OSHA Technical Manual (OTM)
Section II: Chapter 1

[Updated: February 11, 2014]

This document may not reflect OSHA's respirable silica rule published on March 25, 2016.
For more information on the new rule, see **OSHA's Respirable Crystalline Silica Safety and Health Topics Page**.

Personal Sampling for Air Contaminants

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I. Introduction

This chapter provides basic information related to sampling air contaminants. Other reference resources are OSHA's Chemical Sampling Information (CSI) file and the OSHA Field Operations Manual (FOM). Sampling and analytical methods that have been validated by either OSHA or the National Institute for Occupational Safety and

Health (NIOSH) should be used whenever possible. Sometimes the Salt Lake Technical Center (SLTC) will approve the use of procedures developed by other organizations. Only procedures approved by the SLTC should be used. The use of sampling methods not approved by the SLTC may require resampling with an approved sampling procedure. The SLTC is aware that unique sampling situations will arise during some inspections and it is essential that OSHA Compliance Safety and Health Officers (CSHOs) contact, and work closely with, the SLTC whenever questions arise.

Sampling strategies should be planned for a meaningful evaluation of air contaminants and prudent use of limited resources. Screening techniques and devices, such as detector tubes and direct-reading meters, may provide valuable information when their use and their detection limits are appropriate (see Section II: Chapter 3 Technical Equipment: On-Site Measurements). Knowledge of sampling procedures, including sampling media, recommended air volumes, and sample storage precautions, are essential in planning proper sampling strategies.

Bulk samples are sometimes necessary to support analyses of air samples, to document the source of air contaminants or to identify additional hazards. For example, in conjunction with air sampling for organic dusts, it may also be useful to collect bulk samples for analysis of explosibility and flash point to identify additional safety hazards. Or when air sampling for asbestos, it may also be useful to collect one or more bulk samples of suspect building materials to identify the source(s) of airborne fibers if this is not otherwise evident at the work site. Bulk samples are sometimes used in Hazard Communication inspections (i.e., Safety Data Sheet compliance). Consult OSHA's CSI file to determine when bulk samples are appropriate. Bulk samples often require special shipping and handling.

Ensure that appropriate sample shipping and handling requirements are followed and that the mode of shipment is appropriate for the requested analytical service. For example, "Rush Analysis" requires sample shipment with overnight delivery. If samples are for "Rush Analysis," then concurrence by the Area Director is required. Follow all chain-of-custody protocols. Apply tamper-evident seals (Form OSHA-21) to each sample as shown in Appendix G, and ensure that the chain-of-custody information is not obstructed by the seal. Make certain that samples are properly documented using the sampling worksheet, which is accessed through the OSHA Information System (OIS).

II. Pre-Inspection Activities

A. Review Background Information

1. Review and follow the inspection procedures in the FOM (CPL 02-00-159 (Updated to be CPL 02-00-160, August 2, 2016)).
2. As part of the pre-inspection review, determine whether sampling may be required (and then verify during the on-site walk-around). Also during the pre-inspection review, determine whether exposure to more than one chemical may occur. Refer to OSHA's CSI file for the required sampling media, minimum and maximum sampling volume and flow rate, potential interferences, and handling requirements for individual chemical substances. Contact the SLTC for further guidance if necessary.

   Determine whether there are special handling or shipping requirements prior to sample collection. Refer to OSHA's CSI file. For example, some types of samples need to be shipped back quickly and/or on ice. Sampling media for isocyanates need to be stored refrigerated and protected from light until used, and should be extracted in the field to enhance sample recovery.

3. Refer to Sections III.I. through III.N. for specific sampling requirements for:
   - Total dust
   - Respirable dust
   - Crystalline Silica
   - Metals
   - Asbestos

  - Organic vapors and gases

B. Obtain Sampling Media, Equipment and Supplies

1. The Cincinnati Technical Center (CTC) provides sampling media, supplies and equipment as part of the Agency Expendable Supplies Program (AESP) and the Agency Loan Equipment Program (ALEP). The following are some of the sampling supplies that may be obtained through the AESP:
   - Drager Chip Measurement System (CMS)
   - Detector tubes
   - Filter cassettes (such as preassembled asbestos cassettes)
   - Mixed cellulose ester filters (MCEF)
   - Collar clips and gelbands
   - Sorbent tubes, such as charcoal tubes
   - Tube holders, tube openers, collar clips and manifolds
   - Cyclones
   - Tygon tubing
   - Form OSHA-21 seals
   - Duct tape
   - Calibration gas and accessories
   - Shipping supplies
   - Ventilation smoke tube kits

   A listing of supplies available through the AESP may be found on the OSHA Intranet.

   CSHOs may place an order for expendable supplies through the CTC via email or fax. The requesting office is charged for the items delivered. When placing an order, please include "AESP ORDER" in the subject line and the following information in the body of the message:

   - CSHO name and telephone number
   - Office name and address
   - For each item ordered:
     - AESP System ID Number (FES #)
     - Supplier Order Number
     - Brief description of the item(s)
     - Quantity

   The ALEP allows field offices to borrow over 250 pieces of specialized monitoring and other equipment from the CTC. The equipment includes items such as air velocity meters for ventilation assessment, dust and fiber aerosol monitors, multi-gas detectors, indoor air quality meters, air sampling pumps and calibrators, and photoionization detectors (PID). The typical loan period is 30 days, which can be extended, if necessary, depending on demand. Equipment can be shipped overnight if the need is urgent.

   A list of typical sampling equipment available through the ALEP may be found on the OSHA Intranet. Orders for technical equipment may be made through the same email or fax numbers used for expendable supplies. When placing an order, please include "ALEP ORDER" in the subject line and for each item requested include manufacturer and model, a description of the item(s), and quantity.

2. The SLTC provides some specialized sampling media, such as Carbosieve S-III, passive/diffusive samplers, and pre-weighed filter/cassette units for gravimetric sampling and analysis. Gravimetric filters are weighed at the SLTC and shipped to the field assembled in special cassettes to be used for sampling. The cassette/filter

units are returned to the SLTC after sampling for gravimetric determinations and for other analyses. See Appendix A for a discussion of pre-weighed filters. Refer to OSHA's CSI file or to Appendix B for a list of substances for gravimetric determination.

CSHOs may order sampling media from the SLTC using the order form, which is located on the OSHA Intranet, under CSHO Resources, and which lists media available through the SLTC. Appendix D lists the shelf life of sampling media provided by the SLTC.

C. Prepare Personal Air Sampling Equipment

1. Active Sampling
   - Assemble filter cassettes prior to the site visit when practical. Verify that the two halves of the cassette are firmly and completely seated against each other to prevent sample material from bypassing the filter. Do not mix brands of cassette components. A hand press can be used to ensure a good seal between the filter and the cassette halves. Examine the assembled cassette to make certain that the joints fit together securely. Use shrink tape or gel bands around the cassette to cover joints.
   - Ensure sampling pump batteries are fully charged. Battery care is discussed in Section II: Chapter 3. Also, refer to the pump manual for specific battery care guidance.
   - Calibrate personal sampling pumps before and after each day of sampling as described in Appendix F. Disconnect the pump from the charger before calibration. Use the same specific type of sample media in line that will be used for sampling in the field (e.g., filter, sorbent tube); but do not use the actual media used for calibration for field sampling. Where more than one pump will be used in the field, label the pumps to avoid mix-up.
   - Calibrate sampling pumps at the temperature and pressure (altitude) at which samples will be collected. If site conditions are substantially above or below room temperature, calibrate the pumps in a clean area at the site, if possible. Give the pump and calibrator electronics time to equilibrate to the temperature conditions at the site. If not possible, refer to manufacturer's guidance in the equipment manual for temperature corrections and contact the CTC as needed. If sampling will be performed at temperatures below 41°F, check the temperature operating range in the calibrator equipment manual before going to the site, and contact the CTC as needed.
   - To avoid sample mix-up, each sample (i.e., cassette, sorbent tube, impinger media) must be labeled with a unique sample number. Either label each sampler before use, or prepare the OSHA-21 seals beforehand by writing in the sample numbers, and then affixing an OSHA-21 seal immediately after removing the sampling device from the pump after post-calibration. OSHA-21 seals are shown in Appendix G. Note that preweighed gravimetric filters have assigned bar code numbers that can be used for sample identification.
   - Record presampling calibration data (such as pump serial number and flow rate) and the temperature and pressure of the calibration location using the OIS sampling worksheet. This will also serve as the sample submission document for samples requiring analysis by the SLTC.
2. Diffusive (Passive) Sampling
   - Diffusive samplers are convenient air sampling devices that sample gases and vapors and do not require the use of a sampling pump. They are discussed further in section III.N.2 of this chapter. Also refer to the CSI file for diffusive sampling applications and guidance.
   - When using diffusive samplers, it is very important to record the sampling site temperature and pressure using the OIS sampling worksheet.

III. On-Site Inspection Activities

A. Develop Documentation

- Document accurate and complete sampling pump calibration records and field sampling notes using the OIS air sampling worksheet.

  - Ensure accurate and consistent spelling of the inspected establishment name in order to facilitate future database searches.
  - Refer to the Integrated Management Information System (IMIS) Enforcement Data Processing Manual for detailed sample submission instructions.
- Take photographs and/or videos (as appropriate) and detailed notes concerning sources of airborne contaminants, work practices, potential chemical interferences, movement of employees around the workplace during the performance of their duties, engineering and administrative controls, the use of personal protective equipment (PPE), and other factors to assist in evaluating employee exposures.
- Ventilation and/or smoke tube measurements may be helpful in assessing engineering controls, as described in Chapter 3: Section IV.
- Be certain to observe whether the employee wore the sampling equipment properly. This is sometimes an important issue in litigation. Refer to the FOM for a more thorough discussion of inspection documentation procedures.

B. Sampling Strategy and Protocol

As part of the walkthrough, identify the:

- Processes/operations being run
- Tasks performed
- Materials used/materials employees are exposed to
- Work practices used
- Exposure controls in place and how effective they appear to be

Evaluate the chemicals being used. Consider the approximate quantities and utilization rates. For liquids, consider indicators of volatility (e.g., boiling point and vapor pressure). Consider whether handling practices and engineering controls are being used that would increase or decrease exposure. Determine whether exposure is likely to occur as a vapor or an aerosol.

Sample those individuals likely to have the highest workplace exposures (i.e., highest-risk employees) due to the materials and processes with which they work, the conditions in which they work (e.g., distance to exposure source and air movement), the tasks they perform, the frequency of the tasks, and the way in which they perform the tasks (e.g., work habits and employee mobility). For example, in a welding shop, the tall welder who leans over his work may have higher exposures than a shorter welder who is not leaning into the rising plume.

Determine if employees are exposed to more than one chemical, either simultaneously or sequentially. This topic is discussed in Section III.G. Chemical Mixtures.

Determine as soon as possible after the start of the inspection whether air contaminant sampling is required by using the information collected during the walk-around (including any screening samples, such as detector tube results) and from the pre-inspection review. To eliminate errors associated with fluctuations in exposure, conduct representative full-shift sampling for air contaminants when determining compliance with an 8-hour time-weighted average (TWA) permissible exposure limit (PEL). Full-shift sampling is defined as a minimum of the total time of the work shift less one hour (e.g., seven hours of an 8-hour work shift or nine hours of a ten-hour work shift). Make every attempt to sample as much of the work shift as possible, including segments of the greatest exposure. However, no more than eight hours of sampling can be used in the 8-hour TWA calculation (for extended work shifts refer to Section III. E.). A representative exposure sample period may be less than seven hours.

Where relatively high airborne concentrations are anticipated, it may be necessary to replace the sampler during the shift to avoid filter overloading and/or sorbent saturation (refer to Section III.D.5.). Before sampling, check the CSI method to determine flow rate and the minimum and maximum sample volumes needed for each sample. Based on the minimum sample volume and flow rate, determine the minimum duration per sampler.

Equation 1

Minimum sample time = minimum sample volume / flow rate

For example, if the minimum sample volume is 240 liters, and the flow rate is 2 liters per minute (L/min), the sampler could be changed out after two hours, and full-shift sampling could be conducted using four two-hour time segments. However, if the minimum sample volume is 600 liters and the flow rate is 2 L/min, a four-hour sample would be insufficient.

And based on the maximum sample volume and flow rate, determine the maximum duration per sampler.

Equation 2

Minimum sample time = minimum sample volume / flow rate

For example, OSHA Method ID-100 for ethylene oxide specifies a flow rate of 0.05 L/min and a maximum sample volume of 12 liters. For full-shift sampling it will be necessary to sample in segments of no longer than four hours to avoid exceeding the maximum sample volume (12 liters/0.05 L/min = 240 minutes, or 4 hours).

C. Short Term Exposure Limits and Ceiling Limit Values

Many of OSHA's expanded health standards, such as formaldehyde and methylene chloride, include permissible short term exposure limits (STELs), which are generally 15-minute exposure limits. STEL sampling is conducted by taking a breathing zone air sample of 15 minutes duration in accordance with the applicable sampling method in the CSI file.

Many air contaminants in 29 CFR 1910.1000 have a ceiling limit, either in addition to or instead of an 8-hour TWA PEL. In 29 CFR 1910.1000, Table Z-1, these are noted by a (C), while Table Z-2 contains a separate column for acceptable ceiling concentrations. Ceiling exposures are measured by sampling for a duration sufficient to meet the minimum sample volume in the sampling method in the CSI file.

D. Overview of the Sampling Process

1. Select the employees to be monitored and discuss with them the purpose of sampling, how the equipment will be placed, and when and where the sampling equipment will be put on and removed. Stress the importance of not removing or tampering with the sampling equipment. Instruct the employees to notify their supervisors or the CSHO if the sampler requires temporary removal.
2. Place the calibrated sampling equipment on the employee so that it does not interfere with the employee's work performance or safety.
    - Attach the sampling pump to the employee's belt (with the flexible tubing already attached to the pump). Use the minimum length of tubing that is necessary and secure it to the employee to prevent snagging and to avoid interfering with the employee's work. For example, use a collar clip to attach the sampler to the employee's lapel, and tape the tubing to the employee's back between the shoulder blades using duct tape. Collar clips and duct tape are available through the AESP.
    - Attach the sampler (filter cassette, charcoal tube, etc.) to the flexible tubing after removing the outlet plug or cap. For flame-sealed sorbent tubes, break open both the ends at this time.
    - Attach the sample collection device (use a tube holder for glass sampling tubes) to the shirt collar or as close as practical to the nose and mouth in the employee's breathing zone (i.e., in a hemisphere forward of the shoulders within a radius of approximately six to nine inches). The collection device inlet should be oriented in a downward vertical position to avoid gross contamination from airborne debris falling into the collection device. Air should not pass through any tubing before entering the collection device because otherwise the contaminant of interest may be lost to the walls of any tubing that is placed before the inlet (due to adsorption of vapors or electrostatic attraction of particulates).
    - Orient the inlet (vortex finder) to a respirable dust cyclone so that it faces away from the employee.

- For an employee wearing a respirator (including a supplied-air hood for welding or abrasive blasting), place the sampler outside of the respirator. This action is necessary to determine whether the respirator's Assigned Protection Factor (APF) is adequate. For an employee wearing a welding helmet which is not a respirator, the collection device shall be placed under the helmet.

3. Open the inlet to the collection device: e.g., as appropriate to the sampling method, remove the inlet plug and/or face of the filter cassette or plastic end cap for sorbent tubes. Turn on the air sampling pump. After starting, observe the pump operation for a short time to make sure that it is operating correctly. For example, visually check the pump rotameter (if equipped) or digital flow readout, or touch the pump to feel for vibration.
4. Document the sampling pump start time and other required information. For diffusive samplers be sure to record the sampling site temperature and pressure.
5. Strive to sample for at least the **minimum** sampling time or air volume prescribed in the OSHA CSI file. However, this must be balanced against the need to replace the collection medium when overloading of the sampling medium is anticipated or observed during sampling. Overloading is characterized by saturation of the sampling medium. In the case of filters, overloading may be evidenced by the presence of loose material in the filter cassette, darkening of the filter and/or by a reduction in the sampling pump flow rate. For adsorbent media, overloading occurs when the ability of the sampling medium to effectively collect the analyte is compromised. In practice, overloading is difficult to detect and CSHOs should use their observations, experience, and professional judgment to avoid this adverse sampling situation. In general, overloading can be avoided by replacing the collection medium several times during the work shift (once the minimum sample volumes are achieved.)

   If overloading does occur, immediately replace the sampling medium. The sample may still be analyzed, although the reported results are likely to be lower than the actual air concentration.

6. Periodically monitor the employee throughout the workday to ensure that sample integrity is maintained and cyclical activities and work practices are identified. Do not enter areas where sampling is being conducted without the appropriate PPE. Frequent pump checks may be necessary, especially when heavy filter loading is possible. For air sampling filters, verify downward orientation of the sampler inlet and symmetrical deposition of particulate on the filter. There should be no large particles on the filter, since these do not move with the airstream. Check for evidence of tampering with the sample or pump. Ensure that the sampler remains properly assembled and that the tubing does not become pinched or detached from the collection device or from the pump. Check the pump flow readout to be sure the pump is still running. Record any relevant observations. Turn off or remove sampling pumps immediately prior to an employee leaving a potentially contaminated area (such as when he/she goes to lunch or on a break in a clean area). If these areas also appear contaminated and are considered part of the workplace, continue sampling and assess the need for surface contamination measurements (see Section II, Chapter 2, Surface Contaminants, Skin Exposure, Biological Monitoring and Other Analyses). If the pump is turned on and off during the course of the day and/or if the sampling media is changed, document subsequent start/stop times (time on/time off).
7. Before removing the pump at the end of the sampling period, check the pump flow readout (e.g., digital readout or built-in rotameter) to be sure it is still running.
8. Turn off the pump and document the stop time (**time off**).
9. Remove the collection device from the connecting tubing and close both the inlet and the outlet of the collection device as appropriate, for example using caps or plugs.
10. Seal the collection device with a Form OSHA-21 as soon as possible after sampling (see Appendix G regarding Form OSHA-21 seals and sample integrity). The seal should be attached across the sampler inlet and outlet so that evidence of any tampering is visible (see Appendix G, Figures G-1, G-4, and G-5). Appendix G, Figures G-2 and G-3 are photos of **incorrect** applications of Form OSHA-21 seals. Press the seal onto the cassette (or other sampler) to ensure that the adhesive adheres firmly to the cassette/ sampler.

Samples with seals that can be removed without obvious evidence of tampering will be identified as "Proper seals not in place" in the SLTC reports of analytical results.

E. Extended Work Shifts

CSHOs can choose one of two approaches for employees who work extended work shifts beyond eight hours. The decision will depend on the nature of the hazardous chemical and the work activity being performed.

- The first approach is to sample what the CSHO believes to be the worst continuous 8-hour work period of the entire extended work shift (e.g., two consecutive four-hour work periods separated by a lunch break).
- The second approach is to collect multiple samples over the entire work shift. Sampling is done so that multiple personal samples are collected during the first 8-hour work period and additional samples are collected for the extended work shift. Unless a CSHO is dealing with lead, the employee's exposure in this approach is calculated based upon the worst eight hours of exposure during the entire work shift. Using this method, the worst eight hours do not have to be contiguous. Example: for a 10-hour work shift, following the established sampling protocol as per the CSI file, 10 one-hour samples or five two-hour samples could be taken and the eight highest one-hour samples or the four highest two-hour samples could be used to calculate the employee's 8-hour TWA, which would be compared to the 8-hour TWA PEL. Be sure that the sample duration for each individual sample is long enough to meet the minimum sample volume described in the method.

  The lead standards for construction (29 CFR 1926.62) and general industry (29 CFR 1910.1025) require PEL adjustments with respect to extended work shifts (workshifts (longer than eight hours). Similarly, under the Cotton Dust standard (29 CFR 1910.1043), the PEL must be proportionately reduced for extended work shifts for the purpose of determining whether, and for how long, respirators must be worn.

F. Combustion and Thermal Breakdown Products

Certain contaminants are associated with combustion processes. Carbon monoxide (CO) exposures should be suspected whenever combustion-powered equipment, particularly gasoline-powered equipment, is used in areas with limited ventilation. Without a catalytic converter, gasoline-powered equipment typically produces thousands of parts per million (ppm) of tailpipe CO concentrations, as compared to a few hundred ppm produced by propane-powered equipment. The current PEL for CO is 50 ppm. Another combustion byproduct is nitrogen dioxide (NO2), which has a ceiling value of 5 ppm and is a byproduct of propane-fueled equipment.

Exposures to CO and nitrogen oxides are also associated with welding activities, although such exposures are not usually a concern in open shop welding. CO and NO2 sampling should be conducted when welding is performed in confined spaces. Ozone is associated with gas shielded metal arc welding. Safety data sheets (SDSs) for welding electrodes, wire and fluxes should be consulted. Contaminants commonly associated with welding include fluorides (if present in the flux-cored electrodes being used), manganese (if present in the electrodes), chromium and nickel oxide (when welding on stainless steel), and zinc (when welding on galvanized metal). "Weldable paints" may thermally degrade to aldehydes, butyric acid, bisphenol A, and numerous other organic molecules. Sampling for welding is discussed in Section III.L., Metals.

Where heated processes are present in the workplace, it may be necessary to sample for thermal decomposition products. In some cases, these are discussed in the SDSs for the products used at the establishment. In other cases, guidance is available from the SLTC for specific industrial processes. For example, in the polymer resin and plastics industries, machining, torch or laser cutting, or overheating of molding equipment may produce toxic decomposition products such as CO or cyanide. The following thermal decomposition products are associated with specific types of plastic: hydrogen chloride from polyvinyl chloride (PVC); styrene from polystyrene; fluoride compounds from polytetrafluoroethylene (PTFE or Teflon®); cyanide compounds from urethanes; and nitrogen-containing compounds from nylon and acrylonitrile. Further information may be found in industrial hygiene references such as Patty's Industrial Hygiene and Toxicology.

G. Chemical Mixtures

1. Chemical Interactions

Often an employee is exposed to a variety of chemical substances in the workplace simultaneously. In many construction and manufacturing processes, such exposures result in different effects than would be experienced with exposure to only one chemical. This type of exposure can also occur when impurities are present in single chemical operations. When exposure to multiple chemicals occurs, CSHOs should review the health effects information in the CSI to determine whether the chemicals affect the same body organ or physiologic system.

An **additive effect** is one in which the combined health effect of the simultaneous exposures is equal to the sum of the effects of each individual substance alone. For example, the cholinesterase inhibition of two organophosphate pesticides is usually additive when exposure occurs together. Similarly, many solvents have narcotic effects that are considered additive in nature. Below are additional examples of chemicals which have additive effects when exposure occurs together:

- acetonitrile + cyanides
- n-hexane + hexone (methyl isobutyl ketone [mibk]); 2,5 hexanedione or 2,5 hexanediol (all cause peripheral neuropathy)
- carbon monoxide + methylene chloride

A **synergistic effect** is one in which the combined effect of the exposures is much greater than the sum of the individual effects. Classic examples include the synergistic effect of carbon tetrachloride and ethanol on liver toxicity and the synergistic effect on the lungs of smoking and exposure to asbestos.

Potentiation describes a condition in which the target organ toxicity of a particular chemical is markedly increased by exposure to another chemical which does not ordinarily have toxic effects on that organ or system. For example, isopropanol is not a liver toxin, but when combined exposure to isopropanol and carbon tetrachloride (liver toxin) occurs, the liver toxicity is much greater than that due to carbon tetrachloride alone. Ethanol potentiates the toxicity of many other chlorinated hydrocarbons.

Antagonism refers to the situation in which the toxic effects of two chemicals interfere with each other, or the effects of one chemical are actually reduced by exposure to another chemical. This is the basis for many antidotes. Antagonism can occur by several different mechanisms. When chemical antagonism takes place, for example with chelating agents, two chemicals react in the body to a less toxic form. Functional antagonism refers to two chemicals having opposite effects on the same system, such as central nervous system (CNS) stimulants and depressants. Competitive antagonism refers to chemicals acting on the same receptor, such as nicotine and ganglionic blocking agents. Noncompetitive antagonism refers to the toxic effect being blocked by some other means, such as atropine reducing the toxicity of cholinesterase inhibitors.

2. Mixture Formula

OSHA's Air Contaminants standard provides a formula for assessing exposures to chemicals having additive effects [for general industry see 29 CFR 1910.1000(d)(2) and for shipyards see 29 CFR 1915.1000(d)(2)]. This calculation should be used when the components in the mixture pose a combined threat to worker health and components in the mixture have an effect on the same body (target) organ or physiologic system. This formula can be used for exposures occurring simultaneously or for TWA exposures occurring consecutively within the same workshift.

The mixture calculation is expressed as:

Equation 3

$E_m = (C_1 / L_1 + C_2 / L_2) + \ldots (C_n / L_n)$
Where:

E_m = equivalent exposure for the mixture (E_m should be less than or equal to 1 for compliance)
C = concentration of a particular substance
L = PEL

Section IV.D. describes sampling and analytical error (SAE) calculations for use of the mixture formula, and example calculations are provided in Appendix H. In addition, an online calculator is available to CSHOs on OSHA's Intranet (in the Directorate of Technical Support's webpage) which will calculate a control limit for any mixture. Simply input the exposures, limits, and SAEs, and the program will calculate a control limit according to the above equation.

A Mixture Calculator is also available on the OSHA Intranet.

The mixture formula may be used to assess employee exposures to chemicals having synergistic effects. However, since the health effects are generally more severe in this scenario, it may be appropriate to apply an increased penalty. As per Chapter 4 of the FOM, all such cases should be discussed with the supervisor and referred to the Regional Administrator. Use the following resource to determine whether there is evidence for synergistic effects: Chemical Mixture Risk Calculation IRSST.

3. Air Sampling for Mixtures (determining what to sample)

   The following three examples present portions of SDSs for products containing mixtures and illustrate the process of determining which ingredients should be evaluated for potential employee exposure.

Sample Safety Data Sheet #1

Section 1: *Product Name: Formalin Solution, Buffered 10%*
Section 2: *Composition:*

Ingredient	***CAS No.***	***Percent***	***Hazardous***
Methyl Alcohol	*67-56-1*	*1-1.5%*	*yes*
Formaldehyde	*50-00-0*	*4%*	*yes*
Water	*7732-18-5*	*~95%*	*no*

Section 8: *Exposure Controls / Personal Protection*

OSHA Permissible Exposure Limits:

Formaldehyde:
  0.75 ppm TWA PEL
  2.0 ppm STEL
  0.5 ppm Action Level
Methyl Alcohol:
  200 ppm TWA

Section 9: *Physical and Chemical Properties:*

Vapor Pressure (mmHg): Essentially the same as water
Evaporation Rate: Essentially the same as water.

Since the SDS does not report the physical properties for the individual ingredients, it is necessary to look at other reference information to determine the relative volatility of the components. Physical properties for specific chemicals may be found in either the CSI file for each chemical, or in the NIOSH Pocket Guide to Chemical Hazards, which can be accessed from links in each chemical's CSI file.

Excerpts from NIOSH Pocket Guide:

Methyl Alcohol:
Boiling point: 147°F
Vapor Pressure: 97 mmHg

Formaldehyde:
Boiling point: -6°F

Vapor Pressure: > 1atm (1 atm = 760 mmHg)

IDLH: 20 ppm

In comparing the methanol and the formaldehyde, the formaldehyde is present at four times the concentration in the mixture, is considerably more volatile, and has an Action Level which is 1/400th the PEL for methanol. Formaldehyde is a potent irritant with an Immediately Dangerous to Life or Health (IDLH) concentration which is 1/10th the PEL for methanol. Therefore, it is expected that methanol will not make a significant contribution to worker exposure as compared to formaldehyde. Sampling for formaldehyde alone would be considered sufficient. Please note that the CSI states that active sampling, rather than passive badges (diffusive samplers), must be used to sample for formaldehyde where formalin is the source of formaldehyde exposure. Also note that formaldehyde is an OSHA-regulated carcinogen with a substance-specific expanded health standard (29 CFR 1910.1048).

Sample Safety Data Sheet #2

Section 1: *Product Name: Gravure Ink*
Section 2: *Composition:*

Ingredient	***CAS No.***	***Percent***	***PEL (ppm)***	***Other Exposure Limits (ppm)***
Toluene	*108-88-3*	*29%*	*200*	*300 ceiling(OSHA)* *500 peak (OSHA)*
1,2-propanediol	*57-55-6*	*5%*	*none*	*not found*
Xylene (mixed)	*1330-20-7*	*31%*	*100*	*150 STEL* *(NIOSH and ACGIH)*

Section 9 *– Physical Properties: % Volume Volatile: 88.6*

Again, the physical properties information on the SDS does not indicate the relative volatility of the components, so it is helpful to refer to the CSI file, including the NIOSH Pocket Guide.

Excerpts from CSI and/or NIOSH Pocket Guide:

Chemical	**Boiling Point**	**Vapor Pressure**

Chemical	**Boiling Point**	**Vapor Pressure**
Toluene	232°F	21 mmHg
1,2-propanediol	188°C	0.05 mmHg
m-xylene	282°F	9 mmHg

A review of the CSI file for CAS number 57-55-6 reveals the more common name, propylene glycol. The CSI file states that this material is a Food and Drug Administration (FDA)-approved food additive which is "generally recognized as safe." Due to its low concentration, volatility, and toxicity, sampling for this material is unnecessary.

Sampling for both toluene and the xylenes is recommended if significant quantities are used without adequate local exhaust ventilation. Additionally, toluene and xylenes have similar target organ effects, so the exposures should be evaluated as a mixture using the mixture formula. Toluene and xylenes share the following target organs: central nervous system, eyes, skin, respiratory system, liver and kidneys.

Note that this SDS includes references to non-OSHA occupational exposure limits – in particular, limits set by NIOSH and American Conference of Governmental Industrial Hygienists (ACGIH). NIOSH sets Recommended Exposure Limits (RELs), while ACGIH sets Threshold Limit Values (TLVs). Note that while there is no OSHA ceiling value for xylene, there is a NIOSH/ACGIH STEL. For substances with an 8-hour PEL, but no OSHA ceiling/STEL value, the case should be referred to the Regional Administrator (as described in Chapter 4 of the FOM) if exposure exceeds an ACGIH or NIOSH STEL or ceiling value.

Sample Safety Data Sheet #3

Section 1: *Product Name: Indoor/Outdoor Spray Paint – True Blue*
Section 2: *Composition:*

Ingredient	***CAS No.***	***Percent***	***Exposure Limits***	***Vapor Pressure***
Propane	*74-98-6*	*25%*	*PEL 1,000 ppm*	*760 mmHg*
VM & P Naptha	*8032-32-4*	*12%*	*TLV 300 ppm*	*12 mmHg*
Toluene	*108-88-3*	*15%*	*PEL 200 ppm* *TLV 20 ppm*	*22 mmHg*
Light Aromatic Hydrocarbons	*64742-95-6*	*1%*	*Not available*	*4 mmHg*
1,2,4-Trimethylbenzene	*95-63-6*	*2%*	*PEL 25 ppm*	*2 mmHg*
Acetone	*67-64-1*	*30%*	*PEL 1,000 ppm*	*180 mmHg*
Titanium Dioxide (Total Dust)	*13463-67-7*	*0.1%*	*PEL 15 mg/m^3 TLV 10 mg/m^3*	*n/a*

Section 5 *– Fire Fighting Measures:*

Flash Point of Propane: <0°F
LEL 0.7%
UEL 12.8%

The PEL for propane is 1,000 ppm and it constitutes 25% of the mixture. Propane is a "simple asphyxiant," meaning it is nontoxic and acts by displacing oxygen. However, propane is flammable, so it is relevant to monitor for flammable gas.

Among the solvents, the greatest exposures will be to acetone because it is present at the highest concentration (30%) and is very volatile. Toluene should also be sampled since its PEL (200 ppm) is lower than the PEL for acetone (1,000 ppm) and its concentration in the mixture is significantly high (15%). If the spray paint is used in moderate quantities for brief periods outdoors or in a spray booth, the trimethylbenzene would likely not evaporate until after the completion of a brief spray application due to its low volatility. Under those circumstances, it is unlikely that the trimethylbenzene would contribute significantly to the worker's exposure, since it is present at such a low percentage. However, for spray applications of long duration performed without local exhaust controls, the trimethylbenzene should be included because although its concentration in the mixture is low, its PEL is also very low warranting the need to determine the level of exposure. Since these solvents are likely to have similar narcotic effects, the CSI should be reviewed to determine whether they have the same target organs, in which case the mixture calculation should be applied.

The titanium dioxide (TiO2) is present at a very low concentration, is only a nuisance dust, and would be released in a wetted form as part of an aerosol. Gravimetric sampling for the TiO2 is neither necessary nor practical. The light aromatic hydrocarbons can be ignored since they are present at such a low concentration.

H. Field Blanks

Field blanks are used by the lab to determine if contamination has occurred before analysis or during sample handling, shipping, or storage. Field blanks (e.g., sorbet tubes, filters, absorbing solution) are clean sample media that are taken and opened in a clean area at the sampling site, but they are not used to take samples. They should be handled, stored and shipped in the same manner as other sampling media used in sampling air contaminants, with the exception that no air is drawn through them. Field blanks are required for **each** requested analysis and for each lot number of sampling media. Prepare field blanks during the sampling period for each type of sample collected. One field blank will usually suffice for up to 20 samples for any given analysis/sampling period. However, asbestos requires a minimum of two field blanks, even for a single asbestos sample.

Diffusive samplers should be briefly opened in the field in an area on-site where no contamination is expected and then they should be immediately resealed with manufacturer's materials. Diffusive samplers begin to sample as soon as they are opened and continue to sample until they are sealed. Follow sample seal procedures for the field blanks as described in Appendix G.

I. Total Dust

Total dust sampling is used to evaluate exposures to a variety of dusts as shown in Appendix B. Also, use total dust sampling for toxicologically inert, nuisance dusts, whether mineral, inorganic, or organic. These dusts are listed in 29 CFR 1910.1000, Table Z-1 as particulates not otherwise regulated (PNOR) and Table Z-3 as nuisance dust, and in 29 CFR 1915.1000 Table Z as PNOR. Please note that there are both total dust and respirable dust PELs for many PNOR (see Appendix B).

Total dust sampling uses pre-weighed PVC filters to determine the total mass of dust collected during the sampling period. Obtain pre-weighed PVC filters from the SLTC. Use a maximum flow rate of 2 L/min for a maximum sampling time of 480 minutes or eight hours. Visually check the filter during the sampling period to avoid overloading the filter. Overloading may be evidenced by the presence of loose material in the filter cassette, by a darkening of the filter, and/or by a reduction in the sampling pump flow rate. Check for overloading by looking into the inlet of the sampling cassette, using a flashlight if needed.

J. Respirable Dust

Respirable dust sampling uses a cyclone to separate and capture those particles in the size range which would be deposited in the gas exchange region of the lung. Particles too large to be inhaled are collected in a grit pot in the cyclone. The respirable fraction is captured on a pre-weighed PVC filter for gravimetric analysis. Appendix B lists dusts for which respirable sampling should be performed. Obtain pre-weighed PVC filters from the SLTC.

Collect respirable dust samples using a clean 10 mm nylon Dorr-Oliver® cyclone and a pre-weighed PVC filter at a flow rate of 1.7 L/min for a maximum sampling time of 480 minutes (see Figures 1 and 2 shown below, and Appendix I, Figures I-1 and I-2).

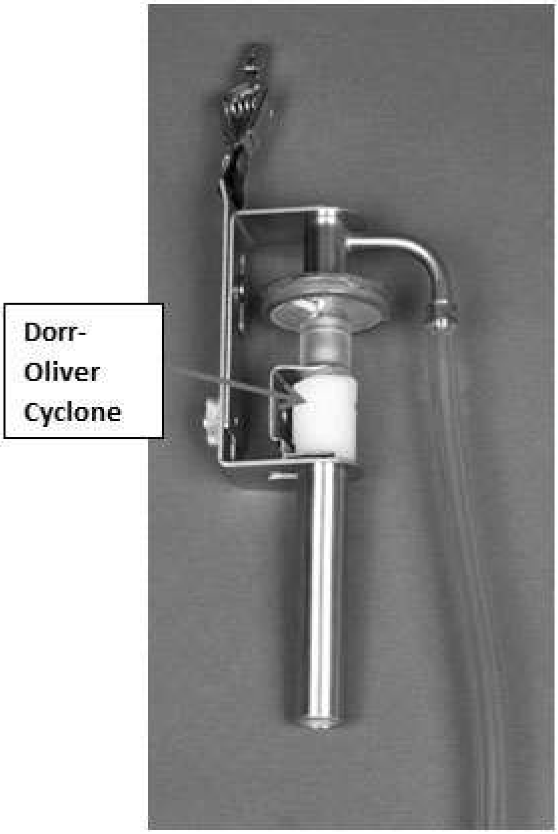

Figure 1. MSA Sampling Train with Dorr-Oliver Cyclone and Cassette

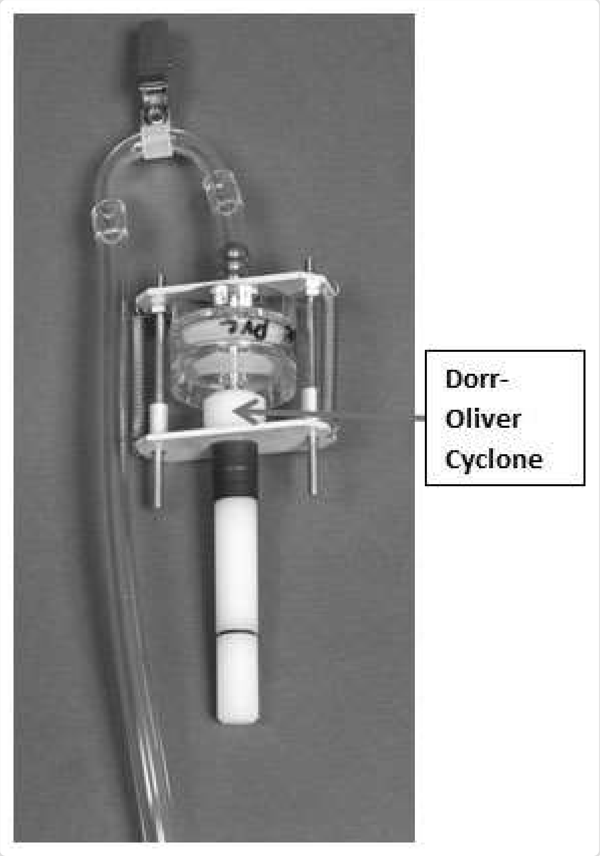

Figure 2. Sensidyne Sampling Train with Dorr-Oliver Cyclone and Cassette

The particle size selective characteristics are determined by the type of cyclone used together with the sampling flow rate. A Dorr-Oliver cyclone set to a flow rate of 1.7 L/min can be used in order to meet the specifications described in Table Z-3 (Mineral Dusts) of 29 CFR 1910.1000, footnote "e." Footnote "e" states that both concentration and percent quartz for the application of the crystalline silica and coal dust limits are to be determined from the fraction passing a size-selector with the characteristics shown in Table 1.

Table 1. Sampling Characteristics of A Size selector

Aerodynamic diameter, μm (unit density sphere)	**Percent passing size selector**
2.0	90
2.5	75
3.5	50
5.0	25
10	0

Although the criteria in Table 1 were written to meet the Dorr-Oliver performance specifications, any technology that meets this size selective sampling criteria can be used. As OSHA maintains a significant inventory of Dorr-Oliver cyclones, they remain the primary equipment for respirable mass fraction sampling.

Note: Adjusting the flow rate of any other sampler design until a 50% cut is achieved at 3.5 μm aerodynamic diameter may not achieve comparable aerodynamic diameters to those specified at the 0, 25, 75, and 90% cut points.

Appendix I contains cyclone assembly and cleaning instructions. Be careful not to overload the filter. Make certain that the cyclone inlet (vortex finder) faces away from the person being monitored.

K. Crystalline Silica

1. Air Samples

   When employees are exposed to silica during abrasive blasting, air sampling should be done outside the abrasive blasting hood.

   Crystalline silica samples are to be collected using a Dorr-Oliver or other suitable cyclone as described for respirable dust samples. A silica sample collected without a cyclone would be a total dust sample and different OSHA PELs apply to respirable and total dust samples. Because of analytical difficulties, CSHOs are discouraged from submitting total dust air samples for silica analysis. The SLTC's silica analysis requires that the particle size distribution of the samples be matched as closely as possible to calibration standards, and this is best accomplished with a respirable sample. If the collected sample is nonrespirable, the SLTC **must** be advised on the air sampling worksheet.

   Contact the SLTC if cristobalite or tridymite analysis is required. In general, cristobalite and/or tridymite are produced under conditions involving the high temperature firing of quartz.

   X-ray diffraction (XRD) is the preferred silica analytical method because of its sensitivity, its minimum requirements for sample preparation, and its ability to identify polymorphs (different crystalline forms) of free silica. Quartz is initially identified by its major (primary) x-ray diffraction peak. If significant levels of quartz are identified, its presence is confirmed using secondary, tertiary, and/or quaternary peaks to eliminate the possibility of interfering crystalline substances. CSHOs should notify the SLTC if any of the following substances are known to be present in the workplace:

   Aluminum phosphate
   Feldspars (microcline, orthoclase, plagioclase)
   Graphite
   Iron carbide
   Lead sulfate
   Micas (biotite, muscovite)
   Montmorillonite
   Potash
   Sillimanite
   Silver chloride
   Talc
   Zircon (zirconium silicate)

   The SLTC results for silica air samples are usually reported under one of four categories:

   - Percent quartz and/or percent cristobalite present in the respirable sample. The analysis of tridymite is performed only when requested and results are qualitative only.
   - Less than or equal to the percent quartz (and/or cristobalite or tridymite). Less than or equal to values are used when the adjusted 8-hour exposure is found to be less than the PEL, based on the sample's primary diffraction peak. The value reported represents the maximum amount of quartz (or cristobalite) that could be present. However, the presence of quartz (or cristobalite) was not confirmed using

secondary and/or tertiary peaks in the sample because the sample results did not show a violation of the PEL.

- Approximate values in units of percent are given for total dust samples. The particle size distribution in a total dust sample is unknown and creates an error in the XRD analysis which limits accuracy to an approximation.
- Nondetected. A sample reported as nondetected indicates that the quantity of quartz (or cristobalite) present in the sample is not greater than the detection limit of the instrument. The detection limit is usually 10 micrograms (µg) for quartz and 30 µg for cristobalite. If less than a full-shift sample was collected, CSHOs should evaluate a nondetected result to determine whether adequate sampling was performed. If the presence of quartz (or cristobalite) is suspected, CSHOs may want to sample for a longer period of time to increase the amount of sample collected.

2. Calculations for Crystalline Silica Exposures

The calculations below are used for determining compliance with the OSHA PELs for crystalline silica. Sample calculations are shown in Appendix J. The *Silica Advisor Genius Calculator* may be used for general industry (mass-based) calculations. Note that the Advisor Genius is not set up to calculate a "millions of particles per cubic foot" (mppcf) measurement.

Construction and Shipyard Calculations:

Construction and shipyard PELs for silica are measured in units of "millions of particles per cubic foot" (mppcf). The particle count methods are no longer used, and have been replaced by gravimetric (weight) methods. To convert gravimetric results for a respirable dust measurement to mppcf, use the following formula:

Equation 4

$mppcf = (0.1)(mg/m^3)$

Before converting mg/m^3 to mppcf, the SLTC's SAE must be applied to the severity (see Equation 9) to determine the upper and lower confidence limits.

The construction/maritime PEL for respirable dust containing silica (as quartz) is determined individually for each sample using the following formula:

Equation 5

PEL (cystalline silica, quartz) = 250 mppcf / % silica + 5

Conversion factors:

1 *mppcf* = 0.1 *mg/m^3 respirable dust* or
1 *mg/m^3* = 10 *mppcf respirable dust*

General Industry Calculations

The general industry PEL for respirable dust containing crystalline silica (as quartz), codified at 29 CFR 1910.1000, is determined individually for each sample using the following formula:

Equation 6

PEL (mg/m^3) = 10 mg/m^3/ 2 + % respirable quartz

The PEL can be calculated either by following the steps below, or by accessing the *Advisor Genius* online at the OSHA website. The Advisor Genius performs the calculations for a respirable dust sample and yields five values: the PEL for the sample, the respirable dust exposure concentration (mg/m^3), the severity, and the upper and lower confidence limits

To determine the PEL for an air sample containing respirable crystalline silica:

- Obtain the respirable dust concentration for the sample. The weight of the respirable dust in the air sample (expressed as mg or µg) is the net filter weight gain, as determined by the laboratory. The sample air volume is then used to express the concentration of respirable dust in air, as mg of respirable dust per cubic meter of air (mg/m^3), as follows:

Equation 7

respirable dust concentration in air (mg/m^3) = ((sample respirable dust weight (mg)) / (total air volume sampled (m^3)))

- Obtain the percent respirable crystalline silica (e.g., as quartz) in the respirable dust sample, determined analytically by the laboratory and derived as follows:

Equation 8

% respirable quartz = (weight of quartz (mg or µg) x 100) / (sample respirable dust weight (mg or µg))

- Calculate the PEL for the sample, using the reported percent respirable quartz entered as a whole number (e.g., if the % quartz is 7%, use the whole number 7) in Equation 6.

To determine whether there is an overexposure, compare the PEL, calculated using Equation 6, with the sample respirable dust concentration, calculated using Equation 8. The severity ratio is determined by the following formula:

Equation 9

The equation above is the same as: Y = X / PEL

Calculate the Lower Confidence Limit (LCL) by subtracting the SAE from the severity:

Equation 10

LCL = Severity - SAE

If the LCL is greater than 1, there is a greater than 95% confidence that the sampled employee's exposure exceeded the PEL, and the employee was, therefore, overexposed to respirable dust containing crystalline silica as quartz.

Calculate the Upper Confidence Limit (UCL) by adding the SAE to the severity:

Equation 11

UCL = Severity + SAE

If the UCL is less than 1, there is a greater than 95% confidence that the sampled employee's exposure did not exceed the PEL.

In the unusual situation where the LCL is less than 1 but the UCL is greater than 1, the employee's exposure relative to the PEL cannot confidently be classified as either over or under and resampling should be considered.

Other factors may have to be considered before arriving at a final exposure value. For example, the TWA calculation may require combining two or more sample results and adjusting to an 8-hour workday. An example is shown in Appendix J.

Where the employee is exposed to combinations of silica dust (i.e., quartz and cristobalite), the additive effects of the mixture will be considered. For the PEL calculation specified in 29 CFR 1910.1000, Table Z-3, the percent silica will be determined by doubling the percentages of cristobalite and tridymite and adding them to the percentage of quartz, according to the following formula:

Equation 12

$$PEL_{mixture} = (10\ mg/m^3) / (\%\ quartz + 2\ (\%\ cristobalite) + 2(\%\ tridymite) + 2)$$

L. Metals

1. Air Samples

   Welding

   When sampling for welding fumes, the filter cassette must be placed inside the welding helmet to obtain an accurate measurement of the employee's exposure. Welding fume samples are normally taken using 37-mm mixed cellulose ester filters (MCEF) and cassettes. If these cassettes will not fit inside the helmet, 25-mm MCEF and cassettes can be used. Extra care must be taken not to overload the smaller 25-mm MCEF when sampling.

   When a welding helmet or face shield is worn, the sampler is placed on the collar or shoulder so that it is beneath the helmet when the helmet is placed down; it must be located in the breathing zone of the employee (a radius forward of the shoulders and within 6-9 inches of the mouth and nose). Studies have shown that the welding helmet alone results in a reduction in the wearer's breathing zone exposures to welding fume. Placing the sampler under the helmet allows a determination of whether respiratory protection is needed.

   Whenever respiratory protection is worn, employee exposure samples must be taken in the breathing zone, but outside the respirator, in order to determine whether the assigned protection factor of the respirator is adequate based on the measured exposures outside the respirator. Some newer styles of negative pressure respirators are designed to fit under a welding helmet. In this case, where an employee is wearing both a welding helmet and a tight-fitting negative pressure respirator, the sampler is placed under the helmet, but outside of the respirator. Where a supplied air welding hood or abrasive blasting hood is worn, the sampler is placed outside the hood, also in the defined breathing zone.

   For analysis of welding fume, OSHA Method ID-125G is preferred. This method allows for analysis of several metals on the same filter. Collect metal fumes using a three-stage 37-mm, 0.8-µm MCEF cassette using a maximum flow rate of 2 L/min. Specify the metals of greatest interest in the OIS air sampling worksheet.

   Gravimetric determination is required for those substances listed in Appendix B. Use pre-weighed low ash PVC filters obtained from the SLTC as described in Section III.I., Total Dust. Low ash PVC filters may be submitted for metals analysis after the gravimetric determination is performed. See OSHA's CSI file for further detail. Be careful not to overload the filter.

   Dust and Fume

   When a toxic metal such as lead is present in a workplace as both dust and fume, it may be necessary to sample separately for the dust and the fume. For example, when hot work will be performed adjacent to areas painted with metallic paints, a total dust sample would be collected, as non-respirable particles may be carried out of the lungs by pulmonary clearance mechanisms and then swallowed. The worker would need to wear two sampling pumps, one for dust and one for fume. For total dust, use a preweighed PVC filter obtained from the SLTC. For the fume, use a MCEF filter. In both cases the flow rate is up to 2 L/min. Similarly, vanadium has separate PELs for fume and respirable dust, necessitating the use of two sampling pumps, one with a MCEF cassette for the fume and the other with a cyclone for the respirable dust.

2. Bulk Samples

Bulk samples are sometimes taken to document the source of the material present in the air. Always attempt to take representative samples for bulk analysis. The SLTC analysts will make a reasonable attempt to homogenize samples submitted by CSHOs, however, excessive sample quantities and highly non-homogenous samples complicate this process. Ideally, bulk samples should contain a minimum of approximately 200 mg, but less than a gram, shipped in glass 20-mL scintillation vials with PTFE-lined caps.

3. Metal Analysis

The SLTC is capable of analyzing a variety of metals in specific compatible combinations depending on the ability of the analytical method to simultaneously dissolve the metals of interest in a given acid matrix, and depending on the stability of the metal on the collection filter. In particular, sampling for hexavalent chromium requires use of PVC or treated quartz filters. Some of the current analyte/matrix combinations are listed below and are defined by specific OSHA sampling and analytical methods. Refer to OSHA's CSI file for the most up-to-date analyte/method combinations:

The following combination of 13 metal analytes can be analyzed simultaneously by Inductively Coupled Plasma (ICP) using OSHA Method ID-125G:

Antimony
Beryllium
Cadmium
Chromium (elemental)
Cobalt
Copper
Iron
Lead
Manganese
Molybdenum
Nickel
Vanadium
Zinc

NOTE: The above combination of analytes has been historically referred to as "ICP" for welding fume samples. Where one or more of the analytes are requested for a given filter sample, a full ICP analysis may be conducted, however, CSHOs should specify which metals are of the most interest in the event samples cannot be analyzed by this method or any other multi-element method. Sometimes, alternative types of samples (e.g., samples taken during abrasive blasting operations) may not be analyzed using OSHA Method ID-125G (ICP) because of analytical difficulties encountered with sample characteristics, heavy sample loadings, analyte solubility limitations, or instrumental limitations. Some of these problematic samples and analytes can be analyzed using other multi-element methods listed below or with one of the OSHA Method ID-121 procedures originally designed for individual metal determinations (e.g., Pb, Cd, Fe). Refer directly to OSHA Method ID-121 to interpret the complex choices and compatibilities of a host of assorted analytes and their various preparation techniques. When questions of analytical capabilities arise, CSHOs are encouraged to contact the SLTC spectroscopy experts for further guidance and discussion of analytical options to suit specific compliance monitoring needs.

The SLTC can analyze the following combination of metal analytes, historically referred to as "solder," using OSHA Method ID-206:

Antimony
Beryllium
Cadmium
Copper

- Lead
- Silver
- Tin
- Zinc

The following combination of metal analytes can be analyzed OSHA Method 1006:

- Arsenic
- Cadmium
- Copper
- Iron
- Lead
- Zinc

M. Asbestos

Collect samples for asbestos using 0.8-µm, 25-mm diameter MCEF cassettes which have been specially designated by the manufacturer for asbestos analysis. The filters must be contained in an electrically conductive cassette assembly that includes a 50-mm extension cowl (see Figure F-5 in Appendix F). An electrically conductive cassette is necessary to prevent loss of fibers to the walls of the cassette due to electrostatic forces. Ensure that the bottom joint (between the extension and the conical black piece) of the cassette is sealed tightly with a shrink band or electrical tape. Make certain that the cassette does not leak. Fasten the (uncapped) open-face cassette to the worker's lapel. Orient the open face downward.

Use a flow rate in the range of 0.5 to 5 L/min. One L/min is suggested for general sampling. For office environments use flow rates up to 5 L/min.

Calibrate as discussed in Appendix F. Do not use nylon or metal (e.g., stainless steel or plated brass) adapters if in-line calibration is done. Do not use the same filter cassette intended to be used for field sampling for sampling pump calibration.

Sample for as long a time as possible without overloading (obscuring) the filter because overloading can lead to an unreadable sample. In a dusty environment, smaller air volumes may be necessary to prevent obscuring the filter (see the discussions on filter overloading in Sections III.D. and III.I.). Instruct the employee to avoid knocking the cassette and, if possible, to avoid using a compressed air source that might dislodge the collected contaminant while sampling. After sampling, replace the face cover and end caps and secure the Form OSHA-21 seal, then post-calibrate the sampling pump.

Approximately 10% of all samples submitted should be blanks, with a minimum of two blanks in all cases.

Where possible, collect and submit a bulk sample of the material suspected to be in the air. Use a wet method for sampling and wear respiratory protection in accordance with regional policy. Submit approximately 0.5 to 1 gram of material in a 20 mL glass scintillation vial with a PolySealTM cap. Be sure to collect samples from all layers and phases (visually distinct types) of the material. A knife or cork-borer may be used. If possible, make separate samples of each different phase of the material, and place each bulk sample in a separate vial. Ship bulk samples and air samples separately to avoid cross-contamination.

Secure and handle the samples so that they will not rattle during shipment or be exposed to static electricity. Do not ship samples in expanded polystyrene peanuts, vermiculite, paper shreds, or excelsior. Tape sample cassettes to sheet bubbles and place in a container that will cushion the samples without rattling.

Asbestos air samples are analyzed by phase contrast microscopy (PCM) to determine fiber counts. However, PCM does not identify fiber type. List any known fibrous interferences present during sampling in the OIS air sampling worksheet, for example, cellulose (paper, wood), fiberglass, fur, or refractory ceramic. Also, note the workplace operation(s) sampled. Bulk samples are analyzed by polarized light microscopy (PLM) to confirm fiber type. If needed, air samples can be subjected to differential techniques to confirm fiber type and percentage.

For unusual sampling conditions or high flow rates, contact the SLTC for more detailed instructions.

N. Organic Vapors and Gases

1. Solid Sorbent Sampling Tubes

   Organic vapors and gases can be collected using several different sampling media including charcoal and other sorbents in sampling tubes (see Figure 3) with low-flow sampling pumps. Refer to OSHA's CSI file for required sampling media, rates, and volumes for specific chemicals.

   Sorbent tube sampling is generally conducted at much lower flow rates than particulate sampling to allow sufficient residence time for the contaminant of interest to adsorb to the sorbent. Sorbent sampling tubes typically contain two sections of sorbent separated by a spacer, such as foam or glass wool. The larger section of sorbent is the primary, and the smaller section is the backup. Orient the back-up section toward the sampling pump. As air is drawn through the sorbent tube, the contaminant of interest will pass into the primary section and bind to the sorbent. When the sorbent in the primary section becomes saturated, contaminant will pass into the back-up section. This is known as **breakthrough**. The lab analyzes the two sorbent sections separately; if greater than 25% of the contaminant is found in the back-up section, this may indicate that sample was lost due to breakthrough. Breakthrough may result in an underestimation of the employee exposure. The lab should notify the CSHO if breakthrough may have occurred.

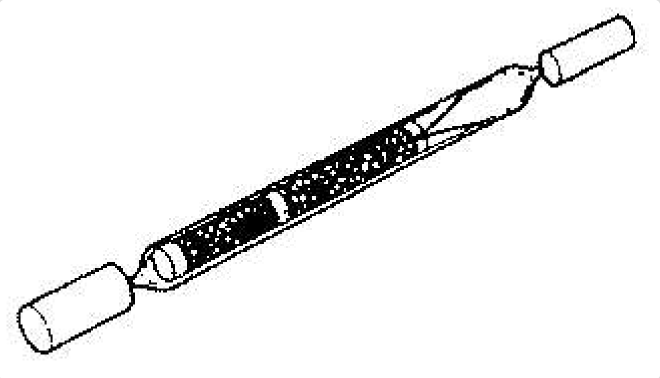

Figure 3. Charcoal Tube with Flame-sealed Ends and End Caps

   Contaminant **migration** may also occur—where contaminant bound in the primary section desorbs and passes into the back-up section after sample collection is completed. There is no way for the lab to distinguish whether material found in the back-up section is the result of breakthrough or migration. To avoid migration, ship samples to the lab without delay. In some cases refrigeration of samples is recommended to reduce migration, for example, in OSHA Method ID-56 for 1,3-Butadiene. Some sampling methods, such as OSHA Method ID-91 for methanol, address the problem of migration by using two sorbent tubes attached in series. The two tubes must be separated from each other and sealed (capped) immediately after sampling.

   Note that other airborne contaminants, including moisture, will compete for binding sites on the sorbent. Sample volumes (flow rate and/or sample duration) may need to be decreased under conditions of high humidity (> 90%) or when competing contaminants are present in relatively high concentrations. Check the CSI file for further information.

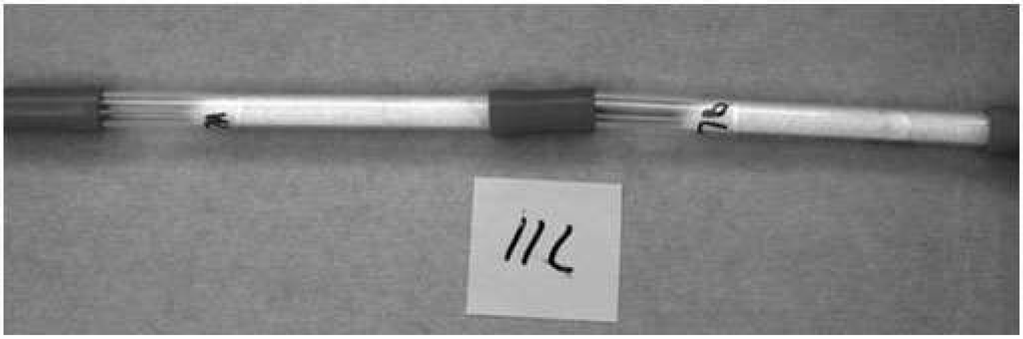

Figure 4. Two Sorbent Tubes in Series

Certain situations require use of multiple sorbent tubes, either in series or in parallel (see Figures 4 and 5). As described above, tubes may be used in series to avoid migration of the analyte of interest from the primary to the back-up sections, or to prevent breakthrough by increasing the sampler capacity. Series sampling may also be used where the contaminant of interest must be chemically converted to a more stable form in order to be retained on the sorbent. For example, nitric oxide is sampled using three sorbet tubes connected in series. The front and back tubes contain molecular sieves impregnated with triethanolamine, and the middle or oxidizer tube contains an inert support impregnated with a chromate salt. The middle tube is not submitted to the lab for analysis, but may undergo a color change indicative of depletion of the oxidizer.

Figure 5. Large Protective Tube Cover for Sorbent Tubes in Series (Photo courtesy of NIOSH)

Sampling tubes may also be used in parallel. Sampling in parallel allows simultaneous sampling for multiple chemicals using different sampling media with the same sampling pump. This would generally be done when multiple airborne contaminants are suspected to be present, and either the analytical method does not allow for analysis of more than one of the components from the same sorbent tube or the methods require the use of different sampling media. For example, in ink manufacture, tubes containing different sorbents would be used in parallel. Sorbent tubes are manifolded together using adjustable flow controllers and tube holders available through the CTC AESP. The airflow through each tube must be adjusted separately, and the combined flow cannot exceed the flow range of the sampling pump. When considering sampling for multiple contaminants operating from the same sampling pump, contact the CTC for further guidance.

Prior to sampling, calibrate the sampling pump as per Appendix F. Do not use the same sorbent tube for pump calibration as will be used for sampling. Immediately before sampling, use a tube opener to break off the ends of the flame-sealed tube to provide an opening approximately half the internal diameter of the tube. Wear eye protection when breaking ends, and be careful not to cut yourself. Do not use the charging inlet or the exhaust outlet of the pump to break the ends of the tube. Insert the sorbent tube into the adjustable low flow controller, slide an appropriate length tube holder over the sorbent tube to shield the sampled person from the sharp ends, and secure the tube holder to the low flow controller. Tube openers (also called tube breakers), holders, and low flow controllers are available through the CTC AESP.

Position the sampling tube vertically so that the opening is pointing downward during sampling. Draw air to be sampled directly into the inlet of the tube. To avoid sample loss, air is not to be passed through any hose or tubing before entering the sorbent tube (except in cases where a very short piece of tubing is used to connect two tubes together that are used in series).

Immediately after sampling, cap the tube with the supplied plastic caps, and seal the tube with a Form OSHA-21 (see Appendix G, Figures G-1 and G-2). The Form OSHA-21 should cover the end caps. If the seal does not cover the end caps because the tube is too long, tape the ends of the seal, using clear plastic tape, so that it is secure and tamper-resistant.

After the samples are properly sealed, post-calibrate the sampling pumps. If the pre- and post- sampling flow rates differ by greater than 5%, note this in the air sampling worksheet. For example, if the pre-calibration flow rate is 50 milliliters per minute (mL/min), the post-calibration flow rate should be between 47.5 and 52.5 mL/min. Likewise, if the pre-calibration flow rate is 200 mL/min, the post-calibration flow rate should be between 190 and 210 mL/min.

Submit the sample for analysis. Do not ship air samples with bulk samples.

2. Diffusive (Passive) Sampling

Diffusive samplers, also known as passive monitors or badges, can be useful for compliance monitoring. The major advantage of diffusive sampling is that no air sampling pump is required. Two common disadvantages are that diffusive samplers are frequently less accurate than active sampling, and that the limit of detection is not always low enough for compliance monitoring, particularly for STEL sampling. As with active sampling, chemical interferences may also be a concern. Figure 6 shows an example of one style of diffusive sampler. Table 2 lists the analytes for which passive diffusive sampling methods have been validated for compliance sampling. Additional airborne contaminants may be identified and quantified by the SLTC, but these analytical results are usually reported as "approximations" and should be used only for screening purposes.

Figure 6. Diffusive Sampler

Record the temperature and barometric pressure at the sampling site in the OIS air sampling worksheet. Temperature and pressure are needed for proper calculation of exposure results for diffusive samplers. Results from samples without the sampling site temperature and pressure will have significantly higher sampling and analytical error values. Check the National Oceanic and Atmospheric Administration's (NOAA) website the same day as sampling to obtain the barometric pressure reported with the local weather forecast for that day. The barometric pressure for the time period sampled can sometimes be obtained by contacting the local weather station or airport. If air pressures are obtained by these means, it is necessary to obtain the unadjusted barometric pressure (station pressure) for compliance applications. **If the barometric pressure value cannot be found, note the time and elevation** where the samples were collected**,** and refer to Appendix M, Equation M-4**.**

Specific sampling instructions for each type of diffusive sampler are supplied with the sampler and included in the OSHA methods that permit diffusive sampling (listed below in Table 2). Diffusive samplers should not be opened until just before sampling because they begin to sample as soon as they are opened. To terminate sampling, properly seal the samplers with the manufacturer's packaging materials. Apply the OSHA-21 seal as shown in Appendix G. Send the sealed sampler and all its accessories to the SLTC for analysis. Interfering substances should be noted in the OIS sampling worksheet. Contact the SLTC for further information regarding diffusive sampler availability and use. Consult OSHA's CSI file for new methods as they become available.

Table 2. OSHA Validated Sampling and Analytical Methods that Permit Diffusive Sampling

Analyte	**Method**	**Sampler**
Benzene	OSHA 1005	SKC 575-002 3M 3520
2-Butanone (MEK)	OSHA 1004	SKC 575-002 3M 3520
Butyl acetate (*n, iso, sec, tert isomers*)	OSHA 1009	SKC 575-002 3M 3520
Ethyl benzene	OSHA 1002	SKC 575-002

Analyte	Method	Sampler
Ethylene oxide	OSHA 49	3M 3551
Formaldehyde	OSHA 1007	AT Aldehyde Monitor 571 SKC UMEx 100 Supelco DSD-DNPH
Hexone (MIBK)	OSHA 1004	SKC 575-002 3M 3520
Nitrous oxide	Kem Medical Products Method	Kem Vapor Trak Nitrous Oxide Monitor
Radon	OSHA-208	E-Perm
Styrene	OSHA 1014	SKC 575-006 3M 3520
Tetrachloroethylene	OSHA 1001	SKC 575-002
Trichloroethylene	OSHA 1001	SKC 575-002
Thoron	Contact OSHA SLTC HRT	E-Perm
Toluene	OSHA 111	SKC 575-002 3M 3520
Xylene (*o, m, p isomers*)	OSHA 1002	SKC 575-002 3M 3520

3. Impingers and Bubblers

In many cases, newer methods, such as specially treated sorbents, have been developed that can be used in place of the methods calling for use of an impinger or bubbler. However, in specialized conditions, such as high humidity, methods requiring an impinger or bubbler must still be used. Appendix C lists the chemicals for which the primary method is a bubbler or impinger method. It is always advisable to check the CSI to see if alternative methods can be used.

Examples of a midget impinger (left side) and of a midget bubbler (right side) are shown in Figure 7. The term midget refers to the volume of the sampler flask. The difference between an impinger and a bubbler is that the jet (inlet tube) of an impinger is tapered and sized to allow sufficient velocity for particles to strike the bottom of the flask and become suspended in the liquid, while the stem of a bubbler is fritted to allow collection of vapors in the solution. Bubblers break incoming air into small bubbles to improve collection efficiency of vapors.

The following suggestions should be followed when using impingers and bubblers:

- Numbers are usually etched into flasks and stems, and matching numbers should be used whenever possible. Take care in preparing impingers and bubblers so that tips or frits are not damaged and so that joints can be securely tightened.

- Rinse the impinger or bubbler with the appropriate collection liquid (absorbing solution) (see OSHA's CSI file). Then add the specified amount of this liquid to the bubbler or impinger flask. Contact the SLTC to obtain the absorbing solutions.
- To prevent overflow, do not add more than 10 mL of absorbing solution to midget impingers or bubblers. Place an empty impinger in series after the impinger (or bubbler) to function as a trap to prevent impinger liquid from being drawn into the air sampling pump. Position this impinger just before the sampling pump; it can be taped to the pump. If an impinger holder or holster is available, tape or secure the holstered impinger to the sampling pump.
- The maximum sampling rate for both midget impingers and bubblers is usually 1.0 L/min, but should be double-checked with the individual sampling method. Because bubblers tend to offer better collection efficiency than impingers, they are preferred over impingers for gas and vapor sampling. Impingers are used only when absolutely necessary for particle counting. Contact the SLTC prior to collecting any samples for particle (dust) counting using impingers.
- The impinger or bubbler can either be hand-held by the CSHO or it can be attached to the employee's clothing using a holster. In either case, it is very important that the impinger or bubbler does not tilt and cause the absorbing solution to flow down the side arm to the hose and into the pump. NOTE: Attach a trap in-line with the pump, if possible.
- In some instances, it will be necessary to add additional absorbing solution during the sampling period to prevent the amount of liquid from dropping below one half of the original amount.

After sampling, remove the glass stopper and stem from the impinger or bubbler flask. Rinse the absorbing solution adhering to the outside and inside of the stem directly into the impinger or bubbler flask with a small amount (1-2 mL) of the sampling liquid. Pour the contents of the flask into a 20-mL glass vial (preferably a scintillation vial with inert cap and liner). Avoid using metal cap liners or other materials that may react with the samples. PTFE cap liners with polypropylene caps are inert to most materials. Rinse the flask with a small amount (1-2 mL) of the absorbing solution and pour the rinse solution into the vial. Tape the cap shut by wrapping the tape in the direction of cap closure to prevent it from coming loose due to vibration. If electrical tape is used, do not stretch the tape too much because it could shrink and loosen the cap.

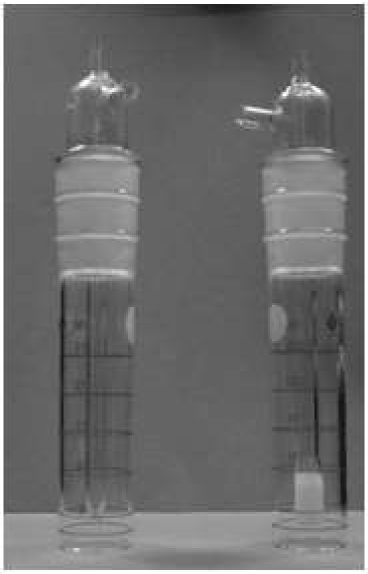

Figure 7. Midget Impinger and Bubbler

4. Gas Sampling Bags and Canister Samplers

OSHA uses gas sampling bags to sample carbon dioxide, carbon monoxide, and nitrous oxide. CSHOs can obtain gas sampling bags from the SLTC. Be certain not to fill the bag to more than 75% of its rated volume, and to close the sampling valve after sampling. Place Form OSHA-21 over the valve(s). Transport the gas sampling bag to the SLTC by ground shipment if it contains particularly hazardous materials or if its odor is particularly offensive.

Gas sampling bags or canisters are sometimes used to collect whole air samples for forensic-type investigations. Call the SLTC for guidance.

IV. Post-Inspection Activities

A. Post-Calibration

1. Post-calibrate sampling pumps as described in Appendix F.
2. Record results of post-calibration for all pumps used in the OIS air sampling worksheet.

B. Complete Documentation

1. Complete the OIS sampling worksheet before sending samples to the lab. CSHOs should be especially diligent in completing the following items:
   - Reporting ID
   - Inspection number
   - Sampling number
   - Establishment name
   - Sampling date
   - Shipping date
   - Person performing sampling
   - CSHO ID
   - Weather conditions
   - Photo(s)
   - Pump checks and adjustments
   - Job location, operation, work location(s), ventilation, and controls
   - Pre-sampling - calibration location temperature and pressure
   - Post-sampling - calibration location temperature and pressure
2. Indicate in the OIS air sampling worksheet if analytical results are to be reported using the actual time sampled (e.g., ceiling or STEL sampling) or if they are to be reported as 8-hour TWA results calculated using zero exposure for non-sampled time portions of the 8-hour period. OSHA TWA-PELs are defined as 8-hour TWA exposures. The SLTC will report sample results using the air volume reported on the OIS sampling worksheet unless otherwise requested by the CSHO.

C. Package and ship samples

- Prepare the samples for transport to the SLTC.
- Submit bulk samples and air samples separately to avoid cross-contamination.
- If any submitted materials could be considered hazardous, consult and follow appropriate shipping regulations to assure safe handling during shipment (See internal procedures or contact the SLTC for instructions).
- Pack the samples securely in a box or other sturdy container to avoid any rattle or shock damage. For asbestos samples, do not use expanded polystyrene packing (Styrofoam™) or other static-producing packaging material. Place samples in a plastic bag so that they do not move freely. Use bubble sheeting or other material as packing. Put identifying paperwork in every package. Do not send samples in unpadded envelopes.
- Ensure that you include a printout of the OIS air sampling worksheet and any applicable SDSs with the samples.

D. Receive sample results

Calculate the exposure severity, which is the ratio of the sampling results to the PEL. Add the SAE to the severity to determine the upper confidence limit, and subtract the SAE from the severity to determine the lower confidence limit. The SAE is reported by the SLTC on the OIS air sampling worksheet. If there is none listed for a specific substance, contact the SLTC.

For mixtures, the CSHO must determine the SAE as described below in Section IV.D.5. If the PEL violation is confirmed, apply the health effects codes as per Appendix L.

All sampling and analytical methods have some degree of uncertainty. The total uncertainty depends on the combined effects of the contributing uncertainties inherent in sampling and analysis, and has historically been called sampling and analytical error or SAE by OSHA. The SAE is used to determine the upper and lower confidence limits as described below. Correct application of the SAE enables CSHOs to make reliable compliance assessments of sample results. The SAE is especially important when sample results are near the PEL.

Error factors determined by statistical methods shall be incorporated into the sample results to obtain the lowest value of the true exposure (with a stated degree of statistical confidence) and also the highest value of the true exposure (also with a stated degree of statistical confidence).

Confidence limits are values at each end of the confidence interval, which is the probable range of the true value. The lower value is called the lower confidence limit (LCL), and the upper value is the upper confidence limit (UCL). The LCL and the UCL are each termed one-sided because the main concern is with being confident that the true exposure is either less or greater than the PEL.

OSHA applies the LCL and UCL with a 95% statistical confidence limit and they are expressed here as $LCL_{95\%}$ and $UCL_{95\%}$. SAEs that provide a one-sided 95% confidence limit have been developed and are reported out on the Air Sampling Report.

If the $UCL_{95\%} < 1.0$, a violation does not exist.

If $LCL_{95\%} < 1.0$ and the $UCL_{95\%} > 1.0$, classify as possible overexposure.

If $LCL_{95\%} > 1.0$, a violation exists.

The $LCL_{95\%}$ and $UCL_{95\%}$ are calculated differently depending upon the type of sampling method used:

1. Sampling Methods

   Sampling methods can be classified into one of two categories:

   - Full-period, Continuous, Single Sampling. Full-period, continuous, single sampling is defined as sampling over the entire sample period with only one sample. The sampling may be for a full-shift sample or for a short period ceiling determination.
   - Full-period, Consecutive Sampling. Full-period, consecutive sampling is defined as sampling using multiple consecutive samples of equal or unequal duration that, if combined, equal the total duration of the sample period. An example would be taking four two-hour charcoal tube samples. There are several advantages to this type of sampling:
     - If a single sample is lost during the sampling period due to pump failure, gross contamination, etc., at least some data will have been collected to evaluate the exposure.
     - The use of multiple samples should result in slightly lower sampling and analytical errors.
     - Collection of several samples allows conclusions to be reached concerning the manner in which differing segments of the workday affect overall exposure.
     - This practice also allows for monitoring peak and ceiling exposures for the appropriate time. Note that there is some loss of sensitivity with consecutive sampling as compared to continuous sampling.

2. Calculations

   If the initial and final sampling pump calibration flow rates are different, use of the highest of the two calibration flow rates will provide the lowest analytical results for compliance purposes. Generally, sampling is conducted at approximately the same temperature and pressure as calibration, in which case no correction for temperature and pressure is required and the sample volume reported to the SLTC is the volume actually measured. Where sampling is conducted at a substantially different temperature or pressure than calibration, consult the operating manual for the sampling pump to determine if the air volume needs to be adjusted. If possible, calibrate the equipment at the site. The air volume reported by the CSHO is used in all subsequent calculations.

   For particulates, the SLTC reports milligrams per cubic meter (mg/m^3) of contaminant using the actual volume of air sampled at the sampling site as reported by the CSHO.

   The SLTC normally does not measure concentrations of gases and vapors directly in ppm. Rather, most analytical methods determine the total weight of contaminant in the collection medium. Using the air volume provided by the CSHO, the lab calculates concentration in mg/m^3 and then converts it to ppm at 25°C and 760 mmHg using Equation M-1 in Appendix M. This ppm result is to be compared with the PEL without adjustment for temperature and pressure at the sampling site. Additional supporting equations are also found in Appendix M.

3. Calculations for Full-Period, Continuous Single Samples

   Obtain the full-period sampling result (X), the PEL, and the SAE. The SAE can be obtained from the OIS air sampling worksheet on the OSHA Intranet or by contacting the SLTC. Divide the full-period sampling result X by the PEL to determine the exposure severity, Y. From Equation 9:

   $Y = X / PEL$

   Compute the upper confidence level at the 95% confidence level ($UCL_{95\%}$) as follows (from Equation 11):

   $UCL_{95\%} = Y + SAE$

   Compute the lower confidence level at the 95% confidence level ($LCL_{95\%}$) as follows (from Equation 10):

   $LCL_{95\%} = Y - SAE$

   Classify the exposure according to the following classification system:

   - If the $UCL_{95\%} < 1.0$, a violation does not exist.
   - If $LCL_{95\%} < 1.0$ and the $UCL_{95\%} > 1.0$, classify as possible overexposure.
   - If $LCL_{95\%} > 1.0$, a violation exists.

   If the results are in the "possible overexposure" category, consider further sampling, taking into consideration the seriousness of the hazard and pending citations. If further sampling is not conducted, or if additional measured exposures still fall into the "possible overexposure" category, the CSHO may wish to carefully explain to the employer and employee representative at the closing conference that the exposed employee(s) may be overexposed, but that there is insufficient data to document noncompliance. The employer should be encouraged to voluntarily reduce the exposure and/or to conduct further sampling to ensure that exposures are not in excess of the PEL.

   See Appendix N for an example calculation for a full-period, continuous single sample using the equations above.

4. Calculations for Full-Period Consecutive Samples

The use of multiple consecutive samples should result in slightly lower sampling and analytical errors than the use of one continuous sample because the inherent errors tend to partially cancel each other. The mathematical calculations, however, are somewhat more complicated. The CSHO should first determine if compliance or noncompliance can be established using a calculation method similar to that noted for a full–period, continuous, single sample measurement, following the instructions in the "Compliance/ Noncompliance Method" box below.

Compliance/Noncompliance Method

Obtain the results of consecutive samples taken during the workshift. Let Xn be the concentration for a given sample, and Tn be the sampling duration for that sample, and n be the sample number:

Also obtain the SAE listed in the OIS air sampling worksheet.

1. Compute the TWA exposure, X.

   Equation 13

   $X = ((X_1\ T_1) + (X_2\ T_2)\ ...\ + (X_n\ T_n))\ /\ (480\ min)$

2. Divide the TWA exposure by the PEL to find Y, the standardized average ().

$UCL_{95\%} = Y + SAE$ *(Equation 11)*

3. Compute the $UCL_{95\%}$ as follows:

$LCL_{95\%} = Y - SAE$ *(Equation 10)*

4. Compute the $LCL_{95\%}$ as follows:

Classify the exposure according to the following classification system:

If $UCL_{95\%} < 1.0$, a violation does not exist.

If $LCL_{95\%} < 1.0$, and the $UCL_{95\%} > 1.0$, classify as possible overexposure and recalculate using the more exact calculation found in Equation 14 below.

If $LCL_{95\%} > 1.0$, a violation exists.

When the $LCL_{95\%} < 1.0$ and $UCL_{95\%} > 1.0$, the results are in the "possible overexposure" region and the CSHO must analyze the data using the more exact calculation for full-period consecutive sampling, as follows:

Equation 14

$LCL_{95\%} = Y - \{SAE \sqrt{[(T_1X_1)^2 + (T_2X_2)^2 + ... + (T_nX_n)^2)]}\} / [PEL(T_1 + T_2 + ... + T_n)]$

See Appendix O for an example calculation for a full-period consecutive sampling using the equations above.

5. SAEs for Exposure to Chemical Mixtures
   As described above in Section III, often an employee is simultaneously exposed to a variety of chemical substances, which may result in additive or synergistic health effects. 29 CFR 1910.1000(d)(2)(i) and 29 CFR 1915.1000(d)(2)(i) specify the computational approach for assessing exposure to a mixture.

Whether using a single PEL or the mixture calculation, the SAE of the individual constituents must be considered before arriving at a final compliance decision. These SAEs can be pooled and weighted to give a control limit for the additive mixture. To illustrate this control limit, the mixture calculation is expressed in the following equation (Equation 3 from above).

$$E_m = (C_1 / L_1 + C_2 / L_2) + \ldots (C_n / L_n)$$

Where:

E_m = equivalent exposure for the mixture (E_m should be less than or equal to 1 for compliance)
C = concentration of a particular substance
L = PEL

If Em > 1, indicating that an overexposure has occurred, then the SAE for each substance also needs to be considered:

Exposure ratio (for each substance)

Equation 15

$$Y_n = C_n / L_n$$

Ratio to total exposure

Equation 16

$$R_1 = Y_1 / E_m, \ldots R_n = Y_n / E_m$$

The SAEs (95% confidence) of the substances comprising the mixture can be pooled to give the SAE of the mixture using:

Equation 17

$$R_{st} = \sqrt{([(R_1 \text{ x } SAE_1)^2 + (R_2 \text{ x } SAE_2)^2 + \ldots (R_n \text{ x } SAE_n)^2])}$$

Equation 18

$$UCL = 1 + R_{St}$$

Equation 19

$$LCL = 1 - R_{St}$$

If Em < LCL then no overexposure has occurred at the 95% confidence level.

If LCL ≤ Em ≤ UCL then the exposure cannot be classified as either under or over the PEL at the 95% confidence level; further sampling may be necessary.

If Em > UCL then an overexposure has occurred (95% confidence).

See Appendix H for an example calculation.

V. Bibliography

American Conference of Governmental Industrial Hygienists. Air Sampling Instruments for Evaluation of Atmospheric Contaminants, Ninth Edition. Cincinnati, ACGIH, 2001.

American Industrial Hygiene Association. Fundamentals of Analytical Procedures in Industrial Hygiene, AIHA Monograph Series. Akron: AIHA, 1987.

Burgess, W.A. Recognition of Health Hazards in Industry: A Review of Materials Processes, Second Edition. Hoboken: John Wiley and Sons, Inc., 1995.

Hesketh, H.E. Fine Particles in Gaseous Media. Chelsea: Lewis Publishers, Inc., August 1986.

Lodge, J.P., Jr. (Ed.). Methods of Air Sampling and Analysis, Third Edition. Boca Raton: Lewis Publishers, Inc., 1988.

McDermott, H.J. Air Monitoring for Toxic Exposures, Second Edition. Hoboken: John Wiley and Sons, Inc., 2001

National Institute for Occupational Safety and Health. Occupational Exposure Sampling Strategy Manual. DHEW (NIOSH) Publication No. 77-173. Cincinnati: NIOSH, January 1977.

National Institute for Occupational Safety and Health. Mixed Exposures Research Agenda: A Report by the NORA Mixed Exposure Team. DHHS (NIOSH) Publication No. 2005-106. Cincinnati: NIOSH, December 2004.

Occupational Safety and Health Administration, U.S. Department of Labor, 2012. Chemical Sampling Information (Online).

Appendix A
Pre-Weighed Filters

The SLTC provides pre-weighed filters for gravimetric analysis. Filter/cassette units, when assembled in a cassette by the manufacturer, are tested for leaks. These filter/cassette units reduce sample preparation time by CSHOs because the filters are weighed at the SLTC and the units are shipped to the field fully assembled and ready for use. The filter/cassette units are returned to the SLTC for gravimetric determinations and additional analyses as needed. The filter medium is 5-μm, 37-mm diameter, low-ash PVC or PTFE (TEFLON). The PVC filters should be used for silica (quartz) analysis, aluminum, and other appropriate substances having high PELs or requiring gravimetric analysis. The PTFE filters are used for asphalt fumes. The filters may be used with or without a cyclone. Other than for silica, if the gravimetric analysis yields a result less than the PEL for the requested substance(s), no further analysis will be provided unless specifically requested. The filter/cassette unit is shown below in Figure A-1. Appendix B includes a partial listing of substances that should be sampled and analyzed gravimetrically using pre-weighed cassettes.

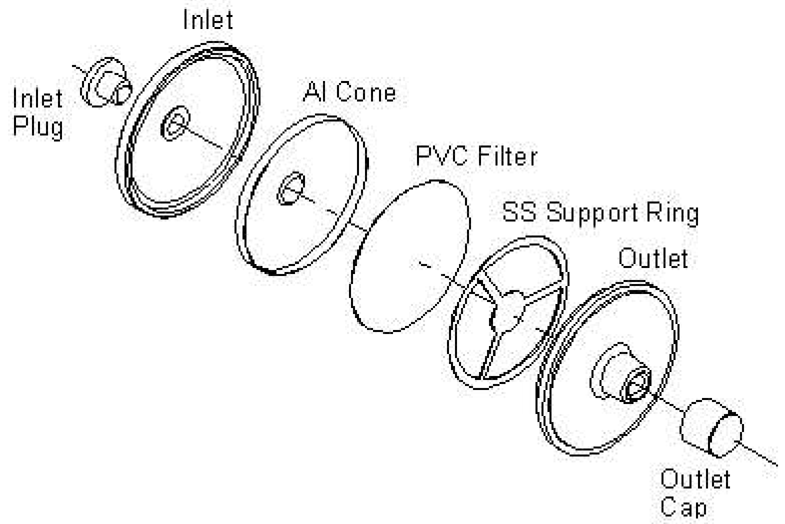

Figure A-1. Filter/Cassette Unit

Due to the slightly smaller size of the filter, check it frequently to avoid overloading. This can be accomplished by looking into the inlet sampling port of the cassette. Use a flashlight, if necessary. Visual observation of the airborne dust in the workplace may assist in determining how frequently to check the filter for overloading. If used with a cassette, do not lift the cyclone in such a way that particles from the grit pot could be deposited on the filter.

As shown in Figure A-1, the inlet side of the cassette is marked on the polystyrene cassette. This is the side of the filter cassette with the aluminum cone antistatic shield. The stainless steel support (Figure A-2) is visible from the outlet side of the assembly. Each of the filter assemblies is bar coded for weighing purposes (Figure A-4). To aid in tracking the filters, please use the barcode number as the sample submission number when completing the OIS air sampling worksheet. A blank should be included with every set of samples.

Figure A-2. Stainless Steel Filter Support

Figure A-3. Outlet View of a Filter Cassette (connect to sampling pump)

Figure A-4. Inlet View of a Filter Cassette (open to atmosphere, pointed downward during sampling)

The filter/cassette assembly can be used with both nylon cyclone and holder assemblies currently in field use; however, the standard MSA coupler (used with a standard 2- or 3-piece cassette) will not fit these cassettes. Another coupler available from MSA (part #457391), which is plastic instead of stainless steel, can be obtained from the CTC.

Appendix B
Substances for Gravimetric Determination

Table B-1. Partial List of Substances for Gravimetric Determination

Substance	**IMIS**	**PEL (mg/m^3)**
alpha-Alumina		
Total dust	0160	15
Respirable fraction	A201	5
Aluminum metal (as Al)		
Total dust	A100	15
Respirable fraction	A110	5
Ammonium sulfamate		
Total dust	0185	15
Respirable fraction	A111	5
Barium sulfate		
Total dust	B101	15
Respirable fraction	B104	5
Bismuth telluride Undoped		
Total dust	0370	15
Respirable fraction	B110	5
Boron oxide		
Total dust	0380	15

Substance	**IMIS**	**PEL (mg/m^3)**
Calcium carbonate		
Total dust	0505	15
Respirable fraction	C130	5
Calcium hydroxide		
Total dust	0515	15
Respirable fraction	C330	5
Calcium oxide	0520	5
Calcium silicate		
Total dust	C112	15
Respirable fraction	C122	5
Calcium sulfate		
Total dust	C104	15
Respirable fraction	C123	5
Carbon black	0527	3.5
Cellulose		
Total dust	0575	15
Respirable fraction	C124	5
Dicyclopentadienyl iron		
Total dust	0904	15
Respirable fraction	D100	5
Emery		
Total dust	1016	15
Respirable fraction	E102	5
Grain dust (oat, wheat, barley)	G109	10
Glycerin (mist)		
Total dust	1363	15
Respirable fraction	G115	5
Graphite, synthetic		
Total dust	1366	15
Respirable fraction	G100	5
Gypsum		
Total dust	1367	15
Respirable fraction	G101	5
Kaolin		
Total dust	1568	15
Respirable fraction	K100	5
Limestone		
Total dust	1593	15
Respirable fraction	L100	5

Substance	**IMIS**	**PEL (mg/m^3)**
Magnesite Total dust Respirable fraction	 M113 1615	 15 5
Magnesium oxide fume Total dust	 1610	 15
Marble Total dust Respirable fraction	 1626 M114	 15 5
Oil mist (mineral)	5010	5
Particulates not otherwise regulated (PNOR) Total dust Respirable fraction	 9135 9130	 15 5
Pentaerythritol Total dust Respirable fraction	 1987 P157	 15 5
Perlite Total dust Respirable fraction	 2035 P101	 15 5
Plaster of Paris Total dust Respirable fraction	 2127 P102	 15 5
Portland cement Total dust Respirable fraction	 0557 P104	 15 5
Rouge Total dust Respirable fraction	 2229 R102	 15 5
Silica Fused Total dust Respirable fraction	 9013	 15 5
Silicon Total dust Respirable fraction	 2235 S120	 15 5
Silicon carbide Total dust Respirable fraction	 2236 S123	 15 5
Starch Total dust Respirable fraction	 2263 S124	 15 5

Substance	IMIS	PEL (mg/m^3)
Sucrose Total dust Respirable fraction	 2285 S130	 15 5
Tantalum, metal and oxide dust	2325	15
Titanium dioxide Total dust	 2440	 15
Vegetable oil mist Total dust Respirable fraction	 V126 V127	 15 5
Zinc oxide fume	2610	5
Zinc oxide Total dust Respirable fraction	 Z102 Z103	 15 5
Zinc stearate Total dust Respirable fraction	 2616 Z104	 15 5
Zirconium compounds (as Zr) Total dust Respirable fraction	 2620	 15 5

Appendix C
Analytes using Impinger or Bubbler as Primary Method (Reference: CSI)

Table C-1. Impinger Methods

Chemical Name	Chemical Abstracts Service (CAS) Number
Amitrole	61-82-5
Benzoyl Chloride	98-88-4
Bladex	21725-46-2
Bromacil	314-40-9
Cumene Hydroperoxide	80-15-9
Dibutylamine	111-92-2
Diethylaminopropylamine	104-78-9

Chemical Name	**Chemical Abstracts Service (CAS) Number**
Diglycolamine	929-06-6
Diisopropylamine	108-18-9
4-Dimethylaminoazobenzene	60-11-7
N-[3-Dimethylamino) propyl]-N,N',N'-trimethyl-1,3-Propanediamine	3855-32-1
Dinitro-o-cresol	534-52-1
Hexamethylenetetramine	100-97-0
Isopropyl m-Chlorocarbaniliate	101-21-3
Kepone	143-50-0
Lindane	58-89-9
Maleic Acid	110-16-7
beta-Naphthol	135-19-3
Oryzalin	19044-88-3
Pentac	2227-17-0
Pentamethyldiethylenetriamine	3030-47-5
Pipron	3478-94-2
p-Nitrophenol	100-02-7
2,3,7,8-Tetrachlorodibenzofuran	51207-31-9
N,N,N',N'-Tetramethylethylenediamine	110-18-9
Tetranitromethane	509-14-8
Thioglycolic Acid	68-11-1
p-Toluenesulfonic Acid	104-15-4

Chemical Name	Chemical Abstracts Service (CAS) Number
Tributylphosphorotrithioate	78-48-8

Table C-1. Bubbler Methods

Chemical Name	Chemical Abstracts Service (CAS) Number
Aldrin	309-00-2
Boron Tribromide	10294-33-4
Boron Trifluoride	7637-07-2
Bromine	7726-95-6
Carbonyl Fluoride	353-50-4
Chlorine	7782-50-5
Chlorine (as Available Chlorine)	7782-50-5
Chlorine Dioxide	10049-04-4
Chlorine Trifluoride	7790-91-2
Cyanide (as CN)	57-12-5
1,1-Dimethylhydrazine	57-14-7
Ethyleneimine	151-56-4
Fluoboric Acid	16872-11-0
Fluorine	7782-41-4
Hydrogen Peroxide	7722-84-1
Hydrogen Selenide (as Se)	7783-07-5
Iron Pentacarbonyl (as Fe)	13463-40-6
Isopropylamine	75-31-0

Chemical Name	**Chemical Abstracts Service (CAS) Number**
Ketene	463-51-4
Lindane	58-89-9
Manganese Cyclopentadienyl Tricarbonyl (as Mn)	12079-65-1
Monomethyl Aniline	100-61-8
Nickel Carbonyl	13463-39-3
N-Nitrosodiphenylamine	86-30-6
Osmium Tetroxide (as Os)	20816-12-0
Pentaborane	19624-22-7
Perchloric Acid	7601-90-3
Perchloryl Fluoride	7616-94-6
Phenylhydrazine	100-63-0
Phosphorus Oxychloride	10025-87-3
Phosphorus Pentachloride	10026-13-8
Phosphorus Trichloride	7719-12-2
Propylene Imine	75-55-8
Rubidium	7440-17-7
Silicon Tetrahydride	7803-62-5
Sulfur dioxide	7446-09-5
Sulfur Monochloride	10025-67-9
Sulfur Tetrafluoride	7783-60-0
Thionyl Chloride	7719-09-7
Triphenylamine	603-34-9

Appendix D
Shelf-Life of Sampling Media

The SLTC will provide an expiration date for sampling media shipped to the field. The date will be printed either on the media itself, on its container, or on its packaging. Return liquid media to the SLTC in the same outer packaging in which it was received.

Table D-1. Shelf Life of Sampling Media Provided by the SLTC

Sampling medium	Shelf Life	Comments
Sodium hydroxide	1 year	Same for all normalities
Hydrochloric acid Sulfuric acid Methanol in water	1 year	Same for all concentrations
Solution for bis-chloromethyl ether (BCME) and chloromethyl methyl ether (CMME)	2 months	Prepared on request*
Hydroxylammonium chloride solutions (for ketene collection)**	2 weeks	Prepared on request*
Hydroxylammonium chloride-sodium hydroxide mixed solutions (for ketene collection)	Stable only 2 hours	CSHO must prepare solution from two component solutions just before use*
Folin's reagent	5 days	Prepared on request*
Diffusive samplers	As per manufacturer	Must be used before the expiration date printed on the monitor package
Nitrogen oxides collection tubes	2 years as per manufacturer	Should be stored in a refrigerator
Sampler for ozone (Nitrite-treated filter collection device)	28 days	Prepared on request*
Coated filter sampler for diisocyanates (MDI, HDI, TDI, etc.)	1 year	Prepared on request*
NaOH coated binderless quartz fiber filters	3 months	Prepared on request*
Treated filter sampler for collection of anhydrides	30 days	Prepared on request*

Sampling medium	Shelf Life	Comments
[*] Give the SLTC at least two days' notice to allow time for reagent preparation. [**]Hazardous goods shipment required both from the SLTC to the field and from the field to the SLTC; Corrosive Liquid, Toxic, UN 2922, Class 8, PGIII.		

Appendix F
Calibration

A. Sampling Pump Calibration

Calibrate personal sampling pumps before and after each day of sampling using one of the techniques described below. Assure that the calibration equipment is within its prescribed calibration interval, and record the serial number of the calibration equipment in your case file and the OIS air sampling worksheet. The SLTC's chemists sometimes use sampling pump calibration data to verify air sample volumes.

If the sampling pump is equipped with a rotameter or digital flow readout, record the reading in the OIS air sampling worksheet. Bear in mind that the accuracy of a pump rotameter is only approximate; it is intended primarily to facilitate setting the flow rate for calibration.

Most of the following examples in this appendix use filter cassettes as the sampling media, but the examples are generally applicable to adsorbent tubes as well.

NOTE: Precision rotameters are no longer used by OSHA for calibration due to the potential for measurement error (e.g., tests with precision rotameters have indicated significant error due to pump pulsation). Inverted burets may still be useful, but their use is discouraged because they are no longer considered a primary calibration standard.

Before pre-calibration, replace or recharge sampling pump batteries as needed. Check the rechargeable Ni-Cad batteries in older pumps before use under load (i.e., turn pump on and check voltage at the charging jack with the sampling device in-line).

Place the same **type** of sampling media in-line during sampling pump calibration that will be used to sample in the field. Do not use the actual cassette and filter intended for sampling use to perform calibration.

B. Pump Calibration for use with Cyclone

The "Jarless Cyclone Calibration" procedure is the recommended method for calibrating a cyclone. A one-liter jar should no longer be used due to technical issues such as leakage of the jar lid.

The purpose of the procedure is to determine whether the sampling pump will be able to maintain the required flow rate as the drop in static pressure grows due to particulates loading up on the filter. The typical pressure drop across a clean 5-µm filter is 2 inches of water pressure. The additional pressure drop from the cyclone is approximately 0.25 inches. As a filter loads up, the additional pressure drop may be as high as 20 inches of water pressure.

The procedure is demonstrated in the video **"Jarless Cyclone Calibration Method"** on the OSHA intranet.

Below is a summary of the basic steps of the procedure:

- Adjust and calibrate the pump to a flow rate of 1.7 L/min with a light load attached;
- Increase the load to 25–35 inches and check to be sure the flow rate is within +/- 5%;

- Remove the load and attach the cyclone to the sampling pump, then verify that the load is at between 2 and 5 inches of water pressure;

Detailed Step-By-Step Instructions

1. Connect the sampling train:
    - Connect the sampling pump to a Tee fitting.
    - Connect the Tee to a pressure gauge and the light load (i.e., a clean 5-μm filter or an adjustable bonnet valve).
    - Connect the load to the air outlet of the pump calibrator (bubble meter).
    - Turn on the sampling pump.
    - If a bonnet valve is used, adjust to create a load of 2–5 inches of water pressure. If a 5-μm filter is used, verify that the pressure drop is 2–5 inches of water pressure. If not, this may indicate leakage around the filter.
    - Set the pump flow rate to 1.7 L/min.
    - Take at least three flow readings and record the average flow rate. Readings should be within +/- 2% of each other.
2. Increase the load:
    - If a bonnet valve is used, adjust to increase the load to 25–35 inches of water pressure. If a 5-μm filter was used for the light load, remove it and replace it with a set of six 0.8-μm filters connected in series (i.e., sandwiched in a four-piece cassette with four backup pads). If the load is not at least 25 inches of water pressure, ensure the cassette is tightly compressed to prevent air from bypassing the filters.
    - Turn on the pump, and then check and record the average flow rate. If the flow is not within +/- 5% under increased load, return the pump to the CTC for repair with a note explaining the problem.
3. Add the cyclone to the sampling train:
    - Disconnect the pump calibrator and remove the load.
    - Attach the cyclone with a clean 5-μm filter in place of the load.
    - Turn the pump on and confirm that the pressure drop is 2–5 inches of water pressure with the cyclone attached.

Refer to the cyclone leak test and cyclone cleaning procedures as described in Appendix I.

Figure F-1. Gilian Gilibrator Pump Calibrator

C. Electronic Flow Calibrators

The Gilian Gilibrator® I and II by Sensidyne® (see Figure F-1) are electronic bubble flow meters, used to calibrate sampling pumps, that provide instantaneous air-flow readings and cumulative averaging of multiple measurements. These calibrators measure the flow rate and display the results as volume per unit of time (e.g., mL/min) and can be used to calibrate most air sampling pumps. Different flow cells are used to accommodate different flow ranges. The middle-sized flow cell is typically used for personal sampling for particulates, while the largest cell is used for high volume area sampling and the smallest cell may be needed for certain low flow sorbent tube methods. The total range with the different flow cells is from 1 mL/min to 30 L/min. Gilibrators **should not** be left plugged into the charger for extended time periods because doing so will decrease the service life of the battery.

Another wet-cell calibrator available in some OSHA field offices is the miniBuck™ as shown in Figure F-2. Its operation is similar to the Gilibrator.

The Bios Defender™ shown in Figure F-3 is an electronic dry-piston flow meter used to calibrate sampling pumps that provides immediate and average readings. The device can be used to calibrate either pressure (labeled inlet) or vacuum (labeled outlet) flow sources. The vacuum port is used to calibrate sampling pumps, and the pressure port is used to calibrate the outlet of sampling pumps used to fill gas sampling bags. The Bios Defender has a lead-acid battery and can be left on charge for an indefinite time without damaging the battery. Different models of the instrument cover an optimum flow range of 5 mL/min to 30 L/min.

Figure F-2. Minibuck Pump Calibrator

If using a Bios Defender to calibrate an MSA Escort® ELF pump, use an isolating flow restriction providing at least 5 inches of water column pressure between the pump and the flow meter. For example, use air sampling media (cassette or sorbent tube) with a Gemini variable orifice. Failure to use such an isolation technique may result in +/- 2% calibration inaccuracy.

The CTC recommends that the Bios Defender not be used in a very dusty environment because dust that flows through the calibrator piston area has the potential to scratch the glass and piston inside the calibrator. The CTC also recommends that neither the Gilibrator nor the Bios Defender flow calibrator be used in corrosive or otherwise contaminated environments.

Properly functioning and calibrated Gilibrators and Bios Defenders have an accuracy of approximately 99%. Use the appropriate Gilibrator flow cell or the Bios Defender model with the appropriate range of airflow for the pump airflow to be calibrated.

Figure F-3. BIOS Defender Pump Calibrator

It is recommended that the flow rates obtained from these devices be reported to three significant figures. For example, a flow rate shown as 1.006 L/min should be reported as 1.01 L/min.

D. Procedures

NOTE: The following instructions and figures were written for the Gilian Gilibrator flow calibrator as shown in Figure F-4, however, the Bios Defender and miniBuck calibrator can be substituted in most cases (for use with MSA Escort ELF pumps, the isolating flow restrictor must be used as described above).

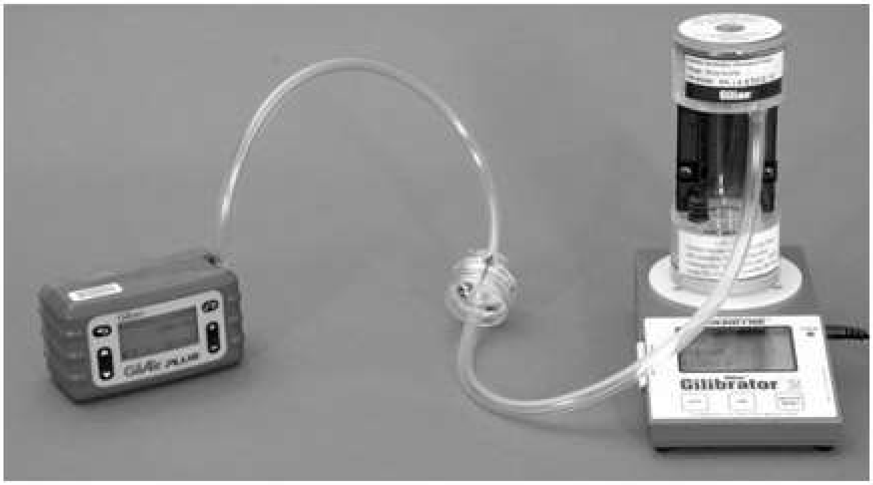

Figure F-4. Cassette Attached to Electronic Bubble Meter for Pump Calibration

1. Perform the calibration at the pressure (altitude) and temperature where the sampling is to be conducted. If this is not possible, consult the operating manual for the sampling pump to determine if the air volume needs to be adjusted for temperature and pressure. Allow the pump to run for one to five minutes before voltage check and calibration. Consult the CTC regarding correction factors if sampling must be performed at freezing temperatures.
2. Connect the collection device, tubing, pump, and calibration apparatus as shown in Figure F-4 for the cassette (or sorbent tube) sampler. Note that cassette adapters (e.g., plastic or metal Luer taper adapters) should not be used. Luer adapters in front of a filter in a calibration train can potentially generate significant back pressure for which some pressure regulating pumps may not be able to compensate, resulting in inaccurate results. Luer adapters behind filters can affect sample distribution across an open-face cassette, and some Luer adapters are long enough that they may even make contact with the backup pad in the cassette. For this reason their use is not recommended. There are commercially available filter cassette holders with integrated connectors that do not have an adverse effect on back pressure.

Figure F-5. Bubble Actuator Button on Gilibrator

3. Visually inspect all plastic tubing connections. Be certain that there are no leaks.
4. Gilibrator: Assemble the Gilibrator as per the equipment manual. Introduce soap solution into the flow cell through the air inlet boss. Add enough soap solution until the angled edge at the bottom of the bubble generator ring is immersed in the solution. After connecting the sampling pump and turning it on, push the button several times to wet the inside of the electronic flow cell with the soap solution.
   Bios Defender: No preparation required.
5. Turn on the pump and adjust the pump rotameter and/or digital flow display (if so equipped) to the appropriate flow rate.
6. Gilibrator: Press the button on the electronic bubble meter. Visually capture a single bubble and electronically time the bubble. The accompanying printer will automatically record the calibration reading in L/min.
   Bios Defender: Press and release the Read button for a single measurement. Press and hold the Read button for consecutive measurements.
7. Adjust the sampling pump to the correct flow rate using the calibrator results. Adjust the sampling pump while it is running.
8. Confirm that the sampling pump is adjusted properly and take additional calibrator readings. Three or more consecutive readings should be taken and should be within about 2% of each other and then averaged.
9. Repeat the procedures described above for all pumps to be used for sampling. The same cassette and filter may be used for calibrations involving the same sampling method. Do not use the actual cassette and filter intended for sampling use to perform calibration.

Figure F-6. Gilibrator Display Panel Showing Flow Rate, Side by Side with Gilair Sampling Pump with Digital Flow Readout

E. Instructions for Calibrating MSA Escort ELF Pumps with "Dry" Piston-Type Calibrators

When calibrating Escort ELF pumps with piston-type calibrators, extra steps must be taken to ensure that the pumps are calibrated accurately. The design of Escort ELF pumps make them susceptible to calibration inaccuracies due to pressure spikes created by the mechanical action of Bios International piston-type calibrators, such as the Defender series models. The rubber-walled pulsation dampeners incorporated into the Escort ELF pump design do not sufficiently compensate for the pressure spikes from the Bios calibrators; as a result, these pressure impulses can produce an uncertainty of over 4% (± 4%) in the calibration accuracy of Escort ELF pumps. **THE ESCORT ELF PUMPS SHOULD NOT BE CALIBRATED USING THE Bios International piston type calibrators BECAUSE THEY CAN PRODUCE AN UNCERTAINTY ERROR OF OVER 4%** (compared to the desired margin of error of ±1%). No other type of pumps are affected by this phenomenon, nor do the Escort ELF pumps suffer this susceptibility when wet cell bubble-type air flow calibrators are used or when the pumps are deployed with air sampling media or filter cassettes.

The manufacturers recommend that an isolating flow restrictor, such as a 0.030-inch orifice, be placed between the pump and the flow meter. The 0.030-inch orifice was shown at the CTC to create about 20 inches of water column (WC) of additional loading to the sampling pump at 2,000 mL/min. This additional loading causes the pump to speed up to maintain the required flow setting, which, in turn, makes the small changes in loading caused by the action of the calibrator's piston to have a negligible effect on the airflow within the Escort ELF pump. The use of a 0.030-inch orifice will ensure that there will be a sufficient load on the Escort ELF pump to mitigate the pressure spikes from the Bios piston-type calibrator across the entire effective flow-rate range of the pump, thus enabling the operator not to exceed the required 1 percent (± 1 percent) pump calibration accuracy.

F. Calibration Procedures for Open-Face Filters

Open-face cassettes are used for asbestos and certain chemicals such as isocyanates, crotonaldehyde, and glutaraldehyde.

1. The appropriate way to calibrate an open-face cassette is to use the cover section which comes with the cassette and attach the tubing directly from the electronic flow calibrator to the inlet port on the cassette cover. Be certain there are no leaks and do not use a Luer adapter. This set-up will provide the least amount of flow resistance and represent the open-face conditions while actually sampling.
2. Perform the pump calibration at the pressure (altitude) and temperature where sampling is to be conducted. If this is not possible, consult the operating manual for the sampling pump to determine if the air volume needs to be adjusted for temperature and pressure.

G. Calibration of Impingers and Bubblers

1. Set up the calibration apparatus as shown in Figure F-6, but instead of using a cassette, attach an impinger or bubbler filled with the amount of liquid absorbing solution specified in the sampling method. If a prefilter or cassette is described in the CSI file, include the correct filter in line. Include an adsorbing solution trap if one is to be used in air sampling.
2. Connect the tubing from the electronic bubble meter to the inlet of the impinger or bubbler.
3. Connect the outlet of the impinger or bubbler to the tubing to the pump. Be certain there are no leaks.
4. Calibrate the pump to the flow rate specified in the CSI file for the sampling method.

H. Maintenance and Care of Electronic Calibrators

Consult the manufacturer's instruction manuals for complete details. Periodically, compare the calibrator to another unit to make sure that it is functioning properly. Return the calibrator to the CTC annually to be calibrated and serviced.

Gilian Gilibrator:

1. For units that are used daily, connect the short length of storage tubing to the air outlet (upper) boss and the air inlet (lower) boss of the flow cell. This will prevent evaporation and concentration of the soap solution. Store in a clean area.
2. For units that will not be used for more than a week, remove the flow cell by unplugging the power/data cord and then gripping the bottom of the flow cell and rotating it one quarter turn counter-clockwise. Caution: gripping the top of the flow cell before turning it can stress and crack the flow cell. Then tip the cell horizontally and drain the soap solution out through the air inlet (lower) boss. Allow the flow cell to air dry completely before storage. Do not leave the calibrator plugged into the charger for extended time periods because doing so will decrease the service life of the battery. Store in the case to protect from breakage or dust accumulation.
3. Check the unit before use. Wipe the outside with a damp cloth if needed. If stored properly, routine cleaning is unnecessary. If there is excessive soap residue inside the flow cell, disconnect it and rinse with warm water. The acrylic flow cell can be easily scratched. Do not allow the flow cell (center tube, where sensors detect the soap bubble) to be scratched or to get dirty. Never clean the cell with acetone, alcohol or other cleaning solutions.
4. Leak testing. If leakage is suspected, perform a leak test as described in the Gilibrator manual. No leakage should be observed. Never pressurize the flow cell with more than 25 inches of water pressure. The CTC performs a leak check as part of their annual service.
5. Calibrator Calibration. The calibrator is factory calibrated using a standard traceable to the National Institute of Standards and Technology. The calibrator is linear throughout the entire range. The CTC will calibrate the unit as part of their annual service.
6. When transporting the calibrator, especially by air, it is important that one side of the storage tube which connects the air inlet and outlet be removed to equalize internal pressure within the calibrator. Do not transport the unit with soap solution or with storage tubing in place.
7. The calibrator soap is a concentrated and sterile solution formulated to provide a clean, frictionless soap film bubble over the wide, dynamic range of the calibrator. The sterile nature of the soap is important in order to prevent residue buildup in the flow cell center tube, which could cause inaccurate readings. The use of any other soap is not recommended. Proper soap solution is available from the CTC's expendable supplies program.

Bios Defender:

1. Do not use liquid solvents or abrasive cleaners to clean the calibrator; wipe only with a cloth lightly dampened with water. Store the instrument in a clean, dry place and with the unit on charge, if possible.
2. Leak testing. Place the manufacturer supplied leak-test accessory (short piece of tubing with a red plug) over the inlet (top port). Press and hold the STOP button and then press the ON button. The display should

read "Leak Test, Invert & Push Read." Invert the unit and push Read. Turn the unit upright and allow it to stand. Make sure that the piston is at the top of the cell. Allow the calibrator to stand until the piston falls; this may take as long as 15–20 minutes. The unit will display "Test OK Press Read" if it passes the test. Repeat the leak test with the leak-test accessory over the outlet (bottom port).

3. Calibration. Bios recommends that the unit be recalibrated by the manufacturer annually. The CTC will calibrate the unit as part of their annual service.

Appendix G
How to Apply Form OSHA-21 to Sampling Media

Figure G-1. Correctly Sealed Charcoal Tube. Charcoal Tube Inside Form OSHA-21

Figure G-2. Incorrectly Sealed Charcoal Tube. End Caps Can Be Removed, Allowing Sample Integrity To Be Jeopardized Without Disturbing the Seal

Figure G-3. Incorrectly Sealed Cassette Allows Access to Inlet/Outlet Ports After Sample Has Been Taken

Figure G-4. Correctly Sealed Cassette With Form OSHA-21 Covering Inlet/Outlet Ports Maintaining Sample Integrity

Figure G-5. Standard Asbestos Cassette (25mm) Correctly Sealed With a Form OSHA-21

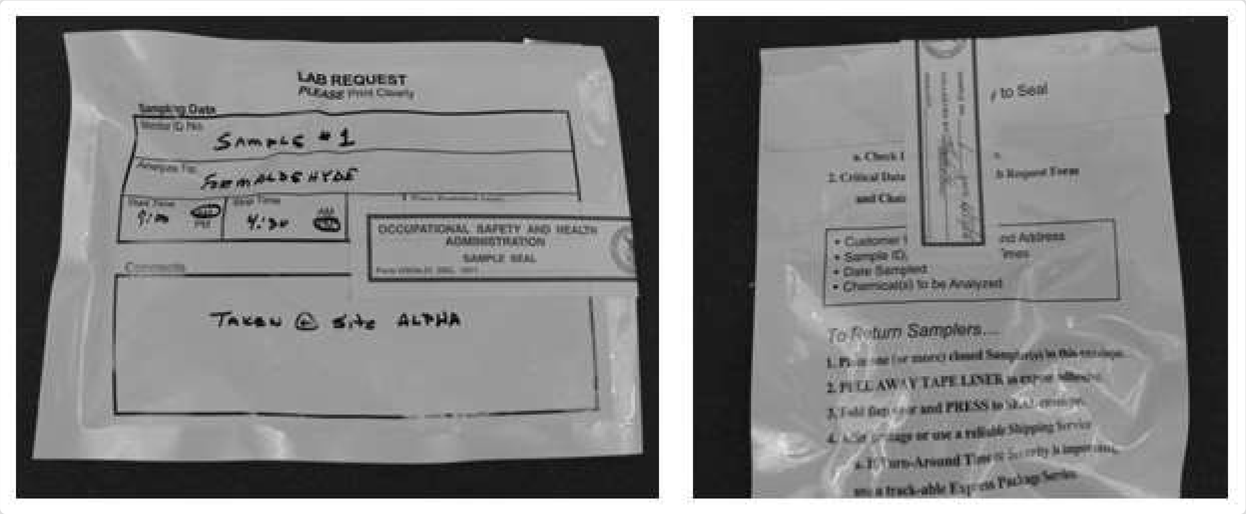

Figure G-6. Passive Monitors Correctly Sealed With A Form OSHA-21

Correctly sealed 3M passive monitor

Appendix H
Example Calculations for Mixtures

As an example, an exposure to three different substances:

Material	8-hr. Exposure (ppm)	8-hr. TWA PEL (ppm)	SAE
Substance 1	500	1,000	0.089
Substance 2	80	200	0.11
Substance 3	70	200	0.18

Using Equation 3 (from Section III.G.2.):

$$E_m = (C_1 / L_1 + C_2 / L_2) + \ldots (C_n / L_n)$$

Where:

E^m is the equivalent exposure severity for the mixture
E^m should be < 1 for compliance
C is the concentration of a particular contaminant
L is the OSHA exposure limit for that substance.

$$E_m = 500/1000 + 80/200 + 70/200 = 1.25$$

Since $E^m > 1$ an overexposure appears to have occurred; however, the SAE for each substance also needs to be considered:

Exposure severity ratio (for each substance) (from Equation 15 from Section IV.D.5. above)

$$Y_n = C_n / L_n$$

Ratio each to total exposure (using Equation 16 from Section IV.D.5.)

$R_1 = Y_1 / E_m, \ldots R_n = Y_n/E_m$

The SAEs (95% confidence) of the substances comprising the mixture can be pooled by:

Equation H-1

$R_{st} = \sqrt{([(R_1)^2 x(SAE_1)^2 + (R_2)^2 x(SAE_2)^2 + \ldots (R_n)^2 x(SAE_n)^2])}$

which is also equivalent to (using Equation 17 from Section IV.D.5.):

$R_{st} = \sqrt{([(R_1 \text{ x } SAE_1)^2 + (R_2 \text{ x } SAE_2)^2 + \ldots (R_n \text{ x } SAE_n)^2])}$

From Equation 18

$\text{UCL} = 1 + \text{R}_{\text{St}}$

From Equation 19

$\text{LCL} = 1 - \text{R}_{\text{St}}$

If Em < LCL then no overexposure has occurred at the 95% confidence level.

If LCL ≤ Em ≤ UCL then the exposure cannot be classified as either under or over the PEL at the 95% confidence level; further sampling may be necessary.

If Em > UCL then an overexposure has occurred (95% confidence).

Using the mixture data above:

Y_1 = 500/1,000	**Y_1 = 500/1,000**	**$R_1 = Y_1/(E_m = 0.4)$**
Y_2 = 80/200	Y_2 = 0.4	R_2 = 0.32
Y_3 = 70/200	Y_3 = 0.35	R_3 = 0.28

$(R_{st})^2 = (0.4 \text{ x } 0.089)^2 + (0.32 \text{ x } 0.11)^2 + (0.28 \text{ x } 0.18)^2$

$R_{st} = \sqrt{((R_{st})^2)} = 0.071$

$UCL = 1 + R_{st} = 1.071$

$E_m = 1.25$

Therefore Em > UCL and an overexposure has occurred within 95 percent confidence limit.

An executable computer program is available on the OSHA Intranet which will calculate a control limit for any mixture. Simply input the exposures, limits, and SAEs and the program will calculate a control limit according to the above equation.

A Mixture Calculator is also available on the OSHA Intranet.

Appendix I
Cyclone Assembly and Cleaning Instructions

A. Cyclone Assembly

Inspect the cyclone parts for signs of wear or damage such as scoring, rifling, or a loose coupler. Replace the units or parts if they appear damaged. Figures I-1 and I-2 show the parts for MSA and Sensidyne cyclones, respectively.

Figure I-1 MSA Cyclone Assembly Parts

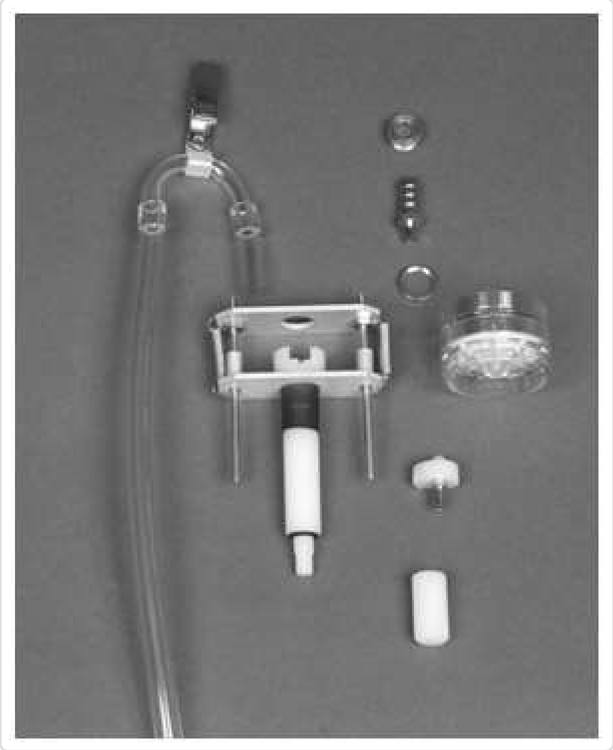

Figure I-2 Sensidyne Cyclone Assembly Parts

B. Cyclone Leak Test Procedure

Leak test the cyclone before use unless it has been leak tested within the past month. A cyclone leak test kit and cyclone leak test procedure are provided in each Area Office for this purpose.

This section summarizes procedures for leak testing of the Dorr-Oliver cyclone samplers used for collecting respirable dust. Further details on this procedure are contained in the Cyclone Leak Test Procedure (CLTP). CSHOs should review the entire leak test procedure before conducting the leak test as summarized below. See the CLTP for more specific procedures regarding leak tests.

Nylon Part Inspection

- Disassemble the cyclone assembly, clean it, and inspect it for cracks and worn fit between parts. Take care not to scratch the inside surface of the cyclone chamber.
- Replace any worn or cracked units or parts.

O-Ring, Tubing, and Filter Leak Test

- Connect the entire cyclone assembly (minus the cyclone body) to the pressure gauge and aspirator, maintaining the normal spacing between the plastic filter adaptor (coupler) and the vortex finder.
- Seal the cyclone vortex finder opening by placing an airtight cap or your fingertip over the hole.
- Hold the cyclone assembly together with one hand.
- With your other hand, squeeze and gently release the aspirator bulb until the pressure gauge reads between 4 inches and 10 inches of water pressure, then fold the tubing halfway between the "Tee" fitting and the aspirator. If the pressure reading is beyond full scale, release the vacuum and try again.
- Observe the pressure gauge reading for 30 seconds. If the pressure drops less than 25%, the leakage is acceptable and the unit passes the leak test. If the pressure drops more than 25%, corrective action is necessary. Sources of leaks include worn or damaged O-rings, cracked or ill-fitting tubing, and leaky pre-weighed filter cassettes.

Note: Leaks between the filter input and the air sampling pump are more disruptive than leaks at the plastic filter adaptor O-rings.

Final Pump-Fault Leak Test

- Connect the cyclone assembly to the pump in the normal sampling configuration with the air sampling pump running at 1.7 L/min.
- Close the inlet to the cyclone with tape or a finger. If the pump bears down and goes into a fault mode, the assembly passes this final, but crude, pump-fault leak test.

C. Cyclone Cleaning

Unscrew the grit pot from the cyclone. Empty the grit pot by turning it upside down and tapping it gently on a solid surface. Clean the cyclone thoroughly and gently after each use in warm soapy water or, preferably, wash it in an ultrasonic bath. Rinse it thoroughly in clean water, shake off excess water, and set aside to dry before reassembly. Never insert anything into the cyclone during cleaning.

Appendix J
Sample Calculations for Crystalline Silica

Reference Formulas

A. Construction/Maritime PEL for Crystalline Silica (Quartz) (using Equation 5 from Section III.K.2.):
PEL (crystalline silica,quartz) = (250 mppcf) / (% silica + 5)

B. General Industry PEL for Crystalline Silica (Quartz) (using Equation 6 from Section III.K.2.):
$PEL\ (mg/m^3) = (10\ mg/m^3) / (2 + \%\ respirable\ quartz)$

C. OSHA-adopted conversion factor:
$1\ mppcf = 0.1\ mg/m^3$ *respirable dust or*

$1\ mg/m^3 = 10\ mppcf$ *respirable dust*

D. Combining multiple silica samples (single analyte) with different percentages and mass:
Recalculated % = ((Pa x Wa) + (Pb x Wb)) / (Wa + Wb)

Where:

P = Lab reported percentage of silica for each sample

W = Mass of silica reported by the lab for each sample

Example 1: Two consecutive samples were collected to monitor the same employee for a combined exposure to silica dusts for one work shift. The analytical results are shown in Table J-1, Sample Silica Exposure Data.

Table J-1. Sample Silica Exposure Data

Sample	Sampling period (min)	Total volume (L)	Respirable weight (mg)	Respirable concentration (mg/m^3)	SLTC results (%)
A	238	405	0.855	2.1	5.2 quartz 2.3 cristobalite ND tridymite
B	192	326	0.619	1.9	4.8 quartz 1.7 cristobalite ND tridymite
Total	430	731	1.474		
Key: ND = Not detectable.					

Calculation of the TWA from the sampling and analytical data:

Step 1. Calculate the percentage of quartz, cristobalite, and tridymite in the respirable particulate collected (using Equation 8 from Section III.K.2.).

Quartz:5.2 (0.855 / 1.474) + 4.8(0.619 / 1.474) = 3.0 + 2.0 = 5.0%

Cristobalite:2.3 (0.855 / 1.474) + 1.7(0.619 / 1.474) = 1.3 + 0.7 = 2.0%

Step 2. Calculate the PEL for the mixture (using Equation 12 from Section III.K.2.):

$PEL_{mixture} = (10\ mg/m^3) / (\%\ quartz + 2(\%\ cristobalite) + 2(\%\ tridymite) + 2)$

$= 10 / (5.0 + 2(2.0) + 2(0) + 2) = 10 / 11.0 = 0.91\ mg/m^3$

Step 3. Calculate the employee's exposure (using Equation 7 from Section III.K.2.). NOTE: 1L = 0.001 m^3

Equation J-1

$Exposure = (Sample\ wt.A + Sample\ wt.B) / (Total\ Volume) = (0.855 + 0.619) / 0.731 = 2.0\ mg/m^3$

Step 4. Adjust (where necessary) for less than 8-hour sampling period.

Equation J-2

$TWA = (2.0\ mg/m^3)(430\ min) / (480\ min) = 1.8\ mg/m^3$

Step 5. Calculate the severity of the exposure (using Equation 9 from Section III.K.2.):

$(1.8\ mg/m^3) / (0.91\ mg/m^3) = 2.0$

After Step 5, the upper and lower confidence limits would be determined by applying the SAE as described in Section IV.D. of this document, and as shown in Examples 2 and 3 below.

Example 2: A sample is obtained for a construction jackhammer operator using the gravimetric sampling method specified in *OSHA Method ID-142*. The sample is run for 240 minutes at a flow rate of 1.7 L/min, yielding a total sample volume of 0.408 m3. The respirable dust collected on the filter is determined to weigh 0.857 mg, resulting in a respirable dust concentration of 2.1 mg/m^3. The SLTC reports that the sample contains 55% quartz. The SLTC also reports an SAE of 0.20 for the sample.

Step1. Determine the jackhammer operator's 8-hour TWA respirable dust exposure (assuming zero exposure for the unsampled portion of the 8-hour shift) (using Equation J-2):

Exposure = 2.1 mg/m^3 x (240 min) /(480 min) = 1.05 mg/m^3 respirable dust

Step 2. Calculate the general industry PEL, assuming the conditions for the jackhammer operator sample containing 55% respirable quartz (using Equation 12 from Section III.K.2.):

PEL (mg/m^3) = (10 mg/m^3) / (2 + 55) = 0.175 mg/m^3

Step 3. Calculate the Severity Ratio (using Equation 9 from Section III.K.2.):

Severity = (sample results (from Step 1)) / (calculated PEL (from Step 2)) = (1.05 mg/m^3) / (0.175 mg/m^3) = 6.0

Step 4. Calculate confidence limits by applying the SAE (Equations 10 and 11 respectively, from Section III.K.2):

Lower Confidence Limit (LCL) = 6.0 - 0.20 = 5.8

Upper Confidence Limit (UCL) = 6.0 + 0.2 = 6.2

Step 5. Based on a confidence limit of 5.8, the sample exceeds the 95% confidence limit for overexposure.

Step 6. Apply the OSHA-adopted conversion factor (using Equation 4 from Section III.K.2.) to the jackhammer operator's exposure result from Step 1 and Reference Formula (B) above:

Exposure = (1.05 mg/m^3)(1 mppcf) / (0.1 mg/m^3) = 10.5 mppcf

Step 7. Calculate the applicable construction PEL for jackhammer operator sample containing 55% respirable quartz (using Equation 5 from Section III.K.2.):

PEL = (250 mppcf) / (55% + 5) = 4.17 mppcf

Step 8. Conclusion. The 8-hour TWA exposure of the jackhammer operator exceeds the construction industry PEL for crystalline silica (quartz).

Example 3: Two samples are obtained for a construction foreman overseeing a concrete drill press operation. Both samples are collected at a flow rate of 1.7 L/min. The duration of Sample A is 238 minutes, yielding a total sample volume of 0.40 m^3. The respirable dust collected on the filter is determined to weigh 0.855 mg, resulting in a respirable dust concentration of 2.1 mg/m^3. The SLTC laboratory reports that Sample A contains 30% quartz. The duration of Sample B is 192 minutes, yielding a total sample volume of 0.326 m3. The respirable dust weight is 0.619 mg, resulting in a concentration of 1.9 mg/m^3. The total weight of respirable dust collected on both samples is 1.474 mg. The SLTC laboratory reports that Sample B contains 25% quartz. The SLTC reports an SAE of 0.16 for both samples.

Step 1. Determine the foreman's 8-hour TWA respirable dust exposure (using Equation 13 from Section IV.D.4.):

Exposure = ((2.1 mg/m^3 x 238 min)) + (1.9 mg/(m^3 x 192 min))) / (480 min) = 1.8 mg/m^3

Step 2. Determine average quartz content since the SLTC provided two different percentages of quartz, using Reference Formula D, above:

Recalculated % = ((30% x 0.855) + (25% x 0.619)) / ((0.855+0.619)) = 28%

Step 3. Calculate the general industry PEL, assuming the conditions for the construction foreman sample containing 28% respirable quartz (using Equation 12 from Section III.K.2):

$PEL(mg/m^3) = (10\ mg/m^3) / (2 + 28) = 0.333\ mg/m^3$

Step 4. Calculate the Severity Ratio (using Equation 9 from Section III.K.2):

$Severity = (1.8\ mg/m^3) / (0.333\ mg/m^3) = 5.4$

Step 5. Calculate confidence limits by applying the SAE (using Equations 10 and 11 respectively, from Section III.K.2):

LCL = 5.4 - 0.16 = 5.24

UCL = 5.4 + 0.16 = 5.56

Step 6. Based on a severity of 5.4, the sample exceeds the 95% confidence limit for overexposure.

Step 7. Apply the OSHA-adopted conversion factor to the construction foreman's exposure result from Step 1 and Reference Formula C above (using Equation 4 from Section III.K.2.):

$Exposure = (1.8\ mg/m^3)(1.0\ mppcf) / (0.1\ mg/m^3) = 18.0\ mppcf$

Step 8. Calculate the applicable construction PEL, (using Equation 5 from Section III.K.2.) for the foreman's samples containing an average of 28% respirable quartz:

PEL = (250 mppcf) / (28 + 5) = 7.58 mppcf

Step 9. Conclusion. The eight-hour TWA exposure of the foreman exceeds the construction industry PEL for crystalline silica (quartz).

Appendix K
Chain of Custody

The SLTC uses OSHA's established chain-of-custody procedures to track whether official Form OSHA-21 seals were properly used to ensure the integrity of samples collected by OSHA CSHOs. The procedure also tracks the history and control of samples received at the SLTC. The chain of custody includes the following dates: the date the sample was collected, the date the sample was shipped to the SLTC, the date the sample was received at the SLTC, the date the analyst received the sample, the date the analysis was completed, the date the analytical results were checked by another analyst, and the date the sample results were released by a supervisor or his/her representative. It is important to follow chain-of-custody requirements because it documents the proper handling of OSHA samples for litigation purposes.

Appendix L
Health Effects Codes

When available, the CSI files contain health effects information, including the applicable Health Effects Codes, for each chemical. The complete list of Health Effects Codes is shown below in Table L-1. The Health Effects Codes indicate the principal health effects of exposure to each substance, and are used to determine the seriousness of a violation and severity of the penalty, based on the guidelines contained in Chapter 4 of the FOM.

Table L-1. Health Effects Codes

Code	Health Effects
HE1	Cancer---Currently regulated by OSHA as carcinogen
HE2	Chronic (Cumulative) Toxicity---Known or Suspected animal or human carcinogen, mutagen (except Code HE1 chemicals)
HE3	Chronic (Cumulative) Toxicity---Long-term organ toxicity other than nervous, respiratory, hematologic or reproductive
HE4	Acute Toxicity---Short-term high risk effects
HE5	Reproductive Hazards---Teratogenesis or other reproductive impairment
HE6	Nervous System Disturbances---Cholinesterase inhibition
HE7	Nervous System Disturbances---Nervous system effects other than narcosis
HE8	Nervous System Disturbances---Narcosis
HE9	Respiratory Effects Other Than Irritation---Respiratory sensitization (asthma or other)
HE10	Respiratory Effects Other Than Irritation---Cumulative lung damage
HE11	Respiratory Effects---Acute lung damage/edema or other
HE12	Hematologic (Blood) Disturbances---Anemias
HE13	Hematologic (Blood) Disturbances---Methemoglobinemia
HE14	Irritation-Eyes, Nose, Throat, Skin---Marked

Code	Health Effects
HE15	Irritation-Eyes, Nose, Throat, Skin---Moderate
HE16	Irritation-Eyes, Nose, Throat, Skin---Mild
HE17	Asphyxiants, Anoxiants
HE18	Explosive, Flammable, Safety (No adverse effects encountered when good housekeeping practices are followed)
HE19	Generally Low Risk Health Effects---Nuisance particulates, vapors or gases
HE20	Generally Low Risk Health Effects---Odor

Appendix M - Conversion Equations (mg/m^3 to ppm)

Equation M-1

$ppm_{NTP} = (mg/m^3)(24.46) / MW$

Where:

24.46 = molar volume at 25°C (298K) and 760 mmHg
MW = molecular weight
NTP = Normal Temperature and Pressure (25°C and 760 mmHg)
mmHg = millimeters of mercury

CSHOs will not usually need to calculate the exposure concentration in ppm at the sampling site (ppm_{PT}) but, if necessary, it can be calculated from the SLTC's results reported in ppm_{NTP} by using the following equation:

Equation M-2

$ppm_{PT} = (ppm_{NTP})(760/P)(T/298)$

Where:

P = sampling site pressure (mmHg)
T = sampling site temperature (K)
298 = normal temperature in degrees Kelvin (273 + 25)
760 = normal atmospheric pressure in mmHg

Equation M-3

Because $ppm_{NTP} = (mg/m^3)(24.46) / MW$

Because $ppm_{NTP} = (mg/m^3)(24.46) / MW$

NOTE: When a contaminant concentration is converted from mg/m^3 and expressed as ppm_{PT}, that value cannot be compared directly to the PEL table without first converting it to its corresponding ppm_{NTP} value.

NOTE: The **barometric pressure** for the time period sampled can sometimes be obtained from the NOAA website or by calling the local weather station or airport. If air pressures are obtained by this route, it is necessary to obtain the unadjusted barometric pressure (station pressure) for compliance applications. The barometric pressure information most readily available from weather and aviation sources is the sea-level adjusted barometric pressure which tends to average about 760 mmHg and does not represent the actual air pressure of worksites much removed from sea level.

If the sources above are not readily available or cannot provide the actual station pressure, then the elevation (Elev) in feet of the worksite can be used to calculate the typical barometric pressure (P) in mmHg using the following equation:

Equation M-4

$$P = 760 \times [1 - (Elev \times 1.6470 \times 10^{-3}) / (295.20 \times (1 + Elev \times 4.9787 \times 10^{-8}))]^{6.3222}$$

Equation M-4 is an adaptation of the atmospheric model equation used in the *U.S. Standard Atmosphere* (1976) using a higher average effective sea-level screen temperature (295.2K) and lower temperature lapse rate (5.4K/km) typically observed over land surfaces within the northern latitudes of the U.S. (19°N to 61°N). For most of the U.S., the barometric pressures obtained with this equation are better estimates of observed station pressures than the 1976 model, and deviate from mean annual station pressures by about 0.24% RSD (percent relative standard deviation) for elevations below 4,300 feet and 0.52% RSD for elevations below 30,000 feet. These deviations are insignificant compared to the estimated 1.6% RSD for combined normal seasonal, storm, and diurnal station pressure variations observed at any elevation within the year. The 1.6% RSD may be assumed if the worksite elevation can be estimated to within 100 feet. A global positioning system (GPS) elevation measurement is typically within 100 feet of the actual elevation. GPS elevation measurements should be made outdoors and away from tall structures. Example calculations using the equation give 723.2 mmHg for an elevation of 1,400 feet above mean sea level and 569.5 mmHg for an elevation of 8,000 feet above mean sea level. Due to Alaska's high latitudes, Equation M-4 is biased high for significant elevations in Alaska; therefore, the station pressure of a nearby weather station is necessary to obtain accurate air pressures for most of Alaska.

Appendix N
Example Calculation for Full-Period, Continuous Single Sample

A single glass-fiber filter and personal sampling pump were used to sample for carbaryl for an 8-hour period. The SLTC reported 6.07 mg/m^3. The SAE for this method is 0.23. The PEL is 5.0 mg/m^3.

Step 1. Calculate the exposure severity (using Equation 9 from Section III.K.2):

$Y = 6.07 / 5.0 = 1.21$

Step 2. Calculate confidence limits

Calculate the $LCL_{95\%}$ (using Equation 10 from Section III.K.2):

$LCL_{95\%} = 1.21 - 0.23 = 0.98$

Because the $LCL_{95\%}$ does not exceed 1.0, noncompliance is not established.

Calculate the $UCL_{95\%}$ (using Equation 11 from Section III.K.2):

$UCL_{95\%} = 1.21 + 0.23 = 1.44$

Step 3. Classify the exposure.

Because the $LCL_{95\%} < 1.0$ and the $UCL_{95\%} > 1.0$, classify as possible overexposure.

Appendix O
Example Calculation for Full-Period, Consecutive Sampling

If two consecutive samples had been taken for carbaryl instead of one continuous sample, and the following results were obtained:

Sample Results		
	A	**B**
Sampling rate (L/min)	2.0	2.0
Time (min)	240	240
Volume (L)	480	480
Weight (mg)	3.005	2.808
Concentration (mg/m^3)	6.26	5.85

The SAE for carbaryl is 0.23

Step 1. Calculate the $UCL_{95\%}$ and the $LCL_{95\%}$ from the sampling and analytical results.

Using Equation 13 from Section IV.D.4.:

$TWA = ((6.26 \text{ mg}) / m^3)(240 \text{ min}) + (5.85 \text{ mg})/m^3)(240 \text{ min})) / (480 \text{ min}) = 6.055 \text{ mg})/m^3$

Using Equation 9 from Section III.K.2:

Exposure severity (Y) = $(6.055 \text{ mg})/m^3) / PEL = 6.055 / 5.0 = 1.21$

Using Equation 10 from Section III.K.2:

Assuming a continuous sample: $LCL_{95\%} = 1.21 - 0.23 = 0.98$

Using Equation 11 from Section III. K.2:

$UCLM_{95\%} = 1.21 + 0.23 = 1.44$

Step 2. Because the $LCL_{95\%} < 1.0$ and $UCL_{95\%} > 1.0$, the results are in the possible overexposure region. To document an overexposure, the CSHO must reanalyze the data using the more exact calculation for full-period consecutive sampling (Using Equation 14 from Section IV.D.4.):

$LCL_{95\%} = (1.21) - (0.23\sqrt{((240 \text{ min})^2 (6.26 \text{ mg})/m^3)^2 + (240 \text{ min})^2 (5.85 \text{ mg})/m^3)^2})) / (5.0 \text{ mg})/m^3 (240 \text{ min} + 240 \text{ min}))$

$= 1.21 - 0.20 = 1.01$

Since the $LCL_{95\%} > 1.0$, a violation is established.

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