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Winter Happens!

Understanding and improving electric vehicle operation in cold weather

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RED RIVER COLLEGE OF APPLIED ARTS, SCIENCE AND TECHNOLOGY

A DECADE OF APPLIED RESEARCH 2004-2014

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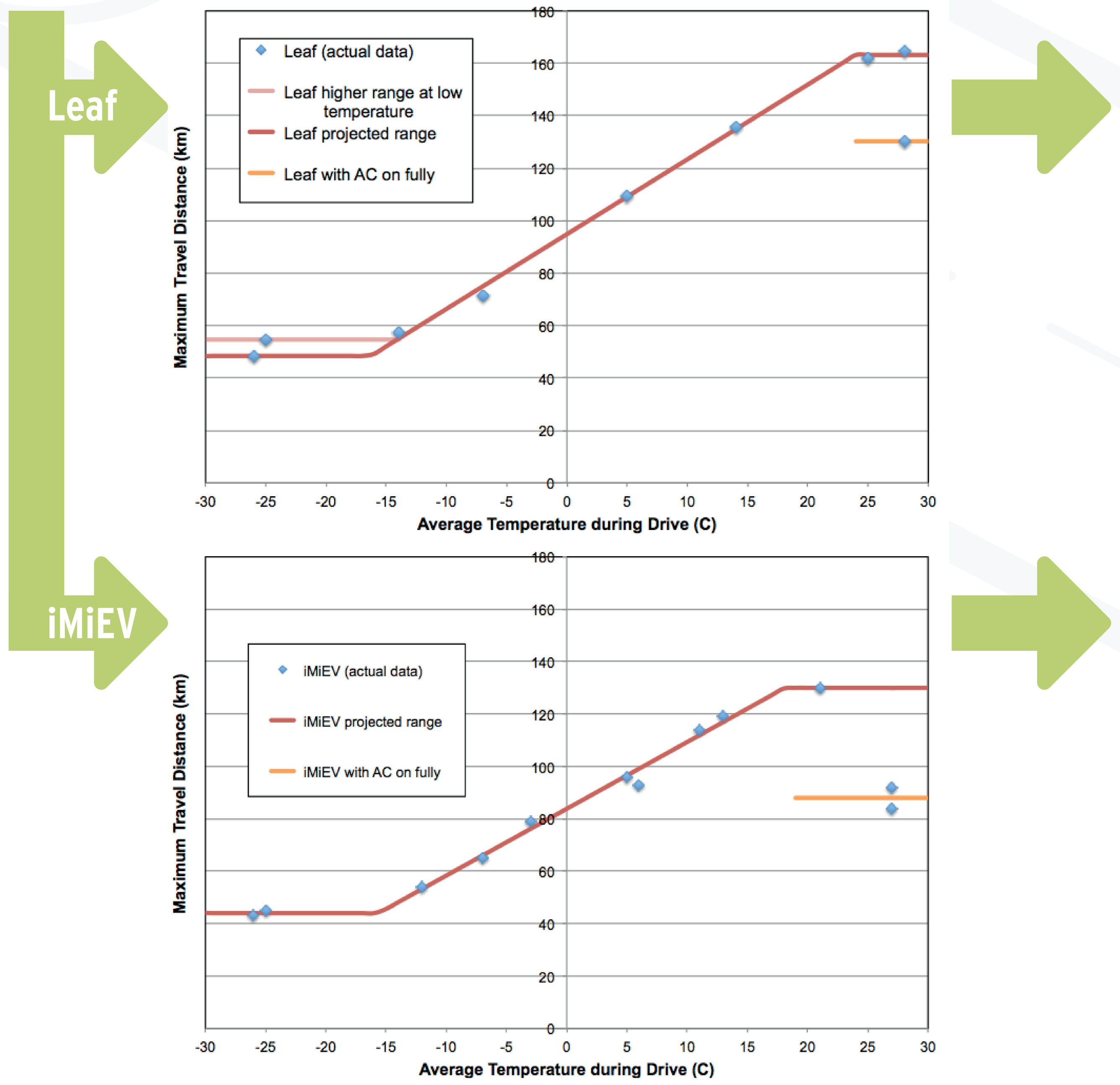
Drive-to-Depletion Test Method

Drive-to-Depletion involved driving until battery was fully depleted and recording distance. Tests involved: two North American version 2012 model Mitsubishi iMiEV, and one 2012 model Nissan Leaf, both models all-electric (BEV). The same driver in all tests travelled using D-mode only in the Winnipeg urban area at net speeds in the range of 35 to 40 km per h. Sufficient heating was used to maintain comfort, but with no AC except in deliberate tests. Temperatures in all cases were referenced to Richardson International Airport (close to RRC), based on the time period of the drive. Selected conditions were at increments of roughly 10ºC across the ambient range.



Abstract

Cold weather operation is a topical issue in Canada for electric vehicles, as well as for other alternative fuel vehicles. Gaining a better understanding and improving cold weather operation will be important to accelerate adoption of electric vehicles across the country.

Part of the technical rationale for the set-up of the Electric Vehicle Technology & Education Centre (EVTEC) at Red River College (RRC) was specifically to understand and help address cold weather operational issues. Cold weather has obvious detrimental impacts on vehicle range, leading to "winter range" anxiety concerns, but the nature of impacts have not been well understood, particularly from the practical perspective of the driver. The effects of ambient operating temperature on all-electric vehicle range have been under systematic evaluation over the past two years for both the Nissan Leaf and Mitsubishi iMiEV, and results will be presented. Additional impacts will also be discussed, as well as a number of strategies to address cold-weather operations.

Drive-to-Depletion Results

Driving to depletion is obvious, but novel, given it is not done frequently. More often, travel estimates combine the distance traveled by the vehicle with the indicated remaining range. As discovered in testing, range indicators for electric vehicles are notoriously unreliable.

Travel data for both models formed the shape of a logistical or "S" curve. Rather than using a sophisticated mathematical model, for simplicity, curves were approximated using three distinct linear sections:

Maximum Range Plateau: At warm temperatures, the Leaf reached about 163 km and the iMiEV about 130 km, consistent with manufacture suggestions. Distance was determined primarily by battery capacity, and not affected by temperature, as long as AC not used.

Middle Linear Section: In the middle section, travel distances for both vehicles were extremely linear relative to operating temperature:

Vehicle	Slope	Intercept (at 0ºC)	r2
Leaf	3.0 km/ºC	95 km	0.99
iMiEV	2.5 km/ºC	84 km	0.98

Minimum Range Plateau(s): At the lower left of the curve, under the coldest operating temperatures, the vehicles reached minimum travel distance, represented by flat plateau(s). This makes sense. Vehicles have limited on-board heater capabilities. Once systems are fully on (main heater, seat heater, rear defogger, steering wheel heater), the vehicle cannot produce additional heat. Driving at lower and lower temperatures depends more on driver tolerance and prioritizing of heating loads (usually windscreen defogging/defrosting as top priority). Minimum travel distances were 48 to 55 km for the Leaf and 44 km for the iMiEV.

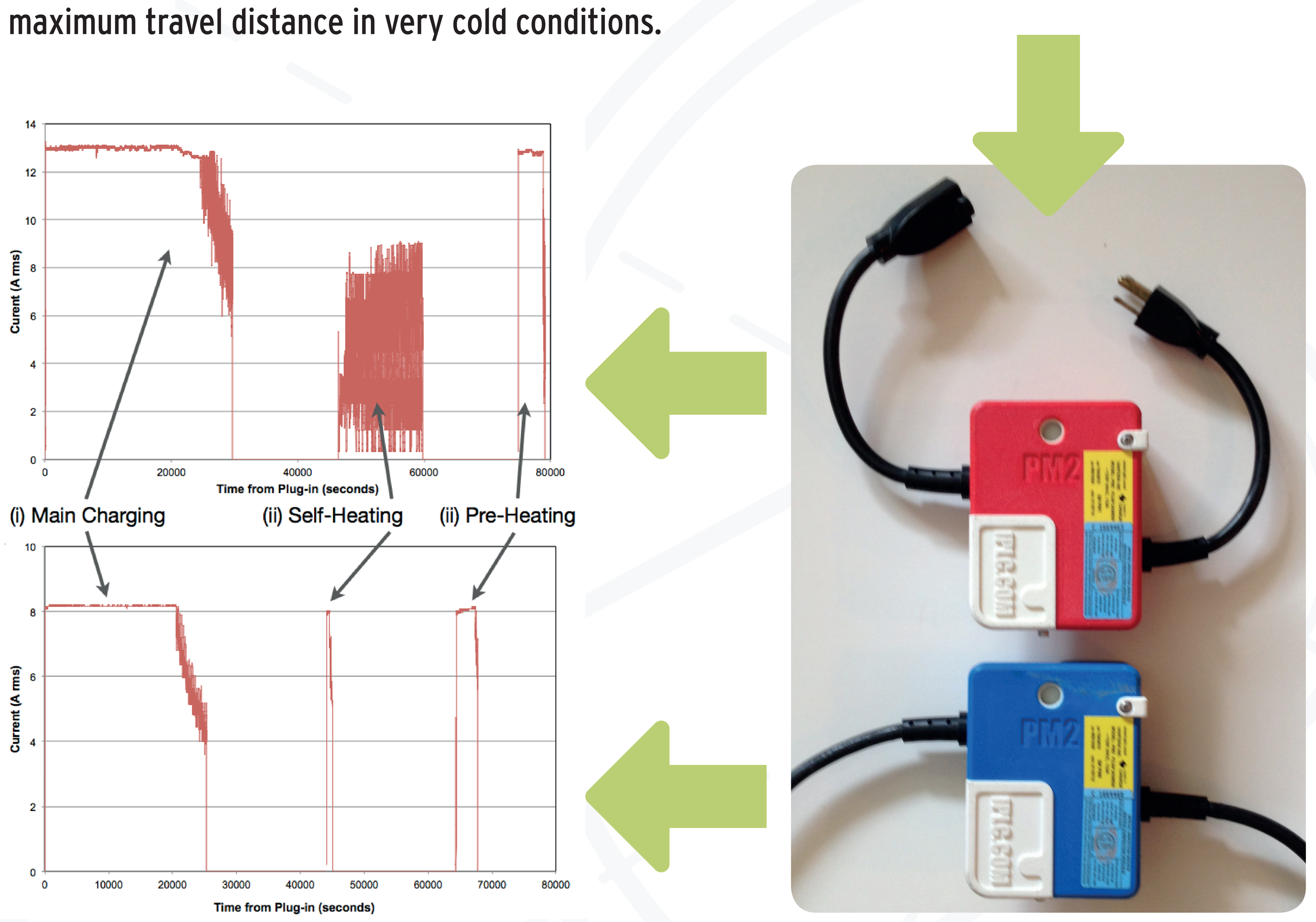
Charge-Monitoring Method

Through winter operation, the charging of vehicles was primarily done at-home, using readily available Level 1 outlets. Monitoring of Level 1 charging was undertaken using the IPLC PM2 meter manufactured by Vantera Inc., and illustrated in the photograph below.

Charge-Monitoring Results

Three types of charging activities were observed using the IPLC PM2 meter, as illustrated in plots below for the two vehicles: (i) Main charging events, which were consistent for each type of vehicle, each showing characteristic curves; (ii) Internal battery-heating events, which drew energy from the grid as part of battery self-conditioning at low temperatures; and (iii) Deliberate preheating events, whereby the driver turned on the climate controls for the vehicle in advance to pre-warm prior to driving.

The iMiEV employs an overall simpler battery control arrangement in that battery self-checks and self-heating event would occur at regular time intervals. The Leaf employs a more sophisticated battery control arrangement, in that battery self-heating would only occur when necessary, but irregularly from the driver's perspective. Further self-heating events for the Leaf might not recharge the vehicle back to full state of charge (SOC), even though ample time was available. This led to the observation of reduced SOC, in turn resulting in potentially reduced maximum travel distance in very cold conditions.



Next Steps:

Further cold weather related testing of electric vehicles is continuing at Red River College.

Detailed results of this work are intended to be published in peer-reviewed literature.

Acknowledgements:

Funding for EVTEC was provided by the Government of Manitoba.

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