Portable Emission Measurement – U.S. EPA Perspective

1st Ever PEMS Conference
March 24, 2011

John Koupal
Director, Air Quality & Modeling Center
Assessment and Standards Division
EPA Office of Transportation & Air Quality
How PEMS is used at EPA

- **Compliance**
  - Field investigation
  - New in-use rules

- **Smartway**
  - Assessing new technologies

- **Emission Inventory Modeling**
  - MOVES
Key Milestones & Drivers

- "ROVER"
  - Patent No. 685946 filed in October 2000
- Technology advancements by industry
- PM Regulations
  - 40 CFR 1065 - linking lab to "real-world" operations
  - Harmonizing regulations with other countries
- In-Use Rules
  - HDIU standards established in 2007
    - Establishing "Not-to-Exceed" (NTE)
    - Multiple years of use by manufacturers
  - NRIU standards being proposed in 2011
- Development of MOVES
EPA PEMS Program Objectives

- Improved methods and techniques
  - How to use equipment in field, safety, SOPs, etc.
- Sample design and recruitment
  - Testing broader population of vehicles
  - Sampling population: RSD, random sampling, $, etc.
- Improved regulations for PEMS usage
  - (CFR 1065)
  - PM measurements
- Improved equipment
- Efficient deployment & data production
Motivation for PEMS in Modeling

- In “Modeling Mobile Source Emissions” (2000), National Research Council made several recommendations to EPA to improve modeling:
  - Support for smaller-scale (project level) analysis
  - Improved characterization of high emitters, heavy-duty vehicles and nonroad sources
  - Improved characterization of particulate matter and toxics
  - Improved model evaluation and uncertainty analysis
  - Improved ability to interface with other models

- These recommendations became the primary objectives for MOVES
What is MOVES2010?

- **Motor Vehicle Emission Simulator**
- EPA’s replacement for MOBILE
- Estimates total emissions & energy use from all on-road sources at national, local or project levels
- Official version released December 2009
  - Replaces MOBILE6.2 as EPA’s official car & truck emissions model for SIPs and conformity determinations
- Based on “modal” emissions
  - Allows finer scale (e.g., project level) modeling
  - No longer limited to data on specific test cycles - greatly broadens data sources to include lab, PEMS, I/M over any cycle
HC Emission Rates By Bin
Source Bin: LDV Gasoline / 1996 MY

- 0-3 year old
- 4-5 year old

VSP (KW/tonne)

HC Mean Emission Rate (g/hr)

< 25 mph
25 - 50 mph
> 50 mph
Distribution of Operating Time by Bin
Light-Duty Cars and Trucks

VSP (KW/tonne)

Fraction of Operating Time

< 25 mph 25 - 50 mph > 50 mph
Why We Like PEMS

- Supports modal emission rate development
- The real world is where the action is
  - Can measure emissions from real (not trace) driving
  - Grades, temperatures, A/C etc. etc.
- Labs are expensive – especially for engines
- They don’t have labs in Denver… Texas… many areas
- We can go to the vehicle – capture vehicle “in the wild”
Challenges with PEMS

- Inherent variability of real world conditions
- “Wild West”
  - Easier access to emission measurement
  - Many 1-2 vehicle test programs out there
  - Different focus, quality standards, methods
- Representing the entire fleet
- Separating emissions and activity
# Strengths and Weaknesses of Different Data Sources

<table>
<thead>
<tr>
<th></th>
<th>Lab</th>
<th>I/M</th>
<th>PEMS</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Emitters</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td></td>
</tr>
<tr>
<td>Fuel, Temperature Effects</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample Size</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td></td>
</tr>
<tr>
<td>Operating Range</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td></td>
</tr>
<tr>
<td>Deterioration Trends</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td>![Smiley Face]</td>
<td></td>
</tr>
</tbody>
</table>
Pollutants covered in MOVES

- **HC** (THC, NMHC, NMOG, TOG, VOC)
- **CO**
- **NO$_x$** (NO, NO$_2$)
- **NH$_3$**
- **SO$_2$**
- **PM$_{10,2.5}$** (OC, EC, sulfate, brake, tire)
- **GHG** (CO$_2$, CH$_4$, N$_2$O)
- **Toxics**
- **Energy** (total, petroleum, fossil)
Emissions Processes in MOVES

- Running
- Start
- Extended Idle ("hoteling")
- Evaporative
  - Permeation, Vapor Venting, Liquid Leaks
- Refueling
  - Vapor loss, Spillage
- Crankcase
- Tire Wear
- Brake Wear
Where does MOVES data come from?

- Depends on pollutant, process, vehicle class
- Historical EPA emission factor testing program
  - Conducted from 1970s through 1990s
- Inspection/Maintenance programs in U.S.
- EPA research studies
  - e.g., Kansas City Gas PM Study
- EPA compliance & in-use data
  - PEMS data used for HDD NOx/CO/HC data for MOVES; only use of PEMS in MOVES2010
- Industry/academic research programs
  - Many CRC programs used in MOVES
EPA PEMS Programs

- MOVES “Shootout” (2001)
- Kansas City LD PM program (2005)
- Diesel Construction “Pilot” program (2008)
- Houston HD “Drayage” program (2010)
- Evaporative Field Leak program (ongoing)
- Tier 2 LD program (ongoing)
The Challenge of Emission Factor Research

- Need very large samples to reflect the tail
  - If sampling fully at random
- RSD and I/M provide these samples, but are a limited snapshot of the total emissions
- PEMS provides on-road emissions, but sample sizes are limited
- Emerging “hybrid” approach:
  - Screen vehicles using RSD
  - Develop stratified samples based on RSD score
  - Test vehicles in each strata with PEMS for on-road emissions
  - Reweight PEMS results according to strata RSD weighting

- Enables much smaller sample sizes
Evaporative “Leaker” Field Study

- Evaporative vapor emissions either contained, or leaking

- Developing groundbreaking approach to quantifying frequency of evap leakers

- Developed method to find evap leakers using roadside remote sensing

- Verified using portable SHED – with PEMS as the analyzer!

Collaborators: CRC, ERG, Colorado
Houston Port HD Drayage Study

- ~ 4,000 RSD hits on 1,900 trucks entering port
- PEMS testing on sample of these, stratified by emission level

Collaborators: TCEQ, ERG, HGAC, PHA
### Developed Model Year and Nox Bins for Field Set and Desired Stratified Sample

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>1</td>
<td>11</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>1978-1993</td>
<td></td>
<td>8</td>
<td>23</td>
<td>69</td>
<td>20</td>
<td>2</td>
<td>122</td>
<td>494</td>
<td>1065</td>
<td>131</td>
<td>65</td>
</tr>
<tr>
<td>1994-1997</td>
<td></td>
<td>1</td>
<td>34</td>
<td>259</td>
<td>175</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998-2003</td>
<td></td>
<td>11</td>
<td>234</td>
<td>636</td>
<td>168</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004-2006</td>
<td></td>
<td>11</td>
<td>65</td>
<td>43</td>
<td>8</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007-2010</td>
<td></td>
<td>15</td>
<td>20</td>
<td>26</td>
<td>4</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Proportional

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>0.0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>1978-1993</td>
<td></td>
<td>0.1</td>
<td>0.4</td>
<td>1.2</td>
<td>0.3</td>
<td>0.0</td>
<td>2.1</td>
<td>8.4</td>
<td>18.2</td>
<td>2.2</td>
<td>1.1</td>
</tr>
<tr>
<td>1994-1997</td>
<td></td>
<td>0.0</td>
<td>0.6</td>
<td>4.4</td>
<td>3.0</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998-2003</td>
<td></td>
<td>0.2</td>
<td>4.0</td>
<td>10.8</td>
<td>2.9</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004-2006</td>
<td></td>
<td>0.2</td>
<td>1.1</td>
<td>0.7</td>
<td>0.1</td>
<td>0.1</td>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007-2010</td>
<td></td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.1</td>
<td>0.0</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Stratified

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1978-1993</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>1994-1997</td>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998-2003</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004-2006</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007-2010</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 1877
Summary

- PEMS has been a game changer for compliance and modeling activities
- EPA developed MOVES in anticipation of PEMS
- However, much work needed to make best use of the data PEMS provides
- EPA research focused on capturing in-use emission distribution, by capitalizing on strong points of RSD and PEMS
  - Cost effective, efficient, robust