PART THREE

Continuous Particulate Monitoring for PM$_{2.5}$, PM$_{10}$, and PMc
# Chapter 7

## Part Three - Continuous Particulate Monitoring for PM$_{2.5}$, PM$_c$ and PM$_{10}$

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Part Three – Continuous Particulate Monitoring of PM$_{2.5}$, PM$_c$ and PM$_{10}$

1.0 Introduction

Traditional particulate monitoring uses pre-weighed filters on which particles are collected over a 24-hour period. This sampling method is labor intensive, requiring an operator to pick-up an exposed filter and install a new clean filter for each sample at each sampling site. Exposed filters must then be transported back to a laboratory for conditioning, weighing, data calculation, and data entry. Samples are normally collected in a one every three day frequency (intermittent sampling). Daily sampling still only produces a particulate concentration averaged over a 24-hour period.

The first continuous particulate monitors, installed in 1995 the Rupprecht and Patashnick (R&P) PM$_{10}$ TEOM®, were installed at two sites in northern Indiana. This was followed roughly 10 years later with the introduction of Met One’s BAM units, and more recently Thermo Environmental’s SHARP monitors and Teledyne API 602 Beta Plus samplers.

The Rupprecht and Patashnick uses a Tapered Element Oscillating Microbalance (TEOM®) methodology to continuously measure particulate matter mass concentrations. Met One utilizes a Beta Attenuation Monitor (BAM), while the Thermo Synchronized Hybrid Ambient Real-Time Particulate Monitor (SHARP) combines nephelometric and radiometric measurements into one instrument. All three have been designated as a USEPA equivalency for PM$_{2.5}$ and PM$_{10}$ monitoring. The Teledyne API 602 Beta Plus (API 602) combines sequential sampling with automated mass measurements (utilizing beta attenuation), and has been designated as a USEPA equivalency method for PM$_{2.5}$, PM$_{10}$, as well as PM$_{10-2.5}$.

1.1 Sampling Method Overview

Ambient air is drawn into sampler through an air inlet followed by an exchangeable filter cartridge or filter tape, where the particulate mass collects. The inlet system is equipped with a sampling head which separates particles of either a 2.5 $\mu$m or 10 $\mu$m diameter (PM$_{2.5}$ or PM$_{10}$). The sampled air proceeds through the sensor unit; microbalance for the TEOM, beta attenuation for the BAM and API 602, and hybrid nephelometer/beta attenuation for the SHARP.

A TEOM makes use of a microbalance system. As the sample stream moves into the microbalance system, it is heated to the temperature specified by the control unit. This heating minimizes the deposition of water due to changes in ambient humidity. The control unit contains a flow controller, which regulates the sample stream through the monitor at flow rates between 0.5 and 6 liters per minute. A hollow tube is attached to a platform at its wide end (Tapered Element) and is vibrated at its natural frequency. As particulate matter gathers on the filter cartridge, the tube’s natural frequency of oscillation decreases. The electronic microbalance system continually monitors this frequency.

The BAM contains a small $^{14}$C element which emits a constant source of high energy electrons. These beta particles are detected and counted by a sensitive scintillation detector. An external
pump pulls a measured amount of dust-laden air through a filter tape. After the filter tape is loaded with ambient dust, it is automatically placed between the source and the detector, thereby causing an attenuation of the beta particle signal. The degree of attenuation of the beta particle signal is used to determine the mass concentration of the particulate matter on the filter tape, hence the volumetric concentration of particulate matter in ambient air.

The SHARP incorporates a hybrid system utilizing two distinct measurement processes in one unit. The sample stream is first passed through the nephelometer where a sensor measures the light scattering caused by the particulate matter aerosol as it passes through an 880 nm illumination beam. Next the aerosol is deposited onto a filter tape. Here the instrument measures particulate concentrations by passing radiation through a known sample area to a detector, similar in principle to the BAM, referencing alpha (Ra) and beta (Rβ) counts to a reference standard.

The API 602 has two separate and independent sample flow controls, filter holders, sample lines, and inlets. They share one beta attenuation measuring system. The channels can be set up to sample PM$_{2.5}$, PM$_{10}$, or PM$_{10-2.5}$ as well as a wide range of flow points. Particulate matter is collected on standard 47mm filters which are moved in pairs (both channels) for measurement. The instrument also has the ability to be set up as a conventional sequential sampler.

![Figure 1](R&P TEOM)
Figure 2
Met One BAM

Figure 3
Thermo Scientific SHARP
2.0 Instrumentation

IDEM uses TEOMs, BAMs, API 602s, and SHARPs for all continuous particulate data collection. Table 1 shows the standard configuration for each, as specified by the manufacturer.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TEOM</th>
<th>BAM</th>
<th>SHARP</th>
<th>API 602</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Flow</td>
<td>16.7 liters per min (1 m³/hr)</td>
<td>16.7 liters per min (1 m³/hr)</td>
<td>16.7 liters per min (1 m³/hr)</td>
<td>16.7 liters per min (1 m³/hr)</td>
</tr>
<tr>
<td>Sample Stream Temperature</td>
<td>50 °C</td>
<td>25 °C</td>
<td>25 °C</td>
<td>Variable (controlled to regulate RH)</td>
</tr>
<tr>
<td>Particulate Matter Concentration Measurement Range</td>
<td>&lt;5 µg/m³ to several µg/m³</td>
<td>0 to 1,000 µg/m³</td>
<td>0 to 1,000 µg/m³</td>
<td>0-2000 µg/m³</td>
</tr>
</tbody>
</table>

2.1 Interferences

These highly accurate and precise instruments can be affected by a variety of outside forces. These include, but are not limited to: vibrations; electrical interferences – such as blackouts, brown outs, power spikes, and magnetic/electric fields; moisture, temperature, and improper siting.
The temperature of the TEOM’s sample stream should be maintained within as narrow a range as possible. Large temperature fluctuations (7 to 8 °F per minute) of the sample stream may cause measurement accuracy to decrease. The decrease is due to the inlet system’s inability to adjust the temperature of the sample to the temperature specified by the software before traveling to the microbalance system. Both the BAM and SHARP have built-in heater assemblies on the down tube, between the sample inlet and instrument, to help moderate both temperature and relative humidity.

Very high background radiation levels can possibly affect the SHARP, BAM, and API 602, as they utilize an internal radiation emitting source.

2.2. Instrument Description

The four real-time particulate monitors, utilized by IDEM’s monitoring network, can be broken down into three parts: the control features, sensor, and inlet.

2.2.1 Control Unit

The control unit houses the following:

- Mass flow controllers and the control electronics for operation.
- The main electrical and air connections to the main power supply, the auxiliary control, and the main vacuum pump/connections.
- The main power switch, status light, and the keypad for operation.

2.2.2 PM₁₀ Inlet or PM₂.₅ Very Sharp Cut Cyclone

A PM₁₀ inlet is designed to allow only particulate matter ≤10 μm in diameter to remain suspended in the sample air stream as long as the flow rate of the system is maintained at 16.67 L/min. The inlet incorporates a rain and bug shield, and is used on the TEOM, SHARP, and BAM. Due to the set up and close proximity of the API 602’s downtubes, it utilizes a European style PM₁₀ inlet. If the monitor is sampling PM₂.₅, a very sharp cut cyclone (VSCC) is placed in-line directly below the PM₁₀ inlet and above the down tube. This cyclone further eliminates suspended particles, allowing only those ≤2.5 μm into the sampler. This combination of PM₁₀ inlet and VSCC is identical to that used in intermittent sampling.

2.2.3 Sensor Unit

The sensor unit houses the mass transducer (TEOM), beta attenuation monitor (BAM/SHARP/API602), or nephelometer (SHARP) sensing units and all included electronic circuit boards with the appropriate wiring for electricity and frequency signal output.

2.3. Ancillary Equipment

Listed below are several (but not inclusive) supplies required for operation of IDEM’s
monitoring network:

- Certified flow rate transfer standards (Bios, Chinook Streamline FTS kit, TriCal, or similar)
- Certified barometer (digital or aneroid)
- Certified thermometer (digital or liquid)
- Certified relative humidity meter (SHARP)
- Certified zero/span foil kit (SHARP)
- Laboratory and maintenance / logbooks and database
- Manufacturer recommended spare parts
- Standard time piece of known accuracy within ±2 min/24hr

3.0 Site Selection

3.1 Siting Requirements

Basic siting criteria for the placement of ambient air samplers are documented in Table 2 in this section. This is not a complete listing of siting requirements; instead, an outline to be used by the operating agency to determine a sampler’s location. Complete siting criteria are presented in 40 CFR Part 58, Appendix E. 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, Section 4.0 of this manual.

As with any type of air monitoring study in which sample data are used to draw conclusions about a general population, the validity of the conclusions depends on the representativeness of the sample data. Therefore, the primary goal of a monitoring project is to select a site or sites where the collected particulate mass is representative of the monitored area.
Table 2
Example of Minimum Sampler Siting Criteria

<table>
<thead>
<tr>
<th>Scale</th>
<th>Height Above Ground</th>
<th>Distance from supporting structure, meters</th>
<th>Other spacing criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Vertical</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Micro</td>
<td>2 to 7 meters</td>
<td>&gt;2</td>
<td>&gt;2</td>
</tr>
<tr>
<td>Middle, Neighborhood, Urban,</td>
<td>2 to 15 meters</td>
<td>&gt;2</td>
<td>&gt;2</td>
</tr>
<tr>
<td>Regional</td>
<td></td>
<td></td>
<td></td>
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</table>

\^ When the inlet is located on a rooftop, this separation distance is in reference to walls, parapets, or penthouses located on the roof.

\^ Distance depends on the height of the furnace or the incineration flues, type of fuel or waste burned, and quality of fuel (sulfur, ash, or lead content). This is to avoid undue influences from minor pollutant sources. As a precautionary measure, the sampler should be placed at least 5 meters from the furnace or the incinerator flue.

3.2. Site Safety and Security

Additional factors not specified in the CFR must be considered in determining where the monitor is deployed. These factors include accessibility under all weather conditions, availability of adequate electricity, and security of the monitoring personnel and equipment. The monitor must be situated where the operator can reach it safely despite adverse weather conditions. If the monitor or part of the monitor (i.e., sample inlet) is located on a rooftop, care should be taken that the operator’s personal safety is not jeopardized by a slippery roof surface during inclement weather. Consideration also should be given to the fact that routine operation (i.e., calibration, maintenance, flow check, and audit) involves transporting supplies and equipment to and from the monitoring site.

To ensure that adequate power is available, consult the manufacturer’s instruction manual for the sampler’s minimum voltage and power requirements. Lack of a stable power source can result in the loss of data, because of power interruptions.
The security of the sampler itself depends mostly on its location. Rooftop sites with locked access and ground-level sites with fences are common. In all cases, the security of the operating personnel as well as the sampler should be considered.

**Photo 1**
Inlets on Terre Haute Lafayette Ave Roof

4.0 Monitor Installation, Calibration, and Operation

4.1 Monitor Installation

All site selections and installations shall comply with siting criteria presented in 40 CFR Part 58, Appendix E. Installation should also adhere to section 3.2 Site Safety and Security in this document. The following is a general guideline for instrument installation. More detailed instructions should be referenced in their corresponding manuals.

Once a site has been selected, and the instrument tested and found to be in working order:

1. Determine the exact location of the monitor and all included equipment, such as pumps. Care should be taken to allow room for both sample and electrical connections.
• The BAM, SHARP, and API 602 instruments must be placed directly below the down tube.
• The TEOM unit itself does not need to be directly below the down tube, but its sensor unit does.

2. Drill or use an existing opening in the structure’s roof to allow for the instrument’s down tube(s). In addition, mount the tripod or other down tube support structure, if needed, and the temperature/pressure sensor.

• The TEOM also has a bypass flow line that is flexible, and can be routed through the shelter’s side or an existing port to alleviate the need for another hole in the roof.

3. Inside the shelter, mount the instrument on a rack using the appropriate hardware or place on a sturdy flat surface, such as a table or counter top.

• Be sure to account for the down tube, as mentioned above.
• If not rack mounting, be sure to properly secure the instrument to account for vibrations.

4. Make all electrical, communication, and air connections. Be sure all packing material, shipping screws, and other similar materials have been removed prior to turning on the instrument.

5. Once installed, power on, allow instrument to warm up, and ensure that all functions are working properly.

4.2. Calibration of Components

4.2.1 Overview of Calibration Procedures

The following is a general guide to calibrating the continuous monitors used by IDEM. For more detailed instructions, refer to the specific monitor’s user manual and the IDEM OAQ instrument specific SOP.

Useful Formulas for Calibration/Verification/Audit Procedures:

Reference Flow

\[ Q_{Ref} = m * \left[ \Delta P * \frac{T_{amb}}{P_{amb}} \right] + b \]

Where:

\[ Q_{Ref} = \text{Reference flow (liters per minute)} \]
\[ m = \text{FTS Slope} \]
Temperature Conversion, Celsius to Kelvin

\[ T_K = T_c + 273 \]

Where:
- \( T_K \) = Temperature in Kelvin
- \( T_C \) = Temperature in Celsius

Barometric Pressure Conversion, mmHg to atm

\[ P_{atm} = \frac{P_{mmhg}}{760} \]

Where:
- \( P_{atm} \) = Pressure in atm
- \( P_{mmhg} \) = Pressure in mmHg

Flow Conversion, True to Standard

\[ Q_{std} = Q_{true} \left[ \frac{298}{T_{amb}} \right] \]

\[ Q_{std} = \text{Standard flow (liters per minute)} \]
\[ Q_{true} = \text{True flow (liters per minute)} \]
\[ T_{amb} = \text{Reference ambient temperature (K)} \]
\[ P_{amb} = \text{Reference ambient pressure (mmHg)} \]

To calculate Reference/Observed Flow Difference

\[ Diff = \left( \frac{Q_{Obs} - Q_{Ref}}{Q_{Ref}} \right) \times 100 \]

Where:
- \( Q_{Ref} \) = Reference flow (liters per minute)
- \( Q_{Obs} \) = Observed flow (liters per minute)
- \( Diff \) = Difference in percent

### 4.2.2 TEOM Calibration Procedure

Equipment required for calibration:
- Certified thermometer/temperature probe
- Certified barometer
- Certified flow transfer standards (FTS, TriCal, deltaCal, or similar)
- Standard time piece of known accuracy within ±2 min/24hr.
- Flow audit adapter (leak check device)
- Pre-weighed calibration filter
- Filter exchange tool
- Calibration forms

Before calibrating the sensors, ensure the sampler time is within 1 minute of local standard time and the date is correct. If an adjustment is made, make note of this.

A. **Ambient Air Temperature and Pressure Verification:**

1. Place a certified thermometer/temperature probe into the TEOM’s ambient temperature sensor mount.
2. On the TEOM control panel, access the Set Temps/Flows screen. Arrow down until the Amb Temp and Amb Pres come into view.
3. Verify that the ambient temperature is within ±2.1 °C and the ambient pressure within ±10.1 mmHg of the transfer standards.
4. If either parameter falls outside the given range, an analog calibration is required. Refer to the TEOM service manual for more information on analog calibrations.
5. Ambient temperature and pressure verifications should be completed before a flow calibration/verification.

B. **Leak Check:**

1. Disable the corresponding channel in the LEADS system.
2. Use the up and down arrow keys on the TEOM to view the main and total flow values.
3. Remove the inlet from the down tube. If present, leave the VSCC in place.
4. Attach a flow audit device to the down tube or very sharp cyclone and close the device.
5. Record the flow values shown on the TEOM on the calibration form. The main flow should be < 0.15 lpm, while total flow should be < 0.6 lpm. Return to the inlet, and slowly open and remove the flow audit device. Replace the inlet on the down tube or VSCC.
6. If the values are higher than the allowable standard, a non-linearity offset value (NOV) may be established. This is done by:
   a. Repeat the first 4 steps of the leak check procedure. Slowly open the flow audit device.
   b. Unplug the pump from the power supply.
   c. Wait several minutes to let the flow rates stabilize, then close the flow audit device.
   d. Record the flow values. Take the original values and subtract the NOV.
e. Remove the flow audit device and replace the inlet.
f. Enable the corresponding channel in LEADS and leave an entry in electronic operator log.

C. Flow Verification/Calibration:
1. Disable the corresponding channel in the LEADS system.
2. Perform a leak check using a flow audit adapter.
3. Locate the flow audit adapter and ensure that the valve of the adapter is in its open position.
4. Remove the size-selective inlet from the flow splitter and replace it with the flow audit adapter.
5. Make sure the flow audit adaptor is in the open position.
6. When in the Main screen, scroll down to the Main Flow and Aux Flow lines. These values represent the actual volumetric flows, as measured by the monitor’s flow controllers.
7. Confirm that these flows are within ± 2% of their set points (3.0 L/min for the Main Flow and 13.67 L/min for the Aux Flow). Any greater deviation may indicate that the in-line filters are plugged or other blockages exist in the system.
8. Attach a reference flow meter to the top of the flow audit adapter.
9. Read the total flow (approximately 16.67 L/min) on the reference flow meter. The total volumetric flow measured by the reference flow meter must be 16.67 ± 1.0 L/min to be acceptable.
10. Disconnect the bypass flow line from the bypass extension on the bottom of the flow splitter located at the sample inlet.
11. Cap the exit of the flow splitter bypass extension with the 3/8-inch Swagelok cap.
12. Read the main flow (approximately 3.0 L/min) on the reference flow meter. The volumetric flow measured by the reference flow meter must be 3.0 ± 0.2 L/min to be acceptable.
13. If the flow readings are within acceptable limits, remove the 3/8-inch Swagelok cap from the flow splitter bypass extension.
14. Install the bypass flow line onto the flow splitter bypass extension.
15. Perform a leak check.
16. Remove the flow audit adapter from the top of the flow splitter.
17. Install the sample inlet onto the flow splitter.
18. Install a new TEOM filter into the mass transducer.
19. Press <F1> or <Run>.
20. Enable the corresponding channel in LEADS and leave an entry in electronic operator log.
D. Mass Transducer Calibration Verification:

1. From any screen press 17<Enter> to access the K0 Confirmation screen. Confirm the Calibration Constant shown on the “Set Hardware” Screen is the same as that shown on the nameplate, located on the left side of the mass transducer support cage.

2. Warm up the system with any filter cartridge that is not the calibration filter, so that all the temperatures are at their normal operating conditions for at least one hour. The airflow through the system should be at its normal value, at or near 16.67 L/min combined main/auxiliary flows, during this period.

3. Disable the corresponding channel on the LEADS system. Enter the Setup Mode on the control unit by pressing the keypad Data Stop. Turn off the air tube heater by setting the set point to 0 on the “Set Temps/Flows” Screen.

4. Unplug the vacuum pump, so there is no flow through the instrument. This prevents particulate contamination of the calibration filter.

5. Scroll through the Menu Screen (using “Stop” Screen and the down arrow on the keypad of the control unit) and select the last item, KO Confirmation.

6. When KO Confirmation is selected, the following screen will appear:

   | K0 Confirm | 209.44188 |
   | Filt Wght  | 0.07903  |
   | 287.53182  | 209.44186 |
   | Audit K0   | 9683     |

7. Use the down arrow keypad to move to the Filt Wght. Input the weight of the preweighed calibration filter, as recorded on the kit data, on the line labeled Filt Wght, by pressing the Edit keypad and then the value.

8. Open the mass transducer and remove the media filter from the tip of the tapered element, using the filter exchange procedure. Close the mass transducer and sensor unit door. Operate the system without a filter and wait for the oscillating frequency shown in the upper right-hand corner of the screen to reach a maximum value. Observe the frequency output next to K0 confirm on the first line of the K0 Confirmation screen. The frequency will increase, peak, and then start to decrease in value. When the frequency peaks, press the First/Last keypad (in the center of the arrow keys) to record this frequency value in the first slot of the third line of the screen. (Note: If you miss the peak you can open and close the transducer again, and observe the frequency a second time to catch the peak value.)

9. Remove the filter tool and filter box containing the calibration filter.
   (Note: The calibration tool can be distinguished from a normal filter tool by its red handle. Do NOT use the calibration filter tool to remove or install any filters except for the calibration filter.)

10. Install the calibration verification filter, with the filter exchange tool provided with the calibration kit, in the instrument. Note that the filter exchanges are normally performed with
the pump on to help the filter become properly seated on the tapered element. Since the pump is not on, take special care to ensure that the filter is properly seated. Close the mass transducer and sensor unit door. Return the calibration tool immediately to the kit and reseal the bag. Again, watch the frequency output and the control unit’s screen, when it peaks to reach a new maximum value.

11. Press the <First/Last> key again to record the frequency f1.

12. The instrument then automatically computes and displays the audit value of the calibration constant, K0, on the line entitled Audit K0. An example of the final screen display is as follows.

<table>
<thead>
<tr>
<th>K0 Confm</th>
<th>209.44188</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter Wgt</td>
<td>0.079303</td>
</tr>
<tr>
<td>287.53182</td>
<td>209.44186</td>
</tr>
<tr>
<td>Audit K0</td>
<td>9683</td>
</tr>
<tr>
<td>Actual K0</td>
<td>9627</td>
</tr>
<tr>
<td>% Diff</td>
<td>0.58</td>
</tr>
</tbody>
</table>

13. The K0 confirmation screen also displays the current K0 value entered in the monitor, and the percentage difference between the audit and currently entered value. The indicated difference should not be more than 2.5% from the original R&P calibration constant.

14. Press F1 to leave the TEOM in OK. Enable the corresponding channel in LEADS and leave an electronic operator log.

4.2.3 SHARP Calibration Procedure

Equipment required for calibration:

- Certified thermometer/temperature probe
- Certified barometer
- Certified flow transfer standards (FTS, TriCal, deltaCal, or similar)
- Flow audit adapter (leak check device)
- Standard time piece of known accuracy within ±2 min/24hr.
- Certified relative humidity meter
- Certified zero/span foil kit
- HEPA filter/adapter
- Calibration forms

Prior to beginning the SHARP calibration, ensure the instrument is operating properly. If the internal sample temperature sensor is to be calibrated, allow the instrument to operate at least one hour with the heating system turned OFF. Also, ensure the sampler time is within 1 minute of local standard time and the date is correct. If adjustment is made, make note of this.

A. Temperature, Relative Humidity, and Barometric Pressure Sensor Calibration

1. Enter the Calibration Menu. Press SET to input the calibration menu code. Change the code
to 4 using the + and - soft keys.

2. Press the YES key to perform a 1 point calibration of the barometric pressure, relative humidity, and all of the temperature sensors.

3. Obtain a reference ambient temperature by placing a certified temperature probe or thermometer near the SHARP ambient temperature sensor. Input the reference reading into the ambient (T1) temperature calibration screen using the + and - keys.

4. Repeat the process for T2 (Sample Temp), T3 (Orifice Temp), and T4 (Heater Temp). Reference temperature values can be obtained by measuring the shelter temperature. Allow an hour for T2, T3, and T4 to equilibrate with each other and the shelter temperature, with the heating system off, before taking a reading.

5. Perform a relative humidity calibration by placing the reference meter’s probe into the sample chamber and closing the door. Allow approximately one hour for equilibration. Input the reading into the relative humidity calibration screen.

6. Input the barometric pressure reading obtained from a certified barometer into the calibration screen.

B. Sample Flow Calibration

1. Before beginning a flow calibration, ensure that the pump is turned off. Remove the inlet and attach a certified flow transfer standard.

2. Turn the pump on through the calibration menu.

3. Press the CAL soft key to input the calibration coefficient using the + and - keys.

4. Adjust the indicated flow rate to match the certified transfer standard using the + and - keys. Allow at least 30 seconds between adjustments for flow equilibration.

5. Repeat the process until the indicated flow is within ±2.1% of the certified transfer standard.

C. Mass Foil Calibration

1. Enter the Foil Calibration screen through the calibration menu and press the YES soft key.

2. Enter the span foil value, as noted on the span foil in the certified foil calibration kit, using the + and - soft keys. Once the correct value is displayed press NEXT.

3. After the beta attenuation chamber opens, cut the filter tape, and pull out from the chamber. Insert the foil holder into the chamber. It should click into place. Once in place, press NEXT.

4. Once the chamber closes, insert the zero foil into the foil holder, press NEXT. The zeroing process should take approximately 200 seconds to complete.

5. With the zero complete, remove the foil and replace with the span foil. After pressing NEXT wait another 200 seconds for the span point to run.

6. A screen showing the old and new mass calibration factors will be displayed. Press YES to change the factors.
7. After the chamber opens again, remove the foil and foil holder. Replace the filter tape, ensuring proper placement through the chamber and across the rollers.

8. Perform a FC+Z (filter change and zero) by pressing the FC+Z soft key before returning the instrument to service.

D. Nephelometer Zero and Calibration

1. Install the HEPA filter on the inlet.

2. Enter the Nephelometer calibration screen through the calibration menu and press the YES soft key.

3. Allow the instrument to run several minutes allowing the nephelometer to stabilize. Press the ZERO soft key to begin the zeroing process. This is an automated process that should last less than two minutes.

4. Once the calibration is complete, exit the calibration menu, lock the keypad, and return the instrument to normal service. Enable the corresponding LEADS channel and leave an electronic operator log entry.

4.2.4 BAM Calibration Procedure

Equipment required for calibration:

- Certified thermometer/temperature probe
- Certified barometer
- Certified flow transfer standards (FTS, TriCal, deltaCal, or similar)
- Standard time piece of known accuracy within ±2 min/24hr.
- Calibration forms

Before attempting a calibration, ensure that the BAM has been powered on and allowed to warm up for at least an hour.

1. Disable the corresponding LEADS channel.

2. Ensure the sampler time is within 1 minute of local standard time and the date is correct. If adjustment is made, make note of this.

3. Obtain a reference ambient temperature reading by placing a certified temperature probe or thermometer near the BAM’s ambient temperature sensor. Use a certified barometer to note the ambient barometric pressure.

4. On the BAM’s control panel, enter the TEST> FLOW menu. Use the NEXT soft key to highlight the AT field. Input the reference temperature obtained in the previous step. Repeat the process to input the barometric pressure in the BP field.

5. Remove the PM$_{10}$ inlet and install the certified transfer standard. If the BAM is sampling PM$_{2.5}$, leave the VSCC in place. Return to the control panel and use the NEXT soft key to move to the first flow point of 15 L/min. The pump will start automatically. Allow the BAM to equilibrate. Input the reference flow reading and press the CAL soft key to correct the
BAM’s reading.

6. Repeat the process for the other two calibration flow levels. The BAM will not change to match until all three points have been entered.

7. Replace the PM\textsubscript{10} inlet on the down tube.

8. Exit the TEST>FLOW menu and leave the BAM in Normal mode.

9. Enable the corresponding LEADS channel and leave an electronic operator log.

### 4.2.5 API 602 Calibration Procedure

**Equipment required for calibration:**

- Certified thermometer/temperature probe
- Certified barometer
- Certified flow transfer standards (FTS, TriCal, deltaCal, or similar)
- Accurate time piece
- Calibration forms

Before calibrating the sensors, ensure the sampler time is within 1 minute of local standard time and the date is correct. If adjustment is made, make note of this.

1. Disable the LEADS channel.
2. Place the certified flow transfer standard onto the sample line of the intended channel.
3. Ensure the instrument is in READY status. Press ENTER then SELECT until Instrument Tools menu is showing.
4. Select the pneumatic circuit (Channel) to be calibrated using the SELECT button. Press enter to confirm.
5. Select Line A Manual Span Test or Line B Manual Span Test and press ENTER.
6. Insert a filter into the Loader and press ENTER.
7. Press ENTER again to turn the vacuum pump on.
8. Regulate the valve opening until the certified flow standard has stabilized on the intended flow.
9. Record the values displayed for \( V, Q_s, Q_i, \) and \( Q_{ref} \).
   
   Where:
   
   \[
   \begin{align*}
   V &= \text{regulation valve position compared with the zero position} \\
   Q_s &= \text{flow rate value measured by the instrument standard conditions} \\
   Q_i &= \text{inlet volumetric flow rate value measured using shelter temperature} \\
   Q_{ref} &= \text{indicated flow using the certified flow transfer standard}
   \end{align*}
   \]

10. Repeat the previous steps for all points along the chosen flow range.
11. Press ESC to stop the calibration procedure.
12. Repeat the process for the other channel.
4.3. Monitor Operation

Each monitor should be operated in accordance with the user’s manual. In general, each should:
1. Be properly sited (refer to section 3 in this part).
2. Be connected to a reliable power source.
3. Have a valid calibration prior to collecting usable data.

5.0 Data Acquisition

Data is collected and stored using the Leading Environmental Analysis and Display System (LEADS) data logging system.

Disable data logger during maintenance, calibrations, and audits. This prevents erroneous results from being considered valid by LEADS.

6.0 Data Validation

Data validation criteria were developed from the instruments’ operation manual recommendations and from staff’s operational experience.
# Table 3

**Data Validation Criteria**

## Flow Rate:

<table>
<thead>
<tr>
<th>Limit</th>
<th>Action</th>
</tr>
</thead>
</table>
| $PM_{2.5} < \pm 4.1\%$ of transfer standard;  
$PM_{2.5} < \pm 5.1\%$ of design value  
$PM_{10}$ Verification $< \pm 7.1\%$ of transfer standard  
$PM_{10}$ Audit $< \pm 10.1\%$ of transfer standard | Data valid. Flow in-calibration. Flows for $PM_{10}$ Calibration will be adjusted if $\geq \pm 4.1\%$ of transfer standard. |
| $PM_{2.5} \geq \pm 4.1\%$ of transfer standard;  
$PM_{2.5} \geq \pm 5.1\%$ of design flow  
$PM_{10}$ Verification $\geq \pm 7.1\%$ of transfer standard  
$PM_{10}$ Audit $\geq \pm 10.1\%$ of transfer standard | Data invalid for verification. Invalid period back to last good flow check. Calibration is performed.  
Data suspect for audit and must be confirmed by verification. |

## Leak Check (TEOM for $PM_{10}$)

<table>
<thead>
<tr>
<th>Limit</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Flow $\leq 0.15$ L/min</td>
<td>Data valid. Pass, no action.</td>
</tr>
</tbody>
</table>
| Main Flow $> 0.15$ L/min            | Data invalid for verification. Invalid period back to last good leak check. Maintenance performed followed by another leak check.  
Data suspect for audit and must be confirmed by verification. |
| Aux Flow $\leq 0.60$ L/min          | Data valid. Pass, no action.                                                                                             |
| Aux Flow $> 0.60$ L/min             | Data invalid for verification. Invalid period back to last good leak check. Maintenance performed followed by another leak check.  
Data suspect for audit and must be confirmed by verification. |

## Leak Check (BAM)
<table>
<thead>
<tr>
<th>Limit</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1.5 L/min</td>
<td>Data Valid. Pass, no action.</td>
</tr>
<tr>
<td>≥ 1.5 L/min</td>
<td>Data invalid for verification. Invalid period back to last good leak check. Maintenance performed followed by another leak check. Data suspect for audit and must be confirmed by verification.</td>
</tr>
</tbody>
</table>

**Leak Check (API 602)**

<table>
<thead>
<tr>
<th>Limit</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>External ≤ 15.1 mL/min</td>
<td>Data valid. Pass, no action.</td>
</tr>
<tr>
<td>External &gt; 15.1 mL/min</td>
<td>Data invalid for verification. Invalid period back to last good leak check. Maintenance performed followed by another leak check. Data suspect for audit and must be confirmed with verification.</td>
</tr>
<tr>
<td>Internal ≤ 5.1 mL/min</td>
<td>Data valid. Pass, no action.</td>
</tr>
<tr>
<td>Internal &gt; 5.1 mL/min</td>
<td>Data invalid for verification. Invalid period back to last good leak check. Maintenance performed followed by another leak check. Data suspect for audit and must be confirmed with verification.</td>
</tr>
</tbody>
</table>

**Temperature and Barometric Pressure:**

<table>
<thead>
<tr>
<th>Limit</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; ±2.1 °C</td>
<td>Data valid. Pass, no action</td>
</tr>
<tr>
<td>≥ ±2.1 °C</td>
<td>Data valid. Site operator recalibrates temperature sensor.</td>
</tr>
<tr>
<td>&lt; ±10.1 mmHg</td>
<td>Data valid. Pass, no action</td>
</tr>
<tr>
<td>≥ ±10.1 mmHg</td>
<td>Data valid. Site operator recalibrates barometric pressure sensor.</td>
</tr>
</tbody>
</table>
7.0 Verification and Performance 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 the group performing the calibrations. Verifications and performance audits should be conducted under the following guidelines:

- Audits must be done without special preparation or adjustments made to the system.
- The individual performing the audit must be someone other than the routine operator and must have a thorough knowledge of all instruments or processes being evaluated.
- All aspects of the verification and audit must be completely documented including the types of instruments and transfer standards, model numbers and serial numbers of instruments and transfer standards, calibration information, etc.
- The samplers in the state of Indiana’s ambient monitoring network have verifications performed monthly by the Ambient Monitoring Section, and audits performed quarterly by the Quality Assurance Section.

Audits should start at the beginning of an hour or at least completed during the hour to minimize data loss.

7.1 Flow-Rate Verification and Performance Audit Procedures

7.1.1 Equipment

- Chinook Engineering Streamline flow transfer standards (FTS).
- Certified digital manometer.
- Certified digital or aneroid barometer
- Certified temperature probe(s) or thermometer(s)
- Accurate time piece
- Relative humidity meter (SHARP)
- Certified zero/span foil kit (SHARP)
- Temperature sensor dummy wires (SHARP)

Equations

**Table 4**

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>mmHg to atmospheres (atm)</td>
<td>mmHg/760</td>
</tr>
<tr>
<td>atm to mmHg</td>
<td>atm*760</td>
</tr>
<tr>
<td>°C to Kelvin (K)</td>
<td>°C + 273</td>
</tr>
</tbody>
</table>

True Flow Calculation
Where:

\[ Q_{true} = m \sqrt{\frac{\Delta P \cdot T_{amb}}{P_{amb}}} + b \]

\[ % \text{Difference} = \left( \frac{Q_{ob} - Q_{true}}{Q_{true}} \right) \times 100 \]

Where:

\[ Q_{true} = \text{True flow rate, } m^3/\text{min} \]
\[ \Delta P = \text{Manometer pressure drop (in Hg)} \]
\[ P_{amb} = \text{Ambient barometric pressure, mmHg} \]
\[ T_{amb} = \text{Ambient temperature K} \]
\[ m = \text{FTS slope} \]
\[ b = \text{FTS intercept} \]

If the sampler requires the conversion of actual/standard flow, use the following equation:

\[ Q_{std} = Q_{a}(P_{a}/P_{std})(T_{std}/T_{a}) \]
\[ Q_{a} = Q_{std}(P_{std}/P_{a})(T_{a}/T_{std}) \]

Where:

\[ Q_{std} = \text{Standard volume flow rate, } m^3/\text{min} \]
\[ Q_{a} = \text{Actual volume flow rate, } m^3/\text{min} \]
\[ P_{a} = \text{Ambient barometric pressure, mmHg} \]
\[ P_{std} = \text{Standard barometric pressure, 760 mmHg} \]
\[ T_{std} = \text{Standard temperature, } 298 \text{ K (25 °C + 273)} \]
\[ T_{a} = \text{Ambient temperature, K (°C + 273)} \]

Relative Humidity (SHARP) calculation

\[ RH_{T2} = RH_{Ref} \times e^{-5161.8\left(\frac{1}{T_{Ref}} - \frac{1}{T_{2}}\right)} \]

Where:

\[ RH_{T2} = \text{SHARP Relative Humidity in %} \]
\[ RH_{Ref} = \text{Reference Relative Humidity in %} \]
\[ T_{Ref} = \text{Reference Ambient Temperature in K} \]
\[ T_{2} = \text{SHARP Sample Temperature in K} \]

Difference, in Percent calculation
\[ Diff = \left( \frac{V_{Obs} - V_{Ref}}{V_{Ref}} \right) \times 100 \]

Where:

- \( V_{Ref} \) = Reference Value
- \( V_{Obs} \) = Observed Value
- \( Diff \) = Difference in percent

7.2 Overview of Verification and Audit Procedures

The following is only a general guide. For more detailed, sampler specific instructions, refer to the user’s manual and instrument specific SOPs. For each sampler, ensure the sampler time is within 5 minutes of local standard time and the date is correct. If not, site operators performing the verification should make adjustments and document this, while auditors should make note and contact the site operator.

7.2.1 TEOM Verification and Audit Procedure (for \( PM_{10} \))

1. Place a certified temperature probe or thermometer near the TEOM’s temperature sensor and allow to equilibrate.

2. Measure and record on the TEOM verification/audit form the ambient temperature (°C) and ambient barometric pressure (mmHg). Allow sufficient time for the temperature probe to equilibrate to ambient conditions and ensure that the probe is not in direct sunlight or not in contact with any surfaces. The TEOM’s ambient temperature should be within 2.0°C while the barometric pressure should be within 10.0 mmHg of the reference values collected.

3. On the control unit, note the observed ambient temperature and pressure. Record the TEOM status/mode, serial number, filter loading, date and time, and the last calibration date.

4. Disable the corresponding LEADS channel and press F1 on the TEOM keypad to flag the data. Note the start time.

5. Access the sample inlet and remove the inlet by gently twisting and lifting. Place a certified flow transfer standard on the down tube. The use of a separate high (total flow) and low (main flow) flow FTS may be required. Allow the flow to equilibrate.

6. Record the pressure drop. Note the TEOM indicated flow. The total indicated flow should be within 10.0% of the reference flow for the audit; greater than ± 7.0% is valid, but will require a recalibration; and within 7.0% of the reference flow for the verification.

7. Remove the green auxiliary line and plug the port.

8. Once more, allow the flow to equilibrate, record the pressure drop, and note the TEOM indicated flow. The TEOM indicated main flow should be ±0.2 L/min of the reference.

9. Remove the plug and reattach the green auxiliary line.
10. Remove the flow transfer standard and replace with a flow audit device for a leak check. Close the flow audit device.

11. Record the flow values for the main and total flows. The main flow value should be \(< 0.15 \text{ L/min}\), the total flow \(< 0.6 \text{ L/min}\).

12. Remove the flow audit device and replace the inlet.

13. Enable the corresponding LEADS channel and leave an electronic operator log entry.

7.2.2 BAM Verification and Audit Procedure

1. A BAM verification/audit should be initiated while the unit is in SAMP/COUNT/COUNTING mode.

2. Place a certified temperature probe or thermometer near the BAM’s temperature sensor and allow to equilibrate. Ensure that the probe is not in direct sunlight or not in contact with any surfaces.

3. Measure and record on the BAM Audit Form the ambient temperature (°C) and ambient barometric pressure (mmHg). The BAM’s ambient temperature should be within 2.0°C, while the barometric pressure should be within 10.0 mmHg of the reference values collected.

4. On the control unit, note the observed ambient temperature and pressure. This can be accessed by pressing the F1 Current key.

5. Press the EXIT soft key and record the BAM status/mode, serial number, filter tape remaining, date and time, and the last calibration date.

6. Disable the corresponding LEADS channel.

7. On the BAM control unit, press the TEST soft key to access the TEST menu. Use the left/right arrows to select PUMP and enter the PUMP screen.

8. The pump should be off before starting a flow audit.

9. Remove the inlet head and attach a certified flow transfer standard. If a VSCC is present, leave in line.

10. Return to the control unit and press the PUMP ON soft key. Note the BAM’s indicated flow.

11. Collect a reference flow from the certified flow transfer standard. The BAM should be within 4% of the reference flow and 5% of the design value. Contact the site operator if it fails.

12. Return to the control unit and press the PUMP OFF soft key.

13. Remove the certified transfer standard and attach a flow audit device to begin a leak check.

14. Return to the control unit and press the PUMP ON soft key. The indicated flow should be \(< 1.5 \text{ L/min}\). Contact site operator if it fails.
15. Press the PUMP OFF soft key. Slowly open and then remove the flow audit device. Replace the inlet.

16. Return to the control unit and press the EXIT soft key twice to get back to the main menu. Select the OPERATE soft key to move to the Operate Mode screen. Ensure that the BAM OPERATE and STATUS commands are ON.

17. Press the NORMAL soft key to return the instrument to normal operation. It should now show the Normal display screen.

18. Enable the corresponding LEADS channel and leave an electronic operator log entry.

7.2.3 SHARP Verification and Audit Procedure

1. Check for any status/error lights and ensure that the instrument is in working order.

2. Measure and record on the Sharp Verification/Audit Form the ambient temperature (°C) and barometric pressure (mmHg). Allow sufficient time for the temperature probe to equilibrate to ambient conditions and ensure that the probe is not in direct sunlight or not in contact with any surfaces. The SHARP’s ambient temperature should be within 2.0°C of the reference value. The SHARP’s barometric pressure should be within 10.0 mmHg of the reference value.

3. Disable the corresponding LEADS channel. Note the start time

4. The SHARP ambient temperature ($T_1$) can be reached through the Operation/Temperature Control System Menu. The ambient barometric pressure ($P_3$) is accessed through the Service Menu / Hardware Diagnostics Menu.

5. For the audit check performed 6 months after an annual calibration, all temperatures and the relative humidity will be checked, as well as the mass foil and nephelometer zero. These procedures are performed like the annual calibration except no adjustments are made (see SHARP calibration procedure in this chapter or consult the instrument manual). All of the temperatures should be within 2.0°C of the reference value and for relative humidity 3.0% RH of the reference value.

6. The SHARP relative humidity and sample temperature values can be found in the Diagnostics Menu.

7. Remove the relative humidity meter, if performed and the temperature probe.

8. Enter the Calibration Menu and unlock the keys. Use the calibration code to unlock the Calibration Menu and enter the Air Flow Menu to turn the pump off.

9. Exit the Calibration Menu and enter the Service Menu. Under the Hardware Diagnostics submenu note the $P_1$ (orifice pressure) and $P_2$ (vacuum pressure) values, which should be close to zero.

10. Remove the inlet from the down tube. If a VSCC is present, leave in place.

11. Attach a certified flow transfer standard to the down tube. Turn the pump on and allow flow to equilibrate for at least 5 minutes.
12. The SHARP indicated flow can be viewed in the Calibration Menu / Air Flow Menu.

13. Compare the SHARP indicated flow with the reference and record on the SHARP Verification/Audit Form. The values should be within 4%. The reference flow should be within 5.0% of the design value.

14. Exit and return to the Calibration Menu / Air Flow Menu and turn the pump off.

15. Remove all verification/audit equipment. Record the operational pump power in the Display Menu.

16. Lock the keys pad and return the instrument to operation. Note the end time, enable the corresponding LEADS channel, and leave an entry in the electronic operator log.

7.3 Verification and Audit Data Reporting

Inform the site or network operator of the verification and audit results as soon as possible after completion. A paper copy may be forwarded to the operator or personnel may view the results in the database. If the audit produces poor results, the auditor should promptly inform the operator verbally and in written form (memo or e-mail).

7.4 Verification and Audit Frequency

The Indiana Department of Environmental Management conducts verifications of all real-time particulate monitors in its network at least once each month and audits quarterly to ensure minimal data loss.

7.5 Systems Audit

A system audit is a review of the total monitoring process from site location, safety, sampling to final analysis, and data reporting; and includes an on-site inspection. System audits are generally done at the initial set up of a network and on an annual or on an as needed basis thereafter. The specific guidelines and procedures for this type of audit are found in Chapter 15 of this manual, Quality Systems Audit Criteria and Procedures for Evaluating Ambient Air Monitoring Networks.

8.0 Precision and Accuracy Assessment

8.1 Precision

Precision is the measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is estimated by the use of a duplicate or collocated sampler at a selected monitoring location in a measurement network. One sampler is designated as the reporting sampler and one sampler is designated as the collocated sampler. The collocated sampler must be maintained, operated, calibrated, and audited in the same manner as the reporting sampler. Precision is calculated from the difference in the concentrations from the reporting and collocated samplers over a calendar quarter.
8.2 Accuracy

The accuracy of the 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. Two flows rates are audited on the R&P TEOM® monitor: the main flow which is approximately 3 L/min and the total flow which is approximately 16 L/min. Only the total flow is used to estimate accuracy. Accuracy 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. IDEM OAQ QAS audits all continuous PM$_{2.5}$/PM$_{10}$ samplers in its monitoring network at least once each quarter. This audit frequency provides additional accuracy, flow rate data, and ensures minimal data loss due to “out-of-calibration” conditions.

9.0 Maintenance

Routine preventive maintenance helps prevent failures of the monitoring processes. The overall objective is to increase measurement reliability and prevent data loss. Follow the manufacturer’s recommended guidelines for routine maintenance procedures.

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 Recommended Maintenance and Frequency

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean PM$<em>{10}$ or PM$</em>{2.5}$ inlet</td>
<td>Monthly</td>
</tr>
<tr>
<td>Large bypass in-line filter exchange</td>
<td>6 months</td>
</tr>
<tr>
<td>Battery test</td>
<td>6 months – change if necessary</td>
</tr>
<tr>
<td>Pump test</td>
<td>6 months (or pump power &gt;95% in SHARP)</td>
</tr>
<tr>
<td>Clean air inlet system</td>
<td>1 year</td>
</tr>
<tr>
<td>Rebuild pump</td>
<td>1 year – or as needed</td>
</tr>
</tbody>
</table>
9.2 As Needed Maintenance

- Exchange fuses
- Clock adjustment
- Resetting system
- System software download

10.0 Forms

*Continuous PM$_{10}$ and PM$_{2.5}$ monitoring use the same calibration and audit forms.
Form 1
TEOM Calibration Form

<table>
<thead>
<tr>
<th>Thermo Fisher TEOM 1405 Calibration Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site:</td>
</tr>
<tr>
<td>AIBS Number:</td>
</tr>
</tbody>
</table>

**Reference Calibration Information**

<table>
<thead>
<tr>
<th>FFS SN</th>
<th>Cert Date</th>
<th>BIOS SN</th>
<th>Cert Date</th>
<th>BP SN</th>
<th>Cert Date</th>
<th>TEMP SN</th>
<th>Cert Date</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Initials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Flow Calibration**

<table>
<thead>
<tr>
<th>AMB Temp</th>
<th>BP</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Main Flow As Found</th>
<th>LPM</th>
<th>Bypass Flow As Found</th>
<th>LPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Set Point</td>
<td>LPM</td>
<td>Low Set Point</td>
<td>LPM</td>
</tr>
<tr>
<td>High Set Point</td>
<td>LPM</td>
<td>High Set Point</td>
<td>LPM</td>
</tr>
<tr>
<td>Mid Set Point</td>
<td>LPM</td>
<td>Mid Set Point</td>
<td>LPM</td>
</tr>
<tr>
<td>Main Flow As Left</td>
<td>LPM</td>
<td>Bypass Flow As Left</td>
<td>LPM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slope</th>
<th>Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sensor Calibration**

<table>
<thead>
<tr>
<th>Ambient Temp:</th>
<th>Barometric Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>AT Screen</td>
<td>BP Screen</td>
</tr>
<tr>
<td>Programmed</td>
<td>Programmed</td>
</tr>
</tbody>
</table>

**Leak Checks**

<table>
<thead>
<tr>
<th>Leak Check 1</th>
<th>Leak Check 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Flow</td>
<td>Main Flow</td>
</tr>
<tr>
<td>Aux Flow</td>
<td>Aux Flow</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pass?</th>
<th>Pass?</th>
</tr>
</thead>
</table>

**Other Calibration Checks**

<table>
<thead>
<tr>
<th>Analog Out</th>
<th>Test Point 1</th>
<th>Actual</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mass Transducer</th>
<th>Programmed</th>
<th>Audit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

**Comments**

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
Form 2
TEOM® PM$_{10}$/PM$_{2.5}$ Audit Form

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Audit Device/Model</th>
<th>Serial No.</th>
<th>Cert Date</th>
<th>Slope (m)</th>
<th>Intercept (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp</td>
<td>VWR Scientific Model 100A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baro Press</td>
<td>Digital Barometer AIR HB-1A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Rate</td>
<td>Chinook FTS - High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chinook FTS - Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
Q_{\text{sw}} = \frac{\rho \cdot L_{\text{final}} - L_{\text{start}}}{P_{\text{amb}}} + b
\]

\[
T_{\text{amb}} = T^\circ C + 273
\]

\[
P_{\text{amb}} = \frac{BP_{\text{mmHg}}}{760}
\]
Form 3
TEOM® PM10 / PM2.5 Verification Form

TEOM PM10 Verification Form

Site: ______________ Date: __/__/__ Initials: ______________

Monitor SN: ___________________________ AQS #: 18 - - - - - -

FTS SN's: High: ______________ Last Cert: __/__/____
Low: ______________ Last Cert: __/__/____
Temperature Ref: ______________ Last Cert: __/__/____
Pressure Ref: ______________ Last Cert: __/__/____

ST: ______ ET: ______ Monitor Status: __________ Filter Loading %: ______

Ambient Temp. Probe TEOM: __________ °C Thermometer: __________ °C
(Should be within 2.0 °C, allow plenty of time for equilibration)

Ambient Pressure: TEOM: __________ atm Barometer: __________ mmHg / __________ atm
(Should be within 10 mmHg or .013 atm.)

Leak Check 1: Follow Tutorial Wizard. SENSOR FILTER MUST BE REMOVED

Main Flow = ___________ LPM (Should drop below 0.15 LPM)
Bypass Flow = ___________ LPM (Should drop below 0.60 LPM)

Flow Audit: Follow Tutorial Wizard: AUDIT SENSOR FILTER MUST BE INSTALLED

Monitor Total Flow = ___________ LPM Monitor Main Flow = ___________ LPM

Audit Total Flow (16.67 LPM +/- 4%) = ___________ - Percent Difference = ______% 
FTS Slope (m): ___________ Intercept (b): ___________ Inches H2O;
% Dif for Design Flow Rate = 100 x [Ref Total Flow - 16.67 / 16.67] : ______ (±5%) Pass or Fail

Audit Main Flow (3.0 LPM +/- 4%) = ___________ - Percent Difference = ______% 
FTS Slope (m): ___________ Intercept (b): ___________ Inches H2O;
% Dif for Design Flow Rate = 100 x [Ref Main Flow - 3.00 / 3.00] : ______ (±5%) Pass or Fail

Leak Check 2: Follow Tutorial Wizard. SENSOR FILTER MUST BE REMOVED

Main Flow = ___________ LPM (Should drop below 0.15 LPM)
Bypass Flow = ___________ LPM (Should drop below 0.60 LPM)

Comments:
________________________________________________________________________
________________________________________________________________________
Form 4:  
BAM Calibration Form

BAM Calibration  
Office of Air Quality – Air Monitoring Branch

Date: __________  Site: ______________  Performed by: __________
Start Time: ______  End Time: ______  Serial Number: ______
Last Cal: ______

Audit Device Information:
FTS SN: __________  Certification Date: ______m: ______d: ______
Thermometer SN: ______  Certification Date: ______
Barometer SN: ______  Certification Date: ______

Audit Data:
Display BP: ______ mmHg  Reference BP: ______ mmHg  Pass or Fail (+/- 10 mmHg)
Display Temp: ______ °C  Reference Temp: ______ °C  Pass or Fail (+/- 2 degrees)

Flow Audit:
Ambient Temp: ______ °C + 273.15 = ______K  Kelvin BP: ______ mmHg/760 = ______ atm
BAM Display: ______ LPM Observed Flow  
Circle one: Standard or Actual?  If in Standard LPM please convert to Actual LPM  
Converted flow: ______ LPM
Manometer Reading: ______ inches of Water  
Reference Flow: ______ LPM  
% Difference: ______ Pass if % Difference < 3%  
Leak Check: ______ Pass if better than 1.5 LPM

Formulas and Conversions:
Reference Flow = m x √(ΔP x T_a)/BP + b
Actual Flow = Standard Flow x (760/298 x (T_ref/P_ref))
% Difference = (Observed Flow – True Flow x 100)/True Flow

Comments: __________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
## Calibration Data:

<table>
<thead>
<tr>
<th>Target</th>
<th>BAM</th>
<th>Reference</th>
<th>Inches of H₂O</th>
<th>Calibrated</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Temp</td>
<td></td>
<td></td>
<td>XXXXXXXXXX</td>
<td>XXXXXXXXXX</td>
<td></td>
</tr>
<tr>
<td>BP</td>
<td></td>
<td></td>
<td>XXXXXXXXXX</td>
<td>XXXXXXXXXX</td>
<td></td>
</tr>
<tr>
<td>Flow 1: 15.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow 2: 18.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow 3: 16.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter Temp</td>
<td></td>
<td></td>
<td>XXXXXXXXXX</td>
<td>XXXXXXXXXX</td>
<td></td>
</tr>
<tr>
<td>Filter RH</td>
<td></td>
<td></td>
<td>XXXXXXXXXX</td>
<td>XXXXXXXXXX</td>
<td></td>
</tr>
</tbody>
</table>

Slope: __________ Intercept: __________
Amb Temp: __________ K Barometric Pressure: __________ atm Post cal Leak Check: __________

<table>
<thead>
<tr>
<th>BAM Output</th>
<th>Multimeter</th>
<th>Zeno Raw</th>
<th>Zeno Scaled</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.200</td>
<td></td>
<td></td>
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<td>0.300</td>
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<td>0.400</td>
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<td>0.500</td>
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<td>0.600</td>
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<td>0.700</td>
<td></td>
<td></td>
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<td>0.800</td>
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<td></td>
</tr>
<tr>
<td>0.900</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Self Test Pass: __________ Intercept Adjustment Required: __________
Reference Membrane Foil Span (ABS): OLD = __________ NEW AVG = __________ % Diff = __________
ABS Test 1: __________ 2: __________ 3: __________ 4: __________
Background Zero: OLD = __________ Zeroed: Y or N NEW = __________
Pump Changed or Rebuilt: __________ Down Tube Cleaned: __________ Nozzle/Vane Cleaned: __________
Flow Controller Filter Changed: __________ Date/Time Adjustment: __________ Mode on Departure: __________
## Form 5
### BAM Audit Form

### BAM Audit Worksheet

<table>
<thead>
<tr>
<th>Site &amp; AQS #:</th>
<th>Drive</th>
<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditor:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sampler:</td>
<td>Met One BAM 1020</td>
<td></td>
</tr>
<tr>
<td>Serial No.:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cal Date:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last Audit/Verification</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Audit Devices

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Serial No.</th>
<th>Cert Date</th>
<th>Slope</th>
<th>Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow: Chinook FTS - High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp: VWR Model 100A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP: Alr HB-1A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Audit Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>QA</th>
<th>BAM</th>
<th>Diff</th>
<th>Limit</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Temperature, °C</td>
<td></td>
<td></td>
<td></td>
<td>0.0</td>
<td>± 2 °C</td>
</tr>
<tr>
<td>Barometric Pressure, mmHg</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>± 10 mm Hg</td>
</tr>
</tbody>
</table>

### Flow Rate Audit

**Flow Conditions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barometric Pressure, mm Hg</td>
<td>0</td>
<td>atm</td>
</tr>
<tr>
<td>Ambient Temperature, °C</td>
<td>0.0</td>
<td>°C</td>
</tr>
<tr>
<td>BAM flow rate, LPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manometer, (inches H₂O)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QA</th>
<th>BAM</th>
<th>Diff</th>
<th>Limit</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>± 4%</td>
<td></td>
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### Leak Check

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak Check, LPM</td>
<td>&lt;1.5 LPM</td>
<td></td>
</tr>
</tbody>
</table>

### Comments
Form 6
BAM Verification Form

Met One BAM 1020 Monthly Verification
New Form
Office of Air Quality – Air monitoring Branch

Date: ___________ Site: ___________ Performed by: ___________
Start Time: _______ End Time: _______ Serial Number: _______
Last Cal: _______

Audit Device Information:
FTS SN: ___________ Certification Date: _______ m: ______ b: _______
Thermometer SN: ___________ Certification Date: ___________
Barometer SN: ___________ Certification Date: ___________

Audit Data:
Display BP: _______ mmHg Reference BP: _______ mmHg Pass or Fail (+/- 10 mmHg)
Display Temp: _______ °C Reference Temp: _______ °C Pass or Fail (+/- 2 degrees)

Flow Audit:
Ambient Temp: _______ °C + 273.15 = _______ Kelvin BP: _______ mmHg/760 = _______ atm

BAM Display: _______ LPM Observed Flow
Manometer Reading: _______ inches of Water
Reference Flow: _______ LPM
% Difference Flow Rate: _______ Pass if % Difference ± 4%
% Difference from Design Flow Rate: _______ Pass if % Difference ± 5%
Leak Check: 1. _______ 2. _______ Pass if better than 1.5 LPM

Nozzle Cleaned: ___________ Self Test Pass: ___________
1st Stage Inlet Changed: old ______ new ______ Date and Time Match Logger: ___________
Operator Log Filled Out: ___________ Channel Reenabled in LEADS: ___________

Formulas and Conversions:
Reference Flow = m × √((ΔP × T₀)/BP) + b
% Difference Flow Rate = (Observed Flow – True Flow) × 100
True Flow
% Difference from Design Flow Rate = (True Flow – 15.7) × 100
16.7
**Form 7**  
**SHARP Calibration Form**

**SHARP Calibration Form**

<table>
<thead>
<tr>
<th>Site:</th>
<th>Instrument Model No:</th>
<th>Instrument Ser. No:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date:</th>
<th>Time:</th>
<th>FTS Ser No:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I. **Sensor Calibration**

   a. $T_1$ Current = _____  $T_1$ Reference = _____  $T_1$ Cal’d = _____
   b. $T_2$ Current = _____  $T_2$ Reference = _____  $T_2$ Cal’d = _____
   c. $T_3$ Current = _____  $T_3$ Reference = _____  $T_3$ Cal’d = _____
   d. $T_4$ Current = _____  $T_4$ Reference = _____  $T_4$ Cal’d = _____
   e. BP Current = _____  BP Reference = _____  BP Cal’d = _____

II. **Flow Calibration**

   a. SHARP Indicated flow = _____ $L$/hour / 60 min = _____ $L$/min
   b. Manometer Reading = _____ in H$_2$O  Slope: _____  Intercept: _____
   c. FTS Flow = _____ $L$/min X 60 min = _____ $L$/hour
   d. Ref. T1 = _____  Ref. BP = _____
   e. Calibrated SHARP flow = _____

III. **Instrument Zero**

   a. Nepheleometer  
      
      As Found  
      As Left  
      
      Neph. Concentration = _____ $ug/m^3$  = _____ $ug/m^3$
      
      Neph. Analog Value = _____  = _____
      
      Zeroed? Circle Yes or NO (if yes, then fill out "As Left")

IV. **Mass Flow Calibration**

   a. Current (Old) Amplification = _____
   b. Audit (New) Amplification = _____
   c. % Difference = 100 x [ (Old - New) / New ] = _____%  

V. **Detector Zero (FC + Z)**

   I. Avg. $R_d$ = _____  Is $R_d$ < 1.0?  YES ____ NO____
   II. Avg. $R_z$ = _____
   III. Avg. $R_{ref}$ = _____

   Is $R_{ref}$ between 40-60% of $R_z$?  YES ____ NO____
SHARP Calibration Form (Continued)

IV. RH Sensor Calibration
   a. RH Current _______ RH Reference _______ RH Calibrated _______

IV. Operational Pump Power = _________ %

III. Other Pressure Sensors
   a. \( P_1 \) @ zero = _______ hPa  Span/Operational \( P_1 \) = _______ hPa
   b. \( P_2 \) @ zero = _______ hPa  Span/Operational \( P_2 \) = _______ hPa

FC+Z Performed? YES or NO _______________________

VSCC and 1st Stage inlet cleaned/replaced? YES or NO _______________________

Date and Time match data logger? YES or NO _______________________

Keypad locked and channel reenabled in LEADS? YES or NO _______________________

Comments:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Form 9
SHARP Verification Form

SHARP Monthly Data Form

Date: ___________ Site: ___________Performed by: ___________

Start Time: ___________ End Time: ___________Serial Number: ___________ Cal Date: ___________

Audit Device Information:

FTS SN: ___________ Certification Date: ___________m: ___________d: ___________

Thermometer SN: ___________ Certification Date: ___________

Barometer SN: ___________ Certification Date: ___________

I. Temperature Sensors Audit  Allowed Diff = ±2°C Pass _______ Fail _______
   A. Ambient Temp. = T₁ = ___________ °C Ref. Amb. Temp. = ___________ °C

II. Pressure Sensors  Allowed Diff = ±10 mmHg Pass _______ Fail _______
   A. P₁ @ zero = ___________ hPa Span/Operational P₁ = ___________ hPa
   P₂ @ zero = ___________ hPa Span/Operational P₂ = ___________ hPa
   B. Amb. Pressure = P₃ = ___________ hPa = ___________ mmHg
      Ref. Amb. Pressure = ___________ mmHg Conversion: mmHg = hPa x 0.75

III. Instrument Zero  Allowed range = -0.5 to 4.0 mg/m³ Pass _______ Fail _______
   A. Nephelometer  As Found  As Left
      Neph. Concentration = ___________ mg/m³ = ___________ mg/m³
      Neph. Analog Value = ___________ = ___________
      Zeroed? Circle Yes or NO (if yes, then fill out "As Left")
   B. Detector [Perform immediately after FC+2]
      1. Avg. Rₘ = ___________ Is Rₘ<1.0? YES _______ NO _______
      2. Avg. Rₛ = ___________
      3. Avg. Rₑ = ___________ Is Rₑ between 40-60% of Rₘ? YES _______ NO _______

IV. Flow Rate Audit  Allowed Diff. = ±4% Pass _______ Fail _______
   SHARP indicated flow = ___________ L/hour / 60 min = ___________ L/min
   Manometer Reading = ___________ in H₂O Slope: _______ Intercept: _______
   FTS Cal audit flow = ___________ L/min X 60 = ___________ L/hour
   % Difference = 100 X [(Sample - FTS)/FTS] = _______%
   % Difference for Design Flow Rate = 100 X [(FTS Cal Audit Flow - 100)/100] = _______% (Allowed ± 5%)

V. Operational Pump Power = _______%
   VSCH and 1st Stage Inlet cleaned/replaced? YES or NO OLD_______NEW_______
   Date and Time match data logger? YES or NO _______
   Keypad locked and channel reenabled in LEADS? YES or NO _______
   Comments: ___________
# Form 10

## API 602 Calibration Form

### Annual Calibration Information

<table>
<thead>
<tr>
<th>Backup Battery Test</th>
<th>Reference Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Temp</td>
<td>Barometer:</td>
</tr>
<tr>
<td></td>
<td>Thermometer:</td>
</tr>
<tr>
<td>As Found:</td>
<td></td>
</tr>
<tr>
<td>Reference:</td>
<td></td>
</tr>
<tr>
<td>Calibrated:</td>
<td></td>
</tr>
<tr>
<td>Room Temp:</td>
<td>Absolute Pressure:</td>
</tr>
<tr>
<td>As Found:</td>
<td>Reference:</td>
</tr>
<tr>
<td></td>
<td>Calibrated:</td>
</tr>
<tr>
<td>Multi-point Flow Calibration</td>
<td></td>
</tr>
<tr>
<td>Line A</td>
<td>Line B</td>
</tr>
<tr>
<td>0.5 L/min</td>
<td>1.0 L/min</td>
</tr>
<tr>
<td>Z</td>
<td>Q</td>
</tr>
<tr>
<td>Qref</td>
<td>Z</td>
</tr>
<tr>
<td>Qref</td>
<td>Z</td>
</tr>
<tr>
<td>Qref</td>
<td>Z</td>
</tr>
</tbody>
</table>

### Monthly Internal Checks:

- **Internal Leak Test**
  - Line A
  - Pass or Fail?
  - Line B
  - Pass or Fail?

- **Internal Flow Test**
  - Line A Error
  - Pass or Fail?
  - Line B Error
  - Pass or Fail?

### Quarterly Checks:

- **External Leak Check**
  - Line A
  - Pass or Fail?
  - Line B
  - Pass or Fail?

- **Beta Span Check**
  - R1: Error %
  - REF
  - TEST
  - R2: Error %
  - REF
  - TEST

### Comments:

<table>
<thead>
<tr>
<th>Internal Leak Test</th>
<th>Line A</th>
<th>Pass or Fail?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line B</td>
<td>Pass or Fail?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Internal Flow Test</th>
<th>Line A Error</th>
<th>Pass or Fail?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line B Error</td>
<td>Pass or Fail?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>External Leak Check</th>
<th>Line A</th>
<th>Pass or Fail?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line B</td>
<td>Pass or Fail?</td>
<td></td>
</tr>
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Form 11
API 602 Audit Form

### API 602 Quarterly Audit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Audit Device</th>
<th>Serial No.</th>
<th>Cert Date</th>
<th>Slope</th>
<th>Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>Chinook FTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient Pressure</td>
<td>Digital Barometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient Temp</td>
<td>VWR Scientific 100A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Warning/Alarm LEDs

#### Line A (PM10) and Line B (PM2.5)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Temperature Audit</td>
<td></td>
</tr>
<tr>
<td>API Ambient Temp</td>
<td>K</td>
</tr>
<tr>
<td>Ambient Temp, K</td>
<td>0 273.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Pressure Audit</td>
<td></td>
</tr>
<tr>
<td>API Amb. Pressure</td>
<td>kPa</td>
</tr>
<tr>
<td>Amb Press., mm Hg</td>
<td>0.0 0.0</td>
</tr>
</tbody>
</table>

#### Line B (PM2.5)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>API QA</td>
<td>0.00 &lt; 0.05</td>
</tr>
</tbody>
</table>

#### Internal Leak Checks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line A (PM10), mL/(min*kPa)</td>
<td>0.00 &lt; 0.15</td>
</tr>
</tbody>
</table>

### Design Flow Comparison

| Design Flow: | 16.67 |

#### Comments

---

**Amb. Temp, °C = 273.15 K**

**Amb. Press, mm Hg = 0.0000 atm**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate, L/min</td>
<td>0.00 &lt; #DIV/0!</td>
</tr>
</tbody>
</table>

**API 602 indicated flow, m³/hour = 0.00 L/min**

**Amb. Temp, °C = 273.15 K**

**Amb. Press, mm Hg = 0.0000 atm**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate, L/min</td>
<td>0.00 &lt; #DIV/0!</td>
</tr>
</tbody>
</table>

---
# Form 12
## API 602 Verification Form

### Teledyne API 602 Beta Plus Monthly Verification

<table>
<thead>
<tr>
<th>Site:</th>
<th>Evansville Buena Vista</th>
<th>Initials:</th>
<th>LAW</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Date:</th>
<th>11/21/2017</th>
<th>Start:</th>
<th>07:00-08:02</th>
<th>End:</th>
</tr>
</thead>
</table>

| REF FTS SN: | 628        | Slope:    | 0.4033      |
| REF Temp SN:| 31017034   | Intercept:| -0.6284     |
| REF BP SN:  | 1049000102 |           |             |

<table>
<thead>
<tr>
<th>Ambient Temperature:</th>
<th>Barometric Pressure:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated:</td>
<td>Indicated:</td>
</tr>
<tr>
<td>278.4</td>
<td>100.3</td>
</tr>
<tr>
<td>Reference:</td>
<td>Reference:</td>
</tr>
<tr>
<td>278.15</td>
<td>100</td>
</tr>
<tr>
<td>Difference:</td>
<td>Difference:</td>
</tr>
<tr>
<td>0.25</td>
<td>0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Line A PM 10:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated Flow:</td>
</tr>
<tr>
<td>1.00</td>
</tr>
<tr>
<td>Manometer:</td>
</tr>
<tr>
<td>6.74</td>
</tr>
<tr>
<td>% Difference:</td>
</tr>
<tr>
<td>-1.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Line B PM 2.5:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated Flow:</td>
</tr>
<tr>
<td>0.99</td>
</tr>
<tr>
<td>Manometer:</td>
</tr>
<tr>
<td>6.64</td>
</tr>
<tr>
<td>% Difference:</td>
</tr>
<tr>
<td>-1.9%</td>
</tr>
</tbody>
</table>

### Monthly Internal Checks:

<table>
<thead>
<tr>
<th>Line</th>
<th>Error</th>
<th>Pass or Fail?</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.23</td>
<td></td>
<td>PASS</td>
</tr>
<tr>
<td>B</td>
<td>0.05</td>
<td></td>
<td>PASS</td>
</tr>
</tbody>
</table>

### Internal Flow Test:

<table>
<thead>
<tr>
<th>Line</th>
<th>Error</th>
<th>Pass or Fail?</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-1.3</td>
<td></td>
<td>PASS</td>
</tr>
<tr>
<td>B</td>
<td>-0.8</td>
<td></td>
<td>PASS</td>
</tr>
</tbody>
</table>

### Quarterly Checks:

<table>
<thead>
<tr>
<th>Line</th>
<th>Pass or Fail?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
</tbody>
</table>

### Beta Span Check:

<table>
<thead>
<tr>
<th>Line</th>
<th>Error %</th>
<th>REF</th>
<th>TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Comments: