ACEA

Correlation ETC – WHTC (updated with additional information)

To support the development of Euro VI emission limits, member companies of ACEA have performed additional engine tests to develop a correlation between the current ETC and the European version of the WHTC (i.e. the UN-ECE Regulation No.49 version).

During the development of the WHDC test cycles, extensive correlation testing was carried out by all the stakeholders and reported to GRPE. All those tests were run with hot engine preconditioning. NOx emissions on the WHTC were found to be in the range 10% to 20% higher than on the ETC, see Figure 1 below. The WHDC procedures were not only compared to ETC but also to the US- and Japanese test cycles.

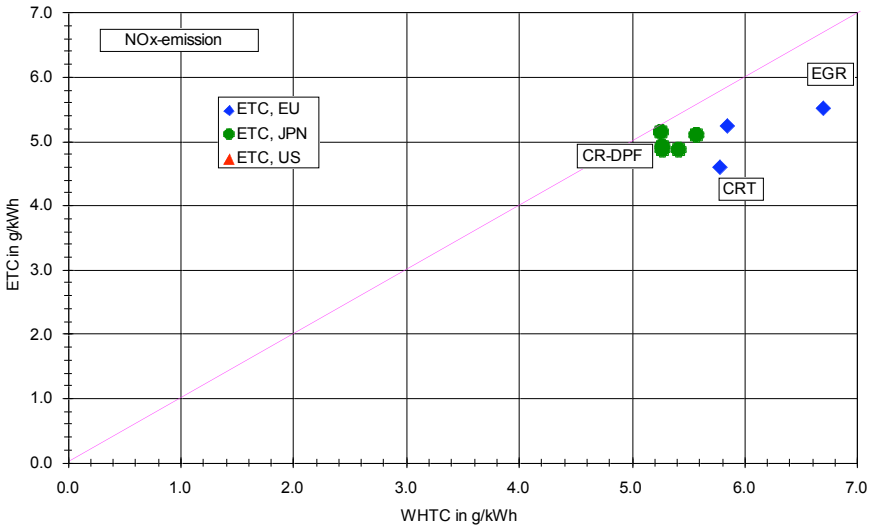

Figure 1: Comparison ETC-WHTC (hot conditioning), GRPE report (2003).

Since the WHTC cycle was developed from a careful investigation of worldwide heavy-duty vehicle driving patterns, the WHTC exhibits a different load factor and a different load/speed distribution compared to the ETC test cycle.

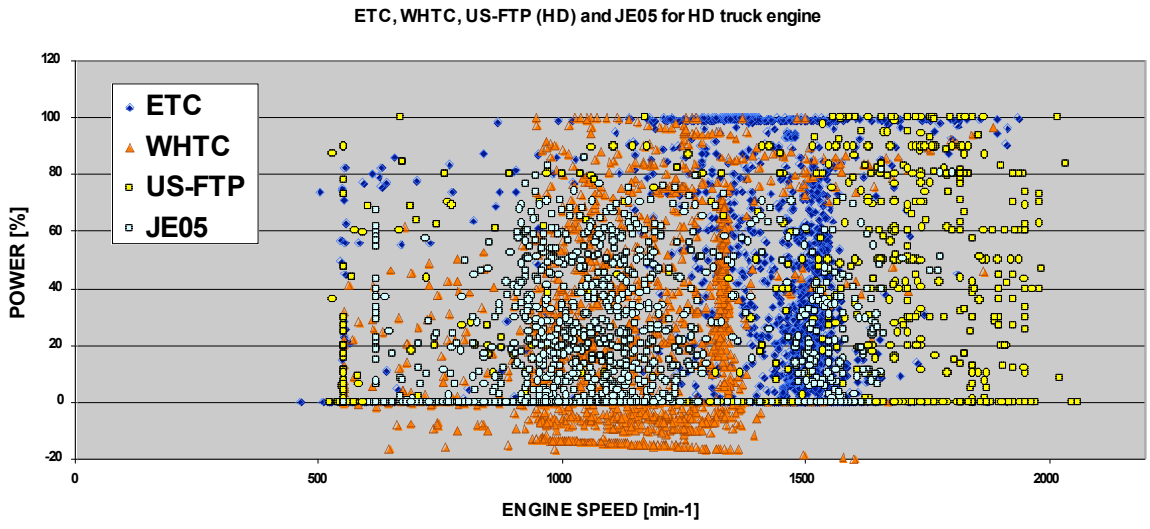

Figure 2: ETC, WHTC, US-FTP and JE05 speed/load distribution for a given engine.

Figure 2 illustrates the speed and load point of different test cycles in the engine map for a given truck engine. Typically engines are optimised to comply with the emission requirements while offering best performance and best fuel economy under conditions of use. For this reason, engine maps might be shaped accordingly and therefore it is very difficult to obtain a simple correlation between very different test cycles operating in different load/speed areas. This conclusion was already drawn in the report of the WHDC validation studies.

When introducing the cold start – hot soak – warm start procedure in the WHTC, new requirements have been added which certainly have a major influence on the engine calibration and, by default, to any test cycle correlation. For this reason, a simple back-to-back testing of current production engines on different test cycles is not meaningful, in particular when engine are equipped with temperature-dependent exhaust aftertreatment systems.

When approaching the evaluation of a test cycle correlation between the ETC and WHTC cycles, ACEA has focused on current / future engine technologies achieving emission levels better than Euro V and have applied engine calibrations taking into account the additional requirements of cold and warm start emission controls.

The following engine tests have been carried out in this program:

Engine	Technology	ETC	WHTC (10% cold / 90% hot)		Comment
			R49 5min soak	20min soak	
A	EGR+DPF	X	X		
B	EGR+DPF	X	X		
C	EGR+DPF+SCR	X	X		Base engine as A
D	EGR+DPF+SCR	X	X		Base engine as B
E	DPF+SCR	X	X		
F	DPF+SCR+thermal	X	X		Base engine as E
G	EGR+DPF+SCR	X		X	Base engine I
H	EGR+DPF+SCR	X		X	Base engine J
I	EGR+DPF	X		X	
J	EGR+DPF	X		X	US2004
K	EGR+DPF	X	X		
Note – all prototype engines except engine J.					

As expected, the correlation between the ETC and WHTC cycles is not uniform as a result of the utilised exhaust aftertreatment technologies and engine calibrations.

The results are summarised in Figure 3, below:

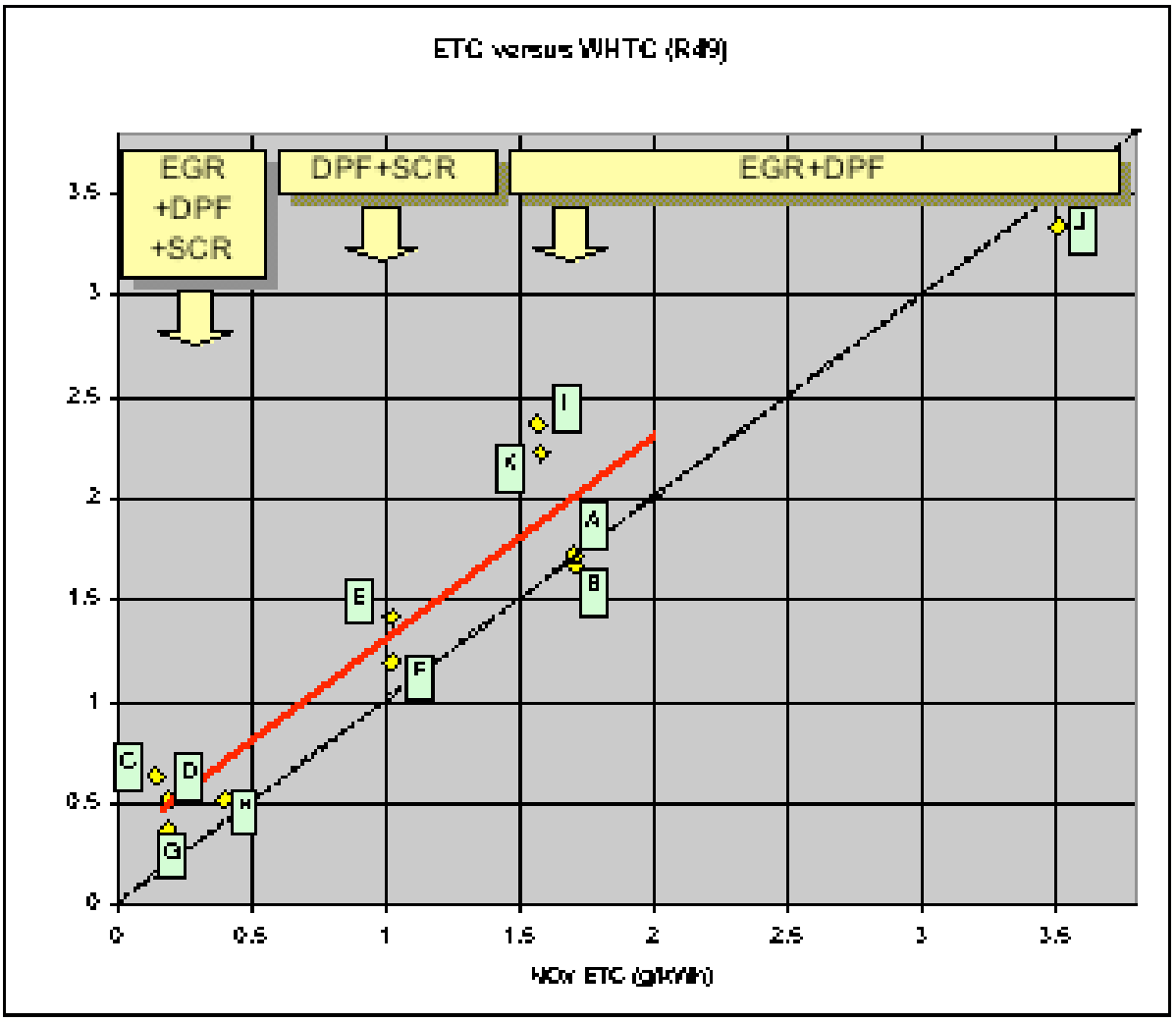

Figure 3: Results ETC-WHDC (R49) correlation study.

As Figure 3 shows, when temperature-dependent exhaust aftertreatment is involved, the WHTC provides higher NOx values. This is a consequence of the warm-up of the exhaust aftertreatment system during a cold start until the 'light-off' temperature of the catalytic system is reached. Thermal management can improve the situation to a certain, but limited, extent.

As shown in Figure 3, there is a fairly consistent offset of the WHTC result independent of the absolute NOx level (in the investigated range) due to the cold operation of the exhaust aftertreatment system.

It is therefore proposed, and supported by the data, that an additive factor of 0.3 g/kWh is applied as follows:

$$NOx_{WHDC} = NOx_{ETC} + 0.3\ g/kWh$$

Concerning PM, HC and CO it is proposed to apply a correlation factor of 1.0 since these pollutants were considered non-critical within this exercise. It should be noted that the above factors/correlations are valid only for the range of tested engine and exhaust aftertreatment technologies.

This investigation is not conclusive on the influence of the soak time on the WHTC result.

Additional information and new data:

- Three additional engine test data from 2 further OEM's have been received (L, M, N) and added to the data evaluation;
- The correlation study now includes data from all ACEA members;
- Cold start and hot soak engine test data is reported (as available) as well as key engine configuration and performance data:

	ETC	WHTC		
		cold start	hot soak	combined
A	1.7	2.23	1.67	1.73
B	1.7	2.4	1.61	1.69
C	0.14	2.38	0.44	0.54
D	0.19	1.88	0.38	0.53
E	1.02	2.5	1.33	1.45
F	1.02	2.2	1.05	1.16
G	0.18	1.34	0.28	0.38
H	0.39			0.53
I	1.6	2.23	2.38	2.37
J	3.5			3.35
K	1.57			2.23
L	1.54	2.69	2.71	2.71
M	0.18	1.27	0.56	0.63
N	0.18	1.18	0.38	0.46

cylinder number	displacement (litre)	max. power (kW)	max. torque (Nm)	technology
6	12.8	362	2237	EGR+DPF
6	12.8	325	2237	EGR+DPF
6	12.8	362	2237	EGR+DPF+SCR
6	12.8	325	2237	EGR+DPF+SCR
6	6	220	1050	DPF+SCR
6	6	220	1050	DPF+SCR+thermal mgmt
6	12.8	335	2237	EGR+DPF+SCR
6	12.8	335	2237	EGR+DPF+SCR
6	12.8	335	2237	EGR+DPF
6	12.8	335	2237	EGR
6	10.5	287	1900	EGR+DPF
6	na	na	na	EGR
6	12.9	355	na	EGR+DPF+SCR
6	12.9	355	na	EGR+DPF+SCR+thermal mgmt

The additional data confirms the offset of the WHTC result in the low-NOx range and the conclusions with respect to the cycle correlation, see Figure 4 below:

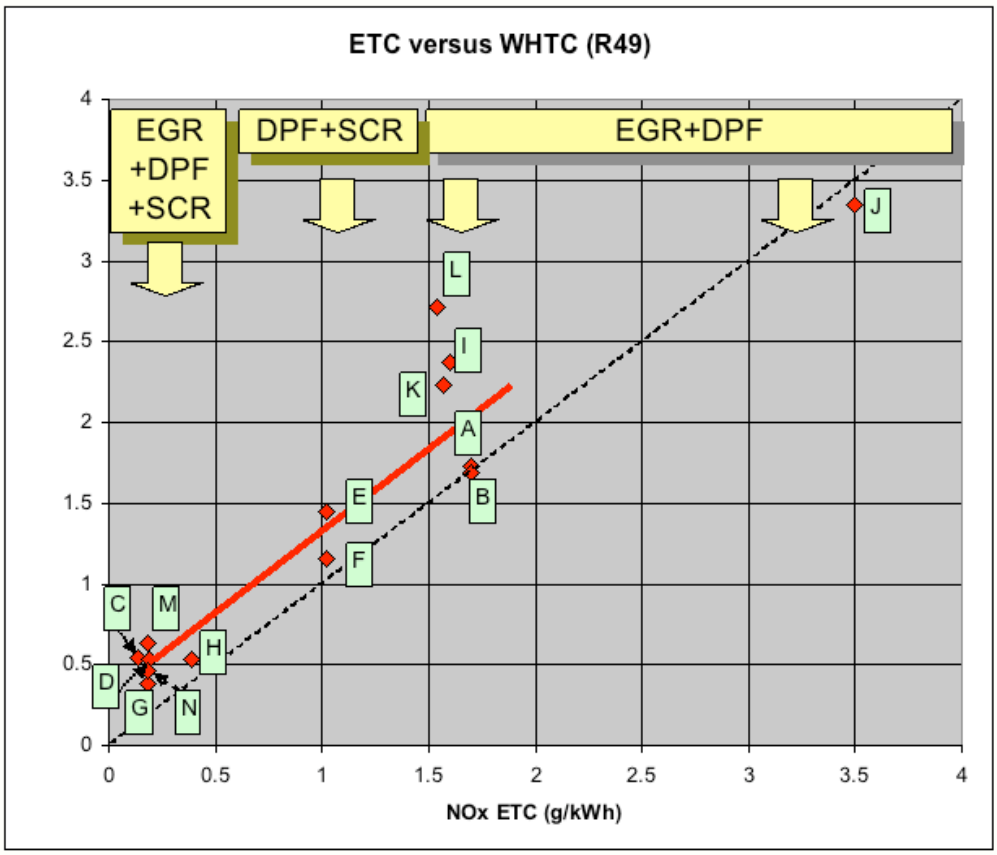

Figure 4: Results ETC-WHDC (R49) correlation study (updated Figure 3).

Evaluating the individual results of cold start, hot soak start and the weighted combination, the following conclusions can be drawn from Figure 5 below:

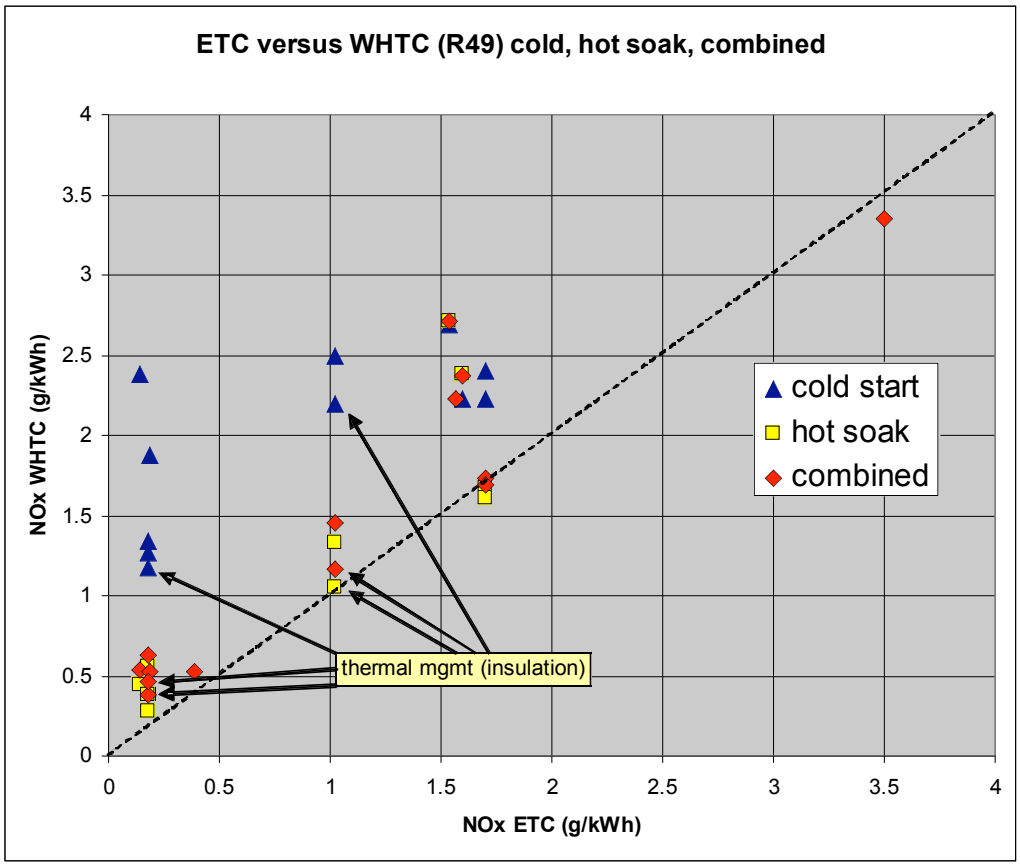

Figure 5: cold start, hot soak start and combined NOx result

- The cold start test results show significantly higher NOx, in particular when exhaust aftertreatment is involved;
- Most of the WHTC hot soak test results (with aftertreatment) are higher than the ETC result. Again, this is influenced by the aftertreatment system;
- Thermal management lowers both the WHTC-cold start and the hot soak test results. At very low emission levels even thermal management will not result in a 1:1 correlation of the hot soak test with the ETC.

Conclusions:

1. The data supports the conclusion that an additive factor of 0.3 g/kWh is applied as follows:

$$NOx_{WHDC} = NOx_{ETC} + 0.3\ g/kWh$$

2. Concerning PM, HC and CO it is proposed to apply a correlation factor of 1.0;
3. These conclusions are only valid for the range of tested engine and exhaust aftertreatment technologies;
4. Thermal management lowers both the WHTC-cold start and the hot soak test results but thermal management will not achieve a 1:1 correlation of the hot soak test with the ETC.

31st May 2007