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# Development of an FRM alignment factor for the Teledyne API (TAPI) Model T640/x Instruments

## 1. Introduction

The Teledyne API (TAPI) installed T640 and T640 with 640x option (collectively herein referred to as **T640/x**) instruments with collocated Federal Reference Method (FRM) samplers are represented in all 10 US EPA regions with a robust data set, including tens of thousands of 24hr data points over multiple years and seasons. In evaluating the collocated data comparability over the past several years, the T640/x instruments have demonstrated a consistent positive bias relative to the SLTs FRM sampler data. Further analysis has revealed the bias to be slightly higher in cooler temperatures with a 20°C inflection point. The T640/x instrument's excellent precision and bias consistency provided an opportunity to update the T640/x particulate matter (PM) mass measurement to better align with FRM data.

On February 7, 2024, the EPA strengthened the NAAQS $PM_{2.5}$ annual standard at 9 $\mu g/m^3$ to better protect public health. This signification reduction in the annual standard for $PM_{2.5}$ encourages manufacturers of regulatory monitors to provide more accurate and precise mass concentration data, especially with comparison to the $PM_{2.5}$ FRM.

To improve the instruments comparability to the FRM, TAPI has developed a mass concentration alignment factor for the T640/x instruments that demonstrates improved consistency relative to the data provided by SLT agency's routinely operated FRM samplers. The alignment factor is included in T640/x software revision (1.4.31.529, or newer), that can be easily uploaded into new and existing (fielded) instruments in the form of a software update. The following report describes the data alignment development project in detail, the method employed, and analysis results demonstrating its effectiveness. TAPI had submitted separate US EPA FEM modification requests for the T640/x designations and received US EPA's approval of this PM alignment factor to the existing US EPA T640/x FEM designations.

## 2. Overview

The T640/x revised mass concentration alignment factor project is specifically intended to improve upon the observed bias of FEM to FRM at monitoring sites having $PM_{2.5}$ mass concentrations that are close to current annual and daily regulatory standards of 9 and 35 $\mu g/m^3$, respectively. Although the focus of this effort was on $PM_{2.5}$ mass concentrations, $PM_{10}$ and $PM_{10\text{-}2.5}$ were included such that the algorithm improvement could be applied to all three ($PM_{10,}$ $PM_{2.5,}$ and $PM_{10\text{-}2.5}$) measurements made by the T640/x instruments.

The T640/x mass concentration alignment factor approach uses information that is readily measured and made available both internally and external to the T640/x instrument. Since SLT agencies typically collect and archive these data, a large and statistically significant amount of the necessary information was readily available over a several year period for analysis and could be used for deriving appropriate alignment factors without the need for further field testing. However, validation testing was conducted on the actual alignment factor technique to confirm success and results are included herein.

With support from the US EPA Office of Air Quality Planning and Standards (OAQPS), officially reported $PM_{10}$ and $PM_{2.5}$ 24hr data were collected from monitoring sites containing T640 or T640x instruments with collocated SLT operated FRM samplers. The range of focus for T640/x and FRM data comparability assessments was 2018-2022 full years, representing hundreds of sites and over 30,000 data points, encompassing all 10 US EPA regions. For development of the alignment factors, 2019 and 2020 full year data were used. For validation, comparability assessments using the revised mass concentration algorithm were performed on collocated 2018 and 2021 full years, and 2022 partial year, based on validated data that was available at the time of analysis. The revised algorithm was also compared to the original Teledyne API T640/x US EPA field trial test data that was used for the initial US EPA FEM application and several additional sites by working directly with SLT agencies. All evaluations demonstrated successful results against the US EPA PM FEM comparability assessment requirements, as well as improved comparability of the data at locations with SLT agency FRM samplers.

The T640/x data alignment approach involves ambient temperature-based slope and offset adjustments to the raw T640/x PM concentration values, and is performed automatically, in real-time by the instrument software. Due to the high level of consistency and precision observed between the T640/x configurations, the alignment factors are identical for both the instrument configurations. The investigation focused on aligning $PM_{2.5}$ measurement data (FEM to FRM), however, the same alignment factors are also applied to the raw T640/x $PM_{10}$ measured data with positive results. Since $PM_{2.5}$ mass is, in most cases, the large fraction of $PM_{10}$ mass, it was assumed that most of the measurement bias would be improved using the same T640/x alignment approach for $PM_{10}$. The calculation of $PM_{10\text{-}2.5}$ mass concentration remains unchanged in both configurations and is calculated as the subtraction of $PM_{2.5}$ from the $PM_{10}$ mass concentration measurements.

## 3. Understanding the Bias

Data included in Figures 1 and 2 below are from the US EPA's Air Quality System (AQS) database, representing certified and valid data collected by State, Local, and Tribal monitoring agencies that submitted the data. As seen in Figures 1 and 2, unadjusted T640/x vs FRM data analysis indicates a consistent positive bias overall, with a demonstrated seasonal dependency year over year.

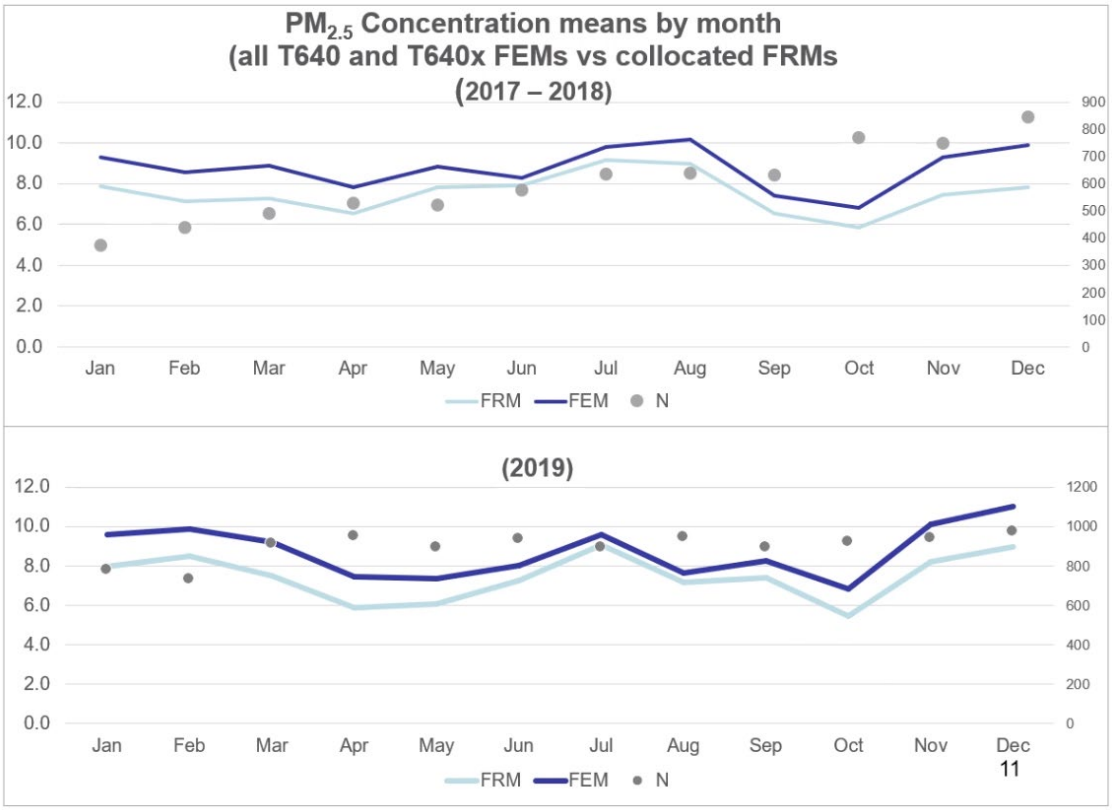


***Figure 1**. 2017-2019 PM2.5 24hr mean T640/x vs FRM data by concentration (X), month (Y), and number of sites (Secondary X). Data included are from the US EPA's Air Quality System (AQS) database, downloaded 09/2020.*

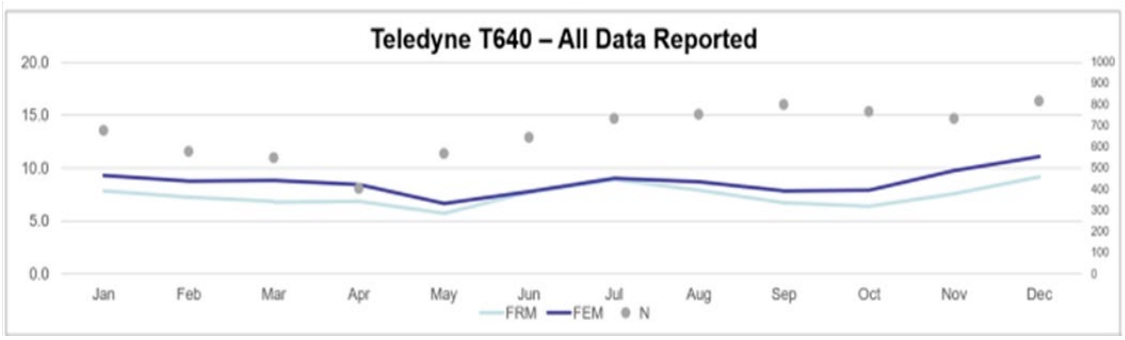


***Figure 2**. 2020 PM2.5 24hr mean T640/x vs FRM data by concentration (X), month (Y), and number of sites (Secondary X). Data included are from the US EPA's Air Quality System (AQS) database, downloaded 02/2022.*

## 4. Alignment Factor Development

Multiple iterations were explored to achieve the best, and most broadly applicable improvement to the T640/x measured data comparisons with SLT FRM data. As noted in Section 2 (Overview), the bias between the T640 and FRM data demonstrates an ambient based temperature dependency. To provide an improvement that would apply across a wide ambient temperature range, an ordinary least squares regression was performed on the data set using data only at/above a specific ambient temperature to statistically isolate an ambient temperature-based inflection point. The results from the regression procedure identified 68°F (or 20°C) as the ambient temperature at which the FEM/FRM comparability

shifts, with the T640/x having a more significant bias compared to the SLT FRM data when ambient temperature falls below 20°C versus periods when the ambient temperature is at or above 20°C.

With this information, the data set was then divided into two groups using the ambient temperature inflection point of 20°C. Two corrective equations to the raw T640/x measured data could then be derived using a linear regression analysis separately on the two groups of data. To validate the alignment factors, multiple comparisons of historically collected data was performed, including the National dataset for 2018 – 2022, and the T640 EPA FEM trial data from 2015/2016.

After refining and validating the ambient temperature-based alignment factor approach on both the national dataset(s) as well as the original T640/x EPA FEM trial data, it was then applied to SLT data obtained directly from cooperative agencies (in several regions) who had validated and collocated T640 and FRM data they could share. In all cases, PM comparability using the alignment factor(s) was successfully tested against collocated FRM sampler data using the US EPA's comparability spreadsheets developed to support FEM Candidate method review specified in 40 CFR 53.35. This data was presented in the individual T640/x FEM designation modification requests to the EPA in early 2023.

## 5. Summary:

Through an iterative process, and with tremendous help from the US EPA Office of Air Quality Planning and Standards (OAQPS), a mass concentration alignment factor was developed for the T640/x instruments in an effort to remove/diminish a consistently observed positive bias for the T640/x and better the comparison to the FRM.

*The alignment factor calculation implemented in the new T640/x software is:*

*- If the ambient temperature is at or below 20°C*
*- - T640/x raw PM value is less than or equal to 10ug/m3, then multiply the T640/x raw PM value by 0.813233*
*- - T640/x raw PM value is greater than 10ug/m3, then use the equation (T640/x raw PM – 1.861)*

*- If the ambient temperature is above 20°C*
*- - T640/x raw PM value is less than or equal to 5ug/m3, then multiply the T640/x raw PM value by 0.813233*
*- - T640/x raw PM value is greater than 5ug/m3, then use the equation (T640/x raw PM – 0.925)*

The slope factors used at lower concentrations (rather than the simple offset subtraction) was implemented to smooth the transition between the offset and slope method at lower concentration, and to also prevent negative values from being calculated at very low concentrations.

On June 12, 2023, Teledyne publicly announced a new software version (1.4.31.529) which included the option to automatically incorporate the above data alignment equations. This announcement included instructions to users for conducting the software update to their T640/x monitors. By January of 2024, State, Local, and Tribal organizations have reported that nearly 100% of the T640/x monitors which report data to AIRNow for locations in the United States have been updated with the Network Data Alignment equations. All T640/x instruments manufactured by Teledyne after June 12, 2023 automatically include the data alignment equations and thus do not require updating.