WLTP:
Specific issues of ‘Pure Electric Vehicle’
Content

- Overview of present discussion on PEV
- ‘All Electric Range’ test: Vehicle not able to follow the cycle
- Combined approach (will be added soon)
- ‘Each phase range estimation’ method:
  - Concept
  - Simulation results
  - Conclusion
- Shortened test procedure:
  - Concept
  - Simulation results (incomplete)
  - Conclusion (incomplete)
Pure Electric vehicle test procedures: Present draft & proposals

Tests required in the present GTR

1] All Electric Range

2] AER City (Low + Mid)

AND / OR

Individual range value may be required

1] Low range

2] Mid range

3] High range

4] Extra high range

Shorten Range test: to reduce the test burden

OR

At this stage we are discussing three types of test procedure/results:

Agreed & confirmed by all

1] All Electric Range => complete WLTC cycle and city cycle (verified during validation phase II)

Under discussion (proposed by Japan)

2] Individual ‘each phase’ range value => Required by Japan, but ACEA wants to avoid extra test burden. Possible to estimate these values by calculation (under discussion)

3] Shortening of range test => This can reduce duration of test (under discussion)
All Electric Range test: Complete cycle tests
Electric Vehicle: Summary

Essai consommation

Essai Autonomie

Autonomie Globale (km)

Conso (wh/km)

State of Charge (SOC)

Essai Autonomie et consommation

Essai Autonomie et consommation ville

All Electric Range (km)

Conso = $\frac{E_{AC}}{AER}$

AER City (km)

Cons City = $\frac{E_{AC}}{AER}$ City
Vehicle not able to follow the drive cycle

- Present GTR draft: Break off criteria is reached when vehicle deviates from prescribed tolerance for 4 seconds or more.
- This may lead to incoherent AER value for low power and capped speed Pure Electric Vehicle
- There are two possible solutions under discussion

Possible solution 1: Based on SAE J1634

- Low powered vehicle & Caped speed vehicle: shall be operated at maximum available power (or full throttle) when the vehicle can not achieve the speed trace within the speed and time tolerance

Possible solution 2: Down scaling

- Low powered vehicle: Down scaling (peak power or 30 minute power)
- Caped speed vehicle: Break off criteria does not apply above the maximum speed of the vehicle
Each phase range estimation
Each phase range estimation: Introduction

- **Test Required in the present GTR**
  - 1] All Electric Range

Range determination on chassis dyno

- 2] AER City (Low + Mid): **Required** in present draft

Individual range value **may be required**

- 1] Low range
- 2] Mid range
- 3] High range
- 4] Extra high range

Range estimation by calculation only

\[
\text{Range}_{\text{Low}} = \text{UBE} \times \frac{\sum_{l=0}^{N_{\text{Low}}-1} \text{ECR}_{\text{Low},l}}{N_{\text{L}}}
\]

- \( E_{\text{ALL,MAX}} \): Total discharge energy [kWh]
- \( R_{\text{MIN}} \): Driven distance [km]
- \( \text{ECR}_{\text{MIN}} \): Energy Consumption Ratio [km/kWh]
- UBE: Usable battery energy from begging to end of test criteria [kWh]
Each Phase Result calculation : Concept

- **Purpose:**
  - Estimate the range & energy consumption value for each phase instead of real test on chassis dyno
  - This calculation method can replace the ‘city range test’ required in the present draft GTR for PEV.

- **Concept:**
  - Complete WLTC cycle range test is performed as required in the present GTR draft
  - Usable Battery Energy (UBE) is measured until the test termination criteria because UBE means the capacity of dischargeable energy.
  - Obligation to measure DC energy (current + voltage) for each phase
  - Only the complete driven phase is considered for range estimation
  - Energy consumption ratio of each phase is calculated and range is determined from UBE and ECR
### Each Phase Result calculation: Method – Example of Low phase cycle

<table>
<thead>
<tr>
<th>Phase</th>
<th>Result Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{dc, L1}$</td>
<td>$E_{dc, M1}$</td>
</tr>
<tr>
<td>$R_{L1}$</td>
<td>$R_{M1}$</td>
</tr>
<tr>
<td>$E_{dc, H1}$</td>
<td>$E_{dc, X1}$</td>
</tr>
<tr>
<td>$E_{dc, L2}$</td>
<td>$R_{L2}$</td>
</tr>
<tr>
<td>$E_{dc, M2}$</td>
<td>$R_{M2}$</td>
</tr>
<tr>
<td>$E_{dc, H2}$</td>
<td>$R_{H2}$</td>
</tr>
<tr>
<td>$E_{dc, X2}$</td>
<td>$E_{dc, L3}$</td>
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<tr>
<td>$E_{dc, M3}$</td>
<td>$R_{M3}$</td>
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<tr>
<td>$E_{dc, H3}$</td>
<td>$R_{H3}$</td>
</tr>
<tr>
<td>$E_{dc, X3}$</td>
<td>$E_{dc, L4}$</td>
</tr>
<tr>
<td>$E_{dc, M4}$</td>
<td>$R_{M4}$</td>
</tr>
<tr>
<td>$E_{dc, H4}$</td>
<td>$R_{H4}$</td>
</tr>
<tr>
<td>$E_{dc, X4}$</td>
<td>$E_{dc, M3}$</td>
</tr>
</tbody>
</table>

**Formula:**

\[
\text{Range}_{Low} = UBE \times \sum_{i=0}^{N_{Low}} \frac{ECR_{Low,i}}{N_L}
\]

- $E_{dc,mN}$: Total discharge energy [kWh]
- $R_{mN}$: Driven distance [km]
- $ECR_{mN}$: Energy Consumption Ratio [km/kWh]
- $UBE$: Usable Battery Energy (DC) from begging to nd of test criteria [kWh]
• The incomplete phase is not considered for calculation.
• In the above example this phase data are not included for calculation of ‘mid phase range’, ‘city cycle range’ and ‘complete WLTC range’.
• But for the ‘Usable Battery Energy’ include this incomplete mid phase.
Each Phase Result calculation : Simulations

- Vehicles: Two different kind of electric vehicles were selected for simulation
  1. Kangoo EV: Utility vehicle, maximum speed of 130 km/h, not able to follow the drive cycle in extra-high phase, SAE J1634 method applied
  2. Zoe: Passenger vehicle, maximum speed of 135 km/h, no problem in following the drive cycle, higher range than Kangoo EV

- Simulation: Following simulations were done one each vehicle for two different mass $T_{M_H}$ & $T_{M_L}$
  1. Range test with sequence L-L-L-L.....
  2. Range test with sequence M-M-M-M.....
  4. Range test with sequence XH-XH-XH-XH.....
  5. Range test with sequence LM-LM-LM-LM.....
  6. Range test with sequence LMHXH-LMHXH-LMHXH-LMHXH.....

- Calculation:
  - As suggested by the proposal, only complete phases were considered for calculation
  - An additional complete WLTC cycle range also calculated to check the overall error margin
Each Phase Result calculation : Kangoo ZE Simulation results

- Test mass Low: 1722 kg

<table>
<thead>
<tr>
<th>Phase</th>
<th>Simulation results</th>
<th>Phase based calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>223,6</td>
<td>224,8</td>
</tr>
<tr>
<td>Mid</td>
<td>203,9</td>
<td>203,9</td>
</tr>
<tr>
<td>High</td>
<td>159,5</td>
<td>160,4</td>
</tr>
<tr>
<td>xhigh</td>
<td>100,6</td>
<td>100,1</td>
</tr>
<tr>
<td>L+M</td>
<td>121,6</td>
<td>121,6</td>
</tr>
<tr>
<td>H+X</td>
<td>143,7</td>
<td>141,9</td>
</tr>
<tr>
<td>WLTC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[\Delta \% \] 0.52\% -0.01\% -0.53\% 0.50\% 0.35\% -1.21\%

- Test mass High: 1939 kg

<table>
<thead>
<tr>
<th>Phase</th>
<th>Simulation results</th>
<th>Phase based calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>210,8</td>
<td>211,5</td>
</tr>
<tr>
<td>Mid</td>
<td>194,4</td>
<td>195,5</td>
</tr>
<tr>
<td>High</td>
<td>156,1</td>
<td>155,9</td>
</tr>
<tr>
<td>xhigh</td>
<td>99,9</td>
<td>99,9</td>
</tr>
<tr>
<td>L+M</td>
<td>200,8</td>
<td>201,5</td>
</tr>
<tr>
<td>H+X</td>
<td>119,9</td>
<td>137,4</td>
</tr>
<tr>
<td>WLTC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[\Delta \% \] 0.34\% 0.55\% -0.12\% 0.58\% 0.33\% 1.08\%

- Simulation results shows that the ‘proposed phase based calculation’ has an error margin of <0.5% for ‘City range’ calculation
- To verify the method we calculate the complete WLTC cycle range with proposed method and we found the error margin to be around 1%
Each Phase Result calculation: Zoe Simulation results

- Test mass Low: 1593 kg

- Test mass High: 1674 kg

Simulation results show that the 'proposed phase based calculation' has an error margin of <0.5% for 'City range' calculation.

To verify the method, we calculate the complete WLTC cycle range with the proposed method and we found the error margin to be <1%.
Each Phase Result calculation: Conclusion

- The simulation results of two different test mass shows that the range of each phase can be estimated by the proposed method with acceptable error margin (≈0.5% ; max ≈1 km)
- Simulation on Kangoo ZE shows that this proposed method can even work well on vehicle which can not follow the drive cycle
- The incomplete phase should not be included in the range calculation
- The city range (L+M) test required in the GTR draft can be replaced by phase based calculation
- The proposed method can also provide result of ‘Low+Mid+High’ range (required in other non-EU countries) results from a single complete WLTC cycle range
Shortening of test procedure
3 Shortening of range test

- Measurement on a Multiple Cycle Test
- All required range estimation by calculation only

Individual range value may be required

1] Low range

2] Mid range

3] High range

4] Extra high range

Test Required in the present GTR

1] All Electric Range

2] AER City (Low + Mid): Required in present draft
Shortening of test procedure: Introduction

- Purpose: Reduce the range test procedure as well as provide 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): @97km/h (65mph) same as SAE J1634
     - Required to ensure that ‘segment 2’ is conducted at a “substantially” lower SOC condition than ‘segment 1’
     - Distance traveled 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.

- The obtained DC energy value can be converted to AC energy (grid energy) by using the RAF.
### Shortening of test procedure: Method

**Segment 1**

- $E_{dc.L1} = E_{dc.M11} = E_{dc.H11} = E_{dc.X11} = E_{dc.L12} = E_{dc.M12}$
- $D_{L11} = D_{M11} = D_{H11} = D_{X11} = D_{L12} = D_{M12}$
- $EC_{dc.L1} = \frac{E_{dc.M11}}{E_{dc.L11}} = \frac{E_{dc.M11}}{D_{M11}} = \frac{E_{dc.H11}}{E_{dc.L11}} = \frac{E_{dc.H11}}{D_{H11}} = \frac{E_{dc.X11}}{E_{dc.L11}} = \frac{E_{dc.X11}}{D_{X11}} = \frac{E_{dc.L11}}{E_{dc.L11}} = \frac{E_{dc.L11}}{D_{L11}}$
- $K_{L11} = \frac{E_{dc.M11}}{UBE} = \frac{1}{2}$
- $K_{H11} = \frac{1}{2}$
- $K_{X11} = \frac{1 - K_{L11}}{3}$
- $K_{L12} = \frac{1}{2}$
- $K_{M12} = \frac{1 - K_{M11}}{3}$

**Segment 2**

- $E_{dc.L21} = E_{dc.M21} = E_{dc.H21} = E_{dc.X21} = E_{dc.L22} = E_{dc.M22}$
- $D_{L21} = D_{M21} = D_{H21} = D_{X21} = D_{L22} = D_{M22}$
- $EC_{dc.L21} = \frac{E_{dc.M21}}{E_{dc.L21}} = \frac{E_{dc.M21}}{D_{M21}} = \frac{E_{dc.H21}}{E_{dc.L21}} = \frac{E_{dc.H21}}{D_{H21}} = \frac{E_{dc.X21}}{E_{dc.L21}} = \frac{E_{dc.X21}}{D_{X21}} = \frac{E_{dc.L21}}{E_{dc.L21}} = \frac{E_{dc.L21}}{D_{L21}}$
- $K_{L21} = \frac{E_{dc.M21}}{UBE} = \frac{1}{2}$
- $K_{M21} = \frac{1}{2}$
- $K_{H21} = \frac{1}{2}$
- $K_{X21} = \frac{1 - K_{L21}}{3}$
- $K_{L22} = \frac{1}{2}$
- $K_{M22} = \frac{1 - K_{M21}}{3}$

**Total discharge energy of the phase $kWh$**

- $E_{dc.mN} = \frac{E_{dc.mN}}{D_{mN}}$

**Driven distance $km$**

- $K$

**Phase scaling factor**

- $UBE$

**Amount of Usable Battery Energy from begging to end of test criteria $kWh$**

\[
E_{dc.Low} = \sum_{i=0}^{N_{Low}} K_{Low,i} \times EC_{dc.Low,i}
\]

\[
Range_{Low} = \frac{UBE}{E_{dc.Low}}
\]
• Vehicles: Two different kind of electric vehicles were selected for simulation

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2. Zoe: Passenger vehicle, maximum speed of 135 km/h, non problem in following the drive cycle, higher range than Kangoo EV

• Simulation: Following simulations were done one each vehicle for two different mass $TM_H$ & $TM_L$

1. Range test with sequence L-L-L-L……
2. Range test with sequence M-M-M-M……
3. Range test with sequence H-H-H-H……
4. Range test with sequence XH-XH-XH-XH……
5. Range test with sequence LM-LM-LM-LM……
6. Range test with sequence LMHXH-LMHXH-LMHXH-LMHXH……
7. Range test with sequence LMHXH-30min@97km/h-LMHXH-CSC@97km/h
Shortening of test procedure: Kangoo ZE Simulation results

- Test mass Low: 1722 kg
- Test mass High: 1939 kg

- Test time reduce from 180 minutes to 140 minutes (-22%)
- The ‘scalling factor’ is not used for ‘city cycle range’ and ‘complete WLTC range’ estimation
Shortening of test procedure: Zoe Simulation results

- Test mass Low: 1593 kg
  - Test time reduce from 230 to 160 min (-31%)
  - The ‘scaling factor’ is not used for ‘city cycle range’ and ‘complete WLTC range’ estimation

- Test mass High: 1674 kg

%∆:

- 0.2%
- 0.4%
- 0.3%
- 2.0%
- -0.6%
- -0.8%

- 0.2%
- 0.4%
- 0.3%
- 2.0%
- -0.6%
- -0.8%

- 0.2%
- 0.3%
- 0.2%
- 1.5%
- -0.5%
- -0.9%
Shortening of test procedure: Conclusion

- The simulation results on Kangoo ZE and Zoe suggest an error margin of <1% for ‘City Range’ and ‘All Electric Range’
- The shortening test method is already accepted in the USA and under discussion in Japan, Brazil
- The city range (L+M) test required in the GTR draft can be replaced by phase based calculation
- The proposed method can also provide result of ‘Low+Mid+High’ range (required in other non-EU countries) results from a single complete WLTC cycle range
- The initial simulation shows that the results from proposed test in the GTR and shortened test procedure gives similar results (2% error margin)
Comments and concerns - STP

ACEA is supporting the Shortening Test Procedure

But:
There is a need of clarification on
• Minimum range above which the method is applicable
• What speed should be applied for the Constant Speed Cycles?
  ➢ Evaluation of the impact of the speed on UBE and the behavior of the battery
    (need of more simulation at different speeds)
  ➢ Real test data (expected from JP tests)
• Duration of CSEm cycle
• Battery behavior (accuracy of the simulation, impact of electro-chemical and thermal effects)
• Acceptable error margin for test results in the evaluation and validation phase