HDV Battery Durability

57th EVE Meeting,

Brussels, September 22nd 2022

Disclaimer

- Intention is to adapt pascar GTR22 two step battery durability monitoring to be suitable for heavy duty vehicles
- Reasons for required adaption:
  - Higher diversity of vehicle types and configurations
  - HDV certification based on component testing, creating challenges for in service checks of batteries
- The following slides do not intend to exclude any further possible solutions
- Differentiation between HDV and LCV-segment may be necessary and is highlighted in the following deck

Elements of passcar GTR suitable for HDV with adaptions

- **Part A: Verification of on board SoH monitor**
  - Physical test of small number of vehicles per family
  - Definition of reference test @BoL required
  - Reference cycle conducted in same manner as in-service check of on-board monitor

- **Part B: Reporting of on-board SoH monitors**
  - Check against MPR
  - Vehicle sampling logic as in GTR22, size to be adapted to HDV
  - Vehicles that have undergone unusual use to be excluded to a certain extend
  - Vehicle samples should reflect normal operation pattern

HDV BD procedure combined approach

1. Reference Certification (Type Approval) — BoL
2. HDV adapted GTR 22 Part A — In-service
3. HDV adapted GTR 22 Part B — In-service

1) Begin of Life (BoL) test as reference for in-service verification
2) In-service verification for monitor accuracy
   i. 1) and 2) must be performed in the same manner to safeguard comparability
   ii. Different measurement principles to be discussed
3) Vehicle sampling logic as in GTR22, size to be adapted to HDV

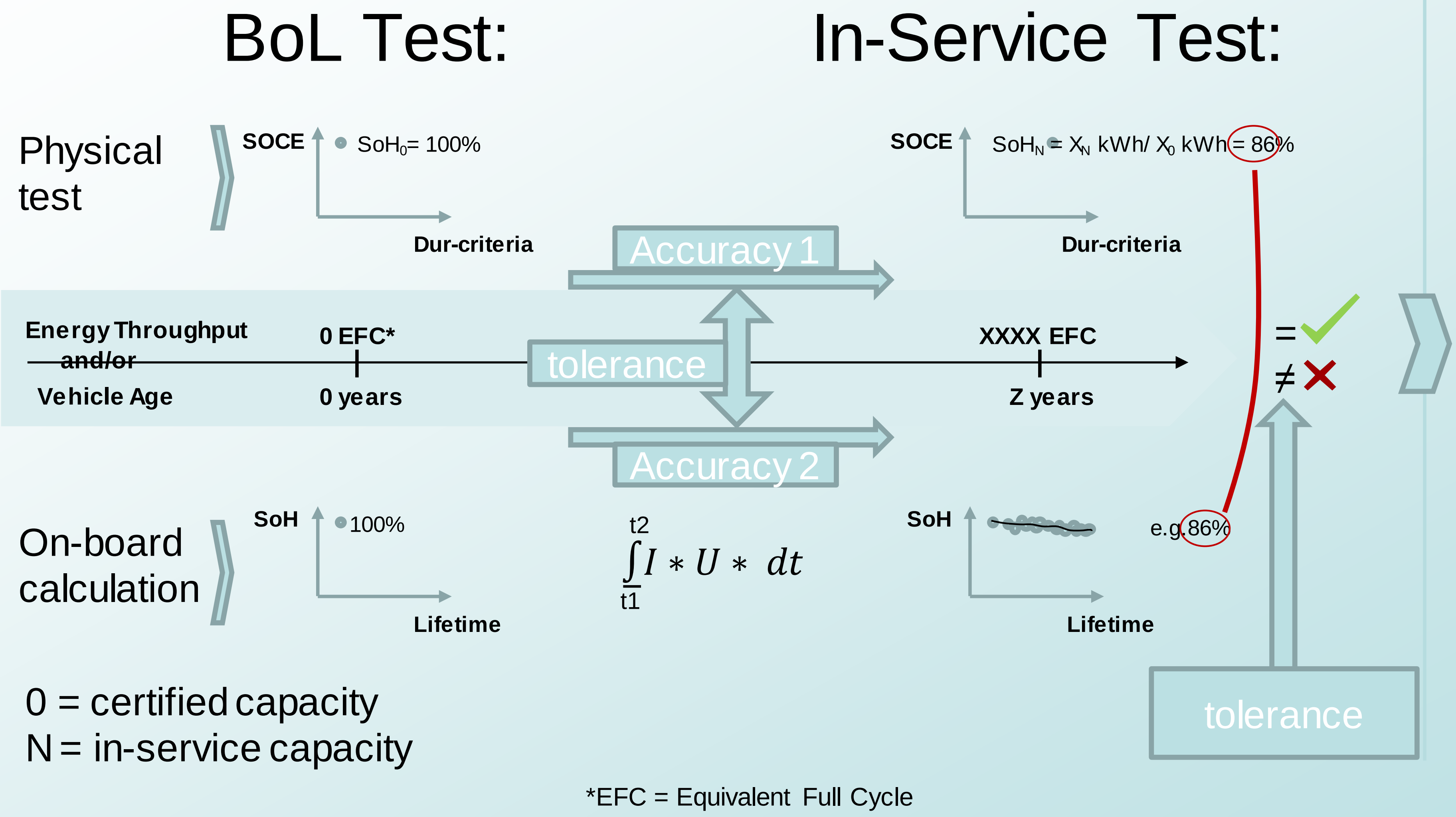
SoH definition for HDV adapation

- SOCR and any reference to range to be omitted as not meaningful for HDV application due wide variety of HDV application profiles.
- SOCE to be kept but new quality threshold of battery (MPR) to be defined on the basis of SOCE.

Proposal MPR:

- Assessment of MPR after a defined counter, which takes battery size into account:
- $\frac{total\ cycled\ energy}{UBE_{certified}} = number\ of\ full\ cycles$ or a certain vehicle age.
- This new counter should be used as a parameter, not as a minimum performance requirement.
- In first phase for defining MPR for SOCE based upon “Total cycled energy” counter or vehicle age should be a monitoring phase.

Part A: Testing procedure & values



Comments

- UBE check via physical test
- SOCE compares kWh withdrawable from battery with value at BoL
- On board SoH monitor checking SoH during vehicle life
- Comparison of SoCE with SOCE status at BoL

Different possibilities for certification and in-service testing of HDV and LCV

Options / Testing	Charge/Discharge test	Chassis-Dynamometer LCV segment[1] only	Battery System testbench	Any other…
Reference test	+ Simple/low effort - Limited power level Total vehicle coverage to be evaluated	+ No limitation of discharge power level + Chassis dyno already established for light duty (in GTR 22) - Additional test procedure for determination of reference value (during type approval)	• Due to complexity and lack of accuracy when dissembling single packs or whole systems and reassamble with virtual vehicle control, OICA came to the conclusion to not consider it as a technical feasible procedure	However, industry continues to develop a universally valid test procedure. Our target is to present results during next IWG EVE.
In-Service test	+ Simple/low effort - Limited power level	+ No fundamental impact on customer vehicles + Vehicle/ Battery operated as customer experience - Need of chassis dyno for ISC testing		

1) No option for heavy duty due to feasibility and availability

Power fade

At this stage there is a lack of knowledge in the field of power fade issues to warrant request for periodical testing.

- Any eventual power fade is mainly related to warranty between OEMs and customers on vehicle performance according to the application.
- Measurement difficulty are present for battery installation power fade due to being a high-powered system.
- Derating of electric machine and or power electronics might prevent exact battery power measurement.
- Potential power fade test of the battery in the vehicle would result in using higher C-rates normally claimed by the vehicle installed powertrain.

At this stage it's unclear whether traction or battery power fade are to be regulated.

Backup

Methods for battery in field aging determination

Constraints

- Measurement shall produce accurate, reproducible results
- Impact of in service test on customer shall be kept as low as possible
- Special equipment could be used for testing, since only a limited number of tests have to be performed in field

Solution strategy

	Battery testbench	Bidirectionalcharger	Road driving
No vehicle disassembly to reduce impact on customer		✓	✓
Minimize wear and risk of damaging	✓	✓	
Controled environment to get reproducible results	✓	✓	

Suggestions:

A test pulse (full charge/discharge cycle) should be applied via charging port. This can be done with a bidirectional charging unit.

Proposed test cycle

Preconditioning
- Charge battery to > 90 %
- Bring vehicle to test temperature

Charging
- Fully charge battery according to operating limits
- Sleep duration of e.g. 1h after automatic power down

Discharging
- Discharge with constant power
- Derating determines end of discharge
- Sleep duration of e.g. 1h after end of discharge

Charging
- Fully charge battery according to operating limits

Suggestions:

- Test temperature should be between 15 and 25 °C in order to reduce testing effort
- Charging should be done without any special measures to achieve good comparability with field operation
- Few vehicle tests inside of boundary conditions should represent fleet

Measured values

The following values could be derived from testing data:

- Total usable energy at constant power
- Full cycle efficiency
- Accuracy of remaining energy prediction
- Battery reference capacity (assumption: single cell voltages and OCV curves are available)
- Accuracy of SoH determined by BMS

The more accurate BMS SoH is, the lower the number of vehicle tests needed to judge field behavior may be.

Boundary conditions that qualify vehicle for testing:

- **Cell temperature** normally distributed with average temperature at Y°C and variance <Z
- **Average SoC** normally distributed with average value Y*% and variance <Z*
- **Depth of discharge (DoD):** share of cycles with DoD >Y**% must be below Z**%

Y,Y*,Y**; Z,Z*,Z** = values of variables tbd.

Constraints

- Measurement shall produce accurate, reproducible results (begin of life vs. in-service)
- Impact of in service test on customer shall be kept as low as possible
- Special equipment could be used for testing, allowing for designated test method
- Should be technology open
- Transition to other legislations (concerning batteries) shall be possible

Solution strategy

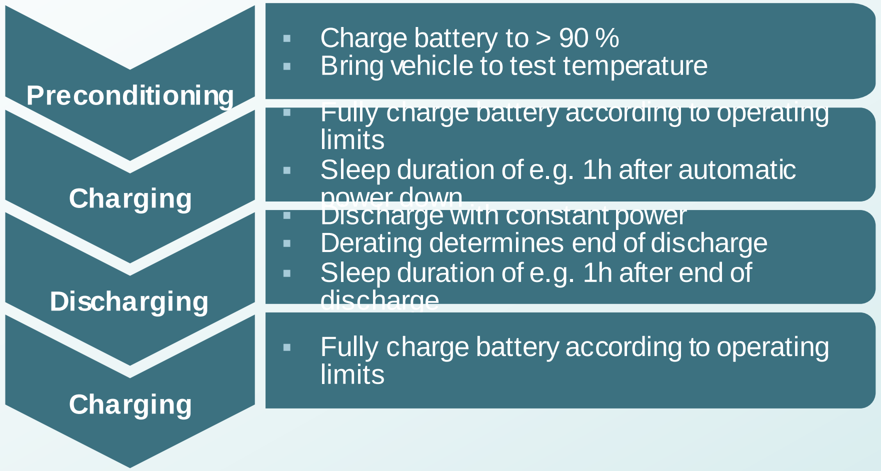
	Battery testbench	Bidirection alcharger	Road driving
No vehicle disassembly to reduce impact on customer		✓	✓
Minimize wear and risk of damaging	✓	✓	
Controled environment to get reproducible results	✓	✓	

Suggestions:

A test pulse (full charge/discharge cycle) should be applied via charging port. This can be done with a bidirectional charging unit.

- Test to be done on vehicle level
- Keep it simple and sound
- No disassembling
- Full system testing only (not on battery pack level)
- Differentiation between High Power and High energy batteries and SOC-windows -> C-Rates for discharging / charging vs. on-board strategy or certain standard (which is to our knowledge not existing yet)
- Proposal: following charge and discharge rates from BMS/vehicle control while procedure within SOC-window

Proposed test cycle



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- The following values could be derived from testing data:
  - Total usable energy at constant power
  - Full cycle efficiency
  - Accuracy of remaining energy prediction
  - Battery reference capacity (assumption: single cell voltages and OCV curves are available)
  - Accuracy of SoH determined by BMS and equipment dependend

The more accurate BMS SoH is, the lower the number of vehicle tests needed to judge field behavior may be. (dependent on the final procedure)

Transferability to other regulations

- E.g. overtake of aging percentage evaluated on system level within the vehicle and apply it to EU 2017/2400 VECTO pack level
- Parallel and serial circiutry shall be same from ISC vehicle family and VECTO vehicle battery setup
- Evaluated ratio between BoL and MoL/EoL capacity could be compared to VECTO ratio

Compliance conditions

- **Indicator: SOCE on UBE basis** after a certain amount of years or energy throughput (in MWh provided by the battery)
  - Years vs. Range or in combination
  - Utilization factor (moving vs. Not)
- Tests of only a few vehicles inside of boundary conditions should represent fleet to limit testing burden for OEM/customers → **family concept**
- Certain vehicle classes / families for which certain CC apply

- **Bidirectional charging station** (ability to charge and discharge) to be used for HDV battery capacity retention test (external equipment may still be necessary)

Example: Passenger car GTR batt. durability

- Warranty analysis US EPA & TEMA model → MPR values and test timing
- OEMs can declare DPR (declared performance requirement) instead of MPR
- Two part in-use verification process, with Part A verifying the accuracy of the monitors and Part B verifying the battery durability against MPR.
  - Part A:
    - Testing of min. 3 vehicles → evaluates the average of the ratios of measured/on-board-indicated SOCE/SOCR from a series of vehicles tested.
    - Pass or additional test → deviation of A = 1+ tolerance (5% granted for single test)
    - Small number of vehicles → Avoid abnormal use by vehicle survey (Annex 1)
  - Part B:
    - remote collection of the on-board SOCE/SOCR values to verify battery durability
    - Abnormal use:
      - make the overall pass decision dependent on more than or equal to 90 per cent of monitor values read from the vehicle sample being above the MPR.
      - 5 per cent of the values taken from smaller durability families that consist of less than 500 vehicles may be excluded from the verification sample in Part B with appropriate reasoning.
  - Families: Monitor Family (Part A) – 1 test for similar monitors for different regions

Power test

- Arguments against general power test:
  - Power normally modulated by OEM over lifetime
  - Constant power for power focused batteries – test could be meaningful