# ExIS Summary and comments to particle losses for various tested PMP type/like VPR systems

## Introduction and background

The main driver behind Particle Measurement Programme (PMP) has been the impact of particles on human health. There is a growing consensus amongst health experts that ultrafine particles (<100 nm diameter) may have the greatest adverse impact on human health. In the past, only particulate mass in vehicle and engine emissions has been regulated.

In 2001, the Governments from France, Germany, the Netherlands, Sweden and United Kingdom agreed to develop new methods and procedures to facilitate the control of ultrafine particles within a regulatory framework. The mandate for the PMP Working Group was to develop new particle measurement techniques to complement or replace the existing particulate mass measurement, with special consideration to measuring particle emissions at very low levels.

The two first phases of the PMP programme improved the filter method for particulate mass emissions and introduced a particle number method. The latter has been manifested in draft new versions of UN-ECE regulations. In phase 3, inter-laboratory correlation exercises for light-duty vehicles and heavy-duty engines have been conducted. For the heavy-duty engines reported now, repeatability and reproducibility of particle number measurements has been investigated by transporting a "Golden" engine and two "Golden" particle measurement systems to each test laboratory.

The next (on-going) task in the PMP programme is a round robin exercise, where laboratories in EU, Japan, Korea and Canada have showed their interest to participate. This programme is to be completed in 2011. Work will also be initiated to develop calibration methods for particle number counters.

## Summary of particle losses for various PMP type/like systems

As pointed out in the draft PMP report, particle losses need to be taken into account to make fair comparisons between different PMP dilution systems. In **Table 1**, a summary of the results from determination of losses is listed.

***Table 1.*** *Particle penetrations through the various PMP type/like systems used in the PMP HD validation exercise.*

| PMP type/like system | P (30 nm) | P (50 nm) | P (100 nm) | Correction |
|---|---|---|---|---|
| SPCS | 71% | 83% | 86% | 1.25 |
| Nanomet JRC & RCE | 68% | 88% | 95% | 1.20 |
| Nanomet LD GPMS | 52% | 65% | 90% | 1.45 |
| Thermodenuder (TD) | 67% | 73% | 77% | 1.38 |
| EMPA's homemade (CVS) | 70% | 71% | 72% | 1.41 |
| EMPA's homemade (direct) | 61% | 63% | 65% | 1.59 |
| Ejector (heated) | 96% | 98% | 100% | 1.02 |
| Ejector (not heated) | 100% | 99% | 100% | 1.00 |

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Most of the results in **Table 1** have been generated using NaCl particles. The APC system AVL is not listed in this table, since they incorporate the correction in the reported particle concentration results. As a short conclusion ExIS can note that there are small differences in the methodology for how the losses have been determined from case to case but these differences should have negligible impact on the results reported.

***Further comments by ExIS***

The graphical representation has been made by ExIS in **Figure 1** to better illustrate the results from the commercial systems discussed above. Options not relevant for direct comparison (i.e. TD, EMPA direct and unheated ejector) have been omitted in **Figure 1**.

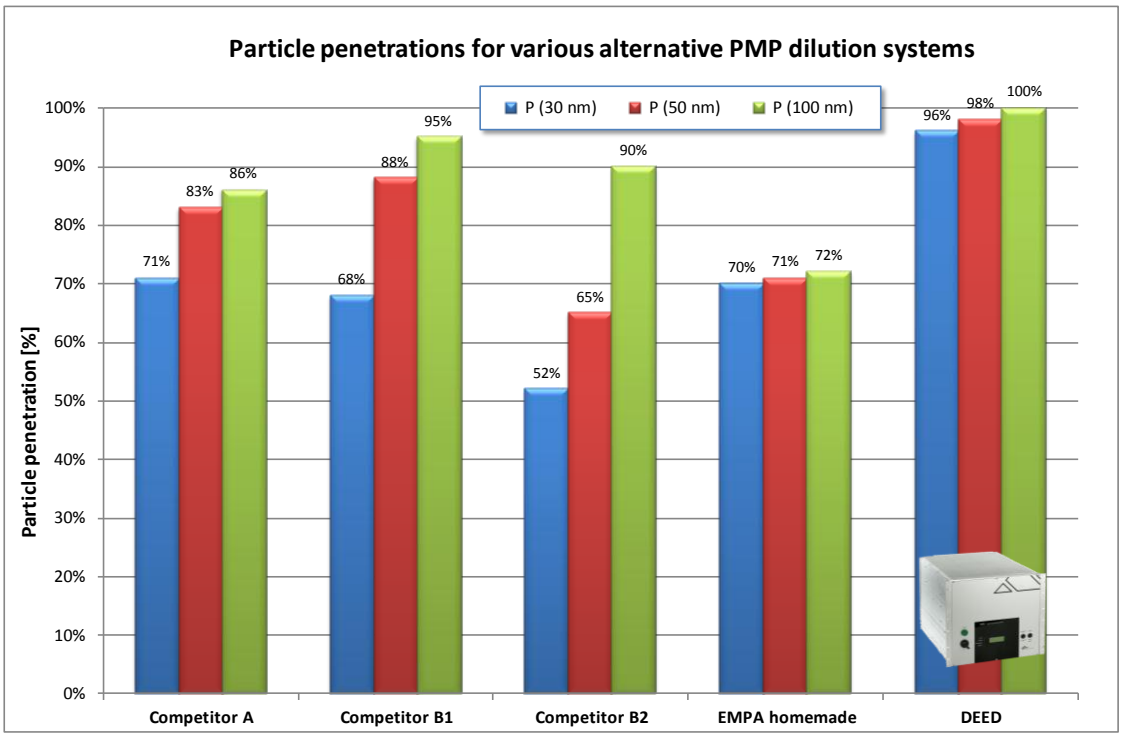


***Figure 1.*** *Particle penetration for various PMP dilution systems*

The comparatively low losses for the double diluter sampling system (DEED) can be noted **Figure 1**. It is also noteworthy that there is a considerable difference in losses for the different size of particles investigated. This implies that a proper calibration of a VPR system to be used in conjunction with a particle counter (CPC), which cannot distinguish between different particle sizes, is practically impossible for those PMP type systems. Very often the peak of the size distribution is between 50 and 100 nm in engine exhaust but this is not always the case. Thus, a proper and universal calibration is very difficult to obtain and you will get both over and underestimations of the results depending on how the size distribution varies. We hope that issues like this will be addressed in the future in the UN-ECE group on PMP measurements.

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## Background information about Dekati DEED dilution system

The modifications in the PMP protocol in spring 2007 enabled significant simplifications of the PMP dilution system. The Dekati Engine Exhaust Diluter (DEED) was designed with this objective in mind. No special user training is required for operation; just switch on, warm up and go! The dilution ratio can be varied in two stages; i.e. high (for high emissions) and low (for low emissions). DEED is based on the ejector diluter principle, which has no moving parts and has a long record of reliable operation. Very low losses minimize the instrument downtime and avoid the calibration issues associated with high losses. Pressure balancing of the diluters eliminates influence of varying CVS pressure. DEED can be combined with any type of particle instrument. It is mounted in a single rack cabinet and can be controlled remotely via the AK protocol.

Additional developments for the DEED dilution system during 2008/2009 were a heated stainless steel sampling line and a "mini-CVS" device with an additional dilution stage for measuring upstream of a DPF, where the overpressure is high and varying. An optional "by-pass" of one of the ejector diluters provides an additional outlet of sample gas for a low dilution ratio of 1:10. This PMP like dilution is advantageous for measuring very low particle levels such as, e.g. after a DPF and the exhaust from gaseous-fuelled engines. This DEED option is available for ordering since early 2010.

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