Technology Update
Regulatory PM Monitoring

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California Air Resources Board
Overview

• Introduction
• PM History
• T640 Evaluation
• Next Steps
Introduction

• A function of my section is to look for better and more reliable technology for our PM monitoring program.

• Talk and share our experience with recent PM instrument evaluation.

• Highlight three field studies with the Teledyne API (TAPI) T640.

• Next Steps?
Particulate Matter

• Is a criteria pollutant.
• Regulated in CA: PM10 and PM2.5.
• Poses risk to our health.
• Measured primarily for areas to determine attainment status.
• Data reporting: AQI, AIRNOW, Ag Burn, etc.
• Requires reliable instrument to provide accurate measurement.
CARB’s PM Monitoring History

* This is the basic timeline for our various PM regulation and monitoring requirements.

- 1970s: TSP
- 1980s: PM10
- 1990s: PM2.5
- 2000s: PM Continuous
- Late 2000s: PM Speciation
CARB’s PM Program

- Dated back to 1970s.
- First started with filter-based FRM sampler.
- Manual sampling.
- Daily averages only.
- Demands for more time-resolved data led to continuous monitoring.

Thermo Partisol 2000
CARB’s PM Program (cont.)

• In early 2000s BAM had become popular.
• Continuous sampling.
• Different options of cut head (FEM vs non-FEM).
• Hourly averages.
• Been used widely by PQAO as a standard PM instrument.
New PM Technologies

Met One
BAM 1022

Met One
BC 1054

Met One
SASS 22L
New PM Technologies (cont.)

- Met One
- EBAM Plus
- Thermo 5030i SHARP
- TAPI 602 Beta Plus
Teledyne API T640

- Continuous monitor.
- Uses scattered light spectrometry.
- FEM designated PM2.5 but also measures PM10 and PMC.
- Minute averages.
- Indoor or outdoor installation

* TAPI has an enhanced version called T640X for FEM PM10 and PMC as well.
# T640’s Quick Specs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Principle</td>
<td>Broadband spectroscopy using 90° white light scattering with Polychromatic LED</td>
</tr>
<tr>
<td>PM Mass Measurements</td>
<td>PM2.5, PM10, PM Coarse (10-2.5)</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>0.1 – 10,000 μg/m³</td>
</tr>
<tr>
<td>Data Resolution</td>
<td>0.1 μg/m³</td>
</tr>
<tr>
<td>Lower Detectable Limit</td>
<td>&lt;0.1 μg/m³ (1-hr average)</td>
</tr>
<tr>
<td>Data Rate</td>
<td>10s to 48hr (user selectable)</td>
</tr>
<tr>
<td>Sample Flow Rate</td>
<td>5.0 LPM within ±1% accuracy</td>
</tr>
<tr>
<td>Communication</td>
<td>Ethernet (TCP/IP Modbus &amp; HTTP Protocols)</td>
</tr>
<tr>
<td>Operating Temp. Range</td>
<td>-40 to +60°C</td>
</tr>
<tr>
<td>Operating Humidity Range</td>
<td>0 to 100% RH, non-condensing</td>
</tr>
<tr>
<td>Dimensions</td>
<td>7”x17”x14” (Unit) + 43” (Heater Tube)</td>
</tr>
<tr>
<td>Weights</td>
<td>19lbs (Unit) + 6lbs (Heater Tube)</td>
</tr>
<tr>
<td>US EPA Designation</td>
<td>US EPA Class III FEM (EQPM-0516-236)</td>
</tr>
</tbody>
</table>
How the T640 setup looks?

New Enclosure
The Touchscreen Interface
The Dashboard
Parameters of Interest

- PM2.5
- PM10
- PM Coarse
- Flowrate
- Relative Humidity
- Ambient Pressure
- Ambient Temp
- Box Temp
- LED Temp
- Sample Temp
- Pump Duty Cycle
Maintenance Checklist

CARB INSTRUMENT MONTHLY QUALITY CONTROL MAINTENANCE CHECK SHEET

API T640 PM MASS MONITOR

Location: __________________________  Month/Year: __________________________
Station Number: ____________________  Technician: _________________________
Property Number: ____________________  Agency: ___________________________

Operator Instructions:
1) Daily: Review station data logger values for correct operation of T640 monitor.
2) Biweekly: Check the system clock.
   Check the ambient temperature and pressure.
   Perform T640 flow check. (5.0LPM ± 0.25LPM)
   Perform T640 zero check. *** No vacuum leak check on this instrument.
3) Monthly: Complete this Monthly Quality Control Maintenance Check Sheet.
   Thoroughly clean the T640 inlet.
   Check pump performance. (PWM value < 80%)
   Check/Adjust PMT with SpanDust™. (Measured peak, limit: 11.3 ± 0.5)
   PMT Peak: ________________  Date Last Performed: ________________
4) Semi-annual: Inspect and clean optical chamber and RH/T sensor.
5) Annual: Inspect sampling line, or as needed.

Transfer Standard Used:

<table>
<thead>
<tr>
<th>Make/Model</th>
<th>Serial/I.D. Number</th>
<th>Date Certified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bi-Weekly Sampler Flow Rate, Ambient Temp, and Pressure Check Results:

<table>
<thead>
<tr>
<th>Date:</th>
<th>Sampler</th>
<th>Standard</th>
<th>Difference</th>
<th>Control Limits*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.0 ± 0.25 LPM</td>
</tr>
<tr>
<td></td>
<td>Flow Rate</td>
<td></td>
<td></td>
<td>± 2 °C</td>
</tr>
<tr>
<td></td>
<td>Ambient Temp.</td>
<td></td>
<td></td>
<td>± 10 mm Hg</td>
</tr>
<tr>
<td></td>
<td>Ambient Press.</td>
<td></td>
<td></td>
<td>&lt; 0.1 µg/m³</td>
</tr>
<tr>
<td></td>
<td>Zero Check</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tools Needed for Checks

- SpanDust Bottle
- Zero Test Kit
- Flow Standard
Zero Test
- Initiate the “Leak Check” from Calibration screen, and watch the PM monitors to drop to zero.
Flow Check
Bi-Weekly Sampler Flow Rate, Ambient Temp, and Pressure Check Results:

<table>
<thead>
<tr>
<th>Date</th>
<th>Sampler</th>
<th>Standard</th>
<th>Difference</th>
<th>Control Limits*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate</td>
<td>4.98</td>
<td>5.01</td>
<td>0.03</td>
<td>5.0 ± 0.25 LPM</td>
</tr>
<tr>
<td>Ambient Temp.</td>
<td>10.9</td>
<td>12.1</td>
<td>1.2</td>
<td>± 2 °C</td>
</tr>
<tr>
<td>Ambient Press.</td>
<td>766.2</td>
<td>763.5</td>
<td>2.7</td>
<td>± 10 mm Hg</td>
</tr>
<tr>
<td>Zero Check</td>
<td>0.0</td>
<td></td>
<td></td>
<td>&lt; 0.1 µg/m³</td>
</tr>
</tbody>
</table>
SpanDust Check

![Image of equipment setup with label for SpanDust 1.28]
• Initiate the “PMT Adjust” and check for the Peak Channel reading.

• The allowed range is ±0.5 of the specified target.

• If PMT check fails, inspect the optical chamber.
After Maintenance Checks

• Alert Messages

• Abnormal Readings (~10 mins)
Field Evaluations

Three different campaigns:

• Sacramento – T Street : Nov-2017 to Sep-2018
  → an urban site in downtown Sacramento

• Chico – East Ave : Oct-2018 to Mar-2019
  → a rural site surrounded with agriculture

• Brawley (Imperial County) : Jul-2018 to Mar-2019
  → a rural site in SoCal near the desert
Sacramento – T Street

24-hr Averaged PM2.5 Comparison

Time series of Daily PM2.5 measurements: T640, BAM25, and FRM from 11/21/2017 thru 9/11/2018
Sacramento – T Street

Hourly PM2.5 Comparison (July-11 to September-10, 2018)
Linear Regression (24-hr Averaged PM2.5)

First 90 Days @ Sac-T

T640 vs BAM25
Daily PM2.5

T640 vs FRM
Daily PM2.5

BAM25 vs FRM
Daily PM2.5

Last 90 Days @ Sac-T

T640 vs BAM25
Daily PM2.5

T640 vs FRM
Daily PM2.5

BAM25 vs FRM
Daily PM2.5
Summary of Sac-T’s Daily PM2.5 comparison between T640, BAM25, and FRM.

<table>
<thead>
<tr>
<th>Y vs. X</th>
<th>First 90 Days</th>
<th>Last 90 Days</th>
</tr>
</thead>
</table>
| T640 vs. BAM25   | $Y = 0.9885X + 0.1323$  
$R^2 = 0.9762$ | $Y = 1.4017X - 0.6547$  
$R^2 = 0.9726$ |
| T640 vs. FRM     | $Y = 1.0087X + 1.1985$  
$R^2 = 0.9864$ | $Y = 1.4014X - 1.8162$  
$R^2 = 0.9783$ |
| BAM25 vs. FRM    | $Y = 1.0005X + 1.3830$  
$R^2 = 0.9870$ | $Y = 0.9885X - 0.4220$  
$R^2 = 0.9738$ |

* During the smoky days, T640 reported ~40% higher than the collocated monitors.
Chico – East Avenue

24-hr Averaged PM2.5 Comparison

Time series of Daily PM2.5 measurements: T640, BAM25, and FRM from 10/1/2018 thru 1/31/2019

Camp Fire
Chico – East Avenue

Hourly PM2.5 Comparison (November 2018)
### Linear Regression (24-hr Averaged PM2.5)

Summary of Chico-East’s Daily PM2.5 comparison between T640, BAM25, and FRM.

<table>
<thead>
<tr>
<th>Y vs. X</th>
<th>Nov-2018</th>
<th>Dec-2018 to Jan-2019</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T640 vs. BAM25</strong></td>
<td>$Y = 1.4388X - 0.6300$&lt;br&gt;$R^2 = 0.9946$</td>
<td>$Y = 1.1999X + 0.4338$&lt;br&gt;$R^2 = 0.9703$</td>
</tr>
<tr>
<td><strong>T640 vs. FRM</strong></td>
<td>$Y = 1.4173X - 1.9535$&lt;br&gt;$R^2 = 0.9986$</td>
<td>$Y = 1.1429X + 0.4944$&lt;br&gt;$R^2 = 0.9798$</td>
</tr>
<tr>
<td><strong>BAM25 vs. FRM</strong></td>
<td>$Y = 1.0174X - 0.8161$&lt;br&gt;$R^2 = 0.9996$</td>
<td>$Y = 0.9343X + 0.4103$&lt;br&gt;$R^2 = 0.9754$</td>
</tr>
</tbody>
</table>

* T640 reported ~43% higher during Camp Fire.
** For wood burning season, T640 reported around 15~20% higher.
Brawley (Imperial County)

Time series of PM10S measurements: T640, BAM10, and EBAM+ from 8/1/2018 thru 3/31/2019
Summary of Brawley’s Daily PM10 comparison between T640, BAM10, and EBAM+.

<table>
<thead>
<tr>
<th>Y vs. X</th>
<th>Overall</th>
</tr>
</thead>
</table>
| T640 vs. BAM10      | \( Y = 1.1294X + 7.6089 \)  
                        \( R^2 = 0.9319 \)  |
| T640 vs. EBAM+      | \( Y = 1.2973X + 3.1476 \)  
                        \( R^2 = 0.9351 \)  |
| EBAM+ vs. BAM10     | \( Y = 0.8782X + 3.1809 \)  
                        \( R^2 = 0.9879 \)  |

* T640’s PM10 in general correlated with other monitors but reported higher. Could it be due to the lower flowrate?
Overall Feedback

- Wood smoke influence on performance... 😊
- More expensive than the BAMs... 😞
- Ethernet-only telemetry... 😞
- Good portability... 😊
- Real-time minute data... 😊
- Multi-parameter measurements... 😊
- Do not require sample filter or tape... 😊
- Low maintenance requirement... 😊
What now?

• Field evaluation for T640 is done.
• All data and findings have been shared with TAPI.
• CARB has no plan for T640 deployment yet.
• T640 still has the potential to be used for other types of monitoring (e.g. oil & gas, or community air).
• Write a staff report to summarize these evaluations.
Questions?

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