

PART 1

OSHA Technical Manual

SECTION II: CHAPTER 1

PERSONAL SAMPLING FOR AIR CONTAMINANTS

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I. Introduction

This chapter provides basic information related to sampling air contaminants. These instructions are essential for acquiring documented and valid exposure data that will be defensible in the event of contested citations.

This chapter is one of a number of references for sampling air contaminants. Other reference resources that should be routinely consulted are OSHA's Chemical Sampling Information (CSI) file and the OSHA Field Inspection Reference Manual (FIRM). The FIRM identifies CSHO responsibilities associated with the majority of their inspection

duties. OSHA and National Institute for Occupational Safety and Health (NIOSH) validated sampling and analytical methods should be reviewed, and when necessary, the Salt Lake Technical Center (SLTC) analytical staff should be consulted. It is extremely important that SLTC-approved sampling procedures or procedures described in the CSI that have been approved by the SLTC be used.

OSHA sampling and analytical methods were developed to provide OSHA with validated methods to monitor workplace exposure to a wide variety of chemical substances. These methods were validated with the use of evaluation guidelines that are published on [OSHA's website](#). The guidelines define sampling and analytical parameters, specify required laboratory tests, statistical calculations, criteria for acceptance, and provide a detailed outline for the written reports. The overall goal of these guidelines is to provide OSHA with sampling and analytical methods that can be clearly defended with evaluation data. These sampling and analytical methods were designed and tested for internal use by OSHA personnel. The use of nonstandard sampling methods may require resampling with a SLTC-approved sampling procedure. The SLTC is aware that unique sampling situations will arise during some inspections and close coordination with the laboratory will provide the best analytical service.

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 requirements such as 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 and to document the source of air contaminants. They are required for certain analyses such as explosibility and flash point testing. They are sometimes used in Hazard Communication inspections (i.e., Material Safety Data Sheet (MSDS) compliance). Consult OSHA's Chemical Sampling Information 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 (see Chapter 4, Sample Shipping and Handling) 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 and make certain that samples are properly documented on the Air Sampling Worksheet Form OSHA-91A (see Figures II: 1-24 and II:1-25 for a completed Form OSHA-91A) and properly sealed with Form OSHA-21 as shown in Appendix II:1-6. Apply the Form OSHA-21 in such a manner that the chain-of-custody information is not obstructed.

II. How to Order Sampling Media

OSHA personnel can order sampling media from the SLTC using the order form located on the OSHA limited access Intranet under CSHO Resources. Charcoal tubes, asbestos pre-assembled filters and cassettes, Form OSHA-21 seals, cyclones, and mixed cellulose ester filters (MCEF) should be ordered from the Cincinnati Technical Center (CTC).

The SLTC provides pre-weighed filter/cassette units for gravimetric sampling and analysis to OSHA personnel. The 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. Refer to OSHA's Chemical Sampling Information file or to Appendix II:1-4 of this document for a list of analytes in this category.

III. General Monitoring Requirements and Guidelines

A. Documentation

It is essential that accurate and complete sampling pump calibration records and field sampling notes be recorded on Form OSHA-91A (Air Sampling Worksheet), which also serves as a sample submission document for samples requiring analysis by the SLTC. Be sure to use designated sample media to perform pre/post calibration. Do not use the same media for calibration and field sampling. SLTC chemists sometimes use sampling pump calibration data to verify air sample volumes. Detailed line-by-line instructions for completing this document are given in Chapter XXI (Air Sampling Worksheet, Form OSHA-91A) of OSHA Instruction IRT 01-00-007 (previously ADM 1-1.31) (The IMIS Enforcement Data Processing Manual for use with the NCR Computer System). Ensure that handwritten information is printed legibly. Accurate and consistent spelling of the inspected establishment name will facilitate future database searches. A completed Form OSHA-91A (Air Sampling Worksheet) is shown in Figure II: 1-24 and Figure II:1-25 of Appendix II 1-8 in this document.

Diffusive samplers are convenient air sampling devices that sample gases and vapors and do not require the use of a sampling pump. OSHA diffusive sampling methodology exists for only a few chemicals. Refer to the Chemical Sampling Information file and the ORGANIC VAPORS AND GASES section of this document for diffusive sampling applications and guidance. When using diffusive samplers, record the sampling site temperature and pressure on the Form OSHA-91A (Air Sampling Worksheet). The barometric pressure for the time period sampled can sometimes be obtained by calling the local weather station or airport or by accessing National Oceanic and Atmospheric Administration information on the Internet. If air pressures are obtained by these means, it is necessary to obtain the unadjusted barometric pressure (station pressure) for compliance applications.

Take photographs (as appropriate) and detailed notes concerning visible airborne contaminants, work practices, potential interferences, workplace movements, and other conditions to assist in determining appropriate engineering controls. Ventilation and/or smoke tube measurements may also be helpful. Be certain to observe if the employees wore the sampling equipment properly. This is sometimes an important issue in litigation. Refer to the FIRM for a more thorough discussion of inspection documentation procedures.

B. Sampling Protocol

Determine as soon as possible after the start of the inspection whether full-shift air contaminant sampling is required by using the information collected during the walkaround (including any screening samples) 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 shift less 1 hour (e.g., 7 hours of an 8-hour work shift or 9 hours of a 10-hour work shift). Make every attempt to sample as much of the work shift as possible and include segments of greatest exposure during the sampling periods. However, no more than 8 hours of sample can be used in the 8-hour TWA-PEL calculation (refer to discussion on [extended work shifts below](#)). A representative exposure sample period may be less than seven hours; however, the final analytical result and associated calculation could still result in non-compliance when averaged over 8 hours.

Extended Work Shifts: Compliance officers can choose one of two approaches for employees who work extended work shifts beyond 8 hours. The choice taken will depend on the nature of the hazardous chemical and the work activity being performed.

1. The first approach is to sample what the compliance officer believes to be the worst continuous 8-hour work period of the entire extended work shift.
2. 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 compliance officer is dealing with lead, the employee's exposure in this approach is calculated based upon the worst 8-hours of exposure during the entire work shift. Using this method, the worst 8-hours do not have to be contiguous. Example: for a 10-hour work shift, following established sampling protocol as per the CSI file, ten 1-hour samples or five 2-hour samples could be taken and the eight highest 1-hour samples or the four highest 2-hr samples could be used to calculate the employee's 8-hour TWA, which would be compared to the 8-hour TWA-PEL.

At the time of this revision, the lead standards for construction and general industry are the only standards that require PEL adjustments with respect to extended work shifts.

To reduce their level of exposure, the occupational exposure to the Cotton Dust standard, [29 CFR 1910.1043](#), has a requirement to adjust extended work shifts when employees are required to wear respirators for a portion of the work shift.

The following guidance provides an overview of the sampling process:

3. Select the employees to be monitored and discuss the purpose of sampling. Inform the employees of when and where the sampling equipment will be removed. Stress the importance of not removing or tampering with the sampling equipment. Instruct the employees to notify their supervisor or the CSHO if the sampler requires temporary removal.

When assembling air sampling filter cassettes, it is crucial to 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 around the cassette to cover joints.

4. Place the calibrated sampling equipment on the employee so that it does not interfere with work performance or safety of the employee. Attach the collection device (filter cassette, charcoal tube, etc.) to the shirt collar or as close as practical to the nose and mouth of the employee's breathing zone (i.e., in a hemisphere forward of the shoulders within a radius of approximately nine inches). The inlet should be oriented in a downward vertical position to avoid gross contamination from airborne debris. The length of the tubing connecting the collection device to the sampling pump should not be excessive and it should be secured to the employee. This will help to prevent the tubing from being snagged or from interfering with the employee's job function. The inlet (vortex finder) for a cyclone should be oriented so that it faces away from the employee. The practice of placing the sampling devices inside personal protective equipment (PPE) applies only to PPE that is not intended to provide respiratory protection such as welding helmets. This sampling is performed to determine if respiratory protection is needed. Sampling outside of the PPE is used to determine if the correct assigned protection factor is being applied. If the PPE has supplied air, such as a welding hood or an abrasive blasting hood, then the sample is placed outside the PPE.

5. Turn on the sampling pump and record the start time (time on) on the Form OSHA-91A (Air Sampling Worksheet). After starting, observe the pump operation for a short time to make sure that it is operating correctly.

6. Record the information required on the Form OSHA-91A, including the sampling site temperature and pressure for diffusive samplers. Be sure to print legibly on all forms.

To ensure that a potential exposure level is effectively measured with respect to a specific regulatory standard, strive to sample for at least the minimum sampling time/air volume prescribed in the OSHA Chemical Sampling Information file when a minimum time is listed. Exceptions to this guideline would be 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 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.

7. 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 personal protective equipment. Frequent pump checks may be necessary, especially when heavy filter loading is possible. For air sampling filters, verify symmetrical deposition of particulate on the filter and the absence of unexpected large particles, or any evidence of tampering with the sample or pump. Ensure that the sampler remains properly assembled and that the hose does not become pinched or detached from the sampling device or from the pump. 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 also Section II, Chapter 2, Occupational Skin Exposure, Biological Monitoring and Surface Contamination (Wipe) Sampling). If the pump is turned on and off during the course of the day and if the sampling media is not changed, record subsequent times (time on/time off) on the Form OSHA-91A (Air Sampling Worksheet).

8. Before removing the pump at the end of the sampling period and if the pump has a rotameter, check the pump to ensure that the rotameter ball is still at the calibrated mark. If the ball is no longer at the mark, record the pump rotameter reading.

9. Turn off the pump and record the stop time (time off) on the Form OSHA-91A (Air Sampling Worksheet).
10. Remove the collection device from the pump, cap or otherwise close the sampler, and seal it with a Form OSHA-21 as soon as possible. The seal should be attached across the sample inlet and outlet so that evidence of any tampering is visible (see Figures II:1-19, II:1-22, and II:1-23.) Figures II:1-20 and II:1-21 are illustrations of incorrect application of Form OSHA-21 seals. Press the seal onto the cassette to ensure that the adhesive adheres firmly to the sampling media surface. Samples with seals that can be removed without obvious evidence of tampering will be identified as "Proper seals not in place" in SLTC reports of analytical results.

11. Indicate on the Form OSHA-91A if analytical results are to be reported as TWA results calculated using the actual time sampled 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. Record results of post-calibration for all pumps used on the OSHA-91A.

12. Prepare the samples for transport to the SLTC for analysis. 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 Section II, Chapter 4 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. Make sure that you include a copy of Form OSHA-91A (Air Sampling Worksheet) with the samples.

IV. Field Blanks

Blank samples 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 except for asbestos, which requires a minimum of two field blanks, even for a single asbestos sample. Field blanks (e.g., charcoal tubes, filters)

should be opened in the workplace but 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. Diffusive samplers should be briefly opened in the field in an area on-site where no contamination is expected and then 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.

V. Total Dust

Collect total dust samples using pre-weighed polyvinyl chloride (PVC) filters at a maximum flow rate of 2 liters per minute (L/min) for a maximum sampling time of 480 minutes or 8 hours. Be careful not to overload the filter. See the discussion on filter overloading in Section III. GENERAL MONITORING REQUIREMENTS AND GUIDELINES, SAMPLING PROTOCOL section of this document.

VI. Respirable Dust

Collect respirable dust samples using a clean 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 II: 1-1, II:1-2, and Appendix II Figure II: 1-18). Appendix II: 1-5 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.

FIGURE II: 1-1.
MSA CYCLONE HOLDER
WITH MSA CASSETTE

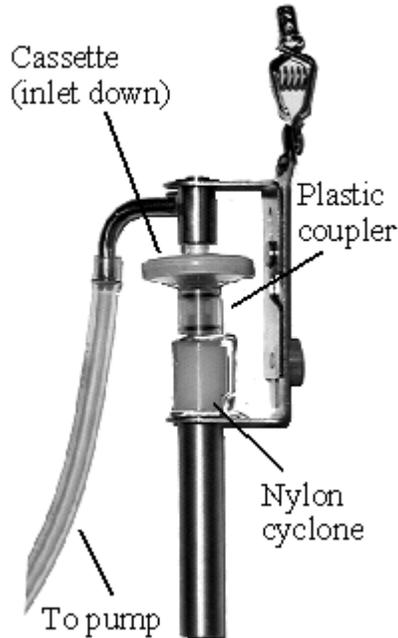
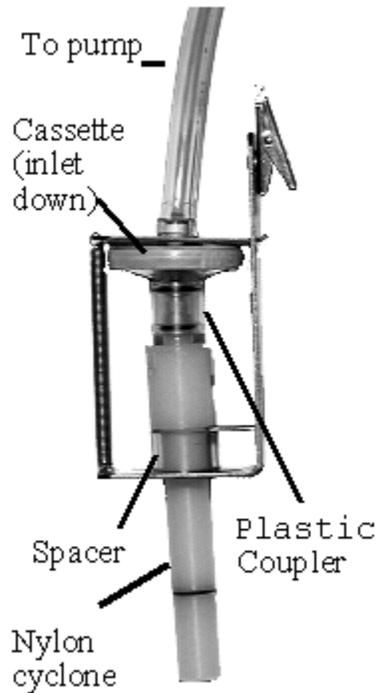


FIGURE II: 1-2.
BENDIX CYCLONE
HOLDER
WITH MSA CASSETTE



VII. Crystalline Silica

A. Air Samples

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

A respirable silica sample collected without a cyclone is a total dust (or nonrespirable) 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. 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 Form OSHA-91A (Air Sampling Worksheet).

Contact the SLTC if cristobalite or tridymite analysis is required. In general, cristobalite and/or tridymite are produced under conditions of 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 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)

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

1. 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.
2. Less-than or equal-to (\leq) 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.
3. Approximate Values in Units of Percent. The particle size distribution in a total dust sample is unknown and error in the XRD analysis may be greater than for respirable samples. Therefore, for total dust samples, an approximate result is given.
4. 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.

B. Bulk Samples

Bulk samples should be submitted for all silica analyses, if possible. Submit as much sample as will fit in a 20-milliliter (mL) scintillation vial. Bulk samples have the following purposes:

- To confirm the presence of quartz (cristobalite and/or tridymite) in the workplace or to assess the presence of other substances that may interfere in the analysis of respirable samples.
- To determine the approximate percentage of quartz (cristobalite and/or tridymite) in the bulk sample.
- To support the evaluation of Material Safety Data Sheets (MSDSs). See comment on page two above.
- A bulk sample must be representative of workplace dust if the material is to be used to chemically resolve interferences that cannot otherwise be resolved.

SLTC's order of preference for bulk samples for an evaluation of personal exposure is:

- A representative settled-dust (rafters, top of equipment, window sills, etc.) sample.
- A bulk sample of the raw material used in the manufacturing process is typically analyzed after evaluating MSDSs.

The type of bulk sample submitted to the SLTC should be stated on the Form OSHA-91A (Air Sampling Worksheet) and be cross-referenced to the appropriate air samples.

Normally, any reported results for bulk sample analysis for quartz (also cristobalite) will be approximate because of the difficulty in matrix and particle size matching of the bulk material with the calibration standards used during analysis.

C. Sample Calculations for Crystalline Silica Exposures

Construction and Shipyard PELs for silica are measured in units of "millions of particles per cubic foot" (mppcf). To convert analytical results for a respirable dust measurement to mppcf, use the following formula: $mppcf = ((mg/m^3)/(0.1))$. SLTC's Sampling and Analytical Error (SAE) must be applied to mg/m^3 (milligram per cubic meter) sample results before conversion to mppcf.

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 percentage of cristobalite and adding it to the percentage of quartz, according to the formula in Step 2 of the discussion below. The PEL mixture pertains to the respirable concentration (see Table 1, Sample Silica Exposure Data).

Example: 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 1, Sample Calculation for Silica Exposure.

Table 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.

$$\begin{aligned} \text{Quartz:} & \quad 5.2 (0.855/1.474) + 4.8 (0.619/1.474) = 3.0 + 2.0 = 5.0\% \\ \text{Cristobalite:} & \quad 2.3 (0.855/1.474) + 1.7 (0.619/1.474) = 1.3 + 0.7 = 2.0\% \end{aligned}$$

Step 2. Calculate the PEL for the mixture.

$$\begin{aligned} \text{PEL}_{\text{mixture}} &= \frac{10\text{mg/m}^3}{\% \text{ quartz} + 2 (\% \text{ cristobalite}) + 2 (\% \text{ tridymite}) + 2} \\ &= \frac{10}{5.0 + 2(2.0) + 2(0) + 2} = \frac{10}{11.0} = 0.91 \text{ mg/m}^3 \end{aligned}$$

Step 3. Calculate the employee's exposure. NOTE: 1L = 0.001 m³

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

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

$$\text{TWA} = (2.0 \text{ mg/m}^3)[(430 \text{ min})/(480 \text{ min})] = 1.8 \text{ mg/m}^3$$

Step 5. Calculate the severity of the exposure. Sampling and Analytical Error (SAE) is applied to analytical results after Step 5. See [Section XI: Sampling and Analytical Error](#) section of this document.

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

VIII. Metals Sampling

A. Air Samples

Collect metal fumes using a three-stage 37-millimeter (mm), 0.8-micrometer (µm) mixed cellulose ester filter (MCEF) cassette. Use pre-weighed PVC filters for those substances listed in Appendix II:1-4. See OSHA's Chemical Sampling Information file for appropriate sampling rates and times. Be careful not to overload the filter. See the discussion on filter overloading in the GENERAL MONITORING REQUIREMENTS

AND GUIDELINES, SAMPLING PROTOCOL section of this document.

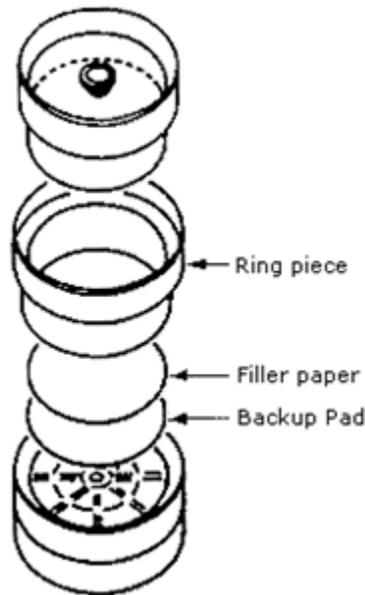
When sampling for welding fumes, the filter cassette must be placed inside the welding helmet to obtain an accurate measurement of the employee's exposure. Welding fume samples are normally taken using a 37-mm MCEF and cassette. If these cassettes will not fit inside the helmet, 25-mm MCEF and cassettes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

NOTE: The practice of placing the sampling device inside personal protective equipment (PPE) applies only to PPE that is not intended to provide respiratory protection such as welding helmets or face shields. This sampling is performed to determine if respiratory protection is needed. If the PPE has supplied air, such as a welding hood or an abrasive blasting hood, then the sample is placed outside the PPE.

B. 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. 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 Polytetrafluoroethylene (PTFE) lined caps. However, it is recognized that these recommended limitations may not always prove practical, and the professional judgment of the CSHO always takes precedence.

FIGURE II: 1-3. EXPLODED VIEW OF A 37-mm THREE-PIECE CASSETTE AND ASSEMBLY ILLUSTRATING PLACEMENT OF THE BACK-UP PAD



C. 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. Some of the current analyte/matrix combinations are listed below and are defined by specific OSHA sampling and analytical methods. Refer to OSHA's Chemical Sampling Information 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 125G.

Antimony
Beryllium
Cadmium
Chromium
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 metals 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 125G (ICP) because of analytical difficulties encountered with sample characteristics, heavy sample loadings, analyte solubility limitations, and instrumental limitations. Some of these problematic samples and analytes can sometimes be analyzed using other multi-element methods listed below or with one of the OSHA Method 121 procedures originally designed for individual metal determinations (e.g., Pb, Cd, Fe). Refer directly to OSHA Method 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 SLTC spectroscopy experts for further guidance and discussion of analytical options to suit specific compliance monitoring needs.

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

Antimony
Beryllium

Cadmium
Copper
Lead
Silver
Tin
Zinc

The following combination of metal analytes can be analyzed by OSHA Method 105:

Arsenic
Cadmium
Copper
Iron
Lead
Zinc

The following combination of metal analytes can be analyzed by OSHA Method 1006 (air samples only):

Arsenic
Cadmium
Copper
Cobalt
Lead
Nickel

IX. Asbestos

Collect samples for asbestos using 0.8- μ m, 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 II: 1-23). 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. Position the open face of the cassette down to minimize contamination.

Use a flow rate in the range of 0.5 to 5 L/min. One liter per minute is suggested for general sampling. For office environments, use flow rates of up to 5 L/min. Do not use nylon or stainless steel adapters if in-line calibration (Figure II: 1-10 and Figure II: 1-12) 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 (see the discussion on filter overloading in the [GENERAL MONITORING REQUIREMENTS AND GUIDELINES](#), SAMPLING PROTOCOL section of this document). 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.

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. Submit approximately 0.5 to 1 gram of material in a glass scintillation vial with a PolySeal™ cap. Place each bulk sample in a separate vial. Ship bulk samples and air samples separately to avoid cross-contamination.

Analysis of asbestos air samples is performed by phase contrast microscopy. Bulk samples are analyzed by polarized light microscopy.

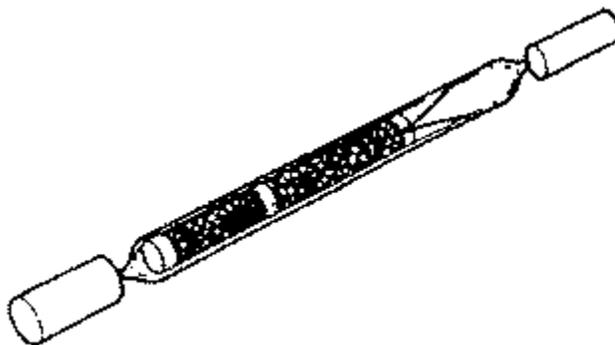
For unusual sampling conditions or high flow rates, contact the SLTC for more detailed instructions.

X. Organic Vapors and Gases

A. Solid Sorbent Sampling Tubes

Organic vapors and gases can be collected using several different sampling media including charcoal sampling tubes (see Figure II: 1-4) with low-flow sampling pumps. Refer to OSHA's Chemical Sampling Information file for required sampling media, sampling rates, and sampling times for specific chemicals. Sampling rates may need to be reduced or smaller air volumes (half the maximum) sampled when the humidity is greater than 90% or when relatively high concentrations of other organic vapors are present. Calibrate the sampling pump as stated and shown in Appendix II: 1-1.

FIGURE II: 1-4. CHARCOAL TUBE WITH FLAME-SEALED ENDS AND END CAPS



Immediately before sampling, 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. When possible, always use tube

holders to shield the sampled person from the sharp ends of sampling tubes.

The smaller section of the sampling medium is the back-up section and it should be positioned closest to the sampling pump. If directional arrows are present on the sampling tubes, point the arrow towards the pump. The tube should be held or attached in an approximately vertical position during sampling. Draw air to be sampled directly into the inlet of the tube. Generally, this air is not to be passed through any hose or tubing before entering the tube except in cases where a short piece of tubing is used to protect the end of the sampling tube (e.g., use of two tubes in series).

Cap the tube with the supplied plastic caps immediately after sampling and seal the tube with a Form OSHA-21 as soon as possible (see Figure II:1-19). The Form OSHA-21 should cover the end caps. If the seal does not cover the end caps, tape the ends of the seal, using clear plastic tape so that it is secure and tamper-resistant. Do not ship air samples with bulk samples.

B. Diffusive (Passive) Sampling

Diffusive samplers (also known as passive monitors or badges), Figure II:1-5, are useful for compliance monitoring. The major advantage of diffusive sampling is that no sampling pump is required. Some diffusive samplers and analytes have been validated for compliance sampling and they are shown in Table 2. Some analytes other than those shown below may be identified and quantitated by the SLTC, but these analytical results are usually reported as "approximations" and should be used only for screening purposes. Temperature and barometric pressure at the sampling site must be provided by the CSHO for proper calculation of exposure results for diffusive samplers. The barometric pressure for the time period sampled can sometimes be obtained by calling the local weather station or airport or by accessing NOAA information on the Internet. If air pressures are obtained by this means, it is necessary to obtain the unadjusted barometric pressure (station pressure) for compliance applications. Results from samples without sampling site temperature and pressure will have significantly higher Sampling and Analytical Error values. Specific sampling instructions for each type of diffusive sampler are supplied with the sampler and in OSHA methods that permit diffusive sampling. 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. Send the sealed sampler and all its accessories to the SLTC for analysis. Interfering substances should be noted on the Form OSHA-91A (Air Sampling Worksheet). Contact the SLTC for further information regarding diffusive sampler availability and use. Consult OSHA's Chemical Sampling Information file for new methods as they become available.

FIGURE II:1-5. DIFFUSIVE SAMPLER



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
ethylene oxide	OSHA 49	3M 3551
formaldehyde	OSHA 1007	AT Aldehyde Monitor 571 SKC UME _x 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	ID-208	E-Perm
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

C. Impingers and Bubblers

Examples of a midget impinger (left side) and of a midget bubbler (right side) are shown in Figure II:1-6. 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.

FIGURE II: 1-6. MIDGET IMPINGER AND BUBBLER



1. 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.
2. Rinse the impinger or bubbler with the appropriate reagent (see OSHA's Chemical Sampling Information file). Then add the specified amount of this reagent to the bubbler or impinger flask. Contact SLTC to obtain these reagents.
3. To prevent overflow, do not add more than 10 mL of liquid to midget impingers or bubblers. Place an empty impinger in series after the impinger (or bubbler) has been used for sampling. Position this impinger just before the sampling pump; it can be taped to the pump. If a holster is available, tape the holstered impinger to the pump. This impinger will function as a trap to collect any liquid lost from the sampling impinger (or bubbler) so that the sampling pump will be protected.
4. The sampling rate for midget impingers is 2.8 L/min. Collect contaminants in a bubbler at a maximum flow rate of 1.0 L/min. 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 SLTC prior to collecting any samples for particle (dust) counting using impingers.

5. 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 reagent to flow down the side arm to the hose and into the pump. NOTE: Attach a trap in-line with the pump, if possible.
6. In some instances, it will be necessary to add additional reagent during the sampling period to prevent the amount of reagent from dropping below one half of the original amount.
7. After sampling, remove the glass stopper and stem from the impinger or bubbler flask.
8. 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 reagent. Pour the contents of the flask into a 20-mL glass vial (preferably a scintillation vial with inert caps and liners). Avoid using metal cap liners or other materials that may react with the samples. Polytetrafluoroethylene (PTFE) cap liners with polypropylene caps are inert to most materials. Rinse the flask with a small amount (1-2 mL) of the reagent 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.

D. 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 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 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 SLTC for guidance.

XI. Sampling and Analytical Error (SAE)

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. Uncertainty in sampling results has historically been called Sampling and Analytical Error by OSHA. Correct application of SAE enables CSHOs to make reliable compliance decisions regarding sample results. SAE is especially important when sample results are near the PEL.

A. Definition of Upper and Lower Confidence Limits

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%}.

B. Determining Sampling and Analytical Errors (SAEs)

SAEs that provide a one-sided 95% confidence limit have been developed and are listed on each Form OSHA-91B (Air Sampling Report) report (most current SAEs). If there is no SAE listed on the Form OSHA-91B (Air Sampling Report) for a specific substance, contact the SLTC.

C. Workplace Variables

Differences in sampling results can occur when workplace variables (process changes, changes in work practices, changing air movement and velocity, etc.) result in variances greater than sampling and analytical errors. Samples taken on a given day are used by OSHA to determine compliance with PELs. However, when the employer has previously monitored the work area, CSHOs should review the long-term pattern and compare it with their sampling results. When OSHA's sample results fit the long-term pattern, it helps to support the compliance determination. When OSHA's results differ substantially from the historical pattern, CSHOs should investigate and determine the cause of this difference.

D. Confidence Limits

One-sided confidence limits can be used to classify the measured exposure into one of four categories:

1. If the measured exposure exceeds the PEL and the $LCL_{95\%}$ of the exposure is greater than 1.0, the CSHO can be 95% confident that the employer is in noncompliance, and a violation is established. (See Equation II:1-6F.)
2. If the measured exposure exceeds the PEL, but the $LCL_{95\%}$ of this exposure is less than 1.0, the CSHO cannot be 95% confident that the employer is in noncompliance. (See Equation II:1-6F.)
3. If the measured exposure does not exceed the PEL and if the $UCL_{95\%}$ of this exposure is less than 1.0, the CSHO can be 95% confident that the employer is in compliance. (See Equation II:1-6E.)
4. If the measured exposure does not exceed the PEL, but the $UCL_{95\%}$ of this exposure is greater than 1.0, the CSHO cannot be 95% confident that the employer is in compliance. (See Equation II:1-6E.)

In categories 2 and 4, the measured exposure can be termed a "possible overexposure."

A violation is not established if the measured exposure is in the "possible overexposure" category. It should be noted that the closer the $LCL_{95\%}$ comes to exceeding 1.0, the more probable it becomes that the employer is in noncompliance. If measured results are in this region, the CSHO should 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.

E. Sampling Methods

The $LCL_{95\%}$ and $UCL_{95\%}$ are calculated differently depending upon the type of sampling method used. Sampling methods can be classified into one of two categories:

5. 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

6. Full-period, Consecutive Sampling. Full-period, consecutive sampling is defined as sampling using multiple consecutive samples of equal or unequal time duration that, if combined, equal the total duration of the sample period. An example would be taking four 2-hour charcoal tube samples. There are several advantages to this type of sampling:
 - g. 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.

 - h. The use of multiple samples should result in slightly lower sampling and analytical errors.

 - i. Collection of several samples allows conclusions to be reached concerning the manner in which differing segments of the work day affect overall exposure.

This practice also allows for monitoring Peak and Ceiling exposures for the appropriate time.

F. 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 mg/m^3 of contaminant using the actual volume of air sampled at the sampling site as reported by the CSHO. The value in mg/m^3 can be compared directly to OSHA PELs for particulates (e.g., 29 CFR 1910.1000).

The SLTC normally does not measure concentrations of gases and vapors directly in parts per million (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 mm Hg using Equation II:1-6A. This ppm result is to be compared with the PEL without adjustment for temperature and pressure at the sampling site.

Equation II:1-6A

$$\text{ppm}_{\text{NTP}} = (\text{mg}/\text{m}^3)(24.46)/\text{MW}$$

where: 24.46 = molar volume at 25°C (298 K) and 760 mm Hg

MW = molecular weight

NTP = Normal Temperature and Pressure
(25°C and 760 mm Hg)

mm Hg = 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 SLTC results reported in ppm_{NTP} by using the following equation:

Equation II:1-6B

$$\text{ppm}_{\text{PT}} = (\text{ppm}_{\text{NTP}})(760/\text{P})(\text{T}/298)$$

where: P = sampling site pressure (mm Hg)

T = sampling site temperature (K)

298 = normal temperature in degrees Kelvin (273 + 25)

Equation II:1-6C

$$\text{Because } \text{ppm}_{\text{NTP}} = (\text{mg}/\text{m}^3)(24.46)/(\text{MW})$$

$$\text{ppm}_{\text{PT}} =$$

$$(\text{mg}/\text{m}^3)(24.46/\text{MW})(760/\text{P})(\text{T}/298)$$

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 by calling the local weather station or airport or by accessing NOAA information on the

Internet. 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 mm Hg 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 mm Hg using the following equation:

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

The above equation 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 (295.20 K) and lower temperature lapse rate (5.4 K/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 ft. and 0.52% RSD for elevations below 30,000 ft. 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 mm Hg for an elevation of 1,400 ft. above mean sea level and 569.5 mm Hg for an elevation of 8,000 ft. above mean sea level. Due to Alaska's high latitudes, the equation above 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.

G. 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 Form OSHA-91B (Air Sampling Report) or by contacting the SLTC. Divide the full-period sampling result X by the PEL to determine the exposure severity, Y. That is:

Equation II:1-6D

$$Y = X / \text{PEL}$$

Compute the upper confidence level at the 95% confidence level (UCL_{95%}) as follows:

Equation II:1-6E

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

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

Equation II:1-6F

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

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.

H. Sample Calculations for Full-Period, Continuous Single Sample (Example)

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.

$$Y = 6.07/5.0 = 1.21$$

Step 2. Calculate confidence limits.

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

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

The $UCL_{95\%}$ is calculated:

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

Step 3. Classify the exposure.

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

I. Calculations for Full-Period Consecutive Samples (Example)

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. If results fall into the "possible overexposure" region using this method, a more exact calculation should be performed

using equation II: 1-6G, below. 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.

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:

Compliance/Noncompliance Method
<ul style="list-style-type: none"> ○ Obtain $X_1, X_2 \dots X_n$, the n consecutive concentrations in one workshift and their corresponding time durations in minutes, $T_1, T_2 \dots T_n$. ○ Also obtain the SAE listed in the Form OSHA-91B sample report form. ○ Compute the TWA exposure, X. $X = \frac{(X_1 T_1) + (X_2 T_2) \dots + (X_n T_n)}{480 \text{ min}}$ <ul style="list-style-type: none"> ○ Divide the TWA exposure by the PEL to find Y, the standardized average (TWA/PEL). ○ Compute the $UCL_{95\%}$ as follows: ○ $UCL_{95\%} = Y + \text{SAE}$ (Equation II:1-6E) ○ Compute the $LCL_{95\%}$ as follows: ○ $LCL_{95\%} = Y - \text{SAE}$ (Equation II:1-6F)

Equation II:1-6G

$$LCL_{95\%} = Y - \frac{SAE \sqrt{(T_1 X_1)^2 + (T_2 X_2)^2 + \dots + (T_n X_n)^2}}{PEL(T_1 + T_2 + \dots + T_n)}$$

J. Sample Calculations for Full-Period Consecutive Sampling (Example)

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

-- Samples --		
	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:

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

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

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

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

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 as follows:

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

$$= 1.21 - 0.20 = 1.01$$

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

K. SAEs for Exposure to Chemical Mixtures

Often an employee is simultaneously exposed to a variety of chemical substances in the workplace. Additive toxic effects on a target organ are common for such exposures in many construction and manufacturing processes. This type of exposure can also occur when impurities are present in single chemical operations. Permissible exposures for mixtures involve the complex problem of additive exposures and their health effects. In addition, 29 CFR 1910.1000 contains a computational approach to assess exposure to a mixture. This calculation should be used when components in the mixture pose an additive health effect. While these calculations can be used for synergistic exposures, a separate assessment must be performed. For synergistic mixtures, an individualized assessment of toxicity using the most current scientific data is conducted to consider the total physiological burden. (See the [OSHA Field Inspection Reference Manual \(FIRM\)](#) for further details). The following is an intranet site available to OSHA personnel that addresses SAEs for exposure to chemical mixtures, Considering Sampling and Analytical Errors (SAEs) for Exposures to Mixtures.

Whether using a single PEL or the mixture calculation, the sampling and analytical error (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 II: 1-6H

C_1	C_2	\dots	C_n
$Y_{\text{mixture}} = \frac{C_1}{L_1} + \frac{C_2}{L_2} + \dots + \frac{C_n}{L_n}$			
L_1	L_2	\dots	L_n

Where:
 Y_{mixture} = equivalent exposure severity for a mixture
(Y_{mixture} should be < 1 for compliance)
 C_n = concentration of a particular substance
 L_n = PEL for a particular substance

For example, to calculate exposure to three different but additive substances:

Material	8-hour exposure	8-hour TWA PEL (ppm)	SAE
Substance 1	500	1000	0.089

Substance 2	80	200	0.11
Substance 3	70	200	0.18

Using Equation 1-6 H: $Y_{\text{Mixture}} = \frac{500}{1000} + \frac{80}{200} + \frac{70}{200} = 1.25$

Because the sum of the severities, $Y_{\text{mixture}} > 1$, an overexposure appears to have occurred, however, the SAE for each substance also needs to be considered:

Exposure severity ratio (for each substance): $Y_n = \frac{C_n}{L_n}$

Ratio each to total exposure: $R_1 = \frac{Y_1}{Y_{\text{mixture}}}$, $R_2 = \frac{Y_2}{Y_{\text{mixture}}}$, ..., $R_n = \frac{Y_n}{Y_{\text{mixture}}}$

For multiple analytes based on multiple analyses on the same sample use $SAE_{\text{mixture}} = SAE_H$ (e.g., where SAE_H is the highest SAE of the analytes measured above the quantitation limit; that provides a more accurate estimate of the SAE_{mixture}).

For analytes based on independent samples (different samplers), the SAEs (95% confidence) of the substance comprising the mixture can be pooled to give the SAE of the mixture using:

$$SAE_{\text{mixture}} = \sqrt{(R_1 SAE_1)^2 + (R_2 SAE_2)^2 + \dots + (R_n SAE_n)^2}$$

The mixture Upper Control Limit (UCL_{mixture}) is equivalent to: $Y_{\text{mixture}} + SAE_{\text{mixture}}$

The mixture Lower Control Limit (LCL_{mixture}) is equivalent to: $Y_{\text{mixture}} - SAE_{\text{mixture}}$

If $UCL_{\text{mixture}} < 1.0$, then an overexposure has not been established at the 95% confidence level.

If $LCL_{\text{mixture}} < 1.0$, and the $UCL_{\text{mixture}} > 1.0$, classify as possible overexposure and further sampling may be necessary.

If $LCL_{\text{mixture}} > 1.0$, then an overexposure has occurred (95% confidence).

Using the mixture data above:

$$Y_1 = 500/1000 \qquad Y_2 = 80/200 \qquad Y_3 = 70/200$$

$$\begin{array}{lll}
 Y_1 = 0.50 & Y_2 = 0.40 & Y_3 = 0.35 \\
 R_1 = Y_1/Y_{\text{mixture}} = 0.40 & R_2 = 0.32 & R_3 = 0.28
 \end{array}$$

$$\text{SAE}_{\text{mixture}} = \sqrt{(0.40 \times 0.089)^2 + (0.32 \times 0.11)^2 + \dots + (0.28 \times 0.18)^2}$$

$$\text{SAE}_{\text{mixture}} = 0.071$$

$$\text{LCL}_{\text{mixture}} = Y_{\text{mixture}} - \text{SAE}_{\text{mixture}}$$

$$\text{LCL}_{\text{mixture}} = 1.25 - 0.071 = 1.18$$

Therefore, $\text{LCL}_{\text{mixture}} > 1$ so an overexposure has occurred within 95% confidence limits. This calculation is also used when considering a mixture exposure such as total welding fumes.

XII. Soil Analysis in Support of the Excavation Standard

Soils analysis at the SLTC is performed to support CSHOs inspection and compliance responsibilities. It also supports citations and legal proceedings.

A representative soil sample from a trench or excavation is sent to the SLTC for analysis. Soil should be placed in a heavy-duty and tear-resistant plastic bag, secured, and sealed with tape to be airtight. Place the first plastic bag in a second heavy-duty plastic bag for additional protection. Sample size can vary from one pint for very fine-grained samples to two quarts for coarse gravel. A typical sample should be approximately one quart and weigh about three pounds. The Form OSHA-91A should not be put in the bag with the soil.

This soil sample is examined and tested according to OSHA Method ID-194. This fully validated method was developed specifically for the OSHA Excavation standard. The required tests take a minimum of four days. SLTC sample results specify the soil type as well as Textural and Structural Classification. The Type Classification will be A, B, or C corresponding to the descriptions listed in the Code of Federal Regulations. When requested, moisture content can also be provided.

Any questions arising from this analysis can be answered by trained soil experts at the SLTC. This analysis helps CSHOs as well as the inspected establishment personnel understand how to properly protect employees from cave-ins and how to properly evaluate protection measures used to comply with existing regulations.

XIII. Custom Services Provided by SLTC

The following services are available on a case-by-case basis at the SLTC. Concurrence from your Area Director in an e-mail (or via other means) sent to SLTC management must be received before SLTC can commit to providing some of these services.

A. Mass Spectrometry

The mass spectrometry laboratory at the SLTC has a number of unique tools to help CSHOs resolve difficult field sampling and analytical issues. For example, mass spectrometry can be used to identify unknown or suspected organic substances found in industrial processes, low level indoor air quality complaints and contaminated water. It can also be used to identify secondary substances that are given off from a heated material.

One of the major functions of the mass spectrometry laboratory is identification and confirmation of analytes measured in gas chromatography (GC) analysis performed at the SLTC. The same separation and identification techniques used to confirm identity of known analytes are also useful to identify an unknown material, investigate possible contamination or batch uniformity in a material from an industrial process, or to check for conformity with a Material Safety Data Sheet.

Volatile organic chemicals in contaminated water can be quantitated by purge and trap, by equilibrium headspace analysis, or by a novel approach involving thermal desorption called "Twister." The "Twister" technology is simple to use and highly sensitive.

Thermal desorption/Gas Chromatograph/Mass Spectrometer (TD/GC/MS) is also useful for investigation of low-level or transient odors, and indoor air quality-type complaints. The SLTC can provide sampling tubes containing three resin beds designed to collect a broad range of volatile analytes. The entire collected sample is thermally desorbed into the gas chromatographic column, providing analysis with maximum sensitivity.

Using a device called a direct insertion probe and a technique called pyrolysis, some thermally labile compounds can be introduced directly into the mass spectrometer source before heat is applied. With another instrument called a PyroprobeTM, materials can be heated to temperatures as high as 1400°C, with subsequent introduction of decomposition products into the GC column. Products released from materials involved in a fire, heated by a welder or blowtorch, or from any process involving heating can be studied in this way.

B. Materials Analysis

The SLTC provides a variety of services to determine the cause of materials failure. Materials failure analysis examines the extent to which the properties of materials or their use contribute to significant investigations, including fatalities. This often involves collaboration of experts in multiple disciplines including metallurgical engineering,

materials science, explosibility, and both inorganic and organic chemistry.

The SLTC has assisted in the investigation of several diverse catastrophes. These investigations have included chemical, gas, and dust explosions and disasters caused by incompatible chemicals and processes; metal and plastic failures; wire, synthetic and natural fiber rope failure; scaffold planking failure; plastic, fiberglass and metal piping failure; radio tower support failure; safety equipment failure; and chain and equipment overloading.

SLTC's services include assistance in searching for industry standards that help support citations, and assistance with finding an accredited laboratory to perform any analysis that is not done at the SLTC. The SLTC tailors the assistance to the particular investigation. The SLTC can either arrange to fully investigate the accident on-site, or to review results from an independent laboratory.

C. Biological Sampling

In the event that a CSHO believes biological monitoring would be valuable to assess and evaluate employee exposure to a substance or mixture of substances, they should first contact their Regional office, SLTC and the Office of Occupational Medicine to determine the most effective approach and technique to obtain the desired result. Biological sampling requires special consideration and will be addressed on a case-by-case basis.

SLTC provides biological (both organism and chemical by-product) sampling and analysis coordination as a service to CSHOs. The SLTC has developed a standard operating procedure to assure consistent sample handling and analysis. Samples collected and analyzed through this procedure are compliant with the SLTC quality-control system and chain-of-custody requirements. SLTC offers contracting services for fungi, bacteria, Legionella, and endotoxin analysis. Other services can be arranged on a case-by-case basis.

Again, before collecting biological samples, CSHOs are requested to contact SLTC for sampling requirements, technical support, assessment, and analytical coordination. SLTC staff will review sampling and analysis plans with CSHOs and make recommendations where appropriate. The purpose of this process is to ensure that prudent sampling is performed.

D. Explosibility Analysis

Because of the complexity of this field, it is strongly recommended that the CSHOs contact the SLTC before taking explosibility samples. This allows the explosibility experts to assist CSHOs in taking appropriate samples, and in tailoring the analysis to provide support for the specific inspection.

The SLTC provides an assortment of analytical and technical information services in

support of inspections involving potential explosion hazards. Analytical testing is performed in support of OSHA inspections pertaining to hazardous classified locations, grain handling, dust collection systems, confined space, and housekeeping. Informational support is offered for litigation, interpretation of analytical results (both in-house testing results and results from contract laboratories), and guidance for sampling and standard applicability. Explosibility experts can help investigate industrial incidents involving explosions. This help may include normal explosibility testing, and research into the reactive nature of the materials in question.

The SLTC can provide analyses for flash points, energetic reactivity of chemicals, and autoignition temperatures. This testing is useful in support of a wide variety of inspections.

E. Carboxyhemoglobin Calculations

Carbon monoxide (CO) exposure is determined by calculations based on post-exposure carboxyhemoglobin (COHb) blood levels provided by non-OSHA medical professionals. The documented SLTC modifications (printed in the supplemental report that accompanies sample results) use a more accurate version of the Coburn, Forster Kane equation than the closed-form version used in the 1972 NIOSH criteria document. The SLTC equation calculates the 8-hour TWA ppm Recommended Exposure Limit (REL) that would result in a 5% COHb level. Poisoning cases generally involve levels above 5% COHb. The calculation also provides an incident-specific SAE designed to deal with the uncertainties in the data. The calculation is performed at the SLTC and the results are critically assessed for accuracy by SLTC staff prior to reporting. SLTC carbon monoxide experts are available to assist CSHOs in acquiring data and in interpreting results.

Following are suggestions to help ensure that the most accurate calculations will be performed.

0. If possible, call one of SLTC's carbon monoxide experts before you go on-site, especially if methylene chloride is used on-site.
1. Before going on-site, download and read the worksheet entitled "Submitting Data for the Carbon Monoxide Calculation at the OSHA Salt Lake Technical Center (SLTC)" that is presently available on OSHA's Intranet at "CSHO Resources, Inspection Preparation, Biological Exposure Assessment." There are additional SLTC contact persons listed on the worksheet. Take the worksheet on-site.
2. Collect vital statistics for victims (age, weight, sex, living or dead).
3. Detail smoking activity (first-hand, second-hand tobacco smoke).
4. Document oxygen saturation-affecting conditions, such as pre- and post-exposure activity levels and oxygen therapy.
5. Provide accurate timelines.
6. List signs and symptoms of suspected exposure.
7. Review the document for accuracy and completeness before submitting it to SLTC.

XIV. Bibliography

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APPENDICES

Appendix II: 1-1.

A. Sampling Pump Calibration

Calibrate personal sampling pumps before and after each day of sampling using one of the techniques described in this document. Assure that the calibration equipment is within its prescribed calibration interval, and record the serial number of the calibration equipment in your case file. If the sampling pump is equipped with a rotameter, record the reading on the Form OSHA- 91A (Air Sampling Worksheet).

Most of the following examples in this section use filter cassettes as the sampling media; however, adsorbent tubes can be substituted for cassettes and the same technique used for calibration of their sampling pumps.

NOTE: Although OSHA allows the use of precision rotameters for sampling pump calibration, this device is no longer recommended and should only be used when absolutely necessary. Tests have indicated significant measurement error due to pump pulsation.

Before 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) (see Section II, Chapter 3, Part III. – Batteries).

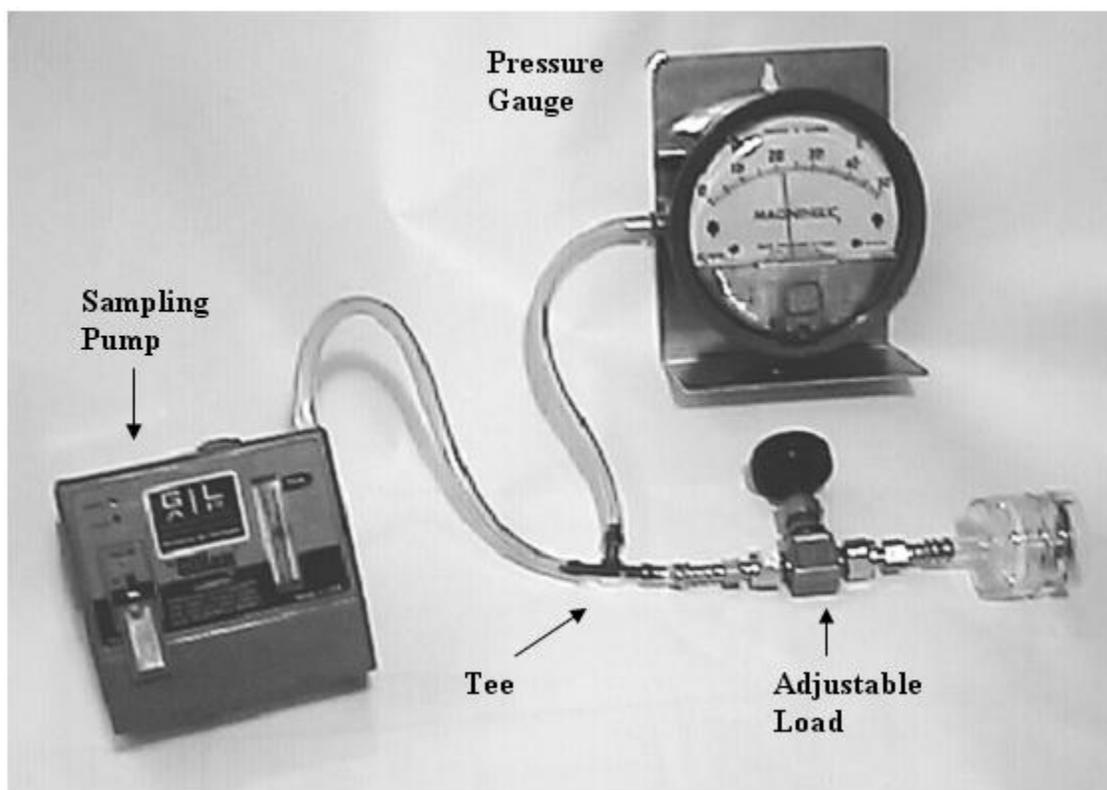
Place the same type of sampling media in-line during sampling pump calibration that will be used to sample in the field. Do not use the actual cassette and filter intended for sampling use to perform calibration.

B. Jarless Calibration of Cyclone/Filter

The following "Jarless Cyclone Calibration" is a method for calibrating the cyclone without a 1-liter jar. This method is included in the NIOSH Manual of Analytical Methods, Fourth Edition.

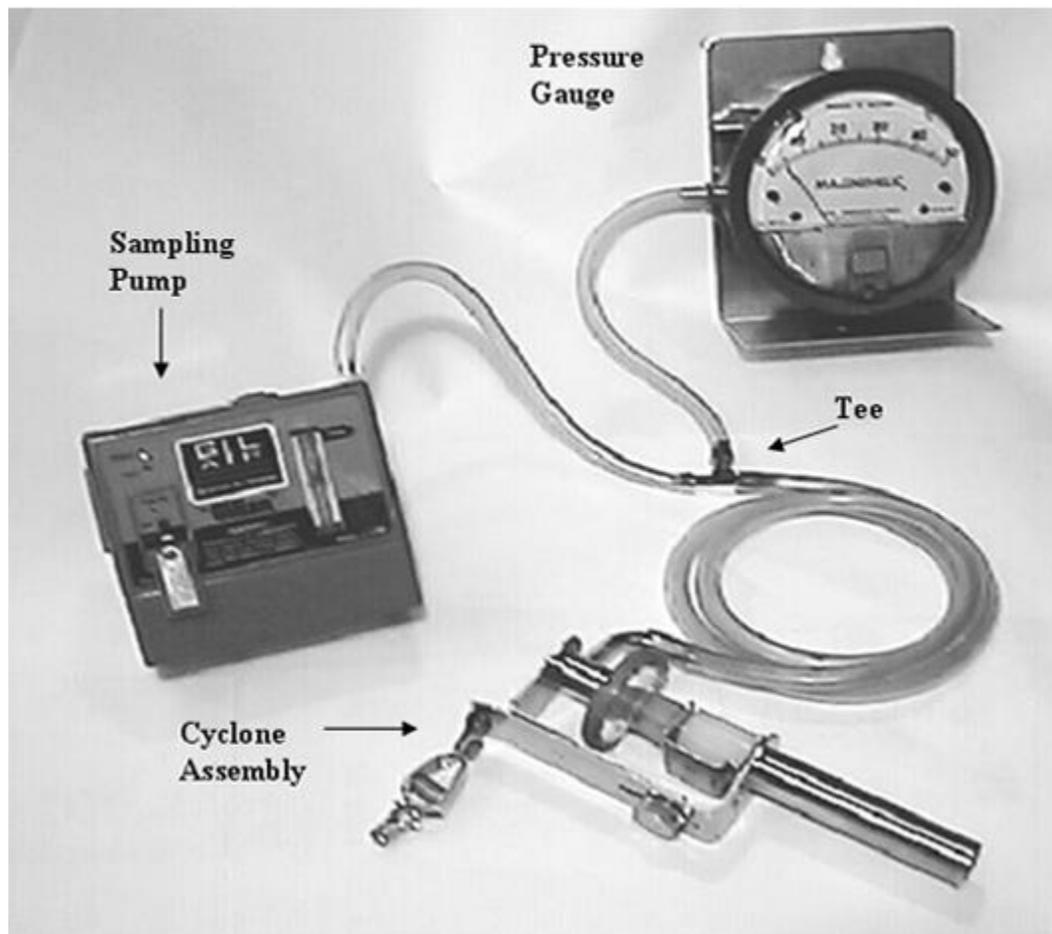
1. Connect the air sampling pump to a TEE fitting, a pressure gauge (0 to 50 inches of water vacuum full scale) or water manometer, a light load provided by an adjustable Bonnet needle valve and a calibrated electronic bubble meter or standard bubble buret (see Figure II: 1-7a).

FIGURE II: 1-7a. SETUP OF JARLESS CYCLONE METHOD WITH ADJUSTABLE LOAD



2. Adjust the air sampling pump to 1.7 L/min as indicated on the bubble meter, and adjust the loading, if necessary, to produce a water indication of 2 to 5 inches on the pressure (vacuum) gauge.
3. Increase the loading by slowly closing the valve until the pressure (vacuum) gauge indicates between 25 and 35 inches of water, and check the flow rate again. The flow rate should remain at 1.7 L/min \pm 5%.
4. Finally, replace the load and bubble meter with the cyclone and a clean filter installed, and verify that the loading caused by the cyclone assembly is between 2 and 5 inches of water pressure (see Figure II: 1-7b). 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.

FIGURE II: 1-7b. SETUP OF JARLESS CYCLONE METHOD WITH CYCLONE ASSEMBLY IN-LINE



5. This calibration method actually performs a dynamic test of the pump under load.

C. Electronic Flow Calibrators

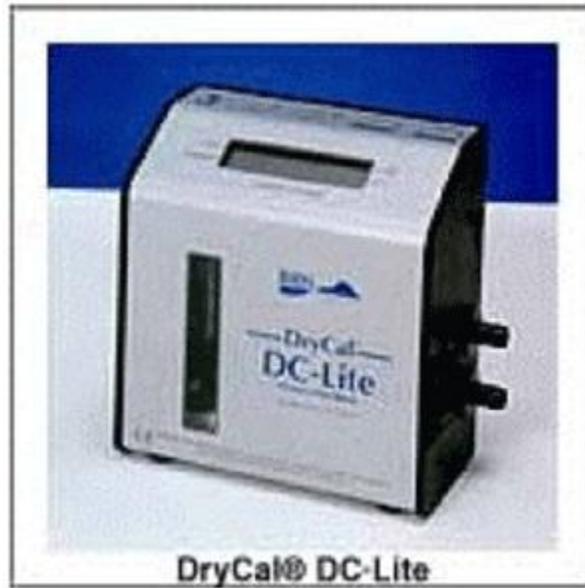
The Gilian Gilibrator® shown in Figure II: 1-8 is an electronic bubble flow meter, used to calibrate sampling pumps, that provides instantaneous air-flow readings and cumulative averaging of multiple measurements. These calibrators measure the flow rate and display the results as volume per unit of time (e.g., mL/min) and can be used to calibrate most air sampling pumps. The range with different cells is from 1 mL/min to 30 L/min. Gilibrators should not be left plugged into the charger for extended time periods because the service life of the battery will be decreased.

FIGURE II:1-8. GILIAN GILIBRATOR PUMP



The Bios DryCal™ DC-Lite® shown in Figure II:1-9 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 DC-Lite 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 1 mL/min to 30 L/min. Do not use the DC-Lite with MSA Escort® ELF pumps because operation of the pump is affected by the DC-Lite.

FIGURE II: 1-9. BIOS DRYCAL™ DC-LITE PUMP CALIBRATOR



The Cincinnati Technical Center (CTC) recommends that the DC-Lite 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 DC-Lite flow calibrator be used in corrosive or otherwise contaminated environments.

Properly functioning and calibrated Gilibrators and DC-Lites have an accuracy of approximately 99%. The appropriate Gilibrator cell or model DC-Lite must be used for the flow to be measured. 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, however, the DC-Lite flow calibrator can be substituted in most cases except for use with MSA Escort ELF pumps.

1. Perform the calibration at the pressure 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 five minutes before voltage check and calibration.
2. Assemble the cassette filter holder using the appropriate filter (or other sampler) for the sampling method. Compress the cassette using a mechanical press or other means of applying pressure. Do not mix brands of cassette components. Examine the assembled cassette to make certain that the joints fit together securely to ensure that the cassette does not leak. Use shrink tape around the cassette to cover joints, but do not rely on the tape to prevent leaks. If a cassette adapter is used to connect the cassette to the sampling

pump, care should be taken to ensure that it does not come in contact with the back-up pad. Cassette adapters can cause moderate to severe pressure drop at high flow rates and can affect the calibration result. If adapters are used for sampling, they should also be used when calibrating. CAUTION: Nylon adapters can restrict air flow due to plugging. Stainless-steel adapters are preferred. Do not use adapters with asbestos filter cassettes.

3. Connect the collection device, tubing, pump, and calibration apparatus as shown in Figure II: 1-10 for the cassette sampler and Figure II: 1-11 for the Dorr-Oliver cyclone sampler.
4. Visually inspect all plastic tubing connections. Be certain that there are no leaks.
5. Gilibrator: Wet the inside of the electronic flow cell with the soap solution by pushing on the button several times.

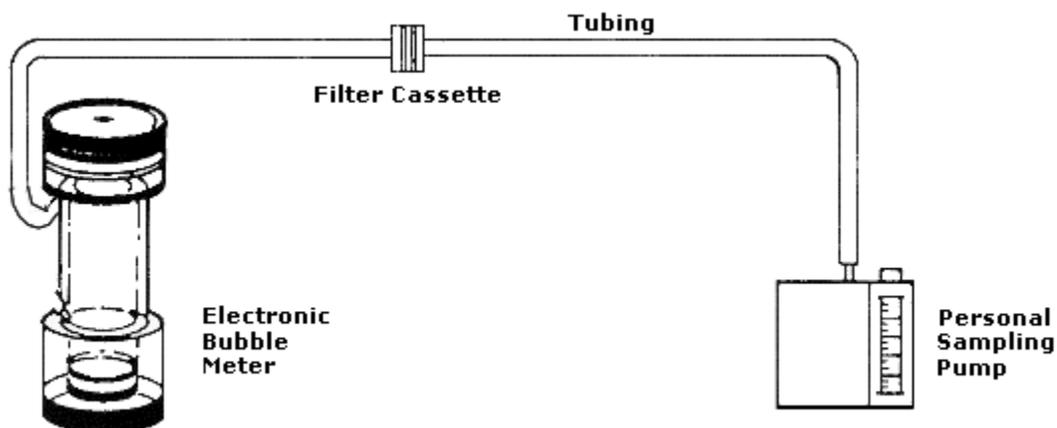
DC-Lite: No preparation required.

6. Turn on the pump and adjust the rotameter (if so equipped) to the appropriate flow rate.
7. 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 liters per minute.

DC-Lite: Press and release the Read button for a single measurement. Press and hold the Read button for consecutive measurements.

8. Adjust the sampling pump to the correct flow rate using the calibrator results. Adjust the sampling pump while it is running.
9. 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.
10. 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 II: 1-10. CASSETTE IS ATTACHED TO ELECTRONIC
BUBBLE METER FOR CALIBRATION**

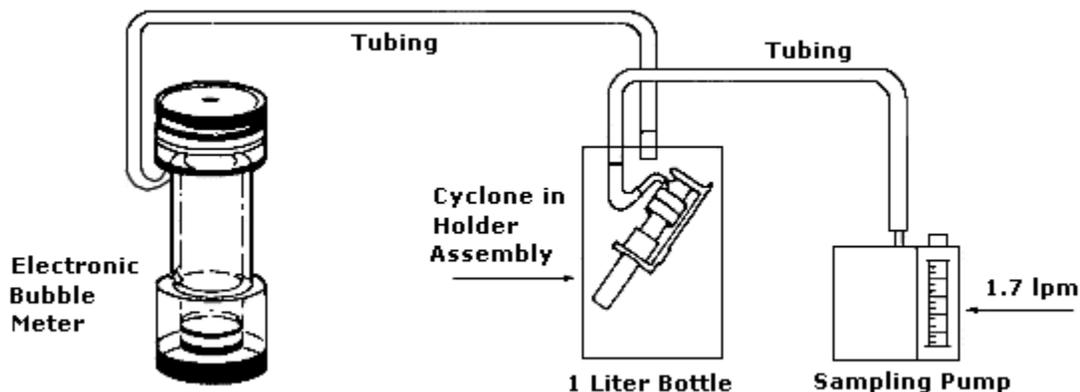


E. Calibration Procedures for Cyclones or for Open-Face Filters

1. Perform the calibration at the pressure 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.
2. Set up the calibration apparatus as shown in Figure II: 1-11. Be certain there are no leaks. A cyclone leak test kit is available from CTC.
3. Place the open-face filter cassette or cyclone assembly in a 1-liter jar. The jar is provided with a special cover. Open-face cassettes are used for asbestos and other chemicals such as isocyanates, crotonaldehyde and glutaraldehyde.
4. Connect the tubing from the electronic bubble meter to the inlet of the jar.
5. Connect the tubing from the outlet of the cyclone holder assembly or from the filter cassette to the outlet of the jar and then to the sampling pump.
6. Calibrate the pump with a light load (typically a 5- μ m, 37-mm filter) and a heavy load (created by slightly pinching the tubing), both pre- and post-sampling. All readings must be within five percent of each other. Detailed instructions on leak testing are available from the CTC and can also be found in Technical Links on OSHA's web page for [silica](#).

See also APPENDIX II: 1-5 CYCLONE ASSEMBLY AND CLEANING INSTRUCTIONS, of this document.

FIGURE II: 1-11. CALIBRATE BY PLACING THE CYCLONE IN A 1-LITER VESSEL ATTACHED TO AN ELECTRONIC BUBBLE METER



F. Calibration of Impingers and Bubblers

1. Set up the calibration apparatus as shown in Figure II: 1-10 and replace the cassette with an impinger or bubbler filled with the amount of liquid reagent specified in the sampling method. (Refer to Chemical Sampling Information file.)
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 Chemical Sampling Information file for the sampling method.

G. 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 CTC annually to be calibrated and serviced.

Gilian Gilibrator:

1. Clean the unit before use following storage. Remove the flow cell and gently flush it in accordance with the manufacturer's recommendations. The acrylic flow cell can be easily scratched. Wipe with cloth only. Do not allow the 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. Use only soap and warm water. When cleaning prior to storage, allow the flow cell to air dry. If stubborn residue persists, it is possible to remove the bottom plate. Squirt a few drops of soap into the slot between the base and flow cell to ease removal.

2. Leak testing. A leak test is described in the Gilibrator manual. The system should be leak checked at 6 inches of water pressure by connecting a manometer to the outlet and evacuating the inlet to 6 inches of water pressure. No leakage should be observed. Never pressurize the flow cell with more than 25 inches of water pressure. CTC will perform a leak check as part of their annual service.
3. Verification of Calibration. The calibrator is factory calibrated using a standard traceable to the National Institute of Standards and Technology. Tests to verify calibrator calibration against a glass 1-L buret should be conducted at 1000 mL/min for maximum accuracy. The calibrator is linear throughout the entire range. CTC will calibrate the unit as part of their annual service.
4. When transporting the calibrator, especially by air, it is important that one side of the seal tube which connects the 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.
5. 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 build-up 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 CTC's expendable supplies program.
6. Do not charge batteries for more than 16 hours. Do not constantly charge the calibrator when not in use because this could damage the battery.
7. Do not store the calibrator for more than a week with soap solution in the cell. Clean the unit and store dry.

Bios DryCal DC-Lite:

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 latex 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 min. 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. CTC will calibrate the unit as part of their annual service.

H. Manual Buret Bubble Meter Technique

When a sampling train requires an unusual combination of sampling media (e.g., glass-fiber filter preceding impinger), the same type media/devices should be in-line during calibration. Do not use the actual filter cassette intended for sampling. Calibrate personal sampling pumps before and after each day of sampling.

1. Allow the pump to run 5 minutes prior to voltage check and calibration.
2. Assemble the cassette filter holder using the appropriate filter for the sampling method. If a cassette adapter is used, care should be taken to ensure that it does not come in contact with the back-up pad.

NOTE: When calibrating with a bubble meter, the use of cassette adapters can cause a moderate to severe pressure drop in the sampling train, which will affect the calibration result. If adapters are used for sampling, then they should be used when calibrating.

3. Connect the collection device, tubing, pump, and calibration apparatus as shown in Figure II: 1-12 or in Figure II: 1-13. Be certain that there are no leaks.

FIGURE II: 1-12. CALIBRATION FOR PERSONAL SAMPLING WITH FILTER CASSETTE USING AN INVERTED BURET

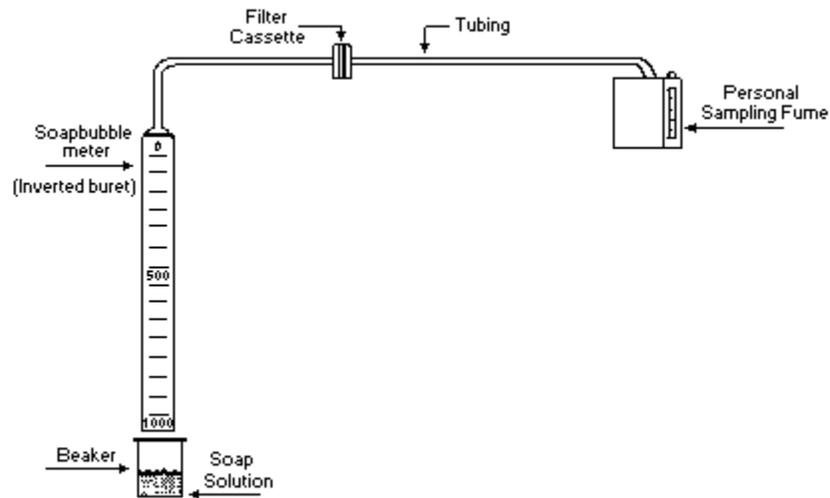
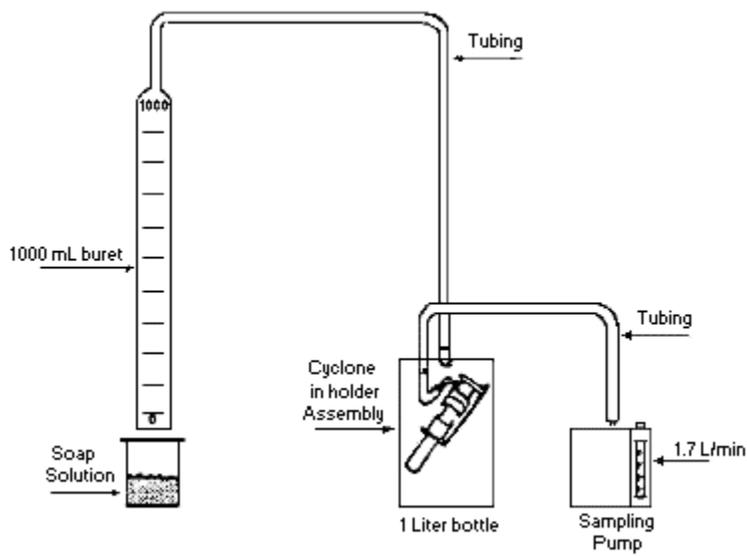


FIGURE II: 1-13. CALIBRATION OF CYCLONE SAMPLER USING AN INVERTED BURET



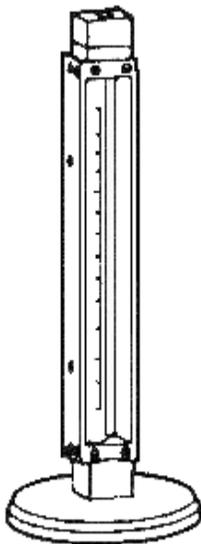
4. A visual inspection should be made of all plastic tubing connections. Be certain there are no leaks.
5. Wet the inside of a 1000-mL buret with a soap solution.
6. Turn on the pump and adjust the pump rotameter (if present) to the appropriate flow rate setting.
7. Momentarily submerge the opening of the buret in order to capture a film of soap.
8. Draw two or three bubbles up the buret in order to ensure that at least one bubble will complete its run.
9. Visually capture a single bubble and time the bubble from 0 to 1000 mL for high flow pumps or 0 to 100 mL for low flow pumps.
10. The accuracy of the timing device should be 99%. If the flow rate is not within the desired range, adjust the flow rate and repeat step 9 until the correct flow rate is achieved. Perform step 9 at least three times.
11. Repeat the procedures described above for all pumps to be used for sampling. The same cassette and filter may be used for all calibrations involving the same sampling method.

I. Precision Rotometer Method

Although OSHA allows the use of precision rotameters for sampling pump calibration, this device is no longer recommended and should not be used unless absolutely necessary. Tests have shown significant measurement error due to pump pulsation. These pulsations are typically not

observable by the user. The precision rotameter (Figure II: 1-14) is a secondary calibration device. If it is to be used in place of a primary device such as a bubble meter, take care to ensure that any error introduced by its use will be minimal and noted.

FIGURE II: 1-14. SINGLE COLUMN PRECISION ROTAMETER



NOTE: The precision rotameter can be used for calibrating the personal sampling pump in lieu of a bubble meter, only if it is:

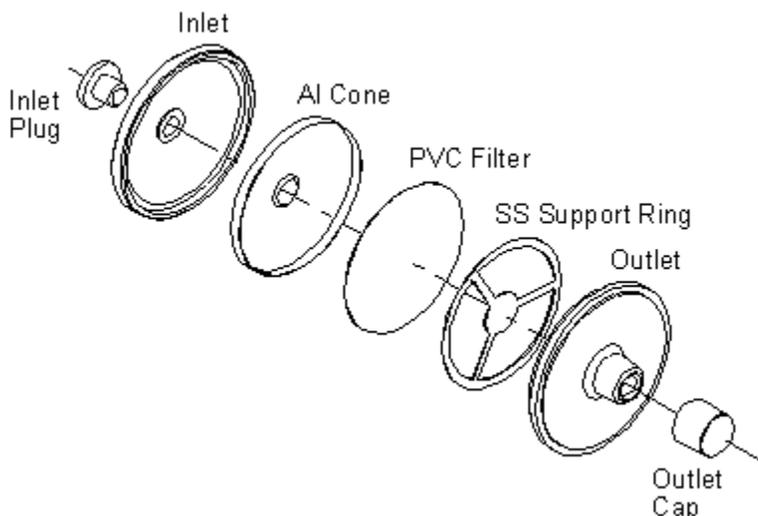
1. Calibrated regularly, at least monthly, with an electronic flow calibrator or with a manual buret bubble meter and an appropriate vacuum source. Calibration points should include duplicate readings at each major division of the rotameter (e.g., 1, 2, 3, etc.). Calibration must bracket the flow rate to be measured with the precision rotameter and will usually contain ten duplicate calibration points including the flow rate of interest. Record the temperature and barometric pressure at which the calibration was performed.
2. Disassembled, cleaned as necessary, and recalibrated.
3. Used with care to avoid dirt and dust contamination, which may affect the flow.
4. Not used at substantially different temperature and/or barometric pressure from conditions present when the rotameter was calibrated against the primary source. If altitude or temperature at the sampling site is substantially different from the calibration site, it is necessary to calibrate the precision rotameter at the sampling site.
5. Used in such a way that the pressure drop across it is minimized.

APPENDIX II: 1-2.

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- μ m, 37-mm diameter, low-ash polyvinyl chloride (PVC) or polytetrafluoroethylene (PTFE or 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 in Figure II:1-15 and should be used only for samples requiring crystalline silica gravimetric analysis or other gravimetric analysis. Appendix II:1-4 is a partial listing of substances that should be sampled and analyzed gravimetrically using pre-weighed cassettes.

FIGURE II: 1-15. 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 II:1-15, 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 II:1-16) is visible from the outlet side of the assembly. Each of the filter assemblies is bar coded for weighing purposes (Figure II: 1-17). To aid in tracking the filters, please use the barcode number as the sample submission number when filling out Form OSHA-91A (Air Sampling Worksheet). A blank should be included with every set of samples.

FIGURE II: 1-17
TOP AND BOTTOM



FIGURE II: 1-16
STAINLESS STEEL FILTER
SUPPORT



Inlet



Outlet

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 II: 1-3.

A. Shelf Life of Sampling Media Provided by the SLTC

Sampling medium	Shelf life	Comments
Sodium hydroxide (all normalities)	6 months	
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		Must be used before the expiration date (if given) printed on the monitor package
Nitrogen oxides collection tubes	2 years	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*

*Give the SLTC at least two days notice to allow time for reagent preparation.

APPENDIX II: 1-4.

<p>Table 4 PARTIAL LIST OF SUBSTANCES FOR GRAVIMETRIC DETERMINATION</p>

Substance	IMIS	PEL (mg/m ³)	Substance	IMIS	PEL (mg/m ³)
alpha-Alumina.....	0160	15	Oil mist (mineral)	5010	5
Total dust.....					
Respirable fraction..	A201	5	Particulates not otherwise regulated (PNOR).....		
Aluminum metal (as Al).			Total dust.....	9135	15
Total dust.....	A100	15	Respirable fraction..	9130	5
Respirable fraction..	A110	5	Pentaerythritol.....		
Ammonium sulfamate.....	0185	15	Total dust.....	1987	15
Total dust.....			Respirable fraction..	P157	5
Respirable fraction..	A111	5	Perlite.....		
Barium sulfate.....	B101	15	Total dust.....	2035	15
Total dust.....			Respirable fraction..	P101	5
Respirable fraction..	B104	5	Plaster of paris.....		
Bismuth telluride Undoped.....	0370	15	Total dust.....	2127	15
Total dust.....			Respirable fraction..	P102	5
Respirable fraction..	B110	5	Portland cement.....		
Boron oxide.....	0380	15	Total dust.....	0557	15
Total dust.....			Respirable fraction..	P104	5
Calcium carbonate.....	0505	15	Rouge.....		
Total dust.....			Total dust.....	2229	15
Respirable fraction..	C130	5	Respirable fraction..	R102	5
Calcium hydroxide.....		15	Silica, amorphous, precipitated and gel.	9050	
Total dust.....					
Respirable fraction..		5			

Substance	IMIS	PEL (mg/m ³)	Substance	IMIS	PEL (mg/m ³)
Calcium oxide.....	0520	5	diatomaceous earth, containing less than 1% crystalline silica	S112	
Calcium silicate.....			Silica, crystalline cristobalite,		
Total dust.....	C112	15	respirable dust.....	9015	
Respirable fraction..	C122	5	Silica, crystalline quartz,		
Calcium sulfate.....			respirable dust.....	9010	
Total dust.....	C104	15	Silica, crystalline tripoli (as quartz),		
Respirable fraction..	C123	5	respirable dust.....	S114	
Carbon black.....	0527	3.5	Silica, crystalline tridymite,		
Cellulose.....			respirable dust.....	9017	
Total dust.....	0575	15	Silica, fused,		
Respirable fraction..	C124	5	respirable dust.....	9013	
Coal dust (less than 5% SiO(2)), respirable fraction..	9040		Silicates (less than 1% crystalline silica)		
Coal dust (greater than or equal to 5% SiO(2)), respirable fraction.....	C120		Mica (respirable dust).....		
			Soapstone, total dust	9025	
			Soapstone, respirable dust.....	S121	
Cotton Dust (The SLTC will supply special pre-weighed cotton dust filters and cassettes on request.)			Talc (containing no asbestos),		
Dicyclopentadienyl iron			respirable dust.....	9030	
Total dust.....	0904	15	Silicon.....		
Respirable fraction..	D100	5	Total dust.....	2235	15
Emery.....			Respirable	S120	5

Total dust.....	1016	15	fraction..		
Respirable fraction..	E102	5	Silicon carbide.....		
Grain dust (oat, wheat, barley).....	G109	10	Total dust.....	2236	15
Glycerin (mist).....			Respirable fraction..	S123	5
Total dust.....	1363	15	Starch.....		
Respirable fraction..	G115	5	Total dust.....	2263	15
Graphite, synthetic....			Respirable fraction..	S124	5
Total dust.....	1366	15	Sucrose.....		
Respirable Fraction..	G100	5	Total dust.....	2285	15
Gypsum.....			Respirable fraction..	S130	5
Total dust.....	1367	15	Tantalum, metal and oxide dust.....	2325	5
Respirable fraction..	G101	5	Titanium dioxide.....		
Kaolin.....			Total dust.....	2440	15
Total dust.....	1568	15			
Respirable fraction..	K100	5			
Substance	IMIS	PEL (mg/m ³)	Substance	IMIS	PEL (mg/m ³)
			Vegetable oil mist....		
Total dust.....	1593	15	Total dust.....	V126	15
Respirable fraction..	L100	5	Respirable fraction..	V127	5
Magnesite.....			Zinc oxide fume.....	2610	5
Total dust.....	M113	15	Zinc oxide.....		
Respirable fraction..	1615	5	Total dust.....	Z102	15
Magnesium oxide fume...			Respirable fraction..	Z103	5
Total particulate....	1610	15	Zinc stearate.....		
Marble.....			Total dust.....	2616	15
Total dust.....	1626	15	Respirable fraction..	Z104	5
Respirable fraction..	M114	5	Zirconium compounds	2620	5

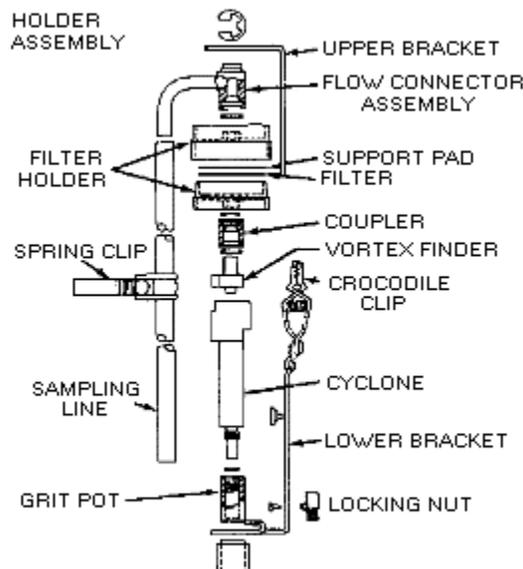
APPENDIX II: 1-5.

CYCLONE ASSEMBLY AND CLEANING INSTRUCTIONS

A. Cyclone Assembly

1. 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.
2. 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. Detailed instructions on leak testing are available from the CTC and through Technical Links on OSHA's web page for [silica](#).

FIGURE II: 1-18. CYCLONE ASSEMBLY



B. 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 (see Figure II: 1-18).

APPENDIX II: 1-6.

CHAIN OF CUSTODY

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 dates the sample was collected, shipped to the SLTC, received at the SLTC, the analyst received the sample, the analysis was completed, the analytical results were checked by another analyst, and the sample results were released by a supervisor or his/her representative. It is important to follow chain-of-custody requirements because it legally documents handling of OSHA samples for litigation purposes.
APPENDIX II: 1-7.

HOW TO APPLY FORM OSHA-21 TO CHARCOAL TUBES AND FILTER CASSETTES
FIGURE II: 1-19. CORRECTLY SEALED CHARCOAL TUBE. CHARCOAL TUBE INSIDE FORM OSHA-21



FIGURE II: 1-20. INCORRECTLY SEALED CHARCOAL TUBE. END CAPS CAN BE REMOVED, ALLOWING SAMPLE INTEGRITY TO BE JEOPARDIZED WITHOUT DISTURBING THE SEAL

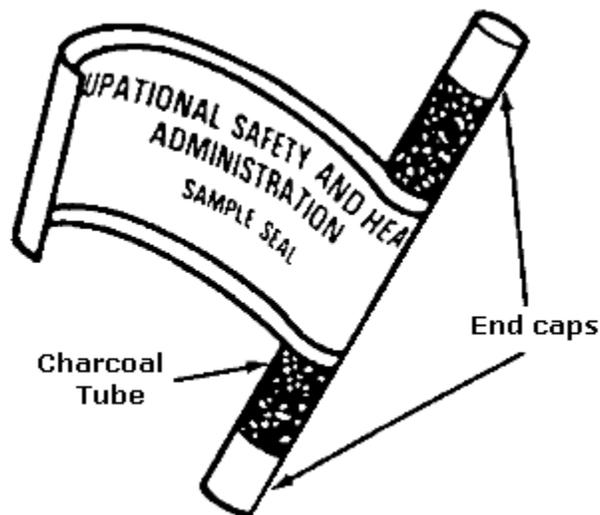


FIGURE II:1-21
 INCORRECTLY SEALED
 CASSETTE ALLOWS ACCESS
 TO INLET/OUTLET PORTS
 AFTER SAMPLE HAS BEEN
 TAKEN



FIGURE II:1-22 CORRECTLY
 SEALED
 CASSETTE WITH FORM
 OSHA-21 COVERING
 INLET/OUTLET PORTS
 MAINTAINING SAMPLE
 INTEGRITY

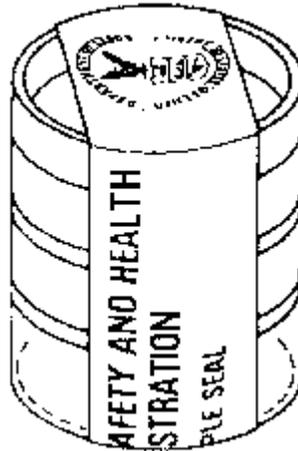
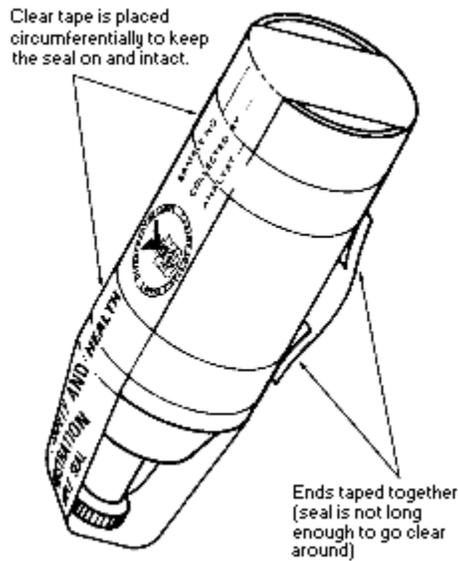


Figure II: 1-23. STANDARD ASBESTOS CASSETTE (25mm) CORRECTLY SEALED
 WITH A FORM OSHA-21



APPENDIX II: 1-8.

FIGURE II: 1-24. FRONT OF COMPLETED AIR SAMPLING WORKSHEET FORM OSHA-91A

Air Sampling Worksheet

U. S. Department of Labor
Occupational Safety and Health Administration



1. Reporting ID 5555555		2. Inspection Number 123456789		3. Sampling Number: 497330105	
4. Establishment Name J & N Casting			5. Sampling Date: 06-14-07		6. Shipping Date: 06-15-07
7. Person Performing Sampling (Signature) Signature			8. Print Last Name RIMA		9. CSHO ID Z1234
10. Employee (Name, Address, Telephone Number): (123) 456-7899			14. Exposure Information	a. Number: 2	b. Duration: 3.5 Yrs/ ea person
11. Job Title: Brass Squeeze Molder Machine Operator - 12 years			12. Occupation Code		c. Frequency: 6 hr./day
13. PPE (Type and effectiveness): Safety glasses and ear plugs, no respirator worn			15. Weather Conditions: Indoors		16. Photo(s): Y
18. Job Description, Operation, Work Location(s), Ventilation, and Controls			17. Pump Checks and Adjustments: 7:30 - ok, 8:30 - ok, 9:30 - ok, 10:30 - ok, 11:30 - ok, 12:30 - ok, 1:30 - ok, 2:30 - ok		

Operates brass squeeze molding machine. Fills and compacts sand into mold. Finished molds placed on pouring lines. There are fans but no exhaust ventilation.

19. Pump Number: 10337	Sampling Data	Cont'd
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20. Lab Sample Number	21. Sample Submission Number	22. Sample Type	23. Sample Media	24. Filter/Tube Number	25. Time On/Off	26. Total Time (in minutes)	27. Flow Rate	28. Volume (in liters)	29. Net Sample Weight (in mg)	30. Analyze Samples for:	31. Indicate Which Samples to Include In TWA, Ceiling, etc. Calculations
	ER300	P	MCEF	ER300	6:30am 1:00pm	360	2.13	766.8		Welding Fume (Lead & Cadmium)	T
					12:30pm 2:48pm	108	2.13	230	= 996.8 Total volume		

32. Interferences and IH Comments to Lab	33. Supporting Samples		34. Chain of Custody		Initials	Date
	a. Blanks: ER302		a. Seals Intact?		Y	N
	b. Bulbs		b. Rec'd in Lab			
			c. Rec'd by Anal.			
			d. Anal. Completed			
			e. Calc. Checked			
		f. Supr. OK'd				

Case File Page	/	of
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OSHA-91A (Rev. 1/84)

[\[Text Version\]](#)

FIGURE II: 1-25. BACK OF AIR SAMPLING WORKSHEET FORM OSHA-91A

[\[Text Version\]](#)

APPENDIX II: 1-9.

FIGURE II: 1-26. COMPLETED SOIL SAMPLING WORKSHEET ON A FORM OSHA-91A

