Heavy-duty industry adaptation of GTR22 on in-vehicle battery durability

EVE IWG - Session 65

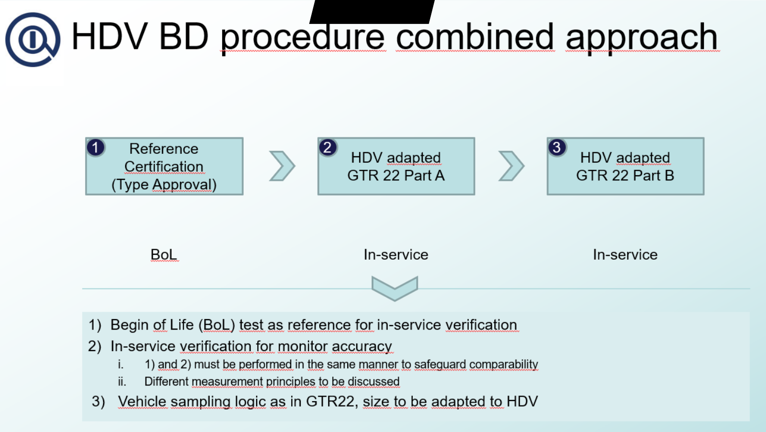
-Hybrid-

October 11th, 2023

General statement

OUR PATH OF COMMON EVE IWG AGREEMENTS UNTIL TODAY

1)



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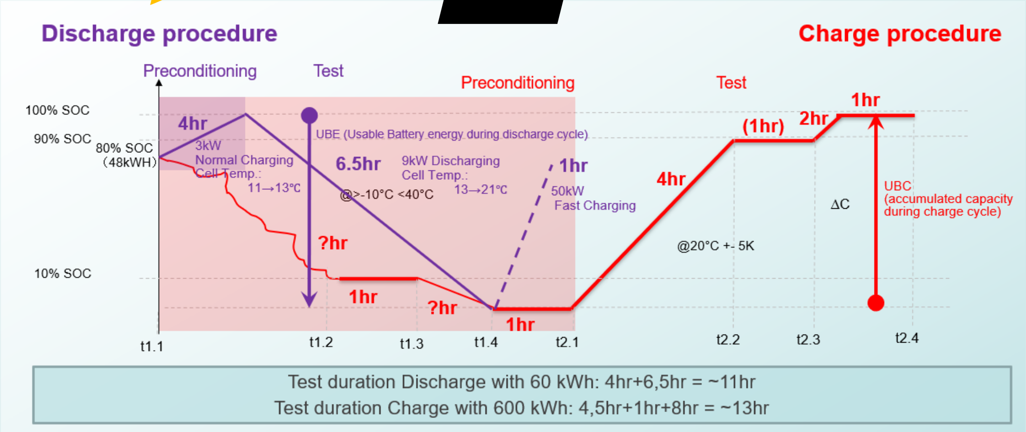

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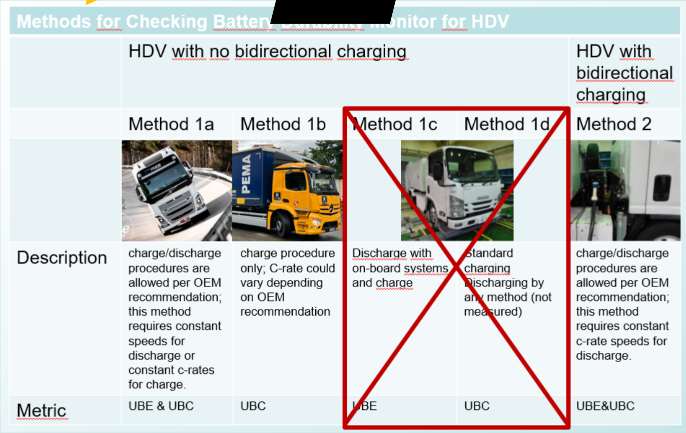


EVE IWG stakeholder‘s Achievements

1) We started with a general orientation early 2022, as a „truckified“ GTR22
2) OICA proposed & measured possible procedures (more to follow…)
3) We aligned on remaining test-candidates with highest potential

AFTER 12 MONTH OF EVALUATION AND FIRST TESTING, OICA WOULD LIKE TO SUMMARIZE THE FOLLOWING

Our working group‘s core challenges

1) **HDV-Trucks are no passenger cars → scale!**
2) **Battery usage (driving + PTO), set up and variety from Truck to Truck is much higher –> complexity!**
3) **Customers demand their Trucks being available for daily operation in full function without any damage → running business!**

<u>**Basic principles:**</u>

1) **Non-invasive measurement procedures:** customer vehicles in service must be operated safely and without damaging the customers’ property

2) **External equipment while driving very problematic (robust measurement, non-invasive, vehicle hardware only for regulation):** Homologation of internal current sensor (high accuracy anyways basis for good battery performance) and checkup via repeated in service measurements

3) **Measurement procedure options charging and discharging:** to recognize different infrastructures and vehicle types

4) **Flexibilities on metrics capacity vs. energy:** taking different accuracies and allowed tolerances into account

5) **Additional lifetime requirement:** full cycle equivalent more meaningful than mileage in heavy duty business.

AFTER 12 MONTH, EVALUATION AND TESTING, OICA WOULD LIKE TO EXPRESS THE FOLLOWING CORE POSITIONS

Methods for Checking Battery Durability Monitor for HDV					
	HDV with no bidirectional charging				HDV with bidirectional charging
	Method 1a	Method 1b	Method 1c	Method 1d	Method 2
					
Description	charge/discharge procedures are allowed per OEM recommendation; this method requires constant speeds for discharge or constant c-rates for charge.	charge procedure only; C-rate could vary depending on OEM recommendation	Discharge with on-board systems and charge	Standard charging Discharging by any method (not measured)	charge/discharge procedures are allowed per OEM recommendation; this method requires constant c-rate speeds for discharge.
Metric	UBE & UBC	UBC	UBE	UBC	UBE&UBC

Part A – Monitor verification: comments

PART A: EXTERNAL MEASUREMENT EQUIPMENT

…Statement EVE IWG 64th meeting
from Aaron Loiselle-Lapointe:

1) ***„We have measured LDV and HDV voltages many times.***
   a) *We often do this without OEM support but have robust procedures to do so safely.*
   b) ***HIOKI*** *is the gold standard for power measurement and*
   c) *we have a voltage divider to ensure that any wire exiting the vehicle to a power analyser is carrying a voltage between 0-10v maximum.*
2) ***Secondly, in regards to standardized voltage tap locations: we have tested vehicles that have voltage taps built into their electric powertrain.***
   a) *They are easy to access* ***<u>despite the battery pack itself being built deeply into the chassis</u>****. I personally like this idea.“*

PART A: POSSIBLE MEASUREMENT STRATEGY

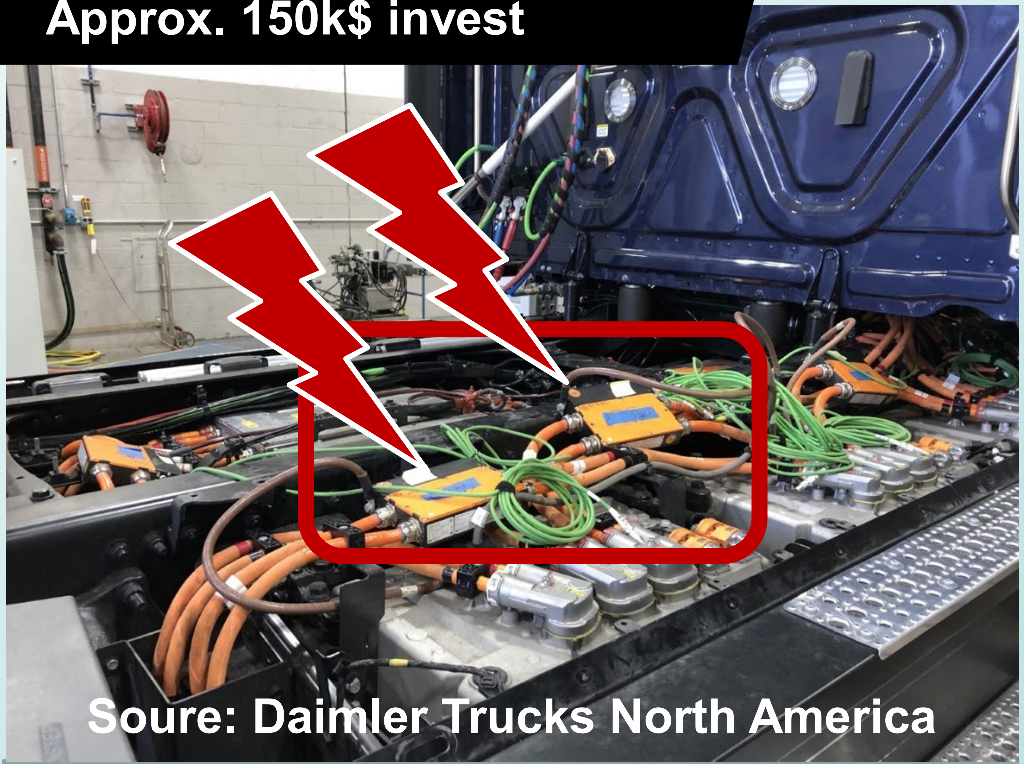
INTERNAL VS. EXTERNAL SENSORS

Battery current
Could be measured using a non-invasive method (measure magnetic field around conductor)
boundary condition: <u>Single wire per potential + non-shielded</u>

Link voltage
Can be measured using the voltage measurement port (only during standstill, adapter needed)

Cell voltage
Sum of cell voltages could be compared with link voltage measurement to check accuracy

⇒ Accuracy of voltage and current sensor <u>could</u> be validated without disassembling HV network
⇒ Still Accuracy of current sensor higher than voltage based on measurement knowledge



Statement: if any external measurement equipment has to be applied, only non-invasive allowed
If HV cables are shielded – (HIOKI) <u>inductive clamps</u> will not work!

PART A: FURTHER ARGUMENTS AGAINST EXTERNAL CURRENT MEASUREMENT TECHNOLOGY IN VEHICLES

HV Breakout-Modul Typ 1.1 Seitenansicht

HV Breakout-Modul Typ 1.1 Ansicht von oben

Metrology in HV system:

- Intervention in the HV circuit of the vehicle
- Disconnect HV lines in front of each battery to install current sensors.
- After that, damaged pipes or new lines are necessary.
- Only possible with highly qualified personnel with special measurement technology.
- Risk of errors, accidents, damage to the HV system.

Analogy to internal combustion engine:

- PEMS measurements also rely on the torque/power signal from the engine control unit.
- The signal is previously homologated in a test bench certification.

Current Sensor Battery:

- Highly accurate. Necessary for OEM to operate cells safely.
- EU specific: If necessary, it could also be validated in battery pack certification on test

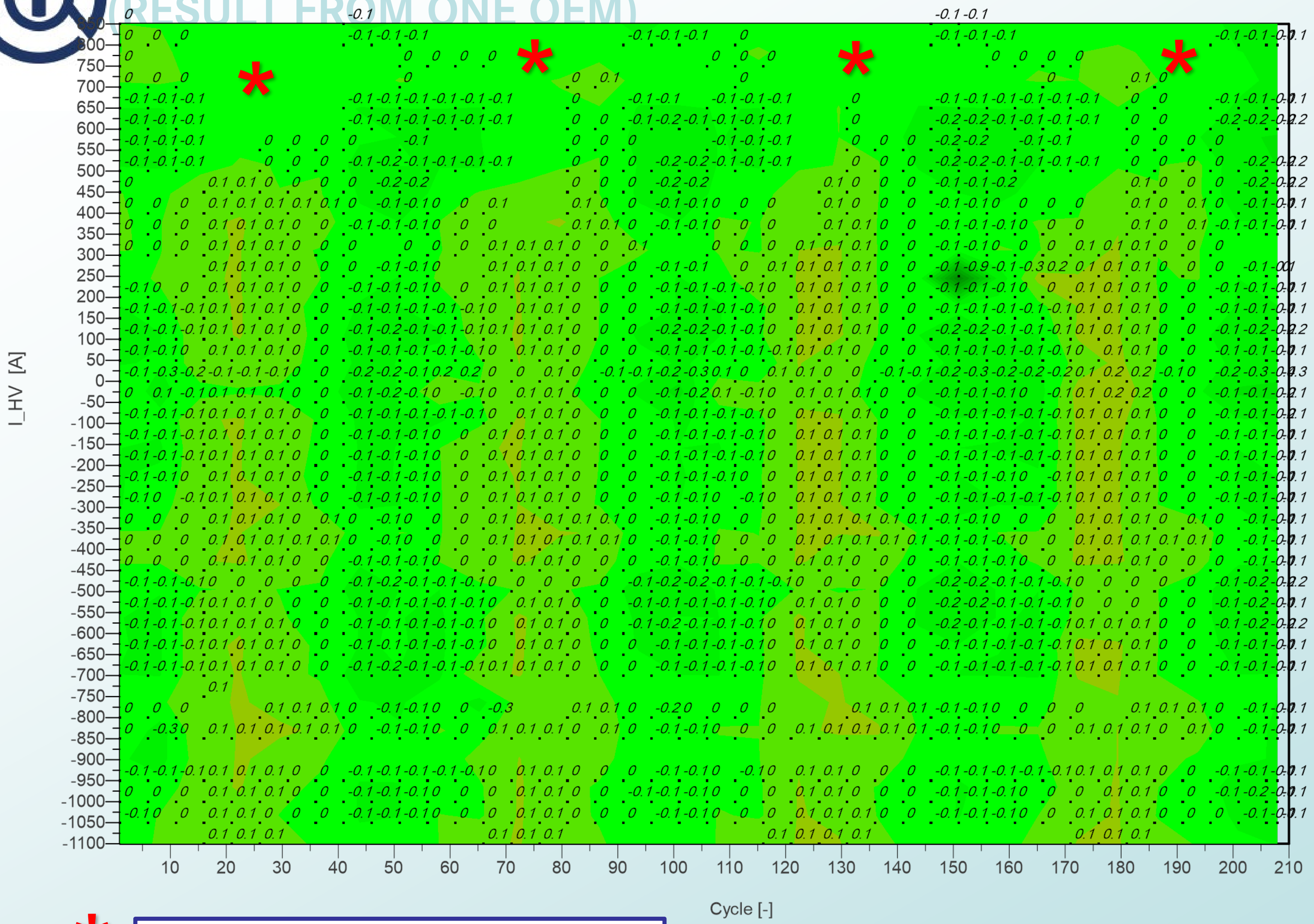
Analogy to UN GTR21, 6.1.2

6.1.2. Required measurements

The test vehicle shall be instrumented with measurement devices for measuring the necessary input values for the power calculation.

As an alternative to use of measurement devices, use of on-board measurement data [for engine speed, intake manifold pressure, and fuel flow rate]is permissible. [Use of onboard measurement data for other measurements is permissible] if the accuracy and frequency of these data is demonstrated to the responsible authority to meet the minimum requirements for accuracy and frequency described in 5.2. [If TP1 is applied for the system power

NEARLY ZERO DEVIATION FROM TEST BENCH CURRENT SENSOR TO BMS (RESULT FROM ONE OEM)



* Load points not possible in cold condition

I_HV: Average Values (1s Stationary)

Deviation Test Bench Current Sensor to BMS [%]:

- X-Axis: Cycles
- Y-Axis: Current Range
- Z-Axis: Middle Value of Deviaton

-> Very good Accuracy
-> No Drift
-> Tendency of warm/cold conditions can be seen

Question:
Since BMS current sensors have already very high accuracies, why would an external measurement be neccessary?

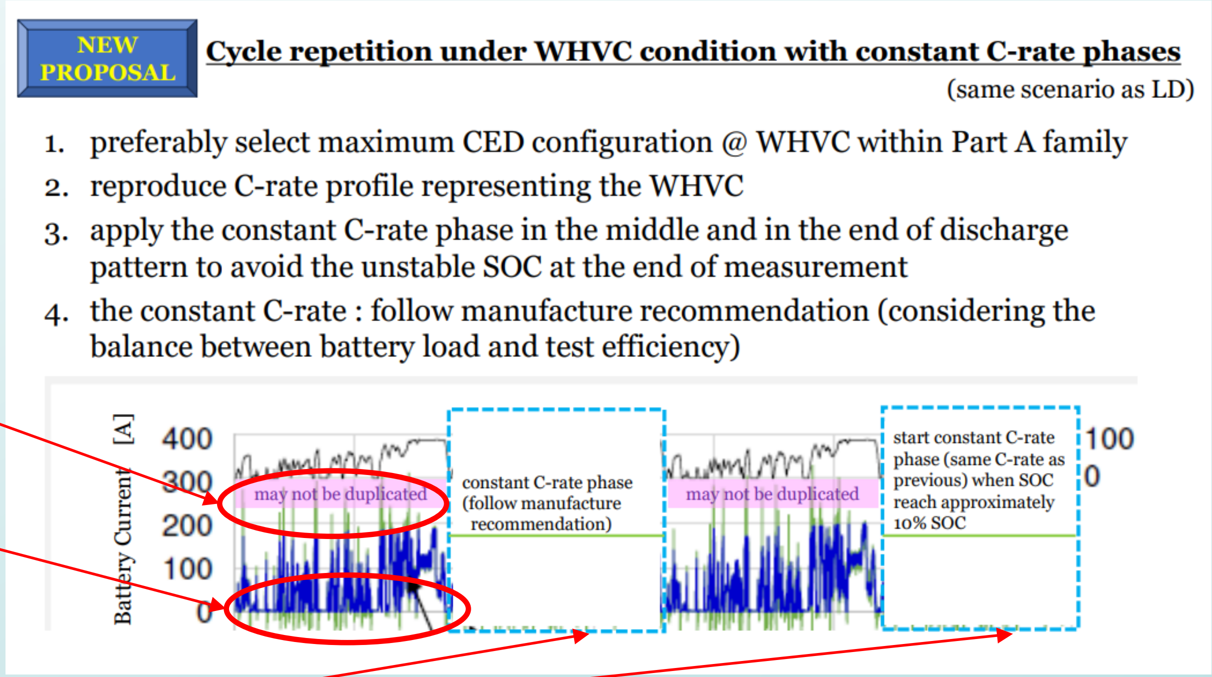
Annex III – Method 2: c-rate determination

METHOD FOR DETERMINATION OF C-RATE DURING DISCHARGE

Japan proposed a new dischage method at the 64th EVE Meeting.
(combination of the profile based on WHVC and the constant C-rate)

Pointing out

- The proposed C-rate profile equivalent to WHVC excludes the maximum charge value and regeneration Value.
  (Dose not cover complete WHVC mode.)



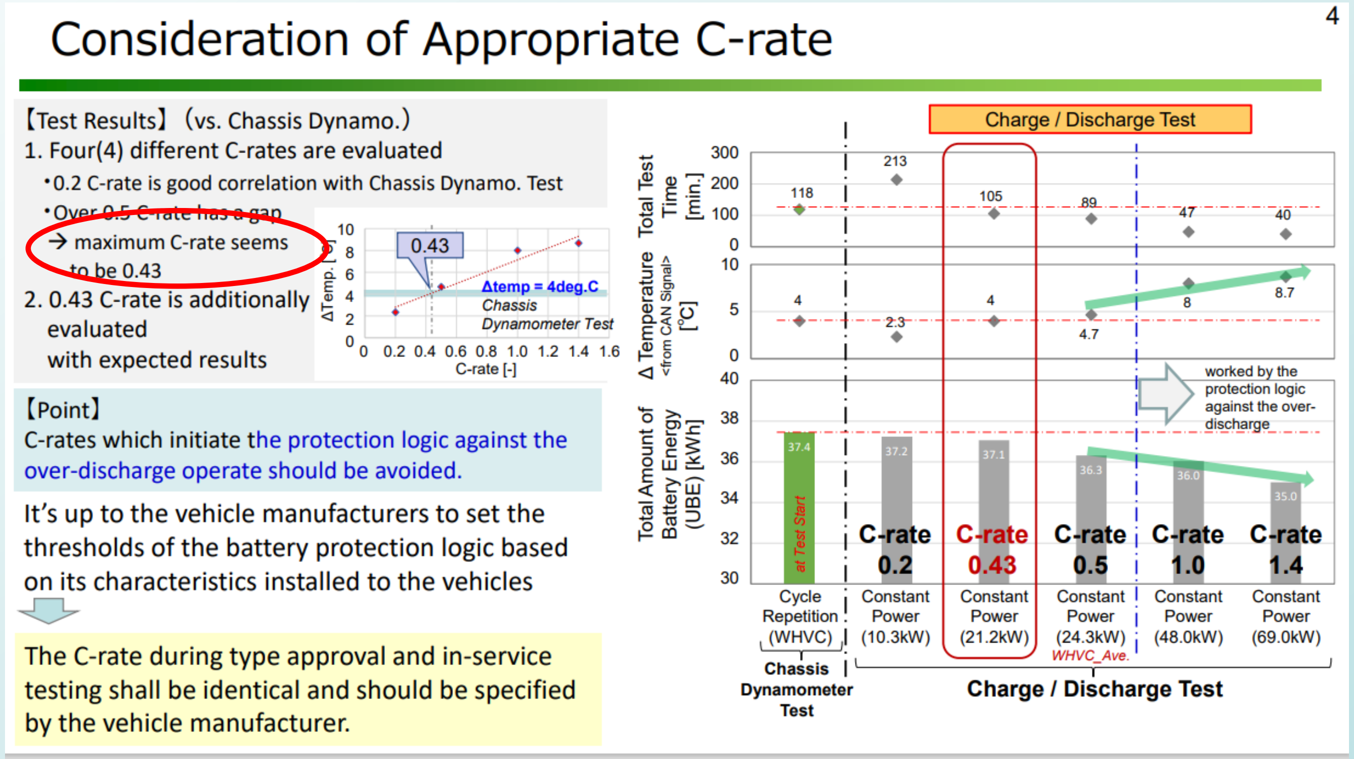
- Constant C-rate (OEM recommendation value) is added in the middle and the end to save time.
  (Still using Constant C-rate.)

METHOD FOR DETERMINATION OF C-RATE FOR BIDI (METHOD 2)

- IN THE 63RD JAPAN PROPOSAL, WHVC DRIVING DISCHAGE AND CONSTANT C-RATE (UP TO C=0.43) DISCHARGE WERE ALMOST THE SAME.

- THE METHOD PROPOSED BY JAPAN AT THE 64TH EVE MEETING ONLY INCREASES THE NUMBER OF TESTING STEPS, AND WE BELIEVE THAT DISCHARGING AT A CONSTANT C-RATE IS BETTER.

- HOWEVER, RATHER THAN USING CONSTANT C-RATE AS THE OEM DECLARED VALUE, WE BELIEVE THAT CLARIFYING HOW TO DETERMINE CONSTANT C-RATE WILL RESULT IN A FAIRER AND SIMPLER TESTING METHOD.



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<u>**The median C-rate of the cumulative frequency of C-rate equivalent to WHVC is defined as Constant C-rate.**</u>

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2. SYSTEM POWER (P) NEEDS TO BE DEFINED FOR WHVC
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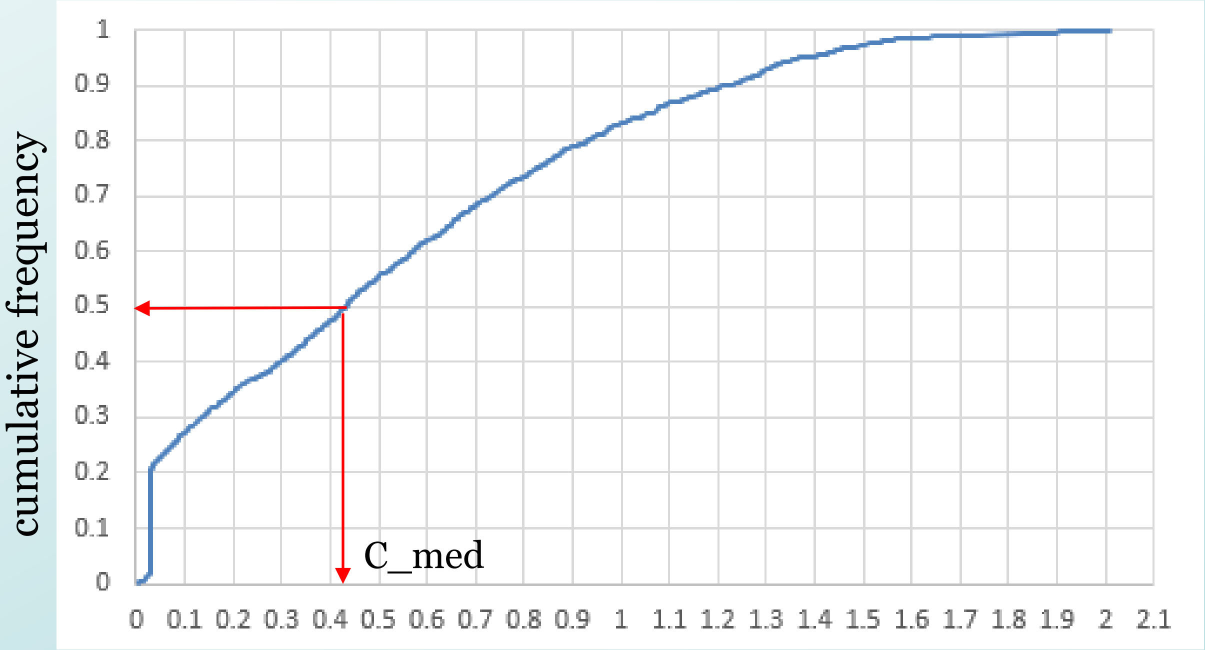

Appendix

At a constant 0.43C, the average accuracy of the external instrument and On-Board sensor over 1800 seconds when measuring UBE using Bidi is,

- ➢ Voltage: -0.15%
- ➢ Current: 0.14%

	Bidi 0.43C const						Criterion : ±1.0%rds				Criterion : ±1.0%rds	
							Voltage				Current	
	CAN Values					Voltage at J/B		-0.15%	Cable at RESS1-J/B	Cable at RESS2-J/B		0.14%
Time[s]	VCU::DISPLAY_CONTROL2::DISP_SOC [%]	CAN_for_EVTruck_dlc8::BMS1_BMU_OUT_1::BATT_V_TOTAL[V]	CAN_for_EVTruck_dlc8::BMS2_BMU_OUT_1::BATT_V_TOTAL[V]	CAN_for_EVTruck_dlc8::BMS1_BMU_OUT_1::BATT_CURRENT[A]	CAN_for_EVTruck_dlc8::BMS2_BMU_OUT_1::BATT_CURRENT[A]	HIOKI PW6001 [V]	Difference between PW6001 and CAN [ΔV]	ΔV/V@PW6001 [%]	HIOKI CT6843 [A]		Difference between CT6843 and CAN [ΔA]	ΔA/A@CT6843 [%]
1200	81	380.7	380.6	-28.4	-27.2	380.0704	-0.5796	-0.15%	28.25	27.44	0.09	0.15%
1201	81	380.7	380.6	-28.4	-27.204	380.0658	-0.5842	-0.15%	28.24	27.43	0.07	0.13%
1202	81	380.7	380.6	-28.4	-27.2	380.0624	-0.5876	-0.15%	28.24	27.43	0.08	0.14%
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1204	81	380.6	380.6	-28.4	-27.2	380.053	-0.547	-0.14%	28.25	27.44	0.10	0.17%
1205	81	380.6	380.6	-28.453	-27.2	380.0496	-0.5504	-0.14%	28.25	27.44	0.04	0.06%
1206	81	380.6	380.6	-28.4	-27.2	380.0444	-0.5556	-0.15%	28.25	27.44	0.10	0.17%
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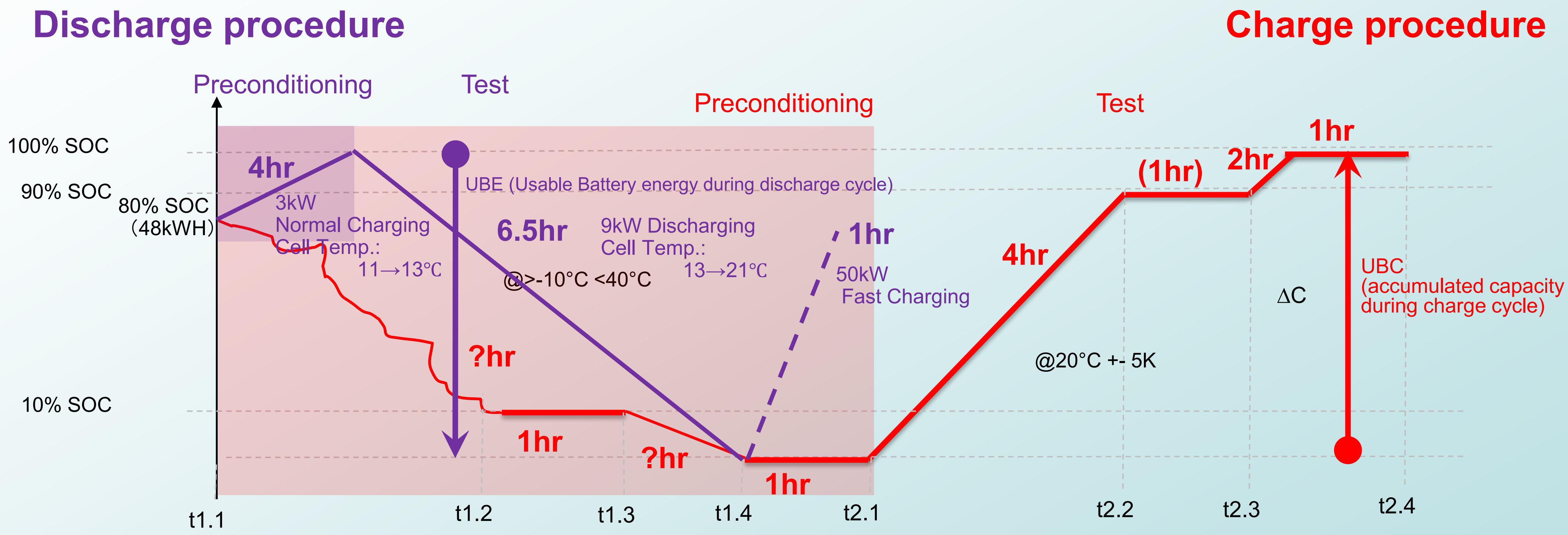
1210	81	380.6	380.6	-28.4	-27.2	380.0288	-0.5712	-0.15%	28.25	27.43	0.08	0.14%

Backup

OICAS MEMBERS MADE FIRST TESTS ON THEIR PROPOSALS (EVE IWG 64TH TEST "1A" AND "1B" AS OPTION FOR BIDI TEST 2)



Test duration Discharge with 60 kWh: 4hr+6,5hr = ~11hr
Test duration Charge with 600 kWh: 4,5hr+1hr+8hr = ~13hr

EU VECTO REGULATION VS. IN-VEHICLE: MEASUREMENT UNCERTAINTIES/MEASUREMENT ERRORS

On Testrig (EU)2017/2400

3. General requirements

The calibration laboratory facilities shall comply with the requirements of either IATF 16949, ISO 9000 series or ISO/IEC 17025. All laboratory reference measurement equipment, used for calibration and/or verification, shall be traceable to national or international standards.

3.1 Measurement equipment specifications

The measurement equipment shall meet the following accuracy requirements:

Table 1

Requirements of measurement systems

Measurement system	Accuracy (1)
Rotational speed	0,5 % of the analyser reading or 0,1 % of max. calibration (2) of rotational speed whichever is larger
Torque	0,6 % of the analyser reading or 0,3 % of max. calibration (2) or 0,5 Nm of torque whichever is larger
Current	0,5 % of the analyser reading or 0,25 % of max. calibration (2) or 0,5 A of current whichever is larger
Voltage	0,5 % of the analyser reading or 0,25 % of max. calibration (2) of voltage whichever is larger
Temperature	1,5 K

(1) "Accuracy" means the absolute value of deviation of the analyser reading from a reference value which is traceable to a national or international standard.
(2) The "maximum calibration" value shall be the maximum predicted value for the respective measurement system expected during a specific test run performed in accordance with this Annex multiplied by a factor of 1.1.

→ During certification on a calibrated test bench a failure of 1% on energy content is accepted just by means of the measuring accuracy.

In Vehicle

- In vehicle measurement accuracy loto be evaluated
- Reproducable boundary conditions in vehicle challenging (e.g. weather, temperature, street conditions, …)

EXAMPLE OF NECESSARY TOLERANCES: EU VECTO REGULATION: CONFORMITY OF PRODUCTION

12.8.2022 EN Official Journal of the European Union L 212/1

II

(Non-legislative acts)

REGULATIONS

COMMISSION REGULATION (EU) 2022/1379

of 5 July 2022

amending Regulation (EU) 2017/2400 as regards the determination of the CO_2 emissions and fuel consumption of medium and heavy lorries and heavy buses and to introduce electric vehicles and other new technologies

(Text with EEA relevance)

3.7.4 Evaluation of results

The conformity of the certified CO_2 emissions and fuel consumption related properties test is passed when all of the following criteria are fulfilled:

(a) $C_{CoP} \geq 0{,}95\ C_{TA}$

where:

C_{CoP}	Rated capacity determined in accordance with paragraph 3.7.2 [Ah]
C_{TA}	Rated capacity determined during component type approval [Ah]

(b) $(\eta_{BAT,CoP} - \eta_{BAT,TA}) \leq 3\%$

where:

$\eta_{BAT,CoP}$	Round trip efficiency determined in accordance with paragraph 3.7.2 [-]
$\eta_{BAT,TA}$	Round trip efficiency determined during component type approval [-]

Impacts

- Measurement accuracy
- System behavior
- Production tolerances

→ CoP allows a deviation of -5% of the certified capacity in production. Partly due to measuring accuracy and partly due to normal tolerances in production.

EXAMPLE GEN2 EACTROS 300 KWH

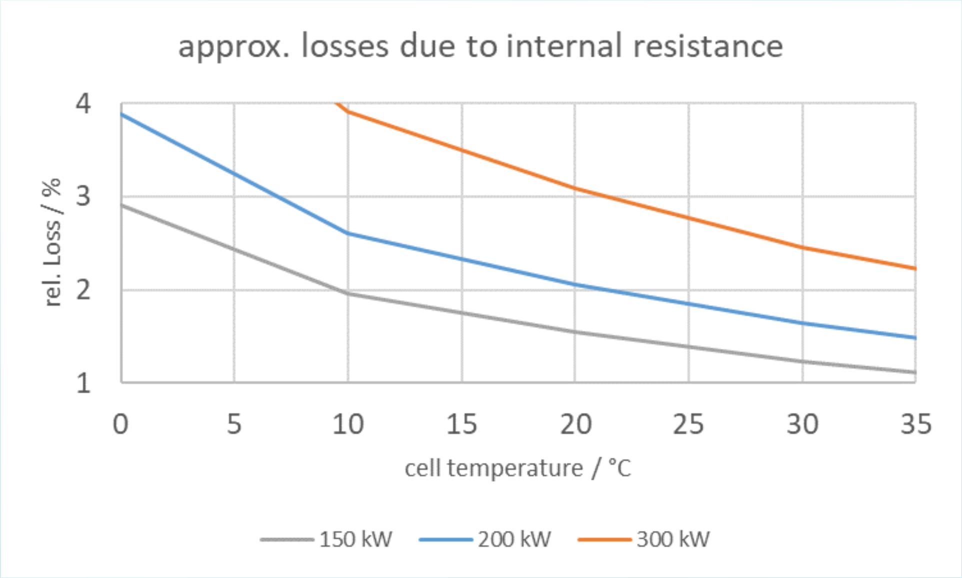
Constant power discharge with different rates:

Capacity:

- ✓ Same amount of charge
- ✓ No impact on determined capacity

Energy:

- – High impact of cell temperature on energy
- – High impact of discharge power on energy
- – Double impact of internal resistance, when recuperation occurs



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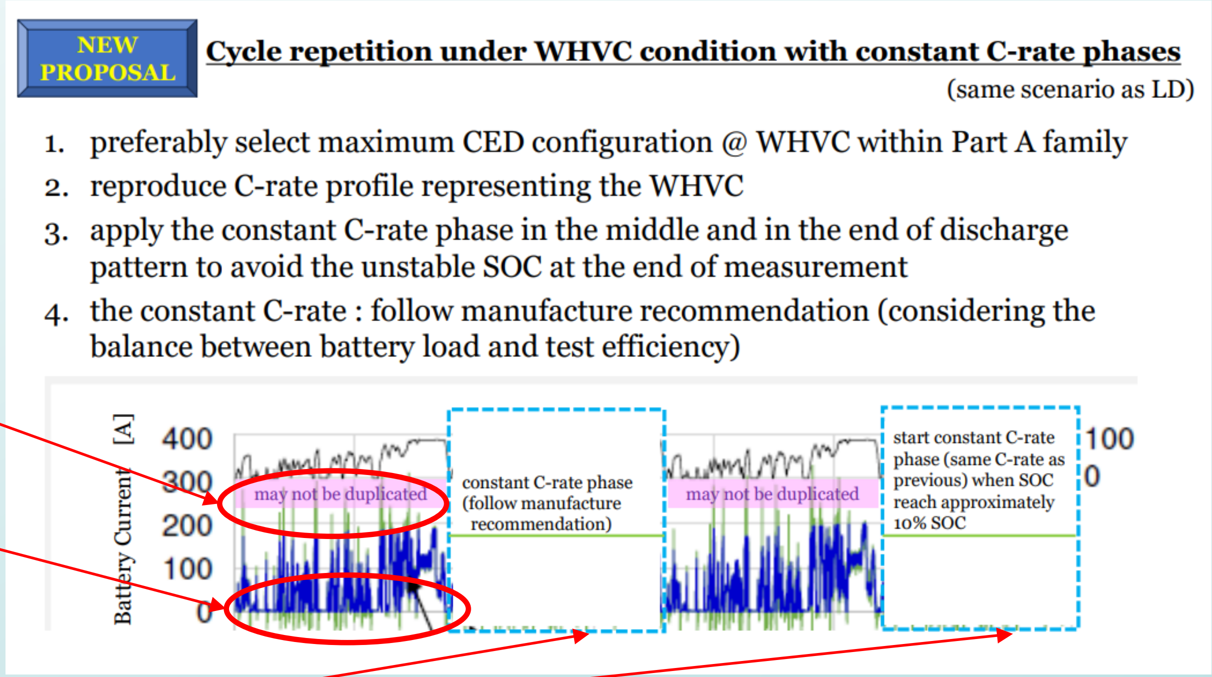

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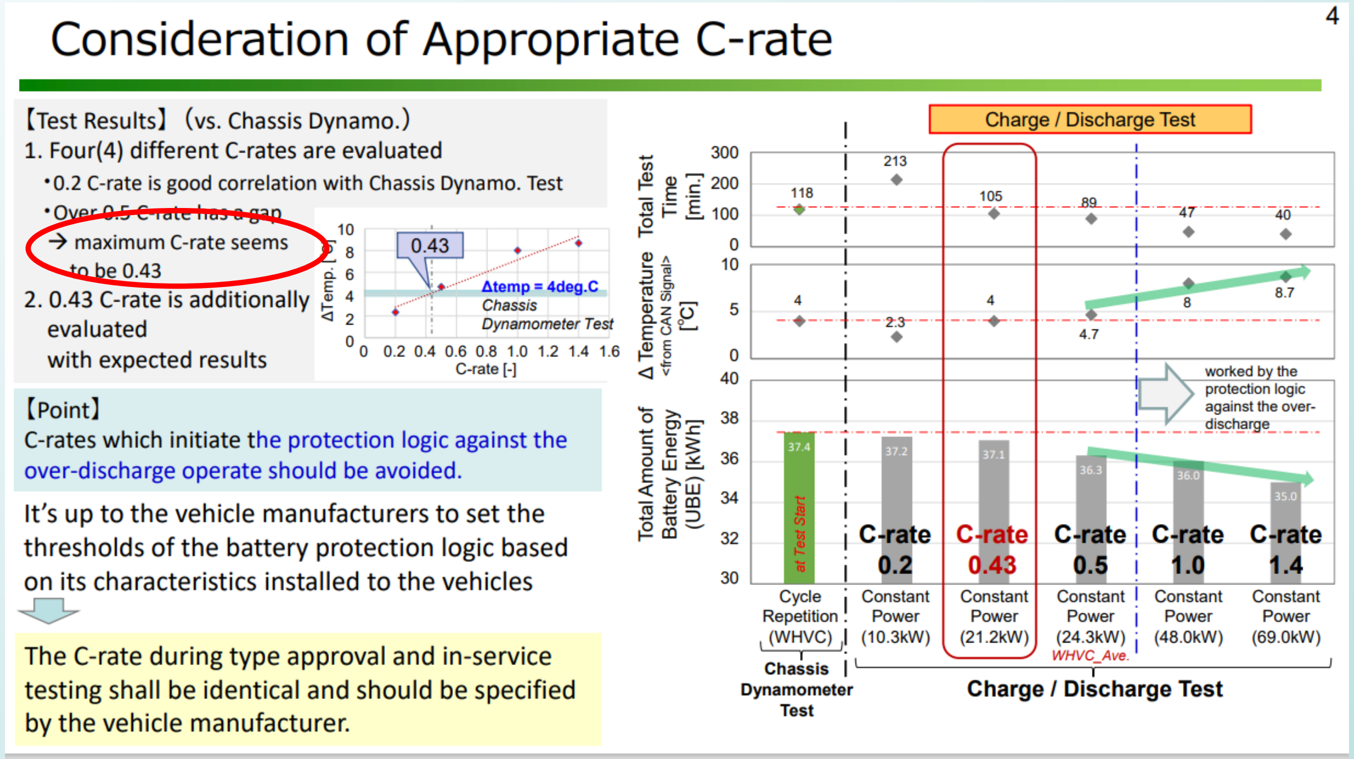

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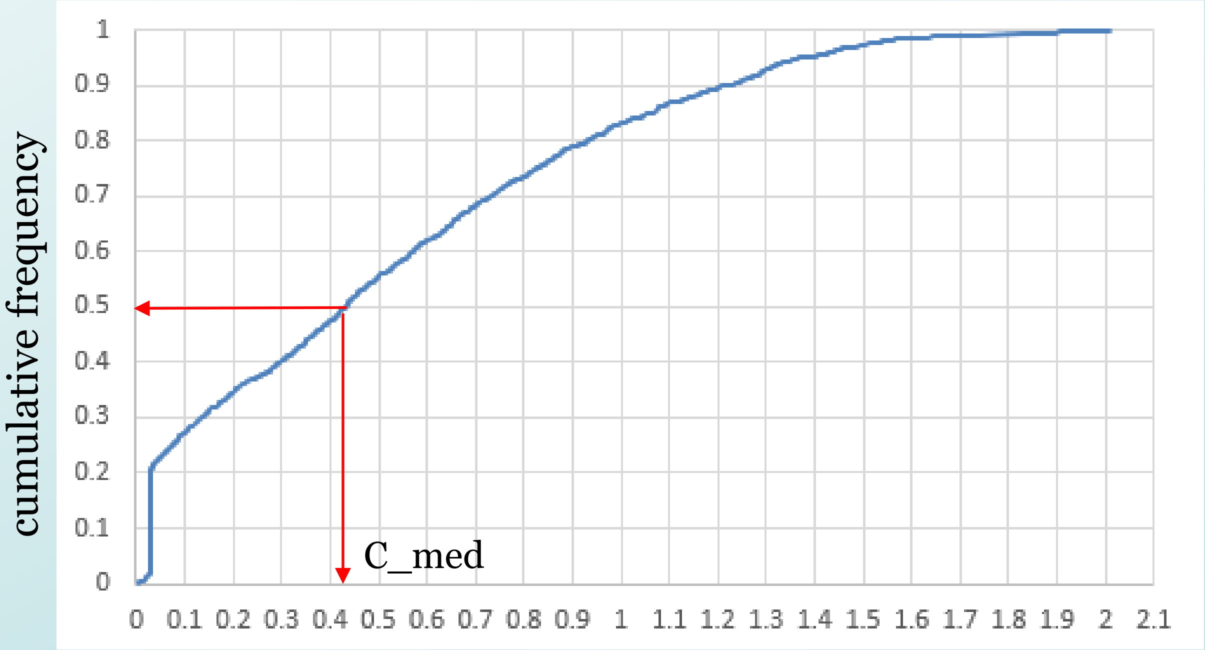

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Regarding JRC table

The JRC table for the 64th EVE Meeting is shown on the below.

Alternative methods for checking Battery Durability Monitor for HDV					
	HDV with no bidirectional charging				HDV with bidirectional charging
	Method 1a	Method 1b	Method 1c	Method 1d	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	Discharge with on-board systems And charg	Standard charging Discharging by any method (not measured)	Virtual Round Trip Efficiency (VRTE) test Charging and discharging in a column
Repeatable	Yes	Partly, if tolerances are set	Poter but n characterist		Yes
C-rate	Constant (different for categories)	Varying but limits could be set	Small and difficult to control	to be set also in this case	Constant
RTE	YES	YES	YES	NO	YES
UBE	Yes	Yes, but it depends on the driving	Yes	Not meaningful Not measured	Yes
UBC	Yes	Yes	Yes	Yes but issues with current leaking	Yes
Alternative Method	HDV Dyno testing with similar driving characteristics				

Delete at 64th EVE-IWG

- Methods 1c and 1d have been deleted.
- Method 1a's reference shall be flexible on charge or discharge procedure
- Method 1b's reference proposed as charge procedure only
- Instead of preconditioning only we should differentiate in:
  - Preconditioning,
  - Measurement,
  - and Aftertreatment. (Detailed explanation on the next page.)
- Regarding Method 2, UBE measurement during charging is not specified, so it is not a VRTE test. (remove VRTE)
- And If Method 1a requires constant speed discharge, Method 2 also requires constant C-rate.
- Constant c-rates at low and high SoC rates are not possible due to battery health reasons (see also (EU)2017/2400, Annex xb)

Regarding JRC table

	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

Preconditioning should be divided into

> Preconditioning
> Measurement
> Aftertreatment

Test Phase_OICA	Method 1a VT	Method 1b DT	Method 2
Preconditioning	**Discharge:** Const. speed driving on test track [+On board discharging]	**Discharge** driving on the road [+On board discharging]	**Charge:** [0.1cNormal charge & soak 6hr]
Measurement Main UBE kWh Sub UBC Ah	**Charge:**	**Charge:**	**Discharge:** ~~VRTE test~~
Aftertreatment	Not necessary	Not necessary	Charge:

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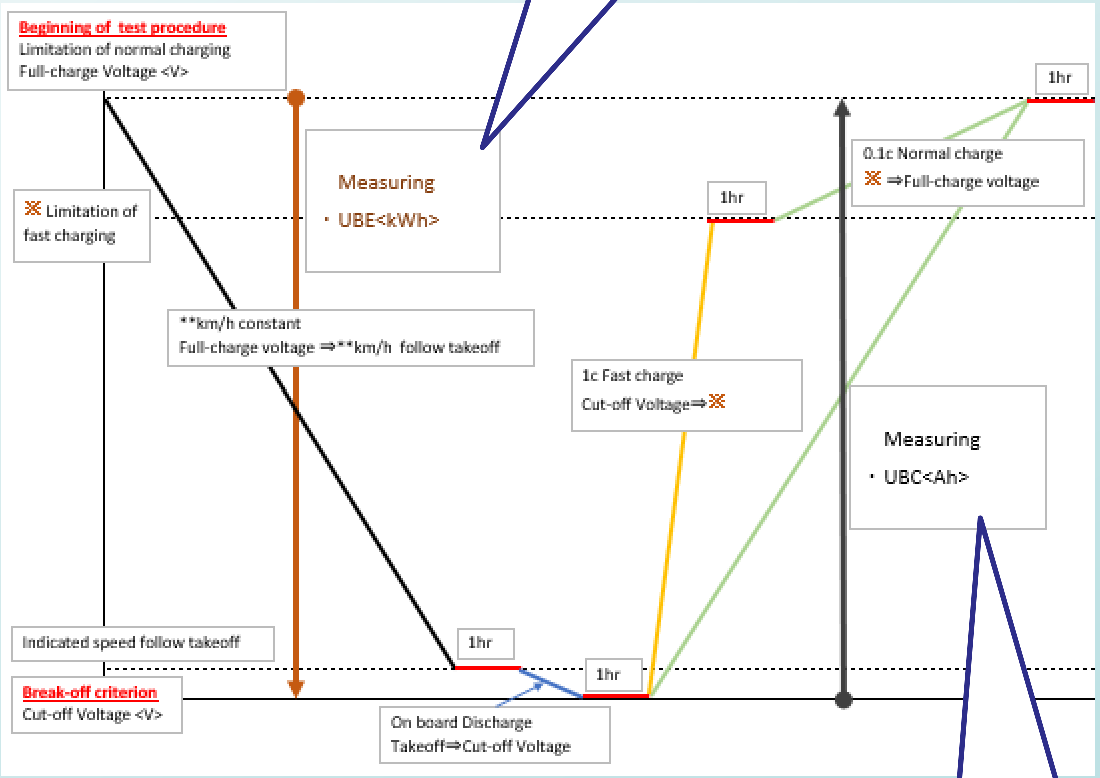
Image of Method 1a

CP favorite?



OICA proposal

Regarding JRC table

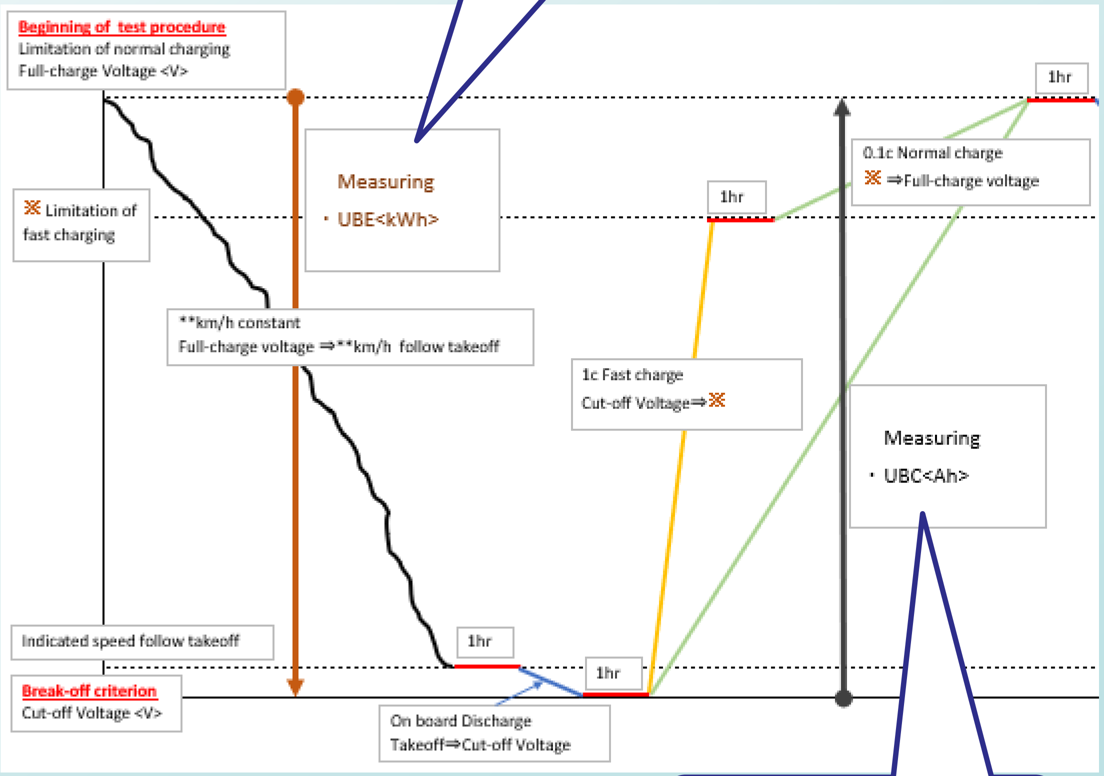
The JRC table for the 64th EVE Meeting is shown on the below.

Alternative methods for checking Battery Durability Monitor for HDV					
	HDV with no bidirectional charging				HDV with bidirectional charging
	Method 1a	Method 1b	Method 1c	Method 1d	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	Discharge with on-board systems And charge	Standard charging Discharging by any method (not measured)	Virtual Round Trip Efficiency (VRTE) test Charging and discharging in a column
Repeatable	Yes	Partly, if tolerances are set	Poter... but n... characterist...		Yes
C-rate	Constant (different for categories)	Varying but limits could be set	Small and difficult to control	to be set also in this case	Constant
RTE	YES	YES	YES	NO	YES
UBE	Yes	Yes, but it depends on the driving	Yes	Not meaningful Not measured	Yes
UBC	Yes	Yes	Yes	Yes but issues with current leaking	Yes
Alternative Method	HDV Dyno testing with similar driving characteristics				

Delete at 64[th] EVE-IWG

Image of Method 1b

CP favorite?



OICA proposal

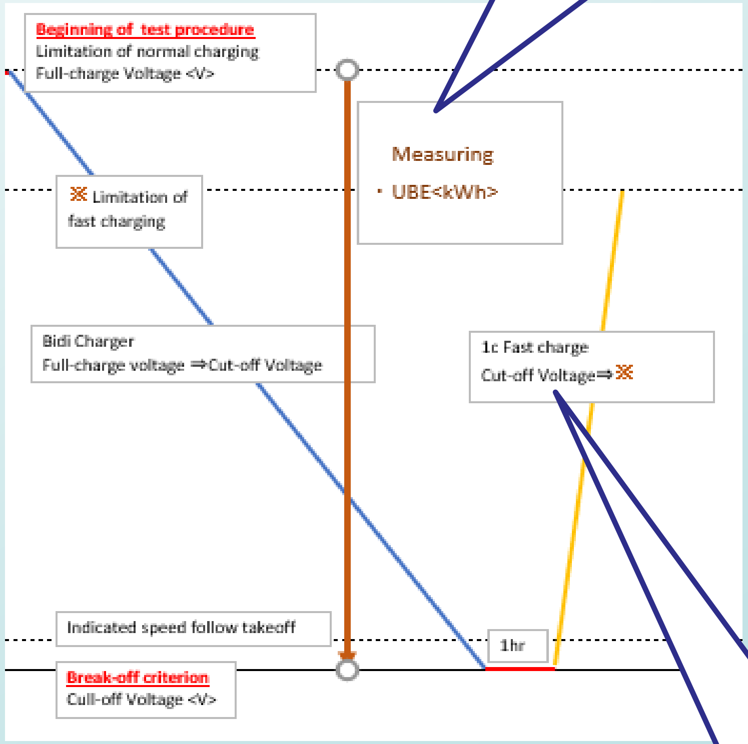
Regarding JRC table

The JRC table for the 64th EVE Meeting is shown on the below.

Alternative methods for checking Battery Durability Monitor for HDV					
	HDV with no bidirectional charging				HDV with bidirectional charging
	Method 1a	Method 1b	Method 1c	Method 1d	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	Discharge with on-board systems And charg	Standard charging Discharging by any method (not measured)	Virtual Round Trip Efficiency (VRTE) test Charging and discharging in a column
Repeatable	Yes	Partly, if tolerances are set	Poter but n characterist		Yes
C-rate	Constant (different for categories)	Varying but limits could be set	Small and difficult to control	to be set also in this case	Constant
RTE	YES	YES	YES	NO	YES
UBE	Yes	Yes, but it depends on the driving	Yes	Not meaningful Not measured	Yes
UBC	Yes	Yes	Yes	Yes but issues with current leaking	Yes
Alternative Method	HDV Dyno testing with similar driving characteristics				

Delete at 64th EVE-IWG

Image of Method 2



CP & OICA agree

It doesn't need to be a VRTE.