Range Measurement Procedure for PEV

Different test/estimation methods: Present situation

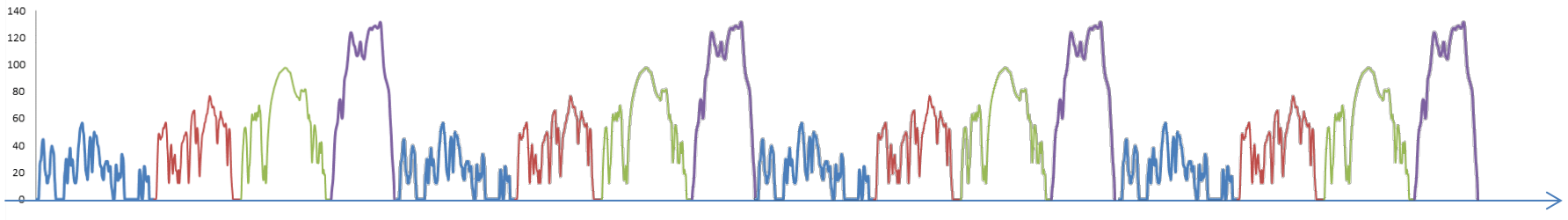
	1 Consecutive WLTC cycle test (Present GTR draft)	2 Each Phase Result calculation	3 Shortening of range test procedure
Status	Accepted	• Under discussion	• Under discussion
Test procedure	• Drive complete WLTC drive cycle (L+M+H+XH)	• Not specific test procedure • Only calculation based on consecutive WLTCs.	• Multiple Cycle Test procedure (combination of WLTC drive cycle and Constant Speed Cycle)
Range & consumption complete WLTC cycle	• Measured	• NA	• Estimated by calculation?
Range & energy consumption value for each phase	• Not measured	• Estimated by calculation	• Estimated by calculation
Validation	• WLTP Validation phase 2	• Partial validation • Low & high value analysis missing	• Partial validation • Low & high value analysis missing • The validation has to be compared to consecutive WLTCs, not to SCT (single cycle test).

2 Each Phase Result calculation : Introduction

Purpose: Estimate the range & energy consumption value for each phase

- Only the complete driven phase is considered for range estimation
- Obligation to measure DC energy (current + voltage) for each phase
- Usable Battery Energy (UBE) is measured until the test termination criteria because UBE means the capacity of dischargeable energy.

2 Each Phase Result calculation : Method – Example of Low phase cycle



$E_{dc.L1}$	$E_{dc.M1}$	$E_{dc.H1}$	$E_{dc.X1}$	$E_{dc.L2}$	$E_{dc.M2}$	$E_{dc.H2}$	$E_{dc.X2}$	$E_{dc.L3}$	$E_{dc.M3}$	$E_{dc.H3}$	$E_{dc.X3}$	$E_{dc.L4}$	$E_{dc.M4}$	$E_{dc.H4}$	$E_{dc.X4}$
R_{L1}	R_{M1}	R_{H1}	R_{X1}	R_{L2}	R_{M2}	R_{H2}	R_{X2}	R_{L3}	R_{M3}	R_{H3}	R_{X3}	R_{L4}	R_{M4}	R_{H4}	R_{X4}
$ECR_{L1} = \frac{R_{L1}}{E_{dc.L1}}$	$ECR_{M1} = \frac{R_{M1}}{E_{dc.M1}}$	$ECR_{H1} = \frac{R_{H1}}{E_{dc.H1}}$	$ECR_{X1} = \frac{R_{X1}}{E_{dc.X1}}$	$ECR_{L2} = \frac{R_{L2}}{E_{dc.L2}}$	$ECR_{M2} = \frac{R_{M2}}{E_{dc.M2}}$	$ECR_{H2} = \frac{R_{H2}}{E_{dc.H2}}$	$ECR_{X2} = \frac{R_{X2}}{E_{dc.X2}}$	$ECR_{L3} = \frac{R_{L3}}{E_{dc.L3}}$	$ECR_{M3} = \frac{R_{M3}}{E_{dc.M3}}$	$ECR_{H3} = \frac{R_{H3}}{E_{dc.H3}}$	$ECR_{X3} = \frac{R_{X3}}{E_{dc.X3}}$	$ECR_{L4} = \frac{R_{L4}}{E_{dc.L4}}$	$ECR_{M4} = \frac{R_{M4}}{E_{dc.M4}}$	$ECR_{H4} = \frac{R_{H4}}{E_{dc.H4}}$	$ECR_{X4} = \frac{R_{X4}}{E_{dc.X4}}$

$E_{dc.mN}$ Total discharge energy [**kWh**]
R_{mN} Driven distance [**km**]
ECR_{mN} Energy Consumption Ratio [**km/kWh**]
UBE Usable Battery Energy from begging to end of test criteria [kWh]

$$Range_{Low} = UBE \times \frac{\sum_{i=0}^{N_{Low}} ECR_{Low.i}}{N_L}$$

2 Each Phase Result calculation : Questions/comments

- It will be difficult to measure the voltage (safety issues)
  ⇒ Is it possible to use the on-board data for ‘current’ & ‘voltage’ information ?

- This method is needing some validation (by real test or simulation)
  ⇒ The validation data - provided by Japan - seem incomplete
    - because the validation result ACEA received from Japan compares the single cycle test (SCT) and the multi cycle test (MCT).
    - Additionally the comparison to consecutive WLTCs is necessary!

- We have to think about the low voltage measurement requirement.

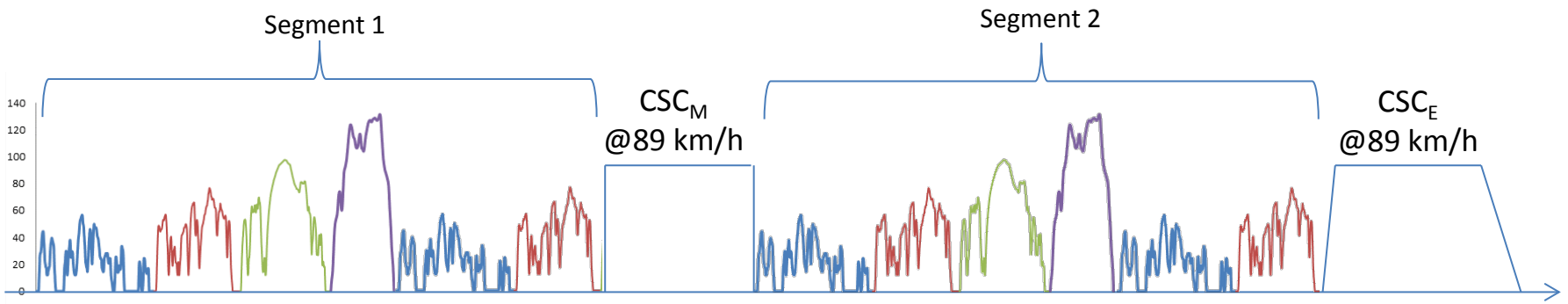
3 Shortening of test procedure : Introduction

- Purpose:
  - Reduction of the range test procedure
  - as well as providing the range & energy consumption value for each phase.

- The multiple cycle test (MCT) consist of 4 parts
  1. ‘Segment 1’-Dynamic drive cycle (L-M-H-XH-L-M) :
  - To quantify the performance associated with WLTC drive cycle at high value of SOC
  2. Constant Speed Cycle-mid (CSCm): @89km/h(55mph) same as SAE J1634
  - Required to ensure that ‘segment 2’ is conducted at a “substantially” lower SOC condition than ‘segment 1’
  - Travelled distance is based on ‘good engineering judgment’
  3. ‘Segment 2’-Dynamic drive cycle (L-M-H-XH-L-M) :
  - To quantify the performance associated with WLTC drive cycle at low value of SOC
  4. Constant Speed Cycle-end(CSCe):
  - Reduce test duration by depleting the battery more rapidly than the established certification drive schedules
  - Prevent inconsistent triggering of end of test criteria that can occur at high power-demand points when a PEV is following a dynamic drive schedule at low states-of-charge.

- Phase Scaling Factors :
  - the phase scaling factors determine the contribution of each phase’s energy consumption value to the total energy consumption for a given drive cycle type.

3 Shortening of test procedure: Method



$E_{dc.L11}$	$E_{dc.M11}$	$E_{dc.H11}$	$E_{dc.X11}$	$E_{dc.L12}$	$E_{dc.M12}$
D_{L11}	D_{M11}	D_{H11}	D_{X11}	D_{L12}	D_{M12}
$EC_{dcL11} = \frac{E_{dc.L11}}{D_{L11}}$	$EC_{dcM11} = \frac{E_{dc.M11}}{D_{M11}}$	$EC_{dcH11} = \frac{E_{dc.H11}}{D_{H11}}$	$EC_{dcL11} = \frac{E_{dc.X11}}{D_{X11}}$	$EC_{dcL11} = \frac{E_{dc.L11}}{D_{L11}}$	$EC_{dcL11} = \frac{E_{dc.L11}}{D_{L11}}$
$K_{L11} = \frac{E_{dc.L11}}{UBE}$	$K_{M11} = \frac{E_{dc.M11}}{UBE}$	$K_{H11} = \frac{1}{2}$	$K_{X11} = \frac{1}{2}$	$K_{L12} = \frac{1 - K_{L11}}{3}$	$K_{M12} = \frac{1 - K_{M11}}{3}$

$E_{dc.L21}$	$E_{dc.M21}$	$E_{dc.H21}$	$E_{dc.X21}$	$E_{dc.L22}$	$E_{dc.M22}$
D_{L21}	D_{M21}	D_{H21}	D_{X21}	D_{L22}	D_{M22}
$EC_{dcL21} = \frac{E_{dc.L21}}{D_{L21}}$	$EC_{dcM21} = \frac{E_{dc.M21}}{D_{M21}}$	$EC_{dcH21} = \frac{E_{dc.H21}}{D_{H21}}$	$EC_{dcX21} = \frac{E_{dc.X11}}{D_{X21}}$	$EC_{dcL22} = \frac{E_{dc.L22}}{D_{L22}}$	$EC_{dcM22} = \frac{E_{dc.M22}}{D_{M11}}$
$K_{L21} = \frac{1 - K_{L11}}{3}$	$K_{M21} = \frac{1 - K_{M11}}{3}$	$K_{H21} = \frac{1}{2}$	$K_{X21} = \frac{1}{2}$	$K_{L22} = \frac{1 - K_{L11}}{3}$	$K_{M22} = \frac{1 - K_{M11}}{3}$

$E_{dc.mN}$ Total discharge energy of the phase **kWh**
D_{mN} Driven distance **km**
K Phase scalling factor
UBE Amount of Usable Battery Energy from begging to end of test criteria **kWh**

$$EC_{dc.Low} = \sum_{i=0}^{N_{Low}} K_{Low.i} \times EC_{dc.Low.i}$$

$$Range_{Low} = \frac{UBE}{EC_{dc.Low}}$$

3 Shortening of test procedure : Questions/comments

- It will be difficult to measure the voltage (safety issues)
  - ⇒ Is it possible to use the on-board data for 'current' & 'voltage' information?
  - ⇒ Do we need additional requirements for the on board voltage data?

- How to decide the constant speed cycle value ?
  (SAE suggest 89 km/h → but: how to justify for WLTC drive cycle?)
  - ⇒ Possible ACEA Proposal: This constant speed should be decided by the manufacturer.

- On principle we agree on this proposal but this needs to be evaluated on vehicle tests or simulation data.
- In case of validation by using simulation data, the simulation model shall be able to cover a lot of non steady impacts.

A : Japan has already provided validation data and it indicates this method well works for also WLTC.
- ⇒ Data provided by Japan (WLTP-DTP-E-Labproc082) lacks 'low' & 'high' data analysis
- ⇒ There is no correlation between the 'subsequent WLTC cycle range' (GTR test procedure) to the total range obtained from the proposed shorten test procedure.

- Additional low & mid parts are repeated (**L22-M22**).
  It is not clear on why only these two phases are considered and not the high & extra-high phase.
  If this is based on some vehicle data then please share the test/simulation data.

  A : L+M combined data is required for EU needs.
  Calculation formula is just sample, ex-H need to be calculated if CP requires.
  - ⇒ We are not talking about the 'L+M' range value.
  - ⇒ We are asking about the purpose of last 'Low & Mid' cycle.