



Particle Number Measurement According to PMP Protocol and Direct Measurement



C. Tyroller¹, I. Sisenco², H.A. Beck¹

¹ MAN Truck & Bus AG, Department of Engineering Powertrain Test Facilities and Services – Analysis

² Technische Hochschule Nürnberg Georg Simon Ohm, Fakultät Verfahrenstechnik

Background

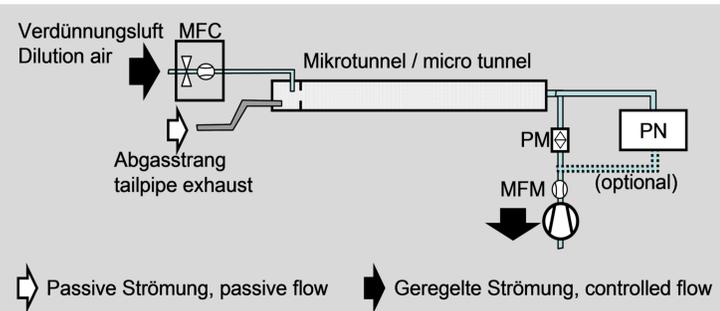
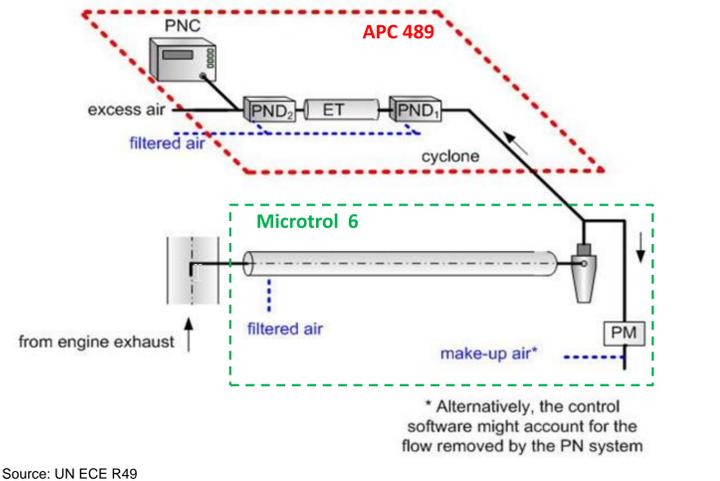
The homologation procedure according to UN ECE Regulation 49 demands particle counting from prediluted exhaust gas. This means the particle counter samples from the partial flow dilution tunnel upstream the gravimetric filter holder.

Interlinking the two systems is a major source of errors because unnoticed sample flow deviations of the particle number counter lead to miscalculation of dilution ratios in the tunnel. A false dilution ratio consequently interferes with both the gravimetric mass analysis as well as the particle counting measurement.

There are two ways to correct the influence of the counter sample mass flow. Either a representative mass flow is fed back downstream of the filter holder or the removed mass flow is taken into account mathematically in the data processing. Feeding back an equal flow poses additional uncertainties.

Meanwhile most particle counting systems have raw exhaust sampling options using high dilution modes. This enables particle counting directly in the undiluted exhaust.

This study compares results of particle number counting measured according to PMP protocol with those measured directly in the exhaust gas.



Experimental Setup

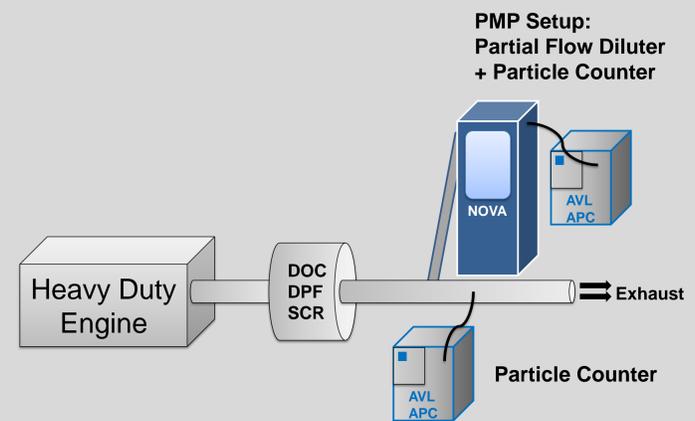
Particles were measured simultaneously with two systems:

- A Partial Flow Dilution Tunnel (Nova Microtrol 6) and a AVL 489 Advanced Particle Counter (APC) measured in-line, conform to PMP-Protocol
- An additional APC sampled in high dilution mode directly from the exhaust gas

Tests were performed with two heavy duty engines: Diesel and CNG

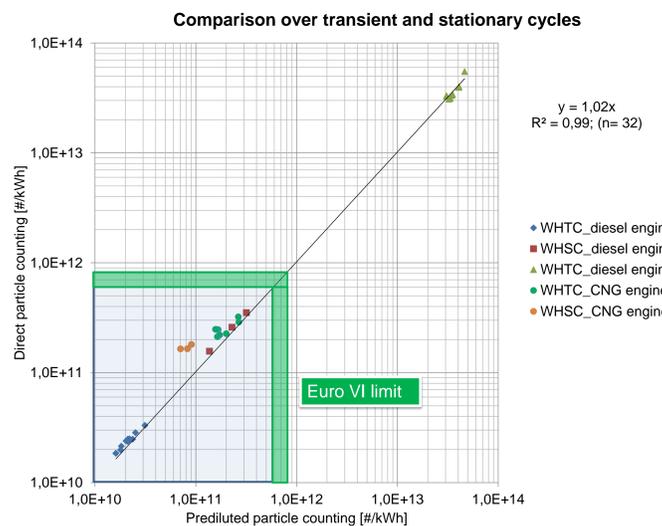
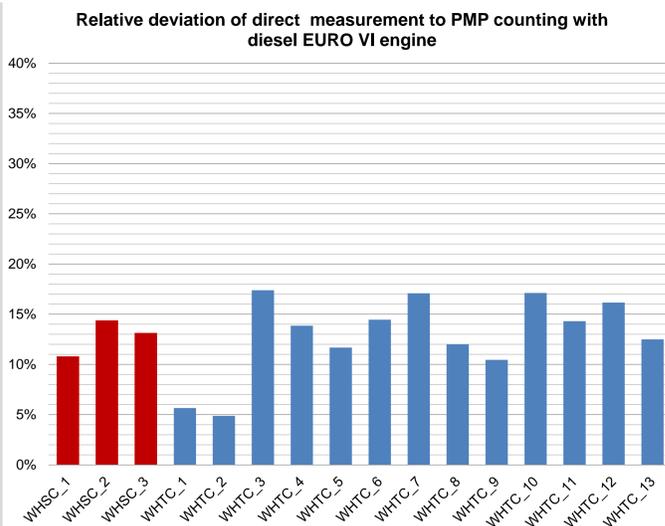
Both engines meet EURO VI emission levels

Test cycles: WHTC and WHSC



Results

- Consistent results with both measurement methods
- Direct measurement tends to overestimate particle number of PMP
- Less than 20% difference between PMP and direct particle counting system with diesel engine
- Larger differences with CNG engines. Further tests necessary
- Measurements without DPF show also good agreement



Conclusion

- Direct particle counting in the exhaust gas of EURO VI Heavy Duty diesel engines leads to comparable results with measurements conducted according to PMP Protocol.
- Sampling upstream of the partial flow dilution tunnel for counting particles as stated in the PMP Protocol poses a possible error source for both, mass and number results. Direct counting separates the two systems and therefore avoids the risk of interferences.
- The direct particle counting method should be introduced as an alternative procedure for EURO VI engine certification.