Laboratory Evaluation
Alphasense OPC-N2 PM Sensor
Background

Three Alphasense OPC-N2 (units IDs: 216, 222, 308) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (07/10/2015 to 08/10/2015) under ambient weather conditions. Now, three new OPC-N2 (units ID: 0508, 1202, 1207) have been evaluated in the South Coast AQMD Chemistry Laboratory under controlled PM concentration, temperature, and relative humidity.

**OPC-N2 PMS1003 (3 units tested):**
- Particle sensors (optical; non-FEM)
- Each unit measures: PM$_{1.0}$, PM$_{2.5}$, PM$_{10}$ mass concentration ($\mu$g/m$^3$)
- Unit cost: ~$450
- Time resolution: 1.4 to 20 seconds
- Units IDs: 0508, 1202, 1207

**GRIMM EDM 180 (ref. method for PM$_{1.0}$, PM$_{2.5}$ mass):**
- Optical particle counter
- FEM PM$_{2.5}$
- Uses proprietary algorithms to calculate total PM, PM$_{2.5}$, and PM$_{1.0}$ mass conc. from particle number measurements
- Cost: ~$25,000

**TSI APS 3321 (ref. method for PM$_{10}$ mass):**
- Aerodynamic particle sizer
- Measures particles from 0.5 to 20 $\mu$m
- Uses a patented, double-crest optical system for unmatched sizing accuracy
- Cost: ~$50,000
Evaluation results guideline

- OPC-N2 v.s. GRIMM PM$_{1.0}$ mass concentration
- OPC-N2 v.s. GRIMM PM$_{2.5}$ mass concentration
- OPC-N2 v.s. APS v.s. GRIMM PM$_{10}$ mass concentration
Evaluation results for OPC-N2 PM$_{1.0}$ mass

OPC-N2 vs GRIMM
**Coefficient of Determination: OPC-N2 PM$_{1.0}$ vs GRIMM**

- Over the full PM$_{1.0}$ concentration range tested (0-230 µg/m$^3$), OPC-N2 units 0508 and 1207 tracked well the diurnal variations as recorded by the GRIMM.

- For this experiment, Unit 1202 did not record valid measurements. Later, Unit 1202 resumed normal data logging by itself.

\[ y = 0.64x - 7.80 \]
\[ R^2 = 0.99 \]

- OPC-N2 units 0508 and 1207 showed very strong correlation with GRIMM PM$_{1.0}$ measurement data ($R^2 = 0.99$) between 0-230 µg/m$^3$.

- The OPC-N2 units overestimated the GRIMM PM$_{1.0}$ concentration.
OPC-N2 PM$_{1.0}$ Accuracy

- Accuracy (20 °C and 40% RH)

<table>
<thead>
<tr>
<th>Steady State (#)</th>
<th>Sensor mean ($\mu$g/m$^3$)</th>
<th>GRIMM ($\mu$g/m$^3$)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.6</td>
<td>13.7</td>
<td>13.4</td>
</tr>
<tr>
<td>2</td>
<td>70.6</td>
<td>35.3</td>
<td>0.3</td>
</tr>
<tr>
<td>3</td>
<td>125.2</td>
<td>67.2</td>
<td>13.8</td>
</tr>
<tr>
<td>4</td>
<td>262.8</td>
<td>153.9</td>
<td>29.2</td>
</tr>
<tr>
<td>5</td>
<td>360.2</td>
<td>230.7</td>
<td>43.8</td>
</tr>
</tbody>
</table>

- The OPC-N2 units showed low to moderate accuracy levels compared to GRIMM PM$_{1.0}$ over the concentration range of 0-230 $\mu$g/m$^3$. Accuracy ranged from 0.3% to 43.8%. In general, OPC-N2 units overestimated the PM$_{1.0}$ mass measured by GRIMM.

OPC-N2 PM$_{1.0}$ Data Recovery & Intra-model Variability

- Data recovery for PM$_{1.0}$ mass concentration from 0508, 1202, and 1207 was 100%, 42.4%, and 100%.
- Low PM$_{1.0}$ measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.
OPC-N2 PM$_{1.0}$ Precision

- Precision (%, Effect of PM$_{1.0}$ conc., temperature and relative humidity)

*100% represents high precision.

Overall, the OPC-N2 units showed high precision for most of T, RH, and PM conc. combinations, except for very high humidity conditions at 5, and 20 °C.

GRIMM’s precision was high across all conditions.
OPC-N2 PM$_{1.0}$ Climate Susceptibility

OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{1.0}$ mass and 5 °C)

- GRIMM
- Unit 0508
- Unit 1202
- Unit 1207

From 15 to 40% RH
To 65% RH

Unit 1202 did not record valid data.

Low Temp – RH ramping (medium conc.)

High Temp – RH ramping (medium conc.)
Evaluation results for OPC-N2 PM$_{2.5}$ mass

OPC-N2 vs GRIMM
Over the full PM$_{2.5}$ concentration range tested (0-300 µg/m$^3$), OPC-N2 units 0508 and 1207 tracked well the diurnal variations as recorded by the FEM GRIMM.

For this experiment, Unit 1202 did not record valid measurements. Later, Unit 1202 resumed normal data logging by itself.

OPC-N2 units 0508 and 1207 showed very strong correlation with FEM GRIMM PM$_{1.0}$ measurement data ($R^2 = 0.99$) between 0-300 µg/m$^3$.

The OPC-N2 units overestimated the FEM GRIMM PM$_{2.5}$ mass concentration.
OPC-N2 PM$_{2.5}$ Accuracy

• Accuracy (20 °C and 40% RH)

<table>
<thead>
<tr>
<th>Steady State (#)</th>
<th>Sensor mean (µg/m$^3$)</th>
<th>FEM (µg/m$^3$)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32.6</td>
<td>16.0</td>
<td>-3.9</td>
</tr>
<tr>
<td>2</td>
<td>93.0</td>
<td>39.9</td>
<td>-33.2</td>
</tr>
<tr>
<td>3</td>
<td>171.8</td>
<td>77.8</td>
<td>-20.9</td>
</tr>
<tr>
<td>4</td>
<td>382.6</td>
<td>193.3</td>
<td>2.1</td>
</tr>
<tr>
<td>5</td>
<td>545.8</td>
<td>299.5</td>
<td>17.8</td>
</tr>
</tbody>
</table>

• The OPC-N2 units showed low accuracy compared to FEM GRIMM PM$_{2.5}$ over the concentration range tested (0-300 µg/m$^3$). Accuracy varied from -33.2% to 17.8%. At low to medium PM$_{2.5}$ concentrations, the sensors overestimated the FEM GRIMM by more than 100%, therefore, the calculated accuracy generated negative values.

OPC-N2 PM$_{2.5}$ Data Recovery & Intra-model Variability

• Data recovery for PM$_{2.5}$ mass concentration from 0508, 1202, and 1207 was 100%, 42.4%, and 100%.
• Low PM$_{2.5}$ measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.
OPC-N2 PM$_{2.5}$ Precision

- Precision (%: Effect of PM$_{2.5}$ conc., temperature, and relative humidity)

- Overall, the OPC-N2 units showed high precision for most of T, RH, and PM conc. combinations, except for high humidity levels at 5 °C, and also at 5 °C/15% RH.

- FEM GRIMM’s precision was also high across all conditions.

*100% represents high precision.*
OPC-N2 PM$_{2.5}$ Climate Susceptibility

Low Temp – RH ramping (medium conc.)

High Temp – RH ramping (medium conc.)

Unit 1202 did not record valid data.

OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{2.5}$ mass and 5 °C)

OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{2.5}$ mass and 35 °C)
**Discussion**

- **Accuracy**: Overall, the OPC-N2 units have low accuracy, compared to the GRIMM PM$_{1.0}$ and PM$_{2.5}$ in the tested range. The OPC-N2 units overestimated the PM$_{1.0}$ and PM$_{2.5}$ mass measured by GRIMM. (refer to slide 6 and 11).

- **Precision**: The OPC-N2 units have high precision for most of tested combinations (PM concentrations, T and RH), except at high humidity levels at 5 °C. (refer to slide 7 and 12)

- **Intra-model variability**: Low intra-model variability was observed between units 0508 and 1207. Unit 1202 had significant data loss, and did not record valid data during the intra-model variability experiment.

- **Data Recovery**: Data recovery from 0508, 1202, and 1207 was 100%, 42.4%, and 100%. Unit 1202 did not record valid data for a period of time, but later it resumed normal performance on its own.

- **Coefficient of Determination**: OPC-N2 units showed very strong correlation/linear response with the corresponding GRIMM PM$_{1.0}$ and PM$_{2.5}$ measurement data ($R^2 = 0.99$ and 0.99, respectively) for mass concentration range between 0 and 300 µg/m$^3$. (refer to slides 5 and 10)

- **Climate susceptibility**: From the laboratory studies, low temperature and high humidity affected the precision of OPC-N2 units. (refer to slide 7 and 12)
Evaluation results for OPC-N2 $PM_{10}$ mass

OPC-N2 vs APS vs GRIMM
Coefficient of Determination: OPC-N2 PM$_{10}$ vs GRIMM and APS

- Over the full PM$_{10}$ concentration range tested (0-200 µg/m$_3$), the OPC-N2 units tracked well the diurnal variations as recorded by the APS and GRIMM.

OPC-N2 vs FEM GRIMM (Conc. ramping, 20 °C, 40% RH)

- APS
- Unit 0508
- Unit 1202
- Unit 1207
- GRIMM

APS density setting = 2.6 g/cm$^3$

Unit 1202 did not record valid data.

PM$_{10}$ mass (µg/m$_3$) 20 °C, 40% RH
1-min mean data

- y = 1.10x - 1.44
- R$^2$ = 0.99

GRIMM PM$_{10}$
Avg. of units 0508 and 1207
PM$_{10}$ mass (µg/m$_3$) 20 °C, 40% RH
1-min mean data

- y = 0.97x - 1.72
- R$^2$ = 0.99

GRIMM PM$_{10}$
Avg. of units 0508 and 1207
PM$_{10}$ mass (µg/m$_3$) 20 °C, 40% RH
1-min mean data

- y = 1.10x - 1.44
- R$^2$ = 0.99
**OPC-N2 vs APS: Accuracy**

- Accuracy* (20 °C and 40% RH)

<table>
<thead>
<tr>
<th>Steady State (#)</th>
<th>Sensor mean (µg/m³)</th>
<th>APS-2.6 (µg/m³)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.7</td>
<td>21.3</td>
<td>86.3</td>
</tr>
<tr>
<td>2</td>
<td>22.0</td>
<td>25.3</td>
<td>85.1</td>
</tr>
<tr>
<td>3</td>
<td>46.5</td>
<td>51.6</td>
<td>89.1</td>
</tr>
<tr>
<td>4</td>
<td>109.3</td>
<td>116.3</td>
<td>93.6</td>
</tr>
<tr>
<td>5</td>
<td>172.5</td>
<td>179.6</td>
<td>95.9</td>
</tr>
</tbody>
</table>

- The OPC-N2 units had high accuracy when compared to APS. The units’ accuracy ranges from 85.1% to 95.9%.

**OPC-N2 PM$_{10}$ Data Recovery & Intra-model Variability**

- Data recovery for PM$_{10}$ mass concentration from 0508, 1202, and 1207 was 96.8%, 9.5%, and 96.8%.
- Low PM$_{10}$ measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.
OPC-N2 PM$_{10}$ Climate Susceptibility

Low Temp – RH ramping (medium conc.)

High Temp – RH ramping (medium conc.)

Unit 1202 did not record valid data.

Unit 1202 did not record valid data.
Discussion

- **Accuracy**: The OPC-N2 units had high accuracy when compared to APS. The units’ accuracy ranges from 85.1% to 95.9%. (refer to slide 17)

- **Precision**: Due to the nature of Arizona test dust, the aerosol concentration showed some variability in the chamber, therefore, the precision could not be estimated. At high humidity levels at 5 °C the OPC-N2 units recorded out of range PM$_{10}$ concentrations in thousands of micrograms per cubic meter. (refer to slide 18)

- **Intra-model variability**: Low intra-model variability was observed between units 0508 and 1207. Unit 1202 had significant data loss, and did not record valid data during the intra-model variability experiment.

- **Data Recovery**: Data recovery for PM$_{10}$ mass concentration from 0508, 1202, and 1207 were 96.8%, 9.5%, and 96.8%.

- **Coefficient of Determination**: OPC-N2 units showed very strong correlation/linear response with the corresponding APS PM$_{10}$ ($R^2 = 0.99$) and GRIMM PM$_{10}$ ($R^2 = 0.99$). (refer to slide 16)

- **Climate susceptibility**: At low temperature and high humidity levels, the OPC-N2 units recorded out of range PM$_{10}$ mass concentrations.