

PART TWO

Total Suspended Particulate Sampling for Metals

Chapter 7
Part Two – Total Suspended Particulate Sampling for Metals
Table of Contents

	Page
1.0 Introduction	1
1.1 Sampling Overview	1
2.0 Facility Requirements	1
2.1 Filter Conditioning and Weighing Area	1
2.2 Calibration and Maintenance Area	2
2.3 Sampling Sites	2
2.4 Ancillary Equipment	2
3.0 Filter Preparation and Analysis	3
3.1 Inspection	4
3.2 Conditioning/Equilibration	4
3.3 Pre Sampling Weighing Procedures	4
3.4 Post Sampling Filter Handling	4
3.5 Post Sampling Weighing Procedures	5
4.0 Sampler Operation	5
4.1 Siting Requirements	5
4.2 Sampler Installation	6
4.3 Sampling Operations	6
4.3.1 Sampling Procedure	6
5.0 Calibration Procedures	7
5.1 Mass Flow Controlled TSP Calibration	8
5.1.1 Calibration Procedure	8
6.0 Determining TSP Concentrations	10
7.0 Performance Audit Procedures	11
7.1 Flow Rate Performance Audit Procedure for TSP Samplers	11
7.1.1 Verification and Audit Equipment	11
7.1.2 Verification and Audit Procedure	12
7.2 Verification and Audit Data Reporting	17
7.3 Verification and Audit Frequency	17
7.4 Systems Audit	18

8.0 Precision and Accuracy Assessment	18
8.1 Precision.....	18
8.2 Accuracy.....	18
9.0 Maintenance	19
9.1 Six Month and One Year Maintenance.....	19
9.2 As Needed Maintenance	19
10.0 Lead Analysis Program	19
10.1 Analysis Quality Control and Quality Assurance.....	20
10.1.1 Lead Strips Audits.....	20
11.0 Forms	20
FORMS	
1. Example Orifice Certification – Range Factor Table.....	21
2. TSP Audit and Calibration Form.....	22
3. TSP Audit Form	23
PHOTOS	
1. TSP Sampler.....	3

Part Two – Total Suspended Particulate Sampling for Metals

1.0 Introduction

On July 1, 1987, the U.S. Environmental Protection Agency (USEPA) promulgated new National Ambient Air Quality Standards (NAAQS) for Particulate Matter (PM). The new NAAQS changed the indicator for particles from Total Suspended Particulates (TSP) to PM₁₀, the latter referring to particles with a mean aerodynamic diameter less than or equal to 10 micrometers (µm). USEPA also revised the level and form of the primary standards by replacing the 24-hour TSP standard with a 24-hour PM₁₀ standard of 50 µg/m³, annual arithmetic mean. The secondary standard was revised by replacing it with 24-hour and annual standards identical in all respects to the primary standards.

Although the TSP NAAQS is no longer in effect, the TSP monitoring method has been retained for the collection of PM for metals analysis (primarily lead). Part 3 of Chapter 7 “Continuous Particulate Monitoring for PM_{2.5} PM₁₀ and PMc” provides information and references for TSP sampling.

1.1 Sampling Overview

Particulate matter in the atmosphere that has no limits on the aerodynamic diameter size is referred to as Total Suspended Particulates (TSP). A high-volume sampler draws a known volume of ambient air at a constant flow rate through a covered housing. Particles are collected on a glass fiber filter during a specified 24-hour sampling period. A constituent of the TSP sample may be metals (i.e., lead) which may be quantified by laboratory analysis. The reference method for sampling is given in 40 CFR Part 50, Appendix L, and CFR Part 50, Appendix B.

2.0 Facility Requirements

Facility requirements for TSP sampling for metals include a central laboratory that includes a filter conditioning and weighing area, a calibration and maintenance area, and individual field sampling stations. Lead analysis is conducted in accordance with USEPA method EQL-0380-044.

2.1 Filter Conditioning and Weighing Area

Although TSP concentrations are no longer used for NAAQS compliance, TSP filters should be treated with the same care as PM₁₀ or PM_{2.5} filters. Therefore, the filter conditioning room should be large enough to accommodate filter processing, equilibration, weighing operations, and filter and record storage. The room should be equipped with the necessary air conditioning equipment to maintain an air temperature between 15 and 30 °C that is constant within ±3 °C and relative humidity less than 50 percent that is constant within ±5%. In addition, certified relative humidity and temperature measurement instruments must be maintained.

2.2 Calibration and Maintenance Area

A sufficiently large area should be designated as the calibration and maintenance test area. It should be equipped with the tools required for routine sampler maintenance (such as brush or motor replacement), orifice certifications, and ancillary equipment maintenance and repair.

2.3 Sampling Sites

All sampling locations must meet the guidelines set forth in 40 CFR Part 50 Appendix L, and Part 58 Appendix D as well as the siting guidelines outlined in Chapter 1, “QA of Air Monitoring” Section 4.0 of this manual. The following factors should also be considered when selecting a monitoring site:

- Samplers should be situated where the operator can access safely regardless of weather conditions. Sampler placement must consider routine operations such as calibration, sample pickup/setup, flow checks, and audits that involve transporting equipment and supplies to and from the monitoring site.
- Availability of adequate electricity to power sampler(s).
- Security of monitoring personnel and equipment. The security of personnel and the sampler itself depends largely on location. Rooftop sites with locked access and ground level sites with fenced compounds should be utilized whenever possible.

2.4 Ancillary Equipment

Listed below are equipment and supplies required for operation of a TSP sampling for metals network. Exact specifications for individual items can be found in the reference method described in 40 CFR Part 50, Appendix L and Appendix M.

- Analytical balance
- Relative humidity indicator
- Sampler (see Photo 1 below):
 1. Aluminum shelter
 2. Motor
 3. Flow Controller
 4. Clock (6-day cycle with On/Off tabs)
 5. Elapsed timer meter
 6. Cone
 7. Filter cassette
- Certified flow rate transfer standard (Hansen orifice)
- Filters
- Certified Barometer (digital or aneroid)
- Manometer (water, oil or digital)
- Certified thermometer (digital or liquid)
- ANSI/ASTM Class 1, 1.1 or 2 mass reference standard weights

- Logbooks and database/laboratory and maintenance
- Filter data cards and envelopes
- Spare parts (i.e., motor brushes & armatures, gaskets)
- Extra/backup equipment (i.e., assembled motors, thermometer, barometer, flow controller)

Photo 1
TSP Sampler



3.0 Filter Preparation and Analysis

Outlined in 40 CFR Part 50, Appendix L and Appendix M are the acceptance criteria for filters used in TSP monitoring for metals.

Glass fiber filters are brittle and are easily broken. Care should be taken at all times to avoid

damage or contamination.

An identification number is printed on each filter by the manufacturer. If filters are to be mailed to a laboratory for analysis, field personnel should be equipped with reinforced envelopes and manila folders for the protection of the exposed filters.

3.1 Inspection

All filters must be inspected for defects before use. An effective method to inspect filters for defects is with a light-box. A light-box uses a low wattage light bulb to illuminate a clear or translucent surface. Laying an 8" x 10" filter on this lighted surface aides in the inspection process. Defective filters should not be used for sampling. Some common defects are:

- pinholes
- loose material
- discoloration
- non-uniform appearance

3.2 Conditioning/Equilibration

Filters should be equilibrated in a controlled environment for at least 24-hours before initial weighing. The relative humidity of the equilibration room should be held in the range of 20 to 45 percent but should not vary more than ± 5 percent of the mean value. Room temperature must be held constant within the range of 15 to 30 °C and not vary more than ± 3 °C. Room conditions must be verified and recorded on equilibration days to ensure compliance of this guideline. Any system malfunctions (heating, air conditioning, etc.) and maintenance activities should be recorded in a laboratory logbook.

3.3 Pre Sampling Weighing Procedures

Filters should be weighed on an analytical balance with the same resolution and precision of the balance used for PM₁₀ filter weighing. Refer to Chapter 7, Part 1, Section 3.3 for balance specifications and pre sampling procedures.

3.4 Post Sampling Filter Handling

Filters that are not to be analyzed immediately should be stored within a protective covering to prevent damage and the loss of particulate matter. A filter holder card provides adequate protection and provides a means to record important sampling information. Care should be used when removing the filter from the sampler. The glass fiber filters are brittle and easily damaged. Once the filter has been removed from the sampler, it may be folded along its long axis with the exposed side in and placed in the filter holder card. If any pieces of the filter are broken loose, place the pieces within the card. The holder card containing the folded filter can now be placed in an envelope for transport to the laboratory for analysis.

If filter cassettes are in use, the operator should elect to leave the “exposed” filter in the cassette for transport back to the laboratory. A cover on the cassette protects the filter from damage or loss of sample. Once returned to the laboratory, the exposed filter may be removed from the cassette and placed in the filter holder card.

3.5 Post Sampling Weighing Procedures

1. All filters must be equilibrated in a conditioning environment for at least 24-hours as described in Section 3.2 of this Part.
2. Repeat Steps 1 through 4 of the filter tare weighing procedure in Chapter 7, Part 1 “Measurement of Particles”, Section 3.3.

4.0 Sampler Operation

Procedures in this section are intended as guidelines for use in a TSP monitoring for metals program that will accurately reflect trends in local or regional air quality. The effectiveness of the monitoring program depends largely on the responsible day-to-day operation of the monitoring site.

4.1 Siting Requirements

Detailed siting criteria are presented in 40 CFR Part 50, Appendix L, CFR Part 58, Appendix E and Chapter 1 of this manual. Some general site factors listed below:

- Samplers should be located farther than 20 meters from tree drip lines.
- Distances from a sampler to any obstacle (such as a building or a wall) must be twice the height that the obstacle protrudes above the sampler.
- Airflow must be unrestricted airflow 270° arc around the sampler inlet.
- Samplers should be located away from furnaces or incinerator flues.
- Spacing from roads and traffic must meet the requirements in 40 CFR Part 50, Appendix L, CFR Part 58, Appendix E.
- Sampler inlets must be a minimum of 2 meters from any collocated TSP sampler, or any other particulate sampler (i.e., PM₁₀, PM_{2.5}).
- Collocated sampler inlets must be located within 1 meter vertically of each other.

Samplers must be located where the operator can reach it safely despite adverse weather conditions. If the sampler is located on a rooftop, care must be taken that the operator’s personal safety is not jeopardized by a slippery roof during rain and ice. Operation of the sampler, calibration, and routine maintenance can involve the transportation of supplies and equipment so safe access must be considered.

Adequate power must be available. Check the manufacturer’s instruction manual for minimum voltage requirements.

4.2 Sampler Installation

1. Check the sampler for all components and proper operation before transport to the field monitoring site.
2. Samplers must be bolted down to a secure palette or mounting platform.
3. Check all power lines for cracks or cuts.
4. Plug the power cord into the line voltage. The use of a ground fault interrupter is recommended. Do not allow any electrical connection to become submerged.
5. Perform a flow rate calibration using the procedure in Section 5.0.

4.3 Sampling Operations

Most high volume samplers have been designed to accept filter cassettes. Loading cassettes in the laboratory or office reduces the risk of damage and contamination. Filters should be kept in protective folders or boxes prior to being loaded into the sample cassettes. Unexposed filters must never be folded or bent. The manufacturer stamps all filters with a unique identification number. Each filter should be placed on the wire screen of the cassette centered with the numbered side down. Poorly aligned filters show an uneven white border after exposure. Do not over tighten the filter cassette because the gasket may stick to the filter causing filter loss and resulting in an invalid sample. Use protective covers over each sample cassette before transport to the monitoring site.

4.3.1 Sampling Procedures

Upon arrival at a monitoring site (initial sample setup, no previous sample):

1. Open the shelter roof and safely secure it. Most units have a latch on the rear of the shelter to prevent the lid from slamming down during sample setup and recovery.
2. Examine the cone's support screen. If it appears dirty or damaged, wipe clean or replace. Remove the protective cover from the filter cassette and position it in the center of the support screen. Tighten the thumbnuts sufficiently to hold the cassette securely and to seat the gaskets. Do not over tighten.
3. Lower the shelter roof and secure.
4. Turn on the sampler and allow the motor to come up to operating speed. Record or confirm the following information on a filter holder/data card:
 - Initial elapsed timer reading (normally the final reading from previous sample)
 - Site name and AQS site identification number*

- Sample run date *
- Filter ID number *
- Flow controller & motor serial numbers*
- Sample set up date
- Setup operator's initials
- Initial flow indicator reading
- Ambient pressure millimeters of mercury (mmHg) and ambient temperature (K)

** Information may be recorded prior to sample setup*

5. Observe the conditions around the monitoring site. Note any conditions that may affect filter particle loading such as fire, construction or demolition.
6. Turn off the sampler and ensure that the timer is "set" for the next sample run date and time.

As soon as possible after sampling has ended, the operator should return to the monitoring site and recover the exposed filter. Particle loss or filter damage may occur if the filter is left in the sampler for extended periods.

1. Record the pick-up date, sample start and finish information, duration, and average flow, temperature and pressure.
2. Observe the conditions around the monitoring site. Note any conditions that may affect filter particle loading (fire, construction, demolition, etc.).
3. Raise the sampler roof and remove the filter cassette. Replace the protective cover.
4. Prepare the sampler for the next run as directed above.

5.0 Calibration Procedures

Calibration is defined as the relationship between an instrument's output and the output of a known reference standard. For samplers that are already in the field collecting data, a verification must be performed prior to a calibration. The components of the TSP sampler that must be calibrated are: flow rate, temperature, and pressure.

The following equipment is necessary for proper calibration of the TSP sampler:

- NIST-certified traceable thermometer or temperature probe capable of measuring ambient air over the expected climate conditions with a resolution of 0.1 °C, with an accuracy of ± 0.5 °C.
- Aneroid or digital barometer capable of measuring barometric pressure over the range

of 500 to 800 mmHg to the nearest millimeter of Hg and referenced at least annually to a standard of known accuracy within ± 5 mmHg.

- Certified orifice transfer standard capable of measuring the operational flow rate of a high volume TSP sampler at standard conditions.
- Digital, water, or oil manometer with a range of at least 0 to 12 inches and 0.1 inch resolution.
- Standard time piece of known accuracy within ± 2 min/24hr.
- Clean glass fiber filter as those used for monitoring.

Flow rate determination as described in this section is made using an orifice transfer standard that has been certified according to the procedure presented in Section 2.2.2 of the USEPA's "Quality Assurance Guidance Document 2.12" and Chapter 6 "Certification Methods of Transfer Standards" of this manual.

Consistency of temperature and barometric pressure units is required and will be expressed in Kelvin ($^{\circ}\text{C} + 273$) and millimeters of mercury (mmHg).

5.1 Mass Flow Controlled TSP Calibration

The mass flow controlled sampler is designed to operate at a flow rate range of 1.1 to 1.7 m³/min at actual (@ act) conditions. Samplers can be calibrated and run at standard conditions but the flow must still calculate to 1.1 to 1.7 m³/min at actual conditions

5.1.1 Calibration Procedure

1. Confirm the date is correct and the time is within ± 1 minute of the local standard time. If > 5 minutes adjust the time and make note of this. If needed, adjust the date and make note of this.
2. Record the ambient temperature (T_a) and station pressure (P_a) on the calibration form. Place the thermometer out of direct sunlight. Ensure that the thermometer bulb or probe is not in contact with any surface. Allow the temperature reading to stabilize before taking the final reading. If the temperature reading has not fluctuated in two to four minutes, record the reading. If a digital thermometer is used, be sure the unit is in the correct scale ($^{\circ}\text{C}$). Next record the pressure reading on the sampler. Temperature and pressure limits are $< \pm 2.1^{\circ}\text{C}$ and $< \pm 10.1$ mm Hg respectively.
3. If a liquid manometer is used for the calibration, check for leaks prior to placement in-line with the orifice.

Check for leaks by blowing gently into the manometer tube. If a flow restriction occurs, then the water level will not flow freely. If the two valves at the top of the manometer are not open completely, a flow restriction may occur. A vapor lock can occur if liquid and air get trapped in the two valves. Once the tube is blown into, the water or oil level will elevate on one side and decline on the other. Place a fingertip over the end of the tube when the

liquid has risen. If there is a leak, the liquid level will slowly drop. If there are no leaks, the liquid level will not change.

If a digital manometer is used, be sure the unit is in the correct measure scale (mmHg), zero adjusted, and that it has sufficient battery power. Carry extra batteries.

4. Check the calibration orifice assembly for leaks.

The calibration orifice assembly consists of an orifice, faceplate, and filter cassette with one clean glass fiber filter. A filter is necessary to provide adequate resistance to flow.

Check the orifice to ensure that it is tightly seated (screwed on) onto the faceplate and that the faceplate gasket is in good condition.

5. Secure the orifice assembly to the sampler. Do not over tighten the nuts as that may result in damage to the faceplate or gasket.
6. Turn on the sampler and allow the motor to come up to operating speed (approximately 3 to 5 minutes). Listen for whistling sounds that may indicate a leak in the system. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by cross-threading of the orifice and the faceplate. Leaks will result in a lower flow rate while torn or improperly aligned filters will result in a higher flow rate.
7. While the sampler is warming up, determine the calibration set-point. The flow rate is adjusted to Standard Reference Conditions (SRC) by using the corresponding flow rate range for TSP of 1.1 to 1.7 m³/min @ ACT. Normally the flow rate is set to 1.30 m³/min @ SRC but some samplers may run in the 1.1 to 1.7 m³/min @ ACT.

Posted on the side of each orifice is certification data. This data consists of a table of true flow rate values with corresponding low and high range factor data. For a true flow rate of 1.30 m³/min, find and record the Low and High Range Factor.

Use following formulas to calculate the desired manometer reading for the flow rate set point:

$$\text{Average Range Factor} = \frac{\text{Low Range Factor} + \text{High Range Factor}}{2}$$

$$\text{Desired Manometer Reading (inches of water)} = \text{Average Range Factor} * \frac{T_a}{P_a}$$

Where:

$$\begin{aligned} \text{Range factor} &= \text{orifice certification data corresponding to orifice flow rate} \\ T_a &= \text{ambient temperature, K} \end{aligned}$$

P_a = barometric pressure, mmHg

Example calculation:

Refer to Form 1 Example Orifice Certification – Range Factor Table

Where:

True Flow of 1.30, Low Range Factor = 16.761 and
High Range Factor = 17.015
 T_a = 20 °C = 293 K
 P_a = 740.0 mmHg

$$\text{Average Range Factor} = \frac{16.761 + 17.015}{2} = 16.888$$

$$\text{desired manometer reading (inches of water)} = 16.888 * \frac{293}{740} = 6.69$$

Given the above ambient conditions and the example orifice certification data, the operator must adjust the flow controller (set point) so that the manometer reads 6.69 inches.

8. Adjust sampler flow controller until the motor is producing a stable flow at the manometer set point as determined above.

After each flow controller adjustment, allow one to three minutes for the flow to stabilize before making further adjustments. After the final adjustment, turn off the sampler then turn on again to see if the sampler will duplicate the set flow rate. If the operator is unable to achieve a stable flow, the flow controller, motor, or both may need to be replaced.

6.0 Determining TSP Concentrations

Measurements of TSP concentrations in the ambient air were used to determine attainment status of the National Ambient Air Quality Standards for TSP. Since this standard has been replaced with a PM₁₀ standard, the following calculations are presented for informational purposes only.

To calculate the concentration of any given TSP sample, the following formula is used where:

$$\text{TSP Concentration, } \mu\text{g/ m}^3 = 10^6 * \frac{(W_g - W_t)}{V_a}$$

W_g = gross filter weight (after sampling)
 W_t = tare filter weight
 V_a = total sample volume in units, m³/min

Total volume = total sample time in minutes * average flow rate, m³/min @ SRC

7.0 Verification and Audit Procedures

The primary goal of a verification and auditing program is to identify problems that may result in suspect or invalid data. The verification checks are performed by the operating agency, who also performs the calibrations. Audits must be performed by another group independent of performing the calibrations. Verifications and audits should be conducted under the following guidelines:

- Audits must be performed without special preparation or adjustments made to the system.
- The individual performing the audit must be someone other than the routine operator and have a thorough knowledge of all instruments or processes being evaluated.
- All aspects of the audit must be completely documented including the types of instruments and transfer standards, model and serial numbers, calibration information, etc.
- The Tisch High Vol+ in the State of Indiana's Ambient Monitoring Network have verifications performed monthly by the Ambient Monitoring Sections, and audits performed quarterly by the Quality Assurance Section

7.1 Flow Rate Verification and Audit Procedures for TSP Samplers

For this procedure, the following is assumed:

- The TSP sampler uses an electronic mass flow controller for flow rate control.
- The sampler has been calibrated to operate at a flow rate that is approximately 1.30 m³/min @ ACT (NOTE: sampler is calibrated at SRC but ACT flow must be in the specific range listed earlier in this chapter).
- The orifice transfer standard has been certified by the Indiana Department of Environmental Management's Quality Assurance Laboratory @ SRC.

7.1.1 Verification and Audit Equipment

The following equipment is required on site:

NOTE: audit equipment cannot be used for calibrations or verifications of the sampler. But the equipment used for verifications can also be used for calibrations of the sampler:

- An orifice flow transfer standard and its associated certification data (slope, intercept, and range factor table).
- A digital or water manometer with a 0 to 16 inch range and a resolution of 0.1 inch.
- NIST-certified traceable thermometer (liquid-alcohol filled or digital) accurate to 0.5°C capable of measuring ambient air over a range of 0 to 50 °C to the nearest 0.1 °C.
- Aneroid or digital barometer capable of measuring barometric pressure over the range of 500 to 800 mmHg to the nearest millimeter of Hg and referenced at least annually to

- a standard of known accuracy with ± 5 mmHg.
- Field Data Sheet or laptop computer with the Office of Air Monitoring Database (OAMD)

7.1.2 Verification and Audit Procedure

Below are the procedures for the verification:

1. Confirm the date is correct and the time is within ± 5 minutes of the local standard time. If >5 minutes adjust the time and make note of this. Confirm the date is correct and if needed, adjust the date and make note of this.
2. Measure and record the observed and reference ambient temperature (T_a) and barometric pressure (P_a) on the audit form.

Place the thermometer out of direct sunlight. Ensure that the thermometer bulb or probe is not in contact with any surface. Allow the temperature reading to stabilize before taking the final reading. If the temperature reading has not fluctuated in two to four minutes, record the reading. Next record the pressure reading on the sampler. Temperature and pressure limits are $< \pm 2.1^\circ\text{C}$ and $< \pm 10.1$ mm Hg respectively.

If a digital thermometer is used, be sure the unit is in the correct measure scale ($^\circ\text{C}$) and that it has sufficient battery power. Carry extra batteries.

3. Record on the verification form the observed flow @ SRC (calibration set point) from the last calibration.

This data is obtained from the calibration form which may be posted inside the sampler shelter or may be obtained from the OAMD.

4. If present, remove the sample filter, cover and store it in a location where it will not be damaged.
5. If a liquid manometer is used for the audit, check for leaks prior to placement in-line with the orifice.

Check for leaks by blowing gently into the manometer tube. If a flow restriction occurs then the water level will not flow freely. If the two valves at the top of the manometer are not open completely, a flow restriction may occur. A vapor lock can occur if liquid and air get trapped in the two valves. Once the tube is blown into, the water or oil level will elevate on one side and decline on the other. Place a fingertip over the end of the tube when the liquid has risen. If there is a leak, the liquid level will slowly drop. If there are no leaks, the liquid level will not change.

If a digital manometer is used, be sure the unit is in the correct measure scale (mmHg),

- adjusted to zero and that it has sufficient battery power. Carry extra batteries.
6. Check the orifice assembly for leaks. The orifice assembly consists of an orifice, faceplate and filter cassette with one clean quartz filter. A filter is necessary to provide adequate resistance to flow. Check the orifice to ensure that it is tightly seated (screwed on) onto the faceplate and that the faceplate gasket is in good condition.
 7. Install the orifice assembly on the sampler. Check that the gaskets are in good condition.
 8. Tighten the faceplate nuts evenly on alternate corners to seat the gaskets. Do not over tighten. When using an audit filter do not use resistance plates with the orifice.
 9. Turn on the sampler and allow it to warm up (3 to 5 minutes).
 10. Ensure that the following is recorded on the audit form:
 - Site name, AQS #, audit date
 - Flow controller and motor serial numbers
 - Reference and observed ambient temperature (T_a) in K ($^{\circ}\text{C} = 273$)
 - Reference and observed barometric pressure (P_a), mmHg
 - Calibration observed flow @ SRC (calibration set point)
 - Audit orifice transfer standard S/N and calibration information
 - Unusual conditions (construction, weather, etc.)
 11. From the manometer, determine pressure drop across the orifice and record as ΔH_2O on the verification form.
 12. Read the indicated flow from the meter in the flow controller.
 13. Calculate the verification flow rate (True Flow @ SRC) through the orifice using the following formula:

$$\text{Orifice Range Factor} = \frac{\Delta H_2O * P_a}{T_a}$$

Where:

T_a = audit temperature, K
 P_a = audit barometric pressure, mmHg

True Flow @ SRC is obtained from the audit orifice certification Range Factor table. This table is posted on the side of the audit orifice.

Example calculation:

Where:

T_a = 22 $^{\circ}\text{C} = 295$ K

$$\begin{aligned} P_a &= 745.0 \text{ mmHg} \\ \Delta H_2O &= 6.2 \text{ inches} \end{aligned}$$

Example Orifice Certification Range Factor Table (Form 1)

From the Example Orifice Certification Range Factor Table, 15.658 is between the range of low 15.514 and high 15.759. In the table this corresponds to a True Flow @ SRC of 1.25 m3/min.

13. Calculate the % difference between the sampler's True Flow @ SRC (Q_{True}) and the sampler's observed flow rate @ SRC ($Q_{Observed}$ from the last calibration).

Where:

$$\begin{aligned} Q_{True} &= \text{True flow rate @ SRC, m3/min} \\ Q_{Observed} &= \text{Observed flow rate @ SRC (flow set at calibration), m3/min} \end{aligned}$$

Example calculation:

Where:

$$\begin{aligned} Q_{True} &= 1.25 \text{ m3/min} \\ Q_{Observed} &= 1.30 \text{ m3/min} \end{aligned}$$

Verification results (flow rate % difference) produce three possible outcomes and actions:

% Difference	Condition / Data Status	Action
$\leq \pm 5.0\%$	Passed / Data Valid	No action is necessary
$> \pm 5.0\%$ and $< \pm 7.1\%$	Failed / Data Valid	Calibrate sampler to avoid potential future data loss
$\geq \pm 7.1\%$	Failed / Data Suspect	Calibrate sampler. Data suspect from last good flow check until sampler has a passing verification or calibrated.

Below are the procedures for the audit:

1. Confirm the date is correct and the time is within ± 5 minutes of the local standard time.
2. Measure and record the observed and reference ambient temperature (T_a) and barometric pressure (P_a) on the audit form.

Place the thermometer out of direct sunlight. Ensure that the thermometer bulb or probe is not in contact with any surface. Allow the temperature reading to stabilize before taking the final reading. If the temperature reading has not fluctuated in two to four minutes, record the reading. Next record the pressure reading on the sampler. Temperature and pressure limits are $< \pm 2.1^\circ\text{C}$ and $< \pm 10.1 \text{ mm Hg}$ respectively.

If a digital thermometer is used, be sure the unit is in the correct measure scale (°C) and that it has sufficient battery power. Carry extra batteries.

3. Record on the audit form the observed flow @ SRC (calibration set point) from the last calibration.

This data is obtained from the calibration form which may be posted inside the sampler shelter or may be obtained from the OAMD.

4. If present, remove the sample filter, cover and store it in a location where it will not be damaged.
5. If a liquid manometer is used for the audit, check for leaks prior to placement in-line with the orifice.

Check for leaks by blowing gently into the manometer tube. If a flow restriction occurs then the water level will not flow freely. If the two valves at the top of the manometer are not open completely, a flow restriction may occur. A vapor lock can occur if liquid and air get trapped in the two valves. Once the tube is blown into, the water or oil level will elevate on one side and decline on the other. Place a fingertip over the end of the tube when the liquid has risen. If there is a leak, the liquid level will slowly drop. If there are no leaks, the liquid level will not change.

If a digital manometer is used, be sure the unit is in the correct measure scale (mmHg), adjusted to zero and that it has sufficient battery power. Carry extra batteries

6. Check the audit orifice assembly for leaks.

The orifice assembly consists of an orifice, faceplate and filter cassette with one clean quartz filter. A filter is necessary to provide adequate resistance to flow.

Check the orifice to ensure that it is tightly seated (screwed on) onto the faceplate and that the faceplate gasket is in good condition.

7. Install the orifice assembly on the sampler.
Check that the gaskets are in good condition. Tighten the faceplate nuts evenly on alternate corners to seat the gaskets. Do not over tighten. When using an audit filter do not use resistance plates with the orifice.
8. Turn on the sampler and allow it to warm up (3 to 5 minutes).
9. Ensure that the following is recorded on the audit form:
 - Site name, AQS #, audit date
 - Flow controller and motor serial numbers

- Reference and observed ambient temperature (T_a) in K ($^{\circ}\text{C} = 273$)
 - Reference and observed barometric pressure (P_a), mmHg
 - Calibration observed flow @ SRC (calibration set point)
 - Audit orifice transfer standard S/N and calibration information
 - Unusual conditions (construction, weather, etc.)
10. From the manometer, determine pressure drop across the orifice and record as $\Delta\text{H}_2\text{O}$ on the audit form.
 11. Read the indicated flow from the meter in the flow controller.
 12. Calculate the audit flow rate (True Flow @ SRC) through the orifice using the following formula:

$$\text{Orifice Range Factor} = \frac{\Delta\text{H}_2\text{O} * P_a}{T_a}$$

Where:

T_a = audit temperature, K

P_a = audit barometric pressure, mmHg

True Flow @ SRC is obtained from the audit orifice certification Range Factor table. This table is posted on the side of the audit orifice.

Example calculation:

Where:

T_a = 22 $^{\circ}\text{C}$ = 295 K

P_a = 745.0 mmHg

$\Delta\text{H}_2\text{O}$ = 6.2 inches

Example Orifice Certification Range Factor Table (Form 1)

$$\text{Orifice Range Factor} = \frac{6.2 * 745}{295} = 15.658$$

From the Example Orifice Certification Range Factor Table, 15.658 is between the range of low 15.514 and high 15.759. In the table this corresponds to a True Flow @ SRC of 1.25 m^3/min .

13. Calculate the % difference between the sampler's True Flow @ SRC (Q_{True}) and the sampler's observed flow rate @ SRC (Q_{Observed} from the last calibration).

$$\% \text{ difference} = \frac{Q_{\text{Observed}} - Q_{\text{True}}}{Q_{\text{True}}} * 100$$

Where:

$$Q_{\text{True}} = \text{True flow rate @ SRC, m}^3/\text{min}$$

$$Q_{\text{Observed}} = \text{Observed flow rate @ SRC (flow set at calibration), m}^3/\text{min}$$

Example calculation:

Where:

$$Q_{\text{True}} = 1.25 \text{ m}^3/\text{min}$$

$$Q_{\text{Observed}} = 1.30 \text{ m}^3/\text{min}$$

$$\% \text{ difference} = \frac{1.30 - 1.25}{1.25} * 100 = 4.0\%$$

Audit results (flow rate % difference) produce three possible outcomes and actions:

% Difference	Condition / Data Status	Action
$\leq \pm 5.0\%$	Passed Audit / Data Valid	No action is necessary
$> \pm 5.0\%$ and $< \pm 7.1\%$	Failed Audit / Data Valid	Ambient should do a follow-up verification and if needed calibrate sampler to avoid potential future data loss
$\geq \pm 7.1\%$	Failed Audit / Data Suspect	Ambient should do a follow-up verification and if needed calibrate sampler. Data suspect from last good flow check until sampler is calibrated or verification passes

7.2 Verification and Audit Data Reporting

After audit completion, verification and audit results should be promptly reported to appropriate personnel and data entered into OAMD. A paper copy may be forwarded to the operator or personnel may view the results in the database. If data is suspect ($\geq \pm 7.1$ percent difference), the auditor should promptly inform the operator orally and in written form (memo or e-mail).

A cell phone is a standard piece of field equipment for IDEM-OAQ-QAS staff. Auditors now have the capability to receive immediate notification of audit results while remaining on-site. If audit results are $\geq \pm 7.1\%$ the auditor must perform the following actions before leaving the site:

- Call the operator with the audit results and request instructions. The operator may ask the auditor not to take any action or to proceed with the next step.
- The auditor may perform a “temporary” calibration of the sampler with the audit device. This calibration will minimize data loss and is in effect until the operator can reach the site to perform any maintenance, equipment replacement, and perform a “permanent” calibration.

7.3 Verification and Audit Frequency

The USEPA requires that State or Local Air Monitoring Stations (SLAMS) monitoring networks audit at least 25 percent of the samplers each quarter thereby auditing each sampler in the network once per year.

The Indiana Department of Environmental Management conducts verifications monthly and audits quarterly of all TSP samplers in its monitoring network to ensure minimal data loss.

7.4 Systems Audits

System audits are an on-site inspection and review of the total monitoring process from initial filter preparation and sampling to final analysis and data reporting. System reviews are generally done at the initial setup of a network then on an annual or on an as needed basis. The specific guidelines and procedures for this type of audit are found in Chapter 15 of this manual, “System Audit Criteria & Procedures for Evaluating Ambient Air Monitoring Networks”.

8.0 Precision and Accuracy Assessment

8.1 Precision

Precision of the TSP monitoring for metals network is measured by the use of duplicate or collocated samplers. Each set of duplicate samplers must be located between 2 to 4 meters from each other, and within 1 meter vertically. One of the samplers in the set is designated as the reporting sampler and data from this sampler is used to report air quality. The second sampler is designated as the collocated sampler and data from this sampler is used to calculate network precision. Calibration, sampling frequency and duration, and analysis must be conducted in the same manner for each sampler. The percentage differences between the lead concentrations ($\mu\text{g}/\text{m}^3$) from the two samplers are used to determine precision. The calculations are described in detail in 40 CFR Part 50, Appendix L and CRF Part 50, Appendix A.

The minimum required number of collocated sites is based on the total number of sites in the reporting agency network:

- 1-5 sites, 1 collocated site
- 6-20 sites, 2 collocated sites
- > 20 sites, 3 collocated sites

Precision estimations may be improved by installing additional collocated samplers. To further improve the representativeness of the precision data, reporting agencies should select collocated sites that have the highest annual mean concentrations.

8.2 Accuracy

The accuracy of the TSP monitoring for metals network is measured by auditing the flow rate performance of the samplers in the network. The percentage difference between the audit flow

rate and the sampler flow rate is used to determine accuracy. The calculations are described in detail in 40 CFR Part 50, Appendix L, CFR Part 50, Appendix A.

The USEPA requires that 25 percent of the samplers within a reporting organization's network be audited for accuracy each quarter. To improve accuracy estimates, additional accuracy flow rate audits may be conducted each calendar quarter. For example, the IDEM-OAQ-QAS audits all TSP samplers in its monitoring network at least once each quarter. This audit frequency provides additional accuracy flow rate data and also ensures minimal data loss due to "out-of-calibration" conditions.

9.0 Maintenance

Routine preventive maintenance helps prevent failures of the monitoring and analytical processes. The overall objective is to increase measurement reliability and prevent data loss. The guidelines below are intended to be general routine maintenance procedures. More detailed information can be found in the manufacturer's instruction manual for individual instruments.

Maintenance records must be kept for each sampler or instrument. These records should contain a history of the sampler, including all replacement parts, suppliers, costs, installation dates, etc.

9.1 Six Month and One Year Maintenance

1. Replace Motor Brushes every 6 months. Follow manufacturer's instructions for the replacement of motor brushes. Replacement frequencies will vary depending on total operating hours of each motor.

A flow controller calibration must be performed after any motor maintenance or motor replacement.

2. Clean the flow controller probe with alcohol and properly align the probe in the throat of the sampler's cone.

9.2 As Needed Maintenance

1. Gaskets should be checked at each setup and replaced if they are worn, cracked, or excessively flat.
2. The inside of the shelter should be routinely cleaned.
3. Motor armatures should be checked during brush change and replaced as necessary.

10.0 Lead Analysis Program

Lead monitoring is conducted using an USEPA method EQL-0380-044. Samples are collected on glass fiber filters which have run for 24 hours in a TSP sampler. On October 15, 2008, the

USEPA strengthened the national ambient air quality standards (NAAQS) for lead. The current standard is now $0.15\mu\text{g}/\text{m}^3$ for a three month rolling average.

10.1 Analysis Quality Control and Quality Assurance

Filters are analyzed at IDEM utilizing USEPA method EQL-0380-044, or Flameless Atomic Absorption Spectrometry method. Samples are run in duplicate and an average is taken of both readings. When analysis is being performed a 10% standard is run with each set of samples.

10.1.1 Lead Strip Audits

Nine lead audit strips are required to be analyzed each quarter. This is comprised of 3 strips at each of two different concentration ranges plus a blank. The lower concentration range is 9-30 $\mu\text{g}/\text{strip}$ and the higher concentration is 60-90 $\mu\text{g}/\text{strip}$ of the NAAQS. At this time the strips are prepared by the QA Laboratory at IDEM and sent to several laboratories, however the USEPA is contemplating the possibility of developing the strips for monitoring laboratories dependent upon interest in the program. The nine strips are sent out quarterly and 2 strips (one low and one high concentration) as well as one blank are analyzed each month. Results are sent to the QA section and evaluated. If results are greater than $\pm 10\%$ then it is recommended that the system be examined to see if the difference can be reduced. If results are greater than $\pm 15\%$ then the cause should be determined and should then be reported back to the QA section.

11.0 Forms

Calibration and audit forms used with TSP monitoring for metals are similar to those used with the PM10 monitoring program. Also, audit and calibration calculation formulas are similar with the major difference of the design flow rate. The PM10 design or normal flow rate is 1.13 m^3/min and the TSP design or normal flow rate is 1.30 m^3/min .

Form 1 Example Orifice Certification – Range Factor Table

Indiana Department of Environmental Management Office of Air Quality – Hi-Volume Orifice Certification			Use the following formulas to directly calculate the true flow: $CM = \sqrt{MR * (BP/760) * (298/Temp)}$ True Flow = (1/Slope) * (CM – Intercept) Where: CM = Corrected Manometer Reading MR = Manometer in inches of water BP = Barometric Pressure in mmHg Temp = Ambient Temp in K (C+273)		
Agency	Cert Date				
STATE QA	23-FEB-2004				
Orifice SN	Slope	Intercept			
10019	1.9431329	0.0472172			
Recertification is Due: 23-FEB-2005					
Flow Rates are corrected to Standard Reference Conditions of 298 K and 760 mmHg. Range Factor = [Manometer Reading * Station Baro Press (mmHg)] / Site Temp (K)					

True Flow (m ³ /min)	Range Factor		True Flow (m ³ /min)	Range Factor		True Flow (m ³ /min)	Range Factor	
	Low	High		Low	High		Low	High
0.90	8.138	8.315	1.14	12.942	13.165	1.38	18.855	19.125
0.91	8.316	8.495	1.15	13.166	13.391	1.39	19.126	19.397
0.92	8.496	8.677	1.16	13.392	13.619	1.40	19.398	19.671
0.93	8.678	8.861	1.17	13.620	13.849	1.41	19.672	19.948
0.94	8.862	9.046	1.18	13.850	14.081	1.42	19.949	20.226
0.95	9.047	9.234	1.19	14.082	14.315	1.43	20.227	20.506
0.96	9.235	9.424	1.20	14.316	14.551	1.44	20.507	20.788
0.97	9.425	9.615	1.21	14.552	14.789	1.45	20.789	21.072
0.98	9.616	9.809	1.22	14.790	15.028	1.46	21.073	21.358
0.99	9.810	10.004	1.23	15.029	15.270	1.47	21.359	21.645
1.00	10.005	10.201	1.24	15.271	15.513	1.48	21.646	21.935
1.01	10.202	10.400	1.25	15.514	15.759	1.49	21.936	22.227
1.02	10.401	10.601	1.26	15.760	16.006	1.50	22.228	22.520
1.03	10.602	10.805	1.27	16.007	16.255	1.51	22.521	22.816
1.04	10.806	11.009	1.28	16.256	16.507	1.52	22.817	23.113
1.05	11.010	11.216	1.29	16.508	16.760	1.53	23.114	23.413
1.06	11.217	11.425	1.30	16.761	17.015	1.54	23.414	23.714
1.07	11.426	11.636	1.31	17.016	17.272	1.55	23.715	24.017
1.08	11.637	11.849	1.32	17.273	17.531	1.56	24.018	24.322
1.09	11.850	12.063	1.33	17.532	17.792	1.57	24.323	24.629
1.10	12.064	12.280	1.34	17.793	18.054	1.58	24.630	24.938
1.11	12.281	12.498	1.35	18.055	18.319	1.59	24.939	25.249
1.12	12.499	12.719	1.36	18.320	18.586	1.60	25.250	25.562
1.13	12.720	12.941	1.37	18.587	18.854	1.61	25.563	25.877

Form 2
TSP Audit and Calibration Form
TSP AUDIT AND CALIBRATION SHEET
General Information

Site:		City:	
County:		AQS#:	
Date:		Initials:	

Ambient Temperature:		°C	Deg K (°C. +273):	
Barometric Pressure:		mmHg		

Monitor Information

Orifice:		Orifice Cert. Date:	
(Current) Flow controller #:		Flow controller Installation Date:	
(Current Motor) #:		Motor Installation Date:	

Audit & Calibration Results

Set Flow = 1.30 m ³ /min = 45.9 CFM			For Hi-vol +			
Range Factor (orifice) = B.P. * inches H ₂ O/ deg. K			Indicated	Actual	Deg. diff.	Limit <i>circle pass or fail</i>
Observed Flow = obtained from orifice range factor table (During audit, set flow = true flow)			T amb			± 2.0 °C/ pass fail
Audit: (Observed Flow - True Flow / True Flow) * 100 = % Diff			P amb			± 10 mmHg/ pass fail
Orifice		Inches H ₂ O	Flow Information		Percent Difference	Meter or instantaneous flow reading (Q std)
			Range Factor	Observed or True Flow		
	Audit:					
For old units	Recal:			1.30		

Cleaned unit? *circle* Yes No If no, state why in comments.

For Hi-vol +: <i>Any no's must be explained in comment section</i>	Audit Barometer/ Temperature Info	
Downloaded data? <i>circle</i> Yes No	Barometer SN	_____
Erased data? <i>circle</i> Yes No	Cert date:	_____
Countdown on unit? <i>circle</i> Yes No	Therm. SN	_____
Ambient Hole clear? <i>circle</i> Yes No	Cert date:	_____

If unit is out of cal for Hi-vol + contact AMS environmental manager specialist

Range: 0.0 - 4.9 % - in cal, data valid 5.0 - 6.9 % -out of cal, data valid 7.0 or higher % -out of cal, data invalid

If an audit could not be performed prior to the calibration, please indicate the reason: _____

If the motor or flow controller was replaced, please indicate:		For calibration on older unit:			
New motor number:		Range factor of 1.30 for orifice	X	temp K	= Inches of water
New Flow controller number:		1		Barometric pressure	
For Hi Volt+					
<u>Slope</u>	<u>Intercept</u>	<u>R- value</u>			

Comments:

Form 3
TSP Audit Form

Indiana Department of Environmental Management Office of Air Quality Quality Assurance Section PM₁₀ / TSP Audit	
Site: _____	Audit Date: _____
AQS #: 18- _____	Performed by: _____
Sampler Information	
Flow Controller SN: _____	Calibration Date: _____
Calibration Temp °C/K: _____ °C / _____ K	Calibration BP (mmHg): _____
Audit Information	
Audit Orifice SN: _____	Orifice Cert Date: _____
T _a - Audit Temp °C/K: _____ °C / _____ K	P _a - Audit BP (mmHg): _____
Δ P-Manometer (" H ₂ O): _____	Range Factor: _____
Flow Controller Meter: _____	Std Flow @SRC (m ³ /min): _____
	Observed Flow @SRC (m ³ /min): _____
Formulas	% Difference: _____
Range Factor = $\Delta P * P_a / T_a$ TSP Observed Flow @SRC = $1.30 @ act * [(Cal BP * 298) / (Cal Temp * 760)]$ PM ₁₀ Observed Flow @SRC = $1.13 @ act * [(Cal BP * 298) / (Cal Temp * 760)]$ % Difference = $(Observed Flow - Std Flow) / Std Flow * 100$	
Site Inspection and Remarks	
ETM working properly: _____ Remarks: Clock working properly (day & time): _____ General condition of site & shelter: _____	