SECTION II: CHAPTER 3

TECHNICAL EQUIPMENT: ON-SITE MEASUREMENTS

Contents:

I. Introduction
II. Direct-Reading Instrumentation
III. Chemical Warfare Agent Detection
IV. Biological Agent Detection
V. Radiation Monitors and Meters
VI. Air Velocity Monitors/Indoor Air Quality (IAQ) Assessment Instrumentation
VII. Noise Monitors and Meters
VIII. Vibration Monitors
IX. Electronic Test Equipment
X. Heat Stress Instrumentation

Appendix II: 3–1. Batteries
Appendix II: 3–2. Availability, Calibration, Maintenance and Repair of Equipment: Cincinnati Technical Center (CTC)
Appendix II: 3–3. Instrument Chart

I. Introduction

The purpose of this chapter is to provide a broad overview of the types of equipment and instrumentation available for use by 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.

II. Direct-Reading Instrumentation

Direct–reading instruments (sometimes termed real-time instruments) provide information at the time of sampling, thus enabling rapid decision-making. These instruments can often provide the trained and experienced user the capability to determine if site personnel are exposed to concentrations which exceed instantaneous (ceiling or peak) exposure limits for specific hazardous materials. 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. Periodic monitoring of airborne levels with a real-time monitor is often critical, especially before and during new work activities. Data obtained from direct-reading monitors can be used to evaluate existing health and/or safety programs and to assure proper selection of personnel protective equipment (PPE), engineering controls and work practices.

The following general considerations apply to instrumentation which might be used in potentially explosive atmospheres or in atmospheres which may contain highly toxic airborne chemicals (as defined by 29 CFR 1910.1200 App. A and noted below) and/or carcinogenic chemicals that may have contaminated surfaces or may be found in airborne concentrations:

III.

1. Instruments shall not be used in atmospheres where the potential for explosion exists (see 29 CFR 1910.307) unless the instrument is listed by a Nationally Recognized Testing Laboratory (see 29 CFR 1910.7) for use in the type of atmosphere present. Check the class and division ratings prior to use. When batteries are being replaced, use only the type of battery specified on the safety approval label. Do not assume that an instrument is intrinsically safe. If uncertain, verify by contacting the instrument's manufacturer or the Cincinnati Technical Center (CTC).

2. For atmospheres containing carcinogens or highly toxic chemicals, a plastic bag should be used to cover equipment to limit contamination. Ensure that the plastic bag is not tightly sealed as this can cause back pressure on the pump. Properly decontaminate all equipment to minimize potential contamination of persons or objects when sampling is complete. To the extent possible, gross decontamination should be performed after use on-site.

NOTE: Definition of Highly Toxic from Appendix A of 1910.1200

"Highly toxic:" A chemical falling within any of the following categories:

(a) A chemical that has a median lethal dose (LD_{50}) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

(b) A chemical that has a median lethal dose (LD_{50}) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.

(c) A chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million (ppm) by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

A. Photoionization Meters

Application and Principle of Operation:

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

The ability of a chemical to be ionized is a function of its ionization potential (IP). 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. Typically, PID detectors will come equipped with a UV lamp at 10–10.6 electron volts (eV). Tables listing the IP for chemicals and their relative sensitivity are generally available from the manufacturer. Higher energy lamps (11.7 eV for the Photovac Model 2020Pro) are available to detect chemicals which have high IPs. For example, methylene chloride requires use of the 11.7 eV lamp for detection because the IP for methylene chloride is 11.35 eV. In general, these higher energy lamps have a much shorter lifetime than the 10.6 eV lamps.

In general, aromatic hydrocarbons such as benzene, toluene and xylene provide a sensitivity of approximately 0.1 ppm with photoionization detection. Unsaturated hydrocarbons, alcohols, ethers, and chlorinated hydrocarbons have intermediate sensitivity by PID, and saturated hydrocarbons such as n-hexane tend to be the least sensitive. For example, n-hexane is approximately 1/10 as sensitive as benzene by PID. While it might be expected that the sensitivity of a chemical would be related to its IP, this is not always the case. For example, benzene with an IP of 9.245 eV, and which has a relatively high sensitivity by photoionization detection, is actually slightly less sensitive than vinyl bromide with an IP of 9.80 eV.

Calibration:

In many instances a reference gas is used to calibrate the PID. Frequently, isobutylene gas in air is used as a calibration gas. The meter can then be used to read directly in isobutylene units. If gases other than isobutylene are measured, the isobutylene units can be converted using the appropriate response obtained from the instrument manual for the PID meter used. For example, if the response factor listed in the manual for benzene (relative to isobutylene) is 0.5 and if a meter which had been calibrated with isobutylene was used to measure benzene, the actual benzene concentration in air will be one half of the meter reading. Thus, if the meter reads 5.8 ppm isobutylene in a benzene atmosphere, the benzene concentration is actually 2.9 ppm. Similarly, if the meter reads 10 ppm isobutylene in an atmosphere of ethyl acetate, the ethyl acetate concentration is 38 ppm because the response factor for ethyl acetate is 3.8.

Many PID meters are programmed with internal response factors based upon isobutylene gas and the instrument can be set up to read ppm for the gas of interest. Direct calibration of the instrument, or verification of the calibration if stored response factors are used to calibrate the instrument, is desirable. This can be done by testing a known concentration of an atmosphere containing the chemical of interest prepared in a gas bag.

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 and also the accumulation of organic deposits on the surface of the lamp will reduce sensitivity. A buildup of film on the lamp will reduce the sensitivity of the meter. The meter also has a reduced sensitivity in high humidity. One manufacturer (RAE Systems) reports up to a 30% reduction in response for measurements in high humidity air when compared to calibration of the same chemical

in dry air. For the most accurate results, it is best to calibrate the meter using representative air.

MicroRAE also reports that a "quenching effect" can be observed in which the UV lamp light rays are scattered by the presence of non-ionizable gas molecules. 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.

Maintenance:

Follow the manufacturer's recommendations for maintaining the detector in optimal condition. This will include routine cleaning of the UV lamp and frequent replacement of the dust filter. Because of the fragile nature of the lithium fluoride window on the 11.7 eV lamps, special precautions must be followed and cleaning should only be done using Freon or chlorinated solvents. 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

Application and Principle of Operation:

Infrared (IR) analyzers are useful for measuring a broad range of inorganic and organic chemicals in air. Depending upon the chemical, the sensitivity of IR analyzers can be sufficient for industrial hygiene purposes. Because most chemicals absorb IR light, an infrared analyzer may not be selective unless the chemical of interest can be measured at a wavelength which is unique for that chemical in the air sample, or the industrial hygienist is able to determine that other interfering chemicals are not present in the work environment. Some of the routine applications for IR analyzers include measuring carbon dioxide in indoor air quality (IAQ) assessments; anesthetic gases, including, nitrous oxide, halothane, enflurane, penthrane, and isoflurane; ethylene oxide; and fumigants, including ethylene dibromide, chloropicrin, and methyl bromide.

IR analyzers emit an infrared light which is generated from a heated metal source. The infrared portion of the electromagnetic spectrum typically used in infrared analysis ranges from the far infrared region at 400 cm^{-1} (25 micrometers) to the near infrared region 4000 cm^{-1} (2.5 micrometers). The amount of infrared light that a chemical absorbs varies with the particular wavelength of light to which it is exposed. For example, acetone, which is a ketone, has a strong, broad absorption band around 1720 cm^{-1}, whereas alcohols have a strong, sharp absorbance band at approximately 3610–3670 cm^{-1}. Because the absorbance of infrared light by a chemical changes with the wavelength of incident light, an absorption pattern, or unique spectrum for the chemical, can be produced by measuring the absorbance of the incident light for a chemical over the 400–4000 cm^{-1} infrared range. This infrared absorbance spectrum can be compared to a library of known chemicals for identification purposes.

For measuring the amount of a chemical in air, a wavelength is selected for which the chemical of interest absorbs the light. The amount of light absorbed by the air sample at this

wavelength would be proportional to the amount of the chemical in the sample if there is no other chemical present in the air which absorbs at that same wavelength. 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 that 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 microns. If methyl acrylate was also known to be present in the air, the 11.0 micron IR wavelength would be selected because methyl acrylate absorbs at 8.4 microns.

The sensitivity of IR detection can also be varied by changing the path length through which the light source passes. This is accomplished by internally mounted mirrors within the analyzer which can vary the path length for the light source for the Miran 205B analyzer from 0.5 meters to 12.5 meters.

Calibration:

The Miran 205B analyzer is pre-calibrated for a list of chemicals which are stored in the instrument library. A sampling loop kit which recirculates a known volume of air is available for the instrument which allows the injection of a known amount of a volatile liquid or gas into the IR sampling cell. In this fashion, the instrument's pre-calibration can be verified prior to and after its use. Instrument zeroing is performed by using a charcoal filter attachment to remove chemicals from the air.

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 ammonia and many alkyl amines, such as methyl amine.

Maintenance:

Field maintenance is limited to replacement of the zeroing filter after 30 uses and replacement of the particulate filter in situations where adsorbed particulates or non-volatile liquids may have contaminated the filter surface. Field calibration is conducted according to the manufacturer's recommendations.

Gas, Oxygen and Explosibility (Combustible Gas) Monitors

C. Gas Monitors

Application and Principle of Operation:

This monitor uses an electrochemical voltammetric sensor or polarographic cell to provide continuous analyses and electronic recording. In operation, sample gas is drawn through the sensor and 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. The sample concentration is displayed directly in parts per million, % oxygen or % LEL (lower explosive limit). Since the method of analysis is not absolute, prior calibration against a known standard is required. Tests have shown the method to be linear; thus, calibration at a single concentration, along with checking the zero point, is sufficient. The oxygen meter displays the concentration of oxygen in percent by volume measured with a galvanic cell. Other electrochemical sensors are available to measure carbon monoxide, hydrogen sulfide, and other gases. Some units have an audible and/or visual alarm that warns of low oxygen levels, LEL or malfunction. These pieces of equipment generally rely on the passive diffusion of air into the detector, however, some applications will require the user to attach a mechanical pump to actively draw air into the sensor.

Calibration:

Calibrate the direct-reading gas monitor with the appropriate calibration (span) gases before and after each use in accordance with the manufacturer's instructions. 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. The unit's instruction manual provides additional details on the calibration of sensors.

Special Considerations:

Interference from other gases can be a problem (see manufacturer's literature).

If the span gas is directly fed into the instrument from a pressurized cylinder equipped with a regulator, the pump must be disconnected from the sensor to avoid sensor damage and the span gas flow rate should be set to match the sampling rate of the pump.

D. Oxygen Monitors

Application and Principle of Operation:

Oxygen measurements are usually made along with combustible gas measurements for confined spaces. Oxygen meters typically use galvanic electrochemical cells (sensors). 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% by volume in air. Normal air contains about 20.9% oxygen. Meter alarms are usually set to indicate an oxygen-deficient atmosphere at concentrations lower than 19.5% and an oxygen-rich atmosphere at concentrations greater than 23.5%.

Calibration:

Calibration is typically accomplished using fresh outdoor air (20.9% oxygen). Calibrate immediately before testing at or near the temperature of the tested atmosphere.

Maintenance:

Oxygen sensors are inherently self-consuming and generally last from 6 to 12 months. Some sensors can be reactivated by returning them to the manufacturer, but in most cases, an exhausted sensor is discarded and replaced with a new one.

E. Explosibility (Combustible Gas) Monitors

Application and Principle of Operation:

These meters use elements which are made of various materials such as platinum or palladium as an oxidizing catalyst. The element is one leg of a Wheatstone bridge circuit. These meters measure gas concentration as a percentage of the lower explosive limit of the calibrated gas.

Calibration:

Before using the monitor each day, calibrate it with a known concentration of appropriate combustible gas (usually methane in air) equivalent to 25-50% LEL full-scale concentration. Follow manufacturer's instructions.

Special Considerations:

Silicone compound vapors and sulfur compounds will cause desensitization of the combustible sensor and produce erroneous (low) readings.

High relative humidity (90%-100%) 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.

In drying ovens or unusually hot locations, solvent vapors with high boiling points may condense in the sampling lines and produce erroneous (low) readings.
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.

For gases and vapors other than those for which a device was calibrated, users should

consult the manufacturer's instructions and correction curves.

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.

F. Detector Tubes

Application and Principle of Operation:

Detector tubes and their associated pumps are portable equipment capable of measuring concentrations of a large number of gases and vapors present in industrial atmospheres. Detector tubes of a given brand are to be used only with a pump of the same brand. A 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. Always review the manufacturer’s recommendations and guidance for chemical–specific detector tubes.

Detector tube pumps can be hand-held during operation (weight: 8-11 ounces), or they can be an automatic type (weight: about 4 pounds) that samples using a preset number of pump strokes. A full pump stroke for either type of short-term pump has a volume of about 100 mL.

There is a wide variety of commercially available detector tubes. Their operation consists of using a pump to draw a known volume of air through a detector tube designed to measure the concentration of the substance of interest. The concentration is usually determined by the colorimetric change of an indicator which is present in the tube contents.

Detector tubes are sealed glass tubes filled with an appropriate indicator chemical to react with a particular gas or vapor and give a color reaction. To make a determination, the seals are broken at each end of the tube and a specific volume of the air being sampled is drawn through by a hand-operated or mechanical pump. Each tube is formulated with a specific reagent (indicator chemical) that absorbs and reacts with the gas or vapor being measured, causing a colorimetric stain. Many of the tubes that are manufactured are of the direct–reading type. In this type, the colorimetric stain varies in length proportionally to the concentration of gas or vapor being measured. The concentration of gas/vapor is read directly off a scale on the side of each tube. There are also chart comparison tubes that work similarly to the direct–reading type. After a sample is taken, the stain length is compared to a printed concentration chart enclosed with each box of tubes. A third type of tube is the color comparison type. In this type, the intensity of color change, rather than the length of stain, is compared to a standard color chart. In addition to these tubes, which give an immediate reaction, long duration tubes for monitoring various toxic gases or vapors throughout the normal workday are available. These tubes can be worn by the employee in a special holder, while a portable lightweight pump continuously draws a measured volume of air through the tube. At the end of the shift, the tube can be evaluated to give a time-weighted average (TWA) exposure for the working day.

It is important that the sampler be aware of the specific manufacturer's direct–reading instrument's degree of precision and be able to report the data's degree of accuracy for a particular measurement technique. For instance, many detector tubes have a degree of precision that ranges from +/- 25% to 35% of the colorimetric change reaction within the detector tube.

Calibration:

Calibrate the detector tube pump for proper volume measurement at least quarterly. Simply connect the pump directly to an inverted buret with a detector tube in-line. Use only detector tubes and pumps from the same manufacturer.

Wet the inside of the 100-mL buret with soap solution. For volume calibration, experiment to get the soap bubble even with the zero (0) mL mark of the buret.

For piston-type pumps, pull the pump handle all the way out (full pump stroke) and note where the soap bubble stops; for bellows-type pumps, compress the bellows fully; for automatic pumps, program the pump to take a full pump stroke. For either type pump, the bubble should stop between the 95-mL and 105-mL marks. Allow up to 4 minutes for the pump to draw the full amount of air. The time interval varies with the type of detector tube being used in-line with the calibration setup.

Also check the volume for 50-mL (one-half pump stroke) and 25-mL (one-quarter pump stroke) if applicable. Permissible error is ± 5%. If the error is greater than ± 5%, send the pump to the CTC for repair and recalibration. Record the calibration information required on the Calibration Log (OSHA-93).

Each day and prior to use, perform a pump leakage test by inserting an unopened detector tube into the pump and attempt to draw in 100 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.

In the event of leakage that cannot be repaired in the field, send the pump to the CTC for repair. Record that the leakage test was performed on the Direct-Reading Data Form (OSHA-93).
Brand-Specific Instructions

DRAEGER, MODEL 31 (BELLOWS):

When checking the pump for leaks with an unopened tube, the bellows should not be completely expanded after 10 minutes. For the DRAEGER ACCURO PUMP (BELLOWS), a 15-minute period is used and the end-of-stroke indicator should not be noticeable after this period.

DRAEGER, QUANTIMETER 1000, MODEL 1 (AUTOMATIC):

A battery pack is an integral part of this pump. The pack must be charged prior to initial use.

One charge is good for 1,000 pump strokes. During extended use periods, it should be recharged daily. If a "U" (under voltage) message is continuously displayed in the readout window of this pump, the battery pack should be immediately recharged. A leak test is performed by turning the system on, setting the pump stroke indicator to "2" or greater, inserting an unopened tube into the holder and pressing the start/stop key. When the second stroke has not started after 30 minutes, the device is considered sufficiently gas-tight.

MATHESON-KITAGAWA, MODEL 8014-400A (PISTON):

When checking the pump for leaks with an unopened tube, the pump handle should be pulled back to the 100-mL mark and locked. After 2 minutes, the handle should be released carefully. It should return to zero or resting position. After taking 100-200 samples, the pump should be cleaned and relubricated. This involves removing the piston from the cylinder, removing the inlet and pressure-relief valve from the front end of the pump, cleaning, and relubricating.

MINE SAFETY APPLIANCES, SAMPLAIR PUMP, MODEL A, PART NO. 46399 (PISTON):

The pump contains a flow-rate control orifice protected by a plastic filter which periodically needs to be cleaned or replaced. To check the flow rate, the pump is connected to a buret and the piston is withdrawn to the 100-mL position with no tube in the tube holder. After 24-26 seconds, 80 mL of air should be admitted to the pump. Every 6 months the piston should be relubricated with the oil provided.

MINE SAFETY APPLIANCES KWIK DRAW™ SAMPLING PUMP, PART NO. 487500 (BELLOWS):

The pump contains a filter disk that needs periodic cleaning or replacement. The bellows shaft can be cleaned and lubricated with automotive wax if operation becomes jerky. This pump is tested for leakage by inserting an unopened tube into the holder, deflating the pump fully and releasing. After 10 minutes the distance of the bellows to the frame should be ½ inch or greater.

GASTEC MODEL GV-100 PISTON SAMPLING PUMP:

When checking the pump for leaks, first confirm that the inlet clamping nut is firmly tightened. Next, push the pump’s handle fully in and align the guide marks on the pump shaft and handle. Then insert a fresh unbroken tube into the rubber inlet of the pump. Pull out the handle fully until it is locked, and wait 1 minute. Unlock the handle (by turning it more than 1/4 turn) and guide it back gradually, applying a little force. Otherwise, the handle will spring back due to the vacuum in the cylinder and may damage the internal parts. Confirm that the handle returns to the initial position and the guideline on the pump shaft is not seen. If this is not confirmed, follow the maintenance procedures explained in the operations manual for the pump, or contact the Nextteq representative for maintenance assistance. The maintenance procedures involve leak checks on the inlet clamping nut and rubber inlet, and performing pump cylinder lubrication.

Special Considerations:

Detector tubes and pumps can be used to measure more than 200 organic and inorganic gases and vapors in air. 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. They should be kept at room temperature for about one hour prior to use. Outdated detector tubes (i.e., beyond the printed expiration date) should not be used unless their performance has been verified.

Several different types and brands of detector tubes have been evaluated for screening use by the Salt Lake Technical Center (SLTC). Information regarding these evaluations can be obtained by contacting the SLTC.

Specific manufacturer's models of detector tubes for individual gases/vapors are listed in OSHA's Chemical Sampling Information files. The specific tubes listed are designed to cover a concentration range near the PEL. Concentration ranges are tube-dependent and can be anywhere from one-hundredth ppm to several thousand ppm. The limits of detection depend on the particular detector tube. Detector tube accuracy varies with tube manufacturer and with each detector tube range as described above.

Be sure to read and follow the manufacturer's instructions regarding corrections that must be made to sample readings for temperature, humidity, and pressure so that readings are valid.

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. Detector tubes generally only give near-instantaneous measurements, thus will not reflect time-weighted average levels of the hazardous substances present. If long-term sampling for TWA measurements is desired, some long-term detector tubes used in conjunction with air sampling pumps or diffusive/dosimeter tubes are available. Otherwise, measurements may be made from gas bags that have slowly been filled at a constant flow rate (such as from the exhaust of a sampling pump) with workplace atmospheres.

G. Mercury Analyzer-Gold Film Analyzer

Application and Principle of Operation:

This instrument measures mercury in air by drawing an air sample over a gold film. The Jerome Model 431X model has a reported practical detection limit of 0.01 mg/m^3. 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. Results can be displayed in mg/m^3 of mercury or total mass of mercury in the air sample collected. Potential interferences which can produce a positive reading include chlorine, nitrogen dioxide, hydrogen sulfide, high concentrations of ammonia, and most mercaptans. These interferences are removed from the air stream ahead of the gold film by drawing the air sample through an "acidic gas filter" which contains sodium hydroxide and soda lime. For use in high chlorine environments, an optional chlorine filter can be used.

Calibration:

Calibration is performed by the manufacturer on a periodic basis. Because of the gold film/mercury interaction, the instrument should produce stable, accurate readings without the need for frequent recalibration.

Special Considerations:

The gold film sensor becomes saturated with mercury after collecting approximately 0.5 mg of mercury, or approximately 50 readings of 0.1 mg/m^3 of mercury. The meter then must be placed on line power and the gold film sensor regenerated at elevated temperature. The accuracy of the readings is a function of the temperature, so it is necessary to allow approximately 30 minutes after regeneration for the sensor to equilibrate.

The instrument readings are sensitive to temperature fluctuations. If a significant temperature change occurs while using the meter, it will be necessary to re-zero the meter at the new temperature.

Maintenance:

Routine maintenance includes periodic replacement of filters and regeneration of the gold film sensor to remove mercury after use of the instrument.

H. Particle Monitors (Condensation Nuclei)
Application and Principle of Operation:

Condensation-nuclei counters are based upon a miniature, continuous-flow condensation nucleus counters that take particles too small to be easily detected, enlarges them to a detectable size, and counts them. Submicrometer particles are grown with alcohol vapor as they pass through a heated saturator lined with alcohol–soaked felt, and then condense the alcohol on the particles in a cooled condenser. Optics focus laser light into a sensing volume.

As the droplets pass through the sensing volume, the particles scatter the light. The light is directed onto a photodiode which generates an electrical pulse from each droplet. The concentration of particles is counted by determining the number of pulses generated. Applications include the testing of respirators and real-time dust monitors.

A counter totals individual airborne particles from sources such as smoke, dust, and exhaust

fumes. Models typically operate in one of three possible modes, each with a particular application. In the "count" mode, the counter measures the concentration of these airborne particles. In the "test" (or fit test) mode, measurements are taken inside and outside a respirator and a fit factor is calculated. In the "sequential" mode, the instrument measures the concentration on either side of a filter and calculates filter penetration.

This instrument is sensitive to particles as small as 0.02 micrometers. However, it is non-specific to variations in size, shape, composition, and refractive index.

Calibration:

Check the counter before and after each use in accordance with the manufacturer's instructions. This procedure usually involves checking the zero of the instrument. Annual calibration is handled through the CTC.

Maintenance:

Reagent-grade isopropyl alcohol for use in these types of instruments can be obtained from the CTC Agency Expendable Supply Program.

Isopropyl alcohol must be added to the unit after 5–6 hours of operation under normal conditions. Take care not to overfill the unit. A fully charged battery pack will normally last for about 5 hours of operation. Low battery packs should be charged for at least 6 hours. Battery packs should not be stored in a discharged condition.
Storage preparation (always follow the manufacturer’s recommendations):

Dry the saturator felt by installing a freshly charged battery pack without adding alcohol. Allow the instrument to run until the LO message (low battery) or the E-E message (low particle count) appears. Some instruments allow you to remove the alcohol cartridge for storage purposes.

Remove the battery pack and install the tube plugs into the ends of the twin-tube assembly.

I. Photodetection

Application and Principle of Operation:

Photodetectors operate by detecting scattered electromagnetic radiation in the near infrared region. Photodetectors can be used to monitor total and respirable particulates. The device measures the concentration of airborne particulates and aerosols including dust, fumes, smoke, fog, mist, etc.

Calibration:

Factory calibration is required.

Special Considerations:

Certain instruments have been designed to satisfy the requirements for intrinsically safe operation in methane-air mixtures.

Maintenance:

When the photodetector is not being operated, it should be placed in its plastic bag, which should then be closed. This will minimize the amount of particle contamination of the inner surfaces of the sensing chamber.

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 following the manufacturer's procedure 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. 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 agents. Generally, use of these detection systems will be limited to specially trained and equipped personnel at SLTC or other specially trained and equipped OSHA personnel. The following summarizes specialized direct reading capabilities that OSHA has access to and should be considered informational by all other personnel. These systems should only be used after consultation with SLTC and under close SLTC guidance.

A. Military Detection Papers/Kits

a. 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 micro liters (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.

b. 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.

c. M256A1 Detector Kit

The M256A1 Chemical Agent Detection Kit is designed to detect and identify chemical agent vapors, including blood (AC & CK), blister (H, HN, HD, CX, L), and nerve (V & G series) agents. The test consists of a series of chemical ampoules that are broken and exposed to the air. The reagents in the ampoules 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 are present. The M256A1 is relatively sensitive, and can detect some of the agents below the Immediately Dangerous to Life or Health (IDLH) levels. The kit also includes booklets of M8 paper for detecting liquid agents.

d. 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 will allow detection of some agents below IDLH levels. It also contains a booklet of M8 paper for use with detection of liquid agents.

B. Colorimetric Tubes

Colorimetric tubes are made by several manufacturers, and their function is essentially the same. They contain a series of tubes which can be used to detect airborne chemical agents, as well as toxic industrial 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 below PEL levels. An example of colorimetric tubes designed specifically for chemical agents is the Dräeger 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, these instruments have poor sensitivity with respect to chemical agents 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.

a. 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), APD2000, 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 interferents that may cause false alarms with an IMS include the following: cleaning compounds and disinfectants that contain 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.

b. 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 into 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 Chromatograph/Mass Spectrometer

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 that 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 occupational TWA levels (PEL/TLV). 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.

An example of a portable GC is the MINICAMS. This instrument is used extensively in Department of Defense depots where chemical agents are stored and used by other agencies in the field. The MINICAMS can provide automatic, quantitative identification of the chemical agents for which it was calibrated.

E. Health Response Team (HRT) Availability

The following equipment is maintained by the HRT for use in chemical agent detection:

a. Military Detection Papers/Kits: M8/C8 paper, M9 paper, M256A1 kits, and C-2 kits.

b. APD2000; 2 IMS detection units as described above. Each OSHA region is also equipped with a single APD2000 unit.

NOTE: The Health Response Team (HRT) also serves as the coordinator for OSHA's Chemical Specialized Response Team (SRT) and can provide additional assistance and technical information regarding chemical warfare agent detection. Special precautions are also necessary to prevent exposure when working with chemical warfare agents, such as PPE and/or other work practices. Contact the HRT for more details.

V. Biological Agent Detection

Sampling and analysis for biological agents is a rapidly growing field. Many techniques and technologies are still under development. There are various factors to consider when sampling for biological agents, such as: method of dispersion for the agent, purpose of the sampling (e.g., to identify the agent, determine extent of contamination, confirm decontamination, etc.), environmental conditions, persistence of the agent, physical state of the agent, area/volume to be sampled, laboratory protocols, and others. It is important to note that biological agents (bacteria, viruses, toxins) are particulates, and therefore, methods are designed for particulate sampling. The following sections highlight some types of equipment that may be used for sampling and detection of biological agents.

A. Surface/Bulk Sampling

a. 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.

b. 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.

c. Vacuum Methods

Vacuum methods can be used when it is necessary to sample very large surface areas or areas that are porous, and it is impractical to use swabs or wipes. They are also useful to gather bulk dust samples for analysis. One method utilizes a high efficiency particulate air (HEPA) vacuum equipped with a dust collection filter sock which is used to capture the sample. Large surface areas can be vacuumed, and the dust gathered in the sock is then analyzed for the presence of biological agents. A similar method uses a portable sampling pump equipped with a filter cassette to "vacuum" particulates from smaller areas, and at lower flow rates. The filter can then be analyzed for biological agents.

d. Agar Plates

Agar plates, also known as "sticky plates", can be used to sample a surface by contacting the plate directly to the surface. The particulates from the surface will adhere to the plate, which can then be analyzed by culture to identify any biological agents. This method has been used by various agencies during investigations of incidents involving 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, since 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. These 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 Andersen Sampler, utilize higher flow rates (around 30 L/min), sample a greater air volume, and, therefore, increase the likelihood of detecting the agent. The Andersen Sampler and similar types of impactors capture the 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 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:

a. 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.

b. 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.

c. 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.

d. Colorimeter: Colorimeters can be used to detect protein from a sample. Again, protein is present in biological organisms, so these instruments can indicate if the material is biological in origin.

e. Protein Paper: Similar to a colorimeter, these paper strips can indicate if a given sample contains protein, and is, therefore, biological.

f. 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

a. Immunoassay/Handheld Assay

An immunoassay test, also known as a handheld assay (HHA), can be performed on an obtained sample to identify a specific agent. These 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 B. anthracis (anthrax) is suspected, the sample is tested using an HHA designed for B. anthracis; a positive result confirms the presence of the organism while a negative result indicates that the sample does not contain that specific organism. The HHA units are small, the test can be performed in the field, and they rely on a visual colorimetric change 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, and high false negative and false positive rates. The results from an HHA test should not be relied upon alone and further confirmatory analysis should always be performed. However, these tests are used widely by first responders as a rapid field test. Although they are presumptive, their results can assist decision makers in taking protective actions, treating potential infections, and involving other authorities as necessary.

b. 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 thirty 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 since it has excellent sensitivity, good specificity, and provides real-time results. Some weaknesses of PCR to consider are the following: potential interferences from other substances in the sample, reagent stability, and sample viability, since PCR will detect the presence of both live and dead organisms, but will not distinguish between the two.

c. Culture

Analysis by culture is considered by many to be the "gold standard" for the analysis 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.

HRT Availability:

The following equipment is maintained by the HRT for use in biological agent sampling and analysis:

a. Handheld Assays for the following agents: anthrax, plague, brucellosis, tularemia, Venezuelan equine encephalitis, staphylococcal enterotoxin B, botulinum toxin, ricin, smallpox, and Q fever.

b. HEPA Vacuums: Two units with filter socks and other supplies specifically for use with biological agent sampling.

c. Andersen Samplers: Two units.

d. Dry Filter Units (DFU): Two units. The DFU is a high-volume air sampler designed for biological agent sampling. It operates at flow rates up to 600 L/min and utilizes a filter pad for capturing the agent.

e. Surface/Bulk Sampling: Various wipe, sponge, and swab sampling kits.

NOTE: The HRT also 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. This information is provided as a reference for specially trained personnel and is not generally intended for CSHO use. Contact the HRT for more details.

VI. Radiation Monitors and Meters

IONIZING RADIATION

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 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 you expect to measure and whether you wish to measure cpm or R/h.

Calibration:

Calibration is performed by the manufacturer on a periodic (usually annual) basis.

HRT Availability:

a. Ludlum Model 3 with 44-9 Pancake GM Detector

The Ludlum Model 3 is a general purpose survey meter fitted with a pancake Geiger

Mueller (GM) detector capable of measuring α, β, γ, and X radiations. This instrument will measure count rates over a range of 0–500,000 cpm.

b. Ludlum Model 2360 with 43-93 Alpha/Beta Scintillator

The Ludlum Model 2360 is a survey meter capable of measuring and discriminating between α and β radiations. It is fitted with a Ludlum 43-93 alpha/beta scintillation detector. The meter will measure count rates over a range of 0–500,000 cpm.

c. Ludlum Model 192 MicroR™ Meter

The Ludlum Model 192 is a low-level (μR/h) γ- and X-radiation exposure-rate meter. The meter has an internal sodium iodide detector capable of measuring dose rates between 0 and 5000 μR/h.

d. Thermo FH40GL Dose Rate Meter with FHZ732GM Pancake Probe

The FH40GL is a stand-alone radiation survey meter equipped with an internal proportional detector capable of measuring γ- and X-radiation exposure rates from 1 μR/h–10 R/h. The unit is also equipped with an FHX732GM pancake GM detector capable of measuring count rates from α, β, and γ radiations over a range of 0.01–100,000 counts per second.

e. Thermo FH40TG Teleprobe™

The FH40TG telescoping probe can be used with the FH40GL to measure γ- and X-radiation exposure rates over a range of 10 μR/h–1000 R/h. The probe is equipped with two GM detectors that can be extended up to 13 feet away from the user, allowing exposure rate measurements to be made at a distance from the source.

f. Thermo RO-20 Ionization Chamber

The RO-20 is capable of measuring exposure rates from β, γ, and X radiations. The instrument is equipped with an air filled ionization detector capable of measuring exposure rates up to 50 R/h.

g. Thermo PM1703M Gamma Pager

The PM1703M is a pager-sized survey meter that can be worn on the belt. The meter contains a Csl(Tl) scintillator-photodiode detector capable of measuring γ- and X-radiation. The instrument will measure exposure rates from 0–5000 μR/h. The PM1703M is a highly sensitive instrument that can be set to alarm when the background varies by a user-set factor. This meter can be used to warn the user that they have entered a radiation area that is above background radiation levels.

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.

Calibration:

Calibration is performed by the manufacturer on a periodic (usually annual) basis.

HRT Availability:

a. Ludlum Model 3030 Alpha/Beta Scalar

The Ludlum Model 3030 is a dual alpha/beta scalar used for sample counting. The instrument has a ZnS(Ag) coated scintillation detector capable of discriminating between α and β radiations. The readout on the front of the instrument reports both α and β counts for the specified period. Counting time can be set from 0.1–30 minutes.

b. Ludlum Model 2000 Scalar with 43-10 Alpha Sample Counter

The Ludlum Model 2000 scalar with 43-10 sample counter is capable of counting samples for α particle emissions. The sample counter has a ZnS(Ag) scintillation detector. Counting time can be set from 6–990 minutes.

c. Thermo HandECount Scalar

The HandECount is a battery or AC powered sample counter used for determining the α and β activity present in a sample. The instrument uses a Palm™ personal digital assistant as the user interface and to record all results. All data may be transferred to a computer via a conduit program. The HandECount will report both α and β counts for a sample.

C. Electronic Personal Dosimeters

Application and Principle of Operation:

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.

Calibration:

Calibration is performed by the manufacturer on a periodic (usually annual) basis.

HRT Availability:

Thermo Electronic Personal Dosimeter (EPD) Mk.2

The Thermo EPD Mk.2 is an electronic dosimeter capable of measuring Hp(10) (deep dose) and Hp(0.07) (shallow/skin dose). It is sensitive to γ and X radiations for Hp(10) measurements, and is sensitive to γ, β, and X radiations for Hp(0.07) measurements. Alarms can be set for accumulated doses and for dose rates for both Hp(10) and Hp(0.07).

Rados RAD-60 Electronic Personal Dosimeters
The Rados RAD-60 is capable of measuring Hp(10) from γ and X radiations. Alarms can be set for both dose and dose rate.

D. Spectroscopy

Application and Principle of Operation:

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.

Calibration:

Calibration is performed by the manufacturer on a periodic (usually annual) basis.

HRT Availability:

EXPLORANIUM™ GR-135N

The EXPLORANIUM™ GR-135N is a handheld isotope identification device. The GR-135N has a sodium iodide detector capable of identifying radionuclides, a GM detector for measuring exposure rate, and a solid-state neutron detector. Spectra from the GR-135N can be downloaded to a computer for analysis and printing.

E. Electret-Passive Environmental Radon Monitoring

Application and Principle of Operation:

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.

Calibration:

Calibration factors are provided for each type of electret. Calibration factors are voltage dependant and instructions for calculating the calibration factors are in the E-PERM manual provided by the manufacturer.

HRT Availability:

The HRT has 12 E-PERM chambers, electrets, and a voltage reader.

F. Radiation PPE and Shielding

In radioactively contaminated areas, PPE is typically used in order to prevent employees 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 since external exposure to alpha particles delivers no dose. Beta particles can travel several meters in air and can penetrate several millimeters into the skin. Beta particle should be shielded using an appropriate thickness of low atomic mass (low-Z) materials such as aluminum or plastics. Shielding beta particles with high-Z materials should be avoided as this can produce bremsstrahlung radiations. 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 HRT also 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. Contact the HRT for more details.

NONIONIZING RADIATION

A. 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 and 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 using these devices.

Calibration:

No field calibration is available. Calibration is performed by the manufacturer on a periodic basis.

HRT Availability:

Narda 8860

The Narda 8860 personal RF monitor is used to monitor occupational exposures to RF sources within the frequency range of 100 kilo Hertz (kHz) – 100 giga Hertz (GHz). The user can select from multiple alarm settings. The unit continuously logs RF exposure levels and reports results based on a shaped frequency response.

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

AIR VELOCITY MONITORS AND METERS

A. Flow Hoods

Application and Principle of Operation:

These instruments measure air velocities at air supply or exhaust outlets. A flow hood (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 the necessity of measuring grille sizes and conducting repeated velometer measurements over the face of the diffuser. With the flow hood, the user 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 flow rate can be calculated. Such applications may be important in assessing ventilation controls, during IAQ investigations, or any time knowledge of the existing volumetric airflow is important (e.g., when an air contaminant

violation exists and the employer is relying on dilution ventilation for contaminant control or when the air flow patterns may be drawing an air contaminant into an unintended space and causing exposure). For more guidance on the appropriate use of flow hoods, please contact SLTC.

Calibration:

No field calibration is available. Periodic factory calibration or equivalent by a laboratory is essential. Equipment should be sent to CTC for coordination and document retention.

Maintenance:

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

B. Thermoanemometer

Application and Principle of Operation:

A thermoanemometer (hotwire anemometer) is a device used to measure air speed (velocity). Thermoanemometers can be used to monitor the effectiveness of ventilation systems and direct exhaust systems. They are valuable when evaluating laboratory hoods for adequate velocity and capture speed. When the area of the hood face or the diffuser is known (or measured) the volumetric airflow can be estimated by taking traverse measurements across the face of the hood or diffuser. Additionally, if a duct has access ports, the interior duct speed can be estimated. A benefit of using the hotwire anemometer over the balometer for volumetric flow measurement is the compact size of the anemometer, but this ease of use becomes more complex once multiple measurements are required (traversing a hood face) and must be balanced against the superior precision and accuracy of the balometer. For more guidance on the appropriate use of thermoanemometers, please contact SLTC.

Calibration:

No field calibration is available. Periodic factory calibration or equivalent by a laboratory is essential. Equipment should be sent to CTC for calibration and document retention.

Maintenance:

These instruments typically require little field maintenance other than battery-pack servicing and zero balancing of analog scales. (Check manufacturer's manual.)

C. Other Air Velocity Meters

Other air velocity meters include rotating-vane and swinging-vane velometers.

NOTE: Barometric pressure and air temperature should be noted when using air velocity meters.

D. Bioaerosol Monitors
Application and Principle of Operation:

A bioaerosol meter, 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. Ninety-five 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 is normally used to collect bacteria, and malt extract agar is normally used to collect fungi. Bioaerosol monitors can be used in assessing sick-building syndrome, or buildings which may have source exposures to molds and bacteria which may be exacerbating or causing 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 these particles.

Calibration:

Bioaerosol meters must be calibrated before use. This can be done using an electronic calibration system with a high-flow cell.

Special Considerations:

Prior to sampling, determine the type of collection media required and an analytical laboratory to provide analysis. The HRT can provide this information. This specialized equipment is available from the HRT with instructions.

Maintenance:

The sampler should be decontaminated prior to use by sterilizer, or chemical decontamination with isopropanol.

VIII. Noise Monitors and Meters

The following sections contain a brief discussion of various types of instruments that may be used for noise monitoring. Refer to OSHA Technical Manual Section III, Chapter 5, "Noise and Hearing Conservation" for additional information.

A. Sound Level Meters

Application and Principle of Operation:

The sound level meter (SLM) is the basic instrument for investigating noise levels. It can be used to evaluate area noise levels, to identify noise sources, estimate employee exposures and aid in determining solutions for noise control. The SLM consists of a microphone, a preamplifier, an amplifier with an adjustable and calibrated gain, frequency weighting filters, meter response circuits, and an analog meter or digital readout. ANSI has classified levels of precision for sound level meters as Type 0 (laboratory standard), Type I (precision measurements in the field), and Type II (general purpose measurements). The Type II meter is most frequently used in the field for employee exposure and noise evaluation purposes.

Most SLMs allow options for linear, A, and C frequency weighting. In addition, either "slow" or "fast" meter response can be selected. With fast response, the meter closely follows the sound level as it changes. A slow response is more sluggish but allows the user to obtain a better average of the changing sound level. The OSHA noise standards require exposure measurements to be made with a slow meter response on the A scale.

Some SLMs have an "impulse" or "peak" response for monitoring impulsive sounds. The peak value is the maximum value of the waveform, while the impulse response is an integrated measurement. Only the peak value should be used when measuring peak levels for compliance with the OSHA 140 decibel (dB) peak sound pressure level.

B. Noise Dosimeters

Application and Principle of Operation:

A noise dosimeter is essentially an SLM that integrates noise levels over the sampling period and calculates the noise dose. It is the primary instrument used for compliance measurements. The noise dosimeter is worn by an individual during sampling to calculate personal noise dose, or it can be placed in a specific location to measure the sound level in that area.

Specific instrument settings can be selected on a noise dosimeter, including exchange rate, frequency weighting, fast or slow response, criterion level, and threshold. Refer to Section III, Chapter 5 for additional information.

C. Octave Band Analyzers

Application and Principle of Operation:

An octave band analyzer is a type of SLM which can separate the monitored noise into specific frequency bands, which is necessary when analyzing noise sources to develop noise control solutions. This information is also useful in selecting hearing protectors by calculating the amount of attenuation for specific frequency bands. Most octave band analyzers filter the sampled noise spectrum into 9 or 10 octave bands, while some analyzers can measure noise in one-third octave bands for an even more detailed analysis. Usually, a Type I (precision) SLM is used for octave band analysis.

D. Sound Intensity Analyzers

Application and Principle of Operation:

Ordinary SLMs measure sound pressure level, which indicates the level of the sound, but not the direction from which the sound is coming. A sound intensity analyzer can measure intensity, which is a measure of both the magnitude and direction of the sound energy. With an intensity analyzer, noise sources can be specifically identified and ranked according to sound power. This analysis can often be performed in environments where the noise is reverberant, since the intensity analyzer indicates the direction of the noise. A sound intensity analyzer is particularly useful for pinpointing noise sources and determining

appropriate engineering controls.

Calibration:

Noise instruments are usually calibrated at the field site before and after each use, according to the manufacturer's instructions. Calibration is accomplished by using an acoustic calibrator which applies a known sound pressure level to the microphone, and the instrument is adjusted to read the proper level. In addition to user calibration, some instruments may require routine factory calibration and maintenance, such as every 1-2 years.

Special Considerations:

Some general considerations for using noise monitoring equipment are listed below. Each type of equipment should be used according to the manufacturer’s instructions. Additional factors to consider are included in Section III, Chapter 5.

a. Batteries should always be checked prior to use.
b. Be careful with microphone cables. Never kink, stretch, pinch or otherwise damage the cables.
c. Use a microphone windscreen when equipment is used outdoors or in dusty or dirty areas.
d. Never use any type of covering on the microphone (e.g., plastic bag or plastic wrap) to protect it from moisture. These materials will distort the noise entering the microphone, and the readings will be invalid.
e. Never try to clean a microphone, particularly with compressed air, since damage is likely to result.
f. Remove the batteries from any meter that will be stored for more than a few days. Protect meters from extreme heat and humidity.

HRT Availability:

The HRT maintains the following specialized noise analysis equipment which can be used for noise exposure and engineering control evaluations:

a. Bruel & Kjaer 2260 Analyzer

The B&K 2260 is a multipurpose Type I sound level meter and octave band analyzer. It can also be operated as a sound intensity analyzer for identifying noise sources and determining engineering controls. In addition, the 2260 includes a building acoustics system for measuring noise decay and determining the reverberation characteristics for a given room. Based on the noise decay data, calculations can be performed to estimate potential noise reduction if absorptive materials are applied to room surfaces, such as the walls and ceiling.

b. Larson Davis Spark™ 705 Dosimeters

The Larson Davis Spark 705 Dosimeter is a super-duty dosimeter contained in a sealed, waterproof, intrinsically safe metal housing. The dosimeters have no controls or displays, which eliminates the possibility of tampering or damage by the individual wearing the

monitor. The dosimeters are programmed and controlled by use of a remote control unit or personal computer. The remote control unit (model 706RC) can also be operated as an additional dosimeter. Data is transferred from the 705 via an infrared port on the dosimeter housing.

IX. Vibration Monitors

The following sections contain a brief discussion of various types of measurements that are of concern when measuring vibration. Human response to vibration is dependant 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. The vibration will generally be measured along 3 (x, y and z) axes.

A typical vibration measurement system includes a device (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 will generally be measured when using a hand-held power tool. First, one must determine the type of vibration that will be encountered since a different accelerometer will be used depending on whether an impact (e.g., jack hammer or chipper) or non-impact (e.g., chain saws or grinders) tool is being used. The accelerometer will be attached to the tool so the axes are measured while the employee grasps the tool handle. The z axis is generally from the wrist to the middle knuckle, the x axis is from the top of the hand down through the bottom of the hand and wrapped fingers, and the y axis runs from right to left across the knuckles of the hand. The measurement should be made as close as possible to the point where the vibration enters the hand.

The frequency-weighting network for hand-arm vibration is given in the International Organization for Standardization (ISO) standard ISO 5349. 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 Hygienist, ISO, BSI). 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 employees.

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. Vibration is measured across three (x, y and z) axes. The orientation of each axis is as follows: 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 generally an accelerometer mounted in a hard rubber disc. This disc is placed in the seat between the operator and the machinery. Care should be taken to ensure that the weight of the disc does not exceed more than about 10% of the weight of the person being measured.

Calibration:

Vibration equipment will not generally be calibrated by the user. These devices will generally be sent back to the manufacturer for calibration on an annual basis.

Special Considerations:

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 hand-held tools. The exposure limits are given as frequency-weighted acceleration. The frequency weighting is based on a scheme recommended in ISO 5349. 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 employees can be exposed repeatedly without severe damage to fingers. ACGIH advises that these values be applied in conjunction with other protective measures, including vibration control.

The most widely used document on whole-body vibration is the "Guide for the Evaluation of Human Exposure to Whole Body Vibration (ISO 2631)." 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 standard:

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 possible exposure allowed for whole-body vibration. There are two separate tables for exposures. One table is for longitudinal (head to toe; z axis) exposures, with the lowest exposure limit at 4 - 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– 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.

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:

a. Batteries should always be checked prior to use.
b. Be careful with electrode cables. Never kink, stretch, pinch or otherwise damage the cables.
c. Remove the batteries from any meter that will be stored for more than a few days.
d. Protect meters from extreme heat and humidity.

HRT Availability:

The HRT maintains the following vibration analysis equipment:

a. Larson Davis Human Vibration Meter - HVM100

The HVM is a portable multipurpose meter which can be used for measurement of whole-body vibration, hand-arm vibration, hand-tool vibration, vibration severity and product compliance testing. It will collect and analyze data in accordance with the most current ISO requirements for hand-arm vibration and whole-body 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 Evaluations

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 tarring. A peak hold button captures peak readings. Usually the gauges are available in lbf, kgf or N units of measure.

Calibration:

Gauge accuracy should be checked periodically to ensure the gauge is within its 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.

X. Electronic Test Equipment

A. Electronic Testing Meters

Application and Principle of Operation:

Electrical testing meters include multimeters, clip-on current meters, megohmmeters, battery testers, ground-wire impedance testers, 120-V AC receptacle testers, ground–fault interrupt testers, electrostatic meters, and AC voltage detectors. Multimeters measure AC or DC voltage or current and resistance. They can check for AC leakage, proper line voltage, batteries, continuity, ground connection, integrity of shielded connections, fuses, etc. Other specialized equipment is described in Appendix II: 3-3.

Calibration:

Few, if any, field calibrations are available. Check manufacturer's manual. Periodic calibration is handled by the CTC.

Maintenance:

No field maintenance is required other than battery-pack servicing.

XI. Heat Stress Instrumentation

The following sections contain a brief discussion of various types of instruments that may be used for heat and heat stress monitoring. Refer to 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 two types of heat stress monitors available through the CTC. One type is a real-time area monitor that measures environmental conditions that contribute to heat stress and the other is a real-time personal monitor that measures the wearer’s body temperature and/or heart rate. The area monitor (Quest model Questemp™ 15 or IST WiBGeT™ model RSS-214) 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 personal monitors provide real-time information on the wearer's physiological condition and work by either inserting a probe into the wearer's ear canal to monitor body temperature (Quest Technologies Questemp II™) or wearing a sensor belt around the waist that monitors heart rate and temperature (Metrosonics hs383 Personal Heat Stress Monitor). Both personal devices can be programmed to alarm when a predetermined temperature or heart rate is exceeded.

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 takes into account the effects of humidity on the body's cooling mechanism and the globe temperature accounts for radiant heat on the employee. 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. Since radiant heat from the sun is not a factor indoors (or outdoors without a radiant heat load), the WBGT is calculated differently for indoor environments; the wet bulb multiplier stays the same, the globe temperature is multiplied by 0.3 and the dry bulb temperature drops out of the formula.

Another personal heat stress monitoring system is available through the HRT. The CorTemp™ personal heat stress monitoring system uses an ingestible temperature sensor that is swallowed by the person being monitored. The capsule transmits the employee's core temperature to a receiver on his/her belt which also receives a heart rate monitor's reading and then transmits both signals to a receiver monitored by an observer up to 100 yards away. Since the sensor must be swallowed, the CorTemp™ system is considered a medical device and must be used under the supervision of a physician.

Calibration:

Most calibration is done annually by the manufacturer. Certain instruments have simple user calibrations that must be performed before each use. The Questemp™ 15 is provided with a calibration module that plugs into the monitor. If the temperatures reported by the module and the monitor differ by more than 0.5 °C, the monitor needs to be returned to the manufacturer for calibration. The Questemp™ II personal heat stress monitor is calibrated to the user's body temperature every time it is used or if the ambient temperature changes by 10°C.

NOTE: Any discussion regarding a specific manufacturer’s product is not meant to imply approval or promotion by 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.

APPENDIX II: 3–1.

A. Batteries

1. Alkaline batteries must be replaced frequently before they become depleted. For any full shift sampling, instrument batteries should be checked with a voltage meter to ensure a full charge, or fresh batteries should be used. When replacing batteries, never mix types (alkaline, carbon zinc, etc.), capacity, or age. Doing so can have negative affects on all the batteries. Remove batteries if equipment will not be used for an extended period of time.

2. Rechargeable Batteries
a. Nickel cadmium batteries (Ni-Cad) are the most common rechargeable battery in industrial hygiene use today. They have numerous advantages over alkaline batteries if they are treated properly. If not treated properly, Ni-Cad batteries can develop a "memory." "Memory" occurs when a battery develops a usage pattern that can prevent the battery from holding a charge for a long usage period.

i. A fully charged Ni-Cad battery will hold 1.35 volts per cell. Batteries are usually rated at 1.2 volts per cell, so you can determine the number of cells a battery contains by dividing the total rated voltage by 1.2.

ii. Do not discharge a multi-cell Ni-Cad battery pack to a voltage level below 1.0 volts per cell; doing this will drive a reverse current through some of the cells and can permanently damage them.

iii. Rechargeable Ni-Cad batteries should be charged only in accordance with manufacturer's instructions. Chargers are generally designed to charge batteries in approximately 8–16 hours at a high charge rate. A battery can be overcharged and ruined when a high charge rate is applied for too long a time. However, Ni-Cad batteries may be left on a proper trickle charge indefinitely to maintain them at peak capacity. In this case, discharging for a period equal to the longest effective field service time may be necessary because of short-term memory imprinting. However, do not let the battery discharge overnight or longer. Turn the instrument OFF when the battery reaches the proper discharge level.

iv. To avoid memory development, batteries should be exercised before field use, and occasionally after being put into field use. Before field use, the battery pack should be charged and discharged to a "low battery" state three times.

NOTE: Battery care is important in assuring uninterrupted sampling. A pump battery pack, for example, should be discharged to the recommended level before charging, at least after every use, and three times before the first use. If the pump is allowed to run down until the battery reaches the low battery Fault condition, the pump should be turned OFF soon after the Fault condition stops the pump. Leaving some pumps (such as the GilAir) ON for a long time after this Fault condition can damage the battery pack. Also, avoid overcharging the battery pack.
b. Nickel-Metal Hydride Batteries (NMH) are similar to Ni-Cad batteries but are less prone to develop a memory and typically offer up to 40% more run time. They should be charged similarly to Ni-Cad batteries, but do not need the periodic discharge to 1.0 volts.

c. Lithium Ion and Lithium Polymer Batteries are the latest in battery technology, offering an

energy density approximately twice that of Ni-Cad batteries, and they also have a very low self-discharge rate.

APPENDIX II: 3–2.

A. Availability, Calibration, Maintenance and Repair of Equipment: Cincinnati Technical Center (CTC)

For information regarding the availability of specific equipment, OSHA staff should access the Cincinnati Technical Center (CTC) website. The CTC calibrates and repairs equipment and instruments, and it serves as a source of technical information on instruments and measurement technology. Equipment servicing information, including service intervals and technical equipment status, can also be found on the CTC website. The OSHA SLTC Program Support Division, including the HRT, also has some specialized equipment available for Agency use.

APPENDIX II: 3–3.

A. Instrument Chart

The information shown in the table below is for reference only. Not every compliance officer or field office will have every type of instrument. Many of the instruments can be found in, and are available through, the CTC's loan program or through the SLTC.

INSTRUMENT USE		
Type of instrument	Measured substance	Application
Physical Measurements		
Electrobalances	Any weighable	Filter weighing
Stop time meter	Time	Calibration
Tachometers	Mechanical speed	Flywheels, belts, cylinders, lathes, etc.
Electrical testers	Electricity	Circuits
Mulitimeters	Electricity	Circuits
Noise dosimeters	Noise	Noisy locations
SLM kits, type 1	Noise	Noisy locations
Omnicals	Noise meter calibration	Noise meters
Vibration meters	Excessive vibration	Bearings, gear trains, housings, walls
Thermoanemometer	Air movement	Ventilation

Hand pumps	Detector tubes	Screening
Pressure guages	Air Pressure	Compressor air lines
Pumps, low flow	Air volume	Sampling with adsorbent tubes
Pumps, medium flow	Air volume	Sampling
Gilibrators	Air pump calibration	Pump calibration
Fibrous aerosol monitors	Fibers in air	Asbestos
Dust monitors	Respirable dust	Mines, sandblasting, dusty operations
	Respirable dust, particles	Indoor air, QNFT
Soil test kit	Soil quality	Trenching, excavating

GAS & VAPOR METERS		
Type of instrument	Measured substance	Application
Double-range meters	Combustible gas, O_2	Confined spaces
Triple range meters	1 Gas, O_2, combustible gas	Confined spaces
Quad range meters	2 gases, O_2, combustible gas	Confined spaces
CO dosimeter	CO	Garages, indoor air quality
Carbon dioxide meter	CO_2	Indoor air quality
Infrared analyzers	CO, CO_2, organic substances	Indoor air, leaks, spills
Hydrogen cyanide monitors	Hydrogen cyanide	Industrial facilities
Hydrogen sulfide meters	Hydrogen sulfide	Farms, sewers
Mercury vapor meters	Mercury	Mercury plants, spills
NO and NO_2 meters	NO and NO_2	Combustion
Ozone analyzers	O_3	Water or air purification, IAQ

RADIATION METERS		
Type of instrument	Measured substance	Application
Heat stress meters	Ambient (environmental) heat	Foundries, furnaces, and ovens
Photoionization	Ionizable substances	Indoor air, leaks, spills
Light meters	Light	Indoor lighting, UV exposure
Nonionizing radiation meters	Nonionizing radiation	Communications, microwaves, heaters
Ionizing radiation meters	Ionizing radiation	Nuclear waste or plants
Electrostatic field tester	Static electric fields	Hazardous locations
RF instruments	Electromagnetic fields	RF heat sealers, VDTs, induction motors

BIOLOGICAL MONITORS		
Type of instrument	Measured substance	Application
Microbial sampler	Microbes	Indoor air quality