Power Pack Testing at Environment Canada’s Testing Facilities
Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations

San Francisco, CA, USA
October 22, 2013
Outline

• Background

• Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations

• Collaborative Test Programs

• Questions
Background

- Canada has a policy of alignment with emission standards and test procedures of the U.S. Environmental Protection Agency (EPA) for the transportation sector.

- The policy of alignment is designed to recognize the highly integrated nature of the vehicle and engine industry in North America.

- Most vehicles and engines offered for sale in Canada are imported and most vehicles manufactured in Canada are exported to the U.S.:
  - Significant focus of compliance and enforcement activities is on importers.

- The Government of Canada is implementing the policy of alignment through initiatives such as the Regulatory Cooperation Council and the Canada-U.S.A. Air Quality Agreement.
HDV GHG Regulatory Initiative

• The Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations were published in Canada Gazette, Part II on March 13, 2013
  – Aligned with U.S. EPA standards and establish GHG emission standards for on-road heavy-duty vehicles and their engines for model years 2014 and later
  – Differences to recognize Canada unique considerations

• Through initiatives such as the Regulatory Cooperation Council and the Canada-U.S.A. Air Quality Agreement, the Government of Canada has been collaborating with the U.S. EPA
“The Government of Canada’s Department of the Environment (Environment Canada) assisted EPA’s development of this rulemaking by conducting emissions testing of heavy-duty vehicles at their test facilities to gather data on a range of possible test cycles, and to evaluate the impact of certain emissions reduction technologies. Environment Canada also facilitated the evaluation of heavy-duty vehicle aerodynamic properties at Canada’s National Research Council wind tunnel, and during coastdown testing.”

U.S. EPA and NHTSA Final Rule
Hybrid Collaborative Program with the U.S. EPA

- Environment Canada conducted and developed hybrid emissions testing at the River Road Test facility in Ottawa to gather data contributing to knowledge base for the development of heavy-duty vehicle GHG rules.

- Objective of the hybrid emissions testing:
  - compare hybrid vs. non-hybrid emission results
  - compare chassis to engine dynamometer testing
  - compare lab-to-lab emission data

- The hybrid emissions testing fed into the U.S. EPA GHG rulemaking:
  - provided data for lab-to-lab validation
  - informed future decisions regarding heavy-duty hybrid test procedures
Hybrid Emissions Testing

• Engine with hybrid power pack and whole vehicle chassis testing were both done with the hybrid system active and inactive
  – Chassis dynamometer:
    ▪ Hybrid class 7 truck
  – Engine dynamometer:
    ▪ Power pack specifications were the same as the vehicle, except for certain simulated vehicle related parameters
    ▪ The engine data was translated into vehicle data for comparison

• Cycles used
  – Steady state 55 mph and 65 mph
  – EPA GHG transient
  – CILCC
  – WCHC
  – Vehicle FTP

• Emissions measured: CO, CO₂, NOₓ, NO, CH₄, THC, PM
Power Pack Testing Details

Schematic of the Heavy-Duty Test Cell #1
Power Pack Testing Setup

- 500HP DC motor
- 2200rpm max speed
- Trunnion mounted
- Load cell torque measurement.
- 5000 pulses per revolution rpm measurement
- Regenerative drive

Dynamometer
## Power Pack Testing Instrumentation

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>Analysis Method</th>
<th>Instrument</th>
<th>Sample Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>Non-Dispersive Infrared Detection (NDIR)</td>
<td>HORIBA Model AIA-210 LE</td>
<td>Continuous Collection</td>
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<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>Non-Dispersive Infrared Detection (NDIR)</td>
<td>HORIBA Model OPE-115</td>
<td>Continuous Collection</td>
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<td>Oxides of Nitrogen (NOₓ)</td>
<td>Heated Chemiluminescence Detection</td>
<td>California Analytical Instruments Model 400-HCLD</td>
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<tr>
<td>Nitric Oxide (NO)</td>
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<td>California Analytical Instruments Model 400-HCLD</td>
<td>Continuous Collection</td>
</tr>
<tr>
<td>Total Hydrocarbons (THC)</td>
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<td>California Analytical Instruments Model 300M-HFID</td>
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<tr>
<td>Particulate Matter (PM)</td>
<td>Gravimetric Procedure</td>
<td>Sartorius M5P-00V001</td>
<td>70mm Emfab Filters</td>
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<tr>
<td>Particulate Matter (PM)</td>
<td>Gravimetric Procedure</td>
<td>1065-CFR Standard Sampling Cabinet</td>
<td>47mm Teflon Filters</td>
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</table>
Challenges

• Physical and system limitations
• Control system: updated engine dynamometer to accommodate power train testing
• Complexity of the system:
  – Wiring
  – CANBus Signals
  – Automated clutch and manual transmission, and regenerative electric motor system
• Simulating chassis testing on an engine dynamometer updated to do power train testing (simulating driver and vehicle)
• Signal simulation (parking brake, braking, etc.)
• Required involvement of the manufacturer
• Active regeneration
• Additional software requirements (J1939, Eaton’s Service Ranger)
CO₂ Results
Summary of the CO₂ Results

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Cycles</th>
<th>EPA vs. EC Powertrain</th>
<th>EPA Powertrain vs. Chassis</th>
<th>EC Powertrain vs. Chassis</th>
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</thead>
<tbody>
<tr>
<td>Active</td>
<td>55 mph</td>
<td>14.7%</td>
<td>-2.6%</td>
<td>12.4%</td>
</tr>
<tr>
<td></td>
<td>65 mph</td>
<td>9.3%</td>
<td>6.7%</td>
<td>15.4%</td>
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<tr>
<td></td>
<td>EPA GHG</td>
<td>2.8%</td>
<td>6.5%</td>
<td>9.0%</td>
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<tr>
<td></td>
<td>CILCC</td>
<td>-1.8%</td>
<td>3.9%</td>
<td>2.2%</td>
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<tr>
<td>Inactive</td>
<td>55 mph</td>
<td>15.5%</td>
<td>-0.6%</td>
<td>15.0%</td>
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<tr>
<td></td>
<td>65 mph</td>
<td>12.1%</td>
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<td>16.3%</td>
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<tr>
<td></td>
<td>EPA GHG</td>
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<td>4.6%</td>
<td>1.4%</td>
</tr>
<tr>
<td></td>
<td>CILCC</td>
<td>-0.6%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Some of the conclusions from the CO₂ results:

- CO₂ powertrain results for the transient cycles compare very well between labs.
- The difference in CO₂ emissions for the steady-state cycles can be explained by the final drive ratio being different between the two labs.
- Offset between powertrain and chassis dyno results are likely due to the lack of accessory loads, cooling system and wheel slip.
Future Plans – Continued
Collaboration for Phase 2

• Environment Canada is continuing to collaborate with the U.S. EPA to support the development of more stringent standards for post-2018 model year heavy-duty vehicles
  – Additional aerodynamic research, emissions testing and tire testing are underway to support the second phase of the U.S. rulemaking

“We expect the technical collaboration with Environment Canada to continue as we implement testing and compliance verification procedures for this rulemaking. We may also begin to develop a knowledge base enabling improvement upon this regulatory framework for model years beyond 2018 (for example, improvements to the means of demonstrating compliance). We also expect to continue our collaboration with Environment Canada on compliance issues.”

U.S. EPA and NHTSA Final Rule
Questions?

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