Transmitted by the expert from OICA

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LIGHT DUTY DIESEL VEHICLE PARTICLE NUMBER ROUND ROBIN

Executive Summary, Recommendations and Conclusions

This document presented by the experts from OICA is an executive summary of the light duty particle number round robin test concerning 2 DPF equipped diesel vehicles, funded by ACEA and contracted out to UTAC. The final full report of the above test is presented as a GRPE PMP documents for the January 2010 session. The original light duty PMP activities included a laboratory verification exercise but did not include the round robin test. This round robin test contributes to the original PMP light duty programme by investigating whether there were significant differences in the way the Particle Number (PN) test protocol could be implemented between laboratories and by evaluating PN protocol measurement uncertainty under type-approval conditions.

The measurement equipment was fully PMP compliant with valid calibration certificates. Whilst the measurement equipment functioned correctly allowing measurements, it is clear from the uncertainties in both repeatability (within one laboratory) and the reproducibility (between different laboratories), that the PN measurement method has a similarly high uncertainty as the PM method (also using the new annex 4a approach), although the sensitivity of the PN measurement is greater than for PM measurement.

There remains further work to do as described below in the executive summary in order to make further improvements in the PN measurement system to reduce the measurement uncertainty.

Summary, Recommendations and Conclusions reproduced directly from UTAC test report GRPE-PMP-25-02 (see http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/pmp25.html)**.**

Summary

The new European regulation 692/2008 regarding motor vehicles with respect to the emissions (Euro5 and Euro6) introduces particle number (PN) measurement for diesel vehicles for Euro5b. On behalf of ACEA, UTAC has carried out a round robin test in seven laboratories and on two DPF diesel vehicles in order to:

- determine whether the PN test protocol is similar in all laboratories or if interpretation flexibility remains in the Euro5b legislative specifications,
- collect enough data to determine the PN protocol measurement uncertainty under type-approval conditions.

The tests took place from November 2008 to April 2009. Each laboratory carried out the tests (on NEDC cycle) with its own PN equipment and according to its interpretation of the legislative specifications.

Overall, the round robin test reached its initial objectives.

For the seven participating laboratories and the three PN equipments used, the regulation specifications did not let any interpretation be significant for the measurement set up; however the influence of interpretations in the calibration procedure has not been studied in this programme. Some recommendations to ensure measurement quality and decrease the variability of the measurement are suggested: ensure a stable PN background, checking the PN traces for electronic artefacts and carrying out the tests when possible in stabilised DPF conditions.

The PN procedure including all its influencing factors (vehicle, PN equipment and environment) has a high variability; its uncertainty (2s) is about 100%. Although the uncertainties are very high,

the protocol is appropriate for type approval as far as the present limits are concerned, but variability still needs to be improved especially when it comes to measuring emissions close to the limit.

The round robin test shows that at the low levels of emissions measured during the programme the biggest part of the variability comes from the sensitivity of PN emissions to the environment and from the variation of the vehicles in terms of PN which are much higher than for gaseous emissions. In order to reduce total variability of the measurement, the implication of the different factors (vehicle, PN equipment, calibration or environment) need to be better understood, further investigation need to be done.

Besides the calibration protocol which is still under discussion, different development trends are possible of which:

- A full error analysis study would identify efficiently the priority actions.
- The carrying out of tests with identical PN equipments set in parallel would give an estimation of the variability inherent to the manufacturing of the fully PMP compliant PN measurement systems.

Linked to the future limit, a similar round robin test should be carried out for gasoline direct injection vehicles.

Recommendations

From the results of this round robin test, several recommendations can be made to ensure the quality of the PN measurements:

- Make sure that the PN background level is stable by ensuring that the HEPA filter is well sealed and that the tunnel is clean. A background below 109 #/km does not influence the following PN measurements regarding the compliance of the vehicle with the regulation (§9).
- Take care to avoid electronic artefacts, unusual spikes can show up (§10.4).
- When technically possible, carry out tests on vehicles in stabilised DPF conditions as recommended in R83 Annex4a §6.6.9.3, it improves significantly the variability.

Conclusions

Overall, the round robin test reached its initial objectives:

- Determine whether the PN test protocol is similar in the seven laboratories and with the three PN equipments tested, or if interpretation flexibility remains in the Euro5b legislative specifications.
- Collect enough data to determine the PN protocol uncertainty under type approval conditions.

The regulation is satisfactory with respect to describing the test procedure in terms of operation during measurement; however the influence of interpretations in the calibration procedure has not been studied in this programme. The PN equipments functioned correctly; still 15% of the non valid tests which is 3% of the total tests carried out were rejected due to PN equipment. No test has been rejected only for PM equipments.

Recommendations to ensure measurement quality and decrease the variability are: ensure a stable PN background, check the PN trace for electronic artefact and carry out the tests when possible in stabilised DPF conditions.

The variability of the method in type approval conditions is globally expressed with the uncertainty, for which the calculated values are summarised in the table below. In the objective of not overestimating the uncertainty of the PN protocol, outlying laboratories results were excluded from

the calculation, as well as the vehicle effect were minimized by taking into account post-regeneration effect for Vehicle 2.

Uncertainty	Absolute	Relative
CO	35 mg/km	25%
HC	4 mg/km	28%
NOx	16 mg/km - 22 mg/km	9% - 12%
CO2	4.5 g/km - 6.8 g/km	2.9% - 4.7%
FC	0.17 L/100km - 0.26 L/100km	2.9% - 4.7%
PM	0.5 mg/km	90% - 210%
PN	In the magnitude of the PN emission level $1.4\ 10^{09}$ - $2.9\ 10^{10}$ #/km when Vehicle 2 data are w/o post-regeneration effect $1.4\ 10^{09}$ – $1.6\ 10^{11}$ #/km when all Vehicle 2 data are taken into account	81% - 144% 144% - 169%

The PN procedure including all its influencing factors (vehicle, PN equipment and environment) has a high variability; its relative uncertainty is of about 100%. The relative uncertainties of PN are comparable to those of PM which sensitivity is sufficient to resolve compliance with the Euro5 and Euro6 PM limits considering the very low levels of PM emissions of modern vehicles. Compared to the uncertainties for CO2 (5%) and NOx (10%), the PN uncertainty remains of course very high.

In stabilised DPF conditions, the protocol can differentiate the round robin test diesel vehicles in terms of PN emissions, when the PM emissions protocol does not. Now the actual uncertainty of the PN measurement remains high in particular for vehicles which PN emissions are close to the limit; the protocol variability still needs to be improved. When considering all the data (including outlying laboratories), whether the DPF is in stabilised conditions or not, the difference in between the minimum and maximum mean values of the laboratories remains to a factor about 4.

The round robin test shows that part of the total variability of the method comes from the PN equipment (a direct comparison shows up to 18% difference between two systems), but at these low levels the variability comes mostly from the sensitivity of PN emissions to the environment and the variation of the vehicles in terms of PN which are much higher than for gaseous emissions.
To focus on improving the factors with the highest contribution and hence to reduce total variability, the implication of the different factors (vehicle, PN equipment, calibration or environment) need to be better understood.

Besides the calibration protocol which is still in discussion, different development trends are possible of which:

- A full error analysis study would orientate efficiently the priority axes to work on.
- The carrying out of tests with identical PN equipments set in parallel would give an estimation of the variability inherent to the manufacturing of the systems.

To look ahead to Euro6a, the protocol should be tested on gasoline direct injection engines.

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