

Section II

(previously Section I of Oregon OSHA's Technical Manual)

SAMPLING, MEASUREMENTS METHODS and INSTRUMENTS

CHAPTER 1: PERSONAL SAMPLING FOR AIR
CONTAMINANTS

CHAPTER 2: OCCUPATIONAL SKIN EXPOSURE

CHAPTER 3: [TECHNICAL EQUIPMENT: ON-SITE
MEASUREMENTS](#)

CHAPTER 4: SAMPLE SHIPPING AND HANDLING

*All information within this section and chapter has been reproduced from the Oregon OSHA
Technical Manual (circa 1996) unless otherwise stated within the
"Chapter Revision Information", located at the beginning of each chapter.*

SECTION II: CHAPTER 3

TECHNICAL EQUIPMENT: ON-SITE MEASUREMENTS

Chapter Revision Information:

- *This chapter was previously identified as Section 1, Chapter 3 in Oregon OSHA's circa 1996 **Technical Manual**. The Section number was modified from Section I to Section II in December 2014 to provide uniformity with the Federal OSHA Technical Manual (OTM).*
- *In December 2014, the original "Technical Equipment" chapter was replaced by Federal OSHA's February 11th, 2014 update "Technical Equipment: On-site Measurements".*
- *In December 2014, Federal OSHA's February 11th, 2014 Technical Manual update "Technical Equipment: On-site Measurements" was customized to make the document's instructions specific to Oregon OSHA's sampling equipment, laboratory and state specific regulations.*
- *In September 2022, the chapter was updated to reflect current Oregon OSHA operating procedures.*

SECTION II: CHAPTER 3

TECHNICAL EQUIPMENT: ON-SITE MEASUREMENTS

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I. Introduction

The purpose of this chapter is to provide a broad overview of the types of equipment and instrumentation available for use by Oregon OSHA personnel. This information is not a comprehensive resource for specific types of instrumentation, nor is it intended to replace the owner's manual. Rather, its purpose is to provide a broad understanding of the principle of operation for the particular type of equipment and an understanding of the capabilities and limitations of the equipment. End users should always follow the owner's manual and manufacturer recommendations regarding the specific operation and maintenance of the equipment being used.

The Oregon OSHA Lab, hereafter referred to as the Lab, serves as a source of technical information for field equipment, both for sampling and for direct reading, and also measurement technology. Much of the equipment and instrumentation discussed in this chapter is available from the Lab. A list of [available equipment](#) may be found on the Lab's section of Oregon OSHA's internal website. Specialized equipment not available from the Lab can be arranged to be borrowed from Federal OSHA's Cincinnati Technical Center (CTC).

Appendix A provides a useful reference chart which summarizes the various types of instrumentation available and typical applications. Appendices B and C describe specialized tools used to evaluate chemical and biological warfare agents, respectively. Use of these tools is overseen by the Salt Lake Technical Center (SLTC) Health Response Team (HRT) and OSHA's Specialized Response Teams (SRTs). Appendix D describes equipment used for detection of ionizing radiation, which is also overseen by the HRT. The Lab has limited capabilities in these specialized fields.

Note that noise monitoring equipment is NOT discussed in this chapter. Section III, Chapter 5 of the Oregon OSHA Technical Manual contains the discussion of noise monitoring equipment. Also, this chapter does not discuss air sampling methods for collection of samples for off-site laboratory analysis. Active and passive (diffusive) personal air sampling methods for air contaminants are discussed in Section II, Chapter 1.

NOTE: Any discussion regarding a specific manufacturer's product is not meant to imply an endorsement or approval by Oregon OSHA, but merely reflects the need to convey specific information which is pertinent to the particular type and brand of instrumentation available for OSHA personnel.

Hazardous (Classified) Locations

Certain workspaces may contain a flammable or explosive atmosphere due to the accumulation of flammable gases or vapors, or combustible dusts and fibers, and are termed "Hazardous locations." Hazardous locations are classified into Class and division based on the type and severity of the explosion hazard as described in [29 CFR 1910.307](#). Sparks from ordinary battery-powered portable equipment commonly used by CSHOs, including cameras, cell phones, tablets and laptop computers, may serve as an ignition source and must never be brought into a hazardous location.

Nationally Recognized Testing Labs test and approve electrical equipment for use in hazardous locations (see [29 CFR 1910.7](#)) Approved equipment, sometimes referred to as intrinsically safe, must be marked with the Class and Division number for which it is approved. Never bring portable monitoring instruments into a hazardous location without first confirming that the instrument is approved for use in that environment. Use only the type of battery specified on the safety approval label, and replace batteries in a nonhazardous area.

II. Equipment Maintenance and Calibration

Service intervals (calibration checks) for equipment are monitored by the Lab and are modeled after the recommendations from the Cincinnati Technical Center. Repairs are performed as needed by the Lab. A small percentage of the equipment needs to be sent to the manufacturer or other certified calibration lab for service and repair.

Pumps, air velocity meters, cyclones, dust monitors, light meters, toxic gas monitors, and the mercury vapor meter are on a two-year service interval. Most other equipment has a calibration check on an annual basis and includes heat stress kits, indoor air quality monitors, primary flow calibrators, and noise dosimeters which are discussed elsewhere. The Lab applies a calibration sticker which includes the due date for the next calibration. Before using field instrumentation, the calibration sticker should be checked to ensure that the instrument is within its calibration due date.

Some equipment must be field calibrated or bump tested prior to use. Consult the instrument equipment manual to determine what field calibration is needed. If the equipment fails field calibration or bump tests, consult the Lab for guidance.

Limitations of Batteries

Proper battery maintenance is essential to ensure reliable performance of battery powered equipment during field use. A variety of battery types are used in different types of portable equipment, as specified by the instrument manufacturer. All battery types will self-discharge to some degree during periods of prolonged storage.

Non-rechargeable batteries need to be removed from the instrument prior to prolonged storage in order to prevent battery leakage which could damage the instrument. Many instruments powered by non-rechargeable batteries will perform a battery life check when first powered on, otherwise check with a voltage meter before full-shift sampling. If low, replace the batteries as appropriate. Never mix types (alkaline, carbon zinc, etc.), capacity, or age, as this can have negative effects on all the batteries.

Rechargeable batteries should generally be left on trickle charge mode for storage. Overcharging, by charging for too long a time period at a high charge rate, can damage the battery. Conversely, discharging below a minimum voltage can also damage the battery. In general, avoid both overnight discharging and overnight charging at a high charge rate. Closely follow the recommendations in the equipment manual. In some cases, an outlet controller (timer) can be used to ensure that batteries are charged for a suitable length of time.

Rechargeable batteries are most reliable when used at least every two to three weeks. Nickel-cadmium (Ni-Cd) batteries are prone to developing “memory” problems, in which the battery will not hold a full charge unless it is fully discharged before recharging. Ni-Cd batteries may need to be reconditioned by charging/discharging two to four times. New batteries should be conditioned in accord with the same process. Nickel metal hydride batteries generally are less prone to memory problems than Ni-Cd, and typically offer longer run time, however they do have a higher self-discharge rate. Lithium ion and lithium polymer batteries typically have higher energy density, lower rates of self-discharge, and are not prone to memory effects.

For sampling pumps, apply appropriate media (may be expired) on a short tube and run the pump until it turns itself off. Check to see if the battery kept up for at least 480 minutes (8 hours); then fully recharge. Repeat this process once a month for best results. Some AirChek 52 pumps do not display the thousands column, for example 17 hours is 1020 minutes and would look like a major fail if looking at the last 3 digits. Stagger the procedure among the pump supply so there are enough remaining pumps for use. Leaving the discharged pump over the weekend should not be a problem but the batteries should be recharged as soon as practical.

Be sure to consult the user’s manual for proper battery care.

III. DIRECT-READING INSTRUMENTATION FOR AIR CONTAMINANTS

Direct-reading (real-time) instruments or monitors provide information at the time of sampling, enabling rapid decision making. These instruments often provide the experienced user the capability to determine if site personnel are exposed to airborne concentrations which exceed instantaneous (ceiling or peak) exposure limits for specific hazardous air contaminants. Direct-reading monitors can be useful in identifying oxygen-deficient or oxygen-enriched atmospheres, [immediately dangerous to life or health](#) (IDLH) conditions, elevated levels of airborne contaminants, flammable atmospheres, and radioactive hazards. Direct reading instruments are particularly useful for identifying point source contamination or emissions. Periodic monitoring of airborne levels with a real-time monitor is often critical, especially before and during new work activities. Direct-reading instruments are useful for performing screening surveys to determine areas where additional evaluation is warranted. Data obtained from direct-reading monitors can be used to evaluate existing health and/or safety programs and to assure proper selection of personal protective equipment (PPE), engineering controls and work practices.

CSHO Safety

Before bringing monitoring equipment or other electrical devices into an area with the potential for an explosion, always check the Class and Division number marked on the instrument. Use only the type of battery specified on the safety approval label, and replace batteries in a nonhazardous area. Do not assume that an instrument is intrinsically safe. If uncertain, verify by contacting the instrument manufacturer or the Oregon OSHA Lab.

For atmospheres or work surfaces contaminated with hazardous chemicals, use a plastic bag to cover appropriate parts of equipment to limit contamination. Ensure that the plastic bag is not tightly sealed as this can cause back pressure on the air sampling pump (if equipped). Properly decontaminate all equipment to minimize potential contamination of other persons or objects when sampling is complete. To the extent possible, gross decontamination should be performed onsite.

Before using a direct-reading instrument, review information in the instrument manual regarding the following characteristics:

- Battery life - how long can the instrument run from battery power?
- Datalogging - can the instrument record readings electronically? If so, how is this information retrieved?
- Size and weight - how practical will the instrument be for short-term breathing zone measurements? Will a cart be needed for moving the instrument around?
- Sampling wand - does the unit have a sampling hose and probe to allow for remote sampling, or to allow breathing zone measurements for larger instruments?

- Warm-up time - how long does the unit need to be powered on before it can produce accurate readings?
- Response time (lag time) - how long is the delay between exposing the inlet to a contaminated atmosphere and obtaining an accurate reading?
- Sensitivity - can the analyte be detected, and what is the minimum contaminant concentration that can be reliably measured or detected?
- Specificity - can the instrument discriminate between one contaminant and another?
- Interferences - are there chemicals which, if present, may produce false readings? Are there chemicals, dusts, or other conditions which may damage the sensor?
- Environmental conditions - what is the acceptable temperature and humidity range for use of the instrument to not affect the accuracy of the readings? What about altitude? Can the unit be used in a dusty environment without damaging the instrument? Are there filters available to protect the instrument in these situations?
- Hazardous areas - can the instrument be used in electrical classified areas?

The sections which follow describe the principal types of direct-reading instrumentation:

- Photoionization detectors
- Infrared analyzers
- Gas, oxygen and explosibility (combustible gas) monitors
- Detector tubes
- Mercury analyzers
- Dust/particulate monitors

A. Photoionization Detectors (PIDs)

Application and Principle of Operation

Photoionization detectors (PIDs) are used for nonspecific detection of a variety of chemicals, particularly volatile hydrocarbons. PIDs are useful for pinpointing contaminant sources, or for identifying concentration gradients throughout a space, because the readout is proportional to the concentration of contaminant present. However, PIDs cannot positively identify contaminants present in an environment. Where more than one airborne contaminant is present, the instrument may not distinguish one from the other.

PIDs use a high energy ultraviolet (UV) light source to ionize chemicals in an airstream. The charged molecules are collected on a charged surface, which generates a current that is directly proportional to the concentration of the chemical in the air being sampled.

The ionization potential (IP) describes the amount of energy needed to induce ionization in a particular chemical. If the energy of the UV lamp is greater than or equal to the IP of the chemical being sampled, then the chemical will be detected. PIDs may be configured with lamps of different energies. Typical lamp energies are 9.5, 10.6, and 11.7 electron volts (eV). The

higher the lamp energy, the greater the number of chemicals that can be detected. For example, benzene (IP 9.25 eV) can be detected with a 9.5 eV lamp, while methylene chloride (IP 11.35 eV) requires use of the 11.7 eV lamp. In general, higher energy lamps have a much shorter lifespan than lower energy lamps. Further, the lamp energy must be lower than background atmospheric gases to be of practical use. For example, the IP of carbon monoxide is 14.01 eV, while the IP of molecular oxygen is 12.08 eV; because the IP of carbon monoxide is higher than for oxygen, a lamp that could ionize carbon monoxide would not be useful for quantifying parts per million (ppm) concentrations of carbon monoxide in the presence of percent concentrations of oxygen (1 percent = 10,000 ppm). Similarly, the IP of many chlorinated hydrocarbons may be too high to be detected by use of a PID.

The amount of electric current (signal response) generated in a PID varies with the chemical to which the PID is exposed, along with the lamp energy. The response factor is the ratio of the detector response for a particular chemical relative to a reference gas, usually isobutylene. The signal response must be multiplied by the response factor to quantify the concentration of the contaminant of interest. Response factors for a large number of chemicals are pre-programmed into the instrument. When sampling in an environment where a single identified gas is known to be present, the display name for that gas is selected and the readout will be automatically corrected using the response factor for that gas. For chemicals which are not preprogrammed into the instrument, the response factor should be determined by exposing the detector to a known concentration of the gas of interest, by preparing a bag sample (i.e., using a nonreactive Tedlar® bag) and following the process described in the instrument manual.

Please note that the response factor also depends on the lamp energy. Ensure that the instrument has been set for the energy of the lamp which has been installed. If an incorrect response factor is applied, the displayed reading would significantly under- or over-estimate the concentration of the contaminant in question. The instrument manual includes a table listing the IP and response factor for a variety of common chemicals.

Calibration

PIDs are calibrated using a reference gas, usually isobutylene. Because the response is linear with concentration, a two point calibration is sufficient. Zero gas contains 0 ppm of contaminant and span gas contains a specified concentration of the reference gas. Calibration gases specified for the instrument being used are available through the Lab. The label should be checked to make sure the expiration date marked on the cylinder has not been exceeded. When multiple sensors are present on the same instrument, the right gas mix is necessary to ensure that the span gases for the different sensors do not adversely affect other sensors on the same instrument.

In most cases a calibration check is sufficient, in which the instrument is “zeroed” in fresh air (such as an office environment), then the calibration gas is applied; if the reading matches the concentration of the span gas, full calibration is unnecessary. A calibration check should be performed before use each day. If the reading is off, a full calibration should be performed using zero gas and span gas. Follow the instructions in the manual to enter calibration mode; the unit will auto calibrate, that is, it will internally adjust the signal response so that the displayed reading matches the span gas concentration. The Lab will perform a full calibration check every two years or as needed.

Performing a calibration check using the chemical of interest is recommended where practical, but may not be necessary or possible. In a well-ventilated area, prepare a bag sample of known concentration of the chemical of interest, select that chemical from the instrument library, and ensure that the reading matches the bag concentration.

Special Considerations

Photoionization sensitivity is dependent upon the age of the lamp and cleanliness of the lamp window. Over time, the output of the lamp will be reduced. A spare lamp is sometimes included in the case. Also, the accumulation of organic deposits or buildup of film on the surface of the lamp will reduce sensitivity.

PIDs are also affected by high humidity. For the most sensitive results, it is best to zero the instrument using representative air; that is, zero the instrument in the field in a “clean” area of similar temperature and humidity. The lamp may need to be cleaned more frequently when used in a high temperature, high humidity environment.

Consult the user manual regarding potential interferences. Water vapor, carbon dioxide, methane, and carbon monoxide can all produce a low reading for the gas of interest if present in the air being sampled due to quenching by these non-ionizable gases.

Maintenance

Follow the manufacturer's recommendations for maintaining the detector in optimal condition. This will include routine cleaning of the UV lamp using methanol and frequent replacement of the dust filter. Exercise caution in cleaning the lamp window, as these are fragile. The exterior of the instrument can be wiped clean with a damp cloth and mild detergent, if necessary. Keep the cloth away from the sample inlet and do not attempt to clean the instrument while it is connected to a power source.

B. Infrared Analyzers (IR)

Application and Principle of Operation

Infrared (IR) analyzers are useful for measuring a broad range of inorganic and organic chemicals in air. The sensitivity of IR analyzers can be sufficient to quantify chemical concentrations below the OSHA Permissible Exposure Limits (PEL) for many chemicals. IR analyzers can also be used to identify unknown chemicals by using spectral matching. These instruments may be heavy and bulky and are generally more suitable for area sampling rather than personal sampling, although they can be used to analyze a bag sample of contaminated air collected in the breathing zone of a worker (e.g., using a Tedlar® bag). IR analyzers can be used for continuous sampling, although battery life is generally not sufficient for full-shift sampling. Some of the routine applications for IR analyzers include measuring carbon dioxide in IAQ assessments; waste anesthetic gases and vapors including nitrous oxide, halothane, enflurane, pentane, and isoflurane; and fumigants, including ethylene oxide, ethylene dibromide, chloropicrin, and methyl bromide. IR analyzers are also used in tracer gas studies, such as fume hood performance testing (although these studies are not generally conducted by CSHOs).

IR analyzers operate by passing IR radiation generated from a heated metal source through a gas sample. The IR radiation is absorbed by the chemical at specific wavelengths determined by the type of bonds present in the molecule. The absorbance is proportional to the concentration of the chemical in the sample. The portable IR analyzer is preloaded with a library of known chemicals. To quantify a known chemical in the environment, the user selects the appropriate wavelength for that chemical from the library. The wave number (number of wavelengths in one centimeter) is commonly used to describe IR spectra. The wave number is the reciprocal of the wavelength and is expressed in cm^{-1} . The infrared spectrum typically used in infrared analysis ranges from the far infrared region at 400 cm^{-1} (25 micrometers) to the near infrared region $4,000 \text{ cm}^{-1}$ (2.5 micrometers). The sensitivity (detection limit) can be increased by increasing the path length through which the light source travels. Generally, the response time is slightly slower for the longer path length.

Where multiple chemicals may be present in the environment, interferences can be a problem. A unique absorbance wavelength must be identified to distinguish one chemical from another. The instrument may offer more than one wavelength for measuring concentrations of the same chemical in order to avoid other chemical interferences. The user needs to assess what other chemicals are likely to be present and select the wavelength least likely to have interferences. In some instances, a weaker absorbance band at a different wavelength is chosen to measure a chemical in air if that alternate wavelength is uniquely absorbed by the chemical of interest.

The selected wavelength for analysis of a chemical is chosen both because the chemical of interest has sufficient absorbance at that wavelength and sufficient specificity to exclude the absorbance of other chemicals. For example, acetone in air absorbs IR at both 8.4 and 11.0 micrometers. If methyl acrylate was also known to be present in the air, the 11.0 micrometer IR wavelength would be selected because methyl acrylate also absorbs at 8.4 micrometers.

An IR analyzer can also be used to identify unknown chemicals by matching measured spectral absorbance with spectra for known chemicals. The NIST/EPA Gas-Phase Infrared Database contains over 5,000 IR spectra for individual chemical gases and vapors.

Calibration

IR analyzers generally only require instrument zeroing to collect a zero background. Conduct field calibration in accordance with the manufacturer's recommendations.

Special Considerations

Infrared analyzers may not be specific for the chemical of interest because other chemicals present in the work environment air may also absorb at the same wavelength. Cell window degradation will occur if the analyzer is used in the presence of strong acids or other caustic gases. To protect the sample cell optics, the cell should be flushed with nitrogen gas or dry air after each use. IR analyzers are complex to use and having a well trained professional available to assist is recommended.

Maintenance

Field maintenance is limited to replacement of the instrument filters after a specified number of uses and in situations where adsorbed particulates or non-volatile liquids may have contaminated the filter surface. All other maintenance should be carried out by trained service personnel.

C. Gas, Oxygen and Explosibility (Combustible Gas) Monitors

A variety of handheld monitors are available from the Lab for single or multi-gas monitoring. Four-way gas meters are available which can monitor carbon dioxide, carbon monoxide, hydrogen sulfide, and combustible atmosphere (LEL). Other multi-gas monitors may incorporate up to six separate sensors to also include an oxygen sensor and a PID sensor, all in one handheld monitor. The sample concentration is displayed in ppm, percent oxygen or percent LEL (Lower Explosive Limit), as applicable.

Multi-gas monitors typically feature datalogging capability, as well as audible and/or visual alarms that warn of IDLH or time-weighted average toxic gas concentrations, low oxygen levels, LEL conditions, or malfunction. These monitors may operate in passive (diffusive) mode, or in active mode, in which a pump module draws air across the sensors. Active mode speeds the response time of the meter, but care must be taken to avoid drawing particulates into the monitor. Active mode is used for remote sampling of hazardous atmospheres and includes an extendable wand, or probe attached to the meter by tubing, which can be introduced into the hazardous atmosphere while the user remains outside the hazardous area (e.g., confined spaces).

Calibration gases for both multi and single gases are available through the Lab. Ensure that the calibration (span) gas is intended for the meter make and model being used. This is particularly important for multi-gas use because some gases in the mixture can adversely affect other sensors in the same meter.

Order of testing: *Confined spaces, such as sewers and well pits, commonly contain a hazardous atmosphere which may be oxygen deficient and contain a flammable or toxic gas. Many flammable gas sensors are oxygen dependent and will not provide reliable readings in an oxygen deficient atmosphere. Therefore, oxygen content must always be determined before taking combustible gas readings. Flammable gases and vapors are tested second because the risk of fire or explosion is typically more life-threatening than exposure to toxic air contaminants. Monitoring for toxicity is usually conducted last. This monitoring process is greatly simplified by using a multi-gas monitor containing sensors for oxygen, LEL, and the relevant toxic gases.*

1. OXYGEN SENSORS

Application and Principle of Operation

Oxygen sensors are typically based on electrochemical (galvanic) cells. The generated current in the sensor, which is produced from an oxidation reaction, is directly proportional to the rate of

oxygen diffusion into the cell. Most meters are calibrated to measure oxygen concentrations between 0 and 25 percent by volume in air. Normal air contains about 20.9 percent oxygen. Meter alarms are usually set to indicate an oxygen deficient atmosphere at concentrations lower than 19.5 percent and an oxygen rich atmosphere at concentrations greater than 23.5 percent. Oxygen concentrations below 19.5 percent may result in difficulty breathing and impaired judgment. Oxygen concentrations below 16 percent result in rapid heartbeat and headache. Sudden physical exertion in an oxygen deficient environment may lead to loss of consciousness. Oxygen concentrations below 12 percent will bring about unconsciousness rapidly and without warning, and are considered IDLH. Oxygen enriched atmospheres present a fire and explosion hazard because ordinary combustible materials will burn more rapidly.

Calibration

Calibration is typically accomplished using oxygen in a calibration gas mix or may be done using fresh outdoor air (20.9 percent oxygen). Calibrate immediately before testing at or near the temperature of the tested atmosphere. The Lab will perform a full calibration check every two years or as needed.

Maintenance

Oxygen sensors are inherently self-consuming and have an expected lifetime of 1 to 3 years. When the unit cannot hold calibration, return it to the Lab for sensor replacement.

2. EXPLOSIBILITY (COMBUSTIBLE GAS) SENSORS

Application and Principle of Operation

Combustible gas sensors use platinum as an oxidizing catalyst, or palladium. Combustible gas meters measure flammable gas concentration as a percentage of the LEL of the calibrated gas. When possible, to maximize the accuracy of the combustible gas readings, calibrate the instrument with the gas that will actually be monitored. If monitoring for combustible atmospheres other than the reference gas (calibration gas) consult the manufacturer's instructions and correction charts to determine a more accurate reading of the true gas concentration. Please note that LEL values for most flammable gases and vapors are a few percent in air and are NOT appropriate for assessing PEL concentrations of flammable toxic gases which are measured at ppm levels.

Calibration

Before using the monitor each day, bump test it with an appropriate calibration gas as described in the user manual or in consultation with the Lab. Consult the instruction manual before calibration, and ensure that the calibration gas is introduced at the proper pressure and flow rate, using the appropriate regulator and adaptors. Over pressurization can damage the sensor. For some instruments with an active sampling pump, the pump must be disconnected from the sensor and the span gas flow rate set to match the sampling rate of the pump.

Special Considerations

- Silicone compound vapors and sulfur compounds will cause desensitization of the combustible gas sensor and produce erroneous (low) readings.
- High relative humidity (90 percent to 100 percent) causes hydroxylation, which reduces sensitivity and causes erratic behavior including inability to calibrate.
- Oxygen deficiency or enrichment, such as in steam or inert atmospheres, will cause erroneous readings for combustible gases. Always note the oxygen concentration reading before assessing the LEL reading.
- In extraordinary circumstances, gas concentrations above the Upper Explosive Limit (UEL) may give a false reading indicating a noncombustible atmosphere; be aware that if air is suddenly introduced into such a space, the atmosphere can quickly become explosive.
- Vapors from liquids with flash points above 90°F such as turpentine, diesel fuel, and jet fuel, may not be adequately detected by combustible gas sensors. Use of a photoionization detector may be more appropriate.
- In drying ovens or unusually hot locations, solvent vapors with high boiling points may condense in the sampling lines and produce erroneous (low) readings. Consider taking readings at several different locations around the oven.
- High concentrations of chlorinated hydrocarbons such as trichloroethylene, or acid gases such as sulfur dioxide, will depress the meter reading in the presence of a high concentration of combustible gas.
- High molecular weight alcohols can burn out the meter's filaments.

Maintenance

The instrument requires no short-term maintenance other than regular calibration and recharging of batteries. Use a soft cloth to wipe dirt, oil, moisture, or foreign material from the instrument. LEL sensors have an expected lifetime of about 3 years.

3. TOXIC GAS SENSORS

Application and Principle of Operation

Available toxic gas sensors include single gas sensors for carbon monoxide, hydrogen sulfide, nitrogen dioxide, sulfur dioxide, chlorine, ammonia, and ozone.

Toxic gas sensors generally use an electrochemical (voltammetric) sensor or polarographic cell to provide continuous analyses. In operation, gas is absorbed on an electrocatalytic sensing electrode after passing through a diffusion medium. An electrochemical reaction generates an electric current directly proportional to the gas concentration.

Interference from other gases can be a problem. Before use, consult the user manual to identify interfering chemicals. Some interfering compounds can result in false positive readings. For example, alcohols can saturate the carbon monoxide sensor and cause high readings in which case the sensor will need to be given several hours to clear out the alcohol. In other cases, the sensor can be damaged, or “poisoned” by exposure to certain compounds, in which case it will need to be returned to the Lab so the sensor may be replaced.

Calibration

Before using the monitor each day, bump test it with an appropriate calibration gas as described in the user manual or as advised by the Lab. Calibration against a known standard is also required and is performed at least every two years by the Lab. Tests have shown the correlation to be linear; thus, calibration at a single concentration, along with checking the zero point, is sufficient. The monitor should be calibrated at the altitude at which it will be used. Changes in total atmospheric pressure caused by changes in altitude will influence the instrument's response.

Consult the instruction manual before calibration, and ensure that the calibration gas is introduced at the proper pressure and flow rate, using the appropriate regulator and adaptors. Over pressurization can damage the sensor. For some instruments with an active sampling pump, the pump must be disconnected from the sensor and the span gas flow rate set to match the sampling rate of the pump.

D. Detector Tubes

Application and Principle of Operation

There is a wide variety of commercially available detector tubes which can be used to measure over 500 organic and inorganic gases and vapors in air. Detector tubes are sealed glass tubes filled with a granular material that is coated with an indicator chemical. The indicator chemical will react with a given gas or vapor and produce a color change. Their operation consists of using a portable pump to draw a known volume of air through the detector tube to measure the concentration of the substance of interest. The color change is read in terms of either the length of stain generated inside the tube or the degree of color change. This color change is compared to a scale printed on the tube or to a reference chart included with the tube kit to determine the airborne concentration.

The handheld pumps are hand-operated or are an automatic type that samples using a preset number of pump strokes. Detector tubes are generally to be used only with a pump of the same brand. The brand of tubes is calibrated specifically for the same brand of pump and may give erroneous results if used with a pump of another brand.

Another option is the Dräger Chip Measurement System (CMS), an accurate and reliable handheld reader based on colorimetric detection which is very useful for spot gas measurements. It combines an electronic based analyzer with substance specific chips that are available through the Lab. Each chip contains 10 capillaries filled with a reagent system. The results of up to 50 measurements can be stored in a data recorder integrated in the analyzer and displayed on the LCD screen.

Important considerations for use of detector tubes include measurement accuracy, limits of detection, interferences, temperature and humidity, shelf life, and the time period for which the color stain is stable after the sample is drawn. Always consult the manufacturer's printed instructions to determine these specifications, along with the required number of pump strokes and the time between pump strokes.

Detector tubes are most useful for screening purposes to determine whether levels of contaminant present in an area warrant further sampling. Detector tubes can also be used for compliance sampling relative to TWA (8-hour time-weighted average), STEL (short-term exposure limit) and Ceiling limits.

Before use, refer to the manufacturer's instructions for the particular tube type. Determine the measurement precision, which is typically +/- 25%, and be sure to record the measurement accuracy when recording the sample result on the Oregon OSHA Information System (OTIS) sampling worksheet. Also, perform a pump leak test as shown in Figure 2.

To use, break the ends with a tube opener, which is generally part of the manufacturer's sampling kit. Attach the tube to the pump of the correct brand. Tubes generally have a directional arrow printed on them. As shown in Figure 1, ensure that the directional arrow is oriented toward the pump. Use the number of pump strokes specified by the manufacturer for that tube type.

FIGURE 1. PROPER INSERTION OF DETECTOR TUBE INTO PUMP.



FIGURE 2. PUMP LEAK TEST.



On each day of use, before taking measurements, perform a pump leakage test as per the user instruction manual. The general procedure is to insert an unopened detector tube into the pump and attempt to draw in 100 milliliters (mL) of air. After a few minutes, check for pump leakage by examining the pump compression for bellows-type pumps, or return to resting position for piston-type pumps. Automatic pumps should be tested according to the manufacturer's instructions. The leak test procedure is shown in Figure 2.

In the event of pump leakage that cannot be repaired in the field, send the pump to the Lab for repair. Detector tubes, including chips for the Dräger CMS, are obtained through the Lab.

Interferences

A limitation of many detector tubes is the lack of specificity of the chemical indicator. Many indicators are not highly selective and can cross-react with other gases and vapors. Manufacturer's manuals describe the effects of interfering contaminants.

Temperature and Humidity

Temperature, humidity and pressure can also affect detector tube readings. Read and follow the manufacturer's instructions regarding corrections that must be made to sample readings for these factors.

Long-Term Sampling

Most detector tubes only give near-instantaneous measurements, and thus will not reflect time-weighted average (TWA) levels of the hazardous substances present. Some long duration tubes for TWA measurements are available. Some are a diffusive/dosimeter type which requires no pump. Others are used with a portable lightweight pump which continuously draws a measured volume of air through the tube. These tubes can be worn by the worker in a special holder. At the end of the shift, the tube can be evaluated to give a TWA exposure for the working day.

Another technique for long-term measurements is to wear a gas sampling bag such as a Tedlar® or Teflon® bag connected to a low flow pump and then periodically measure the concentration of contaminant in the bag with a detector tube to get a TWA exposure over the time period worn. The sampling bag is connected to the outlet from a portable sampling pump set to a calibrated flow rate such as 0.05 liters per minute (50 cubic centimeters per minute). Once the long-term bag sample is collected, an air sample could be extracted in the field by connecting the bag to a detector tube and hand pump. Massage the bag to ensure good air mixing before extracting the air sample. This technique can only be used for assessing contaminants that would not react over time inside the bag. Consult the sampling pump manual to ensure that atmospheres that may be damaging to the pump are not drawn into it.

Storage and Shelf Life

Detector tubes normally have a shelf life of one to two years when stored at 25°C. Expiration dates are generally printed on the box or on each tube. In general, avoid excessively low (less than 35°F) or high (greater than 78°F) temperatures and direct sunlight which can adversely affect the properties of the tubes. Refrigerated storage prolongs shelf life. Detector tubes should not be used when they are cold and should be kept at room temperature for about one hour prior to use. Outdated detector tubes should not be used.

Calibration

Annually, or after any repair or maintenance work, send detector tube pumps to the Lab for volume verification. Consult the Lab if there is reason to suspect that a pump may not be operating properly prior to its scheduled calibration due date.

E. Mercury Analyzer

Application and Principle of Operation

Handheld mercury analyzers can be used for compliance sampling and source and leak detection. These instruments measure airborne mercury vapor by drawing an air sample over a gold film. The mercury adsorbed onto the gold surface changes the resistance of current flow. The change in resistance is a function of the mass of mercury collected on the gold film. The results can be displayed in milligrams of mercury per cubic meter of air (mg/m^3) or total mass of mercury in the air sample collected. The model available through the Lab is the Jerome Model 405, which has a range of detection from $0.5 \mu\text{g}/\text{m}^3$ to $999 \text{ug}/\text{m}^3$ mercury.

Potential interferences which can produce a positive reading include chlorine, nitrogen dioxide, hydrogen sulfide, most mercaptans, and high concentrations of ammonia. Various filters are available from the manufacturer to remove chlorine, ammonia, and other interfering contaminants upstream of the sensor if the internal filter system is insufficient.

Calibration

Due to the gold film/mercury interaction, the instrument will produce stable, accurate readings without the need for frequent recalibration. A calibration check can be performed using the manufacturer's Functional Test Kit. The lab has the mercury meter on a suggested two-year calibration schedule if the meter has been frequently used so that the gold film performance can be checked and internal filters replaced.

Special Considerations

The instrument must be zeroed before use at the temperature at which it will be used. The zero air filter removes mercury vapor, mercaptans, and hydrogen sulfide from the air sample. The instrument should be regenerated after use if the gold film sensor becomes saturated with mercury. The sensor saturation meter will show the percentage of sensor saturation. The regeneration feature must be manually activated and takes 45 minutes to complete.

Maintenance

Upon frequent use of the instrument, routine maintenance includes changing the 0.25-inch frit wire, replacement of the internal filters, and proper battery maintenance. The manufacturer's instructions should be consulted for further details.

F. Dust / Particulate Monitors

1. AEROSOL PHOTOMETERS

Application and Principle of Operation

Aerosol photometers operate by detecting light scattered by particles entering the detection chamber. The amount of light reaching the detector is proportional to the number of particles passing through the detection chamber. Also known as nephelometers, these instruments are used

to monitor particulate matter such as dusts, smokes, mists, and fumes. Some models can be used for monitoring the respirable fraction of dust, and some are small enough to use for personal exposure monitoring. The Lab has models which can measure PM1, PM2.5, respirable, PM10 and PM Total size fractions ranging from 0.001 to 150 mg/m³. Some models are also a fibrous aerosol monitor (FAM), which report the number of fibers per volume of air and are useful for real-time measurements of airborne asbestos.

Calibration

The Lab suggests factory calibration every two years and will arrange as necessary.

Special Considerations

Field zeroing is required prior to use. Certain instruments have been designed to satisfy the requirements for intrinsically safe operation in methane-air mixtures. Relative humidity conditions above 80 percent may result in readings which are higher than the actual dust concentration. Follow the manual for any necessary adjustments.

Maintenance

The unit will be cleaned as part of the calibration service. Follow the user manual in regards to field servicing. After prolonged operation or exposure to particulate-laden air, the interior walls and the two glass windows of the sensing chamber may become contaminated with particles. Although repeated updating of the zero reference will correct errors resulting from such particle accumulations, this contamination could affect the accuracy of the measurements as a result of excessive spurious scattering and significant attenuation of the radiation passing through the glass windows of the sensing chamber.

IV. Air Velocity Monitors/Indoor Air Quality (IAQ) Assessment Instrumentation

NOTE: Always record the barometric pressure and air temperature when using air velocity meters. Refer to the user manual to determine the operating range for temperature and pressure. The measurement uncertainty may be greater when used at temperatures above or below room temperature.

A. Flow Hoods

Application and Principle of Operation

A flow hood or balometer is an instrument used to measure volumetric air flow from supply or exhaust diffusers and grilles. The benefit of using a flow hood is that accurate measurements with a high degree of precision can be quickly obtained without measuring grille sizes and conducting repeated velometer measurements over the face of the diffuser or grille.

The flow hood can measure air volume, check HVAC system balance, verify air flow distribution within and between rooms, and in combination with other data, estimate the percent of outdoor air being supplied to a space. Additionally, if the diffuser area is known or measured, an accurate average linear air velocity can be calculated. Such applications may be important in assessing ventilation controls or conducting IAQ investigations. Other applications include determining volumetric airflow for dilution ventilation and evaluating airflow patterns to ensure that contaminants are not being pulled into unintended work areas.

Calibration

Field calibration is not available; the Lab suggests factory calibration every two years or as needed and will arrange as necessary.

Maintenance

These instruments typically require little field maintenance other than battery pack servicing and zero balancing of the analog scales. Check the manufacturer's user manual for details.

B. Thermo Anemometers

Application and Principle of Operation

A thermoanemometer (hotwire anemometer) is a handheld device with an extendable wand used to measure air speed (velocity). Due to their use of a heated wire, they are generally NOT suitable for use in hazardous areas where intrinsically safe equipment is required. Anemometers can be used to monitor the effectiveness of ventilation systems and local exhaust systems. In general, anemometers are appropriate for measuring laminar (nonturbulent) airflow. Multiple readings must be taken at different points in a plane which is perpendicular to the direction of airflow, and then averaged together. They are valuable when evaluating laboratory hoods for adequate face velocity. When the area of the hood face is known, the volumetric airflow can be estimated by taking multi-point traverse measurements across the face of the hood.

Anemometers can also be used to assess downdraft/sidedraft tables, slot ventilation, and interior duct speed. Interior duct speed can be estimated by taking a multipoint traverse. To ensure accurate readings, a duct traverse should not be taken within three duct diameters of any elbows, branches, fans or transitions due to turbulent airflow in these locations. Anemometers are not as useful for assessing snorkel-type local exhaust, due to generally turbulent airflow in the capture zone of a snorkel. For more guidance on the appropriate use of anemometers contact the Lab.

Ventilation smoke tubes are also available through the Lab and are a helpful complement to the anemometer. Smoke released inside an enclosing hood, such as a laboratory fume hood or spray booth, or outside an exterior hood, such as a snorkel, slot ventilation, canopy hood, downdraft table, or side draft hood, will help visualize whether contaminants will be effectively contained and/or captured. Ventilation smoke will also help determine whether supply air turbulence near a hood may compromise the hood's effectiveness.

Calibration

Field calibration is not available; the Lab suggests calibration every two years or as needed and will perform the service.

Special Considerations

While thermal anemometers can be very accurate, their accuracy may be adversely affected by air turbulence, temperature variations, or dirty probes. Note the manufacturer's limitations of use. Thermal anemometers are generally not intended for use in gas mixtures other than air, corrosive atmospheres, or other hazardous gas streams.

Maintenance

These instruments require little field maintenance other than battery pack maintenance and zero balancing of analog scales, if applicable. Check the manufacturer's user manual for details.

C. Other Air Velocity Meters

Other types of air velocity meters include rotating vane and swinging vane velometers. These are useful in circumstances where a thermo anemometer cannot be used, for example, corrosive atmospheres or other hazardous environments such as those requiring intrinsic safety. Rotating vane anemometers can also be used to assess snorkel-type local exhaust ventilation.

D. Bioaerosol Monitors

Application and Principle of Operation

Assessment of bioaerosols may be useful in certain IAQ investigations. A bioaerosol monitor, usually a two-stage sampler, is also a multi-orifice cascade impactor. This unit is used when size distribution is not required and only respirable-nonrespirable segregation or total counts are needed. 95 to 100 percent of viable particles above 0.8 microns in an aerosol can be collected on a variety of bacteriological agar. Trypticase soy agar (TSA) is normally used to collect bacteria, and malt extract agar (MEA) is normally used to collect fungi. Spore trap cassettes are also available to collect mold. Blood agar is typically used for collection of *Stachybotrys chartarum*.

Bioaerosol monitors can be used in assessing sick-building syndrome, or buildings which may have source exposures to molds and bacteria which may exacerbate or cause illness to the occupants. These samplers are also capable of collecting virus particles; however, there is no convenient or practical method for cultivation and enumeration of viral particles.

Calibration

Bioaerosol meters require a high flow sampling pump which must be flow-calibrated before use, using the same type of sampling media in the sampling train as will be used in the field. The Lab will provide a calibrated high flow pump for sampling.

Special Considerations

Prior to sampling, work with the Lab to determine the type of collection media required, sampling flow rates and times, and the analytical laboratory that will provide analysis. Ample time is required to obtain the appropriate media.

The Oregon OSHA Lab does NOT perform analysis of biological samples in-house. The Lab coordinates analysis of biological samples by contracted laboratories. When considering biological sampling, contact the Lab to discuss sampling requirements, technical support, assessment, and analytical coordination. The Lab staff will review the sampling and analysis plans with the CSHOs and make recommendations where appropriate. The Lab offers contracting services for analysis of fungi, bacteria (such as Legionella), and endotoxin. Other services can be arranged on a case-by-case basis. All biological sampling must have prior management approval.

Maintenance

The sampler should be decontaminated prior to use by sterilization or chemical decontamination by soaking in isopropanol for a few minutes and allowed to dry.

V. Vibration Monitors

Various types of measurements are of concern when measuring vibration and will generally be measured along three axes (x , y and z). Human response to vibration is dependent on several factors including the frequency, amplitude, direction, point of application, time of exposure, clothing and equipment, body size, body posture, body tension, and composition. A complete assessment of exposure to vibration requires the measurement of acceleration in well-defined directions, frequencies and duration of exposure.

A typical vibration measurement system includes an accelerometer to sense the vibration, a recorder, a frequency analyzer, a frequency-weighting network, and a display such as a meter, printer or recorder. The accelerometer produces an electrical signal in response to the vibration. The size of this signal is proportional to the acceleration applied to it. The frequency analyzer determines the distribution of acceleration in different frequency bands. The frequency-weighting network mimics the human sensitivity to vibration at different frequencies. The use of weighting networks gives a single number as a measure of vibration exposure (i.e., units of vibration) and is expressed in meters per second squared (m/s^2).

A. Hand-Arm Vibration

Application and Principle of Operation

Hand-arm vibration is generally measured when using a handheld power tool. First, the type of vibration which will be encountered is determined to ensure the correct accelerometer will be used. Vibration types can depend on whether an impact (e.g., jackhammer) or non-impact (e.g., grinder) tool is being used. The accelerometer will be attached to the tool (or held in contact with the tool by the user) so the axes are measured while the worker grasps the tool handle. The z axis is generally from the wrist to the middle knuckle, the x axis from the top of the hand down through the bottom of the hand and wrapped fingers, and the y axis from right to left across the knuckles of the hand. Measurements should be made as close to the point where the vibration enters the hand as possible.

The frequency-weighting network for hand-arm vibration is given in the International Organization for Standardization (ISO) standard [ISO 5349-1](#) (Mechanical Vibration - Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration – Part 1: General Requirements). The human hand does not appear to be equally sensitive to vibration energy at all frequencies. The sensitivity appears to be the highest around 8-16 Hz (Hertz or cycles per second), so the weighting networks will generally emphasize this range. Vibration amplitudes, whether measured as frequency-weighted or frequency-independent acceleration levels (m/sec^2), are generally used to describe vibration stress (American National Standards Institute, American Conference of Governmental Industrial Hygienists, ISO, and the British Standards Institution). These numbers can generally be read directly from the human vibration meter used. The recommendations of most advisory bodies are based on an exposure level likely to cause the first signs of Stage II Hand-Arm Vibration Syndrome (white finger) in workers.

OSHA does not have standards concerning vibration exposure. The American Conference of Governmental Industrial Hygienists (ACGIH) has developed Threshold Limit Values (TLVs) for vibration exposure to handheld tools. The exposure limits are given as frequency-weighted acceleration. The weighting is based on a scheme recommended in ISO 5349-1. Vibration measuring instruments have a frequency-weighting network as an option. The networks list acceleration levels and exposure durations to which, ACGIH has determined, most workers can be exposed repeatedly without severe damage to the fingers. The ACGIH advises that these values be applied in conjunction with other protective measures, including vibration control.

B. Whole-Body Vibration

Application and Principle of Operation

The measurement of whole-body vibration is important when measuring vibration from large pieces of machinery which are operated in a seated, standing, or reclined posture. Whole-body vibration is measured across three axes (x , y and z). The orientation of each axis is: z is from head to toe, x is from front to back, and y is from shoulder to shoulder. The accelerometer must be placed at the point where the body comes in contact with the vibrating surface, generally on the seat or against the back of the operator. The measurement device is an accelerometer, generally mounted in a hard rubber disc. Care should be taken to ensure that the weight of the disc does not exceed more than about 10 percent of the weight of the person being measured.

Calibration

These devices are sent back to the manufacturer for calibration on an as needed basis.

Special Considerations

The most widely used document on whole-body vibration is [ISO 2631-1](#) (Evaluation of Human Exposure to Whole-Body Vibration – Part 1: General Requirements). These exposure guidelines have been adopted as ACGIH TLVs. The ISO standard suggests three different types of exposure limits for whole body vibration, of which only the third is generally used occupationally and is the basis for the ACGIH TLVs:

1. The **reduced-comfort boundary** is for the comfort of passengers in airplanes, boats, and trains. Exceeding these exposure limits makes it difficult for passengers to eat, read or write when traveling.
2. The **fatigue-decreased proficiency boundary** is a limit for time dependent effects that impair performance. For example, fatigue impairs performance in flying, driving and operating heavy vehicles.
3. The **exposure limit** is used to assess the maximum exposure allowed for whole-body vibration. Two separate tables exist for exposures. One table is for longitudinal (foot to head; z axis) exposures, with the lowest exposure limit at 4 to 8 Hz based on human body sensitivity. The second table is for transverse (back to chest and side to side; x and y axes) exposures, with the lowest exposure limit at 1 to 2 Hz based on human body sensitivity. A separate set of "severe discomfort boundaries" is given for 8-hour, 2-hour and 30-minute exposures to whole-body vibration in the 0.1–0.63 Hz range.

The ACGIH recommendations are based on exposure levels that should be safe for repeated exposure, with minimal risk of adverse effects (including pain) to the back and the ability to operate a land-based vehicle.

Some general considerations for using vibration equipment include:

- Batteries should always be checked prior to use.
- Electrode cables - never kink, stretch, pinch or otherwise damage the cables.
- Remove the batteries from any meter that will be stored for more than a few days.
- Protect meters from extreme heat and humidity.

Oregon OSHA Lab Availability

The Lab maintains the Larson Davis HVM100 Human Vibration Meter, a portable multipurpose meter used for measurement of whole-body vibration, hand-arm vibration, hand-tool vibration, vibration severity and product compliance testing. It collects and analyzes data in accord with the most current ISO requirements for vibration exposures. It measures three input channels simultaneously, and a fourth channel calculates and stores vector sum information. Single and triaxial accelerometers attach to specialized mechanical mounting adaptors to allow measurement on a wide variety of tools and surfaces.

C. Mechanical Force Gauge for Ergonomic Evaluation

Application and Principle of Operation

Mechanical force gauges are frequently used for a wide range of force testing applications including testing of compressive and/or tensile forces. The gauges may be mounted to a test stand for even greater control and consistent results in repetitive testing applications. An easy to read concentric dial measures clockwise direction only. The dial rotates 360-degrees for taring. A peak hold button captures peak readings. Usually the gauges are available in pound, kilogram or Newton units of measure.

Calibration

Gauge accuracy should be checked periodically to ensure the gauge is within calibration limits. The calibration can be verified by applying known weight (adjusted for local gravity) to the extension hook. If adjustment is required, the gauge should be returned to the manufacturer for calibration.

VI. Heat Stress Instrumentation

Refer to the Oregon OSHA Technical Manual, Section III: Chapter 4 - Heat Stress for additional information on heat-related injuries and illnesses.

Application and Principle of Operation

There are multiple heat stress monitors available through the Lab. Heat stress monitors measure real-time area environmental conditions that can contribute to heat stress. The QUESTemp 34 Heat Stress Monitor measures indoor and outdoor wet bulb globe temperatures (WBGT). The temperature values can be data logged and the monitor can also be configured to sound an alarm when a predetermined WBGT is reached.

The area monitors work by taking measurements of the ambient temperature, the wet bulb temperature, and the globe temperature, and then using a formula to determine the WBGT. The wet bulb temperature considers the effects of humidity on the body's cooling mechanism and the globe temperature accounts for radiant heat on the worker. Outdoors, a WBGT is calculated by multiplying the wet bulb temperature by 0.7, the globe temperature by 0.2, and the dry bulb temperature by 0.1. Because radiant heat from the sun is not a factor indoors, or outdoors without a radiant heat load, the WBGT is calculated differently for indoor measurements. For indoor environments, the wet bulb multiplier is calculated the same as for outdoor, the globe temperature is multiplied by 0.3, and the dry bulb temperature drops out of the formula.

Calibration

Calibration is done annually by the Lab. Certain instruments have simple user calibrations that must be performed before each use in accord with the manufacturer's instructions.

VII. Nonionizing Radiation Monitors

Survey Meters and Personal Monitors

Application and Principle of Operation

Radio Frequency (RF) survey meters are used to measure both electric and magnetic fields from RF sources. RF meters must be selected based on the frequency of the radiation that is to be measured. Meters typically have interchangeable probes for measuring electric and magnetic fields. Some meters and probes are capable of performing spatial and temporal averaging for multiple frequencies and displaying measurement results in percent of exposure from guidelines recommended by one of several consensus standards.

RF personal monitors are used to measure personal RF exposures. These monitors are worn on the belt to continuously log personal exposures and provide an exposure result using a shaped frequency response. Induced currents from RF exposure can be measured using a clamp-on induced current meter. Induced currents in the arms and legs can be measured with these devices.

Calibration

These devices are sent back to the manufacturer for calibration on an as needed basis.

Oregon OSHA Lab Availability

The Lab has several monitors available for measuring RF, including a Narda NBM-550 with probes for measuring electric field strength from 0.5 MHz to 6 GHz and magnetic field strength from 5 MHz to 300 MHz. Contact the Lab to determine which meter is best suited for the application. A Holaday HI 3002 Broad Band RF Meter is also available from Federal OSHA's Cincinnati Technical Center and can be pre-arranged to use with sufficient advance notice.

The Holaday HI 3002 Broad Band RF Meter is used to monitor occupational exposures to RF sources within the frequency range of electric fields from 0.5 MHz to 6 GHz and magnetic fields from 5 MHz to 300 MHz. The unit continuously logs RF exposure levels. Note that the exposure limit for microwave radiation in general industry is a 6-minute STEL, and that the primary effect of microwave radiation exposure is heating of body tissues, with the most sensitive organs being the eyes and testes, see [29 CFR 1910.97\(a\)\(2\)\(i\)](#).

APPENDIX A. Instrument Chart

The information shown in the table below is for reference only. Not every field office will have every type of instrument. Refer to the [Oregon OSHA Lab website](#) for specific information.

INSTRUMENT USE		
Physical Measurements		
Type of Instrument	Measured Substance	Application
Stopwatch	Time	Calibration
Tachometers	Mechanical speed	Flywheels, belts, cylinders, lathes, etc.
Ergonomic testing equipment	Force	Force measurements for ergonomic assessment
Electrical testers and multimeters	Electricity	Electrical circuits
Vibration meters	Vibration	Handheld power tools, bearings, gear trains, housings, walls
Thermoanemometer (air velocity meter)	Airspeed	Ventilation assessments
Detector tubes with hand pumps (bellows or piston style)	Chemical air contaminants	Screening, spot measurements
Pressure gauges	Air Pressure	Compressor air lines
Fibrous aerosol monitors	Fibers in air	Asbestos
Dust monitors (particle or respirable aerosol monitors)	Total dust, respirable dust	Mines, sandblasting, road construction, dusty operations, indoor air quality
Gas & Vapor Meters		
Multi-gas meters	Combustible gas (LEL), oxygen (O ₂), carbon monoxide (CO), carbon dioxide (CO ₂), and hydrogen sulfide (H ₂ S)	Confined spaces, underground construction, sewers
Toxic gas sensor, hydrogen sulfide	H ₂ S	Farms, sewers, underground construction
Toxic gas sensor, hydrogen cyanide	HCN	Industrial facilities, electroplating operations
Toxic gas sensor, sulfur dioxide	SO ₂	Paper mills, bleaching operations
Toxic gas sensor, nitric oxide and nitrogen dioxide	NO and NO ₂	Combustion sources, particularly from propane fuel
Toxic gas sensor, chlorine and chlorine dioxide	Cl ₂ and ClO ₂	Bleaching and disinfecting operations, plastics manufacture, chemical synthesis, other industrial operations
Toxic gas sensor, ammonia	NH ₃	Industrial refrigeration, fertilizer, animal feed lots
Toxic gas sensor, phosphine	PH ₃	Semiconductor manufacture, agricultural pesticides
Carbon monoxide monitor	CO	Garages, warehouses, other combustion sources, indoor air quality
Carbon dioxide monitor	CO ₂	Indoor air quality, as a surrogate for other indoor source pollutants
Infrared analyzers	CO, CO ₂ , organic substances	Area surveys to determine locations with highest concentrations, waste anesthetic gases, fumigants, indoor air, leaks, spills
Photoionization Detectors (PIDs)	Hydrocarbons, other ionizable substances	Area surveys to determine locations with highest concentrations, indoor air, leaks, spills
Mercury vapor meters	Hg	Mercury plants, spills
Ozone Analyzers	O ₃	Water or air purification, indoor air

Radiation Meters		
Heat stress meters	Ambient (environmental) heat	Foundries, furnaces, ovens, and outdoor work locations
Light meters	Light (illumination)	Indoor lighting, UV exposure
Microwave meters	Microwave radiation	Communications, microwaves, heaters
Radiofrequency instruments	Electromagnetic fields	RF heat sealers, VDTs, induction motors
Magnetic field testers	Magnetic Flux Density	Magnetic fields
Electrostatic field tester	Static electric fields	Hazardous locations
Ionizing radiation meters	Ionizing radiation	Nuclear plants, nuclear waste, laboratory and medical settings
Biological Monitors		
Microbial sampler	Micro-organisms (microbes)	Indoor air quality

APPENDIX B. Chemical Warfare Agent Detection

There are several methods and types of instruments that can be used in the detection of chemical warfare agents, such as nerve, blister, blood, and choking agents. However, most of these agents (nerve and blister) have extremely low occupational exposure limits, and nearly all the detection methods lack the sensitivity required to provide results at these low levels. It is important to understand the capabilities, uses, and limitations of each type of detection device or instrument. The manufacturer of each system provides clear and specific use instructions with each kit. Users should familiarize themselves with these instructions, know the limitations of each device or instrument, and practice the use of the kits while wearing appropriate PPE in a non-contaminated environment. The following sections highlight some types of equipment that are used for detection of chemical warfare agents. Generally, use of these detection systems will be limited to specially trained and equipped personnel. Chemical warfare agent detection is not offered by the Lab. CSHOs should contact their Health or Safety manager to determine appropriate arrangements to pursue chemical warfare agent detection. The following summarizes specialized direct-reading capabilities and should be considered informational by all personnel.

A. MILITARY DETECTION PAPERS/KITS

1. M8/C8 Detector Paper

The M8 detector paper was developed to detect liquid agents, specifically V- and G-type nerve agents, and H-type blister agents. The C8 paper is equivalent to the M8 paper; the "C" indicates a version manufactured for commercial use. These papers do *not* detect chemical agent vapors. The sheets are impregnated with chemical compounds that change to green, yellow, or red depending on the type of liquid agent encountered. A color chart accompanying the booklet helps determine the type of agent detected. The result is qualitative, but the detector paper has a sensitivity of about 20 microliters (μL) of liquid. Some substances can act as interferences and produce false positives, such as insecticides, antifreeze, and petroleum products. A similar product, termed "3-way" paper is also available. This detector paper is equivalent to the M8/C8 papers, except that it includes an adhesive backing that can be used to apply the paper to equipment or PPE.

2. M9 Detector Paper

The M9 paper detects the presence of liquid nerve and blister agents by turning a reddish color. It does not distinguish the type of agent, nor does it detect chemical agent vapors. It will detect a liquid agent droplet with a diameter of approximately 100 micrometers (μm). Interfering substances that will produce a false positive include petroleum products, antifreeze, and insecticides. The papers come in a roll and are adhesive-backed.

3. M256A1 Detector Kit

The M256A1 Chemical Agent Detector Kit is designed to detect and identify chemical agent vapors, including blood (AC and CK), blister (H, HN, HD, CX, L), and nerve (V and G series) agents. The test consists of a series of chemical ampules that are broken and exposed to the air. The reagents in the ampules react with chemical agent vapors to produce a color change. A color chart and instructions included with the kit are used to determine the type of agent(s) that is/are present. The M256A1 is relatively sensitive, and can detect some of the agents below the [IDLH](#) levels and also includes booklets of M8 paper for detecting liquid agents.

4. C-2 Detector Kit

The C-2 Chemical Agent Detector Kit is used by the Canadian Military for detecting chemical agent vapors. The C-2 kit utilizes various colorimetric detection tubes for identifying nerve, blister, blood, and choking agents. Similar to the M256A1 kit, it allows detection of some agents below IDLH levels and contains a booklet of M8 paper for use with detection of liquid agents.

B. COLORIMETRIC TUBES

Colorimetric tubes are made by several manufacturers and functionally the same. They contain a series of tubes which can be used to detect airborne chemical agents and other toxic chemicals. Conducting a single test with one or more tubes takes two to five minutes to complete. There are some tubes, such as those for blister and nerve agents, which give a qualitative detection of the presence of that family of chemicals up to near IDLH levels. The industrial agents (blood agents and choking agents) can be specifically identified and quantitatively measured in ppm to levels below applicable exposure limits. An example of colorimetric tubes designed specifically for chemical agents is the Dräger Civil Defense Simultest (CDS) Kit.

C. PORTABLE CHEMICAL AGENT DETECTORS

Most types of portable, traditional chemical detection equipment, such as photoionization detectors, flame ionization detectors, electrochemical sensors, infrared analyzers, etc. can be used for chemical agent detection. These types of instruments are discussed in other sections of the Technical Manual. However, due to the acute toxicity of chemical warfare agents at very low concentrations, these instruments lack adequate sensitivity and cannot provide detection below IDLH levels. Some instruments have been developed for use specifically with chemical agents, and research is ongoing. Some of the more popular technologies and instruments are discussed below.

1. Ion Mobility Spectrometers

An ion mobility spectrometer (IMS) operates by drawing air into the instrument where it is ionized with a radioactive source. The ionized molecules travel through a charged tube, where they become separated according to their mass and mobility before reaching a collector electrode. An electronic signature is produced for each ion, which gives an indication of the type and relative concentration of agent present. IMS detectors are used mainly to detect nerve, blister, and blood agents. Examples of IMS detectors include the Chemical Agent Monitor (CAM), Improved Chemical Agent Monitor (ICAM), APD 2000 (Advanced Portable Detector), and SABRE 4000.

These instruments will not detect at levels below IDLH for most chemical agents. They are best used for site reconnaissance, or to screen for contamination on equipment or personnel. Some interferences that may cause false alarms with an IMS include the following: cleaning compounds and disinfectants containing additives such as menthol and methyl salicylate (oil of wintergreen); aromatic vapors, such as perfumes and food flavorings; and exhaust from some motors and fumes from explosives and propellants.

2. Surface Acoustic Wave

Surface acoustic wave (SAW) sensors are comprised of piezoelectric crystals with selective surface coatings. As the mass of a chemical vapor sample flows over the sensors, it is absorbed onto the surface which results in a change in vibration frequency of the sensor. An internal microprocessor in the instrument measures these changes, providing detection and identification of the chemical agent. Portable instruments utilizing SAW technology are available for detection of nerve and blister agents. Examples of SAW instruments include the HAZMATCAD and SAW MiniCAD. As with IMS detectors, SAW instruments will not allow detection of most chemical agents below IDLH levels. However, SAW detectors are less susceptible to false positive alarms from interfering substances.

D. GAS CHROMATOGRAPHS/MASS SPECTROMETERS

Additional instruments that can be used for chemical agent detection and identification are gas chromatographs (GC) and mass spectrometers (MS). These are generally laboratory-type instruments which require skilled laboratory technicians for operation and interpretation of results. A few have been hardened for use in vans and portable handheld units can be used in the field; however, the technicians normally must collect a sample from the suspect material and bring it to the instrument. Currently, the GC or GC/MS is the only instrument that can verify the concentrations of nerve agents down to levels which are below applicable occupational exposure limits. This is important for applications where it is important in determining the appropriate types and levels of PPE or to verify that decontamination is complete.

Note: The Salt Lake Technical Center's Health Response Team (HRT) serves as the coordinator for OSHA's SRTs and can provide additional assistance and technical information regarding chemical warfare agent detection. Special precautions, such as PPE and/or other work practices, are also necessary to prevent exposure when working with chemical warfare agents.

APPENDIX C. Biological Agent Detection

Sampling and analysis for biological agents is a rapidly growing field under constant development. Various factors are considered when sampling for biological agents, including: method of dispersion for the agent, purpose of the sampling (to identify the agent, determine extent of contamination, confirm decontamination, etc.), environmental conditions, persistence and physical state of the agent, area/volume to be sampled, laboratory protocols. It is important to note that biological agents (such as bacteria, viruses, and endotoxins) are particulate matter, and, therefore, detection methods are designed for particulate sampling. Biological agent detection is not offered by the Lab. CSHOs should contact their manager to determine appropriate arrangements to pursue biological agent detection. The following sections highlight some types of equipment that may be used for sampling and detection of biological agents.

A. SURFACE/BULK SAMPLING

1. Swabs

Swabs have been used frequently when sampling surface areas for the presence of biological agents. Swab tips come in a variety of materials, such as cotton, Dacron, polyester, rayon, and foam. Shafts can be comprised of either wood or plastic. Generally, synthetic swab tips with plastic shafts are recommended because they are not of biological origin and will not interfere with DNA-based detection systems. Swabs may be used dry or wetted with a buffer solution. In general, studies have shown that wet swabs have higher collection efficiency than dry swabs.

2. Wipes and Sponges

Wipes and sponges are often used because they can sample larger surface areas and have a higher collection efficiency compared to swabs. They can also be used in a dry or wet fashion. Various styles and materials for wipes and sponges are available. As with swabs, synthetic materials are recommended to eliminate potential interference problems with detection systems.

3. Vacuum Methods

Vacuum methods can be used when necessary to sample large surface areas or surfaces which are porous or irregular, such as carpeting, where it is impractical to use wipes. These methods are also useful to gather bulk dust samples. One method utilizes a HEPA-filtered vacuum equipped with a dust collection filter sock to capture the sample. Large surface areas can be vacuumed, and the dust gathered in the sock analyzed for the presence of biological agents. A similar method uses a portable sampling pump equipped with a filter cassette to "vacuum" particulate matter from smaller areas, and at lower flow rates. The filter can then be analyzed.

4. Agar Plates

Agar plates can be used to sample a surface by contacting the plate directly to the surface. The particles from the surface will adhere to the plate, which can then be analyzed by culture to identify any biological agents.

B. AIR SAMPLING

Air sampling can be performed to determine the presence of airborne biological particulates. Essentially, a volume of air is drawn through a filter or deposited in another medium, and the captured particulates are then analyzed to identify biological agents. High flow rates are generally desirable because this allows higher sample volumes and increases the likelihood of detecting the suspect agents. However, it should be noted that some organisms are fragile, and the high velocities and impact mechanisms may kill the organism during the sampling process.

Low flow air sampling methods consist of traditional personal sampling pumps equipped with capture devices such as filter media or liquid impingers. Low flow methods have the advantage of being small and portable; however, due to their low sample volume they will have a relatively high limit of detection.

Impactors, such as the Six Stage Viable Andersen Cascade Impactor, utilize higher flow rates (around 30 L/min), sample a greater air volume, and, therefore, increase the likelihood of detecting the agent. This and similar types of impactors capture the biological particulate directly on an agar plate which can then be analyzed in a laboratory by culture method.

High volume area samplers are also available for biological agents. These samplers possess flow rates ranging from 200 to 600 L/min, so they are able to sample very large volumes of air. Some instruments deposit the particulate matter on a filter, while others capture it in a liquid solution.

C. GENERIC DETECTION

There are several techniques and instruments available that will allow responders to perform a generic detection for biological agents. These methods will not identify a specific agent, but can be used to determine if a suspect material is of biological origin, and to rule out hoax materials. The following are some examples of equipment types:

1. **Particle Analyzers:** The particle size of a sample can be analyzed and compared to known size ranges for biological materials. If the particle size is too large or too small, biological materials can be ruled out.
2. **Fluorometer:** These instruments will detect the presence of DNA, which is a component of most biological materials. A positive response by the meter for a given sample indicates a biological material, but again, does not identify the material or agent.
3. **Luminometer:** A luminometer operates similarly to a fluorometer except that it will detect the presence of adenosine triphosphate (ATP) in a sample. ATP is another component of a cellular organism, thereby indicating a biological material.
4. **Colorimeter:** Colorimeters can be used to detect protein in a sample. Protein is present in biological organisms so these instruments can indicate if the material is biological in origin.

5. **Protein Paper:** Similar to a colorimeter, these paper strips can indicate if a given sample contains protein, and is, therefore, biological.
6. **pH Paper:** The pH of a sample is tested with pH paper strips; if the pH range is between 5 and 9, the material *may* be biological. If the pH is outside this range (below 5 or above 9), then biological materials can be ruled out.

D. IDENTIFICATION

1. Immunoassay/Handheld Assay

An immunoassay test, also known as a handheld assay (HHA), can be performed on a sample to identify a specific agent. HHA tests rely on an antigen/antibody reaction to identify the suspect agent. The test is presumptive, meaning that a given agent must be suspected and then tested with its specific HHA for confirmation. For example, if *Bacillus anthracis* (anthrax) is suspected, the sample is tested using an HHA designed for *Bacillus anthracis*; a positive result confirms the presence of the organism while a negative result indicates the sample does not contain that specific organism. HHA units are small, can be used in the field, and rely on visual colorimetric changes for sample results. Some HHA systems come with an electronic reader to aid in detecting the colorimetric change.

HHAs are under scrutiny due to limitations on sensitivity and specificity; i.e., high rates of false-negative and false-positive results. Results from an HHA test should not be solely relied upon and further confirmatory analysis should always be performed. However, these tests are useful to first responders as a rapid field test, and although presumptive, their results can assist decision makers in taking protective actions, treating potential infections, and involving other authorities as necessary.

2. Polymerase Chain Reaction

Polymerase chain reaction (PCR) is a system that allows identification of an agent based on its DNA. The DNA from the sample is obtained and reproduced rapidly to produce a quantity that is detectable by the instrumentation. For example, after 30 cycles with the PCR system, one copy of DNA from an agent sample can be reproduced until there are one billion copies, which can then be analyzed and identified.

PCR is performed real-time through detection by fluorescence. During the PCR cycle, DNA-specific "probes" with fluorescent dyes are attached to the DNA sample which allows detection. PCR can be performed in a laboratory, or in the field with semi-portable instrumentation. Specific reagents and supplies are necessary to perform the analysis.

PCR has been useful for biological agent detection because it has excellent sensitivity, good specificity, and provides real-time results. Some weaknesses of PCR to consider are: potential interferences from other substances in the sample, reagent stability, and sample viability. PCR will detect the presence of both live and dead organisms, but will not distinguish between both.

3. Culture

Analysis by culture is considered by many to be the "gold standard" for the identification of biological agents. Samples are sent to a laboratory where they are prepared and applied to an agar plate on which the suspect biological organisms are allowed to grow. After a sufficient period of time (usually 24 hours or more), visible growth can be examined to detect the presence of the biological agent(s). Often, culture is used for the confirmatory analysis of previous detection methods for a given sample (HHAs, PCR). Some disadvantages of culture include delayed results and the procedure will only detect living organisms. Any biological agent that has died before the analysis has begun will not be detected. Note that biological toxins or allergens associated with nonviable/nonculturable agents may still cause health effects.

Note: The Salt Lake Technical Center's Health Response Team (HRT) serves as the coordinator for OSHA's biological SRT and can provide additional assistance and technical information regarding biological agent detection. Special precautions such as PPE and/or other work practices are also necessary to prevent exposure when working with biological agents.

APPENDIX D. Ionizing Radiation Monitors and Meters

The following sections contain a brief description of the types of instruments that may be used for monitoring exposures to ionizing radiation and radioactive materials.

A. SURVEY METERS

Application and Principle of Operation

Radiation survey meters are used to locate and quantify sources of ionizing radiation or to quantify the exposure rate from sources of ionizing radiation. To assess the quantity of radioactive materials present, survey meters are typically calibrated to measure counts per minute (cpm). To measure the exposure rate from gamma (γ) or X radiation sources, survey meters are calibrated to measure roentgens per hours (R/h). Most survey meters have either gas filled detectors or scintillation detectors. Not all survey meters are configured to measure all radiation types. Survey meters must be chosen based on the type and energy of the radiation expect to be measured and whether cpm or R/h are to be expressed.

Calibration

Calibration is performed by the manufacturer on an annual basis.

Oregon OSHA Lab Availability

Technical Associates PUG 1: a general purpose survey meter fitted with a Geiger Mueller (GM) detector capable of measuring alpha (α), beta (β), gamma (γ), and X radiations. This instrument will measure count rates over a range of 0–500,000 cpm.

The following radiation survey meters and techniques are not available from the Lab and is for informational purposes only.

B. SCALARS

Application and Principle of Operation

Scalars are used to analyze samples of radioactive material and to quantify the amount of material present. They are often used to measure the amount of radioactive material in air samples, wipe samples, and nasal swabs. Scalars use the same detector types used in survey meters. These instruments can typically be set to count a sample for a specified time.

C. ELECTRONIC PERSONAL DOSIMETERS

Electronic personal dosimeters are used to measure the dose received by an individual. They are normally worn on the front of the body in the chest area. Most electronic dosimeters measure the deep dose equivalent (Hp(10)) to γ radiation. Some electronic dosimeters also measure the shallow dose equivalent (Hp(0.07)). Most electronic dosimeters allow the user to set alarms for integrated dose and/or dose rates.

D. SPECTROSCOPY

Portable handheld radiation spectroscopy instruments allow the user to identify radionuclides. These instruments typically use a sodium iodide detector with a multichannel analyzer to measure the energy spectrum emitted by a radioactive source. The instrument compares the spectrum to a library of spectra and provides the user with a list of likely sources. Spectra can also be downloaded to a computer if the user wishes to perform the spectral analysis manually or wishes to print the spectra for documentation.

E. ELECTRET-PASSIVE ENVIRONMENTAL RADON MONITORING

The Electret-Passive Environmental Radon Monitor (E-PERM) system is a passive integrating detector system for the measurement of radon (^{222}Rn) or thoron (^{220}Rn) concentrations in air. It consists of a charged Teflon disk (electret), an open-faced ionization chamber, and an electret voltage reader. When the electret is screwed into the chamber, an electrostatic field is established and a passive ionization chamber is formed. The chamber is deployed directly in the area to be measured. Radon gas diffuses passively into the chamber and the α particles emitted from the decay of radon ionize the air molecules. These ions are then attracted to the charged surface of the electret, and the charge on the electret is reduced. The electret charge is measured before and after the exposure with a portable electret voltage reader, and the rate of change of the charge (change divided by the time of exposure) is proportional to the concentration of radon in the area.

F. RADIATION PPE AND SHIELDING

In radioactively contaminated areas, PPE is typically used in order to prevent workers from becoming contaminated, and to minimize the spread of radioactive contamination. The choice of appropriate shielding for ionizing radiation depends on the type and energy of the radiations to be shielded. Alpha particles have very low penetrating power and travel only a few centimeters in air and will not penetrate the dead outer layer of skin. Shielding is generally not required for alpha particles because external exposure to alpha particles delivers no dose. Where particulates contaminated with alpha particles are present, HEPA-filtered respiratory protection is critical to prevent an internal dose. Beta particles can travel several meters in air and can penetrate several millimeters into the skin. Beta particles should be shielded using an appropriate thickness of low atomic mass (low-Z) materials such as aluminum or plastics (e.g., Plexiglas). Shielding beta particles with high-Z materials should be avoided as this can result in production of secondary X radiation (i.e., bremsstrahlung radiation). Gamma and X-rays can travel kilometers in air and can penetrate deep into the human body or pass through it entirely. Gamma and X-rays are most efficiently shielded using an appropriate thickness of high-Z materials such as lead or steel, or with an appropriate thickness of concrete. Neutrons are most efficiently shielded using an appropriate thickness of hydrogenous materials such as paraffin, water, or plastics, or with an appropriate thickness of concrete.

Note: The Salt Lake Technical Center's Health Response Team (HRT) serves as the coordinator for OSHA's radiation SRT and can provide additional assistance and technical information regarding radiation measurements. Special precautions are also necessary to prevent exposure when working with radioactive materials, such as PPE and/or other work practices.