

Supplements to the Scenarios for HDVs

Emission Limits and Test Conditions

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Stefan Hausberger, Konstantin Weller (TUG)
Markus Ehrly (FEV)
& CLOVE Partners



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- The limit scenarios presented for Diesel (HD2, HD3) and gas (HL2, HC2) do not mean we are proposing different limits per technology!

The values presented show the limits which could be achieved with these technologies as basis for the target:

→ One set of limits applicable for all HDVs shall be compiled from the scenarios

- We applied following margins and factors for the values shown in the AGVES on 08.04.2021:
 - 50% added to emission level achievable by technology in worst case test condition to consider OEM development target needs (typical approach needed to consider serial spread of components, uncertainty if worst case condition is known, approach is already applied today for engineering targets of manufacturers..)
 - Factor 1.4 to convert PN23 test data into PN10 (average from H2020-DTT HD tests)



- The limit values
 - 100 Percentile (1xWHTC work cold)
 - “Budget” (3 x WHTC-work cold)
 - 90 Percentile (1 x WHTC work hot)

can be linked mathematically if it is ensured that the “90 percentile” limit counts only hot windows and the highest window is expected in the cold start phase:

“Budget” = $(1 \times 100 \text{ percentile} + 2 \times 90 \text{ Percentile} * Z) / 3$ (limits in mg/kWh)

Z... ratio of 100 Percentile value to 90 percentile value (= ca. 1.3 depending very much on test cycle)

In the development of the limits, the “Budget” and the “hot limit” have been elaborated

The 100 Percentile limits was introduced as add-on limit.

For consistency, we adjusted the 100 percentile to above equation using $Z = 1.0$ for an extra tolerance for the 100P limit.

(100 Perc.Limit = 3 x Budget.Limit – 2 x 90 Perc.Limit)

- The factor 2 for “Extended Conditions” covers any combination of lower temperatures and higher altitudes, and applies only once and only while these conditions persist (i.e. only those parts of the tests that are under extended conditions).

Factor to be reviewed.

Engine tests demanded for CO₂-regulation (Regulations EU 2017/2400 and 2019/318)

- WHTC cold started at 20°C
- WHTC hot start (after cold WHTC and 10' soak time)
- WHSC (as a COP option for CO₂-certification of engines, may be replaced by WHTC)
- Fuel Consumption Mapping Cycle (FCMC)

Currently weighted result of WHTC cold (14%) + hot (86%) is limited for pollutants and has to be met in engine CO₂ certification

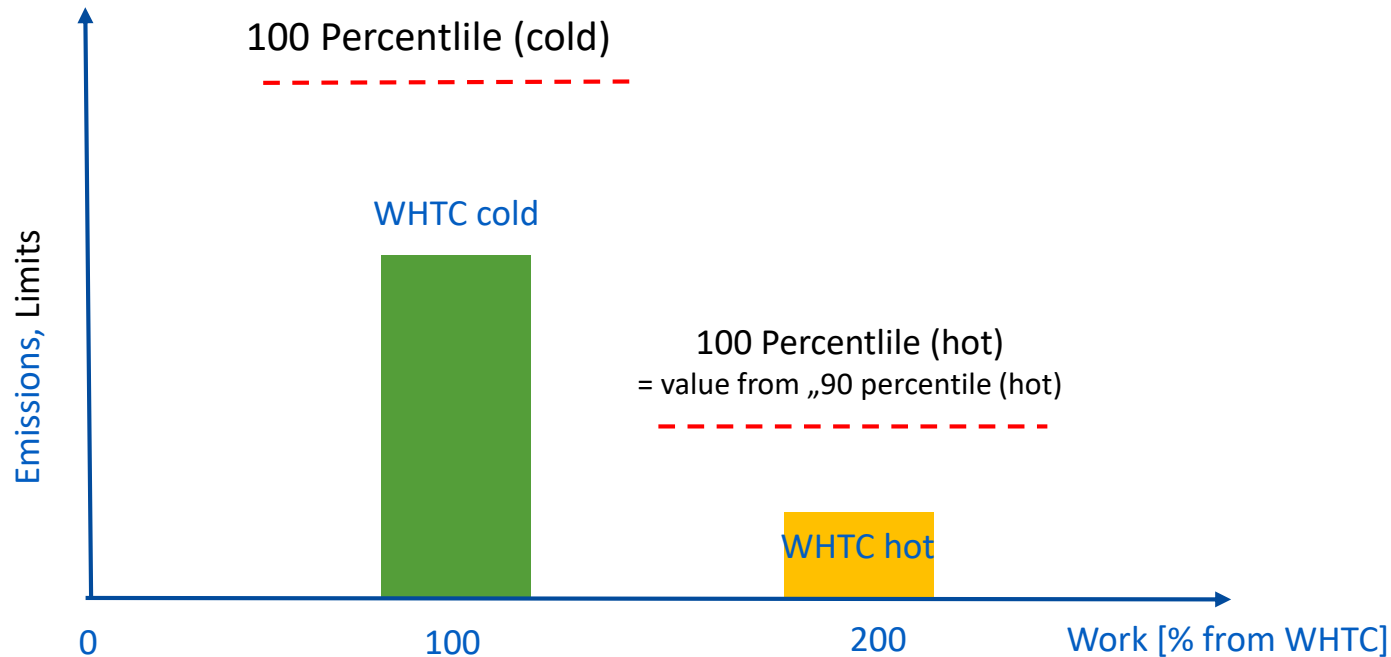
These tests shall also be well covered by the EURO 7 limits to avoid any cycle optimisation for low fuel consumption at cost of high pollutant emissions.

Engine Tests: WHTC

WHTC cold started at 20°C + WHTC hot start (after cold WHTC and 10' soak time):

Option:

- 1) 100% Percentile (cold) limit for first WHTC (also applicable in Option A)
- 2) 90 percentile (hot limit) applied as “100 percentile of MAWs starting after 1xWHTC”
In this case the 2nd hot WHTC would be fully controlled for pollutant emissions.



Fuel Mapping cycle

= hot test due to preconditioning at medium load before 1st map point is tested.

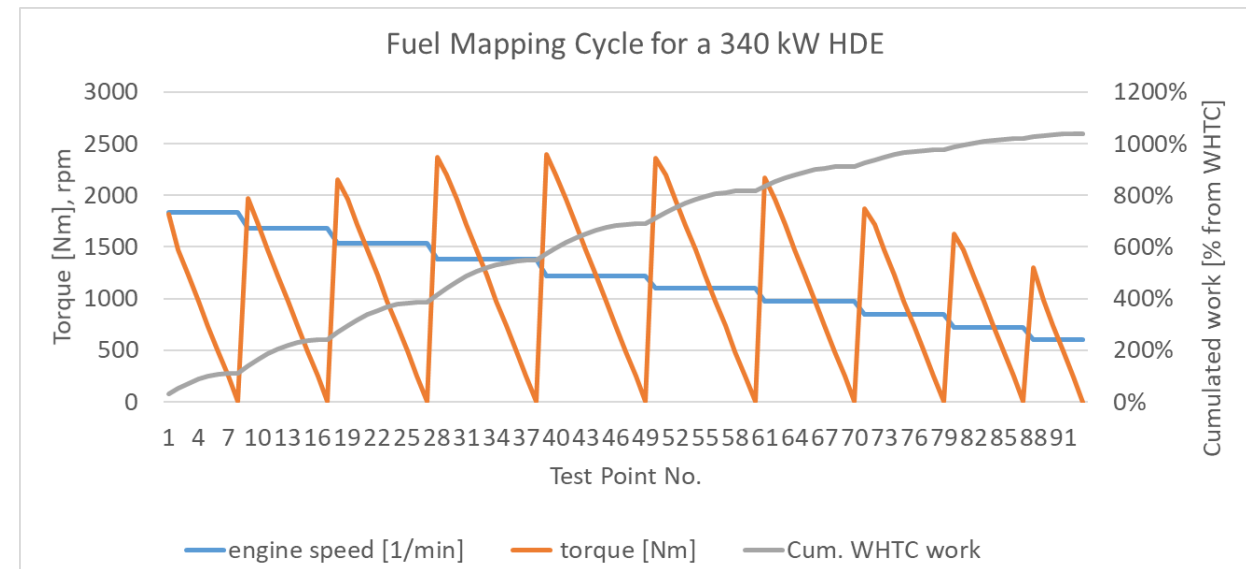
Duration is ca. 10 x WHTC work

Option:

Apply “90 percentile (hot) limit * Z” from HDV test but for 100 percentile of all MAWs in the FCMC.

Z.... Ratio 100/90 percentile, ca. = 1.3 (*value to be reviewed*)

This would cover all engine speed and torque points in fuel map!



- The limit presented for the 90 percentile (hot) for CO from HC2 and HL2 (EU7 CH4 engines) did not consider variable fuel qualities (GR, G25 up to G20) and issues with parallel optimisation of Lambda control for low NOx and low CO.
 - Higher values are now suggested for CO (300 mg/kWh)
 - Higher values are now suggested for CH4 and NMOG (due to higher NMHC in the GR fuel quality and higher CH4 in the G20 fuel)
- We adjusted the 100 Percentiles in this presentation to meet equation shown in “clarification” section for a harmonic picture.



- We considered the following PEMS analyser capabilities, ensuring that the proposed emission limits are always higher than the values below.

Analyser capability limits	NOx	SPN ₁₀	CO	NMOG	NH3	N2O	CH4	HCHO
mg/kWh (#/kWh)	89	1.6 E+10	136	47	17	32	47	29

- Options for start time to build the “hot MAWs” as basis for the hot emission limit values (90 Percentile):
 - Option A: 1st MAW-hot begins 10 minutes after engine start combined with the 90 percentile (hot) limit values
 - Option B: 1st MAW-hot begins after 1x WHTC work is finished (then one may apply limit for 100 Percentile of MAWs instead of 90 Percentile similar to “Option” for FCMC test).

Reminder: the 100 Percentile MAWs for the high limit are counted from 1st to last second of the test.



Summary Emission Limits (updated)

Limit levels achievable for useful life of: N3 > 16t up to 0.7 Mio. Km, other HDVs 0.3 Mio. Km

100 Percentile Limit	NOx	SPN ₁₀	PM	CO	NMOG	NH3	N2O*	CH4*
HD 2 (opt. +cc SCR diesel)	350	5.0E+11	12	3500	200	65	160	100
HD 3 (as HD2+pre-heat)	175	5.0E+11	12	1500	75	65	160	85
HL 2 (LNG as HD2)	350	5.0E+11	12	7500	150	50	225	500
HC 2 (opt. CNG SI)	350	5.0E+11	12	6500	150	70	300	450

Adjusted to meet ca.:
100 Perc.Limit =
3 x Budget.Limit –
- 2 x 90 Perc.Limit”

90 Percentile Limit	NOx	SPN ₁₀	PM	CO	NMOG	NH3	N2O*	CH4*
HD 2 (opt. +cc SCR diesel)	90	1.0E+11	8	200	50	65	60	50
HD 3 (as HD2+pre-heat)	90	1.0E+11	8	200	50	65	60	50
HL 2 (LNG as HD2)	90	1.0E+11	8	300	50	50	60	350
HC 2 (opt. CNG SI)	90	1.0E+11	8	300	50	70	35	300

CO adjusted for NOx-CO trade-off, NMOG adjusted to analyser capabilities.

„Budget“ ≤ 3 x WHTC work	NOx	SPN ₁₀	PM	CO	NMOG	NH3	N2O*	CH4*
HD 2 (opt. +cc SCR diesel)	150	2.0E+11	10	1250	75	65	140	30
HD 3 (as HD2+pre-heat)	100	2.0E+11	10	600	50	65	140	30
HL 2 (LNG as HD2)	150	2.0E+11	10	2700	75	50	200	500
HC 2 (opt. CNG SI)	150	2.0E+11	10	2300	75	70	260	350

NMOG adjusted to analyser capabilities and to GR gas quality.

* Limit composition for CH4 and N2O results in less than 5% share of CO2e emissions vs. tailpipe CO2 (worst case limit for 7.14xWHTC work, average will be lower)

**Thank you very much for
your attention!**

