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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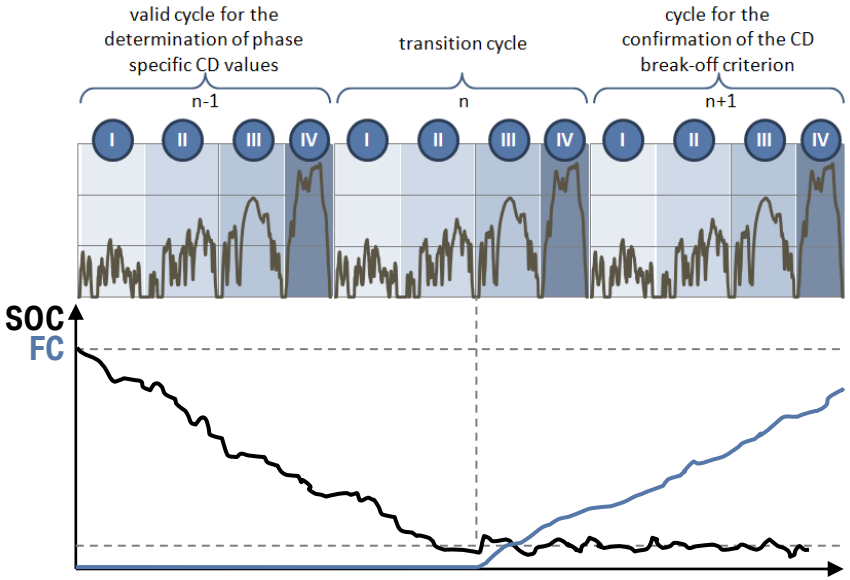
PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.



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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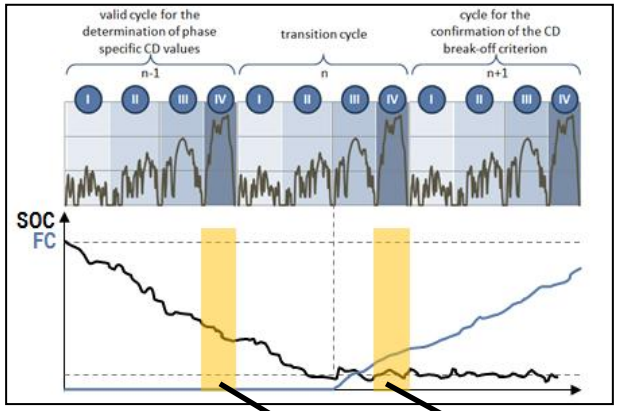
PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.

Transition cycle is included

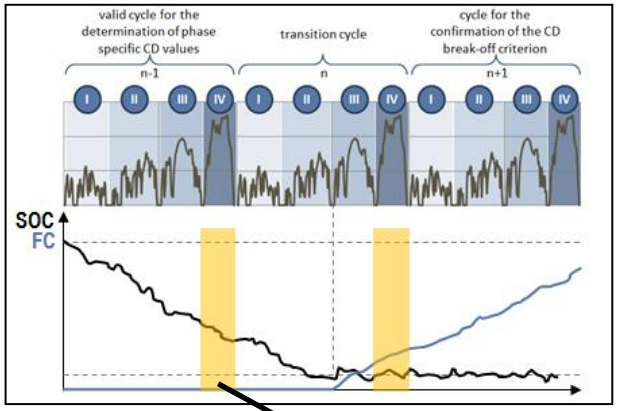


$EC_{AC,ExHigh}$ [Wh/km]	240	-13

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

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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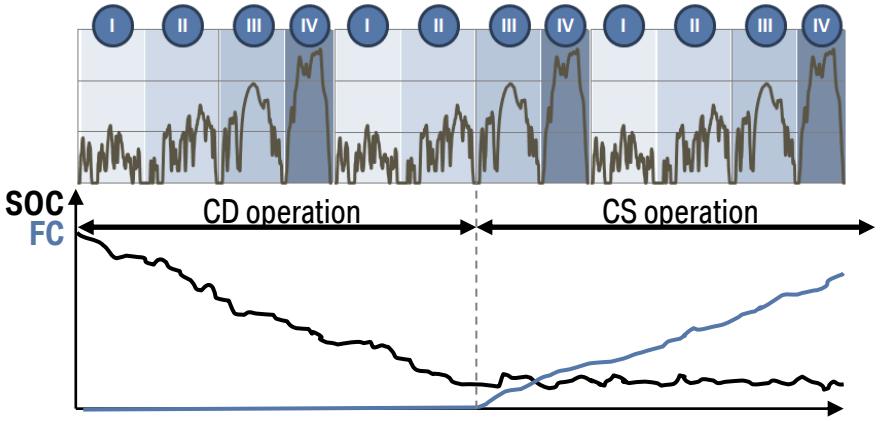
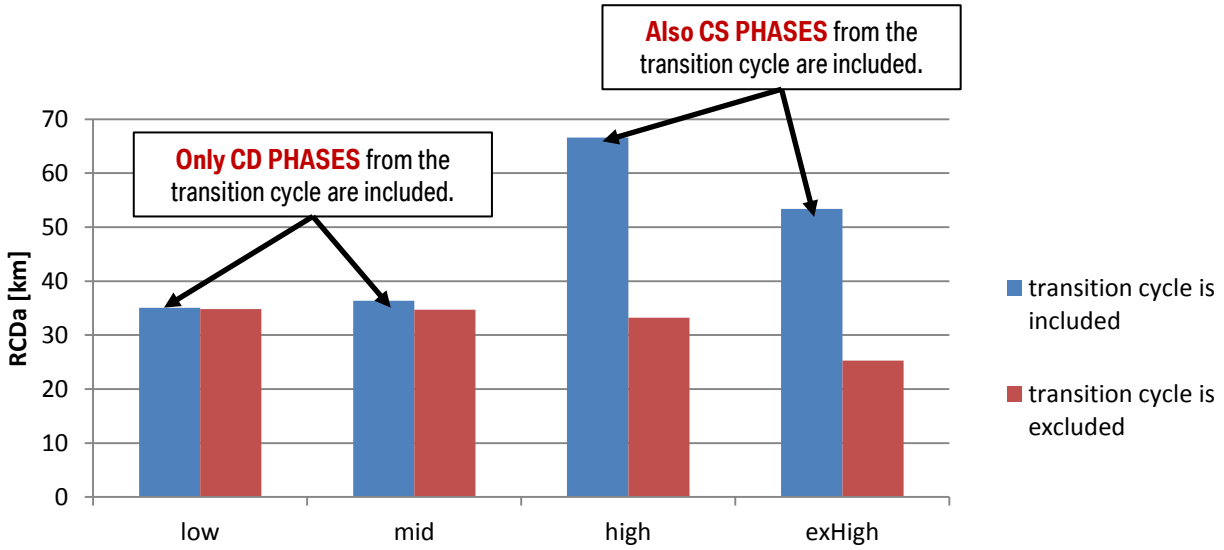
PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.





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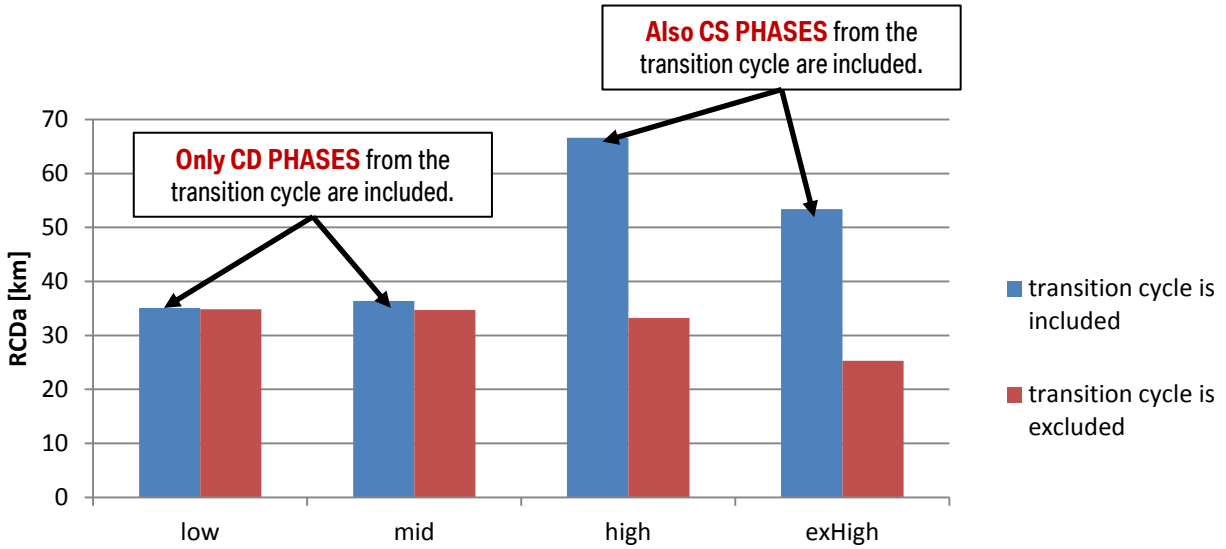
PHASE SPECIFIC ACTUAL CHARGE-DEPLETING RANGE.



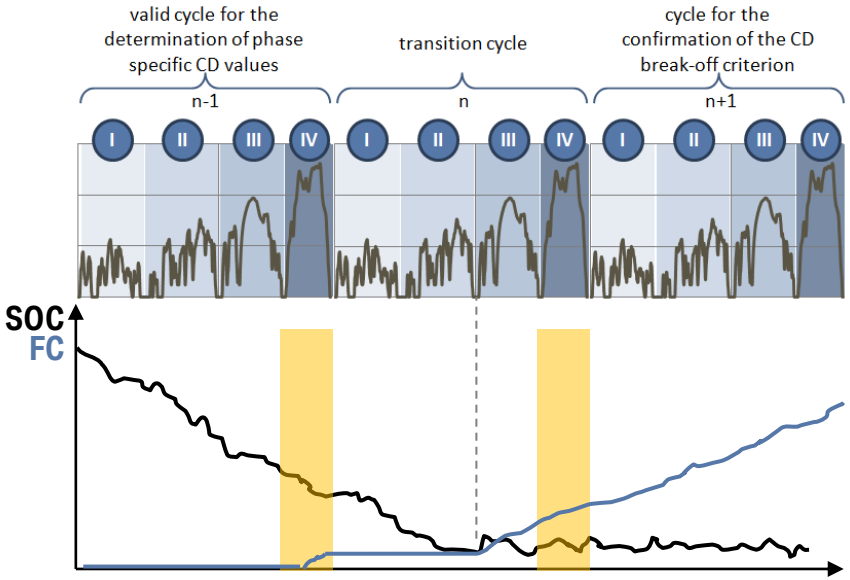
Interpretation of the results:

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)

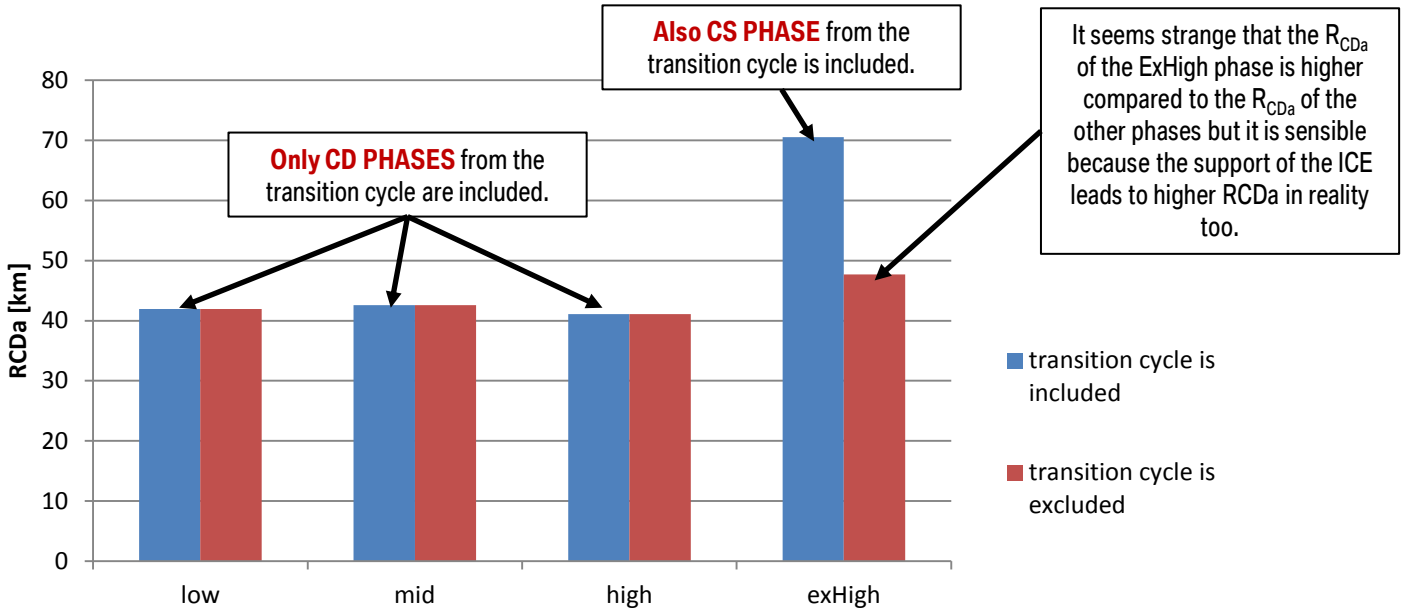
Interpretation of the **second example** that is illustrated above:

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.

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

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

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....

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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...