JRC Opinion on EVS-09-05e

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Background

This document summarizes the opinion of DG JRC on the regulatory text proposed by the US concerning BMS functionality. The proposed US regulatory text (EVS-09-05e.pdf) is based on the US vehicle sequential test report (EVS-6-36e.pdf) which addresses the following tests:

- Extreme temperature protection (failed cooling and heating systems)
- Over-discharge protection
- Over-current and over-voltage overcharge protection
- External short circuit protection

TF4 (REESS in-use) addresses the safety performance of a REESS under the same or similar conditions mentioned in the previous two US documents, however these documents discuss a broader scope of safety related scenarios or test conditions, which only partially overlap with the tests addressed in the draft-GTR. During TF4 meetings there were detailed discussions about external short circuit tests and temperature shock (cycling) among others, but overcharge, over-discharge, and extreme temperature tests were not discussed in detail. Therefore we consider the research performed and proposal made by the US as a valuable contribution to the TF4 discussions.

General observations

1) In our opinion the US proposal and the draft-GTR are aligned to a large extent for several tests. However, the test conditions and methods should be compared by the relevant TF and where appropriate merged to arrive at an optimal solution. In our opinion both draft-GTR and US proposal can be merged to remove certain ambiguities which we believe to exist in the respective test procedure descriptions (e.g. test 'modes'), to arrive at a more robust regulation. Potentialities for merging elements of each proposal are suggested in Table 1 but require further discussion among experts.
2) In general the US proposal is more detailed compared to the draft GTR. While we appreciate the clarity of the description of how to perform the tests (e.g. charging, discharging of different vehicle technologies: HEV, BEV and PHEV), in some cases it may be considered prescriptive (e.g. for the use of the break-out box it mentions the device rather than its function which may possibly be performed by alternative means). General tests conditions, such as ambient temperature, elapse time, SOC set-up, and tolerances, need to be harmonized.
3) A noteworthy difference between both proposals concerns the vehicle 'modes' in which tests should be performed. Modes are generally not defined and the relevance of performing tests in different modes (e.g. charging mode, driving mode) is not always clear. Another difference between the draft-GTR and the US proposals concerns the charging / discharging methods. In the draft GTR a standard cycle is described (with charging/discharging performed under conditions defined by the manufacturer or alternatively expressed in terms of C-rate) which seems to be, with respect to C-rate, more applicable at REESS or subsystem levels (1/3 C is mentioned in draft-GTR). Conversely the UDDS cycle described in the US proposal suits better for vehicle level tests.

Arising from these differences, and relevant for potential merging, the following questions are forthcoming:

- How is a standard cycle performed at vehicle level in the draft-GTR, especially for HEV (where no definition is provided by the manufacturer)?
- How can the UDDS cycling protocol be applied at REESS or subsystem level according to the US proposal?

4) There are two tests in the US proposal which we could not clearly assign as similar to one or more draft-GTR tests. They could potentially be considered as additional tests, namely:

- **Over-current over-charge and over-voltage over-charge protection**: We appreciate that these tests may describe different scenarios. However at this stage we do not see how these tests could result in a different outcome and how they differ from the overcharge protection test in draft-GTR.
- **Low temperature protection**: This scenario is currently not tested in the draft-GTR. While charging at low temperatures may in theory have safety implications, we consider that they are potentially already covered by tests in the draft-GTR (e.g. overcharge test, temperature shock test). In addition the method described to test the vehicle/REESS low temperature protection (one charge and discharge cycle) may not give rise to safety effects arising from processes described in the rationale[1] (i.e. lithium plating). Furthermore Figure 32 in EVS-6-36e.pdf illustrates that the REESS heats up relatively fast during charging / discharging so that the low-temperature conditions (when lithium plating is exacerbated) are not sustained.

In the following Table tests described in both the draft-GTR and the US proposal are compared where these tests are considered to be most similar. This table may be considered as input for discussions on integration/merging of the US proposal into the draft-GTR.

[1] Meike Fleischhammer et al., Interaction of cyclic ageing at high-rate and low temperatures and safety in lithium-ion batteries, Journal of Power Sources 274 (2015) 432-439

	Draft GTR method's description	USA proposal method's description	Comments and suggestion for harmonization
(Over-current) Overcharge protection	- Charging contactor shall be closed - 22±5 or 10° - Starting SOC not mentioned - Charge with constant current at least 1/3C - Until automatic interruption or until twice of the nominal capacity - Perform standard cycle	- Use DC Link - Charging or operational mode (HEV) - Ambient temperature (25°C) - Set 95±2% SOC - Charge with increasing current from 0 to max in 1000 s (additional to Level 1 charging) - 2 h after disconnect with 24 h elapse (observation)	We note that the US proposal differentiates different charging 'modes' for this test. What different 'modes' are there and how are they defined? How relevant are different 'modes' for the test outcome? Should this approach be considered in the draft-GTR? The US proposal does not require performance of a post-test standard cycle thereby omitting a post-test functionality check. Does the US proposal really test the over-current protection? Since the initial SOC is close to 100% the maximum current of the REESS is not reached during the test (see Fig. 41 on p. 671 in US report).
Over-voltage overcharge protection		- Use DC Link - Charging or operational mode - Ambient temperature (25°C) - Set 95±2% SOC - Set maximum or 10% higher trip current/voltage - 2 h after disconnect with 24 h elapse	The link between the US proposal's rationale and the test conditions are unclear. How do the respective overcharge protection tests result in a different test outcome and how do they differ from the overcharge protection test in draft-GTR?
Over-discharge protection	- Mode is not mentioned - 22±5 or 10°C - Discharge with at least 1/3 C - Until automatic interruption or until 25% of the nominal voltage - Perform standard cycle	- Use DC link - Both in driving and charging mode - Set 10% SOC - Ambient temperature - Discharge with at 1kW - Until voltage equals to 0V@DC link or 8 h elapsed	<u>In general the draft-GTR and US proposal tests are comparable.</u> The US proposal differentiates different charging 'modes' for this test? What different 'modes' are there and how are they defined? How relevant are different 'modes' for the test outcome? Should this approach be considered in the draft-GTR? The US proposal does not require performance of a post-test standard cycle thereby omitting a post-test functionality check.

	Draft GTR method's description	USA proposal method's description	Comments and suggestion for harmonization
			Both test end conditions are acceptable. SOC level should be aligned.
Over-temperature protection	-Deactivate cooling if possible -Continuously charged and discharged with a steady current that will increase the temperature of cells as rapidly as possible within the range. - Increase temperature until a limit defined by the manufacturer as operated temperature threshold or if not such a threshold is given until the maximum operating temperature (given by the manufacturer) - Repeat until charge-discharge is limited or the temperature is stabilized for 2h	- Disconnect cooling, if possible - Determine max load power - Set SOC to 100±5% - at the manufacturer's specified maximum operating ambient air temperature and no lower 40±2°C for at least 6 hour 1. Discharge with max power 2. Charge with max power 3. Discharge with max power (only for EV, PHEV) - Terminate the test after 24 hours elapsed	In general the draft-GTR and US proposal tests are comparable. The US proposal differentiates charging 'modes' for this test. What different 'modes' are there and how are they defined? How relevant are different 'modes' for the test outcome? Should this approach be considered in the draft-GTR? Is there a minimum temperature at which to perform the test in the draft-GTR e.g. 40°C as in the US proposal? The max power charge / discharge technique may enhance repeatability/reproducibility – however is it expected that the maximum temperature increase is achieved under these conditions. How many cycles are performed in 24h according to the US proposal (before termination)?
Low temperature protection	No test	- Disconnect heating - Determine max load power - Set SOC to 50% - -20±2°C at least 6 hour 1. Charge with max power 2. Discharge with max power 3. Charge with max power	Potentially new test The REESS heats itself up quickly, as it is seen in Fig.32 on p.659 in US VSTR so low temperatures conditions are not maintained in this test. From the literature Li-plating will probably not cause any safety issues (arising from separator piercing by dendrites) after only one cycle. In general the relevance of this test is not clear.

	Draft GTR method's description	USA proposal method's description	Comments and suggestion for harmonization
Short circuit protection	- Limit the level where all REESS level protection device is functional (no text is provided yet) - Standard SOC set-up - Both charging and driving mode - Connect terminals with 5 mΩ external short (including cabling) - 1 h after REESS temperature is stabilized - Perform standard cycle	- Use DC Link - Ambient temperature (25°C) - Set 95±2% SOC - Drive mode - 2-5 mΩ external short - Monitor until the REESS temperature remain stable for 60 min	In general the draft-GTR and US proposal tests are similar. Draft GTR is considered more comprehensive than the US proposal: -The total external short resistance including cabling, connectors should be at least 5 mΩ - Both charging and driving mode should be tested (separately or in one test). - Performing a standard cycle is favorable after 60 min elapse time.

Table 1. Comparison of essential elements in the US Regulatory text proposal (EVS-6-36e.pdf) and draft-GTR..