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REPORT ON THE DEVELOPMENT OF A GLOBAL TECHNICAL REGULATION CONCERNING: TEST PROCEDURE FOR COMPRESSION-IGNITION (C.I.) ENGINES AND POSITIVE IGNITION (P.I.) ENGINES FUELLED WITH NATURAL GAS (NG) OR LIQUEFIED PETROLEUM GAS (LPG) WITH REGARD TO THE EMISSION OF POLLUTANTS (World-wide harmonized heavy-duty certification (WHDC) procedure)

Submitted by the Working Party on Pollution and Energy (GRPE)

Note: The text reproduced below was adopted by GRPE at its fifty-second session. It is based on ECE/TRANS/WP.29/GRPE/2006/18, not amended. It is submitted to WP.29 and AC.3 for consideration and vote (ECE/TRANS/WP.29/GRPE/52, paras. 7 and 8).

1. OBJECTIVE

The objective of the proposal is to establish a harmonized global technical regulation (gtr) covering the type-approval or certification procedure for heavy-duty engines regarding its exhaust emissions. The basis will be the test procedure developed by the WHDC informal group of GRPE.

Regulations governing the exhaust emissions from heavy-duty engines have been in existence for many years but the test cycles and methods of emissions measurement vary significantly.

To be able to correctly determine the impact of a heavy-duty vehicle on the environment in terms of its exhaust pollutant emissions, a laboratory test procedure, and consequently the gtr, needs to be adequately representative of real-world vehicle operation.

The proposed regulation is based on new research into the world-wide pattern of real heavy commercial vehicle use. From the collected data, two representative test cycles, a transient test cycle (WHTC) with both cold and hot start requirements and a hot start steady state test cycle (WHSC), have been created covering typical driving conditions in the European Union (EU), the United States of America, Japan and Australia.

An emission measurement procedure has been developed by an expert committee in ISO and has been published in ISO 16183. This standard reflects exhaust emissions measurement technology with the potential for accurately measuring the pollutant emissions from future low emission engines. That procedure has been introduced in the gtr.

The WHTC and WHSC test cycles reflect world-wide on-road heavy-duty engine operation, as closely as possible, and provide a marked improvement in the realism of the test procedure for measuring the emission performance of existing and future heavy-duty engines. In summary, the test procedure has been developed so that it would be:

(a) representative of world-wide on-road vehicle operations,
(b) able to provide the highest possible level of efficiency in controlling on-road emissions,
(c) corresponding to state-of-the-art testing, sampling and measurement technology,
(d) applicable in practice to existing and foreseeable future exhaust emissions abatement technologies, and
(e) capable of providing a reliable ranking of exhaust emission levels from different engine types.

The gtr does not contain emission limit values. The limit values could be considered at a later stage.

At this stage, the gtr contains several options for the Contracting Parties. Those options are related to:

(a) the soak period between the cold and hot WHTC
(b) the weighting factor of cold and hot WHTC
(c) the particulate filter material and size
(d) the reference fuel

So further discussions will be needed to harmonize the requirements on those issues.

The performance levels (emissions test results) to be achieved in the gtr will be discussed on the basis of the most recently agreed legislation in the Contracting Parties, as required by the 1998

Agreement.

2. VALIDATION OF THE WORLDWIDE HARMONIZED HEAVY-DUTY CYCLE (WHDC)

The validation of the WHDC test cycle was carried out by RWTÜV Fahrzeug GmbH – Institute of Vehicle Technology – in Germany. The objective of the validation exercise was to gather more knowledge about the driveability of the WHDC test cycles on the one hand, and, on the other hand to compare the existing measurement procedure for gaseous components and particulates to the ISO-procedure developed by the WHDC-sub-group "ISO-Activities" ISO 16183. The work was performed with recent Euro III diesel engines and engines equipped with particulate traps in order to meet Euro IV (or better) particulate matter (PM) limits.

The following cycles were compared in view of driveability studies based on regression analysis between the reference and actual signals of speed and torque:

Steady-state

ESC (European steady-state cycle)
WHSC (worldwide harmonized steady-state cycle)
Japanese 13-mode test

Transient

ETC (European transient cycle)
WHTC (worldwide harmonized transient cycle)
US-FTP (US federal test procedure)

In addition, the engine operating ranges covered by each different cycle were compared. The influence of the engine design concept and the dynamometer control was also subject to the investigations, where it was possible to do so.

For the comparison of the "constant volume sampling" system (CVS) to the ISO 16183 exhaust gas measurement methodology, the components CO, THC, NOx and PM were monitored over each cycle. The CVS measurement was performed via modal analysis. The work was performed under steady state and transient conditions comparing the different regional cycles mentioned above with the WHTC (transient) and the WHSC (steady-state) cycle. Three repeats for each engine were used.

The major aims of the validation exercise were:

(a) A comparison of the final WHTC / WHSC with the regional existing cycles for HD-engines in order to assess the new cycle(s) in view of driveability and applicability for different engine design.

(b) A comparison of the CVS and ISO measurement procedures in order to assess the new methodology in view of type approval or certification applicability, as well as to gather more knowledge of the accuracy and repeatability of both procedures related to different engine design.

(c) To propose modifications to the new procedures if necessary.

The test schedule was designed in order to investigate the influences of the following parameters:

(a) cycles correlation / comparison
(b) comparison of full flow (CVS) PM vs. partial flow (ISO 16183) PM
(c) comparison of diluted gaseous components vs. raw gaseous components
(d) evaluation of the variance of measurement procedures (CVS vs. ISO 16183)
(e) cycle driveability (validation / statistics)

The main conclusions of the validation exercise are the following:

(a) 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 world-driving pattern with worldwide relevance so that this cycle has the closest link to real engine operation.

(b) 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, 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.

(c) 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.

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.

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 a Continuously Regenerating Particulate Traps (CRT) system 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.

(d) Based on the results described in the validation report no proposals for further modifications on the final WHDC cycles were considered necessary. The applicability of the ISO 16183

measurement procedure is given. Even in relatively small engines, more or less passenger car / light-duty vehicle engine derived, heavy-duty applications can be measured with the WHDC cycles and the ISO measurement procedure.

(e) Relating to gas engines:
The final WHDC-cycles showed very good steady state / transient cycle equivalence also for the CNG-engine. Both cycles cover a wider range of the engine map than today's cycles. The driveability of the WHTC in terms of the cycle validation criteria given in the EU and in the United States of America is good to very good. The provisions given in ISO 16183 for the raw measurement of the regulated gaseous components during transient engine operation provide a reliable tool for the application of this measurement and sample methodology for the time being without any adjustment even for gas-engines. The agreement of both procedures (full flow / CVS and raw gas / partial flow) is good so far.

3. ADVANTAGES OF THE GTR

Heavy commercial vehicles and their engines are increasingly produced for the world market. It is economically inefficient for manufacturers to have to prepare substantially different models in order to meet different emission regulations and methods of measuring emissions, which, in principle, aim at achieving the same objective. The gtr enables manufacturers to develop new models more effectively and within a shorter time. Savings linked to the gtr will certainly benefit the consumer.

However, developing a test procedure just to address the economic question does not completely address the mandate given when work on this gtr was first started. The test procedure must also improve the state of testing heavy-duty engines, and better reflect how heavy-duty engines are used today. Compared to the measurement methods defined in existing legislation of the Contracting Parties to the 1998 Agreement, the testing methods defined in this gtr are much more representative of in-use driving behaviour of commercial vehicles world-wide. It should be noted that the requirements of this gtr should be complemented by the requirements relating to the control of the Off-Cycle Emissions (OCE) and OBD (On Board Diagnostic) systems.

As a consequence, it can be expected that the application of this gtr for emissions legislation within the Contracting Parties to the 1998 Agreement will result in a higher control of in-use emissions due to the improved correlation of the test methods with in-use driving behaviour.

4. COST-EFFECTIVENESS

A specific study on cost-effectiveness for this gtr has not been made due to the decision by the Executive Committee (AC.3) to the 1998 Agreement to move forward with this gtr without limit values.

Each Contracting Party adopting this gtr into its national or regional law will be expected to introduce limit values, associated with the use of these new test procedures, at least as stringent as comparable currently existing requirements.

The opinion of GRPE experts is that there are clear benefits associated with the adoption of this regulation.

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