter, the meter needle may rise above the 1.0 (100%) mark and then return to zero. A digital readout may freeze at this level.



CGI Response to Methane (LEL 5.3%, UEL 14%)

The illustration above shows an example of an analog CGI response in various environments. Digital instruments display different types of warnings when concentrations are above the LEL, such as **over**, **high**, or **LEL**.

In interpreting results, the user must consider that a level of a combustible gas or vapor may be well below the LEL while the atmosphere may still be hazardous. Concentrations high enough to result in CGI readings of 10% to 25% of the LEL are likely to be toxic or immediately dangerous to life or health. If toxicity is a concern, a CGI with a ppm scale or another, more sensitive, instrument must be used.

Questions

Briefly summarize the characteristics of a CGI.

Type of atmosphere: ________________________________

Method of detection: ________________________________

*Calibration standard:*________________________________

Check standard: ________________________________

Range of detection: ________________________________

Response time: ________________________________

Power source: ________________________________

Operating temperatures: ________________________________

Key limitations: ________________________________

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Activities

Oxygen Meters

Oxygen meters are used to detect the percentage of oxygen in atmosphere. Most oxygen-sensing devices used by fire departments are calibrated to indicate concentrations between 0% and 25%. Oxygen meters are most useful when used in conjunction with a combustible gas indicator. As discussed in the section on CGIs, it is important to verify that there is sufficient oxygen for proper operation of the CGI. Remember inadequate oxygen (less than 10%) will result in an inaccurate reading, as will oxygen-enriched atmospheres.

Instrument Operation

An oxygen meter has two principal components: an oxygen-sensing device and a meter readout. In some units, air is drawn to the oxygen detector with an aspirator bulb or pump; in other units, ambient air is allowed to diffuse into the sensor.

The detection of oxygen concentration is based on a chemical reaction in a detector cell. Oxygen molecules diffuse through a semipermeable membrane in the oxygen detection cell. Reactions between the oxygen and electrodes produce a very small electric current that is proportional to the sensor's oxygen content. The current passes through an electronic circuit, with the results being translated to a needle deflection or digital readout.

Like CGIs, oxygen meters are adversely affected by certain gases and vapors. In particular, carbon dioxide can permanently affect meter response by interfering with the chemical reaction in the detector cell. The result is that the meter is no longer capable of detecting oxygen. As a general rule, oxygen meters can be used in atmospheres greater than 0.5% (5,000 ppm) CO_2 only with frequent replacement of the oxygen detector cell.

Atmospheres containing oxidizers can produce a false high response on the meter. Like atmospheric oxygen, oxidizers react in the detector, resulting in a higher reading.

Calibrating

Oxygen sensors are affected by the same factors that affect other electrical detection devices, such as humidity and temperature. In addition, electrochemical sensor readings are affected by altitude. At higher altitudes, the partial pressure of a gas decreases, so a meter reading taken at a high altitude will be lower than one taken at sea level. Oxygen sensors provide a good example of this. There are significant changes in meter readings obtained when a meter calibrated at sea level is moved to increasing elevations above sea level as shown below.

Elevation	**Oxygen Reading**
sea level	20.9
500 feet	20.4
1,000 feet	20.1
2,000 feet	19.3
4,000 feet	18.0
6,000 feet	17.3
8,000 feet	15.4
10,000 feet	14.3

It is essential that you adjust these devices to background gases at the same altitude as the atmosphere to be tested. Testing a detector at the station, then using it at a different elevation will probably result in an inaccurate reading.

Question

Why will an oxygen meter calibrated at sea level indicate an oxygen-deficient atmosphere at high altitudes?

Clean ambient air can be used for calibrating an oxygen sensor, given that ambient air should contain 20.9% oxygen. There are also oxygen deficient check gases available. These are often used in combination with a CGI calibration gas for use in calibration checks of combination meters.

Interpreting Results

There may be several reasons for low oxygen levels in ambient atmospheres. Oxygen may be in the process of being displaced by a flammable, toxic, or other hazardous gas or vapor. A low reading may also suggest that there is a chemical reaction taking place that is consuming the oxygen.

Questions

1. *Air is primarily made up of what gases and at what percent?*
2. *If you replace 5% (50,000 ppm) of the total volume of air in a confined space with a toxic or flammable material, how much oxygen will you have replaced?*

Occupational Safety and Health Administration regulations state that atmospheres with 19.5% oxygen and above are safe for use with air-purifying respirators. While an atmosphere of 19.5% oxygen may be acceptable in terms of oxygen concentration, it can still be extremely hazardous due to the presence of other gases and vapors. Approximately 5% of a displacing gas is needed to drop the oxygen concentration by 1%. In many cases, 5% of a gas or vapor is very hazardous. It is important to emphasize that both an oxygen meter and a CGI are necessary for assessing an unknown environment because it is possible to detect a high % LEL concentration without a significant change in oxygen concentration.

An oxygen-enriched atmosphere (greater than 23.5% O_2) is particularly hazardous. Although several instruments can measure oxygen-enriched atmospheres, no testing or other work should ever be performed under such conditions because a spark, arc, or flame could lead to fire or explosion.

Oxygen Meter Summary

Questions

Briefly summarize the characteristics of oxygen meters.

Type of atmosphere: ________________________________

Method of detection: ________________________________

*Calibration standard:*________________________________

Check standard: ___________________________________

Range of detection: ________________________________

Response time: ___________________________________

Power source: ____________________________________

Operating temperatures: ____________________________

Key limitations: ___________________________________

____

Activity

Carbon Monoxide (CO) and Hydrogen Sulfide (H_2S) Meters

There are detectors, similar to oxygen meters, that are designed to provide accurate responses to specific gases. Some combination meters (meters with more than one detector) are referred to as “multigas” or “toxic gas” meters.

Many CGI/O_2 can be equipped with additional sensors. Most instruments equipped with the additional detector are calibrated for carbon monoxide or hydrogen sulfide, both of which are toxic at low concentrations.

Both of these instruments utilize a detector that operates by chemical reaction with the gas. Like the oxygen meter, these meters are subject to interference from other gases or vapors. They are also affected by environmental conditions such as temperature and barometric pressure. When using these meters, operating instructions must be reviewed carefully. Sensors must be calibrated and replaced periodically.

Solid State Sensors

Solid state sensors are found in some newer CGIs and a few chemical-specific instruments. These sensors are typically semiconductors coated with metal oxide compounds and heated to provide stability. Different oxides are used to detect different target gases. Solid state sensors are sometimes called metal oxide sensors.

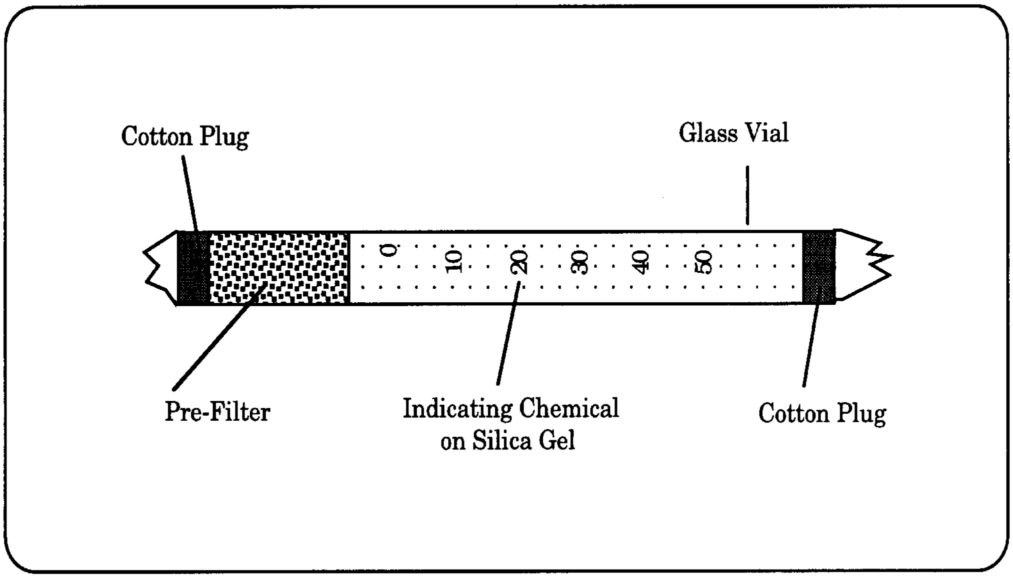
Depending on their proprietary manufacturing method, these sensors can react quickly and with extreme sensitivity. Among other advantages, they require less oxygen for operation, and they can be calibrated for a wide range of gases. They are often used to detect leaks in industrial applications. For example, they are used in the semiconductor industry to check for leaks of gases such as phosphine, arsine, and silane. Solid state sensors require frequent calibration because of sensor drift associated with temperature effects, or other factors. Sensor life is also relatively short.

Activity

Detector Tubes

Detector tubes are very useful for measuring the concentration of known vapor or gas contaminants in air. Detector tubes, however, only indicate if a chemical is present. They should not be used as the sole basis for determining entry into a hazardous atmosphere.

Detector tubes respond to a specific chemical or group of chemicals. The concentration of contaminant is determined by observing the color change in the tube. Depending on the tube selected, the scale may be read in ppm or percent. Some tubes have a millimeter (mm) scale, and the user must refer to a chart to determine the concentration. Other tubes indicate only the presence of a contaminant without indicating the relative concentration.



Detector Tube

Instrument Operation

The testing unit consists of an aspirating pump, a detector tube, and with some models, a stroke counter. The tips of the glass detector tube are broken off and the tube is then connected to a piston-type or bellows-type pump. If there is an arrow on the tube, it should be placed pointing toward the pump since the arrow indicates the direction of air flow.

One full pump stroke draws 100 cc through the tube, regardless of the manufacturer. Instructions for tubes designed with piston-type pumps always include the duration of each pump stroke. Each type of tube requires a certain number of pump strokes and a minimum amount of time between strokes to assure that an adequate sample is taken. If time is inadequate or an insufficient number of strokes are taken, the reading will be inaccurate. Manufacturers' instructions provide the proper procedures to use with each tube, as well as the sampling range.

A vapor or gas contaminant reacts with the indicator chemical in the tube resulting in a color change in the tube. Manufacturers' instructions should describe the color change that indicates a positive reaction and whether the length of the color change is proportional to the concentration of contaminant. Detector tubes are calibrated to one material but typically respond to many other materials that are similar in structure and reactivity. Some manufacturers also produce tubes for groups of gases, for example, aromatic hydrocarbons.

Instructions should also list potential interferences that can cause inaccurate tube readings. The chemical in the tube can react with air contaminants in addition to the gas or vapor to which it is calibrated. A color change in the tube that is different from that expected may indicate that some other vapor or gas is present. Also, interfering gases or vapors may increase or decrease tube response.

Finally, environmental conditions such as barometric pressure, humidity, and temperature can have a direct effect on the chemical reaction in the tube by increasing or decreasing tube response. Manufacturers' instructions may include temperature and humidity conversion factors.

Calibrating

Detector tubes are calibrated to a specific vapor or gas. It is not necessary to do a calibration check, however, it is important to check the expiration date of each box of detector tubes. Also, in order to improve performance and extend the shelf life of tubes, they should be stored at temperatures recommended by the manufacturer. Otherwise, the tubes may not be good, even if they are used prior to the expiration date. Anything that affects a chemical reaction will affect detector tubes. This includes light, especially ultraviolet light. Tubes should be left in their original boxes until used.

The aspiration pump must be checked for leaks prior to sampling. Instructions for leak checks will vary depending on the manufacturer. Often, a leak check is done by inserting an unbroken detector tube into the pump orifice and attempting to aspirate air through the pump. If any air is drawn in, there is a leak in the pump. Any leaks must be repaired prior to use. Also, the pump must be volumetrically calibrated on a quarterly basis to check the volume of air that is drawn with each pump stroke.

Interpreting Results

The detector tube is “read” by noting the number on the tube that corresponds to the point at which the color change ends. Often this is a jagged or faded edge, making it difficult to judge exactly where the color change ends. This can make it difficult to get accurate results from this seemingly simple test. Because the endpoint of discoloration in a tube is usually not definitive, it is helpful to standardize the practice for reading and interpreting tubes. Also, manufacturers’ information should be consulted to determine the tube’s range of accuracy. In an emergency situation, it may be prudent to use the highest reading.
In any case, it is easier to read the tube by comparing an exposed tube to an unbroken tube of the same type.

If the tube is being used in an environment with an unknown contaminant, it is important to remember that several chemicals may mimic the reaction of the calibrant with the tube. The tube reading is still valuable, however, since it indicates that a similar material is present. As previously mentioned, an unexpected color change may indicate that another type of contaminant is present.

In many cases, a negative response from a detector tube is more informative since it can exclude a number of potential chemical contaminants. No color change in a petroleum hydrocarbon tube, for example, indicates that no significant concentrations of gasoline, light fuel oils, diesel, naphtha, kerosene, aromatic hydrocarbon solvents, or other similar hydrocarbons are present.

It may be necessary to use more than one tube to determine the presence or absence of suspected contaminants. Kits offering a decision matrix for identifying unknowns are available.

Questions

Briefly summarize the characteristics of detector tubes.

Type of atmosphere: ________________________________

Method of detection: ________________________________

*Calibration standard:*________________________________

Check standard: ___________________________________

Range of detection: ________________________________

Response time: ___________________________________

Power source: ____________________________________

Operating temperatures: ____________________________

Key limitations: ___________________________________

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Activities

Radiation Survey Meters

At an incident involving radioactive materials, a radiation survey meter is used to determine the type of radiation present (alpha, beta, gamma) and its level. Use meter readings and radiation safety guidelines to delineate safe and restricted zones. In addition to radiation survey meters, personal dosimeters can be used to estimate an individual's dose of radiation; these direct read-out instruments are often the shape and size of a penlight. Consulting with a health professional trained in radiation will help determine the devices that are appropriate for a specific hazardous materials team.

Instrument Operation

One radiation detection device is the Geiger-Mueller tube, also known as a Geiger Counter or GM Counter. In recent years they have been replaced by newer, more accurate technology. A radiation survey instrument commonly found in fire departments today is the Ludlam Meter, named after the manufacturer.

The Ludlum Survey Meter is a portable survey instrument with four linear ranges used in combination with dose rate or cpm meter dials.

Four linear range multiples of x0.1, x1, x10, and x100 are used in combination with the 0-2mR/hr meter dial; 0-200 mR/hr can be read with a range multiplier.

Most radiation survey instruments work on the principle that radiation causes ionization in the detecting media. The ions produced are counted and reflect the relationship between the number of ionizations and the quantity of radiation present.

Many radiation meters have interchangeable detectors. While some detectors are specific to one type of radiation, others may detect alpha, beta, and gamma. Shielding can help in determining the type of radiation involved. For example, if the meter no longer detects radioactive activity when the source is covered with a sheet of paper, then the source is probably emitting alpha radiation.

Calibrating

Radiation survey meters are usually returned to the manufacturer for recalibration. This is because the radioactive source used for calibration may require a license to maintain. Check sources of radiation to ensure that the meter responds.

Interpreting Results

A gamma radiation meter usually reads in milliroentgens per hour (mR/hr) or microroentgens per hour (µR/hr). The unit mR/hr is roughly equivalent to millirem per hour (mrem/hr) for gamma radiation. These units express an exposure rate, that is, the amount of radiation to which an individual would be exposed at the point of measurement. Beta and alpha radiation are also sometimes measured in this way.

Meters with a scale that reads in counts per minute (cpm) are typically used with alpha or beta detectors. These meters are generally used to monitor for contamination.

Background cpm readings can be compared to readings from potentially contaminated items. If these readings are higher than the background radiation, it is likely that the item is contaminated.

Measure source radiation at various distances next. Radiation activity decreases as distance from the source increases.

Team members may encounter radiologic materials as a result of transportation incidents. If radiological packaging is encountered under these circumstances, it is important not to disturb the packaging. The transport index should be noted in the white box on the lower half of the label on the container. This is the maximum dose equivalent rate, expressed in mrem per hour, measured at one meter from the external surface of the container. Shipping papers can be consulted for information about the form of the radioactive source.

Personal Dosimeters

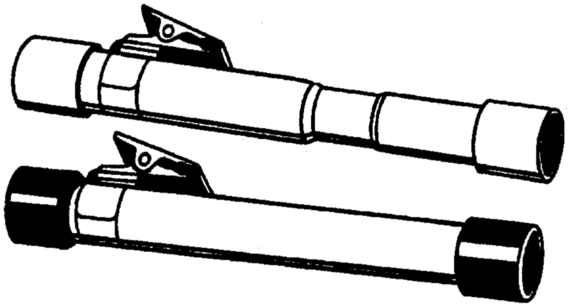
Personal dosimeters monitor the accumulated dose received by the dosimeter. Results of exposure (or non-exposure) can be documented so medical personnel can assist in evaluating radiation related illnesses.

Dosimeters are available in several styles (e.g., pencil, badge, ring). Some types (pencil) can be read on the scene. Most other types are typically sent to a lab for analysis, with a report being generated.

Limitations

The primary disadvantage of personal dosimeters is that they indicate the dose of radiation that has already been received. Dosimeters also do not show how fast the dose is being delivered, unlike survey meters.

Although personal dosimeters are fairly rugged, some can be damaged by shock, heat, light, and moisture.



Pocket Dosimeters

Questions

Briefly summarize the characteristics of radiation survey meters.

Type of hazard: ________________________________

Method of detection: ________________________________

*Calibration standard:*________________________________

Check standard: ________________________________

Range of detection: ________________________________

Response time: ________________________________

Power source: ________________________________

Operating temperatures: ________________________________

Key limitations: ________________________________

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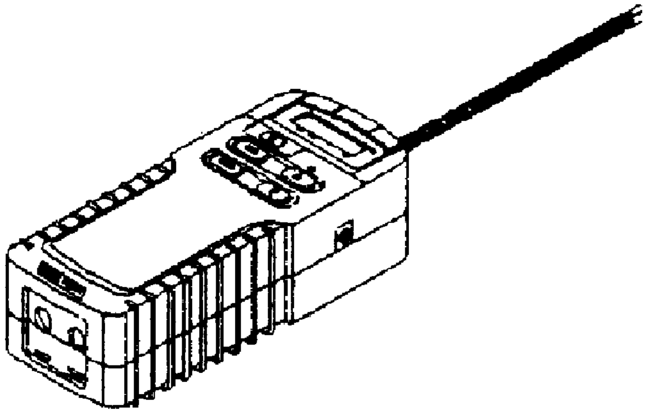
Activities

Photoionization Detectors

Photoionization detectors (PIDs) are general survey instruments designed to detect organic vapors and gases in the low ppm range. They can also detect a small number of inorganic gases, though many of these inorganics are halogens or halogenated compounds. Since these compounds are corrosive, they can damage instruments that are not corrosion resistant. Most PIDs are not corrosion resistant.

Photoionizers are useful for general atmospheric monitoring, characterizing release plumes, screening samples, and evaluating relative differences in concentration from one location to another. They cannot determine the identity of unknowns in the air; they indicate only that there is a high or low concentration of a chemical present.

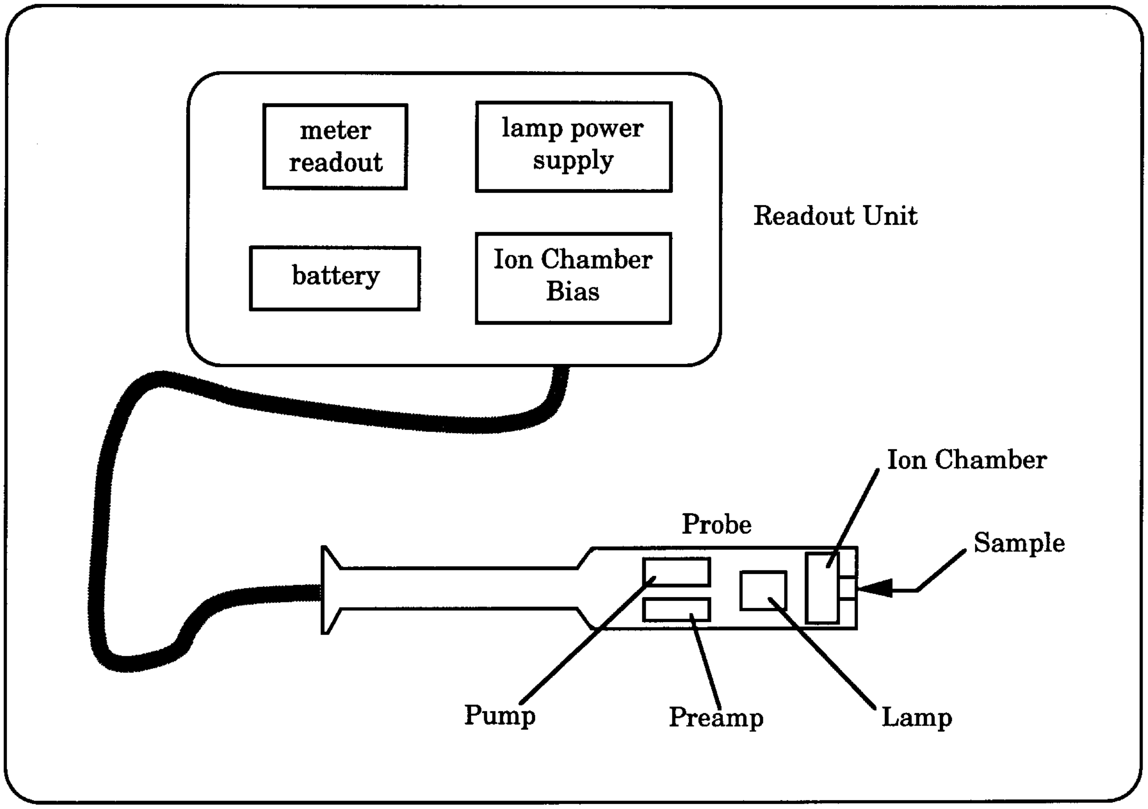


Photoionization Detector

Instrument Operation

Components

The basic components of one commonly used field photoionization unit include a battery, meter readout (analog display or digital), and an ultraviolet (UV) lamp detector.



Portable Photoionization Detector

The HNu photoionizer can be equipped with a chart recorder for documenting instrument readings, but this negates the intrinsic safety warranty and makes it impossible to use it as a portable survey instrument.

In addition to a real-time display, some PIDs have built-in data loggers that can store hundreds of data points. Data can be retrieved by direct printout or by downloading to a personal computer.

Ionization Potentials of Chemicals

In order to understand how a photoionizer works, it is important to understand the process of ionization. Electrons, which are negatively charged particles, are held in orbit around the nucleus of an atom or molecule. The nucleus carries a positive charge, keeping the electrons in their orbits. The energy required to remove the outermost electron from the atom or molecule is called the ionization potential (IP) of that atom or molecule. The IP is a unique value for a specific compound. Ionization potentials are expressed in electron volts (eV). Ultraviolet radiation, as found in the lamp of a PID, is capable of causing this ionization. There are several UV lamps available with varying levels of ionization potentials.

When a chemical compound with an IP less than the eV capacity of the PID’s ultraviolet lamp is bombarded with UV light, it loses electrons. These negatively charged electrons are attracted to a metal grid within the ionization chamber. The grid conducts a small amount of current, and the electrons attracted to the grid produce a change in current. The change is amplified and displayed as a ppm equivalent. So the meter reading is proportional to the current charge, which in turn is dependent on the number of electrons attracted to the grid upon ionization.

Anything that interferes with the light transmission can affect instrument readings. Water vapor (humidity) in the ionization chamber acts like fog on a dark night—scattering and reflecting light back toward the source. Gases that cannot be ionized because of their high ionization potential will affect the instrument in the same way. Meter responses can be decreased dramatically when high humidity or non-ionizing gases are present.

It is important to note that not all chemicals with ionization potentials below the strength of a PID UV lamp will be detected efficiently. How well a chemical ionized is a function of its molecular chemistry, including electron orbits, electron sharing, and the type of molecule. Relative response factors can be applied to help quantify unknown chemicals.

Calibrating

Photoionizers are usually calibrated to benzene at the factory, though isobutylene is also used. A photoionizer cannot discriminate between different vapors and gases; the response it generates is based on its response to the factory calibrant. Consequently, its response may be higher or lower than the true concentration, depending on the relative response of the detector to the contaminant.

Calibration of a photoionizer is not usually checked against a benzene standard due to the health hazards associated with benzene. Instead, a check gas or "span gas" of a known ppm concentration is used to determine whether the instrument is still within factory calibration limits. The instrument should detect the check gas at the correct level when it is properly calibrated. Some PID manufacturers supply check gas information regarding the correct instrument settings, and the ppm readout that should be obtained. Some instruments (MicroTIP, Photon, OVM) have microprocessors that use an internal calibration program. The instrument prompts the user through each step of the calibration procedure. Instruments that are manually checked can be adjusted to compensate for dirty lamps or grids, decreased lamp output, or other instrument factors that may affect readings. The adjustment knob is often called a span potentiometer. The span control adjusts the amplification of the current change, similar to the volume control on a radio. The span setting should be adjusted during the calibration check procedures according to the manufacturers' instructions. This setting must be locked into place and remain unchanged during use. The setting must be documented.

Interpreting Results

When the PID responds to the calibration gas, the reading is equivalent to the actual ppm concentration present, up to around 400 to 500 ppm. Higher concentrations of the calibration gas are not measured accurately by the PID. All responses of the PID are relative to its response to the calibration gas.

When another gas or vapor is present, or when there is a mixture of gases, the meter reading does not reflect the actual concentration present. Rather, it represents a change in the current across the grid as the materials in the air are ionized. A meter response of 22 units represents a current change equivalent to that produced by 22 ppm of the factory calibration gas. For this reason, the readings are often called “ppm calibration gas equivalents” or “ppm benzene equivalents.”

Many materials are not ionized as well as the factory calibration gas, while a few are ionized more easily. In general, consider the meter reading as only an indication of the presence of contaminants and remember that the actual ppm concentration is probably higher than the meter reading. Readings of 5 ppm or more of an unknown gas or vapor may indicate the need for protective clothing and breathing apparatus.

While PIDs can detect many materials at low ppm concentrations that are not detectable by CGIs, they do not detect everything. The absence of a meter response does not mean that there are no contaminants present. It simply indicates that the instrument does not detect the presence of certain vapors or gases.

Questions

Briefly summarize the characteristics of a PID.

Type of atmosphere: ________________________________

Method of detection: ________________________________

*Calibration standard:*________________________________

Check standard: ________________________________

Range of detection: ________________________________

Response time: ________________________________

Power source: ________________________________

Operating temperatures: ________________________________

Key limitations: ________________________________

____

Activities

Flame Ionization Detectors/Organic Vapor Analyzers

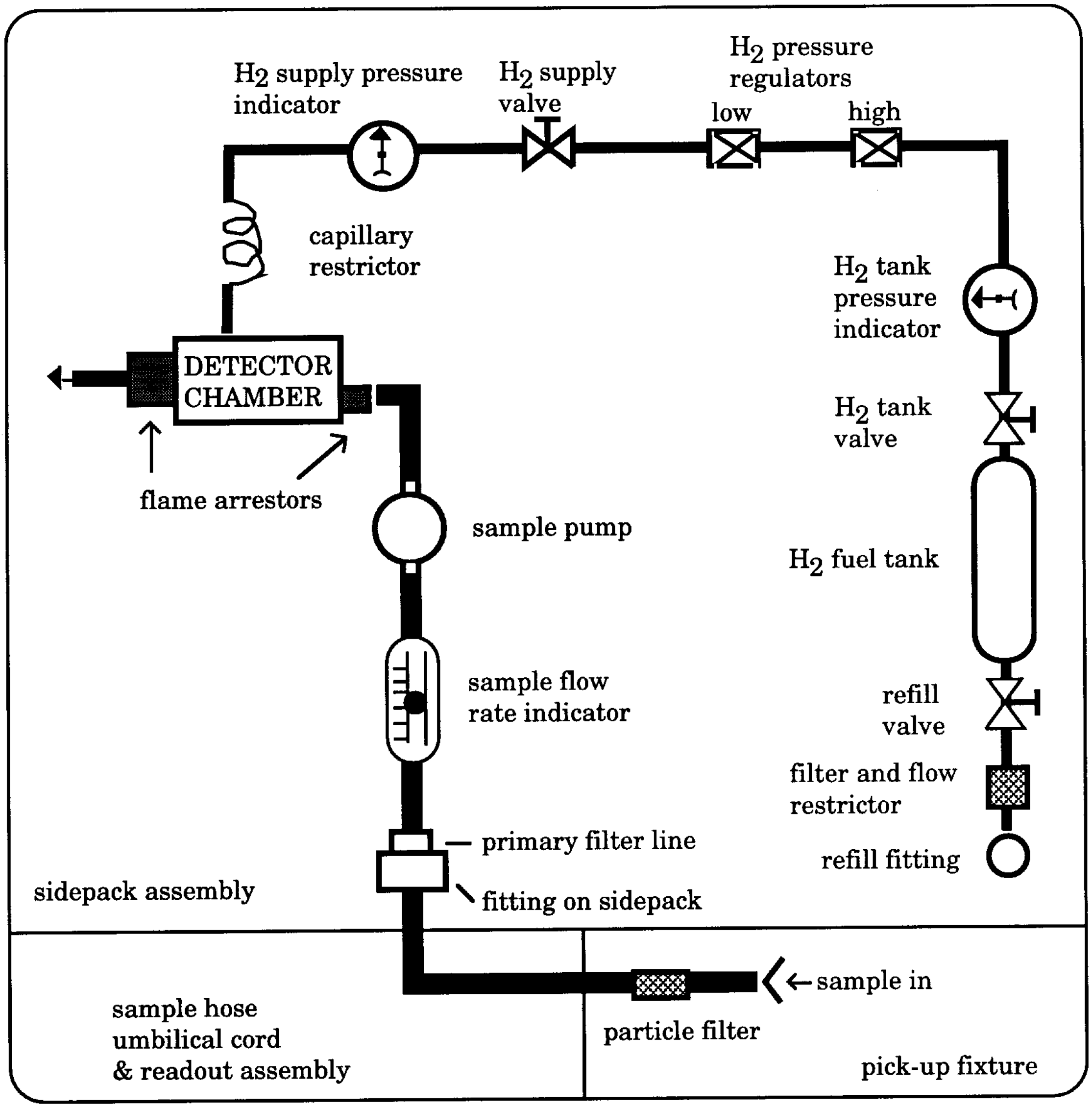
(Optional)

Flame ionization detectors (FIDs) are versatile monitoring instruments. Depending on the model, this instrument can be used for general surveys, or as a qualitative instrument that can help you identify a chemical. Use of a FID as a qualitative instrument requires additional training, skill, and knowledge.

Major FID components include a battery, a combustion chamber where the sample is burned, a detector, a meter readout (analog or digital), and a supply of fuel (usually a cylinder of hydrogen gas or a mixture of hydrogen and nitrogen gases). Some organic vapor analyzers are also equipped with a gas chromatographic option and a chart recorder.

An advantage of FIDs over photoionization detectors is that they are not restricted by the ionization potential of the chemical contaminant because they have very high ionization energy. FIDs detect, with varying sensitivity, any material that can be burned, that is, anything that contains carbon. This includes light hydrocarbon gases such as methane, which has a very high ionization potential. In addition, humidity does not limit their use.

FIDs are generally very sensitive and can read into low ppm ranges, particularly for low weight organic molecules like methane. These instruments are common in the petroleum industry as leak detectors and gas detectors for very low levels of methane, ethane, propane, and butane.



Organic Vapor Analyzer

Instrument Operation

The theory underlying the operation of FIDs is similar to that of PIDs. Organic gases and vapors are burned in a flame, producing carbon ions. The sample of air is drawn into the probe and pumped to the detector chamber by an internal pumping system. Inside the detector chamber, the sample is exposed to a hydrogen flame and burned. A small cylinder of hydrogen in the instrument serves as fuel for the detector. The slightly positive carbon ions are attracted to a grid within the detector. The ions are collected and an electrical current proportional to the hydrocarbon concentration is generated. The charge is amplified and displayed as a ppm equivalent. The meter needle deflects higher when more vapor or gas is present in the sample.

The purity of the fuel supply is very important. Insist on fuel with less than 1 ppm total hydrocarbon contamination (THC). Hydrocarbons present in fuel will be burned and measured by the FID, producing a consistently high background reading. The instrument fuel supply will last approximately six to eight hours of continuous use.

Because these instruments have a flame, a combustible gas indicator ***must*** be used first to establish that the environment is not explosive. Another important limitation is that oxygen must be present in order for a FID to burn the sample. Insufficient oxygen will extinguish the flame.

Some FIDs operate in two different modes: survey mode and gas chromatography mode. Other FIDs offer only a survey mode, which is the most commonly used.

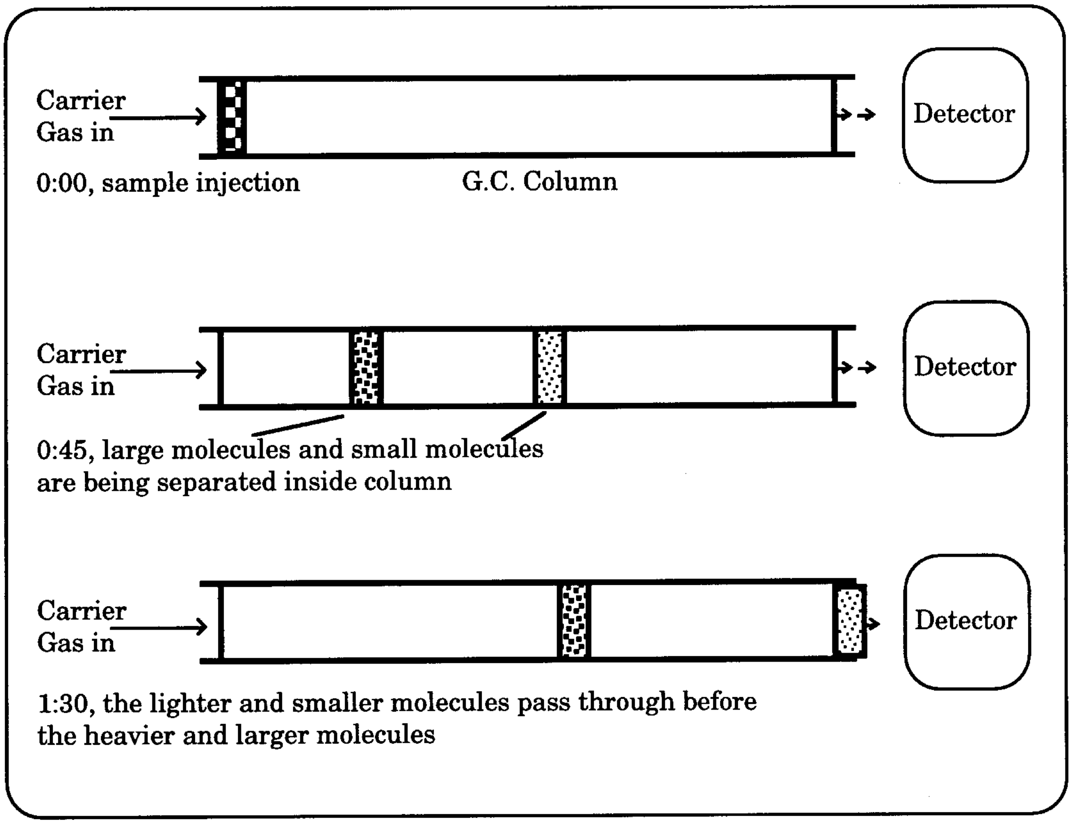
Survey Mode

When operating in the *survey* mode, a FID continually draws air into the combustion chamber where it is burned. The resulting signal is translated on the meter as the concentration of total organic vapors. The meter display has a scale of 0 to 10. This scale can be set to read 0 to 10, 0 to 100, or 0 to 1,000 ppm, or an even greater range by using the appropriate scale factor.

Gas Chromatography Mode

To operate a FID *qualitatively*, it must be equipped with the gas chromatograph (GC) features. In the GC mode, this instrument is able to separate a sample into its different components and detect each of them. Depending on the instrument setup, each component will have a characteristic response to the instrument. Use of the instrument in this way requires extensive training and practice.

A FID in the GC mode works differently than in the survey mode. In the GC mode, the sample to be separated is injected into a column packed with an inert solid; a carrier gas (hydrogen) flows through the column. As the carrier gas forces the sample through a column, the separate components of the sample are retained on the column for different periods of time. The amount of time a substance remains on the column, known as **retention time**, is a function of its affinity for the column material, column temperature, and flow rate of the carrier gas. Lighter molecules, such as butane, are drawn through the column more quickly than larger molecules, such as polypropylene.



Retention Time

The response of an organic vapor analyzer in the GC mode can be compared to a known standard for identification. Also, the user can determine the level of air contaminant downwind of a release by comparing it to readings from the source of the release. To successfully use the organic vapor analyzer in the GC mode, the operator must have a general idea of the vapors and gases that may be present in the sample. Without that knowledge, the instrument will be of minimal use.

Calibrating

FIDs are typically factory calibrated to methane. A known concentration of methane is used for calibration checks to ensure that the instrument is operating within factory calibration standards.

Like the photoionizer, the FID has a span potentiometer. In some models, this is called the "gas select." Each manufacturer specifies the initial span potentiometer setting that should be used during the calibration check. For example, certain Foxboro OVA models should read the standard accurately when the gas select is set at 30. If it does not, the "gas select" can be adjusted.

Questions

Briefly summarize the characteristics of an FID.

Type of atmosphere: ________________________________

Method of detection: ______________________________

*Calibration standard:*______________________________

Check standard: __________________________________

Range of detection: ________________________________

Response time: ___________________________________

Power source: ____________________________________

Operating temperatures: ___________________________

Key limitations: __________________________________

____

Activities

Other Detection Methods (Optional)

Characterization of liquids and solids requires using different methods than air monitoring. Real-time characterization can be accomplished using test kits.

The simplest kits use test paper for determining the presence of a specific hazard or a hazardous characteristic. There are test papers for acids and bases (pH paper), oxidizers and peroxides, and sulfides. Test paper is useful for liquid releases such as acids and bases, oxidizers and peroxides, and sulfides.

When the identity of a spilled material is unknown, one of several kits can be used to determine the contents. Test strips with colorimetric tests for a variety of hazard characteristics and chemicals are available from other manufacturers. Using these strips you can test for oxidizers, fluorides, petroleum products, halogens, and pH.

HazCat® is a field characterization kit that allows you to evaluate the characteristics of an unknown chemical. These kits help determine the class and, in certain cases, the specific chemical. One disadvantage of a HazCat® kit is that it requires handling and measuring test chemicals. Personnel using this kit must be well trained.

Kits such as HazCat® come complete with an extensive user's manual and guidance charts on how to conduct individual tests and evaluate results.

The test kits described above may require a few minutes to several hours to characterize the hazard. Some kits incorporate hazardous chemicals into the test materials. You must be *completely* familiar with the tests and test materials before using such kits to avoid inaccuracies and injuries.

Using Detection Devices

It is essential that team members understand how to use the information obtained from detection devices. This means you must understand the operation, limitations, and proper application of each device. Apply the following basic rules.

1. **Prioritize your monitoring.**

Generally, measure oxygen levels first. If oxygen is less than 21%, a toxic chemical may be replacing part of the air. If the oxygen is higher than 21%, the enriched atmosphere may be flammable.

2. **Select the appropriate instrument.**

Never use a device that cannot detect the substance or measure the concentration you believe is present. Also, be sure your instrument operates properly under existing conditions. For example, an odor of gasoline is reported in a sanitary sewer. The primary hazard is explosive vapor build-up within the sewer system. The appropriate instrument for measuring the hazard is the % LEL CGI, preferably a combination meter that also detects oxygen deficiency. It would be inappropriate to call for just a carbon monoxide or hydrogen sulfide sensor. It would also be inappropriate to use a CGI that measures in ppm equivalents. Further, if the oxygen sensor shows a concentration of less than 10% oxygen within the sewer, the CGI will not operate properly. The result will be a false negative reading.

3. **Remember: "The absence of evidence is not evidence of absence."** From The Cosmos, Carl Sagan

Simply because a device produces no reading does not mean that no contamination is present. The device you are using may not be capable of detecting the type or concentration of contaminant present. For this reason, use multiple types of air monitoring instruments to confirm the presence or absence of contamination.

Questions

Using the scenario of gasoline in the sewer, suppose that there is a sufficient concentration of oxygen in the sewer to use a CGI.

1. *Does a reading of 0% LEL prove that no gasoline is present?*

2. *Does a CGI reading of 15% LEL mean that gasoline is present in the sewer?*

3. *If your answer to the previous question is no, how would you identify the chemical producing the 15% LEL response?*

CGIs can be used with filters to determine the presence of specific chemicals. For example, in the sewer scenario described above, you could attach an activated charcoal filter to the CGI to remove gasoline vapors from the sample before they reach the sensor. Light hydrocarbon gases such as methane pass through the filter, and there will be no decrease in % LEL detected if methane gas is responsible for the meter readout.

4. Never assume only one hazard is present.

Team members may focus on what is perceived to be the primary hazard of a situation and forget that other hazards may also be present. Additional instruments can be used to rule out other potential hazards. For example, if there is 0% LEL and 20.8% oxygen in a sewer vault and a petroleum vapor tube detector tube reading of only 100 ppm, then other hazards must be considered as well. The vault should be assessed for the presence of other materials, such as hydrogen sulfide gas, using the appropriate sensor or detector tube.

5. Use one instrument to confirm another.

In the sewer scenario, detector tubes can be used to determine the concentration of gasoline present, and can verify the information collected using a CGI. If the CGI in the example gave a reading of 10% LEL, and use of the charcoal filter as described above decreased the reading to 5%

LEL, then half the meter reading is caused by another gas, perhaps methane. Detector tubes can be used to measure the actual amount of methane and gasoline present. Concentration readings from each tube, when added together, should correspond approximately to the CGI composite response.

6. Interpret Readings in More Than One Way

With increasing familiarity in instrument use, team members will be able to use readings in other ways. For example, if a CGI is not available for use in the gasoline-contaminated sewer, the hazard can still be assessed. A detector tube can be used to measure the concentration of gasoline or petroleum hydrocarbons in the sewer. Gasoline has an LEL of approximately 1.4% or 14,000 ppm; a tube reading of 1,400 ppm represents 10% of the LEL of gasoline.

The same concept applies to other sensors. A meter reading of 20.4% oxygen indicates only a slight decrease in oxygen concentration. However, it also represents a significant concentration of another gas or vapor that is displacing the oxygen.

7. Establish Action Levels

Action levels are readings or responses to knowns or unknowns that trigger some action. The action taken may include evacuating the area of unprotected or unnecessary personnel, watching meter readings more closely, upgrading levels of personal protection, or leaving the area altogether. These must be based on departmental Standard Operating Procedures (SOPs). The action levels discussed below are accepted by most agencies.

- **% LEL Action Levels**

  The % LEL CGI is a safety meter; it is intended to tell the user whether or not it is safe to be in a particular area. A meter reading of 100% LEL is obviously unsafe. But at what % LEL reading should you become concerned? The answer depends on whether the material is a known or an unknown. If the material is known, and a response curve or factor is available, the action level is 50% of the actual LEL.

Unknown materials have an action level of 25% LEL in the Hot Zone. For many cool burning materials, a 25% LEL meter response can correspond to actual concentrations above 50% LEL. At only slightly higher meter readings, the actual LEL can approach 75% to 100% LEL.

- **Other Action Levels**

  Action levels have been defined by the Occupational Safety and Health Administration and the American Conference of Governmental Industrial Hygienists for workplace exposures to many commonly encountered chemicals. The 8-hour maximum exposure levels can be used as action levels in emergency response. Measurements can establish the appropriate size of the Hot Zone and safe areas for unprotected personnel.

  When the contaminant is unknown, responders must rely on the instruments on hand to provide a general indication of the relative health risks that may be present. A CGI reading of 1% LEL should indicate an action level from a health standpoint. The 1% reading suggests that there are at least 100 ppm (and possibly much more) of a combustible gas present. Similarly, a 0.1% decrease in oxygen concentration may represent a concentration of an unknown of 5,000 ppm. When such readings are obtained, the area should be considered hazardous, requiring appropriate respiratory and skin protection for entry.

- **Protect Instruments From Contamination**

  Instruments can often be protected from contamination at incident scenes if proper precautions are taken. For example, you can wrap the devices in plastic or transport them in covered containers. The sensors, of course, must be fully exposed to air in order to work properly.

If instruments do become contaminated by hazardous materials, they must be decontaminated like any other equipment. If you suspect an instrument has been contaminated, leave it in the Hot Zone with other exposed equipment for later decontamination or disposal.

Activity

Application Exercise

Application Exercise

Instructor Notes

Application Exercise Worksheet

As you practice using the instruments at the work stations your instructor has set up, answer the questions below for each station.

Work Station # _________

1. What is the name of this device?

____

2. What is the primary purpose of this device?

____

3. Does this device carry any approval markings that allow it to be used in potentially combustible atmospheres? If so, what are they?

____

4. List the items you should inspect when doing a field check on this instrument.

____

5. What type of material does the manufacturer recommend you use to conduct a calibration check on this instrument?

____

6. Use the device to sample the substances your instructor has provided and note your findings below.

Sample 1: ____

Sample 2: ____

Sample 3: ____

Sample 4: ____

7. Use the device to sample something outside the classroom or the building. Record the item you sampled and the results.____

____

8. What questions do you have about this instrument?

____

Action Statement

Action Statement

You have just completed the sixth module of the Hazardous Materials Technician course. The topics included:

- General considerations and precautions in hazardous materials monitoring
- Basic sampling techniques
- Evaluating meter readings
- The function and operation of the following instruments:
    - Combustible Gas Indicators
    - Oxygen Meters
    - Carbon Monoxide and Hydrogen Sulfide Meters
    - Colorimetric Detector Tubes
    - Radiation Survey Meters
    - Photoionization Detectors
    - Flame Ionization Detectors/Organic Vapor Analyzers
- A review of other methods of detecting hazardous materials
- Basic guidelines for using detection devices at hazardous materials incidents

Knowing how you respond to emergencies in your first due areas, would you change your actions or habits based on the information covered in this module? Listed below are some suggested actions. Some you may already do, and others may not fit your work environment. If there are actions you have not done in the past, do you think you will begin doing them as a result of this training?

As a result of this training I will:

1. Practice using the detection devices available in my department
2. Practice better sampling techniques
3. Compare measurements among detection devices and with other resources at an incident scene prior to taking action
4. Take more care in selecting the right instrument for the right chemical and the right situation
5. (Create my own action statement)

____

____

____

Appendix A
Activities

Instructor Notes

Oregon Case Study Activity 1

An independent contractor arrives at a local sawmill to inspect a backflow valve on a city water line. The contractor has performed the same annual inspection in the past without encountering problems, and is licensed and certified by the state to perform such inspections. The backflow valve is in an underground vault about 8 feet deep, with about 14 inches of water on the bottom. The contractor removes the manhole cover and enters the vault.

Half an hour later a truck driver notices the open manhole and sees a body floating face down in the water at the bottom of the vault. He notifies the office at the sawmill which requests emergency assistance. Before help arrives, the supervisor at the sawmill attempts a rescue. A few seconds later, a maintenance worker also enters the vault to help. Neither is wearing respiratory protection. Within two to three minutes, both men are unconscious.

Shortly afterward, two police officers and two paramedics—none wearing respiratory protection—also enter the vault. All have to be assisted out. Fire fighters arrive, don SCBA, and remove the three remaining men from the bottom of the vault. Two are found face down in the water; the third is in a sitting position. The contractor and supervisor are pronounced dead on arrival at a local hospital. The maintenance worker is hospitalized.

Tests of the atmosphere at the bottom of the vault reveal the following:

O_2: 7%	CO_2: more than 3%
% LEL: negative	H_2S: negative

State investigators conclude that an algae bloom and bacterial action in the water resulted in 0% free oxygen in the water. Carbon dioxide, a waste product, was liberated and displaced much of the oxygen in the vault.

Questions

1. What hazards were present in the vault?

2. Which detection devices can be used to assess atmospheres like that in the vault?

Operational Checks Demonstration Activity 2

Instructor Notes

Show the operation manual for each instrument and discuss where they are stored. Explain that it is important to review the manuals because they contain information on minimum recommended voltages and the meanings of error messages. Cover the key points as discussed below.

1. **Instruments must have sufficient power.**

2. **Always check the battery power/low battery display before using the device, and recharge, if necessary.**

3. **Adequate warm-up time**
   Meter zeroing
   Cleaning and decontamination
   Maintenance

Calibration and Field Checks
Demonstration Activity 3

Instructor Notes

Explain to the students that under most field conditions readings will be estimates, not exact concentrations. To improve accuracy it is important to have instruments calibrated. Cover the key points as described below.

1. **Detection devices are calibrated to a standard at the factory.**

2. **All instruments must be checked regularly to make sure they are still responding as calibrated.**

3. **Instrument response should be checked against the calibration standard before and after each use.**

4. **Calibration checks should be documented.**

5. **Field checks are mandatory.**

    - **Battery:** Check the power level and compare it to the minimum recommended voltage.

    - **Sensors:** Challenge the sensors to be sure they actually work. Oxygen sensors can be activated with exhaled breath. CGI sensors can be activated with a lighter or fumes from a gas tank on a rig. Radiation survey meters can be activated with a check source. Detector tubes cannot be reused, but checking a tube will allow you to become familiar with the color you might expect to see.

    - **Alarms:** Check that the alarms (audio and visual) sound at the appropriate set points.

    - **Readouts:** Show the students the digital or analog readout on your instrument. The type of readout selected is a matter of personal preference. Digital readouts are sometimes easier to read, while analog readouts most often show trends (increasing or decreasing levels). The type of readout the instrument has is less important than most other instrument factors.

- **Pump:** Demonstrate how the pump works on the instrument. Show how to check that the hoses are properly connected and that the instrument is actually drawing a sample from the end of the hose, not from a leaking connection midstream. Many manufacturers recommend placing a finger over the end of the hose for a second or two. If the pump starts to labor, the sample is properly entering the instrument.

- **Parts:** Show the students all the available parts for your instrument. Many instruments come with external filters, probes, earpieces, chargers, calibration kits, manuals, spare filters, custom cases, etc.

- **Directions:** Again, highlight the importance of following the manufacturers instructions. Let the students know that a telephone number for the manufacturer is in the manual if they need technical assistance.

Review the steps that should be taken for a proper field check for each instrument your hazardous materials team carries.

Propane Case Study Activity 4

In 1987, a firefighter hazardous materials team responded at 2:00 a.m. on a calm cool night to a leaking one-ton propane tank on top of a building. The tank was accidentally damaged as it was being positioned by a construction crane. The crane operator's assistant who was on top of the building was injured. The tank was oriented in a position that allowed propane to flow onto the surrounding ground near the crane. Due to terrain, responders were forced to approach the building from the side opposite the crane. Immediately after the accident, the crane was shut off.

The first-in units were focused on rescuing and treating the injured crane operator's assistant. The hazardous materials team was called in to assess the hazard of the propane tank.

The hazardous materials team instrument operator began monitoring the area using a CGI/O_2 meter and wearing SCBA and turnout gear. No propane was detected despite the obvious damage to an outlet pipe on the propane tank. Hazardous materials team members believed that the leaking propane had auto-refrigerated the tank and the propane leak had sealed itself with ice in the process. Instrument readings confirmed this, and the haz mat team began plans to restart the crane to remove the victim from atop the building.

1. How would you field check this instrument?

2. Where should you monitor for propane?

Prior to starting the crane the hazmat team decided to double check their findings with their backup meter and found combustible levels of propane approximately 100 feet from the building from about the knee level down. They plugged the leak and removed the victim, working on the side of the building opposite the propane cylinder.

It was later discovered that no field check was done and that the instrument had an inoperative combustible gas sensor. The reading, at zero, was inaccurate. The instrument was taken out of service and repaired. The department then instituted a field check procedure.

Detection Activity 5A

Instructor Notes

Demonstrate the detection range of your combustible gas indicators.

Combustible gas meters typically respond to either % LEL or % gas in air.

Questions

1. Your combustible gas meter is calibrated to a gas with an LEL of 1.2% and it is reading 50% of the LEL of the calibration gas. What is the actual concentration you are measuring?

2. Your combustible gas meter is calibrated to a gas with an LEL of 1.3% and is reading 2.6% in air of the calibration gas. What is the actual concentration you are measuring?

3. Is your CGI meter useful in detecting hydrocarbons in the 0-5 ppm range?

4. Will a combustible gas meter detect a radioactive isotope?

Additional Instructions

Your combustible gas meter may have sensors in addition to the CGI sensor. Sensors for oxygen, hydrogen sulfide, carbon monoxide, cyanide, and other chemicals are available. Demonstrate the detection range of each of those sensors.

Oxygen sensors typically detect oxygen levels in the % in air range and alarm at both 19.5% (low alarm) and around 23% (high alarm). You can use the air present in the room as a calibration check for 20.8% O_2 and your exhaled breath to obtain low O_2 readings. Use a medical O_2 bottle to supply O_2 for increased levels of O_2.

Detection Activity 5B

Instructor Notes

Detector tubes typically measure results in parts per million (ppm). Demonstrate to the students how the detection range on a sample detector tube is determined.

Distribute unused detector tubes to the students, along with the directions for those tubes. Discuss how the detection range for different tubes varies depending on the number of pump strokes and the version of tube you have selected. For example, one pump stroke may have a range of 50-700 ppm, 10 pump strokes may have a range of 5-70 ppm. Explain that different versions of detector tubes for the same chemical may be designed for different ranges in air.

Questions

1. Why do detector tubes have different ranges?

2. Will a given detector tube detect any chemical other than the one it is designed for?

Detection Activity 5C

Instructor Notes

Demonstrate the detection range of your radiation survey meter. List the following numbers on the board as a comparison:

300,000 mrem = LD_{50}
25,000 to 100,000 = maximum recommended one time dose for lifesaving purposes
8,000 mrem/year = average annual dose a smoker exposes himself to
5,000 mrem/year = maximum allowable annual dose for a monitored radiation worker
180 mrem/year = average annual dose by U.S. citizen
2 mrem/hour = typical exposure rate used to cordon off a spill area
0.01-0.02 mrem/hour = average background radiation reading

Question

1. Does your radiation survey meter detect background radiation?

Detection Activity 5D

Instructor Notes

Demonstrate the detection range, sensitivity and selectivity of other instruments in your department.

Explain that a properly set low level alarm for LEL on a CGI meter is 10% of the LEL for the gas it is calibrated to. Most CGIs are calibrated to hexane, pentane, methane or propane. In many cases, responders must use CGI meters to measure a gas other than the calibrant gas. In these cases, responders have two options:

1. Calibrate the CGI meter to pentane, hexane or toluene (commonly available calibration gases) and set the alarm level to 10% of the LEL. The meter will respond conservatively for commonly encountered gases and vapors and will most likely indicate that 10% of the LEL is being observed when less than 10% actually exists. This is a practical, efficient simple method for use of CGI meters and minimizes or removes the need for calibration charts and calculations.

2. If the gas being measured can positively be identified, response factors or graphs supplied by the manufacturer of the meter may be used to determine the actual concentration being detected. Using graphs, response curves allow you to convert a meter reading in % LEL to the actual % LEL of the material involved. Response factors are specific numbers by which the meter reading is multiplied in order to obtain the concentration of the actual gas involved. Response curves and factors are specific to each CGI model and manufacturer and should not be interchanged.

Demonstrate how your CGI meter has the alarm set at 10% of the LEL. Use a variety of samples such as gasoline or acetone and show how the alarm will sound when the reading indicates 10% of the LEL, regardless of which material is being sampled.

Relative Response Activity 6

Instructor Notes

Demonstrate how the manufacturer of your CGI recommends application of their response factors, response graphs or response charts.

For example, if your meter is calibrated to pentane, the manufacturer may recommend you apply a response factor of 1.4 when monitoring natural gas. That response factor must be applied as:

10% LEL (observed on meter) x 1.4 = 14% LEL

Response factors vary depending upon the manufacturer and the model of instrument.

Instrument Response Activity 7

Instructor Notes

Using one of your detection devices, time the response of the instrument with and without a sample hose connected. A general rule of thumb is to allow one second for every foot of sample hose. Demonstrate how response time is affected by adding sample hoses of varying lengths.

Evaluate the fastest and slowest instruments you have available for the class and demonstrate to the students their differences in response times. Ask for a volunteer to monitor the time. Again, you can use the samples such as acetone to obtain a reading.

CGI Activity 8A

You respond to a reported hexane spill. Using your CGI with a % LEL readout, you obtain a measurement of 20%.

Questions

1. What is the meter response conversion factor for hexane for your instrument?

2. What is the LEL of hexane?

3. What is the actual concentration of hexane in terms of % LEL and ppm? (hint: 1% in air is 10,000 ppm)

CGI Activity 8B

A facility handling ethylene oxide has a fixed sensor alarm that sounds when high concentrations of the gas are detected. The sensor indicates that there is a concentration of 4,500 ppm of ethylene oxide in the area, but this should be confirmed with another instrument.

Questions

1. The LEL of ethylene oxide is 3%. What reading should be expected on a % LEL CGI (assuming the instrument is calibrated to a gas other than ethylene oxide)?

2. What is the corresponding reading on your meter, applying the appropriate response factors?

CGI Activity 8C

At a cosmetic manufacturing facility, a worker who entered an ethyl acetate storage tank to remove residual liquid and sludge has collapsed inside the tank. A coworker who attempted a rescue has also been overcome and is lying unconscious in the tank. On arrival, fire fighters lower a sample line into the tank and note the following readings from a CGI meter.

90% LEL at the level of the victims
55% LEL at mid-tank
40% LEL at the top of the tank

The LEL of ethyl acetate is 2%.

Question

1. The approximate down-time of victims prior to fire department arrival is 20 minutes. What information would be valuable in determining the likelihood of victim survival?

CGI/O_2 Activity 9

Instructor Notes

Divide the class into groups of two or three to conduct the exercise. Each participant must have the opportunity to use each instrument. You will need the following materials:

- *CGI*
- *O_2 meter*
- *Check gas for each CGI*
- *3 beach balls*
- *Flammable liquids (Soak cotton balls with butane, alcohols, etc. and place them in jars with tight-fitting lids.)*
- *Air Monitoring Instrument Record*

Supervise participants as they use the instruments to determine oxygen concentrations and LEL/UEL of the various samples. Participants need only record the measurements of known samples (those in the beach balls), but should note the reaction of the instruments to the other available samples. Make sure that participants do a field check of their CGI prior to and on completion of monitoring.

Questions

1. What does each reading indicate? What course of action would you take based on the readings?

2. What are the advantages and limitations of each instrument?

3. Two different CGI models have Class I, Division 1, Groups A,B,C, and D approvals. One is approved as “Intrinsically Safe” and the other as “Explosion-Proof.” Can both instruments be used under the same conditions?

4. A subsurface gasoline leak is being monitored with a combustible gas indicator. Initial readings are greater than 50% of the LEL, but as the survey continues, concentrations decline and are finally undetectable by the CGI. Can you account for this?

5. A tank car is leaking carbon dioxide in an area of uneven terrain. What instruments are required for site entry?

6. What is indicated by an 11% oxygen level in a confined space?

Electrochemical Sensor Activity 10

A deep, underground secure storage vault was the site of an electrical failure and subsequent fire. There is concern that computer tapes and microfiche stored at several levels below ground have been destroyed. A combination meter gives the following readings: 20.3% oxygen, greater than 500 ppm carbon monoxide, and 2% LEL.

Question:

Evaluate the possible hazards that may be present.

Detector Tube Activity 11A

A sewage treatment facility has a CGI that appears to be malfunctioning. The meter gives a persistent reading of 100% LEL. The Draeger polytest tube and petroleum hydrocarbon tube each show no color change after the recommended maximum number of strokes.

Questions:

1. Assuming the CGI is functioning correctly, what might account for a persistent reading of 100% LEL?

2. The CGI could be detecting a flammable gas that the detector tubes cannot detect. List those gases then, through a process of elimination, and identify the gas that is most likely present.

3. What tube can be used to verify the presence of the gas detected by the CGI and give an estimate of the concentration present?

4. What is the initial color of the indicating layer and what color change indicates the presence of the gas detected by the CGI?

5. Can it be used to confirm the presence of 100% LEL concentrations?

6. There is no color change when the indicator tube is placed backward in the pump (that is, with the arrow facing away from the pump) during sampling. Is this a valid result or should the test be repeated?

Detector Tube Activity 11B

Instructor Notes

Divide the class into groups of two or three to conduct the exercise. Each participant must have the opportunity to use detector tubes. You will need the following materials:

- *Detector tubes and pump/piston assembly*
- *Contaminants for each detector tube: alcohols, acetone, toluene*
- *Several one-quart jars*
- *Detector Tube Worksheet or record used by your department*

Provide participants with detector tubes appropriate for the available contaminants. For contaminants such as alcohol, acetone, or toluene, add a few drops to an unmarked jar, or place a cotton ball soaked with the material in the jar. Use the contaminants sparingly. By the end of the exercise, it is likely that much of the liquid will evaporate, making the classroom an uncomfortable environment in which to work. In addition, interferences will increase.

Observe participants conducting leak tests prior to sampling. After participants have used the tubes appropriate to the contaminants, encourage them to experiment to observe different responses. For example, have the students sample toluene with an acetone tube. Discuss possible interferences, according to manufacturer's information.

Questions

1. Did you have any difficulty reading the tubes?

2. Were there any interferences?

3. What color change did you observe in each of the tubes

4. What chemical reaction was taking place?

Radiation Meter Activity 12A

You arrive at the scene of a radiation incident. Radiation levels are between 1.5 and 3 mR/hour. Using the detection instrument(s) available in your department, answer the following questions.

Questions

1. What is the operating range of your instruments? Is it designed to detect these levels?

2. What type of radiation does your instrument(s) detect?

3. Does your equipment have a shield? How would you use it in this incident?

4. If you are standing 100 feet away from the source and your instrument is reading 1.5 to 3 mR/hour, what type of radiation are you detecting?

Radiation Survey Meter Activity 12B

Instructor Notes

Divide the class into groups of two or three to conduct the exercise. Each participant must have the opportunity to use the meters available.

You will need the following materials:

- *Radiation detection instruments with a variety of probes used by your department*
- *Radiation sources: alpha, beta, gamma (Sources can be obtained from a variety of vendors, including: The Nucleus, Inc., Oak Ridge, TN 615-483-0008. The sources are license exempt quantities; maximum quantity is 10miCu.)*
- *Shielding: notebooks, aluminum foil, fire fighting clothing, etc.*
- *Rulers (12 inch or longer)*

Instruct the participants that the radiation sources are very small amounts and will not result in significant radiation exposure when used properly. Refer to manufacturer's information for more details. Observe participants as they use a variety of probes for each of the sources. Encourage them to experiment with shielding while measuring various types of radiation. Remind participants of the importance of recording background radiation.

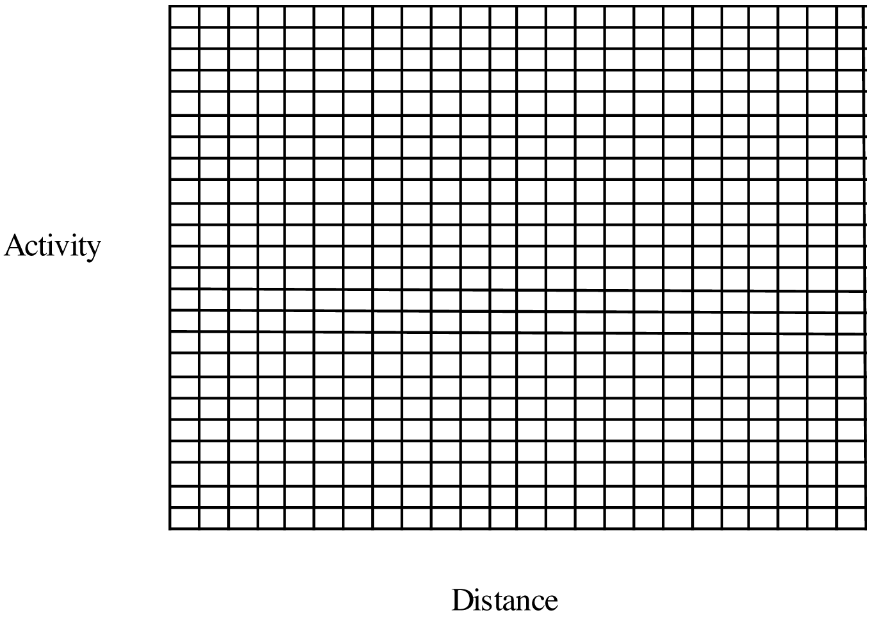
Questions

1. Which instrument(s) is(are) the most sensitive for detecting gamma radiation? Beta radiation? Alpha radiation?

2. How can you distinguish between sources of gamma and beta radiation?

3. What accounts for the different exposure rates of the gamma sources?

4. Use the following grid to graph the relationship between the level of radiation and distance from the source. Take three to four readings, doubling the distance from the source for each reading.



PID Activity 13A

Instructor Notes

Demonstrate how PIDs can be affected by humidity. Explain that one component of a PID sensor is glass. Use a piece of glass, a watch glass, or simply a window and breathe on the glass to fog it. Explain to the students that in a PID meter this fogging from humidity can affect the instrument's operation.

If your instrument has a digital readout, you can demonstrate the effect of sunlight by having the students observe the readout in direct sun.

Some meters are more prone than others to radio interference from units like hand-held radios. You can demonstrate this to the students by keying a microphone to your meters. Observe which meters receive interfering signals, and at what distance the interference occurs.

PID Activity 13B

A drum of partially polymerized methyl methacrylate mixed with methanol is punctured at a facility. Workers notice a small puddle of material and immediately clean it up. Workers adjacent to the area begin to complain of eye and throat irritation. On arrival, you notice a bitter odor. A PID with a 10.2 eV UV lamp is used; a meter reading of 42 units is obtained in the spill area. The IP of methanol is 10.8 eV; the IP of methyl methacrylate is 9.7 eV. The OSHA 8-hour permissible exposure limit (PEL) for methyl methacrylate is 10 ppm, and 200 ppm for methanol.

Questions

1. Knowing the IPs of both chemicals, what is one of the first points to consider before you attempt to use a PID?

2. Will the PID accurately detect both chemicals?

FID Activity 14A

At the methanol and methyl methacrylate spill described in the PID Activity 13B, a FID gives a reading of 380 units. The PID gave a reading of 42 units.

Question

1. Why do the two meters give such different readings?

FID Activity 14B
Vapor Survey Meter

Instructor Notes

Divide the class into groups of two or three to conduct the exercise. You will need the following materials:

- *Photoionization detector*
- *Flame ionization detector*
- *Check gas for instruments*
- *Samples of gases and vapors similar to those used for the CGI exercise. To allow comparison of performance of the instruments, include ammonia (wet cotton ball), and methane. Two of the samples should be known quantities to allow participants to check precision (accuracy) of the instruments.*
- *Air Monitoring Record*
- *Instrument Checklist (to be developed by Instructor)*

Develop an Instrument Checklist to simplify procedures for turning on the machine, checking calibration, and taking measurements. Observe participants checking the calibration of their instruments before and after monitoring. Supervise participants in the use of the instruments on various samples.

Questions

1. Which instrument was most sensitive to each of the unknowns? Why?

2. Compare your results with the identities and concentrations of the unknowns given by your instructor. Which instrument is more precise? Why?

3. How do you think the % LEL CGI would measure each of the unknowns at these concentrations?

.

4. A benzene detector tube indicates a concentration of 95 ppm. An HNu photoionizer calibrated to benzene gives a reading of 215 ppm in the same atmosphere. Why the difference?

5. In a benzene atmosphere, a photoionizer measures 500 ppm. Assuming this value is accurate, what is the percent volume of benzene in air? Does this concentration indicate an immediate flammability hazard?

Comparing Instrument Responses Activity 15

At an isopropyl alcohol spill, you obtain a reading of 10% LEL using your CGI.

1. What is the actual % LEL present?

2. Some of the spilled material may have entered the sanitary sewer by way of an illegal sump pump connection. Your meter gives a reading of 10% LEL when the sample line is lowered into the sewer. What does this suggest?

3. A nursing home is situated 200 yards slightly downhill from the spill area. Hazardous materials team members use a CGI and get readings between 0 and 1% LEL in the first floor social room. Readings in residents' rooms on the second floor give 0% LEL. What does this indicate?

4. How can you confirm the CGI readings?

6. Team members also have a PID with a 10.2 eV UV lamp available. Can this instrument be used to measure low ppm concentrations of isoproyl alcohol? (The ionization potential of isopropyl alcohol is 10.1.)

Appendix B
Manufacturers and Suppliers of Detection Equipment

Manufacturers and Suppliers of Detection Equipment

AIM USA
P.O. Box 720540, Houston, TX 77272-0540; (713) 240-5020

Bacharach Instrument Co.
625 Alpha Drive, Pittsburgh, PA 15239; (412) 963-2000

Bicron Corporation
12345 Kinsman Road, Newbury, OH 44065; (216) 564-2251

CEA Instruments, Inc.
P.O. Box 303, Emerson, NJ 07630; (201) 967-5660

Detector Electronics, Inc.
6901 West 110th Street, Minneapolis, MN 55438; (800) 765-FIRE, (612) 941-5665

Dynamation, Inc.
3784 Plaza Drive, Ann Arbor, MI 48108; (313) 769-0573

Eberline Instrument Corp.
P.O. Box 2108, Santa Fe, NM 87504-2108; (800) 678-7088 or (505) 471-3232

Enmet Corporation
P.O. Box 979, Ann Arbor, MI 48106-0979; (313) 761-1270

The Foxboro Company, Environmental Monitoring Operations
P.O. Box 500
East Bridgewater, MA 02333; (800) 321-0322 or (508) 378-5400

GasTech, Inc.
8445 Central Avenue, Newark, CA 94560-3431; (510) 794-6200

Grace Industries
P.O. Box 167, Transfer, PA 16154; (800) 969-6933 or (412) 962-9231

Heath Consultants
100 Tosca Drive, P.O. Box CS-200, Stoughton, MA 02072; (617) 344-1400

HNU Systems, Inc.
160 Charlemont Street, Newton, MA 02161; (800) 527-4566 or (617) 964-6690

Industrial Scientific Corp.
1001 Oakdale Road, Oakdale, PA 15071; (800) 338-3287 or (412) 788-4353

Ludlum, Inc.
P.O. Box 810, Sweetwater, TX 79556; (800) 622-0828 or (915) 235-5494

Lumidor Safety Products
11221 Interchange Circle, Miramar, FL 33025; (305) 625-6511

Matheson Safety Products
30 Seaview Drive, Secaucus, NJ 07096-1587; (800) 828-4313 or (201) 867-4572

MDA Scientific, Inc.
405 Barclay Boulevard, Lincolnshire, IL 60069; (800) 323-2000

Mine Safety Appliances
P.O. Box 426, Pittsburgh, PA 15230; (800) MSA 2222 or (412) 967-3000

National Draeger, Inc.
P.O. Box 120, Pittsburgh, PA 15230; (800) 922-5518 or (412) 787-8383

Neotronics
P.O. Box 370, Gainesville, GA 30503-0370; (800) 535-0606 or (404) 535-0600

Photovac International, Inc.
25-B Jefryn Boulevard, West, Deer Park, NY 11729; (516) 254-4199

Protech Safety Equipment, Inc.
P.O. Box 4280, Linden, NJ 07036; (800) 526-4121 or (908) 862-1550

Scott Aviation
225 Erie Street, Lancaster, NY 14086; (716) 683-5100

S.E. International, Inc.
P.O. Box 39, Summertown, TN 38483; (615) 964-3561

Sensidyne, Inc.
16333 Bay Vista Drive, Clearwater, FL 34620; (800) 451-9444

Thermo Environmental Instruments, Inc.
8 West Forge Parkway, Franklin, MA 02038; (508) 520-0430

Victoreen, Inc.
600 Cochran Road, Cleveland, OH 44139-3395; (216) 248-9300

Appendix C

Detection Levels

Detection Levels

Odor	Material	Detectable Odor Level	MW
Green and Sweet	Acetaldehyde	About 1 ppm	
Pungent, Fruity	Acetaldehyde	0.004 ppm	44.5
Vinegar	Acetic Acid	About 1 ppm	
Fingernail Polish Remover	Acetone	About 100 ppm	
Acrid, Sharp	Acrylic Acid	Much less that 1 ppm	
Strong Garlic, Coffee	Allyl Mercaptan	0.00005 ppm	74.15
Sharp, Pungent	Ammonia	0.037 ppm	17.03
Unpleasant, Putrid	AMyl Mercaptan	0.0003 ppm	104.22
Benzene	Benzene	About 5 ppm	
Unpleasant, Strong	Benzyl Mercapatan	0.00019 ppm	124.21
Sour Ammonia-like	Butylamine	?	73.14
Putrid, Decaying Flesh	Cadaverine	?	102.18
Pumpkins (foul)	Carbon Disulfide	Less than 1 ppm	
Pungent, Suffocating	Chlorine	0.01 ppm	70.91
Medicinal, Phenolic	Chlorophenol	0.00018 ppm	128.55
Skunklike	Crotyl Mercaptan	0.000029 ppm	90.19
Fishy	Dibutylamine	0.016 ppm	129.25
Fishy	Diisolpropylamine	0.0035 ppm	101.19
Putrid, Fishy	Dimenthyl Sulfide	0.001 ppm	45.08
Decayed Vegetables	Diphenyl Sulfide	0.000048 ppm	186.28
Beer, Gin, Vodka	Ethanol	About 10 ppm	
Decayed Cabbage	Ethyl Mercaptan	0.00019 ppm	62.1
Ammonia	Ethylamine	0.83 ppm	45.08
Rotten Eggs	Hydrogen Sulfide	0.0047 ppm	34.1
Fecal, Nauseating	Indole	?	17.15
Aldehyde/alcohol	Methanol	About 100 ppm	
Sweet Garbage, Solvent	Methyl Ethyl Ketone	About 100 ppm	
Decaying Cabbage	Methyl Mercaptan	0.001 ppm	48.1
Putrid, Fishy	Methylamine	0.021 ppm	31.05
Irritating above 2 ppm	Ozone	0.001 ppm	48
Chloroseptic, Library Paste	Phenol	In ppb level	
Unpleasant	Propyl Mercaptan	0.000075 ppm	76.16
Putrid, Nauseating	Putrescine	?	88.15
Disagreeable, Irritating	Pyrdine	0.0037 ppm	79.1
Fecal, Nauseating	Skatole	0.0012 ppm	131.2
Boat Resin	Styrene	Less than 1 ppm	
Pungent, Irritating	Sulfur Dioxide	0.009 ppm	64.07
Skunklike, Unpleasant	Tert-Butyl Mercaptan	0.00008 ppm	90.19
Skunklike, Rancid	Thiocresol	0.001 ppm	124.21
Putrid, Garlic-like	Thiophenol	0.000062 ppm	110.18
Airplane Glue	Toluene	About 1 ppm	
Ammonia, Fishy	Triethylamine	0.08 ppm	101.19
Elmers Glue	Vinyl Acetate	Less than 1 ppm	
Sweet Plastic, Water (IPA)	Xylene	Less than 1 ppm	

Appendix D

Slide Script

(for Instructors)