position near the area of highest hazard. Fixed area monitoring is not practical if only one instrument is available and a large hazard area may be involved. Survey-style monitoring dedicates at least one person to conducting the survey at the expense of other activities in the response. The frequency and method of monitoring should be site-specific and based on the degree of hazard present and the potential for changing conditions to affect the air concentrations of contaminants.

TERMINATION MONITORING

Emergency response termination procedures may include using air monitoring data as criteria for ending response activities. Air contamination may remain in the hazard area even after the source of the contaminant has been contained or confined. Air monitoring should be performed throughout the hazard area to confirm that all spilled material or sources of contamination have been contained. Also, prior to incident termination, air contamination should be reduced to background levels. At that time, normal traffic (non-response personnel and vehicles) is allowed into the response area. This is especially true of incidents in confined spaces or areas of poor ventilation where hazardous gases or vapors may accumulate.

AIR MONITORING VS AIR SAMPLING

Air surveillance may be accomplished by air monitoring with direct-reading instruments (DRIs) or colorimetric indicators for real-time measurements, and/or air sampling. These two methods are not synonymous and each has advantages and limitations. During a fast-paced emergency response, the need for rapidly available information is critical. Air monitoring with direct-reading equipment has the advantage of providing exposure data almost instantly. However, speed has its price. Most DRIs are not truly selective, but will detect a variety of different chemicals and provide the total amount of all detectable substances present. Colorimetric indicators can provide concentration data on specific chemicals, but environmental conditions in the field can affect the accuracy of the results.

Air sampling is a more accurate means of measuring air contaminants and can often identify specific constituents of a mixture or an unknown substance. Unfortunately, air sampling takes valuable time, often requiring days or weeks to get the results. Also, it can be quite expensive, especially if a rush analysis is required. On-site analytical equipment can reduce the turnaround time, but can be expensive and requires experienced operators to provide meaningful data. Air sampling is discussed later in the chapter.
The circumstances of the incident, the variety of available air surveillance equipment, and the competency of the response personnel are all factors affecting the method or combination of methods selected during an emergency response. The following sections discuss equipment that may be used to conduct air surveillance.

**DIRECT-READING INSTRUMENTS**

While DRIs are usually not complicated to operate, the user must know more than just how to turn the unit on and take a reading. All DRIs have limitations and unique operating characteristics that must be understood for one to correctly interpret the data. For example, combustible gas indicators (CGI) require sufficient oxygen in the atmosphere to support combustion in the detector. In low oxygen conditions (<19.5% oxygen in air), the CGI may show a lower combustible gas level than is actually present. A user who is not aware of this limitation may have a false sense of security regarding the flammability hazard based on inaccurate data. Therefore, familiarity with the instrument is necessary to correctly operate the instrument and interpret the results.

**COMPONENTS OF DRIs**

Direct-reading instruments typically consist of a sensor, amplifier, display, and possibly a pump. The sensor is that part of the instrument that actually detects the presence of a contaminant in the air by means of physical principles related to a chemical or physical properties of the contaminant. Although each chemical has a unique set of properties, the sensor typically responds to general properties or principles that are common to a wide variety of chemicals. For example, combustible gas indicators detect combustion, which may be caused by methane or by xylene. Sensors are unable to distinguish between different chemicals that cause the response. For this reason, DRIs are not able to identify unknown chemicals.

The sensor generates an electrical signal that is proportional to the concentration of the chemical in the air. In most cases, the signal produced by the detector is a small electric current, insufficient to produce a meter reading or display. For this reason, DRIs include an amplifier that receives the signal from the detector and sends the appropriate electric current to the display or readout. In instruments that can be field calibrated, the amplifier is where the adjustment is made. This will be discussed in the section on calibration in this chapter.

Even the most sophisticated and amazing instrument is useless if the data it generates is not communicated to the user. It is the function of the instrument display to
communicate the data in a useful form. Typically, DRIs will have either an analog (needle) or a digital display. The data should be displayed in units appropriate to the hazard being monitored.

Some instruments are capable of measuring over a wide range of concentrations. To accomplish this with an analog display, the display is divided into the appropriate increments and there is a switch that changes the value of each increment. The figure to the left shows a meter display with two types of switch designed to provide both a wide range of measurement and sensitivity to change at low concentrations. In both meters, the first switch position allows more precise measurement but is limited to a small range of concentrations (0-5 ppm). The third position allows measurement that is less precise, but over a wider range of concentrations (0-500 ppm).

If the range of concentrations is not known, the user should start with the widest range of concentrations (third position) and, as possible, switch back to smaller, more precise ranges (second, then first position). If a high concentration causes the meter set to the narrow scale (first or second position) to go to full scale, the needle must recoil to provide the appropriate reading on the wider scale (third position). During this recoil time, a peak reading may be missed. This recoil time is eliminated if the meter is set on the broadest range.

Many instruments contain a pump that will draw the air sample into the instrument detector. The pump will allow the instrument to be used for remote sampling if a length of tubing is attached. Instruments without a built-in pump may provide a bulb aspirator or other mechanical means of drawing air into the sensor area. The alternative is to allow the air to naturally diffuse into a sensor area located on the exterior of the instrument. Instruments designed to continuously monitor the atmosphere and give an alarm when dangerous concentrations exist often use this system to conserve battery power.
COMMONLY USED INSTRUMENTS

Combustible Gas Indicator (CGI)

The CGI uses a hotwire or catalytic sensor to detect the presence of flammable gases or vapors. A catalytic filament carrying an electric current burns flammable or combustible gases or vapors in a sample chamber. An identical filament that is isolated from the contaminated air carries the same current. The heat from the combustion in the sample chamber causes a change in the current passing through the filament. The difference in current between the two filaments is detected in a bridge circuit that produces the signal.

The CGI displays the data as a percentage of the lower explosive limit (LEL) of the calibration gas. A full-scale reading (100% LEL) means the minimum concentration of gas necessary to support a flame is present. The reading should not be interpreted as a direct reading of the concentration of the gas, but the percentage of the LEL of the calibration gas. Some chemicals burn hotter than others, so the sensor responds differently to the various chemicals. Therefore, a relative response factor must be used if a chemical other than the calibration gas is measured. For gases other than the calibration gas, the meter reading must be converted first by use of a relative response factor as described later in this chapter.

If the concentration of flammable gas or vapor is less than the LEL, the CGI will provide a reading of the concentration as a percentage of the LEL. If the concentration is within the flammable range of a gas (concentrations between the lower and upper explosive limits), the needle of an analog meter will remain above the 100% LEL mark. If the concentration goes above the upper explosive limit (UEL), the needle may go to full scale and then quickly drop to zero. This movement could be missed if the operator was not looking at the instrument display at the time. Therefore, many instruments have an alarm system that must be reset by the operator each time the set point is exceeded, so that temporary peaks or concentrations over the UEL are not overlooked.

The CGI is designed to detect the potential for a flammable or explosive atmosphere before one actually exists. That is why a full-scale reading (100% LEL) represents only the minimum concentration necessary to support a flame. Response actions
recommended by the EPA are triggered at readings much lower than the LEL to provide a safety factor. These guidelines are:

- < 10% LEL - continue work with caution
- 10%-25% LEL - continue work with continuous monitoring
- > 25% LEL - explosion hazard; withdraw from the area

There are some limitations to the use of CGIs. The combustible gas sensor is not selective, but responds to any and all flammable gas or vapor that are present. It will not identify unknown contaminants. Also, it will only detect combustible or flammable gases or vapors, not flammable solids. Finally, the detector requires oxygen for the combustion process, so it may not function properly in an oxygen-deficient atmosphere. Nonetheless, it is the best way to detect whether or not a fire potential exists.

Oxygen Meters

Oxygen meters typically use electrochemical sensors. These sensors work by reacting chemical in the sensor with oxygen in the air. The sensor chemical is contained behind a semipermeable membrane that allows the oxygen to diffuse into the solution. The reaction produces a small electric current that is collected by an electrode and is proportional to the concentration of the contaminant in air. The current is amplified and turned into a display of the measured concentration.

The normal concentration of oxygen in air is approximately 20.7%. If the concentration detected during an incident is less than 19.5%, the atmosphere is considered oxygen-deficient and should not be entered without atmosphere-supplying respiratory equipment such as a self-contained breathing apparatus (SCBA) or supplied air respirator (SAR). Atmospheres containing more than 23% oxygen are considered oxygen-enriched and represent an increased combustion hazard.

The chemical reactions of electrochemical sensors may be affected by changes in temperature, humidity, and atmospheric pressure. Other chemicals may interfere with the action of the sensor creating a signal when the contaminant is not present. Electrochemical cells may deteriorate or
be exhausted over time and must be replaced periodically, usually once a year. Using the meter in high concentrations of carbon dioxide and carbon monoxide will shorten the service life of oxygen sensors.

Substance-Specific Detectors

There are a growing number of sensors designed to measure a specific chemical, such as carbon monoxide or hydrogen sulfide. These electrochemical sensors are like the oxygen sensor described above, but with different chemicals. Unlike other sensor types, these sensors will measure a specific chemical and ignore other chemicals that are in the air. This is very useful when you are more concerned about the release of one particular chemical.

These chemical-specific sensors are often placed into instruments, called multigas meters, that also have combustible gas and oxygen sensors. The chemical-specific sensor measures and displays the concentration of the chemical in the parts per million (PPM) range. These results can be compared to exposure limits, as we’ll see later in the chapter.

As with the oxygen meters, chemical-specific sensors will be affected by some other chemicals, called interfering chemicals. They also deteriorate over time and have to be replaced.

Photoionization Detector (PID)

This sensor uses ultraviolet light to break the contaminant into ions that move to electrodes and create an electric current. The PID will detect many organic and some inorganic compounds at concentrations as low as one part per million (ppm) up to one or two thousand ppm. The instrument is used to monitor primarily toxic atmospheres in which low concentrations (parts per million range) can be harmful.

Though PIDs are not selective (i.e. will not focus on one chemical and ignore others), you can rule out some chemicals on the basis of differing ionization potentials. The
strength of the ultraviolet light necessary to ionize a compound (known as its ionization potential or IP) differs for various chemicals and is reported in units called electron volts (eV). For example, the ionization potential for 1,1,1-trichloroethane is 11 eV. If a 9.7 eV lamp is used with the PID, most of the 1,1,1-trichloroethane present in the environment will not be detected, while a chemical with an IP of 9.7 eV or less would be. Thus, the PID becomes selective for chemicals with an IP less than the strength of the UV lamp used. (Some ionization does occur at strengths less than the IP of a compound, but is usually a very small fraction of that which occurs at or above the IP.)

There are some limitations to consider when choosing to use a PID. High humidity and high electromagnetic energy may interfere with the instrument's response. If the UV lamp is dirty, the UV light will be blocked and unable to ionize the chemical, causing the instrument to give an inaccurate reading. Charged particles in the air other than the ions of the contaminant (e.g. dusts, particulates from diesel engines, etc) will collect on the electrode and also cause a false reading. Also, the presence of some chemicals that are not ionized by UV light, most notably methane, will actually cover up the detection of other chemicals.

Flame Ionization Detector (FID)

The FID uses a hydrogen flame to burn the contaminant, resulting in the release of charged ions. Like the PID, the ions are collected on electrodes and cause an electric current "signal". The FID will ionize organic compounds with an IP of 15.4 eV or less. It is not significantly affected by humidity and can measure over a wide range of contaminant concentrations.

Like the PID, the FID has operational limitations that must be considered when choosing to use it. The FID detects only organic compounds. Because the flame requires oxygen, the unit may not function in oxygen-deficient atmospheres. Impurities in the hydrogen used as fuel will be ionized and detected just like
contaminants in the air, causing a false reading. Like the PID, other charged particles may collect on the electrode, interfering with the instrument readout.

Infrared Spectrophotometer (IR)

The IR sensor takes advantage of the fact that chemicals will absorb infrared light at certain discreet wavelengths. Therefore the IR can be fairly selective (i.e. monitor one chemical at a time) on the basis of the wavelength of IR light used. The spectrophotometer shines infrared light of a specific wavelength through a sample chamber into which air from the environment has been pumped. The contaminant molecules absorb some of the light in and the remainder is transmitted. The instrument displays the amount of infrared light transmitted as either percent transmitted (%T) or in absorbance units (AU). This can then be used to calculate the concentration of chemical present in ppm. Some units provide microprocessors to make this calculation automatically for selected chemicals.

Again, there are limitations to consider. Many compounds absorb IR at the same or nearly the same wavelength; therefore, interference may occur when multiple chemicals are present. In other words, a signal indicating absorption at one wavelength cannot be attributed definitively to a single chemical without other supporting evidence. Also, these instruments often require flat, level surfaces free of vibration or movement for proper operation. Therefore, they are not often used in the abusive field conditions of hazmat responses.

Using Toxic Exposure Data

Results obtained from the PID, FID, IR spectrophotometer, or other instruments monitoring exposure to toxic chemicals should be compared to standards for the specific chemical present, if the chemical has been identified. It is important to compare the results to the right standard for the kind of data generated. For instance, OSHA's time-weighted average permissible exposure limit (TWA-PEL) is intended to protect workers that are exposed to the chemical for eight hours a day, five days a week for a normal working life. Since the emergency responder will only be exposed to the chemical for a brief period during a hazmat incident, exposure to a higher concentration may be acceptable. We discuss exposure limits later in the chapter.

Selection criteria for personal protective equipment may be based on results of direct-reading equipment. If the chemical is identified, the selection is straightforward. If the chemical is unknown or if a mixture is being monitored, the
reading should be considered a "total" reading and the appropriate level of protection must be based on different criteria. OSHA’s HAZWOPER regulation requires that teams entering a hazard area believed to contain unidentified contaminants must use the highest level of respiratory protection, such as a self-contained breathing apparatus (SCBA), until more information is available to make a proper selection.

GAS CHROMATOGRAPHY

Identifying components of an unknown mixture is a difficult job at best. One technology that may be used to help in this process is gas chromatography (GC). A GC is not a detection device, but is useful in separating out components of a mixture or, in some cases, in identifying an unknown compound. Some instrument manufacturers have coupled this technology with detectors such as the PID or FID in field instruments. These instruments can operate in the survey mode (detector only) or the GC mode (GC and detector). Because of the time requirements of operating in the GC mode, these instruments cannot simultaneously survey an area and separate the components of a mixture with the gas chromatograph. Nonetheless, the GC can be a valuable tool for identifying and quantifying the components of a mixture.

The GC is essentially a long thin tube (usually coiled) that contains a granular solid medium. A steady flowing carrier gas brings the air sample into the column. Different contaminants in the air adsorb to the medium with different strength bonds and subsequently are released to flow out the other end of the column into a detector (e.g. FID, PID, atomic absorption, mass spectroscopy). The detector is usually attached to a chart recorder that records the concentration detected over time. Based on the strength of the bond, the column temperature, nature of the contaminants, etc., all of a particular chemical or group of chemicals will leave the column at the same time and this time will be different than that of other chemicals.

The length of time from injection of the chemical into the column until it exits the column and is detected is called its retention time. The retention time for a chemical at specific column conditions is constant and is different from chemical to chemical. The temperature of a column greatly affects the retention time of a chemical. Put simply, the individual chemicals in a mixture injected in one end of a GC column will exit the column at different retention times, but all of each chemical will come out at approximately the same retention time. The chart recorder will show a peak for each chemical at the appropriate retention time that can be used to calculate how much of that chemical is in the air.
The practical use of this technology, is that if column conditions (temperature, media type, carrier gas flow rate, etc.) are kept constant and the retention times of individual contaminants in a mixture under those conditions are known (two very big "ifs"), the quantity of each chemical can be determined as it is detected by the detector, and, based on its retention time, it can be identified.

The technology is useful but does have limitations and drawbacks. A major drawback is that it is quite expensive. Also, someone using GCs must be well trained. Many things must be controlled. Calibration standards of each chemical to be detected must be run through the GC under specific conditions to confirm the retention times and response of the detector to the chemical. If your response team has a large variety of potential contaminants and can afford the equipment and training costs to operate a field GC, it can provide you with valuable information about specific contaminants quickly.

CALIBRATION

Direct-reading instruments have electronics, sensors, and often moving parts that may wear down, become dirty, or stop functioning properly. The net result is that the instrument may no longer be giving accurate readings. If the sensor is only detecting part of what is present or the amplifier is only partially amplifying the signal, low readings will be given by the instrument, even if the actual concentration is high. Obviously, this could have disastrous results! For this reason, DRIs must be calibrated or have their calibration checked regularly. Calibration is the process of adjusting the instrument readout to correspond to a known concentration of a gas.

Ideally, each instrument should be calibrated before and after each use. The manufacturer of an instrument will recommend a specific gas that should be used to calibrate it. For instance, the Foxboro Century OVA is calibrated to methane and many combustible gas and oxygen meters are calibrated to methane or pentane. Manufacturers choose the recommended calibration gas that provides the widest
response range for their instrument. Instruments calibrated to the recommended gas will still respond to other gases or vapors that are in the air. However, they will not read the other gases accurately. See the discussion of relative response below.

If an instrument is to be used for an extended period to monitor an atmosphere other than the calibration gas, it may be helpful to calibrate the instrument to respond directly to that gas. To do this, simply attach the instrument to a source with a known concentration of the desired gas and adjust the instrument readout to match the concentration. Specialty gas suppliers recommended by the instrument's manufacturer might be able to supply calibration gases for a variety of contaminants.

Two general types of calibration are "zeroing" the instrument and adjusting the span potentiometer. The first adjustment simply tells the instrument what is considered baseline or zero contamination and would compare to adjusting the idle on a car. The zero adjustment can be used to eliminate readings caused by electronic "noise" in the instrument or background levels of the contaminants. The second adjustment sets the amount of amplification that the instrument should give a signal from the sensor so that the readout corresponds to the actual concentration. The meter reading should be adjusted to match the actual real-time concentration of the calibration gas source.

DRIs may have one or both of the above adjustments accessible to the user. It is important to follow the manufacturer's instructions in the operation and calibration of the instrument. Some instruments are not designed to be calibrated by the user, but should be sent back to the manufacturer for calibration. Even on these instruments, however, the user should be able to check the instrument's response against a known concentration of a calibration gas.

RELATIVE RESPONSE

In nearly all of the DRIs, the meter response is calibrated to one specific gas. If the instrument is used to detect a gas or vapor different from the calibration gas, the reading should be related to the calibration gas. The number values of the reading may under- or overstate the concentration of the contaminant gas, depending on how the instrument responds to that gas. The relationship of the contaminant gas to the calibration gas is referred to as the relative response. Relative response represents the ratio of the meter reading to the actual concentration of the contaminant and is usually expressed as a percent.
For instance, the Foxboro OVA is calibrated to methane. The manufacturer's information states the relative response to allyl chloride is 50% (.50). Therefore, a meter reading of 100 units in an atmosphere of allyl chloride would represent an actual concentration of:

\[
\text{actual concentration} = \frac{\text{meter reading}}{\text{relative response}} = \frac{100}{.50} = 200 \text{ ppm}
\]

The OVA would understate the actual concentration of allyl chloride by half. As a rule, a relative response of less than 100% means the meter reading will be less than the actual concentration present and a relative response greater than 100% means the meter reading will be greater than the actual concentration.

The relative response may be plotted as a curve, comparing the meter reading to the actual concentration. The manufacturer creates these curves by taking meter readings at several different actual concentrations. The instrument's manufacturer may be able to provide relative response factors or curves for specific contaminants that are identified at a hazmat incident.

**INHERENT SAFETY**

DRIs must be safe to use, even in hazardous environments. Because an instrument contains electronics and possibly other ignition sources, it must be constructed in such a way that it will not cause ignition of an explosive atmosphere. The National
Electrical Code by the National Fire Protection Association describes minimum criteria for an instrument to be considered "intrinsically safe". Instruments are typically tested by Underwriters' Laboratory (UL) or Factory Mutual (FM) and must be marked as to the hazardous atmosphere for which they are certified. The code classifies hazardous atmospheres by class, group, and division. Class and group are used to describe the type of flammable material present as follows:

- **Class I** is flammable vapors and gases and is further divided into groups A, B, C, and D based on similar flammability characteristics. Examples include gasoline and hydrogen.
- **Class II** is combustible dusts and is divided into groups E, F, and G. Examples include coal, grain, or metals such as magnesium.
- **Class III** is ignitable fibers such as cotton.

Divisions are used to describe the likelihood that the flammable contaminant will be present in a concentration sufficient to pose an explosion or combustion hazard. **Division I** atmospheres are considered most likely to contain the hazardous substance in flammable concentrations. **Division II** atmospheres have flammable or combustible substances present, but they are typically handled or contained in closed systems that are not likely to generate hazardous concentrations under normal conditions.
A typical marking on an instrument (shown above) is that it is "intrinsically safe for Class I, Division I, Groups A, B, C, and D as approved by FM". This means that the instrument can be used in an atmosphere that potentially contains flammable concentrations of combustible or flammable gases or vapors. Approval of an instrument for use in one hazard class does not mean it can be used in all hazard classes. This approval assumes that the instrument will be used according to the manufacturer's directions and that the user does not modify it.

COLORIMETRIC INDICATORS

Colorimetric indicators provide a means of quantifying air contamination with a reasonable degree of selectivity. Three types of indicators may be used: liquid reagents, chemically treated papers, and glass tubes containing chemically treated solids. The principle of operation is that contaminant in air reacts with a chemical reagent to cause a change in color, which is proportional to the amount of contaminant in the air. Liquid reagent devices are available that produce color changes that are fairly easy to observe. But handling liquids in the field may be awkward and inconvenient. Chemically treated papers are easy to use, but do not typically have a means of controlling the volume of air contacting the paper. Therefore, the accuracy may be affected by factors such as the amount of air movement over the paper.

Because of their ease of use and quick results, the glass tubes containing a chemically treated solid - known as colorimetric or detector tubes - are widely popular. They typically consist of a glass tube containing a granular carrier solid that has been impregnated with a specific chemical reagent. As contaminated air passes through the glass tube, the contaminant reacts with the reagent on the carrier solid to produce a color stain. The air is drawn through the tube by either a hand pump or a battery-powered pump. Thus, the volume of air sampled can be controlled. It should be noted that detector tubes are designed and calibrated for use exclusively with the manufacturer's pump. To use a detector tube with another manufacturer's pump, even if the pump volume is the same, can lead to greatly inaccurate results.
OPERATION OF COLORIMETRIC INDICATOR TUBES

The tubes may operate in one of three ways as shown below. First (A), the pump may be operated until the length of the stain reaches a certain preset point. The number of pump strokes (i.e. the volume of air) required to reach this full stain is compared to a chart to determine the concentration of the contaminant in air. In this case, a high concentration of contaminant in air would require fewer strokes to reach full stain. Secondly (B), a set number of pump strokes (volumes) of air will be drawn through the tube and the length of stain is compared to a calibration scale, often printed on the tube, to determine the concentration. For a set number of pump strokes, a high concentration would cause a longer stain. Thirdly (C), a predetermined number of pump strokes of air are drawn through the tube and the degree or tint of the color change is compared to a chart to determine the concentration. For these tubes a high concentration would cause a deeper or darker color change after a set number of pump strokes. It is critical that the operator of the tube be familiar with the manufacturer's directions and know which mode of operation is used.

Sample pumps must be checked for leaks to ensure that the appropriate volume of air is drawn through the tube. Also, the pump must be allowed to fully complete every pump stroke. Incomplete strokes or leaks in the system will cause less than the appropriate volume of sample air to pass through the tube, potentially resulting in a lower reading than is actually present.

The tubes may be specific for a certain gas or vapor or may detect groups of chemicals, such as alcohols or aromatic hydrocarbons. Tubes that are designed to
detect one chemical will usually react with certain other chemicals (known as interferences) to produce a similar color change. The manufacture will provide a list of known interferences. In general, detector tubes provide an opportunity to make a qualitative and quantitative determination of the presence of a particular chemical.

LIMITATIONS OF COLORIMETRIC INDICATOR TUBES

Some limitations must be considered when detector tubes are used. Detector tube systems have rather poor accuracy, with errors ranging from 25% to 50% for many tubes. The National Institute for Occupational Safety and Health (NIOSH) tested and certified detector tubes at one time, but has since discontinued the practice. Manufacturers generally provide accuracy information with the instructions.

Because a chemical reaction is involved, detector tube accuracy may be affected by such factors as temperature, humidity and atmospheric pressure. Where temperature will significantly affect the performance of the tube, the manufacturer will include compensation factors in the instructions. Colder temperatures will usually slow down the reaction, so if detector tubes are to be used in cold weather, they should be stored in a warm place and carried next to the body. High temperatures may affect the rate of the chemical reaction and may reduce the shelf life as described below.

One source of error in the use of colorimetric tubes is the visual interpretation of the length or degree of color change. The leading edge of the stain may be uneven or may be lighter than the rest of the stain, calling for a judgment on the part of the operator as to what constitutes the end of the stain. The same difficulty applies to judging the degree or tint of color change, even when comparison charts are provided. When in doubt, it is advisable to use the most conservative (i.e. highest) reading so that more protection is provided to the responder and the public.

Detector tubes have a specific shelf life. Chemical reagents will deteriorate over time, even if the tube is not opened and exposed to air. Also, high temperatures may cause the degradation of the reagent. The manufacturer will stamp an expiration date on each pack of tubes. Storing the tubes in a refrigerator may maintain or extend the shelf life, but expired tubes should not be used.
AIR SAMPLING

Air sampling typically involves collection of the contaminant from a known volume of air onto an appropriate sample medium (e.g. activated charcoal, liquid medium, filters, etc.). The contaminant remains associated with the medium until it is removed at the laboratory for analysis. The result of this analysis may be reported as total mass (or volume) of contaminant and can be divided by the total volume of air sampled to calculate the average air concentration for the sample period. Laboratory analytical equipment can provide more accurate qualitative and quantitative analysis of air contaminants than most field air monitoring equipment.

The unpredictable nature and short duration of hazardous materials incidents makes the use of air sampling difficult. In order to accomplish this during an emergency response, planning before an incident is required. Some amount of the equipment and media described below should be kept on hand. Personnel responsible for air monitoring should be able to deploy the equipment rapidly. A qualified laboratory should be available to provide rush analysis. Laboratories are usually very helpful in providing information necessary to plan sampling events.

SAMPLE PERIOD

The length of time over which the sample is to be collected (sample period) will largely be determined by a) the requirements of the analytical method and b) the type of exposure concern. Most analytical equipment and methods require that a minimum amount of contaminant be present on the sample media (minimum detection limit) to be detected. The amount of contaminant deposited on the sampling medium is a function of the concentration of the contaminant in the air and the amount of air sampled. Therefore, sampling a low concentration atmosphere will require a longer sample period to collect enough contaminant for analysis.

The other consideration for the sample period is the type of exposure of concern. If the suspected contaminant produces short-term (acute) effects after brief exposure to a high concentration, a short sample period should be used at times of expected highest exposure in order to minimize the effect of averaging over time. On the other hand, the contaminant may cause long-term or cumulative effects after longer exposure to lower concentrations. In this case, a long sample period would provide data on the average exposure for a longer period of time, perhaps the entire life of the incident. Planning and training before an incident occurs is necessary to make good decisions about the type of sampling to be used during an incident.
SAMPLING SYSTEMS

Two types of sampling systems are used for the collection of air samples: active samplers which draw contaminated air through a sample medium by means of a pump, or passive samplers which rely on natural forces such as diffusion or permeation to collect samples. These systems are described in the following sections.

Active Samplers

Active sampling systems mechanically draw air through a sampling medium that collects the contaminant. In this way, the contaminant contained in a large volume of air is concentrated onto the medium, which is then analyzed in the laboratory. An active air sampling system typically consists of the following components:

- A sampling pump to move air
- Inert tubing to carry the air
- Sampling medium that collects the contaminant

Active sampling systems typically rely on battery-powered pumps to draw air through the sampling media or into a sampler container. Most pumps now have some means of adjusting the airflow rate, which may be specified by the analytical method. Flow rates may vary from a few cubic centimeters per minute (cc/min) to over 10 liters per minute (10,000 cc/min). Pumps with the broadest range of flow rates will offer the most flexibility for air surveillance of a variety of contaminants.

The sampling pump must be calibrated before and after each use to ensure a constant flow rate. Unlike DRIs, active air samplers concentrate the contaminant on a sampling medium for later analysis. In order to get a concentration value, divide the amount of contaminant analyzed by the laboratory by the total volume of air sampled. Therefore, it is essential that the flow rate be kept constant during the sample period so that the total volume of air can be calculated. Calibration of the pump flow rate is the means of ensuring that the flow rate is right and has not changed over the sample period. Because sampling media and tubing may affect the airflow rate, calibration should be performed with the whole sampling system intact.
Passive Samplers

Passive samplers or dosimeters are becoming increasingly popular as alternatives to active sampling methods. These samplers have no moving parts and therefore are relatively easy to use and do not require calibration or maintenance. Some may be read directly, similar to colorimetric tubes and others must be sent a laboratory for analysis.

Passive samplers may be classified as either diffusion or permeation type samplers. Diffusion samplers have a sorbent media that is separated from the contaminated air by a grid section. This grid creates a layer of stagnant air between the contaminated air (high concentration) and the sorbent material (low concentration), forming a concentration gradient. If given the opportunity, chemicals will move from areas of high concentration to areas of low concentration by natural molecular forces. Thus, the air contaminant will naturally move to the sorbent media from the air.

Permeation samplers take advantage of similar natural forces, but a membrane covers the sample medium. The membrane may be permeated (passed through) by certain chemicals and not by others, thus screening out unwanted contaminants. As the chemical permeates through the membrane, it is collected by the sorbent medium on the other side.

SAMPLING MEDIA

Air sampling methods for gaseous and vapor contaminants make use of a variety of sample collection media, including solids, liquids, long duration colorimetric tubes, and sampling bags. When solid sorbents are used, contaminants in the air adsorb to the solid medium itself or to a chemical coating on the medium. Two widely used solid sorbents are activated charcoal and silica gel. Other solid media include porous polymers such as Tenax and Chromosorb and specialty sorbents for unique uses. The sampling and analytical method will specify the medium to use.
Sampling with a liquid medium typically involves drawing contaminated air through a liquid which absorbs the contaminant. The liquid is contained in an impinger or a bubbler that allows for contact between the contaminant that is either reactive or soluble and the liquid reagent. The liquid is then sent to a laboratory for analysis.

Airborne particulates, including liquid and solid aerosols, are typically sampled using filter media. The two most common types of filters are fiber mesh and membrane (thin polymer membranes or sheets with tiny holes). As contaminated air is drawn through the filter media, the particulates are impacted and trapped on the filter that is sent to the laboratory.

In some cases it may be desirable to collect samples of the air in a gas bag for analysis outside the hot zone. This may be the case when an unidentified contaminant is present in high concentrations. The use of multiple colorimetric indicator tubes takes time and could easily be conducted by personnel outside of the hot zone where a lower level of protection is appropriate. Analysis on site by gas chromatography may also be desired. Shipment of the bag offsite to a laboratory may not be practical because a) the bag may leak, b) the chemical may permeate through the wall of the bag, or c) the chemical may simply degrade over the time required for shipment. Therefore, any analysis must be conducted on site.

The sample can be collected by attaching inert tubing to the exhaust port of a sampling pump and to the inlet of the gas bag and placing the pump inlet in the area to be sampled. This procedure draws contaminated air through the pump, so only pumps certified inherently safe should be used if explosive gases or vapors may be present. Also, the potential for incompatibility between the contaminant and the materials used in the pump must be considered.

LABORATORY ANALYSIS

Once air has been drawn through a collection medium, the sample container is sealed and sent to an analytical laboratory. Gas or vapors are then desorbed (removed) from the collection media and run through analytical equipment (often a gas chromatograph with appropriate detector) for analysis. The analysis may be both
qualitative (what is present) and quantitative (how much is present), depending on whether the contaminant has been identified.

The results are usually reported in mass units (milligrams, mg, or micrograms, µg) or in volume units (microliters, µl). Then the total amount detected is divided by the total volume of air sampled (expressed as liters or cubic meters) to calculate an average concentration for the sample period. The units often used for air concentrations are milligrams of contaminant per cubic meter of air (mg/M³). This is a mass (mg) to volume (cubic meters) relationship and is not the same as parts of contaminant per million parts of air (ppm), which is a volume-to-volume relationship. There are formulas available to convert between the two concentration units.

Samples of particulates may be analyzed in two ways. First, the exposed filter media is weighed on a very sensitive scale and that weight is compared to the pre-exposure weight of the filter. The added mass is the mass of the particulate in the air that was sampled. The sample mass is divided by the total volume of air sampled to obtain an average concentration. This is called gravimetric analysis and is usually used for dust particles.

The other particulate analysis involves fiber counting. A filter that has been exposed to contaminated air is turned clear and the fibers on a portion of the filter are counted under a microscope. Using mathematical formulas, the number of fibers per cubic centimeter of air is calculated. This type of analysis is most commonly used for determining airborne asbestos concentrations.

USING AIR SURVEILLANCE DATA

The point of air surveillance is to gather information that can be used to make decisions during an emergency response. Air monitoring with direct-reading instruments provides immediate information, but the results may not be chemical-specific. Air sampling data provides concentration data that is chemical-specific and accurate at lower levels, but it often isn’t available until after the incident is terminated. However we get the data, we need to compare the information to a standard to determine risk and to make good response decisions. Let’s look at the different standards that are available.
Occupational Exposure Limits

A number of different agencies, both government and professional, publish exposure limits. These are simply maximum acceptable concentrations of chemicals in the air over a given period of time. There are a number of terms and abbreviations related to which agency publishes the limits and over how much time they are applied. Most of the limits are intended for normal workplace exposures, not emergencies.

The terms used for who sets the limits are as follows:

- **PEL** – Permissible Exposure Limit or Published Exposure Level
  This is OSHA’s *legally* enforceable regulatory limit.

- **TLV** – Threshold Limit Value – *recommended* limit set by the American Conference of Governmental Industrial Hygienists (ACGIH)

- **REL** – Recommended Exposure Limit – *recommended* limit set by the National Institute for Occupational Safety and Health (NIOSH)

- **WEEL** – Workplace Environmental Exposure Limit – *recommended* limit set by the American Industrial Hygiene Association

Each of these kinds of limits can be expressed in one or more of the following ways. The difference is over how long *(exposure duration)* the limit is applied.

- **TWA** – *Time weighted average* – This limit is an average concentration over a period of time, usually 8-hours. It is intended to protect the worker against long-term *(chronic)* health effects.

- **STEL** – *Short-term exposure limit* – This limit is an average concentration for a 15-minute period. It is intended to protect against short-term *(acute)* health effects.

- **C** – *Ceiling limit* – This limit is the concentration of a contaminant in air that should never be exceeded.

Each of these agencies reviews toxicology information and sets the limits. If workers’ exposures (what they actually breathe) are kept below these concentrations, most will not suffer any health effects. It is important to remember that some people are more sensitive to chemicals and may suffer effects, even at the lower levels.
The above exposure limits are established to protect workers in normal occupational settings. These limits are set very low because workers may be exposed to them repeatedly for months or even years. This means, however, that the limits are usually many times lower than the levels needed to protect emergency response personnel for brief exposures. In many cases, it would be unnecessarily conservative to compare emergency exposures to the PEL or TLV for a chemical.

Another problem with using occupational exposure limits in emergencies is when exposure occurs to people in the community. The general public is more likely to include people such as very young or elderly, and less healthy individuals. In this case, exposure limits intended to protect “healthy workers” may not be appropriate.

Emergency Exposure Limits

There are exposure limits established for use in emergency response situations. These limits take into account the problems mentioned above. Because emergencies involve so many potential problems, the limits are only estimates and are not intended to draw clear lines between “safe” and “unsafe.” They do provide guidance that responders can use with good judgment to make decisions.

Immediately Dangerous to Life and Health (IDLH). This limit is established by NIOSH for chemicals in the workplace. People exposed to concentrations higher than the IDLH without respiratory protection may suffer an effect within 30 minutes that makes them unable to rescue themselves. NIOSH intends that only the highest level of respiratory protection be used in exposures above the IDLH level.

Emergency Exposure Guidance Level (EEGL). The Committee on Toxicology of the National Research Council established the EEGL and its companion the Short-term Public Emergency Guidance Level (SPEGL). The EEGL was established for about 70 substances and intended as a maximum level that young healthy military personnel could be exposed to during work in a single instance of a chemical release. The SPEGL was developed as maximum level of exposure for the general public, but only for 4 substances. The same committee has published guidelines for how to develop Community Emergency Exposure Levels based on toxicological data, but has not published any further lists of actual exposure levels.

Emergency Response Planning Guidelines (ERPG). The American Industrial Hygiene Association publishes these limits that are actually a series of three limits for each chemical. The limits, ERPG-1, ERPG-2, and ERPG-3, represent estimates
of progressive levels where certain types of health effects would occur. They are defined as follows:

- **ERPG-1.** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving clearly defined, objectionable odor.
- **ERPG-2.** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual’s ability to take protective action.
- **ERPG-3.** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

An example of these levels is methanol with the following values:

- ERPG-1 = 200 ppm
- ERPG-2 = 1000 ppm
- ERPG-3 = 5000 ppm

AIHA provides full documentation for the guidelines that includes summaries of the animal toxicity data and human experience that is used to set the levels. There are 95 guides in the 2000 edition.

**Using the Data**

If air surveillance data can help identify and quantify the released material, responders can select the proper protective equipment. Potential health effects can be predicted and monitored if the chemical identity and exposure data are available.

Even if laboratory results are obtained too late for use during the incident, the data may be useful in clean up efforts to select the appropriate protective equipment based on actual exposure data. Also, the data may be used to help prepare for future responses to similar incidents. Emergency responders
could estimate air concentrations during a future incident involving the same material based on air sampling results obtained during the initial incident. In order to make the comparison, sufficient information about site conditions must be reported to allow knowledgeable individuals to assess the impact of differing conditions (e.g. higher temperature, larger quantity release, higher humidity, etc.) on the concentration.

SELECTING AIR SURVEILLANCE EQUIPMENT

GENERAL CONSIDERATIONS

Technological advances in air monitoring and air sampling equipment have resulted in a wealth of choices for the consumer. As in any other market, enterprising manufacturers present their products in the best possible light and make impressive claims about how they perform. The hazmat team must decide on which equipment to purchase only after careful consideration. This section will describe some important factors in making the decision.

Budget

This area is mentioned first not because it is most important, but because it is the consideration most likely to limit the options of the team. Air surveillance equipment ranges in cost from detector tube kits that can be purchased for under $1000 to field gas chromatography units costing over $15,000. Add to that the costs for accessories, maintenance, and training of operators, and it becomes apparent that equipment can represent a significant investment of money that should be made carefully.

Hazards

The list of hazardous materials present at the facility should be reviewed to determine what specific materials are most likely to be involved in a release and the type of hazard they would represent. The hazmat team should be capable of detecting each type of hazard at the facility (e.g. oxygen-deficient, flammable, toxic, or radioactive atmospheres). This may involve a single piece of equipment or several different types, depending on the variety of materials used.
Selectivity

Selectivity refers to the ability of equipment to monitor one chemical or group of chemicals to the exclusion of others. Selectivity is useful when only a few chemicals are used at a site or when one specific chemical poses a higher hazard than others. Selectivity allows the user to focus on a particular hazard with a greater degree of confidence. However, this inability to detect other chemicals would not be practical in a situation where multiple hazards are likely to be encountered, such as when public sector hazmat teams are called to transportation incidents.

In considering selectivity, it is important to remember the problem of interferences described in the discussion of colorimetric indicators. The sensors of single-gas monitors will usually respond to certain other chemicals if they are present. If a single-gas detector is purchased, potential interferences should be determined from the manufacturer's information.

Operating Range

The range of concentrations that can be measured by an instrument is referred to as its operating range. An important part of the operating range is the lower detection limit or the lowest concentration of chemical in air that will cause a response by the instrument. The appropriate range will depend on the hazard to be monitored.

For example, a combustible gas meter, which measures in the range of percent (parts per hundred), would not be appropriate for monitoring exposure to gases which are toxic at concentration in the range of parts per million. A concentration of the gas that is high enough to be detected by the combustible gas meter would be much higher than the toxic exposure limit. On the other hand, an instrument designed to monitor toxic exposures may not have a sufficient upper range to monitor the flammability of a gas. Some instruments are capable of operating in both the percent and the ppm range.

Ease of Operation

Instruments should be easy to operate and read the results. Instruments that are difficult to operate will slow down responders or require too much of their attention, perhaps causing them to miss important visible information during an entry. A bulky or hard to operate instrument may limit the activities the responder can perform during an entry, forcing additional entries. The buttons, switches and knobs should be easy to operate, even while wearing gloves.
PLANNING PURCHASES

As mentioned previously, the hazmat team will probably not have an unlimited budget with which to purchase equipment. This usually means that the air surveillance equipment will have to be purchased and accumulated over time. Therefore, the hazmat team should use the above considerations to prioritize purchases.

Before purchasing equipment, investigate the resources available locally. Equipment used by the plant health and safety department to monitor for compliance with OSHA chemical exposure limits may be available for use in emergency situations. As facilities purchase new equipment, the old equipment may be available for purchase by hazmat teams at other facilities. Industrial facilities with similar potential hazards that are located in an area may decide to pool their resources and purchase equipment to be shared in the event of an emergency at any facility.

Another option is to rent air monitoring equipment, thus eliminating purchase and maintenance costs. The major drawback of renting is delivery time, unless the equipment is available locally. Typically, rental companies can ship equipment by overnight carriers for use the following day, but that may be too late for use during the response. Also, rental charges may be high depending on the equipment and any minimum rental periods.

Planning is an important part of the decision to purchase equipment for air surveillance. The materials present at a facility that would represent the greatest and most immediate airborne hazard should be determined based on factors such as quantity stored, handling procedures, flammability, and toxicity. Equipment capable of detecting or monitoring these conditions should receive first priority in considerations for equipment purchases. After high priority hazards are addressed, equipment for other potential hazards can be added as budgets permit.

In some cases the most immediate threat will be a potential for fire or explosion and a combustible gas indicator would be the first priority. Because the CGI requires sufficient oxygen to function, combination detectors that simultaneously monitor oxygen content and combustible gases should be considered. These instruments are available from many manufacturers and costs range from $1500 to $3500. Since the instrument can be used to detect most combustible or flammable gases or vapors, the instrument makes a good initial investment, especially if multiple flammable chemicals are present on site. The instrument should be able to be calibrated in the field, as discussed in the Calibration section of this chapter.
Radioactive sources such as those used in gauges or testing equipment used in industrial facilities are usually tightly contained and do not represent an exposure hazard to workers nearby. However, in an emergency such as a fire or explosion, the containment may be compromised and emergency responders may unknowingly be exposed to harmful radioactivity. Radioactivity can only be detected with monitoring equipment. Therefore, proper radiation detection equipment such as a Geiger-Mueller or an ion chamber detector, should be available to responders called to an incident where radioactive material may be present. Radiation survey meters are available for about $1000. Be sure that the survey meter selected is capable of monitoring the type (alpha, beta, or gamma) of radiation used at the site.

If a particular chemical poses a high or unique toxic threat at lower concentrations, an instrument capable of monitoring that specific chemical should be considered. Hand-held instruments that monitor chlorine, hydrogen sulfide, carbon monoxide, and other specific chemicals are available for costs starting at several hundred dollars. These instruments can detect concentrations as low as 1 ppm and provide some degree of selectivity. As discussed above, the potential that the instrument may detect other chemicals must be considered.

Another option for detecting specific chemicals is the use of colorimetric indicator tubes. Though the accuracy of the data varies by plus or minus 25% or more, these tubes provide "quick and dirty" detection of hundreds of specific chemicals. Many manufacturers have assembled "hazmat kits" that contain the hand-held pump and a variety of tubes for commonly encountered contaminants and sell for up to $1000. A facility with a limited number of contaminants present may decide to purchase the pump kit ($200 - $500) and a few boxes of tubes ($35 - $50 each) for only those contaminants present on site. It is important to remember that the tubes have a limited shelf life. They should be checked regularly and purchased in relatively small quantities to avoid throwing away a large number of outdated tubes.

If many different toxic chemicals are potential hazards at a facility or if somewhat higher accuracy is needed, more expensive instruments such as a PID, FID, or Infrared Spectrophotometer are available. These instruments can be calibrated to provide a direct reading of the air concentration of the chemical and can show fluctuations in the concentration over time. They are capable of monitoring a wide variety of different chemicals and, when properly calibrated, provide a more accurate reading than that of colorimetric indicators. The costs of the instruments start at about $4500 for a PID and can go well over $15,000 for field gas chromatographs with one of these detection methods.
SUMMARY

Exposure to hazards present in the air is difficult to control, so information about the extent of airborne hazards can be very important to decisions about protecting the public and response personnel. The principles and equipment available to gather this information can vary widely in complexity and usefulness. Understanding these principles and equipment can mean that valuable information is available to the emergency responder. On the other hand, failure to understand or plan for air surveillance during a response can lead to a lack of information, or worse yet, misinterpretation of information and bad decisions. Training, planning, and resources are the keys to successful implementation of air surveillance during an emergency response.
COLORIMETRIC INDICATORS

Colorimetric indicators provide a means of quantifying air contamination with a reasonable degree of selectivity. Three types of indicators may be used: liquid reagents, chemically treated papers, and glass tubes containing chemically treated solids. The principle of operation is that contaminant in air reacts with a chemical reagent to cause a change in color, which is proportional to the amount of contaminant in the air. Liquid reagent devices are available that produce color changes that are fairly easy to observe. But handling liquids in the field may be awkward and inconvenient. Chemically treated papers are easy to use, but do not typically have a means of controlling the volume of air contacting the paper. Therefore, the accuracy may be affected by factors such as the amount of air movement over the paper.

Because of their ease of use and quick results, the glass tubes containing a chemically treated solid - known as colorimetric or detector tubes - are widely popular. They typically consist of a glass tube containing a granular carrier solid that has been impregnated with a specific chemical reagent. As contaminated air passes through the glass tube, the contaminant reacts with the reagent on the carrier solid to produce a color stain.

The air is drawn through the tube by either a hand pump or a battery-powered pump. Thus, the volume of air sampled can be controlled. There are two kinds of hand-operated pumps – bellows or piston. The bellows pump is spring-loaded and draws air in by collapsing a bellows and allowing it to expand. The piston pump pulls a spring-loaded piston in a cylinder to draw air into the expanding cylinder. Both types of pumps have pump stroke completion indicators.

It should be noted that detector tubes are designed and calibrated for use exclusively with the manufacturer's pump. To use a detector tube with another manufacturer's pump, even if the pump volume is the same, can lead to greatly inaccurate results.
OPERATION OF COLORIMETRIC INDICATOR TUBES

The tubes may operate in one of three ways as shown below. First (A), the pump may be operated until the length of the stain reaches a certain preset point. The number of pump strokes (i.e. the volume of air) required to reach this full stain is compared to a chart to determine the concentration of the contaminant in air. In this case, a high concentration of contaminant in air would require fewer strokes to reach full stain.

Secondly (B), a set number of pump strokes (volumes) of air will be drawn through the tube and the length of stain is compared to a calibration scale, often printed on the tube, to determine the concentration. For a set number of pump strokes, a high concentration would cause a longer stain.

Thirdly (C), a predetermined number of pump strokes of air are drawn through the tube and the degree or tint of the color change is compared to a chart to determine the concentration. For these tubes a high concentration would cause a deeper or darker color change after a set number of pump strokes. It is critical that the operator of the tube be familiar with the manufacturer's directions and knows which mode of operation is used.

Sample pumps must be checked for leaks to ensure that the appropriate volume of air is drawn through the tube. Also, the pump must be allowed to fully complete every pump stroke. Incomplete strokes or leaks in the system will cause less than the appropriate volume of sample air to pass through the tube, potentially resulting in a lower reading than is actually present.
The tubes may be specific for a certain gas or vapor or may detect groups of chemicals, such as alcohols or aromatic hydrocarbons. Tubes that are designed to detect one chemical will usually react with certain other chemicals (known as interferences) to produce a similar color change. The manufacture will provide a list of known interferences. In general, detector tubes provide an estimate of what and how much of a particular chemical is present.

LIMITATIONS OF COLORIMETRIC INDICATOR TUBES

Some limitations must be considered when detector tubes are used. Detector tube systems have rather poor accuracy, with errors ranging from 25% to 50% for many tubes. The National Institute for Occupational Safety and Health (NIOSH) tested and certified detector tubes at one time, but has since discontinued the practice. Manufacturers generally provide accuracy information with the instructions.

Because a chemical reaction is involved, detector tube accuracy may be affected by such factors as temperature, humidity and atmospheric pressure. Where temperature will significantly affect the performance of the tube, the manufacturer will include compensation factors in the instructions. Colder temperatures will usually slow down the reaction, so if detector tubes are to be used in cold weather, they should be stored in a warm place and carried next to the body. High temperatures may affect the rate of the chemical reaction and may reduce the shelf life as described below.

One source of error in the use of colorimetric tubes is the visual interpretation of the length or degree of color change. The leading edge of the stain may be uneven or may be lighter than the rest of the stain, calling for a judgment on the part of the operator as to what constitutes the end of the stain. The same difficulty applies to judging the degree or tint of color change, even when comparison charts are provided. When in doubt, it is advisable to use the most conservative (i.e. highest) reading so that more protection is provided to the responder and the public.

Detector tubes have a specific shelf life. Chemical reagents will deteriorate over time, even if the tube is not opened and exposed to air. Also, high temperatures
may cause the degradation of the reagent. The manufacturer will stamp an expiration date on each pack of tubes. Storing the tubes in a refrigerator may maintain or extend the shelf life, but expired tubes should not be used.

HAZMAT Kits

Each of the detector tube manufacturers offers a hazmat kit. These kits include a pump and several preselected types of tubes. The selected tubes respond to several common chemicals, but also to numerous interfering chemicals as well. This allows the same tube to indicate whether these other chemicals are present. These kits can be used to help classify unknowns at a hazmat release. They include a flow chart decision matrix that allows the user to rule out or identify classes of chemicals in a systematic process.

These kits are not intended to exactly identify the material involved if nothing else is known. But if they are used with preliminary information, they can help narrow down the choices responders have to choose from.

SUMMARY

Detector tubes offer a simple test to determine if a particular material is present at a hazardous materials incident. They also estimate how much may be present. But they have limitations and they must not be treated as absolutely accurate tests. So, if your team uses them, allow a reasonable safety factor for any decisions that are made based on their results.