EU-Commission
JRC Contribution to EVE IWG:
In-vehicle battery durability e-HDVs breakout C-rate

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e-HDVs tests: C-rate discussion

Open points to be discussed

- C-rate, constant or variable, depending on the test method
- C-rate calculation method
- Accuracy, tolerance, boundary conditions, deviation of the UBE measured across the testing methods
- End of discharge criterion, safety provision for on-road tests, requirements
- C-rate calculation based on the nominal battery energy
- C-rate charging , RTE calculation, …
- …

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e-HDVs tests: C-rate discussion

- Three testing methods: Method 1a, Method 1b, Method 2

  ➢ **C-rate to be defined** →**suggestion to define a reference speed instead of a C-rate**

- Constant C-rate vs variable C-rate ➡ constant C-rate seems favourable for simplicity of the test procedure to be applied;

- Different proposals on the C-rate calculation or testing methods:

Method 1a

  ➢ ~~- a C-rate representative of a range of driving power values from different mission profiles or driving cycle~~

  ➢ ~~- with a constant C-rate defined as the median C-rate of the cumulative frequency of the C-rate profile equivalent to WHVC~~

  ➢ ~~- a constant C-rate corresponding to the most representative operational driving speed for vehicle category and mission profile~~

  ➢ - a constant speed corresponding to the most representative operational driving speed for vehicle category and mission profile

  ➢ - a C-rate in the range of [C/6 or less, C/2]

  ➢ ~~- multiple C-rate calculation based on driving cycle~~ →possibility to set more than one constant speed

Method 1b

  ➢ - Variable C-rate but limits could be set →Still to be discussed

Method 2

  ➢ ~~- reproduce C-rate profile representing the WHVC with constant C-rate phase in the middle and in the end of discharge pattern to avoid the unstable SOC at the end of measurement~~

  ➢ - a constant C-rate equal or less than C/5 or C/2.3 (0.2C or 0.43C) and with the highest normal charging power available [≤150kW] as defined in paragraph 6.1.1 of this GTR

  ➢ - a power derived from the most representative operational driving speed for vehicle category and mission profile

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e-HDVs tests: C-rate discussion

- Three testing methods: Method 1a, Method 1b, Method 2

  ➤ **Additional questions**

- Same C-rate calculation procedure for all the test methods (1a,1b,2) ? 1a and 2 correlated

- Deviation of the UBE measured across methods? Accuracy? Equivalence of testing method 1a, 1b, 2 ? 1a and 2 correlated

- End of discharge criterion ?

  ➤ The end of discharge criterion is reached when the cut-off voltage as defined by the manufacturer is reached. →Method 1a,1b, 2. Suggestion to define a new provision for Method 2

  ➤ System cannot maintain power any longer →Method 1a,1b,2

  ➤ Test track and on-road test: safety provision + on-board discharge? Accuracy? Deviation in respect to Method 2 needed? Still to be discussed

- C-rate calculation based on nominal battery capacity. C-rate = power/nominal battery energy ok

- RTE calculation for all methods: charge C-rate equal to discharge C-rate →Still to be discussed

  ➤ Method 1a: ? Or to long charging time so different provision?

  ➤ Method 1b: ? Or to long charging time so different provision?

  ➤ Method 2: a C-rate equal or less than C/5 or C/2.3 (0.2C or 0.43C) and with the highest normal charging power available [≤150kW] as defined in paragraph 6.1.1 of this GTR

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e-HDVs tests: Method 1a

- **Outcome from breakout group**

  - ➢ Test in Method 1a with <u>characteristic speed</u> (to be specified: regional speed etc.)

    - different speed around regions

    - but same methodology and test procedure

  - ➢ Regional specific speed and payload in agreement with authorities (GVW, GCW)

  - ➢ With a C-rate in the range of [C/6 or less, C/2], as check, not to have unwanted battery behaviour

  - ➢ Family definition: to consider adding a provision in Part A family to account for different vehicle configurations and battery size

  - ➢ Considering defining a guideline for the harmonisation of the characteristic speed

    - Boundary conditions or information for speed definition

    - Urban, extra-urban, highway, country road, …

    - Suggested speed range, values to avoid …

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e-HDVs tests: Method 1b

Still to be discussed

➢ Test in Method 1b with characteristic speed (to be specified what is referring to: regional speed etc.)

- different speed around regions
- but same methodology and test procedure

In the discussed table:
- Variable speed but limits could be set
- Tolerances of the average speed to be discussed

- Setting tolerance on the average speed of the test?
- On-road driving might help to verify/suggest C-rate and speed tolerance setting?

➢ Japan suggests Method1b as optional

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e-HDVs tests: Method 2

- **Outcome from breakout group**

  - ➢ Test in Method 2 with a <u>constant power</u> derived from the most representative operational driving speed for vehicle category and mission profile

    - different around regions

    - but same methodology and test procedure

  - ➢ Regional specific speed and payload in agreement with authorities (GVW, GCW)

  - ➢ With a C-rate in the range of [C/6 or less, C/2], as check, not to have unwanted battery behaviour

  - ➢ Family definition: to consider adding a provision in Part A family to account for different vehicle configurations and battery size

  - ➢ Considering defining a guideline for the harmonisation of the characteristic speed

    - Boundary conditions or information for speed definition

    - Urban, extra-urban, highway, country road, …

    - Suggested speed range, values to avoid …

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e-HDVs tests: End of discharge criterion

➢ The end of discharge criterion is reached when the cut-off voltage as defined by the manufacturer is reached. →Method 1a,1b, 2. Suggestion to define a new provision for Method 2

➢ System cannot maintain power any longer →Method 1a,1b,2

➢ Test track and on-road test: safety provision + on-board discharge?

➢ Accuracy? Deviation in respect to Method 2 needed? Still to be discussed

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e-HDVs tests: discussion table to be filled in

Type of vehicle	Test procedure	~~C-rate constant~~ Constant representative speed			Constant representative power	~~C-rate variable~~			Calculation method Speed or power definition		End of discharge criterion, safety provision, etc.	Charging C-rate		Deviation across the testing methods	C-rate based on nominal battery energy
		Single/constant ~~C-rate~~ speed (different for categories)	Multiple /variable ~~C-rate~~ speed (different for category)	C-rate equal or less than C/5 and with the highest normal charging power available [≤150kW]	Single/constant power (different for categories)	~~C-rate profile representing the WHVC~~	~~WHVC (median, weighted average)~~	~~Different mission profiles or driving cycle (median, weighted average)~~	Characteristic speed for vehicle category and mission profile	~~C-rate in the range of [C/5, C/3]~~		Equal to discharge C-rate	Normal or ultra-fast [>150kW]		
HDV without bidirectional charging	Method 1a	With characteristic speed: different speed for regions but same methodology and test procedure	To consider more than one constant speed for Method 1a	-	-				Regional specific speed and payload in agreement with authorities (GVW, GCW) With a C-rate in the range of [C/6 or less, C/2], as check Family definition Part A Guideline for the harmonisation of characteristic speed		Cut-off voltage Break –off criterion System cannot maintain power any longer				
	Method 1b		Regional specific speed and payload in agreement with authorities (GVW, GCW) Variable speed but limits could be set Tolerances of the average speed to be discussed Japan suggests Method1b as optional	-	-				Variable speed but limits could be set Tolerances of the average speed to be discussed		Cut-off voltage System cannot maintain power any longer Break –off criterion safety provision + on-board discharge				
HDV with bidirectional charging	Method 2				With a constant power derived from the most representative operational driving speed for vehicle category and mission profile as method 1a: different around regions but same methodology and test procedure				The power shall be derived from the most representative operational driving speed for vehicle category and mission profile as defined in Method 1a		Cut-off voltage Percentage voltage drop System cannot maintain power any longer Suggestion to define a new provision for Method 2				

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Thank you

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e-HDVs tests: Test procedures table

Methods for Checking Battery Durability Monitor for HDV		
HDV with no bidirectional charging		**HDV with bidirectional charging**
Method 1a	Method 1b	Method 2
Description Discharge by standard average speed with tolerances on test track And charge	Discharge by driving on the road with average speed with higher tolerances And charge	Virtual Round Trip Efficiency (VRTE) test Charging and discharging in a column
Repeatable Yes	Partly, if tolerances are set	Yes
C-rate **Constant (different for categories)**	**Variable but limits could be set**	**Constant**
RTE YES	YES	YES
UBE Yes	Yes, but it depends on the driving	Yes
UBC Yes	Yes	Yes
comment **tolerances of the average speed to be discussed** **Proposal from Japan on different constant speeds in the test**	**tolerances of the average speed to be discussed**	
C-rate calculation method		
Reference section (charge/discharge) Comment from OICA test data: flexible due to measurement results charge/discharge (RTE to be discussed RTE with tolerance in addition)	Comment from OICA test data: due to measurement results charge event as reference (RTE to be discussed RTE with tolerance in addition)	Comment from OICA: reference charge or discharge and RTE with tolerance in addition
Alternative Method	HDV Dyno testing with similar driving characteristics	
Feasibility voltage sensor, voltage measurement, under discussion		
discharge vs charge UBE vs UBC UBE in discharging discharge and charge RTE		

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