



T640 & T640x Validation Templates

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Interim Teledyne T640 Continuous PM_{2.5} Local Conditions Validation Templates

NOTE: This validation template attempts to provide the critical criteria, frequency and acceptance criteria for checks, calibrations, and maintenance; and verification/calibration standards recertification frequencies and acceptable ranges for the Teledyne T640 (FEM: EQPM-0516-236). This validation template was developed specifically for the Teledyne T640 through a collaboration between EPA, Teledyne, and S&I operators. The template lists criteria considered the most important. Criteria are established to ensure that data are complete, accurate, and comparable to filter-based FRMs. The Teledyne Advanced Pollution Instrumentation Model T640 PM Mass Monitor Automatic Equivalent Method: EQPM-0516-236 states "...and operated in accordance with the Teledyne Model T640 Operations Manual"; therefore, criteria, frequency, and acceptance ranges stated in the current manual are identified by **bold and italics** font. Criteria stated in the FEM designation are also in **bold and italics** font. More detailed information on the operation of the Teledyne T640 is available in *Standard Operating Procedure Teledyne Model 640 Real-Time Continuous PM Monitor* developed by EPA.

EPA requests that regions and monitoring organizations report back to OAQPS on significant data loss resulting from implementation of this template. As a reminder, the check frequencies listed in this document are minimal requirements; checks may be completed more frequently to minimize data loss.

Where appropriate, 40 CFR Part 58 App A and 40 CFR Part 50 App I, requirements (also bold and italics) apply to the Teledyne T640; however, not all FRM criteria are considered critical due to the nature of the measurement principle and design of the instrument.

1) Criteria (T640)	2) Frequency	3) Acceptable Range	Information /Action
CRITICAL CRITERIA- T640 PM_{2.5} Continuous, Local Conditions			
Sampler/Monitor Designation	NA	<i>Meets requirements listed in FEM designation</i> Confirm method designation on front panel or just inside instrument.	1) 40 CFR Part 58 App C, Sec. 2.1 2) NA 3) 40 CFR Part 53 & FRM/FEM method list
Firmware of monitor	<i>At setup and as updated</i>	1. <i>Must be the firmware (or later version) as identified in the published method designation summary.</i> 2. <i>Firmware settings must be set for flowrate to operate and report at "local conditions" (i.e., not STP).</i>	1) FEM: EQPM-0516-236 2) EPA T640 SOP 3) 1. FEM: EQPM-0516-236 2. 40 CFR Part 50 App N, sec. 1 (c)
Data Reporting Period	Report every hour	1. The calculation of an hour of data is dependent on the design of the method. 2. <i>A 24-hour period is calculated in AQS if 18 or more valid hours are reported for a day.</i>	See operator's manual. Hourly data are always reported at the start of the hour on local standard time. 40 CFR Part 50 App N, Sec 3 (c)
Sampling Instrument			

Agenda — *(30 minutes)*

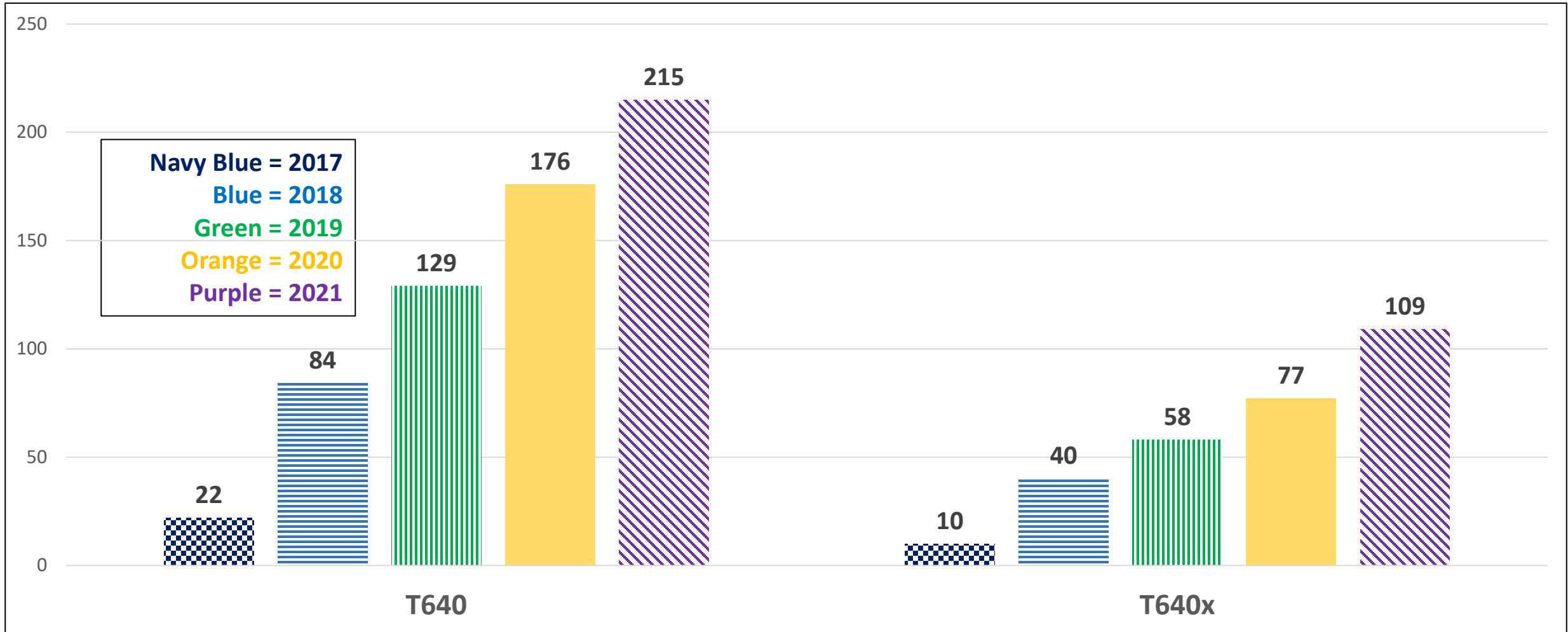
- T640 and T640x summary of method
- Data Quality of methods
- What is a Validation Template
- Applying a validation template to T640 and T640x data.

Summary of T640 and T640x Method

Method Component	T640	T640x
Inlet	T-API custom inlet	EPA-approved omnidirectional PM ₁₀ inlet
Sample Flow	5 lpm	16.67 lpm (total) 5 lpm to monitor
Sample Conditioning	Aerosol Sample Conditioner (ASC) where a heater is used to ensure that the measured aerosol's RH does not exceed 35%.	
Measurement Method	Broadband spectrometry using 90° white-light scattering with Polychromatic LED. T640 calculates the aerodynamic mass fraction of PM _{2.5} and PM ₁₀ aerosol based on an algorithm which converts the measured light scattering signal from 64 channels (combined from 256 channels) to PM _{2.5} and PM ₁₀ mass concentrations.	
Sample Period	1 – hour data are reported. Each 1 – hour period is based on sixty 1 - minute averages that use a 10-min rolling average of the PM mass concentration	
Resolution	0.1 µg m ⁻³	
Approvals	PM _{2.5} FEM <i>(PM₁₀ LC data is available and may be reported for AQI)</i>	PM _{2.5} FEM PM ₁₀ FEM PM _{10-2.5} FEM



T640 and T640x PM_{2.5} Continuous FEMs Reporting to AQS parameter code 88101 - Comparing last five years.



Summarizing Federal Reference Method (FRM), T640 and T640x Federal Equivalent Methods (FEMs) Data Quality (2019 – 2021)

Method	Collocated Precision 24-hour (values $\geq 3 \mu\text{g}/\text{m}^3$) (%)	Collocated Precision 1-hour (2021 only) (values $\geq 3 \mu\text{g}/\text{m}^3$) (%)	Bias to PEP audits (values $\geq 3 \mu\text{g}/\text{m}^3$) (%)	Bias to SLT FRM (values $\geq 3 \mu\text{g}/\text{m}^3$) (%)	Notes
FRMs	7.6	NA	-8.0	-	Mean FRM of 8.3 $\mu\text{g}/\text{m}^3$ (222,877 values). Range for this is 0 – 593 $\mu\text{g}/\text{m}^3$.
	5.0	4.7			
			15.2	23.5	

Note: The goal for acceptable measurement uncertainty is defined for precision as an upper 90 percent confidence limit for the coefficient of variation (CV) of 10 percent and ± 10 percent for total bias. These goals are applied across a PQAQ.

Overview of EPA Validation Templates

- Intended to provide consistent validation of a method across the US.
- Three criteria: critical, operational, and systematic criteria, where each criterion has a different degree of implication about the quality of the data.
- For each criterion, members of a workgroup considered how significantly the criterion impacted the resulting concentration
 - This was based on experience from workgroup members, experience from non-workgroup members, and feasibility of implementing the criterion.
- **Critical Criteria** - Observations that do not meet each and every criterion on the Critical Criteria should be invalidated unless there is a compelling reason and justification for not doing so.
- **Operational Criteria** - Criteria that are important for maintaining and evaluating the quality of the data collection system.
 - Violation of a criterion or a number of criteria may be cause for invalidation.
- **Systematic Criteria** - Those criteria which are important for the correct interpretation of the data but do not usually impact the validity of a sample or group of samples.
- The Validation Templates provide the critical criteria, annual multipoint verifications/calibrations, and verification/calibration standards recertification frequencies and acceptable ranges.

Critical Criteria in Magenta

Operational Criteria in Yellow

Systematic Criteria in Blue

<https://www.epa.gov/amtic/ambient-air-monitoring-quality-assurance>

See: [QA Handbook Appendix D Validation Templates \(PDF\)](#)

T640 Validation Template - Critical Criteria

Note: We are focusing on the T640 validation template. The T640x validation template is nearly identical except the inclusion of critical criteria for the second (external) pump to provide the 16.67 lpm needed for operation of the PM₁₀ inlet.

1) Criteria (T640)	2) Frequency	3) Acceptable Range	Information /Action
CRITICAL CRITERIA- T640 PM_{2.5} Continuous, Local Conditions			
Sampler/Monitor Designation	NA	<i>Meets requirements listed in FEM designation</i> Confirm method designation on front panel or just inside instrument.	1) 40 CFR Part 58 App C Sec. 2.1 2) NA 3) 40 CFR Part 53 & FRM/FEM method list
Firmware of monitor	<i>At setup and as updated</i>	1. <i>Must be the firmware (or later version) as identified in the published method designation summary.</i> <i>Firmware settings must be set for flowrate to operate and report at "local conditions" (i.e., not STP).</i>	1) FEM: EQPM-0516-236 2) EPA T640 SOP 3) 1. FEM: EQPM-0516-236 2. 40 CFR Part 50 App N. sec. 1 (c)
Data Reporting Period	Report every hour	1. The calculation of an hour of data is dependent on the design of the method. <i>A 24-hour period is calculated in AQS if 18 or more valid hours are reported for a day ^{1/}.</i>	See operator's manual. Hourly data are always reported as the start of the hour on local standard time 40 CFR Part 50 App N. Sec 3 (c)
Sampling Instrument			
TSP Sampling Inlet	<i>At Setup</i>	<i>TAPI 5-Lpm sample inlet (P/N: 081050000)</i>	1) FEM: EQPM-0516-236 2) EPA T640 SOP 3) 1. FEM: EQPM-0516-236
One-point Flow Rate Verification	<i>every 30 days each separated by 14 days</i>	$\leq \pm 4.1\%$ of ± 5.0 LPM design flowrate	1, 2 and 3) 40 CFR Part 50, App.L, Sec. 9.2.5, 40 CFR Part 58, Appendix A Sec. 3.2.1
PMT verification	every 90 days	$\leq \pm 1.5$ of SpanDust TM value stated on bottle	1) Teledyne T640 manual 2) EPA T640 SOP 3) To meet DQO set forth in 40 CFR Part 58, Appendix A Sec. 2.3.1.1

T640 Validation Template – Operational Criteria

OPERATIONAL CRITERIA- T640 PM _{2.5} Continuous, Local Conditions			
<i>One-point Temp Verification</i>	every 30 days	$< \pm 2.1^{\circ}C$	1) Teledyne T640 manual 2) EPA T640 SOP 3) Teledyne T640 manual
<i>Pressure Verification</i>	every 30 days	$< \pm 10.1 \text{ mm Hg}$	1) Teledyne T640 manual 2) EPA T640 SOP 3) Teledyne T640 manual
<i>Leak Check (Zero Test)</i>	every 30 days	$\leq 0.2 \mu\text{g}/\text{m}^3$	1) Teledyne T640 manual 2) EPA T640 SOP 3) Teledyne T640 manual
Span Deviation Tracker	Daily	If flagged	1, 2 and 3) Recommended. Teledyne representatives suggest monitoring this metric as a leading indicator of potential instrument malfunction.
Signal Length	Daily	Logged	1, 2 and 3) Recommended. Teledyne representatives suggest monitoring this metric because it is useful when diagnosing instrument malfunction (e.g., deviation from design flow rate).

T640 Validation Template – Operational Criteria (continued)

Annual Multi-point Verifications/Calibrations			
Pressure Verification/Calibration	on installation, then every 365 days and 1/calendar year	$< \pm 10.1 \text{ mm Hg}$	1) Teledyne T640 manual 2) Method 2.12 Sec. 6.5 3) Teledyne T640 manual
Flow Rate single-point Verification/ Calibration	Electromechanical maintenance or transport or Every 365 days and 1/ calendar year	$< \pm 2.1\%$ of transfer standard	1) 40 CFR Part 50, App.L, Sec. 9.2. 2) 40 CFR Part 50, App.L, Sec. 9.1.3, Method 2.12 Sec. 6.3 & Table 6-1 3) Recommendation
Precision			
Collocated Samples	every 12 days for 15% of sites by method designation	$CV < 10.1\%$ of samples $\geq 3 \mu\text{g}/\text{m}^3$	1) and 2) 40 CFR Part 58 App A Sec. 3.2.3 3 Recommendation based on DQO in 40 CFR Part 58 App A Sec. 2.3.1.1
Accuracy			
Temperature Audit	every 180 days and at time of flow rate audit	$< \pm 2.1^\circ\text{C}$	1, 2 and 3) Method 2.12 Sec. 11.2.2
Pressure Audit	every 180 days and at time of flow rate audit	$< \pm 10.1 \text{ mm Hg}$	1, 2 and 3) Method 2.12 Sec. 11.2.3
Semi Annual Flow Rate Audit	Twice a calendar year and 5-7 months apart	$< \pm 4.1\%$ of 5.0 LPM design flowrate	1 and 2) 40 CFR Part 58, App A, Sec. 3.2.2 3) Method 2.12 Sec. 11.2.1

T640 Validation Template – Operational Criteria

(continued)

Shelter Temperature			
Temperature range	during operation	0 - 50°C	1) Teledyne T640 manual 2) Recommendation 3) Teledyne T640 manual
Temperature Control	Daily (hourly values)	< 2.1° C SD over 24 hours	1, 2 and 3) QA Handbook Volume 2 Sec. 7.2.2
Temperature Device Check	every 180 days and twice a calendar year	< ± 2.1° C	1, 2 and 3) QA Handbook Volume 2 Sec. 7.2.2
Monitor Maintenance			
<i>Inlet Cleaning</i>	<i>every 30 days</i>	<i>cleaned</i>	1,2 and 3) Teledyne T640 manual
Downtube Cleaning	every 90 days	cleaned	1) Teledyne T640 manual 2 and 3) Method 2.12 Sec. 8.4
<i>Inspect and clean optical chamber and relative humidity/temperature (RH/T) sensors</i>	every 180 days and twice a calendar year. More frequently with high loading	cleaned	1) Teledyne T640 manual 2) EPA T640 SOP 3) EPA T640 SOP
<i>Change Disposable Filter Unit</i>	Annually or when Pump PWM value approaches 80%.	cleaned/changed	1) Teledyne T640 manual 2) EPA T640 SOP 3) EPA T640 SOP
<i>Inspect Downtube and ASC to ensure vertically plumbed</i>	every 90 days	<i>Plumb (90° from instrument horizontal axis)</i>	1) Teledyne T640 manual 2) Recommendation 3) Teledyne T640 manual
<i>Check Pump Performance</i>	every 30 days	<i>PWM value 30 < 80%</i>	1) Teledyne T640 manual 2) EPA T640 SOP 3) Teledyne T640 manual
<i>Inspect inner and outer sample tubes</i>	<i>every 30 days</i>	<i>Inspected Cleaned as needed</i>	1,2 and 3) Teledyne T640 manual
Manufacturer-Recommended Maintenance	per manufacturers' manual	per manufacturers' manual	

T640 Validation Template – Systematic Criteria

SYSTEMATIC CRITERIA- T640 PM _{2.5} Continuous, Local Conditions			
<i>Siting</i>	every 365 days and once a calendar year	<i>Meets siting criteria or waiver documented</i>	1) 40 CFR Part 58 App E, Sec. 2-6 2) Recommendation 3) 40 CFR Part 58 App E, Sec. 2-6
<i>Data Completeness</i>	<i>Annual Standard</i>	$\geq 75\%$ <i>scheduled sampling days in each quarter</i>	1, 2 and 3) 40 CFR Part 50, App. N, Sec. 4.1 (a)(b)
	<i>24- Hour Standard</i>	$\geq 75\%$ <i>scheduled sampling days in each quarter</i>	1, 2 and 3) 40 CFR Part 50, App. N, Sec. 4.2 (a)(b)
<i>Reporting Units</i>	<i>all data</i>	$\mu\text{g}/\text{m}^3$ <i>at ambient temp/pressure (PM_{2.5})</i>	1. 2 and 3) 40 CFR Part 50 App N Sec. 3.0 (b)
<i>Rounding convention for data reported to AQS</i>	<i>all concentrations</i>	<i>to one decimal place or as reported by instrument</i>	1. 2 and 3) 40 CFR Part 50 App N Sec. 3.0 (b)
<i>Annual 3-yr average</i>	<i>all concentrations</i>	<i>nearest 0.1 $\mu\text{g}/\text{m}^3$ (≥ 0.05 round up)</i>	1,2 and 3) 40 CFR Part 50, App. N Sec. 3 and 4 Rounding convention for data reported to AQS is a recommendation
<i>24-hour, 3-year average</i>	<i>all concentrations</i>	<i>nearest 1 $\mu\text{g}/\text{m}^3$ (≥ 0.5 round up)</i>	1,2 and 3) 40 CFR Part 50, App. N Sec. 3 and 4 Rounding convention for data reported to AQS is a recommendation

T640 Validation Template – Systematic Criteria (continued)

Verification/Calibration Standards Recertifications - All standards should have multi-point certifications against NIST Traceable standards			
<i>Flow Rate Transfer Std.</i>	every 365 days and once a calendar year	$< \pm 2.1\%$ of NIST Traceable Std.	1) 40 CFR Part 50, App.L Sec. 9.1 & 9.2 2) Method 2.12 Sec. 4.2.3 & 6.3.3 3) 40 CFR Part 50, App.L Sec. 9.1 & 9.2
Field Thermometer	every 365 days and once a calendar year	$\pm 0.1^\circ$ C resolution, $\pm 0.5^\circ$ C accuracy	1, 2 and 3) Method 2.12 Sec. 4.2.2
Field Barometer	every 365 days and once a calendar year	± 1 mm Hg resolution, ± 5 mm Hg accuracy	1, 2 and 3) Method 2.12 Sec. 4.2.2
Clock/timer Verification	Every 30 days	± 5 min/mo**	1 and 2) Method 2.12 Sec. 4.2.1 3) Recommendation
Precision			
Single analyzer (collocated monitors)	every 90 days	Coefficient of variation (CV) $< 10.1\%$ for values $\geq 3.0 \mu\text{g}/\text{m}^3$	1,2 and 3) Recommendation in order to provide early (quarterly) evaluation of achievement of DQOs.
<i>Primary Quality Assurance Org.</i>	<i>Annual and 3-year estimates</i>	<i>90% CL of CV $< 10.1\%$ for values $\geq 3.0 \mu\text{g}/\text{m}^3$</i>	1,2 and 3) 40 CFR Part 58, App A, Sec. 4.2.1 and 2.3.1.1
Bias			
<i>Performance Evaluation Program (PEP)</i>	<i>5 audits for PQAOs with ≤ 5 sites</i> <i>8 audits for PQAOs with > 5 sites</i>	$< \pm 10.1\%$ for values $\geq 3 \mu\text{g}/\text{m}^3$	1,2 and 3) 40 CFR Part 58, App A, Sec. 3.2.4, 4.2.5 and 2.3.1.1



Questions?

Additional Slides

Standard Operating Procedures (SOPs) for PM Continuous FEMs

Use of these SOPs is not required but should be useful to provide the level of detail and instruction necessary to carry out successful operation and maintenance of the PM FEMs.

- SOP for the Teledyne T640; Federal Equivalent Method EQPM-0516-236 for PM2.5
- SOP for the Teledyne T640x; Federal Equivalent Method EQPM-0516-238 for PM2.5

**Standard Operating Procedure
Teledyne Model 640
Real-Time Continuous PM Monitor**

See “Methods” at: <https://www.epa.gov/amtic/amtic-pm25-monitoring-network>


Technical System Audit (TSA) Checklist

The TSA checklist is intended to support auditors and managers in conducting a Technical Systems Audit of PM continuous FEMs.

Available TSA checklist:

- PM Continuous TSA Checklist – Teledyne T640/T640x

Technical Systems Audit Checklist for the Teledyne T640 or T640x PM Continuous Monitors

Date:			
Question #	Item	Response	Comments
			<p>EQPM-0516-236 US EPA Continuous PM_{2.5} FEM Ambient Particulate Monitor</p> <p>*Federal Equivalency Method (FEM) designations are in accordance with 40 CFR Part 53. The unit must be equipped with the designated accessories and operated in accordance with the operations manual.</p> <p>EQPM-0516-238 US EPA Continuous PM₁₀ FEM Ambient Particulate Monitor</p> <p>EQPM-0516-239 US EPA Continuous PM₁₀ FEM Ambient Particulate Monitor</p> <p>EQPM-0516-240 US EPA Continuous PM_{10-2.5} FEM Ambient Particulate Monitor</p> <p>*Federal Equivalency Method (FEM) designations are in accordance with 40 CFR Part 53. The unit must be equipped with the designated accessories and operated in accordance with the operations manual.</p>
4	What is the serial number and year of manufacture? These can be found on the back of the monitor. Serial number is identified as "S/N"	S/N: _____ Year: _____	<p>Example from back panel of the monitor.</p>  <p>MODEL: T640 S/N: 157 PW: 070800000 YEAR: 2017 PWR: 100-240V~47-63Hz 75W RING: 1-10000 OPTION# T640X</p>
5	Are there any concerns about the location of the monitor inside the walk-in shelter or small modular shelter?	<input type="checkbox"/> Yes <input type="checkbox"/> No	This is largely professional judgement. Items of concern might include substantial vibration where monitor is set-up; AC blowing directly on down-tube with no insulation on downtube; or poor access to monitor.
6	Is an instrument manual for the PM _{2.5} continuous monitor available at the station (hardcopy or digital)? If so, what is the date on the manual?	<input type="checkbox"/> Yes <input type="checkbox"/> No Date: _____	The latest instrument manual version is dated: 20 April 2021. Please check the manufacturer's website for latest version. Note: one manual covers both the T640 and T640x.

See "PM Continuous Technical System Audit (TSA) Checklists" at: <https://www.epa.gov/amtic/amtic-pm25-monitoring-network>

PM Assessment Tools Available Now

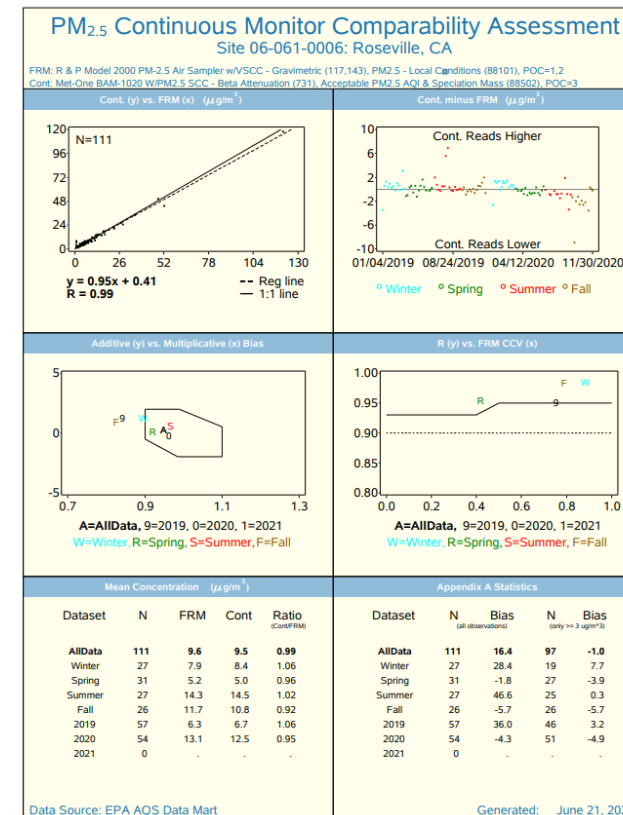
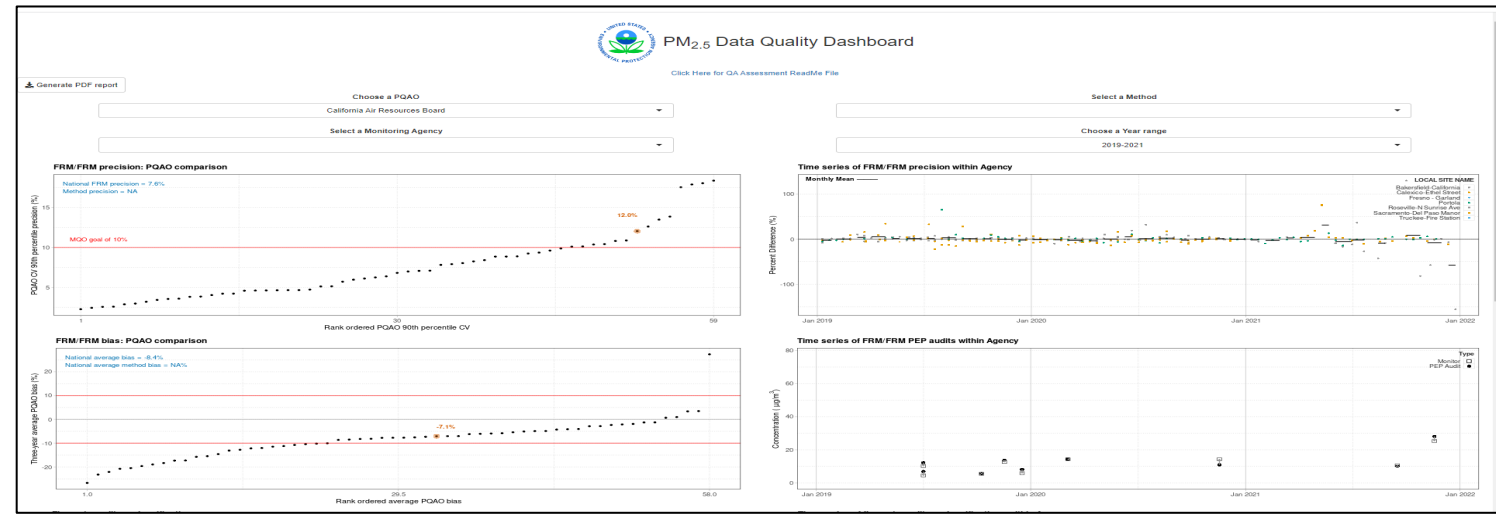
<https://www.epa.gov/amtic/amtic-ambient-air-monitoring-assessments>

• PM_{2.5} FRM Data Quality Dashboard

- Determine if your FRM data are acceptable (meet MQO's) and look like other agencies or are an outlier?
- Consider the concentrations being experienced at your sites when evaluating MQOs

• PM Continuous Monitor Comparability Assessment

- One page assessment per collocated pair.
- Compare your collocated site of interest to other similar paired sites in your network and networks around you.
- Available for PM_{2.5} and PM₁₀



T640x Validation Template - Critical Criteria

1) Criteria (T640x)	2) Frequency	3) Acceptable Range	Information /Action
CRITICAL CRITERIA- T640x Continuous, Local Conditions (PM_{2.5}) and STP (PM₁₀)			
<i>Sampler/Monitor Designation</i>	NA	<i>Meets requirements listed in FEM designation</i> Confirm method designation on front panel or just inside instrument.	1) 40 CFR Part 58 App C Sec. 2.1 2) NA 3) 40 CFR Part 53 & FRM/FEM method list
<i>Firmware of monitor</i>	<i>At setup and as updated</i>	1. <i>Must be the firmware (or later version) as identified in the published method designation summary.</i> <i>Firmware settings must be set for flowrate to operate and report at (1) "local conditions" for PM_{2.5} and (2) STP for PM₁₀.</i>	1) FEM: EQPM-0516-238/239 2) EPA T640x SOP 3) 1. FEM: EQPM-0516-238/239 2. 40 CFR Part 50 App N. sec. 1 (c)
Data Reporting Period	Report every hour	1. The calculation of an hour of data is dependent on the design of the method. <i>A 24-hour period is calculated in AQS if 18 or more valid hours are reported for a day ^{1/2}.</i>	See operator's manual. Hourly data are always reported as the start of the hour on local standard time 40 CFR Part 50 App N. Sec 3 (c)
Sampling Instrument			
PM10 Inlet	At Setup	Must be a Louvered PM10 size selective inlet as specified in 40 CFR 50 appendix L, Figures L-2 through L-19	1) FEM: EQPM-0516-238/239 2) EPA T640x SOP 3) FEM: EQPM-0516-238/239
<i>Average Flow Rate</i>	<i>every 24 hours of operation; alternatively, each hour can be checked</i>	<i>average within ±5% of 16.67 liters/minute at local conditions</i>	1, 2 and 3) 40 CFR Part 50 App L Sec. 7.4.3.1
<i>Variability in Flow Rate</i>	<i>every 24 hours of op</i>	<i>CV ≤ 2%</i>	1, 2 and 3) 40 CFR Part 50, App L Sec. 7.4.3.2
<i>One-point Flow Rate Verification (Total Flow)</i>	<i>every 30 days each separated by 14 days</i>	<i>< ± 4.1% of transfer standard</i> <i>< ± 5.1% of flow rate design value</i>	1, 2 and 3) 40 CFR Part 50, App.L, Sec. 9.2.5, 40 CFR Part 58, Appendix A Sec. 3.2.1
<i>One-point Flow Rate Verification (Sample Flow)</i>	<i>every 30 days each separated by 14 days</i>	<i>< ± 4.1% of transfer standard</i>	1, 2 and 3) 40 CFR Part 50, App.L, Sec. 9.2.5, 40 CFR Part 58, Appendix A Sec. 3.2.1
<i>PMT verification</i>	every 90 days	≤ ± 1.5 of SpanDust™ value stated on bottle	1) Teledyne T640 manual 2) EPA T640x SOP 3) To meet DQO set forth in 40 CFR Part 58, Appendix A Sec. 2.3.1.1