

Nico Schütze, 07.05.2015

PSV FOR OVC-HEV IN CHARGE-DEPLETING.

**BMW
GROUP**



PSV FOR OVC-HEV IN CHARGE-DEPLETING.

PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.

On the way to R_{CDa}

1st step:
$$EC_{AC,p} = \frac{\sum_{j=1}^{n-1} EC_{AC,p,j} \times d_{p,j}}{\sum_{j=1}^{n-1} d_{p,j}}$$

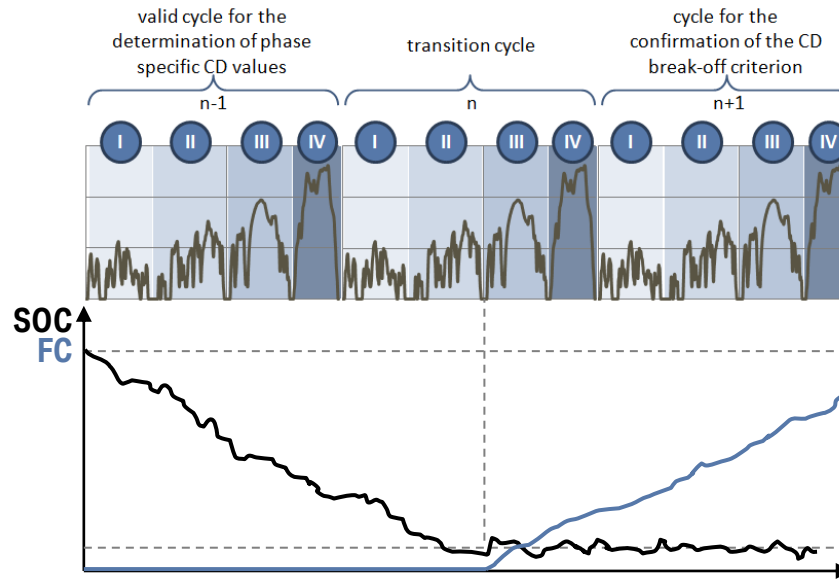
2nd step:
$$R_{CDa,p} = \frac{E_{AC}}{EC_{AC,p}}$$

→ It is very important whether the transient cycle of the test is included or excluded for the calculation of the $EC_{AC,p}$ because it is used for the calculation of the estimated R_{CDa} .

→ If the R_{CDa} is calculated, the “**virtual**” transition cycle of driving consecutive phases (e.g. high...high...high) is of course considered in the background.

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PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.



Interpretation of the example that is illustrated above:

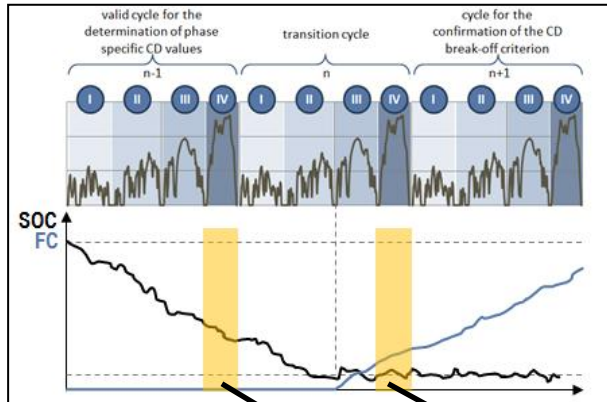
- i. The vehicle is able to drive the 1st cycle and the 2nd low- and mid-phase pure electrically.
- ii. Due to the empty storage in the 2nd high phase the vehicle starts using fuel.
- iii. The 3rd cycle fulfills the CD-break-off criterion, hence the 2nd cycle is the transition cycle.

→ The next page compares the difference between including and excluding the transition cycle for the calculation of the electric energy consumption followed by the calculation of R_{CDa} .

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PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.

Transition cycle is **included**

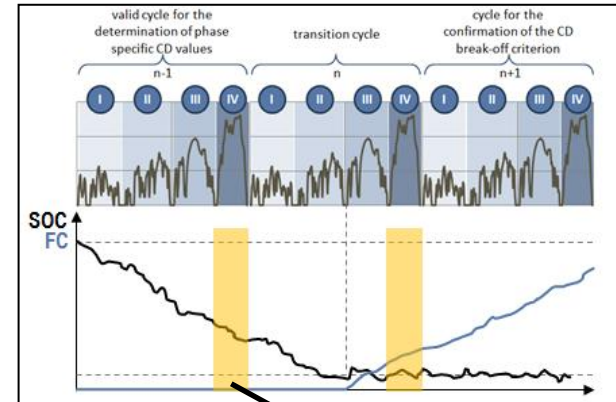


$EC_{AC,ExHigh}$ [Wh/km]	240	-13
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1st step: $EC_{AC,ExHigh} = 114$ Wh/km

2nd step: $R_{CDa,ExHigh} = 53$ km

Transition cycle is **excluded**



$EC_{AC,ExHigh}$ [Wh/km]	240
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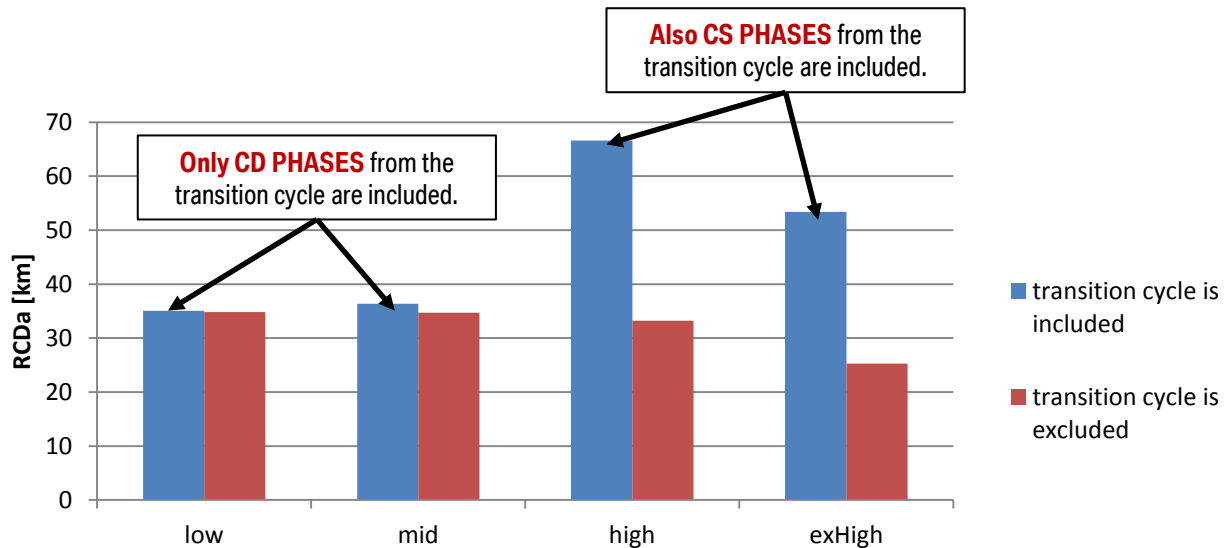
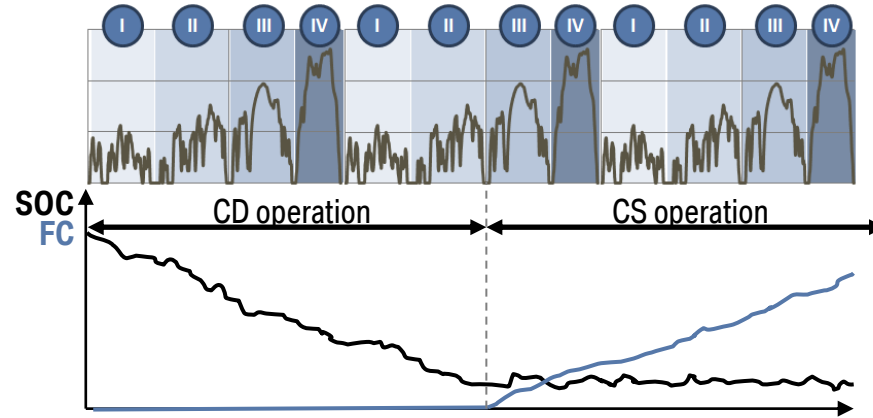
1st step: $EC_{AC,ExHigh} = 240$ Wh/km

2nd step: $R_{CDa,ExHigh} = 25$ km

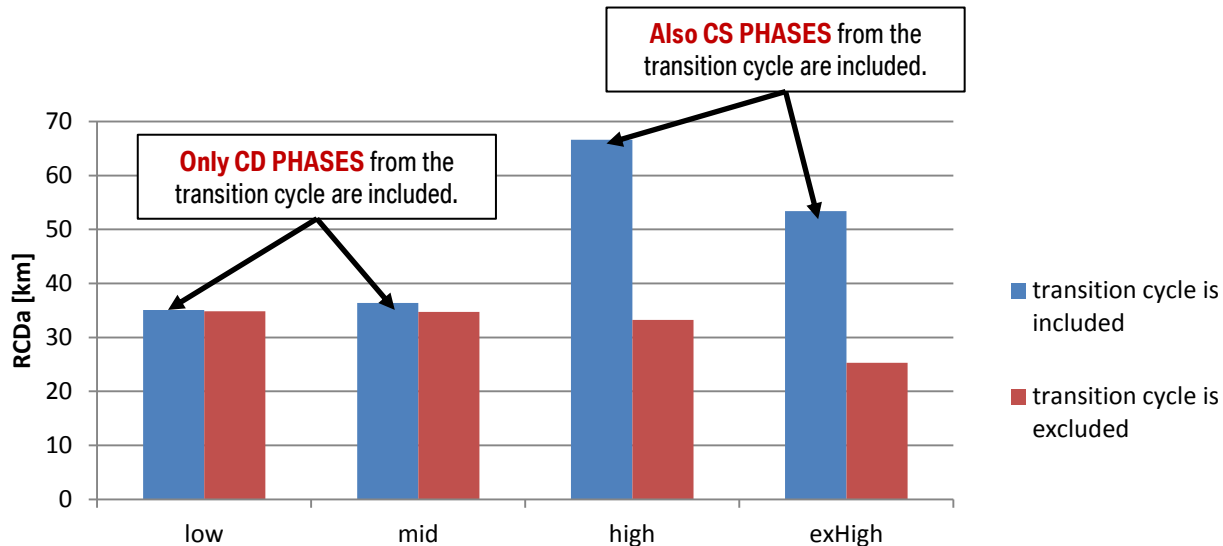
In this case including the transition cycle leads to +112 % actual charge-depleting range.

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PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.



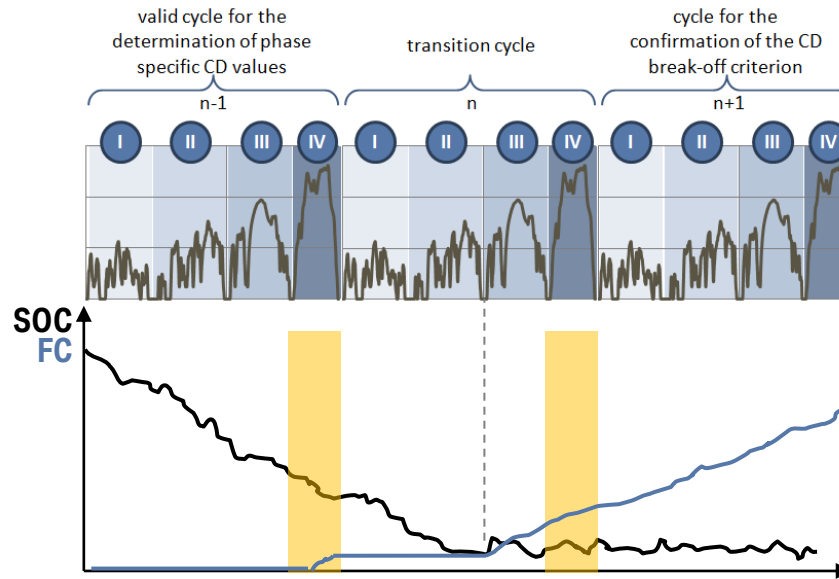
PSV FOR OVC-HEV IN CHARGE-DEPLETING. PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.



Interpretation of the results:

- i. As long as **only CD phases** are included from the transition cycle, the difference between including and excluding the transition cycle is **negligible**.
- ii. As soon as **CS phases** are included, the difference between including and excluding the transition cycle is **non-negligible**. In these cases excluding the transition cycle provides a much more representative R_{CDa} (also for customer information).

PSV FOR OVC-HEV IN CHARGE-DEPLETING. PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.



(Differences can be seen if this page is compared to [page 3](#))

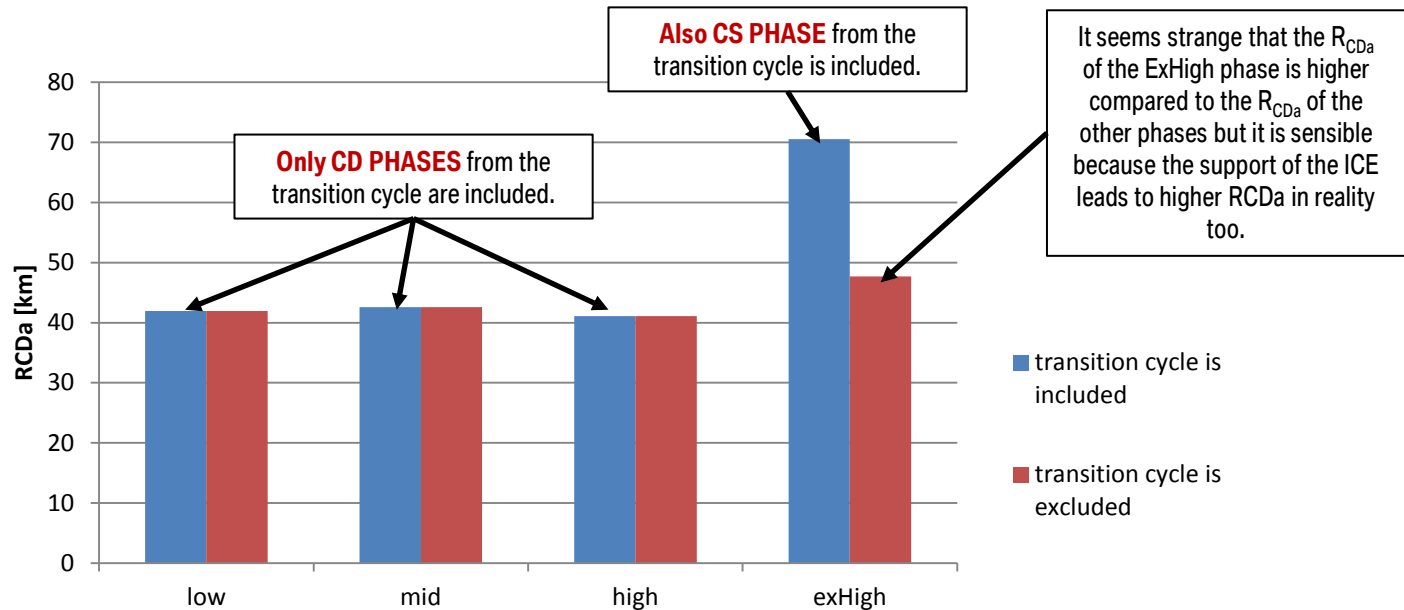
Interpretation of the **second example** that is illustrated above:

- i. The vehicle is able to drive the 1st cycle and the 2nd low- and mid-phase **under charge-depleting conditions. There is a power triggered start of the ICE in the 1st ExHigh phase under charge-depleting conditions.**
- ii. Due to the empty storage in the 2nd high phase the vehicle starts using fuel under charge-sustaining conditions.
- iii. The 3rd cycle fulfills the CD-break-off criterion, hence the 2nd cycle is the transition cycle.

→ The next page compares the difference between including and excluding the transition cycle for the calculation of the electric energy consumption followed by the calculation of R_{CDa} .

PSV FOR OVC-HEV IN CHARGE-DEPLETING.

PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.



Interpretation of the **second example** results:

- i. As long as only CD phases are included from the transition cycle, the difference between including and excluding the transition cycle is negligible.
- ii. As soon as CS phases are included, the difference between including and excluding the transition cycle is non-negligible. In these cases excluding the transition cycle provides a much more representative R_{CDa} (also for customer information).
- iii. The approach that excludes the transition cycle also works for vehicles with power triggered start of the ICE

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SUMMARY & CONCLUSION.

Summary:

- 1) Excluding or including the transition cycle has no impact on the equation (equation stays the same in both cases).
- 2) Excluding the transition cycle avoids the usage of CS phases. The exclusion of CD Phases has a negligible impact on the R_{CDa} .
- 3) Including the transition cycle leads to highly unrepresentative R_{CDa} customer information if CS phases belong to the transition cycle.
- 4) Excluding the transition cycle also works for vehicles with a start of the ICE under charge-depleting conditions.

Conclusion:

The transition cycle should be excluded.

Alternatively to the exclusion of the whole cycle a criterion for the identification of CD phases or the identification of CS phases within the transition cycle is necessary but not available at the moment.

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PROPOSAL FOR R_{CDA} DRAFTING.

x.x.x. Phase specific actual charge-depleting range ($R_{CDA,p}$)

x.x.x.1. The phase specific actual charge-depleting range derived from the charge-depleting type 1 test for vehicles its first cycle is the transition cycle shall be calculated as follows below, if both of the following requirements are fulfilled for the considered phase p:

1.) The CO_2 mass emission of the considered phase is lower than [80] % of the corrected charge-sustaining CO_2 mass emission of the considered phase.

2.) The sum of electric energy change of all REESS of the considered phase is higher than x % of the cycle energy demand of the considered phase.

$$R_{CDA,p} = \frac{E_{AC}}{EC_{AC,p}}$$

where:

$R_{CDA,p}$ is the actual charge depleting range of the considered phase p, km;
 E_{AC} is the recharged electric energy from the mains, Wh;
 $EC_{AC,p}$ is the electric energy consumption of the considered phase p, Wh/km;

and

$$EC_{AC,p} = EC_{DC,p} \times k_{DCAC}$$

where:

$EC_{DC,p}$ is the electric energy consumption of the considered phase p based on the REESS depletion according to ..., Wh/km;

k_{DCAC} is the conversion factor to consider the charging losses to the measured REESS depletion, -;

and

$$k_{DCAC} = \frac{E_{AC}}{\sum_{j=1}^{n_{CD}} \Delta E_{REESS,j}}$$

where:

$\Delta E_{REESS,j}$ is the sum of electric energy changes of all REESS of phase j, Wh;
 n_{CD} is the number of phases driven up to the end the transition cycle n according to....

COMMENT:
Additional criterion
to avoid infinite or
negative R_{CDA} .

PSV FOR OVC-HEV IN CHARGE-DEPLETING.

PROPOSAL FOR R_{CDA} DRAFTING.

x.x.x.2. The phase specific actual charge-depleting range derived from the charge-depleting type 1 test, for vehicles its first cycle is not the transition cycle, shall be calculated as follows:

$$R_{CDA,p} = \frac{E_{AC}}{EC_{AC,p}}$$

where:

$R_{CDA,p}$ is the actual charge depleting range of the considered phase p, km;
 E_{AC} is the recharged electric energy from the mains, Wh;
 $EC_{AC,p}$ is the electric energy consumption of the considered phase p, Wh/km;

and

$$EC_{AC,p} = \frac{\sum_{j=1}^{n-1} EC_{AC,p,j} \times d_{p,j}}{\sum_{j=1}^{n-1} d_{p,j}}$$

COMMENT:
transition cycle is excluded

where:

$EC_{AC,p,j}$ is the electric energy consumption of the considered phase p of cycle j based on the REESS depletion according to ..., Wh/km;
 $d_{p,j}$ is the distance driven in the considered phase p of cycle j, km;
 n is the number of cycles driven up to and including the transition cycle;

and

$$EC_{AC,p,j} = EC_{DC,p,j} \times k_{DCAC}$$

where:

$EC_{DC,p,j}$ is the electric energy consumption of the considered phase p of cycle j based on the REESS depletion according to ..., Wh/km;
 k_{DCAC} is the conversion factor according to...