Electric Vehicle Battery Durability Testing and Evaluation

Status Update and Work-Planning for the 24th UN ECE EVE IWG Meeting
October, 2017

ecoTECHNOLOGY for Vehicles Program
Transport Canada
Transport Canada’s ecoTECHNOLOGY for Vehicles (eTV) Program

- eTV tests, evaluates and provides expert technical information on advanced light-duty vehicle (LDV) and heavy-duty vehicle (HDV) technologies that are available or anticipated to be available in the Canadian market over the next 10-15 years.

- eTV program testing and evaluation results:
  - guide the proactive development of codes, standards, and regulations;
  - support the development of non-regulatory industry codes and standards that anchor industry efforts to integrate new vehicle technologies.

- eTV testing priorities are focussed on addressing knowledge gaps, particularly where new innovations have potential environmental or safety implications.

- Current eTV LDV projects deal with a range of technologies such as electric vehicles, advanced aerodynamic devices, low rolling resistance tires, advanced ICEs, alternative fuels, and hydrogen fuel cell vehicles.
Overview

- Electric Vehicle Testing – Status Update
- Plug-in Hybrid Vehicle Testing – Previous and Future Work
- Battery Testing – Status Update
- eTV Program Work-Planning - Beginning new 3-year project cycle (2018-2021)
  - Opportunity to propose new projects or continuation of work
On-Going Electric Vehicle Testing

• **Overview**
  
  • Two 2015 EVs accumulating mileage in Ottawa, Canada up to 100,000 km
  • Dynamometer testing at 15,000 km intervals
  • On-road CAN bus monitoring
  • BEV1 charged using 50 kW DC fast charge
  • BEV2 charged using 7.2 kW AC Level II
  • 65,000 km accumulated

• **Preliminary Results**
  
  • Full Recharge Energy (FRE) decreased by 6.2% (BEV2) and 9% (BEV1)
  • Usable Battery Energy (UBE) decreased by 6.8% (BEV2) and 10% (BEV1)
  • Driving range decreased by 7% (BEV2) and 11% (BEV1)
  • Interim results presented at EVS-30
  • Sharing data with EU-commission JRC
PHEV Testing

- Project Partners: Environment and Climate Change Canada / Natural Resources Canada
- Available resources/results from previous work:
  - 2012 PHEV x 3 (some baseline compliance-type testing)
  - Fleet vehicles in Ottawa with CAN bus data logging since 2013
  - One vehicle has on-road PEMS testing between 7,500 km and 8,000 km
- Goal: Add higher mileage test points

<table>
<thead>
<tr>
<th></th>
<th>Air Pollutants</th>
<th>CO₂</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEV</td>
<td>?</td>
<td>?</td>
<td>N/A</td>
</tr>
<tr>
<td>PHEV</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>PEV</td>
<td>N/A</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
PHEV Testing

- Dynamometer testing (SAE J1711) at higher mileages
  - Study changes in all-electric range, charge depleting range, air pollutants, greenhouse gas emissions
- Addition of high mileage vehicles in 2018
  - 2012 PHEV x 2 with ~150,000km (used vehicles, no activity data available)
- Results available in spring 2018

Draft Test Matrix (odometer reading - km)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Lab Testing 1 Complete</th>
<th>On-Road Testing Complete</th>
<th>Lab Testing 2 Analysis in-progress</th>
<th>Lab Testing 3 Winter 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHEV1</td>
<td>3,500</td>
<td>8,000 (PEMS)</td>
<td>22,000</td>
<td>TBD</td>
</tr>
<tr>
<td>PHEV2</td>
<td>N/A</td>
<td>18,000</td>
<td>48,000</td>
<td>~60,000</td>
</tr>
<tr>
<td>PHEV3</td>
<td>N/A</td>
<td>N/A</td>
<td>44,000</td>
<td>~80,000</td>
</tr>
<tr>
<td>PHEV4</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>~150,000</td>
</tr>
<tr>
<td>PHEV5</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>~150,000</td>
</tr>
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</table>
On-going Work – Battery Testing Methods

- Project Partners: Environment and Climate Change Canada / National Research Council of Canada (technical lead)
- Investigate the durability of EV batteries at low temperatures using standard and High Precision techniques
- Standard Battery cycling using high precision low temperature units on “fresh” and high mileage accumulated EV cells
- Investigation of the use of High Precision Cycling (HPC) to test EV battery cell durability.
  - Comparison of HPC to standard battery cycling methods
  - Use of HPC to determine if durability of a cell can be determined on a shorter timeline than traditional battery testing protocols
  - Use of HPC with high precision thermal testing system for controlled temperature experiments
  - Comparison of HPC results on “fresh” and high mileage accumulated EV cells
On-going Work – Battery Testing Methods

- Access to a variety of EV battery cells, leveraging crashed vehicles (no visible signs of compromised RESS) from Transport Canada
- Rate mapping at four temperatures (-15, -5, 5, 15°C) and voltages (4.0, 4.1, 4.2, 4.3V) to determine operational range.
- Long term durability testing on standard battery chargers at two temperatures
- Investigate use of HPC with large format EV cells + high precision thermal management
- Comparison of results from HPC and standard cycling
- Report expected in Spring 2018

Test Matrix for 2017-18, subject to change depending on availability

<table>
<thead>
<tr>
<th>Cell</th>
<th>Vehicle</th>
<th>MY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prismatic</td>
<td>Toyota Prius PHEV</td>
<td>2012</td>
</tr>
<tr>
<td>Pouch</td>
<td>GM Volt</td>
<td>2013 (&quot;fresh&quot; and &quot;high mileage&quot;)</td>
</tr>
<tr>
<td>Pouch</td>
<td>Nissan Leaf</td>
<td>2014 (&quot;fresh&quot; and &quot;high mileage&quot;)</td>
</tr>
<tr>
<td>18650, various capacities and manufacturers</td>
<td>Not EV cells</td>
<td>N/A</td>
</tr>
</tbody>
</table>
On-going Work – High Precision Cycling

Lifetime prediction of cells that show only drastic failure

Lifetime prediction of cells that show gradual capacity loss

High Precision Thermal Testing For 18650s

**eTV Work Plan Development**

**eTV Work Plan Development Process:**

- **eTV DG Steering Committee** establishes initial drivers and broad **priority areas** for further development.

- A series of **eTV Working Group** (LDV & HDV) and **bilateral meetings** are conducted with program partners to develop a **detailed project Work Plan** based on the identified priority areas.

- These meetings also help identify **knowledge gaps** and interdepartmental **opportunities for collaboration**.

- A collection of proposed projects and areas of focus for 2018-21 will then be **tabled for approval by the DG Steering Committee** as **eTV Work Plan 2018-21**.

**Proposed Thematic Priorities for 2018-21:**

**eTV DG Steering Committee identified 5 thematic priorities to guide Work Plan 2018-21 development:**

- **Off Road Sector Pollutants**
- **Green Transit**
- **Emerging LDV Technologies**
- **Emerging HDV Technologies**
- **Connectivity and Automation**
Towards eTV Work Plan 2018-21

• There is an opportunity to propose projects to support the UN ECE EVE IWG, with projects starting in April 2018.

• Are there remaining knowledge gaps that could be addressed with testing and evaluation?

• Are there specific emerging technologies and vehicles that should be on eTV’s radar for testing and evaluation?
MERCI / THANK YOU

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PHEV Testing

- How battery durability could affect emissions on J1711 utility weighted calculation:

\[ Y_{UFW} = \sum_{i=1}^{lastCDcycle} \left[ UF(i \times D_{cycle}) - UF((i-1) \times D_{cycle}) \right] \times Y_{Cd_i} + \left[ 1 - UF(R_{CDC}) \right] \times Y_{CST} \]

- \( Y_{UFW} \) = Utility Factor weighted exhaust emissions of a particular measured gas, in grams/mile
- \( UF(x) \) = Appropriate Utility Factor fraction at a given distance “x” (see Appendix A)
- \( Y_{Cd_i} \) = Mass emissions for the "i"th test in the FCT of a particular measured gas, in grams/mile
- \( Y_{CST} \) = Weighted mass emissions for the CST of a particular measured gas, in grams/mile as calculated in Equation 31
- \( D_{cycle} \) = Distance in miles of a single drive schedule (NOTE: not actual driven distance)