Air Pollution Control Division

Technical Services Program

APPENDIX PM8

Standard Operating Procedure for the Operation of the TAPI Model T640 Particulate Monitor

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TALBE OF CONTENTS

TABLES

FIGURES

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Standard Operating Procedure for the Operation of the API Model T640 Particulate Monitor

1 Scope and Applicability

The Model T640 represents the "Next Generation" version of the real-time PM Mass monitor to measure particulate matter in ambient air. Please refer to the original Teledyne – API manual for a full description and background information on the method.

1.1 Introduction

The Model T640 PM Mass Monitor is an optical aerosol spectrometer that converts optical measurements to mass measurements with sharp accuracy by determining sampled particle size via scattered light at the single particle level according to Lorenz-Mie Theory.

1.2 Method Overview

Briefly, the sampling head draws in ambient air with different-sized particles, which are dried with the Aerosol Sample Conditioner (ASC) and moved into the optical particle sensor where scattered light intensity is measured to determine particle size diameter. The particles move separately into and through the analyzer via an optically differentiated measurement volume that is homogeneously illuminated with polychromatic light. The polychromatic light source, an LED, combined with a 90° scattered light detection achieves a precise and unambiguous calibration curve in the Mie range, resulting in a large size resolution.

Each particle generates a scattered light impulse that is detected at an 85° to 95° angle where amplitude and signal length are measured; the amplitude (height) of the scattered light impulse is directly related to the particle size diameter.

The T-aperture and simultaneous signal length measurements within the analyzer eliminate possible interference, which can be characterized by the partial illumination of particles at the border of the measurement range.

1.3 Format and Purpose

The sequence of topics covered in this SOP follows the *Guidance for Preparing Standard Operating Procedures (SOPs) EPA QA/G-6 (April 2007)*. This method was also written to help field operators understand why (not just how) key procedures are performed.

2 Summary of Detection Method

The quantification of light scattering by particles can be accomplished by using an established theory referred to as Mie Scattering or Lorenz-Mie Scattering. Light scattering in this regime occurs when the diameters of atmospheric particles are similar to the wavelengths of the scattered light. Dust, pollen, smoke and microscopic water droplets are common causes of Mie scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates in cloudy conditions. Mie scattering simply refers to the equations used to quantify the amount of light scattered.

3 DEFINITIONS

The CDPHE/APCD/TSP QAPP contains an appendix of acronyms and definitions. Any commonly used shorthand designations for items such as the sponsoring organization, monitoring site, and the geographical area will be defined and included in this SOP or in the QAPP Appendix P2.

4 HEALTH AND SAFETY WARNINGS

Chemical Hazards

Gas Hazards

Electrical Hazards

1. Always use a third ground wire on all instruments.

2. If it is necessary to work inside an analyzer while it is in operation, use extreme caution to avoid contact with high voltage inside the analyzer. The analyzer has high voltages in certain parts of the circuitry, including a 110 volt AC power supply. Refer to the manufacturer's instruction manual and know the precise locations of these components before working on the instrument

3. Avoid electrical contact with jewelry. Remove rings, watches, bracelets, and necklaces to prevent electrical burns.

4. Always unplug the analyzer whenever possible when servicing or replacing parts.

Physical Hazards

1. The TAPI Model T640 light source contains a light emitting diode (LED) radiating UV and visible light. Precautions must be taken to prevent looking directly at the UV light with unprotected eyes. NEVER touch or look directly into the Model T640 light source.

5 CAUTIONS

To prevent damage to the equipment, the following precautions should be taken:

1. In the event that it is necessary to clean the optical bench, be careful to avoid damaging the interior of the sample chamber. Avoid dropping the instrument. This may damage the instrument and necessitate expensive repairs. Use maintenance procedures outlined in the manufacturer's instruction manual.

2. Keep the interior of the analyzer clean.

3. Inspect the system, especially the sampling train, regularly for structural integrity.

4. To prevent major problems with leaks, make sure that all sampling lines are reconnected after required checks and before leaving the site.

5. Inspect tubing for cracks and leaks.

6. It is recommended that the analyzer be leak checked after replacement of any part of the sampling train.

6 INTERFERENCES

The T640 utilizes a sample humidity control system, Aerosol Sample Control (ASC), to remove water of the aerosol to avoid false particle size. Its operation includes an air sensor for measuring ambient temperature and humidity in order to dynamically adjust the heating of the ASC tube for moisture/humidity compensation.

7 PERSONNEL QUALIFICATIONS

General Personnel Qualifications are discussed in the CDPHE/APCD/TSP QAPP main body.

8 APPARATUS AND MATERIALS

8.1 Monitoring Equipment

8.1.1 Analyzers

8.1.1.1 API T640 Spectrometer

The API T640 has several main components, discussed below. The layout of the instrument chassis is presented here, in Figure 1:

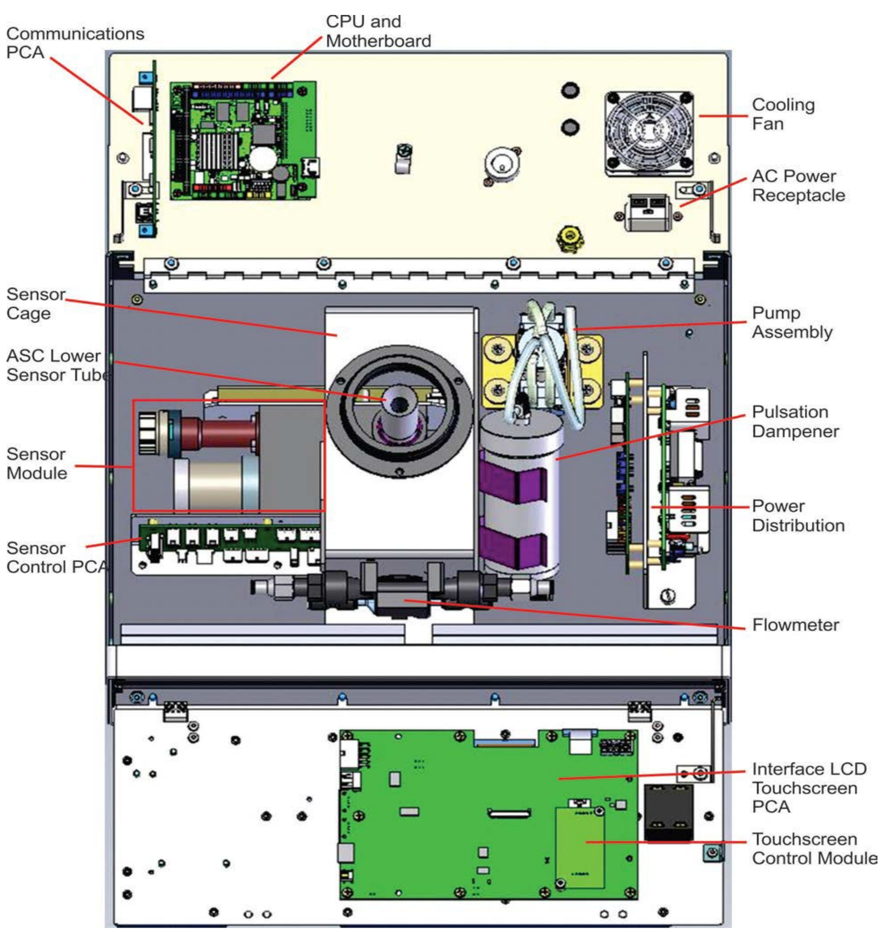


Figure 1: API T640 Layout

8.1.1.1.1 API T640 Inlet

The inlet for the T640 is not size selective and allows transmission of all particle sizes.

8.1.1.1.2 API T640 Aerosol Sampling Conditioner (ASC)

The ASC removes water from the sample stream to avoid attributing extra water as additional particle size. Its operation includes an air sensor for measuring ambient temperature and humidity in order to dynamically adjust the heating of the ASC tube for moisture/humidity compensation.

8.1.1.1.3 Optical Particle Sensor

The optical particle sensor is the main sensor in the instrument. This sensor analyzes the particles, categorizing them by size, count, and in conjunction with the flow sensor, making the conversion to a mass concentration.

8.1.1.1.4 Flow Sensor and Pump Control

The T640 measures mass flow in conjunction with actual ambient temperature and pressure to control flow to actual volumetric conditions. The flow stream is designed to sample at 5 lpm, a feedback loop triggers the pump drive voltage adjustments to maintain a constant volumetric flow. The actual volumetric flow is reported and used in concentration calculations. The internal vacuum pump is a 24V DC pump controlled by a pulse-width modulation (PWM) feedback control for consistently accurate flow to the sensor.

8.1.2 Instrument Shelter

A shelter is required to protect the analyzer from precipitation and adverse weather conditions, maintain operating temperature, provides security and electrical power. The following are operation shelter temperature requirements for the SLAMS and NCore networks (US EPA, 2013) (US EPA, 2005).

> SLAMs: 5-38 °C (20-30 °C preferred), evaluated on hourly averages at <± 2 °C Standard Deviation over 24 hours.
>
> NCore: 20-30°C, evaluated on hourly averages, daily changes in hourly temperature should not exceed ± 5 °C over a 24-hour period.

8.1.3 Data Acquisition System

The APCD employs three different models of onsite, data acquisition system equipment (DAS) in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, and the Agilaire 8872 data logger. The 8816 model is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. The following are descriptions of these data loggers.

ESC 8816 Data Logger

The ESC Model 8816 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8816 is designed around an expansion bus that gives the user great flexibility in configuring the unit with a combination of analog and serial input and output (I/O) types.

For more details, refer to Appendix D1 of this QAPP, APCD’s Datalogger & Central SOP or the individual operator manuals (Environmental Systems Corporation, 2001).

ESC 8832 Data Logger

The ESC Model 8832 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8832 is designed around an expansion bus that gives the user great flexibility in configuring the unit with almost any combination of input and output types. It is the successor to the 8816 data logger and is more robust in numerous areas. Of significance is expanded memory, faster processing speeds, faster communication speeds, remote Ethernet communications and polling and Modbus enabled communications with peripheral devices.

For more details, refer to Appendix D1 of this QAPP, APCD's Datalogger & Central SOP or the individual operator manuals (Environmental Systems Corporation, 2006).

Agilaire 8872 Data Logger

The Model 8872 is a Windows-based data logger, a departure from the earlier 8816 / 8832 embedded systems designs. The 8872 includes a number of hardware and software features to ensure that the device matches the field reliability of the 8832, while offering the convenience of a Windows-based platform and integration with Agilaire's AirVision software.

The core of the 8872 is a fan-less PC, typically equipped with 2 GB of RAM. The device can be equipped with a 160 GB standard hard drive or, more commonly, a 64 GB solid state flash drive (SSD). For all digital versions of the 8872, the remainder of the enclosure simply provides convenient universal serial bus (USB), serial, and VGA I/O connections in a standard 3U rack mount enclosure, a form factor similar to the 8816 / 8832 family. However, the 8872 also supports traditional analog/discrete I/O via a variety of internal I/O modules and a protection / connector board to provide familiar detachable terminal block connections to the back. The layout of the connections is designed to make the unit easy to use as a 'drop in' replacement for an 8816 or 8832. (Agilaire, 2013)

For more details, refer to Appendix D1 of this QAPP, APCD's Datalogger & Central SOP or the individual operator manuals.

8.1.4 Wiring, Tubing and Fittings

The instrument is supplied with the ASC and enough stainless steel to extend the entire sampling train to a height above the sampler of approximately 4 m. The tubing extension must be cut to fit each installation. Additionally, the system comes with a 'slip coupler' to be installed between the ASC and extension tube to allow the sample line to be separated inside a shelter. This will ease PMT response verification (see 9.4.10).

8.1.5 Spare Parts and Incidental Supplies

Refer to the Troubleshooting and Maintenance sections of the Instrument Manual for a complete description of necessary sampling supplies.

Table 1: Model T640 Spare Parts List

Part #	Description
DU0000146	Filter Tape for T640
DU0000196	Flow calibration pad
TU0000034	Static dissipative inlet tubing (8-ft)
DU0000148	PM2.5 inlet at 5-lpm
KIT0000400	Inlet mounting kit
WR0000008	Power Cord

WR0000101	RS-232 Cable (6-ft)
WR0000258	RS-232 Null Modem adapter
FT0000338	3/8”-1/4” NPTF Reducer

8.2 Calibration Equipment

8.2.1 Ambient Pressure Calibration

8.2.2 Flow Calibration

- Flow Transfer Standard (4.0 – 6.0 lpm)
- Digital Manometer (± 0.1 inH_2O)
- Ambient temperature sensor (± 0.1˚C)
- Ambient pressure sensor (± 0.1 mmH_2O)

8.2.3 Spectrometer Calibration

- TAPI SpanDust™

9 Operation and Maintenance

9.1 Logs and Forms

All actions at the site, scheduled and non-scheduled, are logged on forms. These forms are collected monthly, reviewed and filed together; three complete calendar years of forms are maintained by APCD. The intent of these forms is to be able to recreate events and actions taken well after the fact. The forms in routine use are:

Figure 2: Monthly Verification/Maintenance Form

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Air Pollution Control Division - Technical Services Program

API 640 PM Continuous Regular Maintenance/Sampler Verification Form

TIME PERIOD: 02.01.23 to 02.28.23

SITE/SAMPLER DATA

Site Name: Chatfield API 640

Sampler Model: API 640

Sampler S/N: SN 903

AQS ID: 080350004

Site Visit	#1	#2	#3	#4	#5	#6	#7	#8
Operator								
Date								
Time								
Vis. Insp								
Instrument Inspection								
Alerts (make comm)								
PMT Setting								
PUMP PWM								
LED Temp °C								
BOX Temp °C								

FTS S/N: IA177L FTS m = 0.2273 FTS b = -0.4855 Therm. S/N: 0 Barometer S/N: 0

Four Week Instrument Verification

Site Visit #	Leak Rate OK?	Clock Current	Clock Standard (± 15 Minutes)	Ambient Temp. Current	Ambient Temp. Standard (± 2°C)	Ambient Pres. Current	Ambient Pres. Standard (± 10 mmHg)	FTS Pressure (ΔH2O)	Flow Current	Flow Standard (± 4% RA)	ID of Flow Device Used

Visit #	Time	Describe Action Taken	Time On	Initials

LIST OF SCHEDULED EVENTS/ SCHEDULED DATES:

Scheduled Events: # 2 4-wk verification, 1st Stage Inlet Cleaning **SCHEDULED DATE: 02.15.23**

NOTE: IF FLOW IS FOUND TO BE OUTSIDE THE RANGE OF 4.85 - 5.15 LPM NOTIFY APPROPRIATE APCD PERSONNEL IMMEDIATELY.

Flow Equation: $Q = ((T/P)*\Delta H_2O)^{1/2})*M + B$;

Where T(degK) = degC + 273.15 and P(atm) = 640 Instrument pressure/760

9.2 General Operations

9.3 Instrument Calibration

9.3.1 Pressure Calibration

- From the Main Screen – Calibration – Pressure Cal.
- Compare the “Measured Pressure” in this screen to the Pressure Standard.
- Press the value button in the “Actual Pressure” field, enter the value measured by the Pressure Standard, and press the “Calibrate” button on this screen.
- The user will be prompted to verify the adjustment, accept the prompt.

- Make a note of the results on the T640 Maintenance/Verification form.

9.3.2 Flow Calibration

- Perform a leak check as per Section 9.5.6.
- Setup your FTS and manometer (or other NIST traceable flow measurement device) with the appropriate inlet for the flow to be calibrated.
- Connect the Flow Standard to the flow audit adaptor (after removing the HEPA filter used to zero check the analyzer). Wait at least one minute for the flow to re-stabilize.
- With the T640 running, go to the Calibration>Sample Flow Cal menu.
- Compare the "Measured Flow" in this screen to the standard flow, as calculated in Section 9.5.7.3.
- Press the value button in the "Actual Flow" field, enter the value measured by the FTS, and press the "Calibrate" button on this screen. The Measured Flow value should change to closely match the Actual Flow within a few seconds.
- Take an additional manometer reading to verify that the current instrument flow is reading 5.0 lpm.
- Remove the FTS and flow audit adaptor, reinstall the sample inlet.

9.3.3 PMT Adjustment

- A PMT adjustment only needs to be made if the PMT response fails to meet criteria in Section 9.5.10
- If the Peak Channel reading is not at 11.3, ± 0.5, then adjust the PMT Setting by pressing the Peak Adjust left (decrement) or right (increment) buttons to center the Peak voltage. Each press of a button is 1 volt, so press the Peak Adjust button by as many times as the number of volts the reading is off.

9.4 Routine Preventative Maintenance and Scheduled Activities

The Model T640 PM monitor requires regular maintenance, system checks, and verifications. APCD recommends these activities be performed according to the following schedule.

Table 2: Routine Service and Maintenance Activities

Item	Frequency
Instrument status check	Weekly
Verify Date/Time (if not set to update automatically)	Weekly
Inspect the sample line tubing	Monthly
Inspect Optical Chamber/Clean if Necessary	Monthly
Perform leak check	Bi-Monthly
Instrument Verification, calibrate if necessary	Bi-Monthly
Inspect/replace by pass filter cartridge	Monthly
Clean Instrument Inlet	Monthly
Check PMT response/PMT Adjustment	Monthly
Verify Pump Performance	Monthly
Inspect/Clean T/RH sensor	Every six months

9.5 Maintenance Procedures

9.5.1 Disable/Enable Analyzer in Data Logger

<u>ESC 8816/ 8832</u>

Disable analyzer data channel:

From the top level menu, to disable a data channel from reporting to the data logger, the user must:

- Choose menu options **CDM** (**C Configuration Menu** > **D Configure (Data) Channels** > **M Disable/Mark Channel Offline)** to view the list of available channels.
- From the keyboard, using the down arrow button, scroll to the target channel name and hit the **Enter** or **Return** key.
- Next, hit the **Esc** (Escape) key twice to get back to top level menu.
- Select menu option **DF** (**D Real-Time Display Menu** > **F Display Readings w/flags**) to ensure the proper machine was disabled. You should see the letter "D" within parenthesis and adjacent to the targeted channel indicating it has been disabled.

Enable analyzer data channel:

From the top level menu to enable the data channel to resume reporting to the data logger, the user must:

- Choose menu options **CDE** (**C Configuration Menu** > **D Configure (Data) Channels** > **E Enable /Mark Channel Online)** to view the list of available channels.
- From the keyboard, using the down arrow button, scroll to the target channel name, and hit the **Enter** or **Return** key.
- If all machines/instruments and/or channels are already on line, the user will receive a message stating "No channels are offline" at the bottom left screen. Otherwise a list of channel names will appear.
- Next, hit the **Esc** key twice to get back to the top level menu.

- Select menu option **DF** (**D Real-Time Display Menu** > **F Display Readings w/flags**) to ensure the proper channel was enabled. You should see parenthesis adjacent to the targeted channel without the letter "D" inside indicating the machine/instrument channel is enabled and reporting to the data logger.

Agilaire 8872

Disable analyzer data channel:

- After logging in to AirVision™, if the Site Node Logger Toolbox is not open, from the top level menu select the **Home** tab > **Utilities** > **Site Node Logger Toolbox** > then select the **Channels** tab.
- Identify the channel to be disabled. At the right side of the form, under the "Disabled" heading, click on the row with the target channel name. This action will change the channel state from "False" to "True" indicating that it is now disabled and not reporting to the data logger.

Enable analyzer data channel:

- After logging in to AirVision™, if the Site Node Logger Toolbox is not open, from the top level menu select the **Home** tab > **Utilities** > **Site Node Logger Toolbox** > then select the **Channels** tab.
- Identify the channel name to be enabled. At the right side of the form, under the "Disabled" heading, click on the row with the target channel name. This action will change the channel state from "True" to "False" indicating that it is now enabled and will now report to the data logger.

9.5.2 Instrument Status Check

The Alerts log may be useful in diagnosing faults. Table 3 lists some of the Alerts that are triggered by faults, describes their likely causes, and suggests possible places to begin troubleshooting. The Alerts log may be accessed through the Main Screen.

Table 3: Model T640 Alerts

Message	Description	Possible Solution(s)
System Reset	Warning raised when the system is reset	Normal power cycle occurred? If not, check external power source.
Sample Flow High	The Sample Flow is greater than 5.25 lpm	Check pneumatic fittings. Re-calibrate flow.
Sample Flow Low	The Sample Flow is less than 4.75 lpm	Check pneumatics. Check for blockages. Re-calibrate flow.
Bypass Flow High	The Bypass Flow is greater than 12.25 lpm	Check pneumatic fittings. Re-calibrate flow.
Bypass Flow Low	The Bypass Flow is less than 11.08 lpm	Check pneumatics. Check for blockages. Re-calibrate flow.
Sample RH High	The Sample RH is above the setpoint	Check if ASC is plugged in. Check control board if ASC control LED is illuminated. Check if water is in the sensor.
Check LED	If the LED temperature is equal to the box temperature, the LED may be OFF	Cycle power. Call Tech Support.
Check PMT	The PMT HV setting is out of range (800 – 2200)	Check Sensor with SpanDust™. Perform an optical chamber cleaning. Call Tech Support.
Sample Flow Slope OOR	The Sample Flow Calibration Slope is Out Of Range	Check pneumatics for leaks. Re-run flow calibration. Call Tech Support.
BYPS Flow Slope OOR	The Bypass Flow Calibration Slope is Out Of Range	Check pneumatics for leaks. Re-run flow calibration. Call Tech Support.
Check Int Pump	Check the internal pump if the PWM is > 80	Check pneumatics for blockages. Check pneumatics for leaks.

		Check flow calibration. Replace pump.
Sample Temp Warning	Sample Temperature Warning (>60)	Check ASC (is it latched ON?) Ensure proper climate and ventilation for instrument.

For a complete description on deciphering status codes refer to Table 4.2 of the TAPI *Model T640 User Manual.* Note the presence of any alerts or status condition on the T640 Field Form

9.5.3 Verify Date/Time (Weekly)

- Compare the Date/Time on the T640 with logger date/time.
- If Date/Time deviates from logger time for more than 0 minutes then change the instrument time through the Main Screen – Setup – Instrument – Date/Time Settings.

9.5.4 Inspect sample tubing

- Look inside the sampling line for debris or dust on the walls.
- If needed, push a rag or a paper towel through the line; then use a can of compressed gas made specifically for electronics to blow through the line for final cleaning.

9.5.5 Inspect optical chamber (Clean if necessary)

- Remove the ASC support, which straddles the sensors.
- Four screws secure that support to the floor of the instrument, two on each footing.
- Locate the optical cell, the cup at bottom of optics chamber and its tubing, and the Relative Humidity and Temperature (RH/T) sensor. Remove optical cell from optics chamber, and remove cup, including its tubing, from optics chamber bottom; detach RH/T sensor tubing from DFU filter.
- Clean the optics chamber interior surfaces, ensuring to include windows, with a lint-free cloth.
- Use a can of compressed gas made specifically for electronics to blow any dust or other debris from the optics chamber, from the cup, from the bottom of the optics chamber, and from the tubing.
- When finished, reassemble optics chamber components; reinsert cup to bottom of optics chamber; reconnect tubing from cup in bottom of chamber to RH/T sensor and from RH/T sensor to the DFU filter, and reinstall the ASC support, ASC and downtube.
- Close instrument, and perform a PMT sensor check (see section 9.4.10) with the SpanDust.™

9.5.6 Leak test (Monthly)

Note: Never subject the T640 to vacuum as would normally be the approach during a leak check. Leak checking the T640 is accomplished by performing a Zero Test of the instrument.

- Remove the inlet, install the flow audit adaptor (fitted with a HEPA filter).
- Observe the PM values on the front panel display.
- Within a few minutes, the PM values should be at zero.
- If the PM values are not reading zero, then there may be a leak in the system above the optical sensor (i.e. from the optical sensor nozzle up to where the HEPA filter was fitted).
- It is also possible the HEPA filter being used is either bad or leaking. Always have a second filter handy to check.

- If the PM values do read zero, then there is not a leak above the optical sensor.
- Note the results on the T640 Maintenance/Verification Form.

9.5.7 Verification Procedure (For monthly QC verifications or for quarterly audits.)

9.5.7.1 Temperature Verification

Note: The ambient temperature sensor on the T640 cannot be calibrated. Any notable differences indicates the sensor needs to be replaced.

- Install the standard temperature sensor probe into the solar shield.
- The T640 is configured so that the instrument's ambient temperature is noted on the Main Screen.
- Record the instrument and standard ambient temperature on the T640 Maintenance/Verification Form.

9.5.7.2 Pressure Verification

- Note the standard ambient pressure.
- The T640 is configured so that the instrument ambient pressure is noted on the Main Screen.
- Record the instrument and standard ambient pressure on the T640 Maintenance/Verification Form.
- Should the results not be within 10 mmHg the instrument pressure needs to be recalibrated, see Section 9.3.1

9.5.7.3 Flow Verification

APCD utilizes nozzle-based flow transfer standards (FTS) for flow verifications. This approach requires a certified FTS, manometer, and barometer.

- Perform a leak check (Section 9.5.6).
- Perform an ambient pressure verification (Section 9.5.7.2).
- With the flow audit adaptor still installed from the leak check, remove the HEPA filter from the train.
- Install a FTS that measures flow in the correct range (5 lpm).
- Zero and install the manometer, record the pressure drop (ΔH_2O) through the FTS on the T640 Maintenance/Verification Form.
- Note the current instrument flow on the Main Screen.
- Calculate FTS flow with the equation:

$$Qa = (Ta/Pa * \Delta H2O)^{1/2} * M_{FTS} + B_{FTS}$$

Where

Qa = FTS flow, alpm
Ta = ambient temperature, Kelvin
Pa = ambient pressure, atmospheres
M_{FTS} = FTS certified slope
B_{FTS} = FTS certified intercept

- Note the results on the T640 Maintenance/Verification form.
- If the range of Qa is outside of 5.0 ± 0.2 alpm reverify the flow.
- If the range is still outside the acceptable range perform a flow calibration (Section 9.3.2).

9.5.8 Inspect/Replace by-pass cartridge filter

- Power off the pump from the Setup>Vars>Pump Control menu.
- Pull open the instrument's front panel, using the front panel finger grips.
- Noting its orientation, remove the old filter cartridge by detaching from the pneumatic quick-connect fittings, and replace with a new filter cartridge matching the orientation.
- Ensure the filter is seated snugly with no gaps.
- Power on the pump from the Setup>Vars>Pump Control menu.

9.5.9 Clean Instrument Inlet

- Power off the pump from the Setup>Vars>Pump Control menu.
- Remove the sampling inlet from the sampling line.
- Disassemble the sampling inlet: two screws at base of inlet and base plate.
- Carefully and thoroughly remove any dust deposits from inside of the inlet.
- Remove any insects or other debris from the filtering screen.
- Clean all the components using water and a mild detergent.
- Dry all components thoroughly with a clean cloth and blow compressed air through nozzles.
- Check and, if needed, replace the o-rings located on the outside and the inside of the base plate, and grease them with vacuum grease.
- Re-assemble the sampling inlet, sliding the baseplate back into the base of the inlet body, making sure to line up with the screw holes. The screws should be put back in to hand-tight pressure.
- Reconnect sampling line.
- Power up the pump from the Setup>Vars>Pump Control menu.

9.5.10 Check PMT response

Note: The PMT Verification uses SpanDust™, a monodisperse dust with a specific refractive index. All T640 PMTs have a very specific response to this span dust which allows for the sensor to be checked in the field for possible drift caused by contamination of the optics. It is important to note that this is simply a mechanism to check the PMT response to particles with a specific and known refractive index.

- Navigate to the PMT Adjust screen, Main Screen – Calibration – PMT Adjust.
- Remove the T640 sample inlet or the T640X Option sample inlet and press the Start button on this screen to suspend normal data acquisition and start this adjustment process.
- Prepare the SpanDust™ bottle by uncapping the "air intake" at the bottom of the silica gel drier attached to the bottle.
- Place the tube from the SpanDust™ bottle into the top of the Upper Inlet Tube for the instrument making sure the tube fits snugly inside the downtube.
- Gently tap the SpanDust™ bottle to barely agitate the contents just enough to allow the dust to be pulled into the sensor, and allow 30 seconds for the Peak Channel reading in this screen to respond.
- If the Peak Channel reading is not at 11.3, ± 0.5, then follow the procedure in Section 9.3.3.
- Once the Peak Channel reading is at 11.3, ± 0.5, reattach the sample inlet and press the Stop button to stop the adjustment process and resume normal data acquisition.

9.5.11 Verify Pump Performance

Note: The T640 has been configured so that the PUMP PWM and Vale PWM are displayed on the Dashboard.

- Pump PWM should be running between 35% and 80%.
- Valve PWM should be running between 35% and 85%.

9.5.12 Inspect/Clean RH/T Sensor

10 SAMPLE PRESERVATION AND ANALYSIS

Continuous particulate spectrometer samples receive no special preparation prior to analysis.

11 TROUBLESHOOTING

11.1 Environmental Factors

Environmental conditions can play a role in the operational characteristics of analyzers. Some external factors may be constant while others are sporadic in nature. External factors to check include:

- Is the shelter temperature stable throughout the day?
- Is vibration from other equipment causing an effect?
- Is the air conditioner or heater blowing directly on the instrument?

11.2 General Factors

11.3 Instrument Troubleshooting

11.3.1 Instrument Status

The Alerts screen shows the status of any active warning. While Alerts can be cleared from the Alerts page, all alerts are documented and stored in the Home>Utilities>Alerts Log. The following table identifies the common alerts, additional alerts can be programmed by the user through the Setup – Events menu.

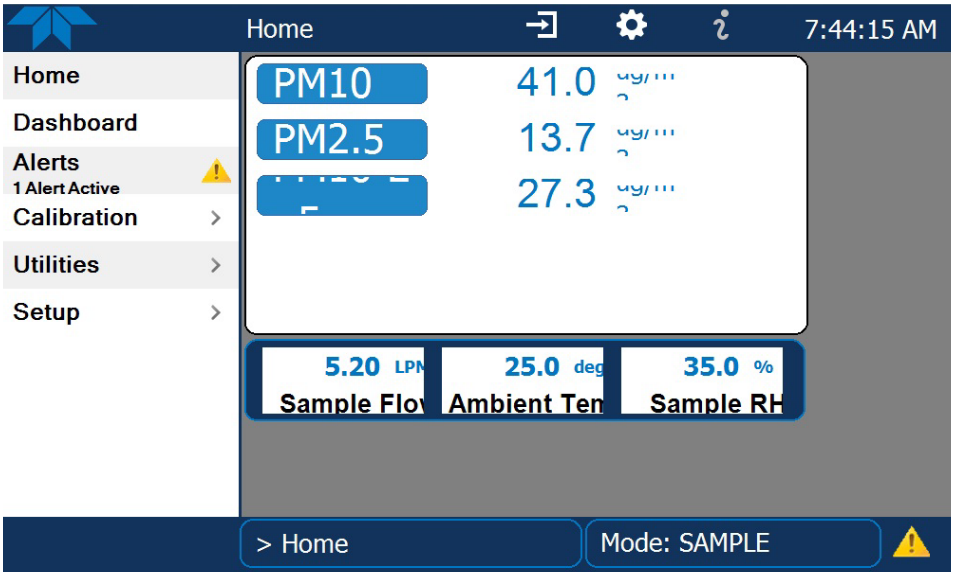
Table 4: Modbus Alert Register

Modbus Register	Alert Condition
0	Box Temp Warning
1	Flow Alarm
2	System Fault Warning
3	System is OK
4	System Reset Warning
5	Temperature Alarm
6	System Service Warning
7	OPC Instrument Warning
8	Sample Temperature Warning

Tablel 5 presents a list of status conditions, the reason for the code and possible solutions.

11.3.2 Start Up Checks

Figure 3: T640 Main Screen



Should there be an issue with instrument startup refer to Table 5 to begin to identify the specific issue

Table 5: Startup Screen Errors

Check	Description	Error	Solution
Communication	Communication PC to optical chamber controller	hardware problem	check cables
Instrument Data	Obtain SN from the optical chamber controller	hardware problem	check cables
Storage	CF card operation	CF card error	get new CF card & software
Configuration Settings	read setting from the setup file	setup file error	restore setup file from one of the older setup files
Valves	operation of the ball valve	ball valve not moving	check cables
Chamber	optical chamber movement test	locked chamber or hardware error	unlock chamber or service needed
Pump & flow	test if pump is working	pump fail or tubing connections	service or verify tubing connections
Device Monitoring	Win CE operating system test	faulty application file	Install new software, get new CF card

11.3.3 Unacceptable quality control results

The T640 is programmed to understand the range of acceptable quality control checks. Should a test fall outside of these given ranges an instrument status code will be generated. The following table identifies the possible errors, the associated cause, and proposed solutions.

11.3.4 Additional Troubleshooting

Additional troubleshooting can be arranged by contacting the manufacturer.

12 Data Acquisition, Calculations, and Data Reduction

All data are now collected, stored, and retrieved digitally from data loggers. The terms data logger and onsite data acquisition system are used interchangeably throughout this SOP.

12.1 Data Acquisition

The APCD/TSP data acquisition system (DAS) is comprised of three components: an onsite primary data acquisition system that collects data from all continuous monitoring equipment, an onsite secondary data acquisition system, or back-up system that collects data from the continuous monitoring equipment, and a centralized central polling system that routinely collects data from the primary data acquisition system and stores it in a SQL database for processing and validation. In regards to the T640 the instrument itself operates as the secondary data acquisition system.

12.1.1 Primary Onsite Data Acquisition Systems

The APCD employs three different models of onsite DAS in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, and the Agilaire 8872 data logger. The 8816 data logger is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. See Section 8.0.3 for a more detailed description of these data loggers and Appendix D1 of this QAPP.

12.1.2 Secondary Onsite Data Acquisition Systems

The T640 carries substantial on board memory. The data can be downloaded to a flash drive by using the 'Export' tab in the 'Data' menu. Data should be downloaded from the unit once per month soon after the end of each month.

12.1.3 Central Polling System

The APCD uses the AirVision software package for its central data management system. "AirVision is a centralized data management and polling software system that is used to acquire, edit, validate, analyze, and report air quality data. AirVision supports open data acquisition and data imports thru modular drivers that can be added to provide connectivity to a data source. The system has combined data editing and quality control tools that can be utilized in evaluating and validating data in the post-processing environment. The post-processing environment allows user control of the data from the management of raw data within the server environment through the exporting of validated data through built in reports or for external statistical evaluations and reporting. A more detailed description of this application can be found in Appendix D1 of this QAPP, APCD's Data Logger and Central Polling Standard Operating Procedure." (Agilaire, 2009)

<u>Central Polling Daily Tasks</u>

- Task managers within Air Vision polls data from remote air quality monitoring sites at the top of each hour, at a minimum. Some sites may be polled at a greater frequency depending upon data needs. Data from each site is stored in a SQL database and made available for review and analysis after polling has been completed.
- Ambient data on the AirVision Central polling computer is reviewed every business day in the morning, the previous 24 hours (or 3 days on Mondays) worth of data is reviewed for completeness and accuracy. This data review is used to determine if a physical site visit is required.
- Low level (precision) and high level (span) test gas sequences are run on alternate days. The precision and span level tests are followed by a zero test and a two-minute recovery period. The results are reviewed each morning and plotted on control charts. It is the responsibility of one individual within TSP to review the daily Zero/Span results, plot them on the control charts, and notify the technician responsible of any out of control condition. "Out of control" is defined as:
  a. trending toward warning limit as defined on the control chart
  b. points plotted exceeding the warning limit
  c. points plotted exceeding the action limit as defined on the control chart

12.2 Calculations and Data Reduction

As mentioned above, data collected on a DAS are available as soon as the averaging period is complete. Data are polled automatically via modems (analog phone, wireless cellular, or DSL) by the Central polling computer hourly. If needed, sub-hourly polls or remote checks can also be performed.

Data from the continuous air monitoring equipment are generally stored at hourly and minute resolution averages. The software on the Central polling computer stores the downloaded minute and hourly averages and is capable of aggregating these averaging intervals into larger averaging intervals such as 8-hour or 24-hour averages.

A more detailed description of the DAS is given in the CDPHE/APCD/TSP QAPP and in the manufacturers' manual.

12.2.1 Post Collection Processing

13 DATA MANAGEMENT AND RECORDS MANAGEMENT

13.1 Data Management

Data are generated from the analyzer at intervals internally set, ranging from an averaging time of 1 minute to 1 hour. The data is collected by the on-site data logger as near-real-time data (1 minute averages from the instrument provide data stability) and is aggregated into 15 minute averages, which are in turn aggregated into 1-hour averages. Note the capacity of the on-site data logger is limited to three time-base averaging intervals. The Central polling computer collects these averages routinely. The data channels from the T640 collected by the on-site data logger are presented here, in Table 6:

Table 6: API T640 Data Collection & Diagnostic Metrics

Data Field	Description	Purpose
PMFine	Scattered light spectrometry for PM2.5, USEPA Class III FEM	To report PM2.5
PM10ltp	Scattered light spectrometry for PM10	To report PM10 at local temperature and pressure
PM10stp	PM10ltp converted to standard conditions from local conditions	To report PM10 at standard temperature and pressure
Sample Flow	Sample flow rate, lpm	Valid range of sample flow between 5.0 lpm ± 3%
LED Temperature	LED temperature	Should be greater than box temperature
Box Temperature	Instrument internal temperature	Ensure Box temperature < 60degC
P3	API calculated diagnostic metric	45 - 55
PMT HV	Detector voltage	Verify data, range of acceptable values between 800 and 2200
Int Pump PWM	Internal pump pulse width modulation	Verify data, range of acceptable values should be less than 80%
Sample Temp.	Sample Temp	Verify data, range of acceptable values should be less than 60degC

Valid data are sent to the EPA centralized Air Quality System (AQS) database for long-term storage. Additionally, the data are stored and archived by the APCD/TSP in electronic format. Monthly electronic data files and related material packets (maintenance forms, etc.) are produced.

A more detailed description of the data management is given in Appendix D1, the Datalogger & Central SOP in the CDPHE/APCD/TSP QAPP.

13.2 Records Management

Continuous ambient air monitoring data are archived in electronic format. Electronic data and calibration files from the primary DAS are archived.

14 Quality Assurance and Quality Control

Quality assurance and quality control are two terms commonly discussed, but often confused. Quality assurance refers to the overall process of ensuring that the data collected meet previously stated Data Quality Indicators (DQI) and associated measurement quality objectives (MQOs). The principal DQIs are precision, bias, representativeness, completeness, comparability, and sensitivity. The principal MQO's are parameter specific and are listed in CDPHE's Appendix MQO of this QAPP. Guidance for developing DQI's and MQO's is given in EPA's Quality Assurance Handbook (US EPA, 2013). Quality control covers specific procedures established for obtaining and maintaining data collection within those limits.

14.1 Quality Assurance

The goal of the quality assurance program is to control measurement uncertainty to an acceptable level through the use of various quality control and evaluation techniques. The entire Quality Assurance effort put forward by the APCD is too large to include here. The scope of this SOP will describe efforts taken by site operators and data validation personnel to ensure the quality of the data collected meets standards set forth in various sections of the *Code of Federal Regulations*. For a complete description of the Quality Assurance and Quality Control process undertaken by the APCD, see the appropriate quality assurance appendices in the QAPP. Two of the most significant Quality Assurance procedures are described below.

14.1.1 Audits

Audits are evaluation processes used to measure the performance of effectiveness of a system and its elements. APCD quality assurance staff performs two types of audits. These audits are performed at a frequency as described in Appendix QA1 of APCD's QAPP.

Systems Audits - A systems audit is an on-site review and inspection of an ambient air monitoring program or air monitoring site to assess its compliance with established regulations governing the collection, analysis, validation, and reporting of ambient air quality data.

Performance Audits - A performance audit is a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst, laboratory, or measurement system. Two types of performance audits discussed below.

- Monitoring Organization Performance Audits - These performance audits are used to provide an independent assessment of the measurement operations of each instrument being audited. This is accomplished by comparing performance samples or devices of "known" concentrations or values to the values measured by the instruments being audited. Detailed information about how specific audits are performed can be found in the Quality Assurance SOPs section.
- National Performance Evaluation Program (NPEP) **–** These performance audits are implemented at the federal level although some programs may be implemented by the monitoring organizations if certain requirements are met.

14.1.2 Data Quality Assessment

Data Quality Assessment is used to assess the type, quantity, and quality of data in order to verify that the planning objectives, Quality Assurance Project Plan components, and sample collection procedures were satisfied and that the data are suitable for its intended purpose. Data Quality Assessment is a five-step procedure for determining statistically whether or not a data set is suitable for its intended purpose. This assessment is a scientific and statistical evaluation of data to determine if it is of the type, quantity, and quality needed and is performed annually by quality assurance staff to check if objectives were met.

14.2 Quality Control

Quality Control is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the EPA. Quality control includes establishing specifications or acceptance criteria for each quality characteristic of the monitoring/analytical process, assessing procedures used in the monitoring/analytical process to determine conformance to these specifications, and taking any necessary corrective actions to bring them into conformance.

Quality control refers to procedures established for collecting data within pre-specified tolerance limits. These pre-specified tolerances are defined in the Measurement Quality Objectives Appendix and as defined in APCD's QAPP. While all Quality Control procedures are important, the most significant procedure employed by the APCD is the routine measurement of a known test gas by gaseous analyzers. All procedure documented in this SOP are Quality

Control procedures because they allow the analytical systems to continue running in exceptional condition and serves to minimize out-of-control conditions as defined by APCD MQO's. By definition, the creation and use of this SOP is a Quality Control function. All Quality Control procedures are described in various sections of this SOP and Appendix QA1 of this QAPP. Three of the most significant Quality Control procedures are described below.

14.2.1 Performance and Precision Tests

A primary quality assurance task carried out by site operators is the performance of routine inspection and maintenance. The APCD performs three types of QC checks on the T640. These two tests are leak checks, instrument verification and PMT response.

14.2.2 Calibrations

Calibration of an analyzer or instrument establishes the quantitative relationship between the actual value of a standard, be it an environmental reading or volumetric flow, and the analyzer's response (chart recorder reading, output volts, digital output, etc.). It is the goal of APCD to perform calibrations on all analyzers annually or as needed.

For instructions on calibrating the T640 see 9.3.

Documentation is an important component of the quality control system. Extensive certification paperwork and log sheet must be rigorously maintained for procedures, standards and analyzers. APCD takes special care to prepare and preserve backup copies of all data, especially calibration data. All data and supporting documentation should be held on-site for a minimum of three calendar years then sent for offsite archive. See the Data Handling SOP D3 of this QAPP for additional information.

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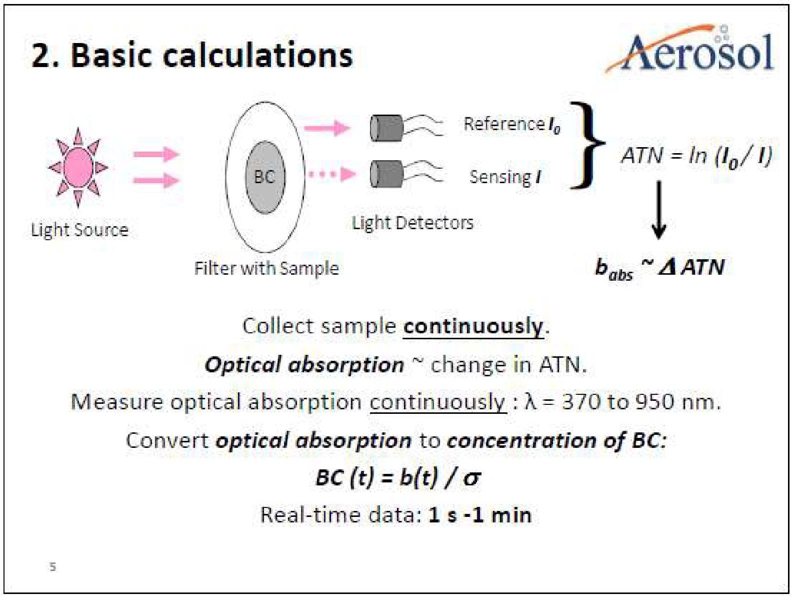
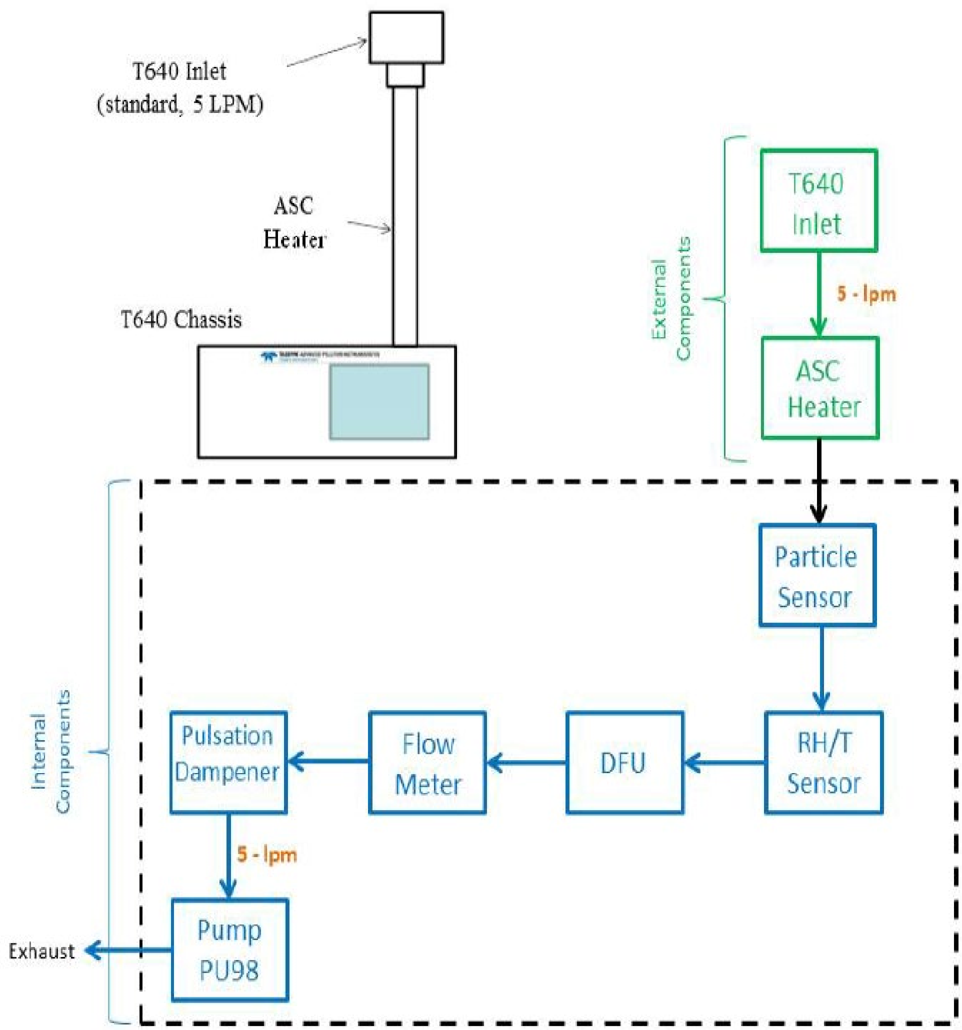


Figure 4. Model T640 Particulate Matter Monitor Operating Principle


T640 Inlet
(standard, 5 LPM)
ASC
Heater
T640 Chassis
External
Components
T640
Inlet
5 - lpm
ASC
Heater
Internal
Components
Particle
Sensor
RH/T
Sensor
DFU
Flow
Meter
Pulsation
Dampener
5 - lpm
Pump
PU98
Exhaust

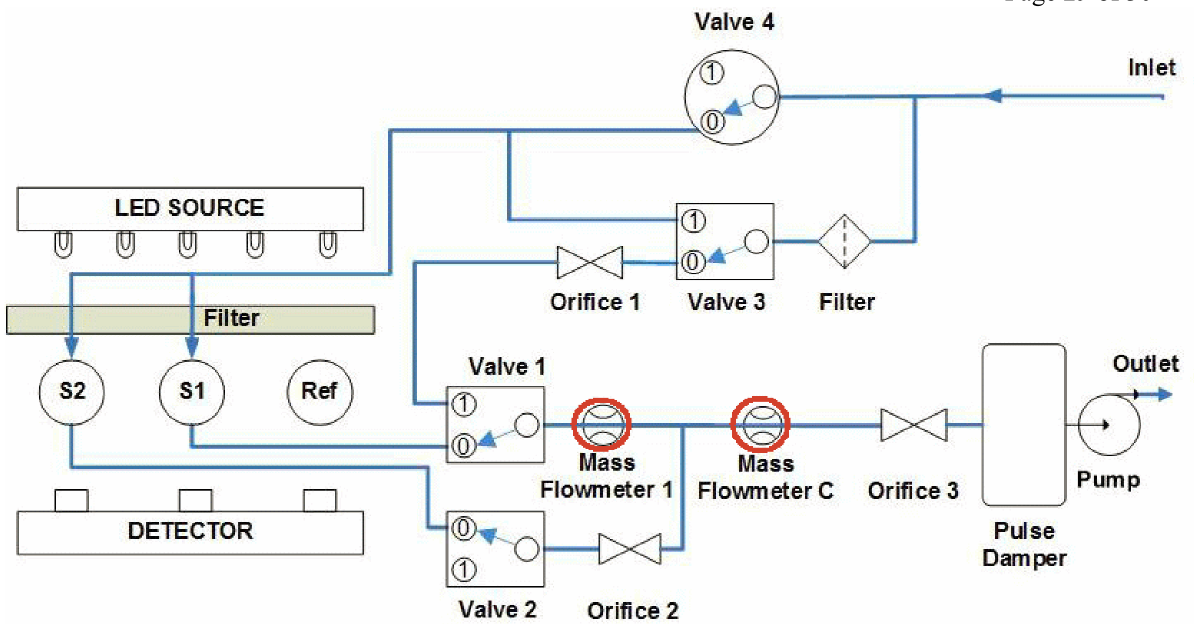


Figure 5. Model T640 Flow Diagram

TAPI T640 Monthly Service/Maintenance Form

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Air Pollution Control Division - Technical Services Program

API 640 PM Continuous Regular Maintenance/Sampler Verification Form

TIME PERIOD: 02.01.23 to 02.28.23

SITE/SAMPLER DATA

Site Name: Chatfield API 640
Sampler Model: API 640
Sampler S/N: SN 903
AQS ID: 080350004

Site Visit	#1	#2	#3	#4	#5	#6	#7	#8
Operator								
Date								
Time								
Vis. Insp								
Instrument Inspection								
Alerts (make comm)								
PMT Setting								
PUMP PWM								
LED Temp °C								
BOX Temp °C								

FTS S/N: IA177L FTS m = 0.2273 FTS b = -0.4855 Therm. S/N: 0 Barometer S/N: 0

Four Week Instrument Verification

Site Visit #	Leak Rate OK?	Clock Current	Clock Standard ± 15 Minutes	Ambient Temp. Current	Ambient Temp. Standard ± 2°C	Ambient Pres. Current	Ambient Pres. Standard ± 10 mmHg	FTS Pressure (ΔH2O)	Flow Current	Flow Standard ± 4% RA	ID of Flow Device Used

Visit #	Time	Describe Action Taken	Time On	Initials

LIST OF SCHEDULED EVENTS/ SCHEDULED DATES:

Scheduled Events: # 2 4-wk verification, 1st Stage Inlet Cleaning **SCHEDULED DATE: 02.15.23**

NOTE: IF FLOW IS FOUND TO BE OUTSIDE THE RANGE OF 4.85 - 5.15 LPM NOTIFY APPROPRIATE APCD PERSONNEL IMMEDIATELY.

Flow Equation: $Q = ((T/P)*\Delta H_2O)^{1/2})*M + B$;

Where T(degK) = degC + 273.15 and P(atm) = 640 instrument pressure/760