Heavy-Duty Diesel Vehicle Emissions Modeling in California’s EMFAC Model

Mobile Source Analysis Branch
Air Quality Planning and Science Division
California Air Resources Board

November 3, 2016
Outline

- Heavy Duty Diesel Vehicles in California
  - The need for NOx reduction
  - Emission contribution
  - Importance of emission controls under low load/low speed conditions

- California Emission Modeling
  - Zero mile rates
  - Deterioration
  - Speed Correction Factors
  - Vehicle activity

- Efforts to Improve HD Diesel Truck Emissions Modeling in EMFAC2017

- Low NOx Regulatory Support
Heavy Duty Diesel Vehicles in California


- Reaching Federal ozone standards in 2031 requires an 80 percent reduction in NOx emissions from today.

- Heavy-duty trucks over 8,500 pounds are currently responsible for about 33 percent of total statewide NOx emissions (all sources)

- A National Heavy Duty Low NOx Engine Standard can reduce NOx emissions from heavy duty vehicle (>8,500 lbs. GVWR) by approximately 30% in 2031.
  - A California-Only standard can only reduce emissions by 14%.
Aftertreatment Technologies Used to Meet Today’s 2010 Engine Standards

- Current standard:
  - NOx: 0.20 g/bhp-hr
    - Selective Catalytic Reduction (SCR)
  - PM: 0.01 g/bhp-hr
    - Diesel Particulate Filter (DPF)

Reference: [http://www.dieselforum.org](http://www.dieselforum.org) (modified)
Heavy Duty Vehicles in California (Above 8,500 lbs. GVWR)

- 2010+ Heavy Duty Vehicles (>8,500 lbs. GVWR)
- Pre-2010 Heavy Duty Vehicles (>8,500 lbs. GVWR)
- Light Duty Vehicles (<8,500 lbs. GVWR)

Based on EMFAC2014 v1.0.7

All fuel types are included – Gasoline, Diesel, and Natural Gas
Heavy Duty Vehicles in California (Above 8,500 lbs. GVWR)

NOx Emissions - Calendar Year 2031

- **2010+ HDV (Speed < 25 mph)**: 34%
- **2010+ HDV (Speed ≥ 25 mph)**: 29%
- **Pre-2010 Heavy Duty Vehicles (>8,500 lbs. GVWR)**: 13%
- **Light Duty Vehicles (≤8,500 lbs. GVWR)**: 24%

*Source: EMFAC2014 v1.0.7*

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Emission Modeling

Modeling emissions from heavy duty vehicles consists of four major components:

1. Zero-mile emission rate (ZMR) – Fleet average UDDS emission rates while trucks are new
2. Speed Correction Factors (SCF) – A method to correct emission factors at different driving speeds (i.e., duty cycles)
3. In-Use Emission Deterioration (DR) – Increase of emissions over time within the in-use fleet caused by tampering, malfunctioning, and mal-maintenance of engine components, and emission control systems
4. Activity - Metrics of vehicle operation such as vehicle miles traveled (VMT), hours of idling, number of trips, etc.

\[
\text{Emissions (tons/day)} = \text{Emission Rate} \times \text{Activity}
\]

\[
\text{Emission Rate (g/mi)} = (\text{ZMR} + \text{DR} \times \text{Odometer}) \times \text{SCF}
\]
**In-Use Emission Measurements**

- In-use vehicle emission testing is a key to ARB’s emission inventory development
- In-use trucks are tested on a chassis dynamometer over six different cycles

<table>
<thead>
<tr>
<th>Test Cycle/Mode</th>
<th>Average Speed (mph)</th>
<th>Duration (sec)</th>
<th>Length (mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDDS</td>
<td>18.8</td>
<td>1063</td>
<td>5.55</td>
</tr>
<tr>
<td>Creep</td>
<td>1.8</td>
<td>253</td>
<td>0.12</td>
</tr>
<tr>
<td>Transient</td>
<td>15.4</td>
<td>668</td>
<td>2.85</td>
</tr>
<tr>
<td>Cruise</td>
<td>39.9</td>
<td>2,083</td>
<td>23.1</td>
</tr>
<tr>
<td>High Speed Cruise</td>
<td>50.2</td>
<td>757</td>
<td>10.5</td>
</tr>
<tr>
<td>Idle</td>
<td>0</td>
<td>600</td>
<td>N/A</td>
</tr>
</tbody>
</table>

- ARB is also deploying PEMS to measure real-world emission rates
Zero Mile Emission Rates

Running Emission Rates

- Emission rates based on test data collected over UDDS cycle
- Test results back-projected to “zero-mile” using emission increase rates
  - For example if test data is collected from trucks with 60,000 miles, results are back-projected to estimate emissions rates for trucks at **zero miles** (i.e., zero mile emission rate)
- For 2007-2012 model years, zero-mile rates weighted by sales fractions of different certification levels

Idle Emission Rates

- Based on test data collected over idle cycle and corrected for different accessory loads

Start Emission Rates

- Derived from on-road PEMS test data
Speed Correction Factors

- HD trucks are driven under a variety of different duty cycles depending on their vocational usage (line-haul vs. last mile delivery)
- Modeling emissions from trucks requires emission rates at different vehicle speeds
- Emissions associated with different driving cycles (i.e., speeds) are estimated using Speed Correction Factors (SCF)
- Speed correction factors in EMFAC are ratio of emission rates at other speeds relative to emission rate at 18.8 mph (UDDS)
Emissions Deterioration
(Engine Component and Emission Control System Failure)

- Emissions increase over time
- For diesel engines, deterioration is caused by
  - Natural degradation of after-treatment systems
  - Tampering and mal-maintenance (T&M)
  - Component malfunction
- Deterioration rates are modeled as a function of
  - Frequency of engine tampering and malfunction
  - Emissions impact of tampering and malfunction

<table>
<thead>
<tr>
<th>Model Year</th>
<th>2007-09 (DPF)</th>
<th>2010-12 (SCR/DPF)</th>
<th>2013+ (SCR/DPF/OBD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx Emission Increase over 1M Miles</td>
<td>113%</td>
<td>312%</td>
<td>220%</td>
</tr>
</tbody>
</table>
2010+ HDV Start Emissions

- SCR effectiveness is highly temperature dependent.
- ‘Start’ emission levels are produced before the SCR catalyst reaches its working temperature.
- For EMFAC2014, cold/warm start emissions are derived from on-road PEMS testing data.
- Start emissions are modeled using:
  - Emission rate per start (g/start)
  - Number of starts per day

\[
\text{Start Emissions (g/day)} = \text{Cold Start ER} \times \# \text{ of Cold Starts} + \text{Warm Start ER} \times \# \text{ of Warms Starts}
\]
Heavy Duty Vehicle Activity

- Truck and Bus populations are based on:
  - Department of Motor Vehicles (DMV) Registration
  - International Registration Plan (IRP)

- Mileage accrual rates (VMT per vehicle) based on 2002 Vehicle Inventory and Use Survey

- Number of starts and soak time distribution
  - GPS and Telematics data collected through contracted studies

- Fleet turnover accounts for the impact of ARB’s in-use regulations such as:
  - 2014 Truck and Bus Rule
  - Statewide Drayage Truck
  - Solid Waste Collection Vehicles
  - Public Agencies and Utility (PAU)
Modeled NOx Emissions in 2031
2010+ Heavy Duty Diesel Trucks
(Above 33,000 lbs. GVWR)

- Running Emissions: 69%
- Start Emissions: 17%
- Idle Emissions: 14%

Source: EMFAC2014 v1.0.7
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Efforts to Improve HD Diesel Truck Emissions Modeling in EMFAC2017

- Dyno testing of late model HD trucks
- Truck & Bus Surveillance Program
- PEMS testing of late model HD trucks
- Contracted field studies (e.g., RSD, Tent study)
- Deterioration rates updates
  - Frequencies of tampering and mal-functions
  - Emission impact rates
- Collaborating with industry partners (e.g., Cummins Inc.)
- ARB/Cummins emission inventory workgroup
Low NOx Regulatory Support

- EMFAC model will be used to assess emission benefits associated with *Low NOx standards*.

- Similar to other ARB’s regulatory efforts, EMFAC model will be updated based on *latest available* data to support this regulation.

- Staff is currently seeking inputs related to available data sources on:
  - Low NOx diesel and CNG engines
  - Heavy duty truck emission deterioration
Contact Information

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