Informal document No. **GRPE-49-16**

(49th GRPE, 10-14 January 2005,
agenda item 1.1)

COMMISSION OF THE EUROPEAN COMMUNITIES

ENTERPRISE DIRECTORATE GENERAL

Contract Number FIF 20020686

Heavy-Duty Engine Validation of World Harmonised Duty Cycle (WHDC)

Final Report May 2004

by

Dipl.-Ing. Leif-Erik Schulte
Dipl.-Ing. Michael Motzkau
Dipl.-Ing. Heinz Steven
Dipl.-Ing. Ralf Schiebelhut

RWTÜV Fahrzeug GmbH
Institute of Vehicle Technology
Engines / Commercial Vehicles Division

P.O. Box 103261

D-45032 Essen

3 Summary and Conclusions

3.1 WHDC cycle validation

The final WHDC-cycles showed very good steady-state / transient cycle equivalence in terms of cycle work and NOx-emissions. Both cycles cover a wide range of the engine map. Five speeds are used for the WHSC- (steady-state) cycle compared to three for the ESC-cycle currently applied in the EU. This ensures that a wider part of the engine map is tested. The WHTC- (transient cycle) was developed on the basis of an analysis of real-driving pattern with worldwide relevance so that this cycle has the closest link to real engine operation (**Chapter 2.5 *ff***).

3.2 Driveability of the final WHDC test cycles

The driveability of the transient cycle in terms of the cycle validation criteria given in the EU and in the US is good to very good. Since more worldwide driving patterns are considered /2/, the final WHTC does not have as many dynamic parts as the ETC-cycle based only on European driving pattern. For that reason the validation criteria are a little easier to match than for an engine operated on the ETC. However, state of the art engine dynamometer technology is capable to meet the validation criteria even for more dynamic cycles than the ETC (**Chapter 2.6 and 2.7**).

3.3 Comparison of the new and existing measurement procedures

The capability of partial flow dilution systems operated according to ISO 16183 for particulate matter measurement under transient conditions was proven. The partial flow system showed good to very good comparability to the well-established full flow dilution-CVS-system. This was demonstrated by the absolute deviations between the systems as well as by some improved repeatability of the partial flow system with respect to particulate matter measurement (**Chapter 2.3 *ff***).

The PM analysis by extraction showed no significant differences in the particulate matter composition sampled by a partial flow system.

For the raw measurement of the regulated gaseous components the same statement can be given. Also here the provisions given in ISO 16183 provide a reliable tool for the application of this measurement and sample methodology for transient operation of an engine (**Chapter 2.4 *ff***).

The agreement of both procedures (full flow / CVS and raw gas / partial flow) was good over the entire measurement programme.

For both the particulate matter and the gaseous components, good measurement accuracy becomes more difficult to achieve as soon as very low general emission levels are reached due to the fact that the limit of detection of the measurement systems is being approached. The raw gas measurement has some advantage here since no concentration reduction through dilution is given. Due to the higher gas concentrations in the raw gas the ISO 16183 measurement procedure is more reliable.

Some of the results of the engines equipped with CRT-System (*engine 1* and *engine 2*) could not be used for comparison and correlation purposes due to the very low emission values reached by such technologies for PM, CO and HC. However, it was demonstrated that also in this case the new ISO 16183 procedures are fully applicable with even some advantage compared to the established CVS-procedure.

3.4 Adaptation of final WHDC cycles

Based on the results described within this report no proposals for further modifications on the final WHDC cycles are necessary. The applicability of the ISO 16183 measurement procedure is given. The results on *engine 4* (small capacity, high rated speed) show that even relatively small, more or less passenger car / light-duty vehicle engine derived, HD applications can be measured with the WHDC cycles and the ISO measurement procedure.

3.5 Outlook for Otto-cycle engines

All WHDC-validation and -measurement programmes carried out so far only covered diesel engines. For throttled engines (Otto-cycle LPG and CNG for heavy-duty purpose), the applicability of the ISO procedure is not proven yet. Additionally, the WHTC driveability for throttled engines has to be validated, since such engines do not have the direct response behaviour of a diesel engine. This will be evaluated in a further WHDC validation step.