

# 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, ...
- ...

# e-HDV's 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]
- Method 1b
  - - multiple C-rate calculation based on driving cycle → possibility to set more than one constant speed
  - - 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 [ $\leq 150\text{kW}$ ] 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

# 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**
      - Break –off criterion →**Method 1a,1b**
      - Japan\*: an indication on a standard on-board instrument panel to stop the vehicle →**Method 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 [ $\leq 150\text{kW}$ ] as defined in paragraph 6.1.1 of this GTR
    - **Constant power [kW] from kW on speed limits or constant C-rate from speed limits**

# e-HDV tests: Method 1a

- **Outcome from breakout group**
  - Test in Method 1a with characteristic speed (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  $[C/6 \text{ or less}, C/2]$ , 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 ...
    - **To consider more than one constant speed for Method 1a**

# e-HDV's 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 or delete it

# e-HDVs tests: Method 2

- **Outcome from breakout group**

- Test in Method 2 with a constant power or constant C-rate 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  $[C/6 \text{ or less, } C/2]$ , 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

## Other options:

- constant C-rate seems to be the favourable option
- 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  $[\leq 150\text{kW}]$  as defined in paragraph 6.1.1 of this GTR
- Same C-rate as Method 1a?

# 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
- Break-off criterion → Method 1a, 1b
- An indication on a standard on-board instrument panel to stop the vehicle → Method 2
- Test track and on-road test: safety provision + on-board discharge?
- Accuracy? Deviation in respect to Method 2 needed? Still to be discussed



# e-HDV's tests: open questions

- More than one characteristic speed: i.e. a given vehicle with a given energy capacity with more than one possible characteristic speeds, urban, extra-urban and highway. Shall it be the most used speed to be selected? The worst case? More than one speed value?
- Test track or road grading ?
- Breaks for the driver?
- HD-OVC-HEVs:
  - CD test? vehicle's test operation mode?
  - Break-off criterion for Method 1a and Method 1b ?
  - Energy change correction procedure after break-off ?

# e-HDV's tests: discussion table to be filled in

Type of vehicle	Test procedure	C-rate-constant Constant representative speed		Constant C-rate	Constant representative power	C-rate-variable	Calculation-method Speed or power definition			End of discharge criterion, safety provision, etc.	Charging C-rate/power		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)		
HDV without bidirectional charging	Method 1a	<p><b>Breakout group:</b> With characteristic speed: different speed for regions but same methodology and test procedure</p> <p><b>JAMA/OICA:</b> constant vehicle speed[km/h] at each GVW/GCW vehicle weight condition based on speed limits It's difficult or impossible for buses or many kind of body application trucks to set up the test vehicle weight with GVW. JAMA-HD thinks unrealistic measuring UBE/UBC in constant speed - Method1a-discharge on ISC. These buses and body application trucks can have a measured UBE/UBE by only the maximum normal charging power - Method1a-charge or the constant discharging power - Method2.</p> <p><b>Japan*:</b> to delete this</p>	<p>To consider more than one constant speed for Method 1a</p> <p><b>Japan*:</b> please refer sheet "discharge pattern" final vehicle speed is lowest one</p>					<p><b>Breakout group:</b> Regional specific speed and payload in agreement with authorities (GVW, GCW)</p> <p>With a C-rate in the range of [C/6 or less, C/2], as check</p> <p>Family definition Part A : to consider adding a provision in Part A family to account for different vehicle configurations and battery size</p> <p>Guideline for the harmonisation of characteristic speed</p> <p><b>Japan*:</b> Regional specific speed and <b>payload in agreement with authorities</b> (GVW, GCW)</p> <p>With a C-rate in the range of [C/6 or less, C/2], as check</p> <p>Family definition Part A</p> <p>Guideline for the harmonisation of characteristic speed</p>		<p><b>Breakout group:</b> Cut-off voltage</p> <p>Break –off criterion</p> <p>System cannot maintain power any longer</p> <p><b>Japan*:</b> Cut-off-voltage Break –off criterion (exceeds the tolerance for 4 consecutive seconds or more)</p> <p>System cannot maintain power any longer</p>	<p><b>JAMA/OICA:</b> constant power[kW] from KW on speed limits or constant C-rate from speed limits</p> <p><b>Japan*:</b> normal</p> <p><b>Japan*:</b> to delete this</p>			
	Method 1b		<p><b>Breakout group:</b> Regional specific speed and payload in agreement with authorities (GVW, GCW)</p> <p><b>Variable</b> speed but limits could be set</p> <p>Tolerances of the average speed to be discussed</p> <p><b>Japan* suggests</b> Method1b as optional/to be deleted</p>					<p><b>Breakout group:</b> Variable speed but limits could be set</p> <p>Tolerances of the average speed to be discussed</p> <p><b>Japan* suggests</b> Method1b as optional/to be deleted</p>		<p><b>Breakout group:</b> Cut-off voltage</p> <p>System cannot maintain power any longer</p> <p>Break –off criterion</p> <p>Safety provision + on-board discharge</p> <p><b>Japan* suggests</b> Method1b as optional/to be deleted</p>				
HDV with bidirectional charging	Method 2		<p><b>Japan*:</b> allow to apply as a manufacture option if c-rate @ maximum speed is less than V2X upper limit (duplicate at least minimum and maximum speed)</p>	<p><b>Breakout group:</b> C-rate equal or less than C/5 and with the highest normal charging power available [≤150kW]</p> <p><b>Japan*:</b> to delete this</p>	<p><b>Breakout group:</b> With a constant power derived from the most representative operational driving speed for vehicle category and mission profile as method 1a:</p> <p>different around regions</p> <p>but same methodology and test procedure</p> <p><b>JAMA/OICA:</b> constant power[kW] from KW on speed limits or constant C-rate from speed limits</p> <p><b>Japan*:</b> to delete this</p>			<p><b>Breakout group:</b> The power shall be derived from the most representative operational driving speed for vehicle category and mission profile as defined in Method 1a</p> <p><b>JAMA/OICA:</b> constant power[kW] from KW on speed limits or constant C-rate from speed limits</p> <p><b>Japan*:</b> to delete this</p>		<p><b>Breakout group:</b> Cut-off voltage</p> <p>Percentage voltage drop</p> <p>System cannot maintain power any longer</p> <p>Suggestion to define a new provision for Method 2</p> <p><b>Japan*:</b> Cut-off-voltage Percentage-voltage drop System cannot maintain power any longer</p> <p>Suggestion to define a new provision for Method 2</p> <p><b>an indication on a standard on-board instrument panel to stop the vehicle</b></p>	<p><b>JAMA/OICA:</b> constant power[kW] from KW on speed limits or constant C-rate from speed limits</p> <p><b>Japan*:</b> why is the recharge needed?</p> <p><b>Japan*:</b> why is the recharge needed?</p>			

# Thank you

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# e-HDV's 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	<b>Constant (different for categories)</b>	<b>Variable but limits could be set</b>	<b>Constant</b>
RTE	YES	YES	YES
UBE	Yes	Yes, but it depends on the driving	Yes
UBC	Yes	Yes	Yes
comment	<b>tolerances of the average speed to be discussed</b> <b>Proposal from Japan on different constant speeds in the test</b>	<b>tolerances of the average speed to be discussed</b>	
<b>C-rate calculation method</b>			
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 in discharging		
UBE vs UBC	discharge and charge RTE		