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.

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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

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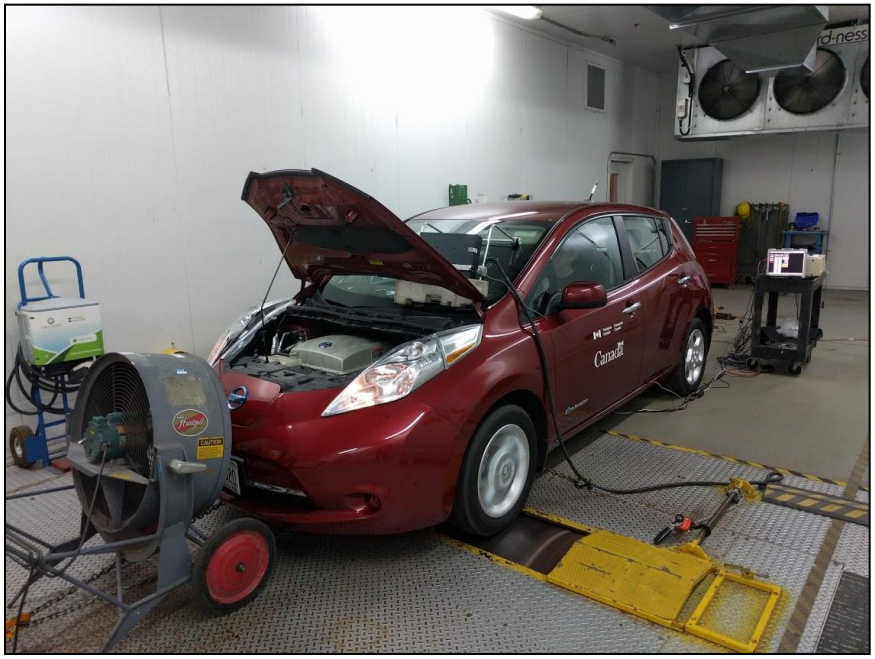
On-Going Electric Vehicle Testing

- **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

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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

Draft Matrix of Environmental Goals and Vehicle Types (EVE - 22)

	Air Pollutants	CO_2	Range
HEV	?	?	N/A
PHEV	?	?	?
PEV	N/A	?	?

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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)

Vehicle	Lab Testing 1 Complete	On-Road Testing Complete	Lab Testing 2 Analysis in-progress	Lab Testing 3 Winter 2018
PHEV1	3,500	8,000 (PEMS)	22,000	TBD
PHEV2	N/A	18,000	48,000	~60,000
PHEV3	N/A	N/A	44,000	~80,000
PHEV4	N/A	N/A	N/A	~150,000
PHEV5	N/A	N/A	N/A	~150,000

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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

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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

Cell	Vehicle	MY
Prismatic	Toyota Prius PHEV	2012
Pouch	GM Volt	2013 (“fresh” and “high mileage”)
Pouch	Nissan Leaf	2014 (“fresh” and “high mileage”)
18650, various capacities and manufacturers	Not EV cells	N/A

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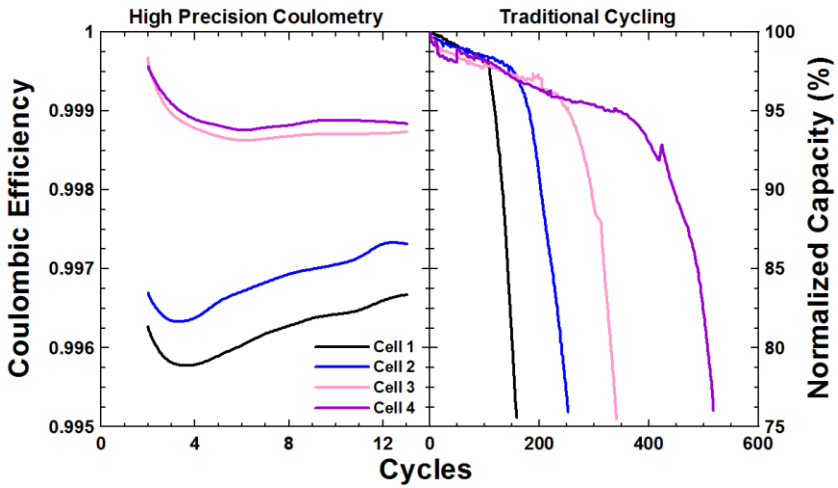
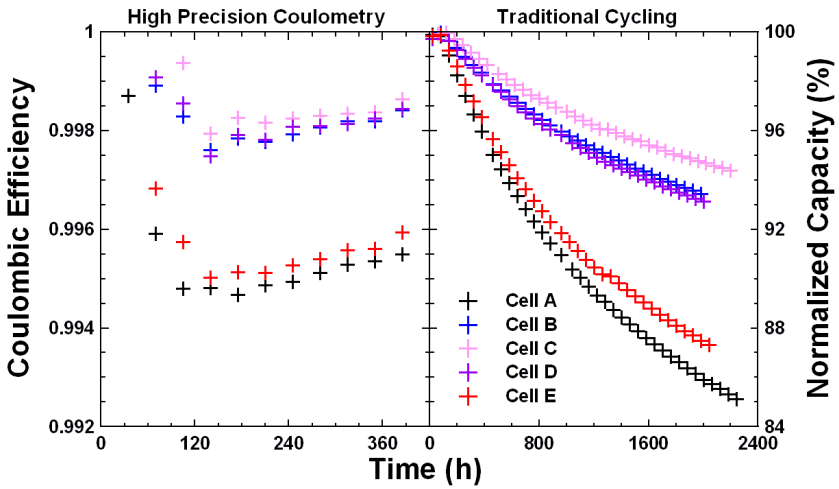
On-going Work – High Precision Cycling

High Precision Thermal Testing
For 18650s



Lifetime prediction of cells that show only drastic failure



Lifetime prediction of cells that show gradual capacity loss

From Burns *et. al.* J. Electrochem. Soc. **160**, A1451 (2013).

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eTV Work Plan 2018-21 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 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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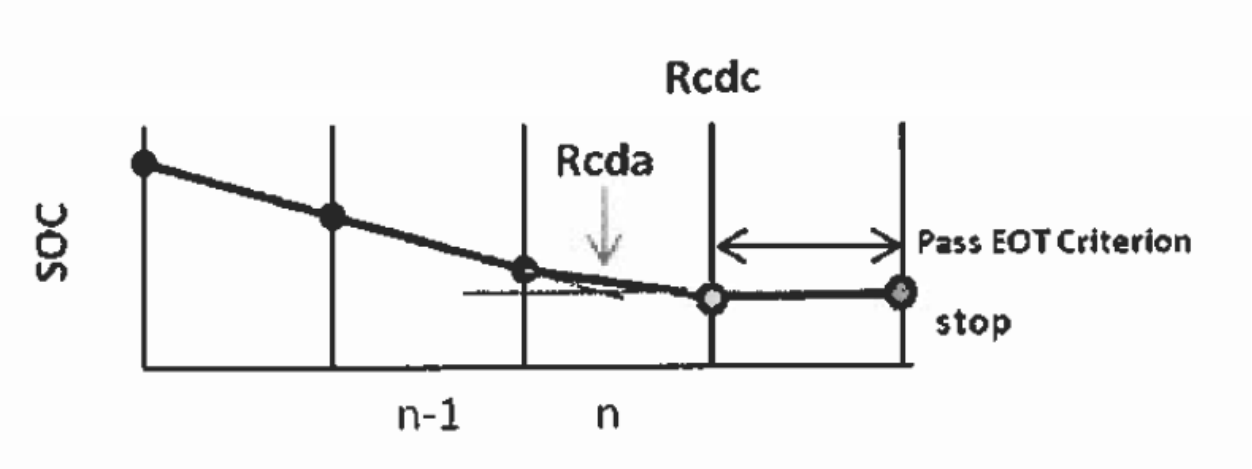
PHEV Testing

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



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

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_{CDi}	=	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)

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