Development of Chemically-Resolved Speciation Profiles for Attainment Planning

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California Air Resources Board

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Attainment plans provide the blueprint for areas in non-attainment of ambient air quality standards.

Air quality modeling is an important tool to support the attainment plans.

Chemically-resolved inventory is one of the key components for air quality modeling.

Speciation profiles are used to create the chemically-resolved inventory.

CARB speciation program: http://www.arb.ca.gov/ei/speciate/speciate.htm
CARB Speciation Profiles

- **Consumer Products Profiles**
  - Based on survey data

- **Gasoline Vehicle Emission Profiles**
  - 1991, eliminated lead
  - 1996, set specifications for sulfur, aromatics, benzene, etc.
  - 1999, eliminated MTBE
  - 2004, E6 gasoline fuel
  - 2010, E10 gasoline fuel

- **Ocean-going vessel PM profiles**
  - July 1, 2009, 0.26% MGO or 0.5% MDO
  - Jan. 1, 2012, 0.1% MGO or 0.1% MDO
Require heavy-duty diesel trucks that operate in California to be upgraded to reduce emissions:

* Beginning 1/1/2012, newer heavier trucks and buses must meet PM filter requirements.
* Starting 1/1/2015, lighter and older heavier trucks must be replaced.
* By 1/1/2023, nearly all trucks and buses will need to have 2010 model year engines or equivalent.
Effect of DPF on PM Emissions

- DPF reduces the PM emissions by several orders of magnitudes
- The fraction of EC in PM greatly decreases after applying DPF

Herner et al. EST, 2011, 45(6)
### Selected Studies for Profile Making

<table>
<thead>
<tr>
<th>Field</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Type</td>
<td>Chassis dynamometer, Engine dynamometer</td>
</tr>
<tr>
<td>Engine Model Year</td>
<td>from 1984 to 2007</td>
</tr>
<tr>
<td>Aftertreatment</td>
<td>Non-aftertreatment; Aftertreatment: <em>trap, DPF, oxidant catalyst, CRT, CCRT, V-SCRT, Z-SCRT, DPX, EPF, EGR/CGI+(DOC)CDPF</em></td>
</tr>
<tr>
<td>Diesel Fuel</td>
<td>Diesel 2, Jet A, CLSF, ECD, ECD-1, F-T, low aromatic diesel, pre-93 diesel, reformulated diesel, LSD, ULSD</td>
</tr>
<tr>
<td>Test Cycle</td>
<td>Idle, creep, cruise, HW, CBD, CCS, HCS, CSHVR, FTP, MC, transient, UDDS, CARB 5-modes, 16-hour</td>
</tr>
</tbody>
</table>
## Model Year/After-treatment (MY/AT) Grouping

<table>
<thead>
<tr>
<th>Engine Model Year (MY)</th>
<th>Exhaust After-treatment (AT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>without</td>
</tr>
<tr>
<td>Pre 1994</td>
<td>G1</td>
</tr>
<tr>
<td>1994-2002</td>
<td>G3</td>
</tr>
<tr>
<td>2003-2006</td>
<td>G5</td>
</tr>
<tr>
<td>2007-2009</td>
<td>/</td>
</tr>
<tr>
<td>2010 and newer</td>
<td>/</td>
</tr>
</tbody>
</table>
MY/AT Profile for HDDT: G1

**HDDT-G1-Idle**
- Weight Fraction
- Profile Number: D10007 (<500) D20027 (<500) D20028 (<500) D20050 (<500)

**HDDT-G1-Cruise**
- Weight Fraction
- Profile Number: D10011 (<5000) D10005 (<500) D20030 (<500) D20052 (<500)

**HDDT-G1-Transient**
- Weight Fraction

Legend:
- All others
- Sulfate
- Nitrate
- EC
- OM

(Fuel sulfur level, ppm)
MY/AT Profile for HDDT: G3

HDDT-G3-idle

HDDT-G3-Cruise

HDDT-G3-Transient

Profile Number
(Fuel sulfur level, ppm)

Weight Fraction

0.0 0.2 0.4 0.6 0.8 1.0

D10008 (500) D20017 (500) D20018 (500) D20022 (500) D20023 (500) D20044 (500) D20047 (500) D20066 (15)

D10006 (500) D20020 (500) D20025 (500) D20046 (500) D20049 (500) D20053 (15)


All others
Sulfate
Nitrate
EC
OM
MY/AT Profile for HDDT: G4

HDDT-G4-Idle

HDDT-G4-Cruise

HDDT-G4-Transient

Profile Number
(Fuel sulfur level, ppm)
MY/AT Profile for HDDT: G5

HDDT-G5-Idle

HDDT-G5-Cruise

HDDT-G5-Transient

Profile Number
(Fuel sulfur level, ppm)

Weight Fraction

D20038 (<500)
D20041 (<500)
D20040 (<500)
D20043 (<500)

D20039 (<500)
D20042 (<500)

All others
Sulfate
Nitrate
EC
OM

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MY/AT Profile for School Bus

SB-G3-Transient

SB-G4-Transient

SB-G6-Idle (uncatalyzed DPF)

SB-G6-Cruise (uncatalyzed DPF)

SB-G6-Transient (uncatalyzed DPF)
MY/AT Profile for Transit Bus

TB-G1-Transient

TB-G2-Transient

TB-G3-Transient

TB-G4-Transient

TB-G6-Transient (hybrid)

Profile Number (Fuel sulfur level, ppm)

Weight Fraction

- All others
- Sulfate
- Nitrate
- EC
- OM
MY/AT Profile for Engine

E-G1-transient

E-G3-cruise

E-G4-cruise

E-G7-transient

Profile Number
(Fuel sulfur level, ppm)

Weight Fraction

D10025 (<500)
D10026 (<500)
D10027 (<500)
D10028 (<500)
D10023 (<15)
D10024 (<15)

D20039 (<500)
D20042 (<500)

D10030 (<500)
D10032 (<500)

D20071 (<15)
D20072 (<15)
D20073 (<15)
D20074 (<15)

Weight Fraction

D20071
D20072
D20073
D20074

D10025
D10026
D10027
D10028

D10023
D10024

D10030
D10032

D20039
D20042

All others
Sulfate
Nitrate
EC
OM

California Environmental Protection Agency
Air Resources Board
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Summary of MY/AT Profiles
## Assumptions

<table>
<thead>
<tr>
<th>Type</th>
<th>Cycle</th>
<th>MY/AT</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>G1</td>
</tr>
<tr>
<td>HDDT</td>
<td>Idle</td>
<td>4252</td>
</tr>
<tr>
<td></td>
<td>Cruise</td>
<td>4253</td>
</tr>
<tr>
<td></td>
<td>Transient</td>
<td>4254</td>
</tr>
<tr>
<td>School Bus</td>
<td>Idle</td>
<td>4252</td>
</tr>
<tr>
<td></td>
<td>Transient</td>
<td>4254</td>
</tr>
<tr>
<td>Transit Bus</td>
<td>Idle</td>
<td>4252</td>
</tr>
<tr>
<td></td>
<td>Transient</td>
<td>4269</td>
</tr>
<tr>
<td>Engine</td>
<td>Cruise</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transient</td>
<td>4274</td>
</tr>
</tbody>
</table>
California HDDV Fleet Composition
Profile for Each Calendar Year

\[ F_{Y_k}^{S_j} = \sum_{i=1-8} \left( F_{G_i}^{S_j} \times P_{G_i}^{Y_k} \right) \]

* \( F_{Y_k}^{S_j} \): weight fraction of Species \( j \) in the CY profile for Year \( k \) fleet;

* \( F_{G_i}^{S_j} \): Weight fraction of Species \( j \) in the MY/AT profile for Group \( i \) (\( i=G1, G2, G3, G4, G5, G6, G7 and G8 \));

* \( P_{G_i}^{Y_k} \): CY fleet composition fraction of Group \( i \) vehicles in the fleet of Year \( k \), weighted by \( \text{PM}_{2.5} \) mass.
## Calendar Year Specific Profiles

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>HDDT</th>
<th>SB</th>
<th>TB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Idle</td>
<td>Cruise</td>
<td>Transient</td>
</tr>
<tr>
<td>2007</td>
<td>6071</td>
<td>6072</td>
<td>6073</td>
</tr>
<tr>
<td>2008</td>
<td>6081</td>
<td>6082</td>
<td>6083</td>
</tr>
<tr>
<td>2009</td>
<td>6091</td>
<td>6092</td>
<td>6093</td>
</tr>
<tr>
<td>2010</td>
<td>6101</td>
<td>6102</td>
<td>6103</td>
</tr>
<tr>
<td>2011</td>
<td>6111</td>
<td>6112</td>
<td>6113</td>
</tr>
<tr>
<td>2012</td>
<td>6121</td>
<td>6122</td>
<td>6123</td>
</tr>
<tr>
<td>2013</td>
<td>6131</td>
<td>6132</td>
<td>6133</td>
</tr>
<tr>
<td>2014</td>
<td>6141</td>
<td>6142</td>
<td>6143</td>
</tr>
</tbody>
</table>
HDDT Transient Profiles

Graph showing weight fraction for different years.
## Profile Assignment

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Cycle</th>
<th>EICSUB Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDDT</td>
<td>Cruise</td>
<td>Motor Coach, PTO, T6 Ag, T6 CAIRP heavy, T6 CAIRP small, T6 instate construction heavy, T6 instate construction small, T6 instate heavy, T6 instate small, T6 OOS heavy, T6 OOS small, T7 Ag, T7 CAIRP, T7 CAIRP construction, T7 NNOOS, T7 NOOS, T7 other port, T7 POAK, T7 POLA, T7 tractor, T7 tractor construction</td>
</tr>
<tr>
<td></td>
<td>Transient</td>
<td>T6 public, T6 utility, T7 public, T7 single, T7 single construction, T7 SWCV, T7 utility</td>
</tr>
<tr>
<td>SB</td>
<td>Transient</td>
<td>SBUS</td>
</tr>
<tr>
<td>TB</td>
<td>Transient</td>
<td>All Other Buses</td>
</tr>
</tbody>
</table>
Summary

* The year-specific composite diesel PM profiles are able to reflect the CARB truck and bus regulation.

* The MY/AT profile pool needs to be updated with new testing data for newer vehicles.

* Speciation profile development is meeting the challenges posed by new technology or regulations.

* The inventory categories needs to be changed to face the emerging air quality issues.
Thank you!

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