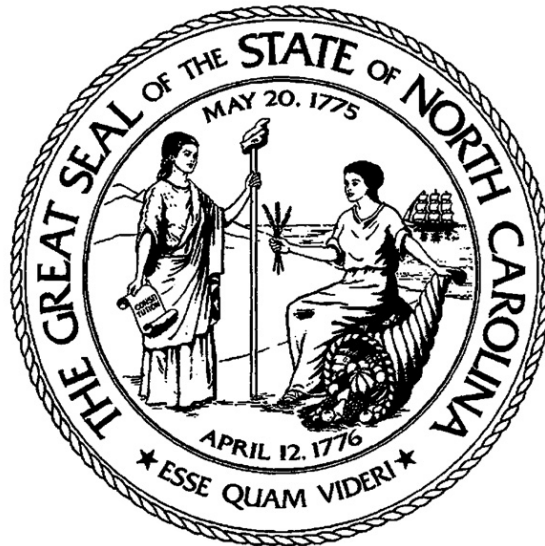


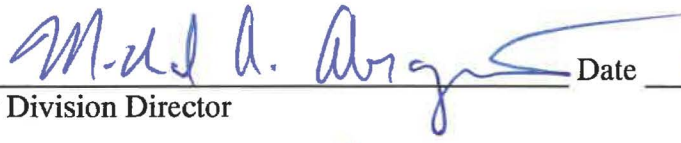
Standard Operating Procedure 2.47
Section 2:
Teledyne Model 640X Standard Procedures for Operators

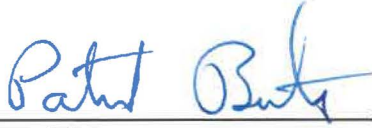
Revision 2020




Standard Operating Procedure Approval

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1.0 SCOPE AND PURPOSE

The U.S. Environmental Protection Agency (EPA) began regulating fine particles in July 1997. The regulation established the gravimetric based federal reference method (FRM) in the Code of Federal Regulations (CFR) at 40 CFR Part 50, Appendix L. On August 26, 2015, the EPA designated a new federal equivalent method (FEM) in the Federal Register (EQPM-0516-238). The new FEM was approved for measuring the concentration of fine particles in the ambient air using scattered light spectrometry for measurement. This document has been prepared to assist the field operators with the North Carolina Division of Air Quality (NCDAQ) to use the EPA equivalent method to monitor the ambient atmosphere for particles with an aerodynamic diameter of 2.5 μm or less ($\text{PM}_{2.5}$), known as fine particles. Fine particles are formed in the atmosphere from gases such as sulfur dioxide, reactive oxides of nitrogen, and volatile organic compounds. Sources include power plants, diesel trucks, wood stoves, and industrial processes.

The objective of this Standard Operating Procedure (SOP) is to familiarize the station operator with the activities used in the collection of air monitoring data. The accuracy of data obtained from any instrument depends upon the instrument's performance and the operator's skill. It is important that the station operator become familiar with both this SOP as well as the manufacturer's operation manual in order to achieve a high level of data quality.

2.0 SAMPLER DESCRIPTION AND ASSEMBLY

2.1 Description of the T640X Monitor

The Model T640X PM Mass Monitor is an optical aerosol spectrometer that converts optical measurements to mass measurements by determining sampled particle size via scattered light at the single particle level according to Lorenz-Mie Theory. Briefly, the sampling head draws in ambient air, which are dried (i.e., brought below 35% RH) 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 the T-aperture through 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 (height) and signal length are measured; the amplitude of the scattered light impulse is directly related to the particle size diameter. The T-aperture and simultaneous signal length measurements eliminate border zone error, which is characterized by the partial illumination of particles at the border of the measurement range.

There are no known interferences to the collection of PM_{2.5} and PM₁₀ using this method; however, surface roughness and other variables do affect sizing algorithms in all light scattering instruments. Since the PM concentration output is based on a calculation using the last 10 minutes of data, the operator should wait a minimum of 10 minutes after reassembly of the instrument before turning the data system to “On Scan”.

The following document describes the operation and field technician responsibilities for the Teledyne API Model T640X. The T640X is a real-time, continuous particulate matter (PM) mass monitor that uses scattered light spectrometry for measurement; specifically, it employs broadband spectroscopy using 90° white-light scattering with polychromatic light-emitting diode (LED).

There are two designated methods using the T640 instrumentation. The model T640 with 640x option (T640X) is an approved Federal Equivalent Method (FEM) for PM₁₀ [EQPM-0516-239], PM_{2.5} [EQPM-0516-238] and PM_{10-2.5} [EQPM-0516-240]. The T640X operates at a total flow rate of 16.7 lpm and this SOP is written specifically for this method. The model T640 is an approved FEM for PM_{2.5} [EQPM-0516-236]. The T640 also measures PM₁₀ and PM_{10-2.5}, but only the PM_{2.5} fraction meets FEM requirements. The T640 operates at a total flow rate of 5.0 lpm.

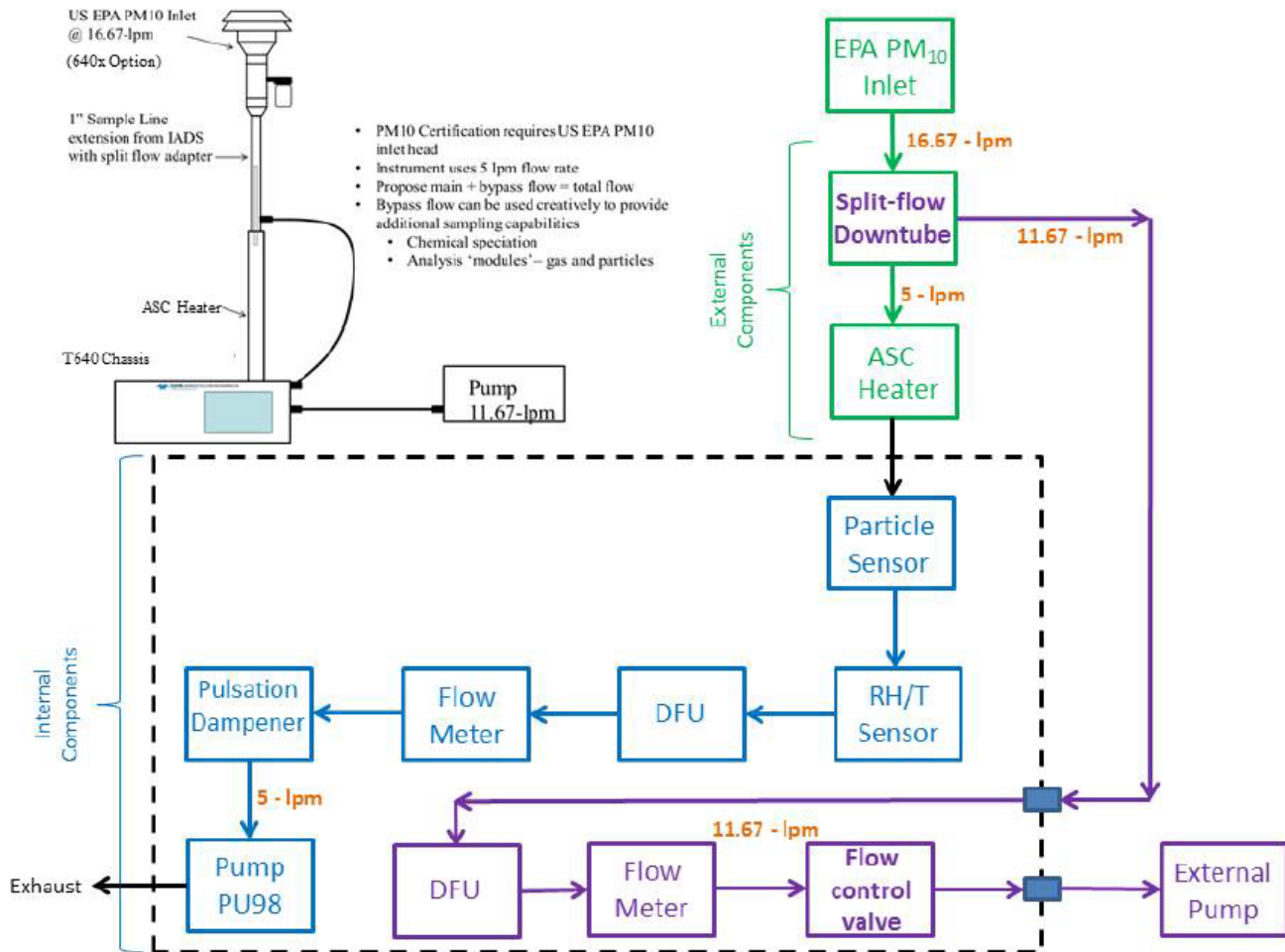


Figure 1. T640X Pneumatics.

2.2 Assembly of the T640X Monitor

Verify that there is no apparent external shipping damage. If damage has occurred, please contact ECB or the Raleigh Central Office Particulate Chemist. With no power to the unit, carefully remove the top cover of the instrument and check for internal shipping damage by carrying out the following steps:

1. Carefully remove the top cover and check for internal shipping damage. Remove the cover screws located on the sides of the instrument. Slide the cover backward until it clears the instrument's front bezel. Lift the cover straight up.

2. Inspect the interior to ensure all circuit boards and other components are intact and securely seated.
3. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure they are firmly and securely seated.
4. Verify that all of the optional hardware ordered with the unit has been installed. These are listed on the paperwork accompanying the instrument.

Whether the Monitor is set up on a bench or installed in an instrument rack, be sure to leave sufficient ventilation clearance (4 inch minimum required).

The ASC requires an inlet nozzle and an adapter for installation. The black inlet nozzle to the optical sensor is specific to the instrument (not interchangeable to other T640 instruments).

1. Insert the black inlet nozzle through the center of the support collar into the top of the optical sensor, seating it tightly so that the nozzle's upper o-ring flange is flush with the upper surface of the sensor body.

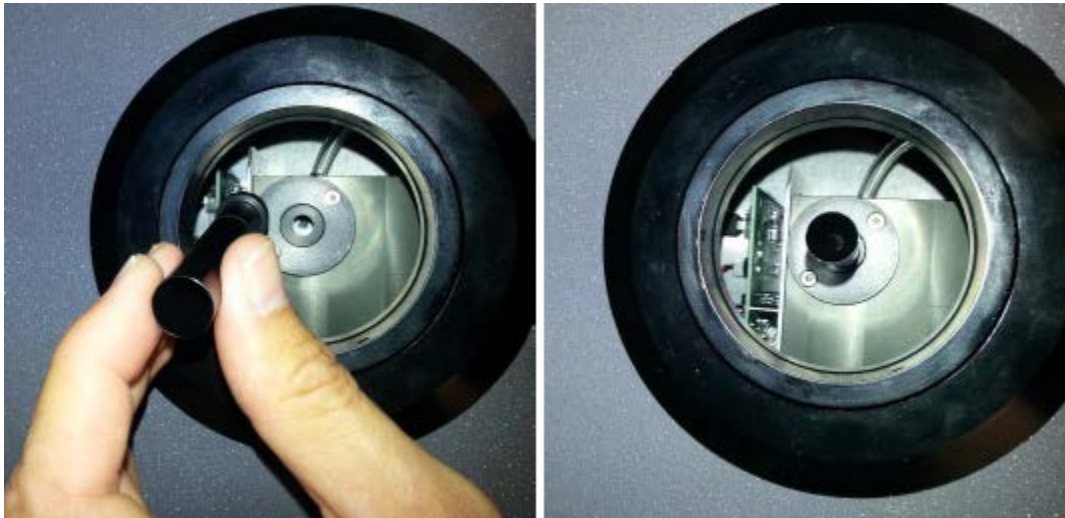


Figure 2. Nozzle Installation.

2. Slide the aluminum adapter over the black inlet nozzle, ensuring its base is flush with the top of the optical sensor.

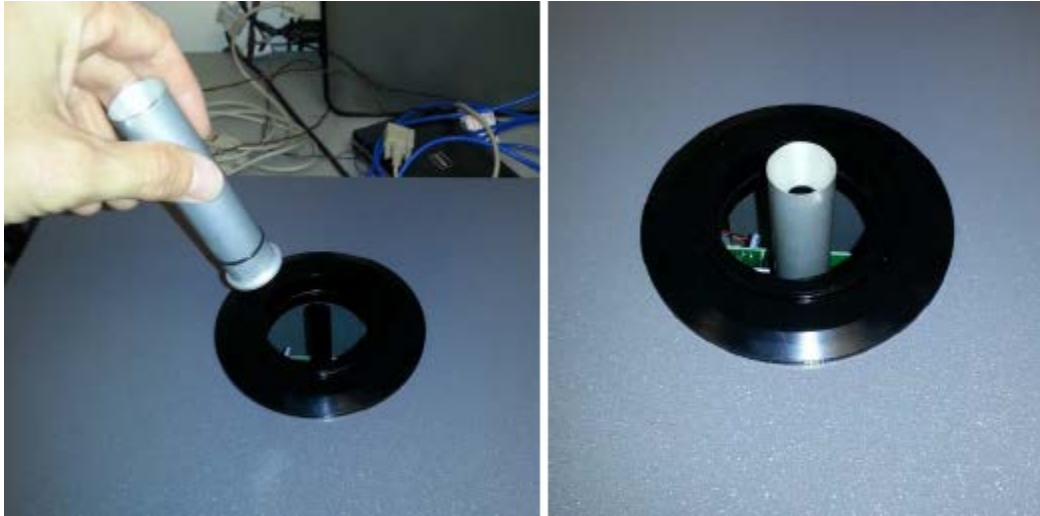


Figure 3. Aluminum Adapter.

3. Attach the water collector to the PM10 inlet.
4. Assemble the inlet and the ASC as depicted in Figure 3, ensuring the parts fit snugly with no gaps. Note that if to be installed in a shelter with roof penetration, leave the inlet with water collector off for the time being.
5. Lower the ASC into the support collar, ensuring it fits straight with no gaps.
6. Plug the ASC wiring into the rear panel connector.
7. Plug the ambient temperature probe connector into its respective rear panel electrical port.
8. Route probe outside and insert into solar shield, ensuring solar shield maintains vertical orientation.

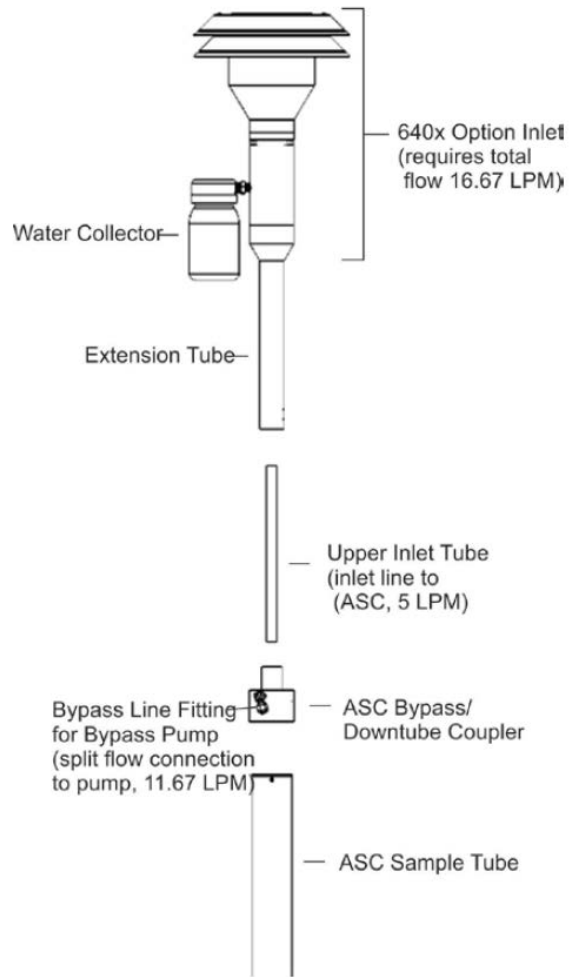


Figure 4. T640X Inlet and ASC Assembly.

3.0 SUMMARY INFORMATION SPECIFIC TO THE INSTRUMENT

3.1 Safety Precautions

To avoid damage to the monitor, ensure that the AC power voltage matches the voltage indicated on the monitor's model/specifications label located on the rear panel before plugging the T640X into line power. High voltages are present inside the instrument. Ensure that the power cord being used is capable of carrying the power rating of the instrument (see rear panel label). Note:

- Power connection must have functioning ground connection.
- Do not defeat the ground wire on power plug.
- Turn off instrument power before disconnecting or connecting electrical subassemblies.
- Do not operate with cover off.

Some repair and troubleshooting operations need to be carried out with the monitor open and running. Use common sense when operating inside a running monitor. Exercise caution to avoid electrical shocks and electrostatic or mechanical damage to the monitor. Do not drop tools into the monitor or leave those after your procedures. Do not short or touch electric connections with metallic tools while operating inside the monitor. For monitors installed in small shelters, beware of external elements (i.e., weather conditions) when performing maintenance exposing the monitor.

3.2 Siting Criteria

The installation of the T640X should follow the siting criteria requirements in 40 CFR Part 58, Appendix E in order for the sampled filters to be considered valid. General siting criteria include:

1. Being >20 meters from a tree, and at least 10 meters from a tree drip line,
2. Being >1 meter horizontally away from another probe,
3. Having the probe inlet located 2-15 meters above ground,
4. And being twice the distance from a structure or tree that acts as an obstruction, as the structure or tree protrudes above the inlet.

4.0 LOGBOOK SETUP, SITE VISIT PROCEDUES AND CHECKS

4.1 Initial Setup of the Electronic Logbook

An electronic logbook (e-log) must be created for each site at the beginning of the calendar year or upon setup. The T640X e-log consists of the spreadsheets listed in Table 1. The most current e-log version can be obtained from the Internet Based Enterprise Application Management (IBEAM) documents module, the Ambient/Documents/PM Monitoring SharePoint folder or by contacting the RCO particulate matter lead.

Table 1. Description of E-Log Spreadsheets.

E-Log Spreadsheet	Description
Instructions	Setup of site information (Site Name, AQS ID, SiteID2). Provides a summary of operational evaluations and sampler maintenance for users.
Event Summary	Table for users to track dates of verifications, audits, and maintenance.
Calibration	Table for documenting sampler calibrations.
Verification Audit	Table for documenting all verifications and audits.
Maintenance Log	Table for documenting monthly, quarterly, and annual maintenance activities, as well as, leak checks, clock verifications, etc.

Initial setup of the e-log requires selecting the site name from a pull down menu on the “Instructions” tab of the e-log (Figure 1). The AQS ID, pollutant, and T640X type field will automatically populate based on the site name.

4.1.1 Guidance for Useful Logbook Documentation

EPA has been providing guidance on record keeping requirements for QA/QC programs. In particular, EPA has discussed the role that logbooks play in providing proof that QAPPs and SOPs are being followed. According to EPA, logbooks should, at a minimum, provide the following to be a useful tool for documenting the operations conducted at a monitoring site:

1. Purpose – Define the purpose of this site visit. Tell why you are there. Is it to replace a filter? Did you note something in the previous data download that is indicating a problem? Are you experiencing data drops and want to see if anything is wrong? In a couple of sentences, tell

what you intend to do. Don't say routine maintenance, say instead: "noted fluctuations in flow while reviewing the 5-minute average data". Be specific.

2. Appearance – Tell how you found the site. If the site was secure, say so. If you noted a problem, or a changed condition, then document it in a couple of sentences: "construction has taken place in the vacant lot next to the site since my last visit".
3. Action – Tell what you did. In a few short sentences describe the actions you took at the site: "cleaned the PM10 head and replaced one of the two gaskets". In particular, you might want to document any site computer updates that were run. Just things like that.
4. Results – Were you successful? Did you accomplish your goals? If so, then say so: "completed the monthly and quarterly maintenance and returned the monitor to "Wait" mode". If not, then say so: "failed as-left leak check, contacted ECB".
5. Response – Is the equipment operating within specifications set in SOP? If so, then great, note that fact in the logbook and you are done. If not, then what did you do? If something is wrong then reach out for help and document it: "contacted Scott at ECB, he will be here presently with a new FRM."
6. Reviewers should add their comments: "reviewed above, approved operator action." Or: "upon review noted deviation from SOP".

4.2 Site Visit Procedures and Checks

4.2.1 Site Inspection

Before entering the station, the perimeter should be inspected for damage. Extreme weather conditions, neglect of station maintenance or vandalism that may have resulted in damage to the site since the operator's last visit. Once the operator has approached the site, she/he should first:

1. Check for any obvious sampler malfunctions. For example, check to see that the equipment is running, the pumps are operating and the instrument is cycling properly.
2. Note any unusual odors or noise. An unusual odor may indicate a point source of a pollutant or a strange new noise can indicate a malfunction in the equipment.

These observations should be recorded in the station log book and may prove to be invaluable if the data is challenged. The station operator is responsible for making several observations during the station inspection. Any of the above described observation must be thoroughly detailed in the site log book.

It is the operator's responsibility to maintain the monitoring site. Routine maintenance includes keeping site clean and being observant of potential problems. Examples of potential problems include:

1. Accumulation of dirt and debris.
2. Infestation by rodents or insects.
3. Overgrowth of vegetation around the site.

4.2.2 Site Logbook

A station log book must be maintained at each monitoring site and should accurately reflect site operations. The log book will be identified with the station name and station number. All entries shall include the date, time, operator, maintenance on equipment and equipment changes. Additional information should include: maintenance performed on the station, abnormal traffic patterns or nearby construction. If the data is challenged, the information recorded in the logbook is invaluable. A written record of observations concerning abnormal operations or localized occurrences is critical if a violation of ambient air standards were recorded during this period.

4.2.3 Equipment Inspection

There are several routine duties that must be performed each time an air monitoring station is inspected. These duties include equipment inspection, performing calibrations, assisting during audits, documentation, and making necessary adjustments or repairs to the instruments.

It is suggested that each station operator consult the T640X Particulate Monitor Operation Manual and compile personal notes on troubleshooting as they gain experience with the instruments. The operator is encouraged to contact ECB or the manufacturer when attempting any repairs.

The operator's manual is the best resource the station operator has for the information on the operation and maintenance of the T640X monitor.

5.0 MONITOR SETUP

5.1 User Interface

The T640X uses a touchscreen display to control the features and functionality of the monitor. Figure 3 shows the front panel layout, which has the display screen, two USB ports for peripheral device connections: mouse and keyboard as alternatives to the touchscreen interface, or flash drive for uploads/downloads.



Figure 5. Front Panel.

5.1.1 Home Page Screen

The home page shows the menu tabs in a column on the right and displays the parameter name(s) and concentration reading(s) in the main portion of the screen; below that are meters displaying readings of three additional parameters. At the top of the interface are user tools and at the bottom are navigation buttons and indicators.



Figure 6. Home Page Screen.


Three meters at the bottom of home page display user-selectable parameters and their values. To select, go to the home configuration page by touching the configuration button  and following the onscreen instructions. The home page can also be configured through the Setup Menu.



Figure 7. Home Configuration Screen.

Figure 8 shows an example of a plot generated when the user presses the parameter name, concentration value or a meter on the home screen.

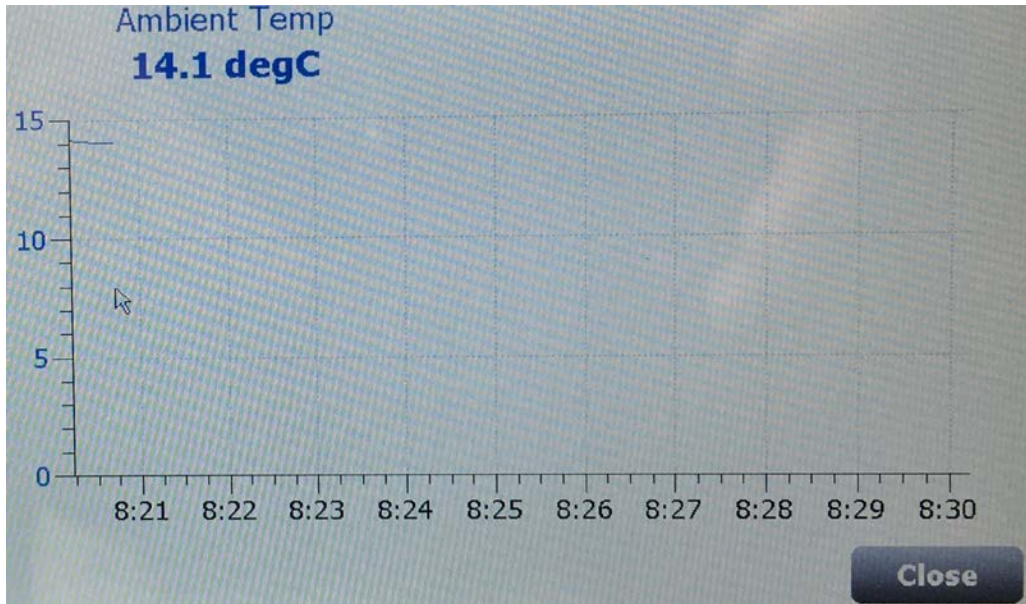


Figure 8. Ambient Temperature Graph.

5.1.2 Dashboard

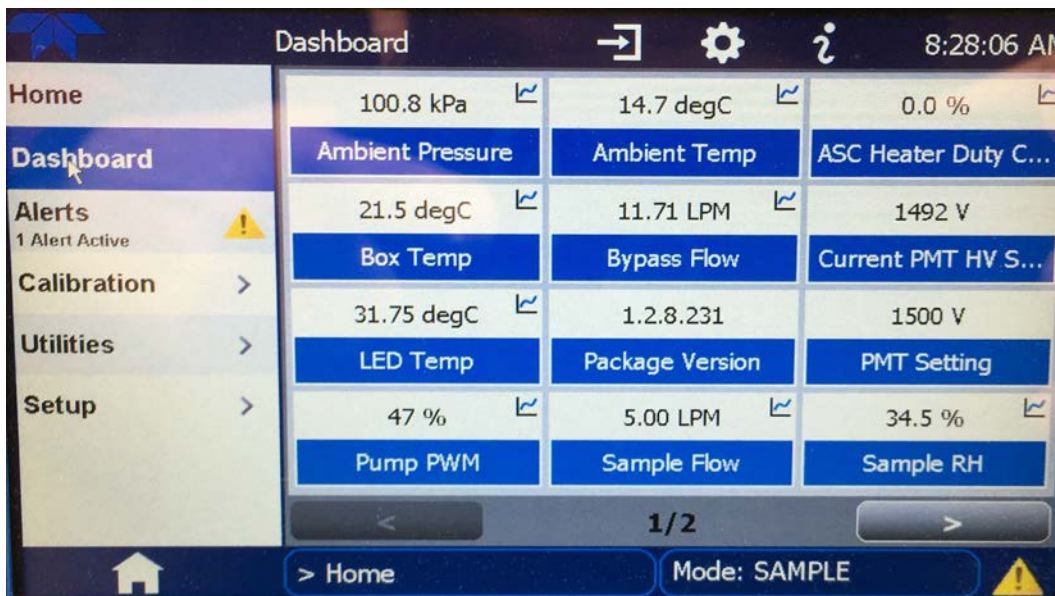


Figure 9. Dashboard Screen.

The Dashboard Screen shows an array of user-selected parameters and their values. If there is a graphing icon in the upper right corner of a parameter, pressing that parameter displays a plot.

Configure this page either while in the Home>Dashboard screen by touching the configuration button  or through the Home>Setup>Dashboard.

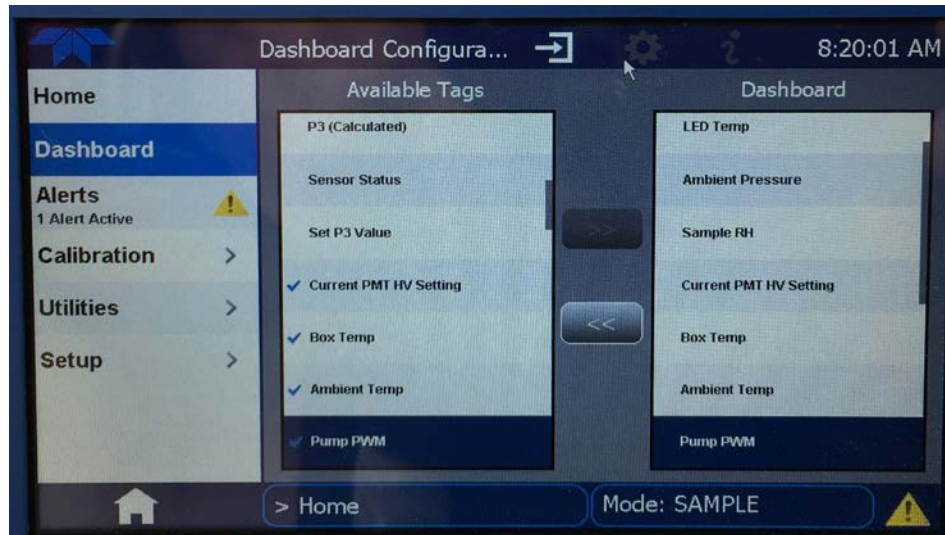




Figure 10. Dashboard Configuration.

1. To add a parameter for display in the Dashboard, make a selection from the Available Tags column and press the right-pointing button .
2. To remove a parameter from the Dashboard, select a tag from the Dashboard column and press the left-pointing button .

5.1.3 Alerts Screen

The Alerts screen shows the status of any active warning conditions or user-configured events. While Alerts can be cleared from the Alerts page, all alerts are documented and stored in the Home>Utilities>Alerts Log.

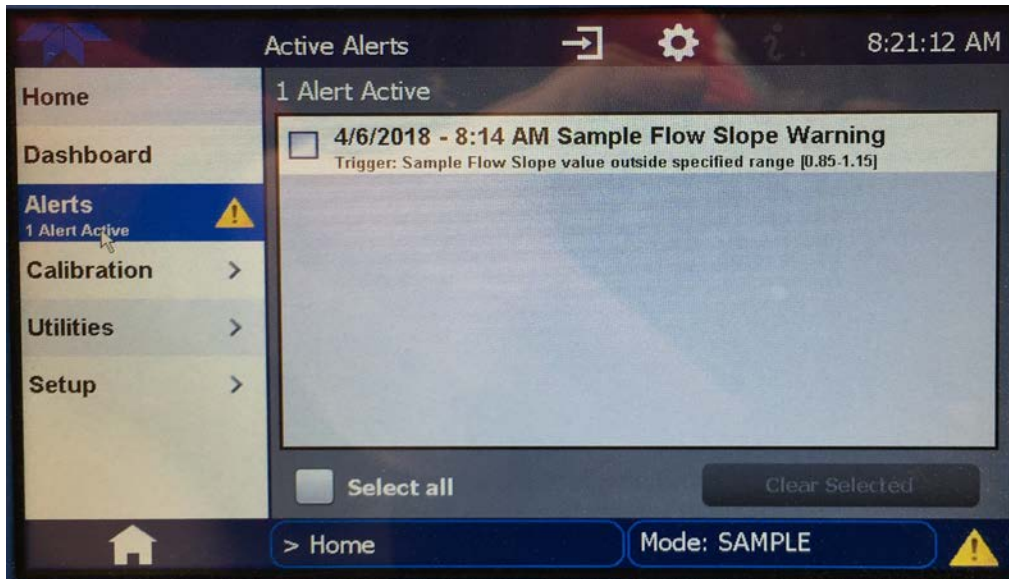


Figure 11. Alerts Log Screen.

5.1.4 USB Utilities Screen

The USB Utility screen serves multiple purposes using a flash drive connected to the instrument's front panel USB port. One purpose is used in data logging for transferring data from the instrument to a flash drive. Another is updating firmware. A third purpose, which is not yet available, is copying a configuration from one instrument to other instruments.



Figure 12. USB Utility Screen.

5.2 Monitor Setup

The T640X user interface is a touchscreen display. All of the features and functions for monitor setup are accessed using the touchscreen.

5.2.1 Powering Up and Warm Up Period

The T640X power switch is located on the front panel of the monitor. When the power is switched on, the main menu screen should appear after a few seconds.

Upon initial startup, allow the instrument to run for at least 10 minutes to reach stable operating conditions. This applies any time the unit is powered up after being off for more than one minute or power outage. It may be necessary to discard the first hour of data after the T640X is turned on, or after being downed for maintenance.

After warm-up, navigate to the Dashboard screen to verify that the Monitor is functioning within allowable operating parameters. If not all test functions and values are displayed, touch the configuration icon to insert additional functions into the Dashboard. These functions can also be used as diagnostic tools for troubleshooting a performance problem.

5.2.2 Time and Date Setup

The T640X clock time must agree with NIST time to within ± 1 minute, Eastern Standard Time. The Date/Time Settings menu allows changes to time zone, hour, minutes after the hour, and date, including auto-adjust for Daylight Savings Time.

1. Select the appropriate time zone.
2. Press the “Date/Time” field to make adjustments.
3. Press <Date> or <Time> to toggle between screens and select the correct settings from the scrolling menus.
4. Press <Done> when finished.

Note: Do not select the option for the monitor to automatically adjust for daylight saving s time.

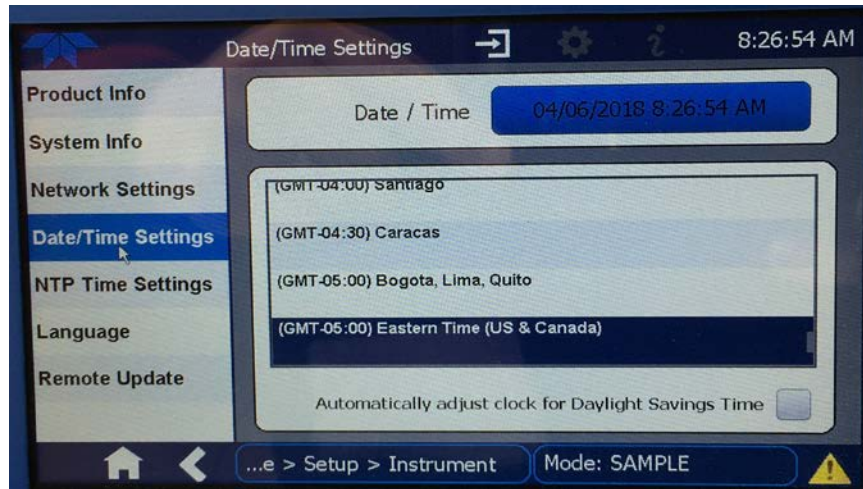


Figure 13. Time and Date Configuration Screen.

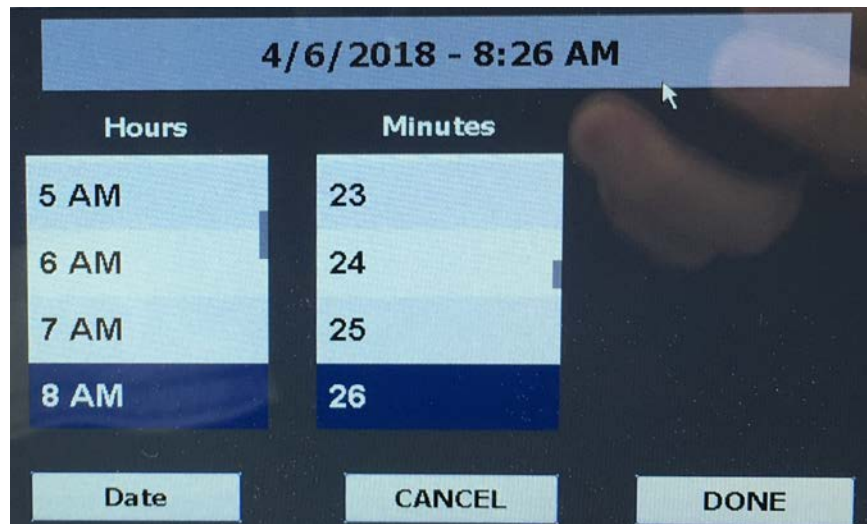


Figure 14. Scrolling Time Menu.

6.0 CALIBRATION

It is a good practice to complete all outstanding maintenance activities prior to initiating a full calibration. *Note: A flow verification must be completed prior to a calibration if the sampler was previously operating at the site.* New samplers installed at a site do not need a flow verification prior to a calibration because there is no collected data to envelope. Annual calibrations are required within 365 days of the prior calibration.

Note: If the monitor is being turned on for the first time, or being restarted after a period of stoppage, it is recommended that the user allow the T640X LED to warm-up for 10 minutes prior to performing a leak check or PMT adjustments.

There are three parameters of the monitor that can be calibrated:

1. Pressure sensor calibration;
2. Flow sensor calibration and re-verification; and
3. PMT calibration using SpanDust™.

6.1 Calibration Requirements

A calibration is required under the following circumstances:

- Upon initial sampler set up.
- Each calendar year and no more than 365 days from the last calibration.
- After a sampler is replaced.
- After a sampler is moved or relocated, no matter the distance.
- After the pump or flow controller is replaced.
- If flow check or a flow audit are not within specifications.
- If the device once used for flow calibration needs to be used as the audit device.
- If the sampler is without power for longer than 48 hours and the flow verification fails.

6.2 Calibration Equipment



Figure 15. BGI Tetra Cal with Optional Temperature Probe.

All device certifications must be current within 365 days of use. Listed below is the necessary equipment needed for completing a calibration:

- A high-efficiency particulate air (HEPA) filter assembly with a flow audit adapter.
- A certified Tetra Cal unit or Streamline Flow Transfer Standard (FTS).
- If using a FTS, a digital, water or oil manometer, capable of measuring to a tenth of an inch of water.
- If using a FTS, a 12-18" piece of 1/4" diameter Tygon® tubing to connect the FTS to the manometer.
- A glass thermometer capable of measuring to the nearest half a degree Celsius, that is traceable to a National Institute of Standards and Technology (NIST) standard, or the thermistor probe included with a certified Tetra Cal unit.
- A digital barometer, that is NIST traceable, or the barometer that is part of a certified Tetra Cal unit.
- The most recent revision of the T640X electronic logbook.

Note: If using a glass thermometer, hang the thermometer from the shaded side of the ambient temperature probe's solar shield or sampling inlet. Allow all devices, whether a Tetra Cal or digital barometer, to equilibrate for approximately 10 minutes, making sure to keep them out of direct sunlight.


6.3 Calibration E-Log Setup

1. Open the most recent scrolling e-log for the site. If this is a new site or the first visit of the calendar year, obtain the proper e-log from the IBEAM documents module, the Ambient/Documents/PM Monitoring SharePoint folder or by contacting the RCO particulate matter lead.
2. Select the "Calibration" tab of the e-log.
3. Enter in the information for all of the white boxes under the Visit Information, Thermometer information, Manometer Information, Barometer Information, Tetra Cal or FTS information sections.
4. Do not proceed if any of the devices fail the certification requirement (certified within 365 days of use).

6.4 Calibration "As Found" Leak Check

The internal components of the T640X are not meant to be under strict vacuum as what would normally be done in a leak test. In order to avoid damage to internal components, it is recommended that the inlet never be capped (air tight) while the instrument pumps are running.

A zero test is a way to check for leaks that do not involve pulling a vacuum on the system. *Note: no adjustment is made if the zero test is not acceptable, rather troubleshoot the instrument until resolved.* For this procedure, ensure data are "Off Scan." Take the following steps to perform an "as found" leak check:

1. Remove the inlet and fit a HEPA filter (Figure 16) to the sample port. Ensure tubing is not kinked.
2. Observe the PM values on the front panel display. Press either "Home" or the  key.
3. Within approximately 10 minutes the PM values should be at zero (0.0) for each PM metric. If data reach 0.0, accept the zero test and move to step 5. If data are in the range of 0.1 to 0.3, accept the data and troubleshoot. If after ten minutes the data are still at 0.4 or greater, identify the data as suspect in Envista and troubleshoot. If the PM values are not reading zero, then it's likely to be one of two issues:

- 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). Troubleshoot by checking each connection between monitor and HEPA filter and ensuring there is a good seal or:
- It is possible the HEPA filter being used is either bad or leaking. It is recommended to have a second filter handy to check.



Figure 16. Leak Check Adapter with HEPA Filter.

4. If after ten minutes from any adjustment, values don't reach zero (0.0), troubleshoot and repeat steps above.
5. Once PM values reach zero (0.0) for each PM metric, disconnect the HEPA filter.
6. Read and record the stated value of the zero test in the "Calibration" page of the e-log.

6.4.1 Alternative Procedure for Walk-in Shelters

For walk-in shelter installations, a single operator will be challenged to review data on the front panel of the monitor while performing verifications and calibrations on a roof. Two operators could be used; however, in most cases this is not practical. To allow verifications and calibrations for walk-in shelter applications, Teledyne has a slip coupler which can be utilized to allow audit devices and SpanDust™ to be used from inside the shelter. The procedure for use of the slip coupler does not apply to zero tests as the HEPA filter should be installed on the downtube where the PM10 inlet is normally connected to the downtube on the roof. Also, the procedure for verifying ambient temperature needs to be conducted on the roof so that the routine ambient temperature probe can be checked. For this procedure, ensure data are “Off Scan.” For all other verifications and calibrations, where necessary, the following applies to using a slip coupler:



Figure 17. Slip Coupler in Normal Position and Lifted Vertically.

1. Holding the downtube above the slip coupler with one hand, lift the slip coupler with your other hand from its current position to a height just high enough that the slip coupler is no longer touching the aluminum downtube. The downtube above the slip coupler should be held in a consistent vertical position so that the seal between the downtube and roof flange is maintained.
2. Carefully move the T640X monitor chassis and ASC away from the downtube so that there is enough clearance for the audit device to be attached. This requires moving the base of the monitor (Figure 16).



Figure 18. Slip Coupler Moved to the Side to Allow Monitor Use with Audit Devices.

3. Detach the ambient temperature probe on the back of the monitor and temporarily attach the short cable temperature probe so that the temperature inside the shelter is being used for calculations of flow.
4. Perform remaining verifications and where applicable, calibrations. A verification of the short temperature probe is also recommended.
5. With all verifications and calibrations complete, detach short cable temperature probe and re-attach the ambient temperature probe from the roof.
6. Align the T640X monitor chassis so that the ASC is directly below the slip coupler.
7. Holding the downtube above the slip coupler with one hand, reengage the slip coupler back to its original position with your other hand. The downtube above the slip coupler should be held in a consistent vertical position so that the seal between the downtube and roof flange is maintained.

6.5 Ambient Pressure Sensor Calibration

The pressure must be calibrated prior to the flow because the actual flow is calculated using both ambient temperature and pressure. *Note: A sensor calibration always requires a flow calibration afterwards.* For the Pressure Cal and the two Flow Cal menus, note that the “Measured” parameter provides the value measured by the instrument; the “Actual” parameter is the value that is to be input from the reading measured by the external auditing device. For this procedure, ensure data are “Off Scan.” Take the following steps to perform a pressure sensor calibration:

1. With the NIST traceable device operating and measuring the ambient pressure, navigate to the Pressure Cal Menu (>Calibration >Pressure Cal) on the T640X.
2. Compare the “Measured Pressure” in this screen to the NIST standard.

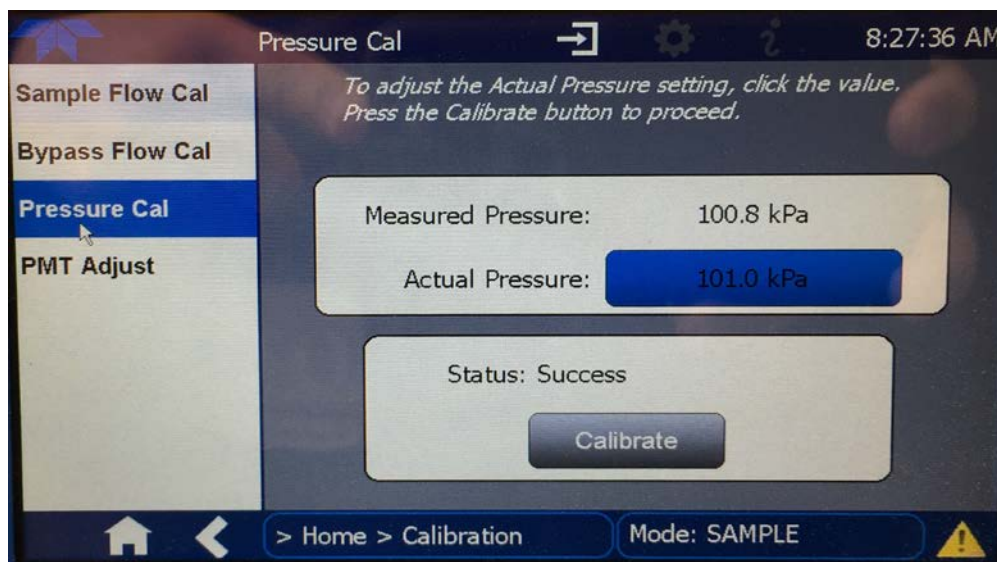


Figure 19. Pressure Calibration Screen in kPa.

3. If the two values differ by more than +/- 10 mm Hg, then press the value button in the “Actual Pressure” field; enter the value measured by the NIST standard and press <Enter>. Then press the <Calibrate> button on the screen. The monitor pressure value should change to closely match the NIST pressure within a few seconds.
4. Read and record the stated pressures in the “Calibration” tab of the e-log.

6.6 Ambient Temperature Sensor Verification as Part of a Full Calibration

The ambient temperature probe can be verified; however, there is no available way to calibrate this sensor. Temperature probes that do not meet the expected tolerance of $\pm 2^{\circ}\text{C}$ of NIST should be inspected and cleaned. Cleaning of the gill screen may also help to ensure air can pass freely to the probe. A spare temperature probe should be available in case the verification continues to fail the acceptable tolerance. Temperature verifications can be conducted either with the instrument in normal operation or with the unit operating, but “Off Scan”. The following procedure applies to a temperature verification:

1. Obtain the ambient temperature reading from the front panel of the T640X monitor. Alternatively, ambient temperature can be obtained through the dashboard on the main screen.
2. Hold the temperature probe of the audit device in close proximity to the gill screen holding the ambient temperature probe of the T640X. *Note: If there is direct sun, ensure the audit probe is held behind the gill screen relative to the sun so that the gill screen casts a shadow on the audit device temperature probe (Figure 20).*
3. Wait at least one minute for the audit device temperature to stabilize.
4. Record audit device ambient temperature and T640X ambient temperature to the “Calibration” tab of the E-log.
5. Compare audit temperature to T640 ambient temperature and if off by more than $\pm 2^{\circ}\text{C}$, troubleshoot and repeat.
6. If verification cannot meet tolerance replace temperature probe.



Figure 20. Proper Shaded Locations.

6.7 Flow Calibration

Flow calibrations are conducted on the sample flow (5 lpm) and the bypass flow (11.67 lpm) by going to the Sample Flow Calibration Menu (>Calibration >Sample Flow Cal). *Note: a calibration of total flow (16.7 lpm) is not available, rather the sample and bypass flows are individually calibrated.* Once a flow is calibrated, a post calibration flow evaluation should be performed to a tolerance of $\pm 2\%$. Total flow verification of a monitor is acceptable if within $\pm 3\%$ of an audit device.

Flow calibrations should be conducted after all verifications and a pressure calibration have been performed, as necessary. Conduct the flow calibrations and post calibration flow evaluations of the flows in the following order:

1. Calibrate the sample flow (5 lpm).
2. Conduct a post calibration flow evaluation for the sample flow (5 lpm) to ensure reading of monitor is within $\pm 2\%$ of NIST device. *Note: a 2% tolerance is to ensure that the flow sensor of the instrument is reading reasonably close to expected immediately following a flow calibration.*
3. Calibrate the bypass flow (11.67 lpm).
4. Conduct a post calibration flow evaluation for the bypass flow (11.67 lpm) to ensure reading of monitor is within 2% of NIST device.
5. Perform a post calibration flow evaluation for the total flow (16.67 lpm) to ensure reading of monitor is within 3% of NIST device.

6.7.1 Calibration of Sample Flow (5.0 lpm)

1. Ensure data are “Off Scan.” Disconnect auxiliary flow line from side of aerosol sample conditioner (ASC). Ensure auxiliary flow line is not blocked and only pulling in ambient air.



Figure 21. ASC and Auxiliary Flow Line.

2. Cap Swagelok fitting at side of ASC.
3. Set up your NIST-traceable flow standard transfer device with the appropriate inlet for the flow to be calibrated. Ensure audit device is appropriately sized for 5.0 lpm flow.
4. Remove the inlet from upper inlet tube.
5. Connect the Flow Standard to the top of the upper inlet tube. Ensure the tubing connecting the inlet to the flow standard is not kinked.
6. With the T640X running, go to the Calibration > Sample Flow Cal menu.
7. Wait at least one minute for the flow to stabilize.
8. Compare the measured flow in this screen to the flow standard (Figure 19). Press the <Start> button (this disables the internal data logging), and then <Actual Flow>. Enter the value

measured by the flow standard and press <Enter>, then press the <Calibrate> button on this screen. The measured flow value should change to closely match the actual flow within a few seconds.

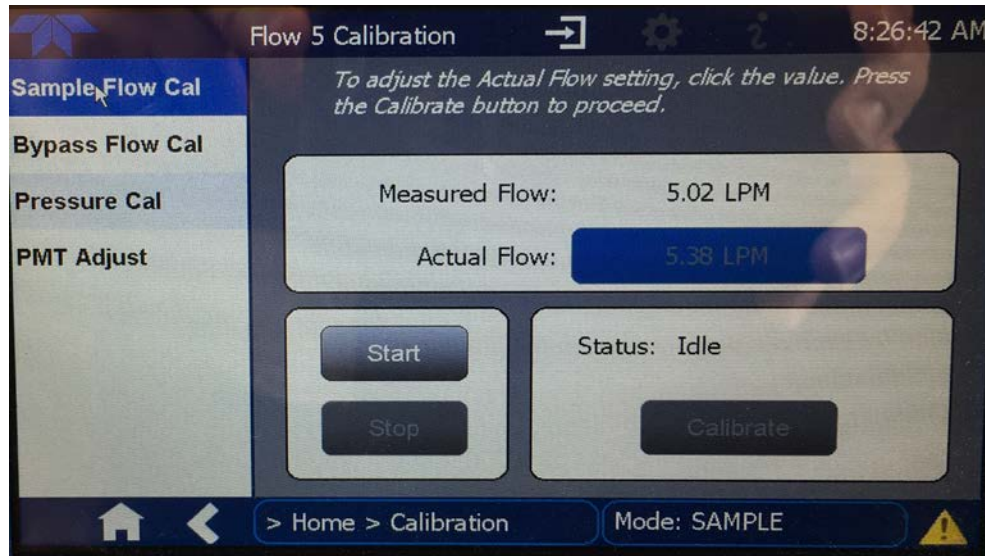


Figure 22. Sample Flow Calibration Screen.

9. Read and record the stated flows in the “Calibration” tab of the e-log. If sample flow meets expected 2% tolerance (4.90 – 5.10 lpm), then proceed to step 10. If the sample flow is outside of the acceptable tolerance, repeat starting with step 6 to perform a calibration of the sample flow.
10. Disconnect Swagelok cap from ASC. Reattach bypass line, unless a bypass flow calibration is to be performed as described below.
11. Press <Stop> on the sample flow calibration menu to end the sample flow calibration procedure and return to normal operation.

6.7.2 Calibration of Bypass Flow (11.67 lpm)

A calibration of the bypass flow is only needed upon start-up or if the total flow verification does not meet the acceptable tolerance and the sample flow has already been verified and/or calibrated. For this procedure, ensure data are “Off Scan.”

1. Connect the NIST-traceable flow transfer standard device to the bypass line that was disconnected in the sample flow verification procedure above. Ensure fitting(s) connecting flow transfer standard and bypass line are secure and not leaking.



Figure 23. Flow Standard Connected to the Bypass Line.

2. With the T640X running, go to the flow calibration menu: >Calibration >Bypass Flow Cal.
3. Wait at least one minute for flow to stabilize.
4. Compare the measured flow in this screen to the flow standard. Press the <Start> button (this disables the internal data logging), and then <Actual Flow>. Enter the value measured by the flow standard and press <Enter>, then press the <Calibrate> button on this screen. The measured flow value should change to closely match the actual flow within a few seconds.

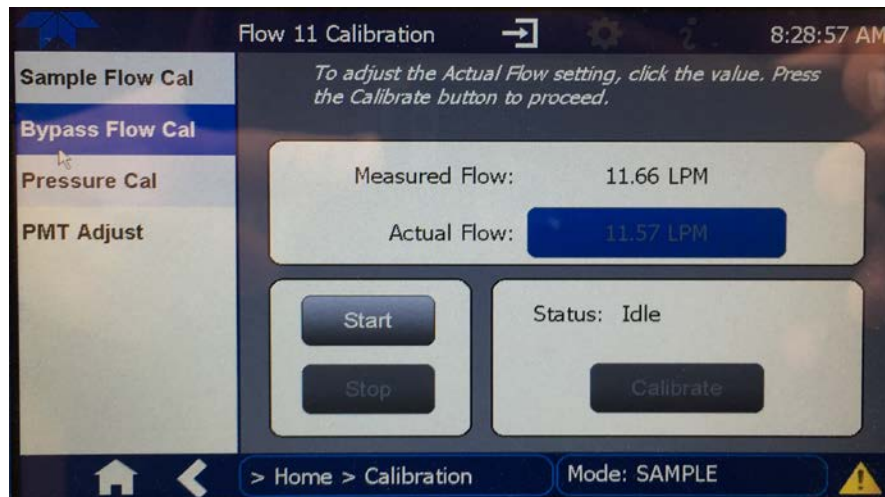


Figure 24. Bypass Flow Calibration Screen.

5. Read and record the stated flows in the “Calibration” tab of the e-log. If sample flow meets expected 2% tolerance (11.44 – 11.90 lpm), then proceed to step 6. If the sample flow is outside of the acceptable tolerance, repeat starting with step 2 to perform a calibration of the bypass flow.
6. Reattach bypass line to ASC.
7. Press <Stop> on the sample flow calibration menu to end the sample flow calibration procedure and return to normal operation.

6.7.3 Post Calibration Flow Evaluation

For the evaluation procedure, ensure data are “Off Scan.”


1. Set up your NIST-traceable flow standard transfer device with the appropriate inlet for the flow to be calibrated.
2. Remove the inlet from upper inlet tube.
3. Connect the flow standard to the top of the upper inlet tube. Ensure the tubing connecting the inlet to the flow standard is not kinked.



Figure 25. Flow Audit Adapter with Flow Standard Connected.

4. With the T640X running, go to main menu or dashboard to review the total flow (16.67 lpm).
5. Wait at least one minute for the flow to re-stabilize.
6. Compare the T640X total flow to the flow standard and determine if these values differ by more than 3%, (16.17 – 17.17 lpm). Record the flow standard and the T640X total flows to the “Calibration” tab of the e-log.

6.8 Calibration “As Left” Leak Check

1. Remove the inlet and fit a HEPA filter to the sample port. Ensure tubing is not kinked.
2. Observe the PM values on the front panel display. Press either “Home” or the  key.
3. Within approximately 10 minutes the PM values should be at zero (0.0) for each PM metric. If data reach 0.0, accept the zero test and move to step 5. If data are in the range of 0.1 to 0.3, accept the data and troubleshoot. If after ten minutes the data are still at 0.4 or greater, identify the data as suspect in Envista and troubleshoot. If the PM values are not reading zero, then it’s likely to be one of two issues:

- 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). Troubleshoot by checking each connection between monitor and HEPA filter and ensuring there is a good seal or:
- It is possible the HEPA filter being used is either bad or leaking. It is recommended to have a second filter handy to check.



Figure 26. Leak Check Adapter with HEPA Filter.

4. If after ten minutes from any adjustment, values don't reach zero (0.0), troubleshoot and repeat steps above.
5. Once PM values reach zero (0.0) for each PM metric, disconnect the HEPA filter.
6. Read and record the stated value of the zero test in the "Calibration" tab of the e-log.

6.9 Particle Sensor PMT Calibration

Once all verifications and any necessary calibrations to the pressure and flow systems are complete, an adjustment of the Particle Sensor PMT may be performed using SpanDust™. A calibration of the PMT is an adjustment in the field for drift caused by contamination of the optics.

Note: Careful attention needs to be made to ensure a minimum amount of SpanDust™ enters the sample tube during an adjustment of the PMT and that repeats of this calibration are kept to a minimum.

Note: If the monitor is being turned on for the first time, or being restarted after a period of stoppage, it is recommended that the user allow the T640X LED to warm-up for 10 minutes prior to performing a leak check or PMT adjustments.



For a step by step demonstration of the PMT Adjustment, use the QR code below to view a video by Teledyne API. This video is also available at: <https://www.youtube.com/watch?v=pZYnXwYwtIs>



Figure 27. QR Code for PMT Adjustment Video.

For this procedure, ensure data are “Off Scan.”

1. Navigate to the PMT Adjust screen: >Home >Calibration >PMT Adjust.
2. Press the Start button on this screen to suspend normal data acquisition and start this adjustment process.

3. Remove the T640X sample inlet.
4. Prepare the SpanDust™ bottle by uncapping the “air intake” tubing on the cap of the bottle.
5. Place the tube from the SpanDust™ bottle into the top of the upper inlet tube for the instrument.
6. Ensure that the silicone tube fits snugly inside the aluminum inlet tube, and do not allow the bottle to hang, as it could dislodge the silicone tube from the inlet tube.
7. 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.
8. Record the peak channel reading and the SpanDust™ value in the “Calibration” tab of the e-log. If the peak channel reading is acceptable (± 0.5 of SpanDust™ value stated on bottle) then proceed to step 13.
9. If the peak channel is not acceptable, then retry one more time by pressing the <Stop> button, then the <Start> button on the T640X, then proceed with step 7 above.
10. If after two tries the peak channel reading is not within ± 0.5 of the SpanDust™, then adjust the PMT Setting by pressing the Peak Adjust left  (decrement) or right  (increment) buttons to center the peak voltage (Figure 28). 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.

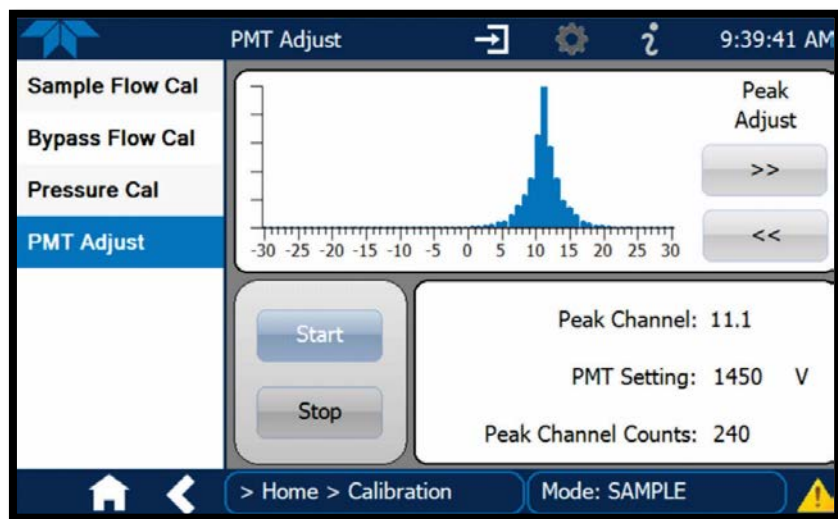


Figure 28. PMT Adjustment Screen.

11. Allow 30 seconds for the peak channel reading in this screen to respond, and if it is not ± 0.5 of SpanDustTM value stated on bottle, repeat the process. This could take several tries over a long period when conducted in a humid environment.
12. Once the Peak Channel reading is ± 0.5 of SpanDustTM value stated on bottle, record the value in the “Calibration” tab of the e-log
13. Reattach the sample inlet and press the <Stop> button to stop the adjustment process and resume normal data acquisition.
14. Wait 10 minutes, review data on home screen of T640X, and then bring unit back “On Scan” in the data system.

7.0 QUALITY CONTROL

A **Flow Verification** must be performed once every thirty days (a.k.a. Monthly Verification). It is a test of the monitor's sensors against certified standards. It is preferred, **but not required**, that the verification be completed with devices that are different from the devices used for the calibration. A flow verification is also required before any action that requires the operator to envelope the data (e.g. moving the monitor, performing maintenance that will break the sampling pathway or shutdown). A flow verification is also required after a power outage lasting more than 48 hours. A monthly flow verification cannot be completed on the same day as a calibration unless it is the final day of the calendar month.

A **Mid-Month Verification** is a test of the monitor's sensors against certified standards. The mid-month verification was implemented to avoid invalidating large amounts of data if a monthly flow verification fails. The mid-month verification must follow a verification by 14 to 18 days. The mid-month verification process is the same as the monthly verification procedure. The audit replaces the mid-month verification in the second month of each calendar quarter.

An **Audit** must be performed every quarter. It should be performed in the second month of each calendar quarter if possible. It is a test of the monitor's sensors against certified standards **that were not used** for the previous calibration, monthly verifications or mid-month verifications. Standards that have been recently recertified (having been used for calibrations/verifications and not used since) are candidates for becoming audit equipment. Audits are also to be performed by personnel other than the normal site operator. If the audit cannot be performed during the second month due to abnormal circumstances (such as the monitor being inoperable or extreme weather events), the mid-month verification must be completed instead. The audit should then be performed in place of the mid-month verification during the third month, before the quarter ends.

All device certifications must be current within 365 days of use. Listed below is the necessary equipment needed for completing a calibration:

- A high-efficiency particulate air (HEPA) filter assembly with a flow audit adapter.
- A certified Tetra Cal unit or Streamline Flow Transfer Standard (FTS).
- If using a FTS, a digital, water or oil manometer, capable of measuring to a tenth of an inch of water.
- If using a FTS, a 12-18" piece of 1/4" diameter Tygon[®] tubing to connect the FTS to the manometer.
- A glass thermometer capable of measuring to the nearest half a degree Celsius, that is traceable to a National Institute of Standards and Technology (NIST) standard, or the thermistor probe included with a certified Tetra Cal unit.

- A digital barometer, that is NIST traceable, or the barometer that is part of a certified Tetra Cal unit.
- The most recent revision of the T640X electronic logbook.

Note: If using a glass thermometer, hang the thermometer from the shaded side of the ambient temperature probe's solar shield or sampling inlet. Allow all devices, whether a Tetra Cal or digital barometer, to equilibrate for approximately 10 minutes, making sure to keep them out of direct sunlight.

7.1 Tolerances and Corrective Actions for Verifications, Checks, and Audits

At the time of the writing of this SOP, EPA has not produced a table of Data Quality Objectives (DQOs) as is common for other parameters. These objectives would give guidance to the best acceptable tolerances for verified actions with the monitor. For now, NC DAQ has selected the DQOs below for use with the T640X. When an established set of DQOs are made available by EPA, NC DAQ will adopt them immediately at that time. If any parameter fails the tolerance listed in Table 2, corrective action is required as indicated. **Note: Do not perform a calibration until after you have verified, checked, or audited all of the parameters.**

Table 2. Operation Evaluations.

CRITERIA	TOLERANCE	FREQUENCY	CORRECTIVE ACTION
External Leak Check	< 0.1 µg/m ³	<ol style="list-style-type: none"> Before and after any flow verification. During each quarterly audit. 	Make sure all hoses are well connected. If unit fails to pass, call ECB and Particulate Lead.
Ambient Temperature Verification or Audit	± 2 °C of NIST Thermometer	<ol style="list-style-type: none"> During each monthly and mid-month check. During each quarterly audit. 	Perform a flow verification prior to an ambient pressure adjustment. Follow with complete calibration. If unit fails to pass, call ECB and Particulate Lead.
Ambient Pressure Verification or Audit	± 10 mm Hg of NIST Barometer	<ol style="list-style-type: none"> During each monthly and mid-month check. During each quarterly audit. 	Perform a flow verification prior to an ambient pressure adjustment. Follow with complete calibration. If unit fails to pass, call ECB and Particulate Lead.
Post Calibration Evaluation	5.0 lpm ± 2% 11.67 lpm ± 2% 16.67 lpm ± 3%	After each monitor calibration	Calibrate again. If unit fails, call ECB and Particulate Lead.
Monthly Verification	5.0 lpm ± 10% 11.67 lpm ± 5% 16.67 lpm ± 3%	<ol style="list-style-type: none"> Each calendar month. Power outage > 48 hours 	Investigate the cause for the failure. If no other cause is identified other than monitor drift, perform a calibration. If unit fails to pass, call ECB and Particulate Lead.
Mid-Month Verification	5.0 lpm ± 10% 11.67 lpm ± 5% 16.67 lpm ± 3%	14-18 Days after Flow Rate Verification (in non-audit months)	Investigate the cause for the failure. If no other cause is identified other than monitor drift, perform a calibration. If unit fails to pass, call ECB and Particulate Lead.
Quarterly Audit	5.0 lpm ± 10% 11.67 lpm ± 5% 16.67 lpm ± 3%	Quarterly (preferably the second month)	Investigate the cause for the failure. If no other cause is identified other than monitor drift, perform a calibration. If unit fails to pass, call ECB and Particulate Lead.


7.2 Verification or Audit: E-Log Setup

1. Open the most recent scrolling e-log for the site. If this is a new site or the first visit of the calendar year, obtain the proper e-log from the IBEAM documents module, the Ambient/Documents/PM Monitoring SharePoint folder or contact the RCO PM lead.
2. Select the “Verification Audit” tab of the e-log.
3. Enter in the information for all of the white boxes under the Visit Information, Thermometer information, Manometer Information, Barometer Information, Tetra Cal or FTS information sections.
4. Do not proceed if any of the devices fail the certification requirement (certified within 365 days of use).

7.3 Verification or Audit “As Found” Leak Check

The internal components of the T640X are not meant to be under strict vacuum as what would normally be done in a leak test. In order to avoid damage to internal components, it is recommended that the inlet never be capped (air tight) while the instrument pumps are running.

A zero test is a way to check for leaks that do not involve pulling a vacuum on the system. *Note: no adjustment is made if the zero test is not acceptable, rather troubleshoot the instrument until resolved.* For this procedure, ensure data are “Off Scan.” Take the following steps to perform an “as found” leak check:

1. Remove the inlet and fit a HEPA filter to the sample port. Ensure tubing is not kinked.
2. Observe the PM values on the front panel display. Press either “Home” or the  key.
3. Within approximately 10 minutes the PM values should be at zero (0.0) for each PM metric. If data reach 0.0, accept the zero test and move to step 5. If data are in the range of 0.1 to 0.3, accept the data and troubleshoot. If after ten minutes the data are still at 0.4 or greater, identify the data as suspect in Envista and troubleshoot. If the PM values are not reading zero, then it’s likely to be one of two issues:
 - 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). Troubleshoot by checking each connection between monitor and HEPA filter and ensuring there is a good seal or:

- It is possible the HEPA filter being used is either bad or leaking. It is recommended to have a second filter handy to check.



Figure 29. Leak Check Adapter with HEPA Filter.

4. If after ten minutes from any adjustment, values don't reach zero (0.0), troubleshoot and repeat steps above.
5. Once PM values reach zero (0.0) for each PM metric, disconnect the HEPA filter.
6. Read and record the stated value of the zero test in the "Calibration" page of the e-log.

7.4 Verification or Audit: Ambient Pressure and Ambient Temperature

The pressure measurement of the T640X is for the ambient pressure in which the instrument is operated. No direct pneumatic connection to the instrument needs to be made to perform this check and data are not affected.

1. With the Pressure Standard operating and measuring the ambient pressure in the same room as the T640X monitor, navigate to the Pressure Cal menu: >Calibration >Pressure Cal. Alternatively, pressure can be obtained through the dashboard on the main screen.
2. Compare the measured pressure in this screen to the audit pressure standard. Record the flow standard and the T640X total flows to the “Verification Audit” tab of the e-log.
3. If the two values differ by more than +/- 10 mm Hg, note on “Verification Audit” tab of the e-log and continue with the remaining verifications.

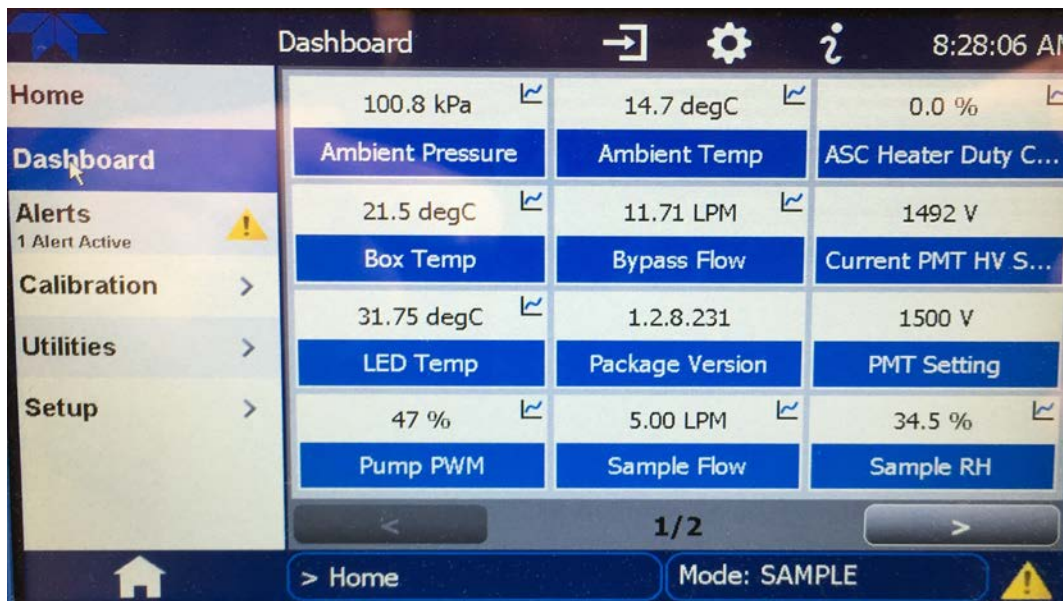


Figure 30. Ambient Temperature Calibration Screen.

The ambient temperature probe can be verified; however, there is no available way to calibrate this sensor. Temperature probes that do not meet the expected tolerance of +/-2 C from a temperature standard should be inspected and cleaned. Cleaning of the gill screen may also help to ensure air can pass freely to the probe. A spare temperature probe should be available in case the verification

continues to fail the acceptable tolerance. Temperature verifications can be conducted either with the instrument in normal operation or with the unit operating, but “Off Scan”. The following procedure applies to a temperature verification:

1. Obtain the ambient temperature reading from the front panel of the T640X monitor. Alternatively, ambient temperature can be obtained through the dashboard on the main screen.
2. Hold the temperature probe of the audit device in close proximity to the gill screen holding the ambient temperature probe of the T640X. If there is direct sun, ensure the audit probe is held behind the gill screen relative to the sun so that the gill screen casts a shadow on the audit device temperature probe.
3. Wait at least one minute for the audit device temperature to stabilize.
4. Record audit device ambient temperature and T640X ambient temperature to the “Verification Audit” tab of the e-log.
5. Compare audit temperature to T640X ambient temperature and if off by more than $\pm 2^{\circ}\text{C}$, troubleshoot and repeat.
6. If verification cannot meet tolerance, replace temperature probe.



Figure 31. Proper Shaded Locations.

7.5 Verification or Audit: Total Flow (16.7 lpm) and Sample Flow (5.0 lpm) Verification

Flow verifications for total flow (16.7 lpm) and sample flow (5.0 lpm) can be conducted with the instrument operating normally so long as the data are “Off Scan”. The flow calibration screens can be accessed at: >Calibration >Sample Flow Cal and >Calibration >Bypass Flow Cal. Alternatively, ambient temperature can be obtained through the dashboard on the main screen.

The flow verifications and calibrations should be conducted in the following order:

1. Verify total flow: 16.67 lpm. Whether acceptable or not move to next step.
2. Verify sample flow: 5.00 lpm Whether acceptable or not move to next step.
3. Verify bypass flow: 11.67 lpm. If total, sample and bypass flows meet acceptable tolerances, you are done with the flow portion of your audit or verification.
4. If any flow is not acceptable, calibrate the sample and bypass flows and repeat the verification.

7.5.1 Verification of Total Flow (16.67 lpm)

For the verification procedure, ensure data are “Off Scan.”

1. Set up your NIST-traceable flow standard transfer device with the appropriate inlet for the flow to be calibrated.
2. Remove the inlet from upper inlet tube.
3. Connect the flow standard to the top of the upper inlet tube. Ensure the tubing connecting the inlet to the flow standard is not kinked.
4. With the T640X running, go to main menu or Dashboard to review total flow (16.67 lpm). Wait at least one minute for the flow to re-stabilize.
5. Record audit device flow and T640X total flow to the “Verification Audit” tab of the e-log. Compare the T640X total flow to the NIST device flow and determine if these values differ by more than $\pm 3\%$, (16.17 – 17.17 lpm). If the total flow meets the expected tolerance, then you are done with the total flow verification. If total flow is outside of the acceptable tolerance, you will still need to perform a sample and bypass flow verification.

6. Move to verifying sample flow (5.0 lpm).



Figure 32. Flow Audit Adapter with Flow Standard Connected.

5.5.2 Verification of Sample Flow (5.0 lpm)

For this procedure, ensure data are “Off Scan.”

1. Disconnect auxiliary flow line from side of ASC. Ensure auxiliary flow line is not blocked and only pulling in ambient air.
2. Cap Swagelok fitting at side of ASC.
3. Set up your NIST-traceable flow standard transfer device with the appropriate inlet for the flow to be calibrated. Ensure audit device is appropriately sized for 5.0 lpm flow.
4. Remove the inlet from upper inlet tube.
5. Connect the flow standard to the top of the upper inlet tub. Ensure the tubing connecting the inlet to the flow standard is not kinked.



Figure 33. ASC and Auxiliary Flow Line.


6. With the T640X running, go to the Calibration > Sample Flow Cal menu. Alternatively, you can view sample flow from the dashboard.
7. Wait at least one minute for the flow to re-stabilize.
8. Record to the “Verification Audit” tab of the e-log. Compare the measured flow in this screen to the NIST flow standard and determine if these values differ by more than $\pm 10\%$, (4.5 – 5.5 lpm). If the sample flow meets expected tolerance, then you are done with the sample flow verification. If sample flow is outside of the acceptable tolerance you still will need to perform a bypass flow verification.
9. Disconnect Swagelok cap from ASC. Reattach bypass line, unless a bypass flow verification is to be performed as described below.

7.5.2 Bypass Flow Verification and Calibration (11.67 lpm), If Necessary

For this procedure, ensure data are “Off Scan.”

1. Connect the NIST-traceable flow transfer standard device to the bypass line that was disconnected in the sample flow verification procedure above. Ensure fitting(s) connecting flow transfer standard and bypass line are secure and not leaking.
2. With the T640X running, go to the flow calibration menu: >Calibration >Bypass Flow Cal. Alternatively, you can view sample flow from the dashboard.
3. Wait at least one minute for flow to stabilize.
4. Record to the “Verification Audit” tab of the e-log. Compare the “Measured Flow” in this screen to the Flow Transfer Standard and determine if these values differ by more than 5% (11.09 – 12.25 lpm). If bypass flow meets expected tolerance, then proceed to step 5. If bypass flow is outside of the acceptable tolerance you still will need to perform a sample flow verification.
5. Record to “Monthly QC and Maintenance Sheet”.
6. Reattach bypass line to ASC.

7.6 Verification or Audit: “As Left” Leak Check

1. Remove the inlet and fit a HEPA filter to the sample port. Ensure tubing is not kinked.
2. Observe the PM values on the front panel display. Press either “Home” or the  key.
3. Within approximately 10 minutes the PM values should be at zero (0.0) for each PM metric. If data reach 0.0, accept the zero test and move to step 5. If data are in the range of 0.1 to 0.3, accept the data and troubleshoot. If after ten minutes the data are still at 0.4 or greater, identify the data as suspect in Envista and troubleshoot. If the PM values are not reading zero, then it’s likely to be one of two issues:
 - 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). Troubleshoot by

checking each connection between monitor and HEPA filter and ensuring there is a good seal or:

- It is possible the HEPA filter being used is either bad or leaking. It is recommended to have a second filter handy to check.
4. If after ten minutes from any adjustment, values don't reach zero (0.0), troubleshoot and repeat steps above.
 5. Once PM values reach zero (0.0) for each PM metric, disconnect the HEPA filter.
 6. Read and record the stated value of the zero test in the "Calibration" page of the e-log.

7.7 Verification or Audit: PMT Setting

Once all verifications to the pressure and flow systems are complete, a verification of the Particle Sensor PMT may be performed using SpanDust™.

Note: Careful attention needs to be made to ensure a minimum amount of SpanDust™ enters the sample tube during an adjustment of the PMT and that repeats of this calibration are kept to a minimum.

Note: If the monitor is being turned on for the first time, or being restarted after a period of stoppage, it is recommended that the user allow the T640X LED to warm-up for 10 minutes prior to performing a leak check or PMT adjustments.

For a step by step demonstration of the PMT Adjustment, use the QR code below to view a video by Teledyne API. This video is also available at: <https://www.youtube.com/watch?v=pZYnXwYwtIs>



Figure 34. QR Code for PMT Adjustment Video.

For this procedure, ensure data are “Off Scan.”

1. Navigate to the PMT Adjust screen: >Home >Calibration >PMT Adjust.
2. Press the <Start> button on this screen to suspend normal data acquisition and start this adjustment process.
3. Remove the T640X sample inlet.
4. Prepare the SpanDust™ bottle by uncapping the “air intake” tubing on the cap of the bottle.
5. Place the tube from the SpanDust™ bottle into the top of the upper inlet tube for the instrument.
6. Ensure that the silicone tube fits snugly inside the aluminum inlet tube, and do not allow the bottle to hang, as it could dislodge the silicone tube from the inlet tube.
7. 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.
8. If the peak channel reading is acceptable (± 0.5 of SpanDust™ value stated on bottle) then proceed to step 12.
9. If the peak channel is not acceptable, then retry one more time by pressing the <Stop> button, then the <Start> button on the T640X, then proceed with step 6 above.
10. Allow 30 seconds for the peak channel reading in this screen to respond, and if it is not ± 0.5 of SpanDust™ value stated on bottle, repeat the process.
11. If after two tries the peak channel reading is not within ± 0.5 of the SpanDust™, then adjustment of the PMT setting is required as found in Section 4.9.

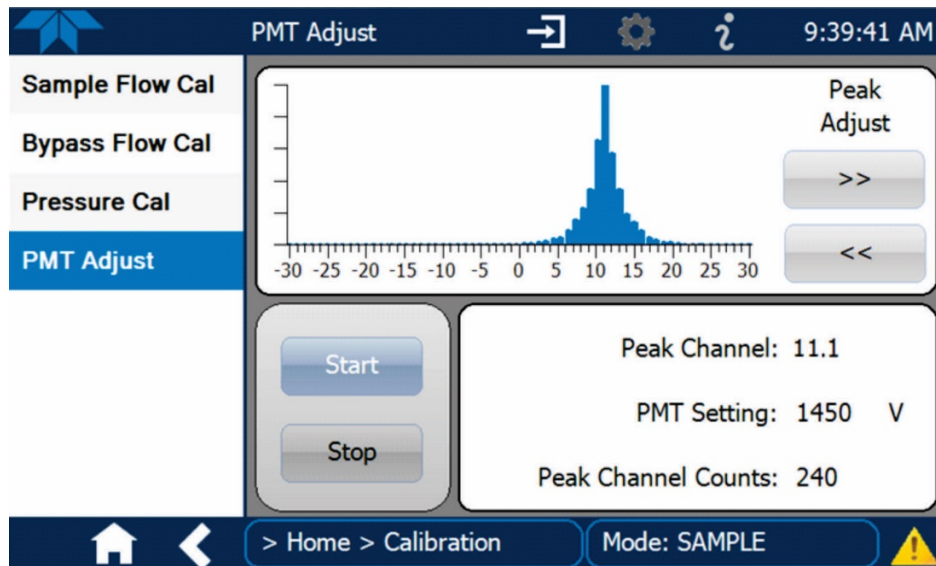


Figure 35. PMT Adjustment Screen.

12. Once the Peak Channel reading is ± 0.5 of SpanDust™ value stated on bottle, record the value in the “Verification_Audit” tab of the e-log
13. Reattach the sample inlet and press the <Stop> button to stop the adjustment process and resume normal data acquisition.
14. Wait 10 minutes, review data on home screen of T640X, and then bring unit back “On Scan” in the data system.

8.0 MAINTENANCE

All sampler maintenance must be recorded on the “Maintenance Log” tab of the e-log. An “as found” and “as left” leak check must be performed if any maintenance item requires the operator to break the seal of the sampling train.

It is recommended that operators carry the following items in their field maintenance kit:

- Can of compressed air with tube
- Cotton Tipped Applicators
- Phillips Head Screwdriver
- Vacuum grease (silicone based)
- 91% Isopropyl Alcohol for cleaning the VSCC and PM10 head
- Distilled water
- Cotton cloth or Shop Towels
- Kimwipes
- O-rings for the VSCC and
- Downtube cleaning kit

Table 3. Summary of Maintenance Activities.

Maintenance Activity	Frequency
<ul style="list-style-type: none"> • Check T640X clock • Download data, settings, and alarm files 	Every 14 – 18 days
<ul style="list-style-type: none"> • Clean PM10 Head • Empty water collection bottle • Inspect inner and outer sample tubes • Check pump performance • Wipe down interior and exterior of the shelter. 	Every 30 days
<ul style="list-style-type: none"> • Check/Adjust PMT • Verify T640X settings • Clean the temperature probe and gill screen • Check seals on shelter doors 	Every 91 days
<ul style="list-style-type: none"> • Inspect and clean optical chamber 	Every 181 days
<ul style="list-style-type: none"> • Change the disposable filter unit (DFU) 	Every 365 days

8.1 Cleaning the T640X PM10 Inlet

The PM10 inlet has two primary components: The Acceleration Assembly and the Collector Assembly (Figure 36). These components must be disassembled and cleaned every 30 days.



Figure 36. The PM10 Inlet Components.

8.1.1 Disassembling the Inlet

1. Remove the PM-10 head by lifting the inlet up and off the sample tube.
2. Using Figure 37 as a guide, unscrew the collector assembly from the accelerator assembly by turning the top portion counterclockwise.

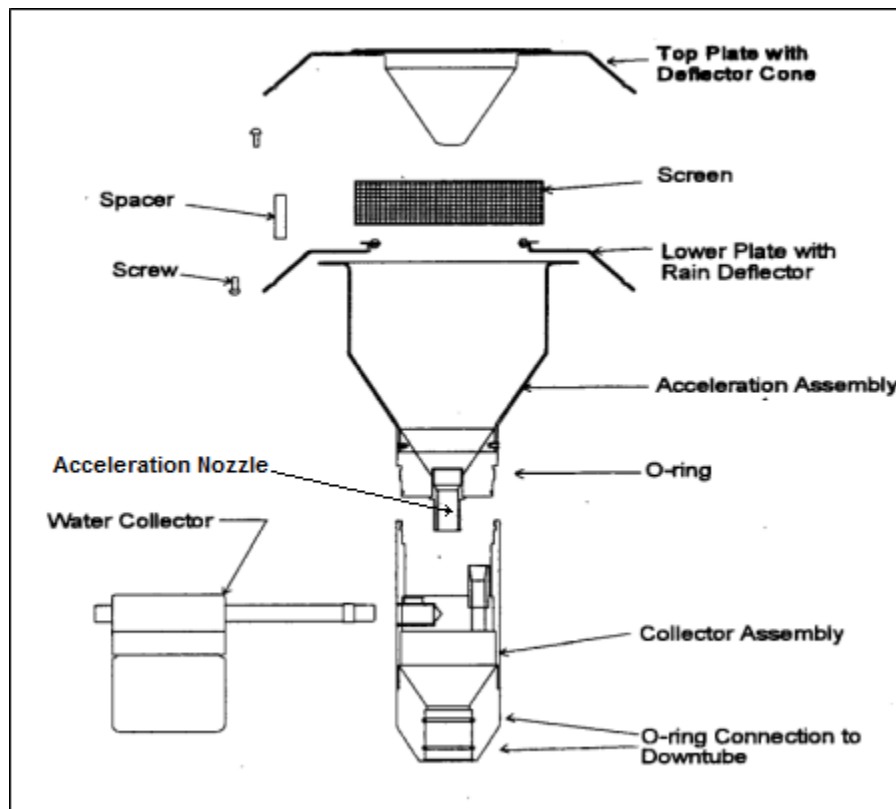


Figure 37. Exploded view PM-10 Inlet Assembly.

8.1.2 Cleaning and Maintaining the PM10 Accelerator Assembly

1. Remove four Philip head screws from the top and remove the top plate.
2. Clean the top plate with a lint-free cloth and water (or alcohol).
3. Remove the insect screen from the lower plate and clean.
4. Clean the lower plate with a lint free cloth and water (or alcohol) with particular attention to the internal sides of the acceleration chamber.

5. Use water (or alcohol) and a cotton swab to clean the acceleration nozzle.
6. Inspect the large o-ring between the accelerator and collection assembly. Lightly lubricate with the vacuum grease if necessary.
7. Reinstall the insect screen and screw the top plate back onto the bottom plate of the Acceleration Assembly.

8.1.3 Cleaning and Maintaining the PM10 Collector Assembly

1. Clean the threads of the Collector Assembly to ensure smooth separation and assembly.
2. Clean the Collector Assembly walls, bottom plate and three vent tubes using a cloth, water (or alcohol) and cotton swab.
3. Clean the hole in the collector plate where the condensate runs to the moisture trap with a cotton swab.
4. Remove the rain jar and clean with a cloth. Inspect the brass nipple. Replace rain jar and lightly coat the threads with grease.
5. Inspect the two inlet tube o-rings for wear and lightly grease if necessary.
6. Reassemble the collector assembly by hand tightening.
7. Place the reassembled PM10 head back onto the sampler tube.

8.2 Changing the Disposable Filter Units (DFUs)

There are two DFUs on the T640X, one internal filter for the 5.0 lpm pump and one external for the 11.67 lpm pump. If changing one filter, it is recommended that the other filter also be changed. For this procedure, ensure data are “Off Scan.”

8.2.1 Internal Pump Filter

1. Power off the internal pump from the control menu: Setup> Vars> Pump > Edit> Off >Done.
2. Remove screws at sides of front panel, if installed.
3. Pull open the instrument’s front panel, using the front panel finger grips (Figure 38).

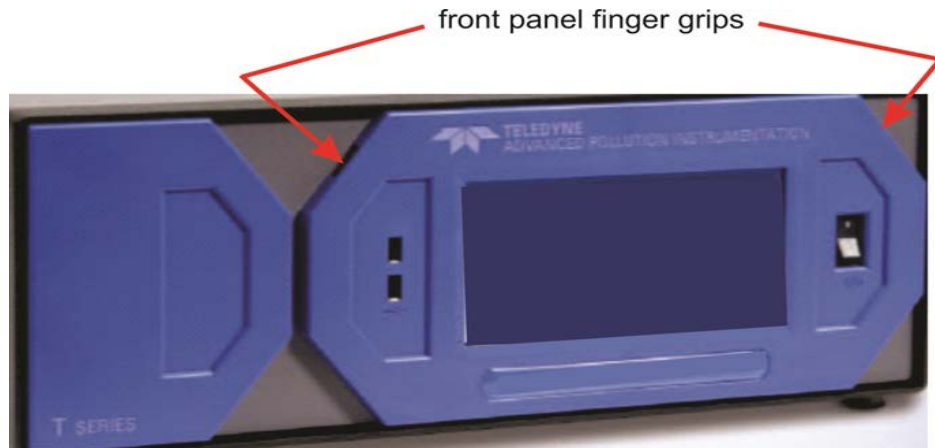


Figure 38. Opening the Front Panel.

4. Write “New” and today's date on the filter with a sharpie (recommended).
5. Noting its orientation, remove the old DFU by detaching from the pneumatic quick-connect fittings, and replace with a new DFU matching the orientation (Figure 39).

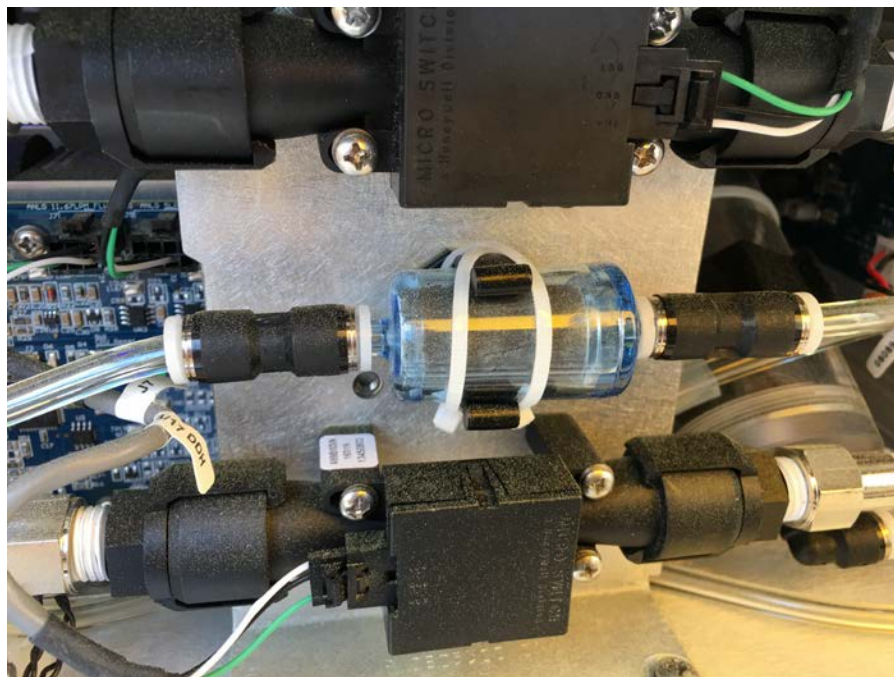


Figure 39. Internal DFU.

6. Power on the internal pump from the control menu: Setup> Vars> Pump > Edit> Auto >Done.
7. Review internal pump flow in Dashboard or Home Screen to ensure the 5.0 lpm flow is reading as expected: >Main Menu > Home >Dashboard.

8.2.2 External Pump Filter

1. Unplug or turn off electrical switch, if available, to the external pump.
2. Write “New” and today's date on the filter with a sharpie (recommended).
3. Noting its orientation at back of instrument, detach the filter from the quick-connect fittings and replace with new filter (Figure 40).

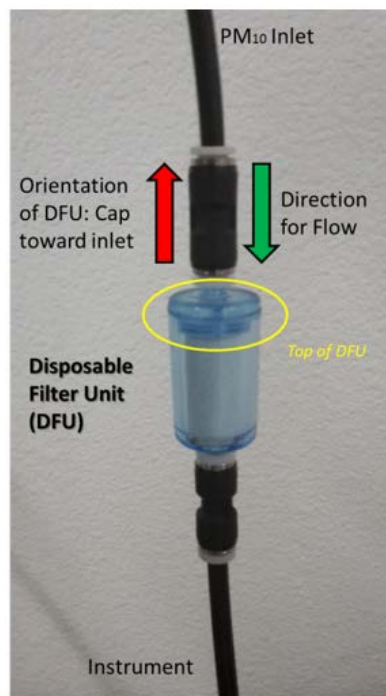


Figure 40. External DFU.

4. Ensure the filter is seated snugly with no gaps.
5. Plug the bypass pump electrical cord back in or otherwise turn on pump.

6. Review internal pump flow in Dashboard or Home Screen to ensure the 11.67 lpm flow is reading as expected: >Main Menu > Home >Dashboard.
7. Allow 10 minutes for the system to return to reliable operation. Ensure the data acquisition system is reengaged.

8.3 Checking Pump Performance

There are two pumps associated with the T640X. One pump is internal (operating at 5.0 lpm). The second pump is external (operating at 11.67 lpm). The 5.0 lpm pump must maintain proper flow for measurement accuracy; while the combined flow of the internal and external pump (i.e., 16.67 lpm) ensure that the PM₁₀ inlet is operating at its designed flow for a PM₁₀ cut-point. Check performance levels in the Dashboard (if these parameters are not found in the Dashboard, configure the Dashboard to add them).

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

If the performance levels are out of range, refer to Table 5 for troubleshooting guidance.

8.4 Cleaning the Optical Chamber and the RH/T Sensor

Cleaning the optical chamber and sample lines connecting to the chamber is expected at least every 6 months and more often if issues are suspected; however, it can be a somewhat tedious procedure, especially for installations in small shelters located outside. Before starting, carefully consider and plan for an appropriate amount of time to perform this procedure, including disassembly and reassembly, as well as all associated verifications and calibrations. For outdoor shelters, additionally consider if any precipitation or extreme weather is forecasted. As much as four hours may be need to fully complete the procedure for outside installations and two hours for indoor ones when using a slip coupler. Also, we highly recommend taking a few photos with a smart phone or similar prior to disconnecting any of the sample lines inside the monitor.

For this procedure, ensure data are “Off Scan.”

1. Power down the monitor and unplug.
2. Power down the bypass pump.

3. Disconnect ASC power line from the back of the instrument.
4. Disconnect bypass flow line from top of ASC using 9/16" wrench.
5. Adjust slip coupler and move monitor to the side so that there is enough room for ASC to be removed.
6. Remove and clean both the extension tube and upper inlet tube that sit directly above the ASC.



Figure 41. Extension Tube and Upper Inlet Tube Over the ASC.

7. Remove ASC by carefully lifting up from monitor chassis.
8. Remove and clean the aluminum adapter that fits over the black inlet nozzle. Check the O-ring that sits on the adapter for cracks or breaks; clean and/or replace as necessary.



Figure 42. Aluminum ASC Adapter.

9. Remove and clean the black inlet nozzle sample tube that fit on top of the optical cell.



Figure 43. Inlet Nozzle.

10. Unscrew monitor lid (may have 4 screws, 2 on each side) and lift lid off of monitor chassis.
11. Recommend taking photos of the sample line connections with a smart phone or similar. Then disconnect sample lines from leading to the components on the ASC support.

12. Remove the ASC support, which straddles the sensors. Four screws secure that support to the floor of the instrument, two on each footing. *Note: it's possible to clean the optics without removing the ASC support; however, removing the ASC support will allow more room to access the tubing lines and optical chamber.*

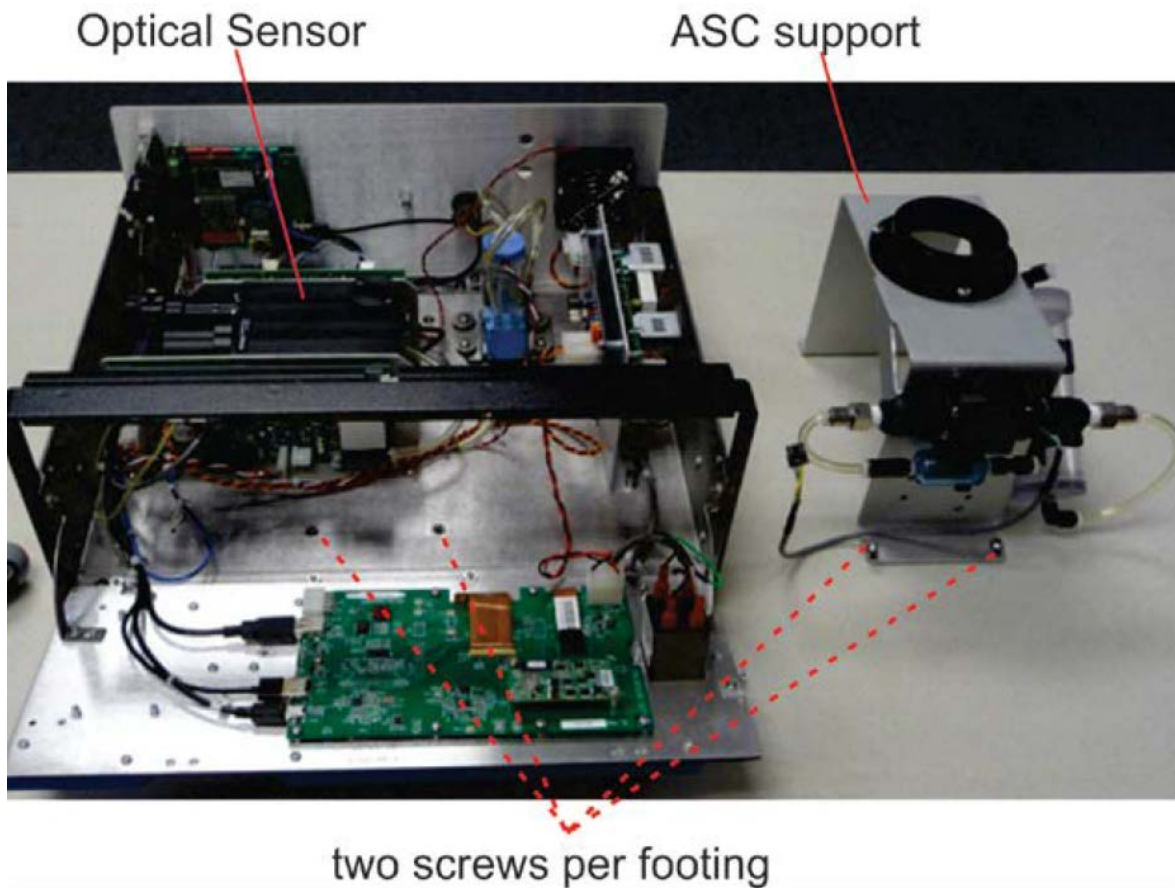


Figure 44. Optical Chamber and RH/T Sensor Access.

13. Locate the optical cell, the cup at the bottom of optics chamber and its tubing, and the relative humidity and temperature (RH/T) sensor.

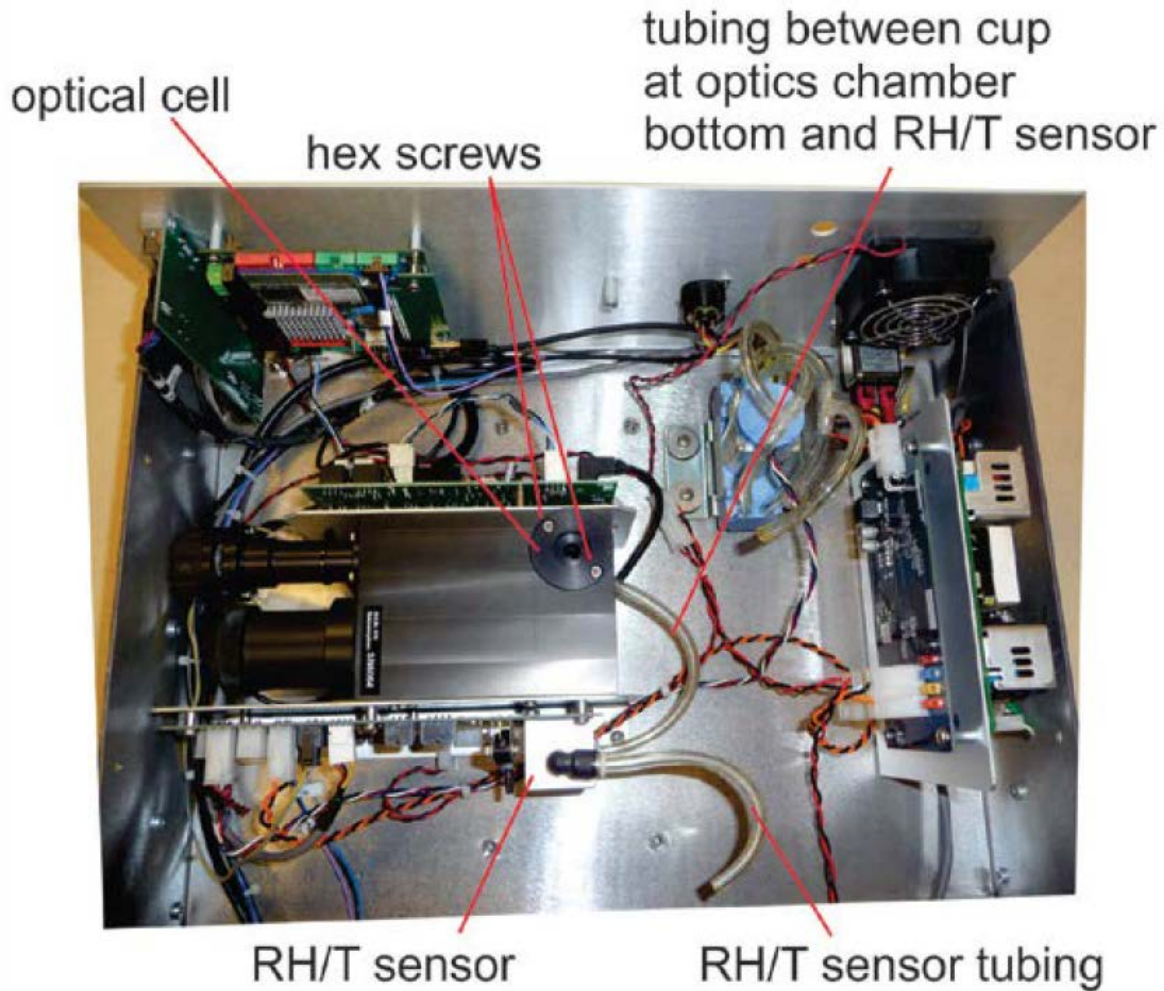


Figure 45. Location of Optics Chamber and RH/T Sensor.

14. Remove optical cell from optics chamber, and remove cup, including its tubing, from optics chamber bottom; detach RH/T sensor tubing from DFU filter. It is very important that all components are disassembled before blowing air into the chamber.

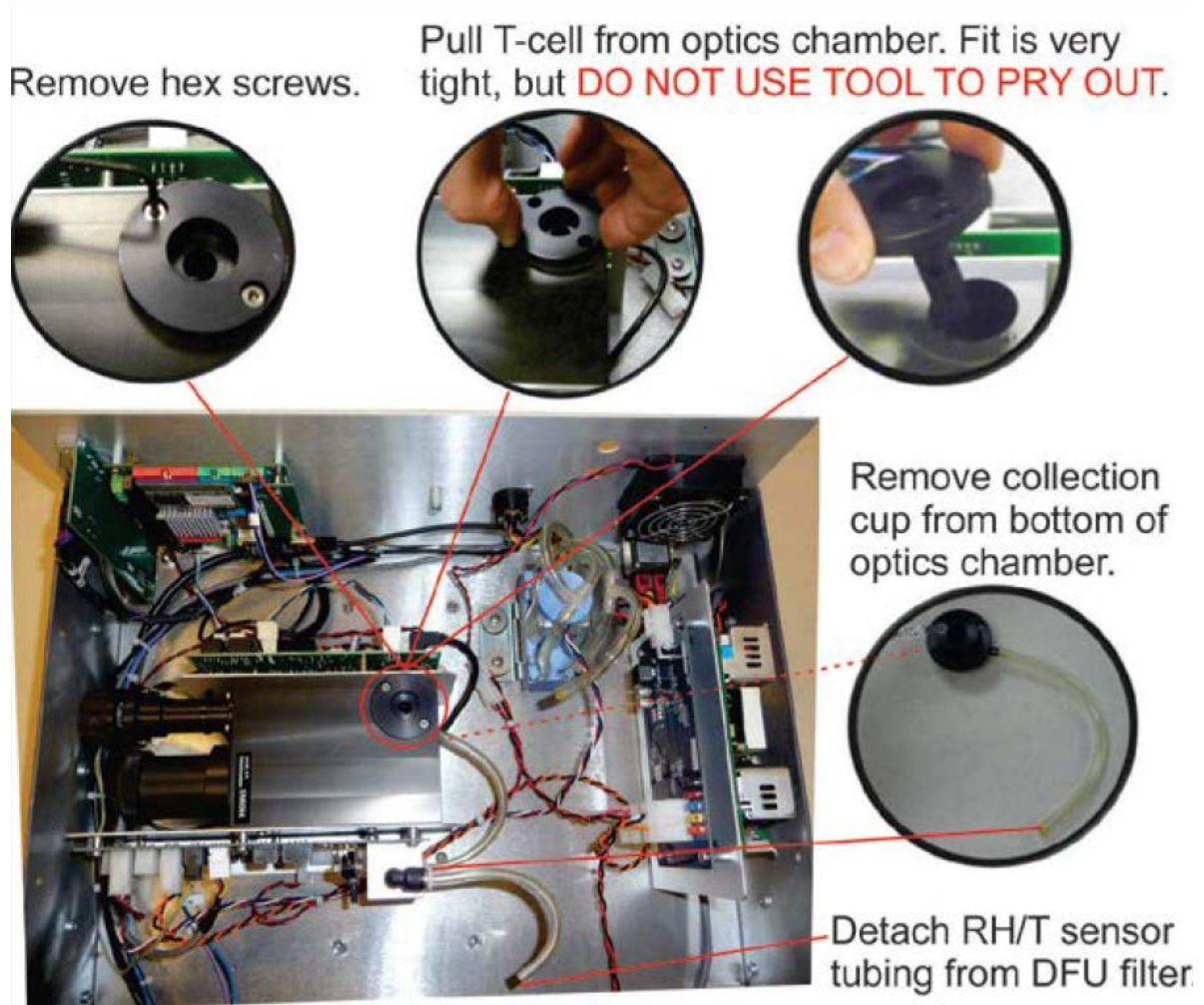


Figure 46. Optical Chamber Disassembly.

15. Clean the optics chamber interior surfaces, ensuring to include windows, with a lint-free cloth.



Figure 47. Optics Chamber Windows.

16. Use canned air made specifically for dusting 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.



Figure 48. Final Dusting.

17. 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, reinstall the ASC support, re-connect all power and flow lines, and move monitor back in line so that the slip coupler can be reconnected.

18. Close instrument and power back both bypass pump and monitor.

19. Perform a zero test.

20. Perform a PMT sensor check with the SpanDust™.

8.5 Inspecting the Sample Tubes

Look inside the sample tubes for debris or dust on the walls. If needed, push a rag or a paper towel through the tubes; then use canned air made specifically for electronics to blow through the line for final cleaning. However, do not completely block a sample tube still under vacuum, as the sample flows should never be blocked while the unit is still operating.

9.0 DATA HANDLING

9.1 DATA MANAGEMENT

Data collected by the T640X at the monitoring site will be stored on a data acquisition system (DAS). Data can be remotely polled for upload into a centralized database. Please ensure that data backups are conducted on a regular basis.

The in situ DAS will be a commercially available computer based unit capable of retrieving digital records from the station instruments via an Ethernet connection. It will store 1 minute averages from the instruments. The instrument will store approximately 1 year of data internally and data can be retrieved at any time to fill in any missing data in the database due to transfer issues.

Table 4 lists the parameter, method, and unit codes for the T640X and T640 data.

Table 4. Parameter, Method, and Unit Codes.

Parameter Description	Parameter Code	Method Code for T640 at 5.0 lpm	Method Code for T640X at 16.67 lpm	Units	Unit Code
PM _{2.5}	88101	236	238	Micrograms/cubic meter (LC)	105
PM ₁₀ - LC	85101	236	239	Micrograms/cubic meter (LC)	105
PM _{10-2.5} LC	86101	236	240	Micrograms/cubic meter (LC)	105
PM ₁₀ STP	81102	not available	239	Micrograms/cubic meter (25C)	001

9.2 RECORDS MANAGEMENT

Field site visits will be stored in site log books documenting access to the monitoring sites and the key activities performed. Details on routine QC and maintenance are recorded to the “Monthly QC and Maintenance Sheet” in the electronic logs.

9.2.1 Downloading Monitor Data from the T640X

In the Utilities>USB Utilities screen, instrument data can be downloaded to a flash drive, as presented here.

1. Press <USB Utilities> menu to open the utility page.
2. Insert a flash drive into a front panel USB port and wait for the status field to indicate that the drive has been detected and available buttons are enabled.
3. To copy the data to the flash drive, press the <Start> button next to “Download DAS Data from Instrument.”
4. Wait for the Status field to indicate that the transfer is complete and the cancel button becomes the done button.
5. Press the <Done> button, then remove the flash drive.

10.0 QUALITY ASSURANCE AND DATA HANDLING

10.1 Daily Data Review

Each regional office should set up their polling computer to distribute automated reports each morning. Contact ECB or the Data Acquisition Manager for more information.

The polled T640X data must be reviewed on a daily basis (preferably in the morning) by the regional office staff. The T640X concentration should be reviewed. It is at the discretion of the regional ambient monitoring coordinator (RAMC) as to how this process should be executed. At a minimum, each T640X operator should review their site data on a daily basis and report abnormalities to either the RAMC or the RCO particulate matter lead.

If the average daily PM_{2.5} concentration exceeds 35 µg, alert the RAMC and the RCO particulate matter lead immediately. The daily maximum PM_{2.5} concentrations should be below 30 µg.

10.2 Field Operator Quality Assurance

Upon arriving at the site, the field operator is responsible for ensuring that the monitor has collected what appears to be valid data since the previous site visit. This includes reviewing the alarms and collected data. Below is a suggested list of items that operators should be verifying during each site visit:

- Possible changes near the site that could bias the data (fires, construction, etc.)
- Encroachment of wildlife or vegetation
- Vandalism
- Obstructions of the inlet
- Alarms on the screen of the T640X
- Abnormalities in the T640X downloads:
 - Ensuring that there are no gaps in the data
 - Investigating repetitive patterns of numbers
 - Checking the ambient temperature data (no abnormal trends, repeating values)

10.3 Regional Ambient Monitoring Coordinator Quality Assurance

The regional ambient monitoring coordinator (RAMC) is responsible for reviewing all raw data and logbooks prior to submitting the data to RCO. The specific QA duties for the regional ambient monitoring coordinator are described in the following sections.

10.3.1 T640X Download Review

The RAMC is responsible for reviewing the T640X download data, alarms, and settings to ensure that there are no abnormalities, similar to those described in Section 8.2:

- Ensuring that there are no gaps in the data
- Ensuring that repetitive patterns of numbers have been addressed
- Checking the ambient temperature data (no abnormal trends, repeating values)

10.3.2 Electronic Logbook Review

The e-logs are an additive yearly scrolling document. The RAMC must review the e-log for each site on a monthly basis. E-log reviews are recommended, but not required, to be conducted every 15 days to ensure the operators and the monitors are meeting the necessary requirements.

1. The RAMC must review all e-logs for completeness, verifications, audits, calibrations, and monitor problems. Specifically, the RAMC must verify that:
 - There is a monthly and mid-month verification (or audit) for each calendar month.
 - All devices used were within certification dates.
 - Audit devices were different from the monthly verification devices.
 - All leak checks passed.
 - All monitor issues and missing data are clearly documented in the comments.
 - Monthly, and quarterly maintenance items were completed.
 - There is downloaded data (alarms, data, and settings) for all collected data.
2. The RAMC and the operator should discuss any discrepancies, errors, concerns, or questions before the e-log is submitted to RCO.
3. The RAMC must sign and date each e-log record before submission to the RCO. There are RAMC review spaces on the “Maintenance”, “Calibration”, “Site Visit”, and “Verification Audit” pages. The RAMC should only make corrections in the comments section of the e-log to preserve the initial documentation of the operator.

4. The RAMC must bring any problem or suspect problem that affects the validity of the data to the attention of the RCO particulate matter lead by e-mail or telephone within 5 business days of discovery. It is recommended that the RAMC alert the RCO particulate lead as soon as possible to discuss corrective actions.
5. After e-log approval, the RAMC must post the reviewed e-logs at P:\Ambient\Incoming\RegOffices.NC\your region within fifteen days from the start of each month.

10.4 Monthly DAS Review

Below are the steps for reviewing the T640X DAS data:

1. Ensure that the T640X parameter is included in the initial T640X DAS data as soon as RCO posts the file to P:\Ambient\Pub\RegOffices.NC.
2. Open Envista and open to the T640X section.
3. Go through the data report and add the null data codes (Appendix A) for all documented site activity. This includes audits, verifications, maintenance, site visits, power outages, etc. Each hour must have either a valid data point or a null data code.
4. Explain in the comments each use of the null data code.
5. Verify the T640X DAS data with the T640X download data.
 - a. Pick three random days in the month and select the highest and second highest concentrations for review.
 - b. Open the T640X data download for the corresponding days and verify that the T640X download concentration is within $1 \mu\text{g}/\text{m}^3$ of the concentration in the T640X DAS data. If the values are not within $1 \mu\text{g}/\text{m}^3$, alert the RAMC and RCO particulate matter lead. The analog output from the T640X might need to be calibrated. In the event that the concentrations are not within the desired range, the T640X download data should be used in replacement of the T640X DAS data.
 - c. In the comments section of the T640X DAS data, record the T640X download values.
6. Look at the concentration values after the T640X is changed from maintenance mode to sampling mode. The first hour of sampling after an activity requires the concentration to be voided. Immediately following a null code, if the concentration is negative, staff should void the data until the concentration stabilizes.

11.0 TROUBLESHOOTING AND CORRECTIVE ACTIONS

This section provides guidance for resolving fault conditions and possible flow and calibration problems.

1. To review Alerts, select >Alerts.
2. Document any alerts, including date and time to the “Verification Audit” tab of the e-log.
3. To clear alerts, select the following: >Alerts >Select >Clear Selected. Then select the home button.
4. If alerts reappear, then there is something wrong and this need to be diagnosed. See below:

11.1 Fault Diagnosis

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 provides possible solutions.

Table 5. Alerts and Recommendations.

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 set point	Check if ASC is plugged in. Check control board if ASC control LED is illuminated.

Message	Description	Possible Solution(s)
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.
Sample Flow Slope OOR	The Sample Flow Calibration Slope is Out Of Range (OOR)	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.
Check Internal Pump	Check the internal pump if the PWM is > 80	Check pneumatics for blockages. Check pneumatics for leaks. Check flow calibration. Replace pump.
Check Ext Pump	Check the external pump and/or bypass flow control valve if valve PID > 85	Check pneumatics for blockages. Check pneumatics for leaks. Check external pump. Check flow calibration. External pump, or bypass flow control valve may need replacing.
Sample Temp Warning	Sample Temperature Warning (>60)	Check ASC (is it latched ON?) Ensure proper climate and ventilation for instrument.

Message	Description	Possible Solution(s)
Box Temp Warning	Box Temperature Warning (>60)	Ensure proper climate and ventilation for instrument.
AMB Press Slope OOR	Ambient Pressure Calibration Slope is out of range	Check calibration (make sure units match calibration device). Replace pressure sensor. Call Tech Support.

11.2 Flow Problems

If a flow auditing device indicates any problems with flow, check to ensure the following:

- all connections are seated tightly and evenly (no gaps);
- the inlet is not clogged or blocked;
- the pumps are running and are within their PWM range (35% - 80%);
- the DFU appear reasonably clean and changed within last 12 months;
- ensure flow audit device is operating properly (e.g., is the unit appropriately charged).

After making any adjustments, run a flow calibration and recheck the flow rate. If problems persist, contact ECB and the RCO lead for assistance.

12.0 REVISION HISTORY

13.0 REFERENCES

User Manual for the T640X PM Mass Monitor, Prepared by Teledyne Advanced Pollution Instrumentation, San Diego, CA

United States Code of Federal Regulations, (2006) Title 40 Part 50 Appendix L, Reference Method for the Determination of Fine Particulate Matter as PM_{2.5} in the Atmosphere. Prepared by the US Government Publishing Office

United States Code of Federal Regulations, (2013) Title 40 Part 50 Appendix N, Interpretation of the National Ambient Air Quality Standards for PM_{2.5}. Prepared by the US Government Publishing Office

United States Code of Federal Regulations, (2013) Title 40 Part 58 Appendix E, Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring. Prepared by the US Government Publishing Office

Appendix A: Frequently Used PM Data Validation Codes

Table 6. Frequently Used PM Data Null Codes (Void Codes).

Code	Qualifier Description
AA	Sample Pressure out of Limits
AB	Technician Unavailable
AC	Construction/Repairs in Area
AD	Shelter Storm Damage
AE	Shelter Temperature Outside Limits
AF	Scheduled but not Collected
AG	Sample Time out of Limits
AH	Sample Flow Rate or CV out of Limits
AI	Insufficient Data (cannot calculate)
AJ	Filter Damage
AK	Filter Leak
AL	Voided by Operator
AM	Miscellaneous Void
AN	Machine Malfunction
AO	Bad Weather
AP	Vandalism
AQ	Collection Error
AR	Lab Error
AS	Poor Quality Assurance Results
AT	Calibration
AV	Power Failure
AW	Wildlife Damage
AX	Precision Check
AZ	Q C Audit
BA	Maintenance/Routine Repairs
BB	Unable to Reach Site
BC	Multi-point Calibration
BE	Building/Site Repair
BI	Lost or damaged in transit
BJ	Operator Error
BK	Site computer/data logger down
BN	Sample Value Exceeds Media Limit
SA	Storm Approaching
SV	Sample Volume out of limits

Table 7. Frequently Used PM Data Qualifier Codes (Flags).

Code	Qualifier Description
1	Deviation from a CFR/Critical Criteria Requirement
2	Operational Deviation
3	Field Issue
4	Lab Issue
5	Outlier
6	QAPP Issue
CB	Values have been Blank Corrected
CC	Clean Canister Residue
CL	Surrogate Recoveries Outside Control Limits
FB	Field Blank Value Above Acceptable Limit
FX	Filter Integrity Issue
HT	Sample pick-up hold time exceeded
LB	Lab blank value above acceptable limit
MD	Value less than MDL
NS	Influenced by nearby source
QP	Pressure Sensor Questionable
QT	Temperature Sensor Questionable
QX	Does not meet QC criteria
SQ	Values Between SQL and MDL
SS	Value substituted from secondary monitor
SX	Does Not Meet Siting Criteria
TB	Trip Blank Value Above Acceptable Limit
TT	Transport Temperature is Out of Specs.
V	Validated Value
VB	Value below normal; no reason to invalidate
W	Flow Rate Average out of Spec.
X	Filter Temperature Difference or Average out of Spec.
Y	Elapsed Sample Time out of Spec.