Submitted by the EVE Secretariat

Informal Document EVE-28-01e
(27^{th} session: October 16^{th}-17^{th}, 2018)

Report of the 28th Session of the
Electric Vehicles and the Environment Informal Working Group (EVE IWG)

Location:	Ottawa, ON
Time / Date:	9h00-17h30 October 16^{th}-17th, 2018
Chair:	Mr. Michael Olechiw (USA)
Vice-Chairs:	Mr. Tetsuya Niikuni [Not Present]
	Ms. Chen Chunmei (China) [Not Present]
Secretary:	Mr. Andrew Giallonardo (Canada)

1. Welcome, introductions (Agenda item 1)

Mr. Mike Olechiw the chair of the EVE IWG thanked the members for their attendance and welcomed everyone to Ottawa. There were roughly 20 participants in the room and on the phone.

The EVE IWG reviewed the meeting agenda and made a few changes to the schedule (document EVE-28-02-Rev4e). Two goals of the meeting reflected in the agenda, focused on the topics of in-vehicle battery and system power determination.

In lieu of requirements for the 29^{th} EVE meeting in Geneva, the goal for in-vehicle battery durability was to outline a report and the group's consensus positions on the topic's importance and to determine recommended paths forward. Following preliminary validation testing that is supporting the groups work on a power determination Global Technical Regulation (GTR), the goal for the work on power determination was to discuss current test results, provide an update on the ISO test procedure with respect to the GTR draft and to work on overall drafting of the GTR.

2. Report of 27^{th} EVE meeting report (Agenda item 2)

Mr. Andrew Giallonardo reviewed the report (EVE-27-15e) from the 27^{th} EVE meeting held in Geneva, Switzerland in June 2018. Mr. Giallonardo quickly reviewed the major outcomes of the meeting and indicated that the EVE IWG would accept comments on the report for the next 30 days. Members are encouraged to review the report and provide feedback.

3. Updates from WLTP (Agenda item 3)

Mr. Matthias Nägeli provided an update on the activities of the WLTP IWG. His presentation (EVE-28-10e) reported on the topics discussed at the last IWG WLTP meeting in Tokyo, Japan. These topics concerned the adoption of amendment #5 and the drafting deadline of its working document. The presentation also reported on the vehicle M concept for pure ICE vehicles, REESS voltage measurement, drive trace index for EVs, REESS charging definition, fuel cell vehicles, the amendment of Annex 8 post processing, low temperature for EVs and durability concerning WLTP topics that affect electrified vehicles.

The vehicle M concept for pure ICE vehicles, which is in the WLTP interpolation method, includes a concept that allows the extension of the interpolation range of pure ICE vehicles from 30 to 40g/km CO2. A concept in the context of (N)OVC-HEVs where the interpolation range can be extended from 20 to 30 g/km of CO2 (charge-sustaining), is already in place for electrified vehicles. WLTP updated that the text on electrified vehicles needs to be aligned with the newly amended text of the pure ICE vehicles which is part of amendment #5 of GTR No. 15[1].

On REESS voltage measurement, SG EV and IWG WLTP concluded and approved of a solution to the application of instantaneous voltage leading to unjustified CO2 benefits for the manufacturer when applying REESS balance correction. The unjustified CO2 benefit effect was based on joule heat losses, which are dependent on non-linear battery parameters. The solution and outcome of WLTP's discussion on this was allow only a fixed voltage in the context of RCB correction. The Subgroup EV agreed to use nominal voltage as the fixed voltage since it is in use in another location in the GTR-Annex of electrified vehicles. EVE IWG members also discussed the relation of instantaneous voltage with heat losses and CO2 values and their resulting benefits. Mr. Mike Safoutin asked why the EVE IWG chose instantaneous voltage in the beginning. Mr. Nägeli responded that the group wanted to give options to manufacturers and that it is easier to take the nominal value.

WLTP and SG EV concluded and approved that it was necessary to update the current text to make it clear how EVs should be treated in the case of the drive trace index. This was required as it was not clear in the current application of drive trace indices in RMSSEE and IWR required by GTR 15.

[1] www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/grpedoc_2019.html

4. Presentation on EV battery cell testing from Dean Macneil (Agenda Item 4)

Mr. Dean Macneil from the National Research Council in Ottawa presented ongoing research on battery durability cell testing in collaboration with Transport Canada and Environment and Climate Change Canada. The research focused on the durability of the battery cells when exposed to low and high temperatures. Most of the research focused on low temperatures, as there was more concern with EV operation in extended low temperature operations. Details of this research looked at what affects battery lifetime and the effects of cold or hot weather, fast charging, thermal management, cell construction and material choice.

Previous work on the cells focused primarily on 18650 battery cells due to safety concerns. The current work focuses more on EV cells that have higher capacities and lifetimes. Transport Canada provided two PHEV vehicle batteries with high mileage for the tests. A PEV was also provided for testing.

Mr. Macneil highlighted some difficulties of working with EV cells for low temperature testing. These included the nature of the EV batteries which absorb and give off heat and affect the stability of the temperature in the environment for testing and the safety concerns of extended testing at low temperatures. These concerns required specialized chambers to perform accurate testing.

Areas of research that were analyzed for the tests included analysis of rate performance through monitoring of voltage with normalized discharge of cells and analysis of battery lifetime through normalized discharge capacities vs cycle number parameters. One of the PHEVs showed very good rate capability but the PEV and the other PHEV were not doing as well on rate capabilities.

High precision cycling was used to predict lifetime and durability. However, this method was only able to estimate durability in shorter timeframes due to its slow cycling rates. It also required very stable temperatures and low cycling rates. The high precision cycling method looked at coulombic efficiency vs cycle number to reflect the life cycle. Despite high mileage cells, the cells still indicated 99.7% to 99.75% efficiency.

An analysis of various cell chemistries was also conducted which show various electrolytic compositions of battery types. The capacities of these electrolytes were found to vary with temperature and it was apparent that the electrolytes did have an effect on the durability of the batteries in various temperature conditions.

EVE IWG members showed a lot of interest in the research that was conducted, particularly on the effect of electrolyte compositions on in-vehicle battery durability.

Ms. Annika Ahlberg-Tidblad noted how manufacturers when talking to their battery suppliers can present different application profiles with the same cell but obtain different lifetime estimations in different applications. She asked Mr. Macneil how he expects the issue of different lifetime estimations with different application profiles to be addressed.

Mr. Macneil responded that the high precision work is more of an indication and that some manufacturers place a lot of power in the electrolyte formulations. Given a fundamental baseline, if manufacturers know which electrolyte formulation works better in which application then if given a fundamental baseline and if manufacturers perform high precision work slowly they can assess how good it could be for the battery. He noted that it is a growing area of research.

Mr. Macneil also noted that it is not an easy subject as a lot of the durability is left to the thermal management imposed by the manufacturers and that some of the systems are over designed but it may mean that the batteries last a long time. However, if manufacturers decide to cut costs then the quality of the thermal management systems would affect the durability.

Ms. Ahlberg-Tidblad asked Mr. Macneil what can be expected from consumer cells from performance. They both agreed that EV cells are at the top in terms of performance.

Mr. Macneil noted that the energy efficiency of battery cells is hard to find in other products but that the target of a durability requirement could come down to the needs in different markets when dealing with cell components that are optimized to a particular performance. He noted that it would be hard to change or improve that more. The biggest thing that manufacturers can do is deal with state of charge and temperature management to prolong battery life.

5. Presentation on EV mileage, accumulation and charging from Aaron Loiselle (Agenda items 5)

Mr. Aaron Loiselle and Mr. Kieran Humphries presented a project on the impacts of mileage accumulation and fast charging on EV range and energy that the Emissions Research and Measurement Section at Environment and Climate Change Canada is pursuing. The project work aids in answering some questions on how mileage accumulation, vehicle aging and fast charging can affect the useable battery energy, full recharge energy and energy consumption on a battery electric vehicle. The project work is ongoing and expected to conclude in early 2019.

The project tested two identical battery electric vehicle models by accumulating mileage on the vehicles on prescribed test routes. Chassis dynamometer testing through the SAE J1634 method was conducted every 15,000 km up to odometer readings of 105,000 km. Tests also looked at how fast charging affected the vehicles. Parameters and data used to analyse the impacts of mileage accumulation and fast charging included measurements of temperature, energy consumption, battery energy levels and accumulated mileage as well as calculated range values.

The energy consumption levels were compared with DC fast charging and AC level 2 charging between the two test vehicles. Energy levels were measured at different times of the year as the vehicles accumulated mileage. It was found that there was a natural spread in the energy consumption of both battery electric vehicles at different temperatures. The vehicle with the battery charged using DC fasting charging was found to use slightly higher levels of energy consumption than the vehicle charged with level 2 AC charging. After 78,000 km of mileage was accumulated, it was found that the battery aging and degradation did not impact the energy consumption of the battery electric vehicles in the test.

The energy metric analysis of the vehicles looked at the trends in useable battery energy measured as direct current and full recharge energy from the grid shown as both alternating current and direct current vs the vehicle mileage accumulated. The results are preliminary but show general trends of decreasing energy levels as the vehicles reach higher levels of accumulation.

After 78,000 km of mileage accumulation on the vehicles, the range was found to decrease in the vehicles. This decreased range indicated that energy consumption values would have increased in the testing rounds where more energy would be required to travel the same distance. Analysis of the reduced range for one of the BEVs was found to be due to a decrease in the efficiency of energy transfer from the battery to the wheels of the vehicle while the other BEV reduced range was more attributed to the proportional decrease in the useable battery energy.

Mr. Loiselle noted the work of the of the Technology and Mobility Assessment platform of the Joint Research Centre in Italy whose work combined two models that account for calendar ageing and cycle fade effects on lithium based batteries. He mentioned that the specifications of this project's test BEV were used as an input into the TEMA model and the results from mileage accumulation project had good correlation and agreement with the TEMA model results.

Ms. Martha Christenson, from Transport Canada who is also involved in the accumulation project, also noted that they are launching a taxi project next spring to demonstrate electric taxi fleet in Ottawa along with the associated infrastructure. They are currently working out details for the project and conducting analysis onf where to place charging infrastructure and establishing taxi shift use with vehicle charge. They will also conduct lab assessments of the vehicles.

6. Review of updated ISO document (Agenda item 6)

Mr. Mike Safoutin briefly went through some changes in the updated version of the ISO procedure. He noted that the drafting group will need to go through the final version of the ISO document and to ensure that the version is reflected in the GTR document appropriately.

It appeared that there were only minor changes between the draft ISO and the final ISO version. It appeared that there were some small changes to align more with WLTP. The EVE IWG drafting group on power determination looked at these details more closely in the drafting session that was schedule for the 3rd day of the meeting.

7. OICA accelerated ageing test method (Agenda Item 7)

Ms. Ahlberg-Tidblad made a brief presentation (EVE-28-16e) on accelerated ageing test method. She noted four main types of battery performance degradation, which are capacity fade, power fade, irreversible swelling and power efficiency fade. The operating conditions that affect the battery ageing were also noted as the discharge rate, the charge rate, the State of Charge window of battery operation, battery temperature in operation and idle time..

In current battery ageing practices, there involves two parameters in two cell/battery degradation. These are charge and discharge cycles and calendar ageing. Accelerated ageing processes can be achieved by cycling the batteries at higher current loads to short the time of electrical throughput, by increasing the state of charge window and by increasing the temperatures. Ms. Ahlberg-Tidblad showed the EVE IWG group data some literature examples of ageing mechanism research. The examples showed were on the dependence of battery duty cycle and temperature and the dependent of charge current and SOC window.

Ms. Ahlberg-Tidblad concluded that in battery life testing there are significant limitations, such as simplified charge-discharge cycles, theoretical SOC windows at fixed values, faulty test methods that do not consider all parameters that lead to battery ageing, risks associated with unrepresentative ageing mechanisms in acceleration, complex interactions that make ageing mechanisms not additive in nature. There are also risks associated with creating unjustified bias with increasing typical test parameters values. She noted that significant tailoring of a test method to a specific battery configuration is required to achieve equivalent ageing for fair durability comparisons between different battery systems and that if a physical regulatory durability test is required then equivalent ageing across battery system technologies must be the objective of the test procedure which would raise a number of questions.

OICA's position summary on this topic is that since the traction battery technology is still in a period of rapid development and change, a regulatory accelerated ageing test is premature. There is a high risk of unjustified technology bias and unrepresentative ageing conditions. The battery ageing and understanding of the degradation mechanisms is extremely complex and would require customization for each manufacturer which is difficult for a global test procedure. Battery life testing and estimation is also very time and resource consuming as it can take several years for confident results. Life estimation models are under development but contain a number of uncertainties leading to large variations in degradation due to customer usage, and different applications that make the models complex.

Mr. Olichew asked if vehicle manufacturers are doing accelerated testing. Mr. Safoutin replied that there is ongoing work on it amongst manufacturers.

8. Battery Durability Summary of Efforts and Path Forward (Agenda Items 7 and 8)

Ms. Elena Paffumi from the Joint Research Centre (JRC) continues to update the EVE IWG group on JRC's in-vehicle battery durability research. In her presentation, EVE-28-13e, Ms. Paffumi updated the EVE IWG group on the additional scenarios undertaken in the models.

In the June EVE IWG meeting, Ms. Paffumi presented scenarios of different duty cycles that were representative of more EU geographic areas. The scenarios also included additional databases. Previous scenarios included a focus on NCM-LMO chemistry and year estimates on reaching 80% capacity fade, 100,000 km and 160,000 km.

The newest scenarios include new preliminary ambient temperature studies that include warm and cold temperatures, new duty cycles representative of other EU geographic regions and ambient temperature or customer profiles.

Some members have asked about the inputs and outputs of the TEMA model. The following figure shows the inputs and outputs of the JRC TEMA model.

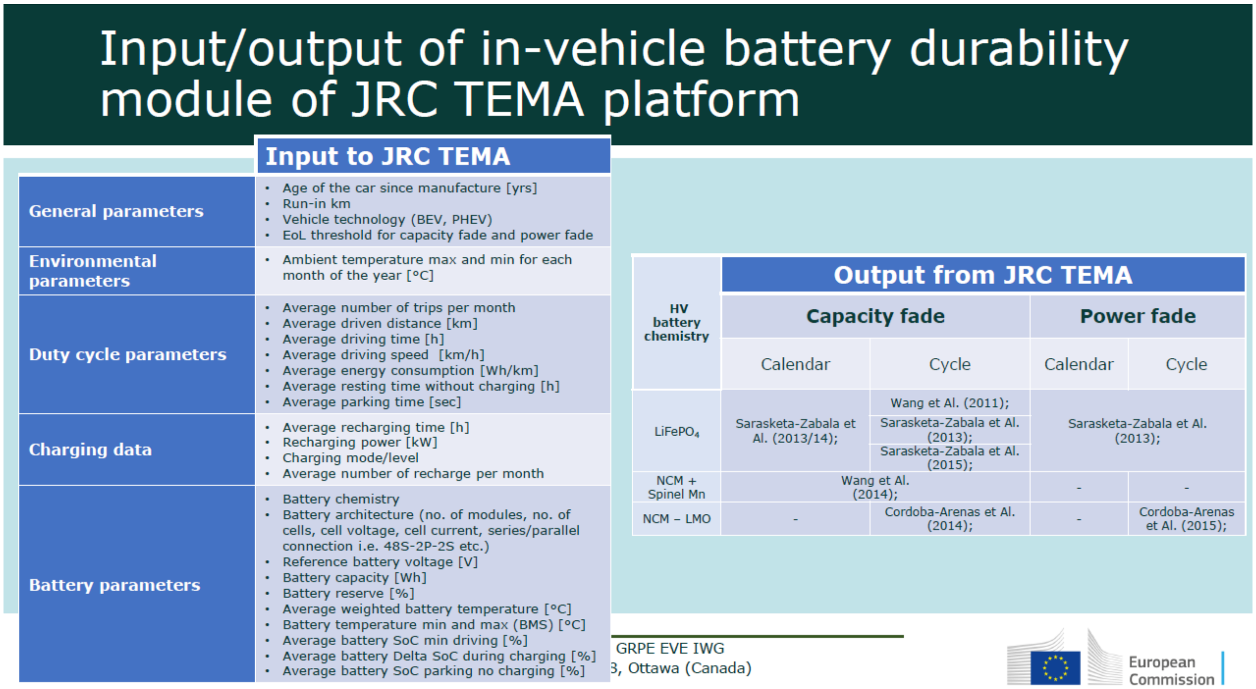

Figure 1: Slide 22 from document EVE-28-13e, inputs and outputs of JRC TEMA model

Further to Ms. Paffumi's presentation, Mr. Mike Olechiw lead the discussion on a path forward on battery durability. Ms. Ahlberg-Tidblad noted that if regulations drive costs higher than it can decrease the availability and feasibility of ensuring the penetration of advanced vehicles. Ms. Ahlberg-Tidblad expressed interest in addressing the concerns through warranty.

Mr. Olechiw noted that WLTP is confident that they will want to control air pollutants. He asked the EVE IWG group about range and energy consumption.

Mr. Matthias Nägeli responded that WLTP is aware that customers are sensitive on range at the moment and that they need to use the chassis dyno to determine range. He noted that if there is a requirement to provide an efficiency value already then there could be a simple way to derive range from efficiency.

9. Review of status Part B mandate report and discussion (Agenda Item 9)

Mr. Mike Olechiw and Ms. Kendelle Anstey showed the EVE IWG the draft of the status part B mandate report for the January EVE IWG meeting in Geneva. EVE IWG members provided feedback and a few action items were developed to improve and add to the report.

10. Method of stating energy consumption update (Agenda Item 11)

Mr. Giallonardo presented document EVE-28-15e, which was a presentation he made in September to the Group of Experts on Cleaner Energy Production (CEP) regarding the prospect of assuming leadership of the work to develop a method of stating energy consumption. The CEP group has not confirmed if they are interested in taking over the work on the method of stating energy consumption. Canada will continue to look for a group that would take over the leadership of the method of stating energy consumption project as the CEP group considers the project.

11. Day 2 – Validation test results (agenda item 14)

EVE IWG members who conducted validation testing presented their results. These included presentations from the EU JRC, JASIC in Japan, KATRI in Korea, the U.S. EPA, and ECCC in Canada.

Ms. Elena Paffumi presented the EU JRC's results. The EU JRC is collaborating with OICA to conduct the validation tests. Two OICA vehicles were tested in June and July at JRC's VeLA 8 lab in Ispra, Italy. Since the testing period, the processing of the results took place with results still under discussion.

Ms. Paffumi discussed the specifications of the vehicles used for the test in document EVE-28-14e and the equipment used to obtain the data. Eight tests were conducted on one of the vehicles and eleven on the other. The vehicle with eight tests had five repetition at the same speed and a full State of Charge (SOC) of the REESS. One test was conducted at low state of charge of the HV REESS and other tests were conducted with different speeds. Similarly, the other vehicle had four tests repeated and an additional test that explored the speed at which maximum power occurs.

Post-processing of the results indicated that the 2-second moving average window for peak power calculation was over the 10 seconds at maximum acceleration. The results of the vehicles are still being analyzed.

Ms. Paffumi noted that the fuel flow rate meter was only installed on the second vehicle as there was not enough time to install on the first vehicle. There was also some discussion regarding the length of warm up time and importance of ensuring that the battery temperature is appropriate for the tests as the battery warms up for the tests.

Mr. Nägeli noted that the goal of the validation program is to see how well TP1 and TP2 are working and how repeatable the processes are working. Ms. Ahlberg-Tidblad and Mr. Nägeli discussed the need to look into test-to-test variability within TP1 and TP2 before TP1 and TP2 results can be assessed. There was some discussion amongst EVE IWG members that the use of the procedure outside of WLTP could make manufacturers nervous about proceeding before a robust repeatable procedure is developed. There were also discussions relating to how to correct for tire slippage in the tests by tracking wheel speed versus dyno roll speed.

After the results of EU JRC's tests in collaboration with OICA were presented, Mr. Shinichi Abe presented JARI's test results. The presentation provided insights on the measurement devices and calculations as well as the factors that affect the output results of the power determination tests. It was mentioned the road surface power output in the validation tests are greatly affected by the characteristics of the tires, the vehicle restraint method and other factors. Due to the large errors, correcting these factors is necessary. Mr. Shinichi noted in his presentation that a possible reason for TP1 always resulting in a larger value than TP2 is due the roller surface measurement not appropriately being corrected in the right way.

Following Mr. Shinichi's presentation, Mr. Mike Safoutin presented on the U.S. EPA's validation test results for the power determination GTR. He went over specifications and details about how the U.S. EPA conducted their tests. The U.S. EPA tested a 2013 Malibu Eco and a 2013 Chevrolet Volt.

He noted that in Europe the TP2 test is easier as the data is much more readily available however, in North America the research is more classified.

Mr. Safoutin discussed the test conditions and results. Mr. Bryan Roos asked Mr. Safoutin how the batteries are charged between runs. Mr. Safoutin responded that they did some light braking and coasting to get natural regeneration.

There was discussion amongst EVE members surrounding the temperatures of the procedure in the conditioning phase since the transmission fluid temperature was difficult to stabilize in the method specified in the draft GTR. There were also discussions surrounding which modes to use the vehicles for performing the tests and also working the dyno in constant speed mode.

Mr. Kubodera noted that the conditioning is done in road-load mode but constant speed mode and that 20 minute conditioning is not sufficient for transmission fluid to reach steady state. He mentioned that it may need 60 minutes to reach stable transmission fluid temperatures. Mr. Kubodera noted that the conditioning cycle is to avoid electrical system de-rating due to heat, but also avoid heat viscosity impact of cold transmission fluid.

Mr. Aaron Loiselle presented on Canada's validation testing. Canada tested a 2016 GM Volt and a 2018 BMW 530e. Mr. Loiselle discussed the vehicle settings used for the tests and instrumentation and measurements taken. He went thoroughly through the test procedures and discussed the preliminary results of the tests. Mr. Loiselle noted some key factors in his results of both vehicles. He noted that the gearbox multiplier does not take into account the wheel rolling resistance and the additional resulting power loss, and that the effect of this results in lower TP2 test results.

Mr. Dongseok Choi presented on Korea Automobile Testing and Research Institute (KATRI)'s validation testing. KATRI conducted their tests on a hub dyno instead of a chassis dyno and tested the 2017 Hyundai Ioniq hybrid. Mr. Choi presented some proposals to improve the validation tests. These proposals were to add a hub dynamometer option to the test instrumentation and to exclude the first power test result in the calculation of the system power due to a lower sustained power. Mr. Choi also presented Korea's preference for TP2 and sustained power for determination of HEV system power.

12. Discussion of GTR draft open issues and GTR vs annexed GTR (Agenda items 15-18)

Mr. Safoutin went through the list of items that the drafting group has so far considered which is shown in document EVE-28-11e. He also went over the main points of the considerations for the GTR vs an Annexed GTR, reflected in document EVE-28-04e. The drafting group and EVE IWG members seem to be more in favor of a separate GTR. The drafting groups preference would be to proceed with a stand-alone GTR. A presentation on this was to be presented at the AC.3 meeting in November, 2018 for approval to go ahead with a stand-alone GTR.

Mr. Tetsuya Niikuni called in to the meeting to discuss the notification of Japan's points on terms of reference.

13. Final remarks, closing (Agenda items 9 and 10)

Mr. Olechiw thanked members for their participation and the leadership team for their continued support.

The next EVE meeting will be hosted in Geneva in January. A future EVE IWG meeting will be held in Sweden in late March or early April, 2019.