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"Sampling methodology influences on modern Diesel particle number size distribution measurements"

Abstract:

The set up and the conditions under which gravimetric particulate measurements of diesel vehicles are conducted are regulated. This is not the case for particle number size measurements namely SMPS and ELPI measurements. It will be shown, how the sampling locations (tailpipe – CVS), parameters such as dilution ratio, material (connecting / sealing material), temperatures, residence time and the measurement history of connecting tubes influence the measured quantities. In case of the nanoparticle problematic it was investigated to use an one step high dilution instead of a thermodesorber to avoid nucleation particle artifacts. Engine load and fuel sulphur influences were also investigated in respect to the various parameters mentioned above.

Introduction

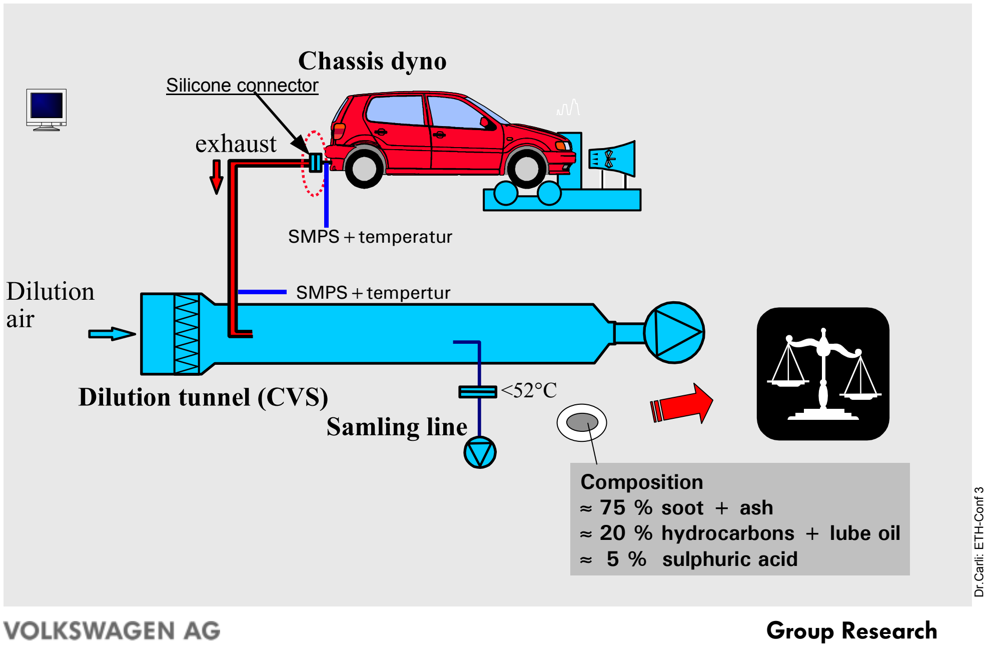
The set up and the conditions under which gravimetric particulate measurements of diesel vehicles are conducted is regulated and properly defined to make comparable evaluations possible. This is not the case for particle number size measurements. In a project conducted together with Matter Engineering AG the various influences on number size distribution measurements by set up, sampling conditions, engine load and fuel quality and the measurement instruments themselves were investigated. Many results were already presented at the last years Nanoparticle Conference (2001):

- Sample probe design has no significant influence on nanoparticle NSD measurements
- Tubing with electrostatic loading ability lose significant numbers of nanoparticles
- Measuring NSD at higher load the formation of nucleation particles occurs, especially with high sulphur fuel
- Already little variation of CVS-DR has a strong effect on particle number and size (no reproducible measurements possible)
  - Provoke nucleation: Low DR, cold humid dil-air, high sulphur fuel
  - Avoid nucleation: High DR > 50, hot dil-air, sulphur free fuel
- The combination oxidation catalyst, high sulphur fuel content and high engine load seems to be the main cause for nucleation particles
- No significant nucleation particle effect observed from transfer line (Diesel)
- Relationship between aerodynamic and mobility diameter depends on particle morphology (density), morphology changes dependent on load and fuel quality
- High discrepancy in particle number and size comparing SMPS's – instruments only good for relative measurements as long as no reliable standard exists

The 2002 presentation is about
- an additional investigation to evaluate connector and sealing material particle effects from the CVS transfer line
- our experience with alternative exhaust dilution systems for particle measurements.

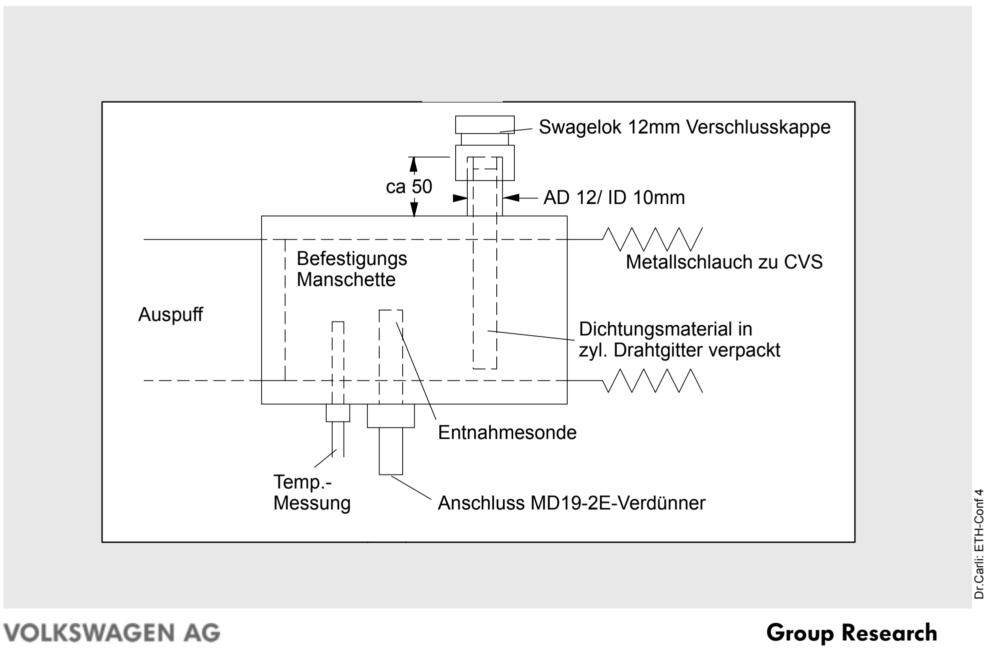
At Volkswagen we made bad experiences with silicone material connectors between the end of the vehicle tailpipe and the CVS tranferline. As the silicon material gets hot we observe a huge increase in the particle number.

Figure 1: Experimental set up



We build up an adapter were material samples of silicon, teflon and rubber material from testing facility in Biel was introduced into a perforated tube and mounted this adapter between the end of the tailpipe and the transferline to CVS.

Figure 2: Adapter with samples between tailpipe and transferline



The Temperature was measured before the sample and at the end of the transfer line. The measurements were conducted with two SMPS´s in parallel (see figrure 1). A gasoline vehicle was used to generate hot exhaust.

When we did the first test with the hot exhaust from the petrol vehicle without any sample to measure the background particle level we observed a unexpected huge number of particles. The transferline which was in normal use before was identified to be the source because after one hour "burn out" at 400°C this effect vanished.

Figure 3

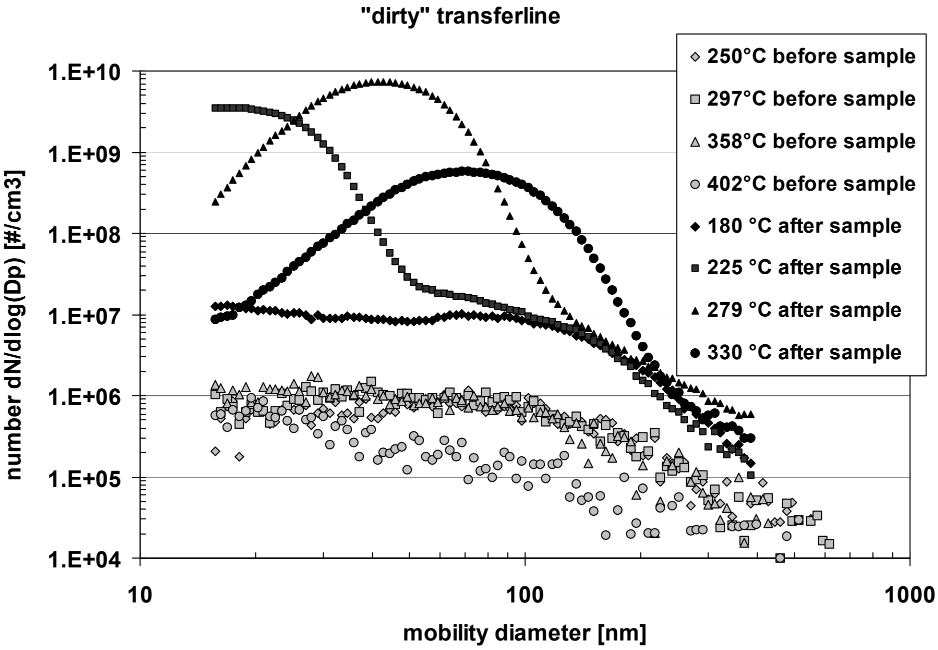


Figure 4

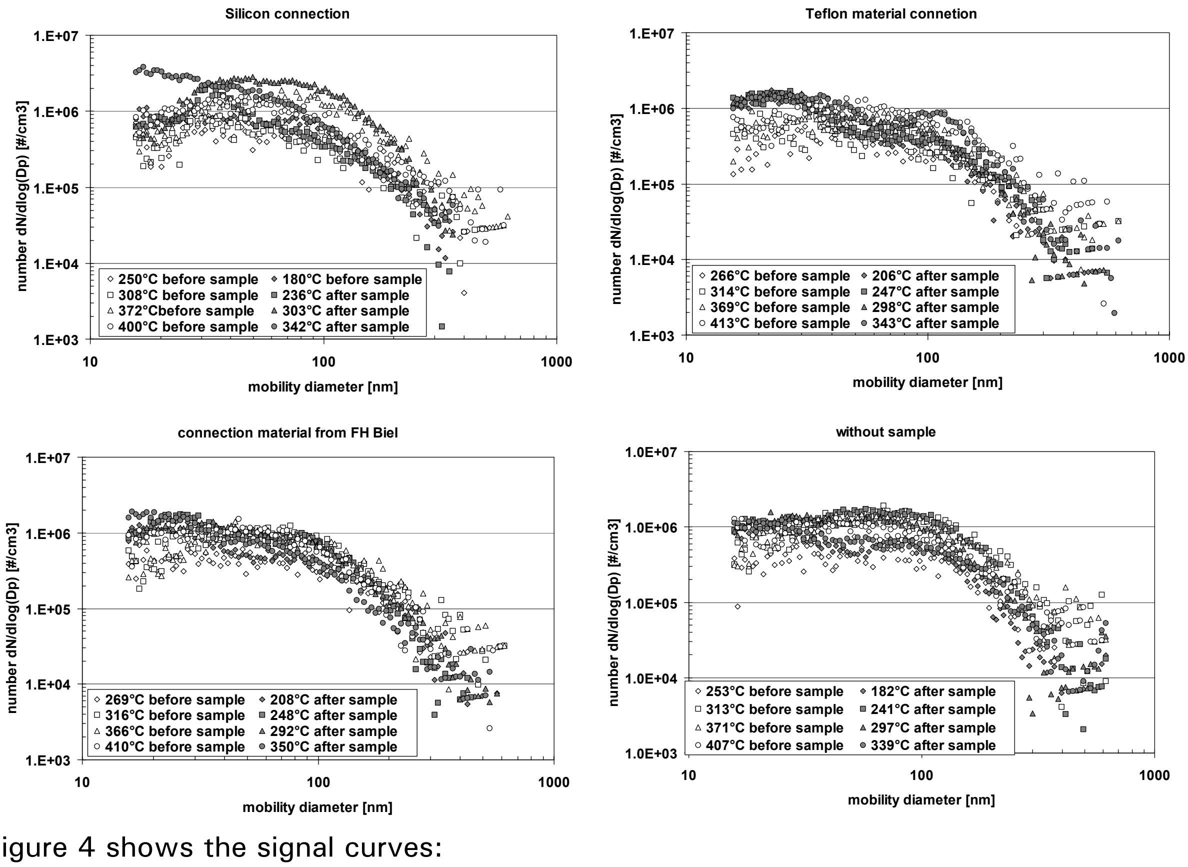


Figure 4 shows the signal curves:

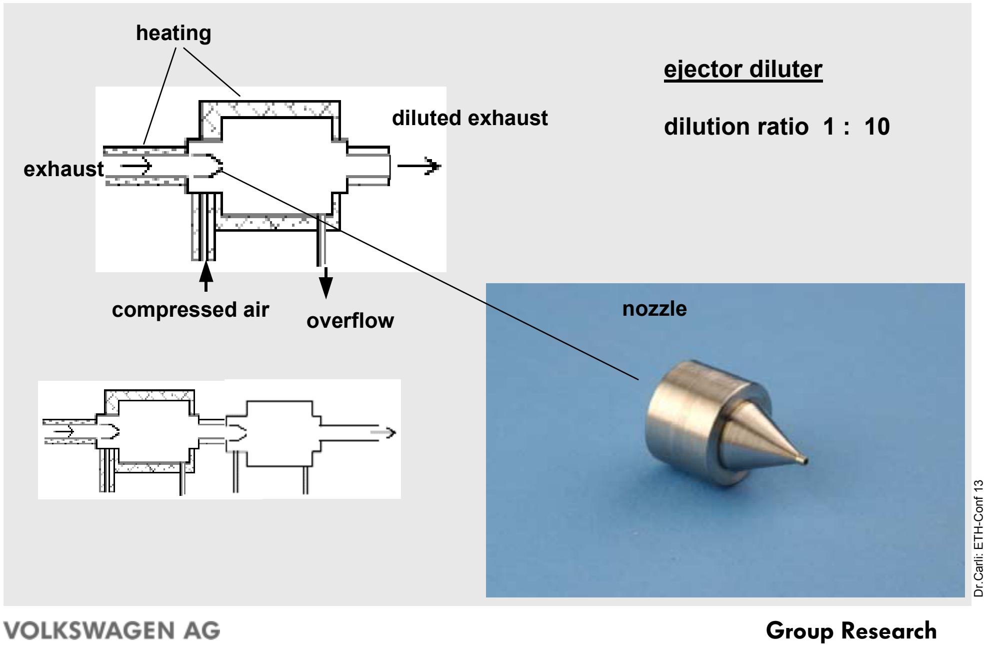
- Without sample – backgroud
- Silicone sample – significant generation of particles
- Teflon and additional sample – no signifcant higher particle emission under this conditions

Concluding statements:

- All connection and sealing material used in the hot sampling train should be tested for particle effects.
- The transferline is potentially a source for artefact particles if the exhaust temperature niveau raises.

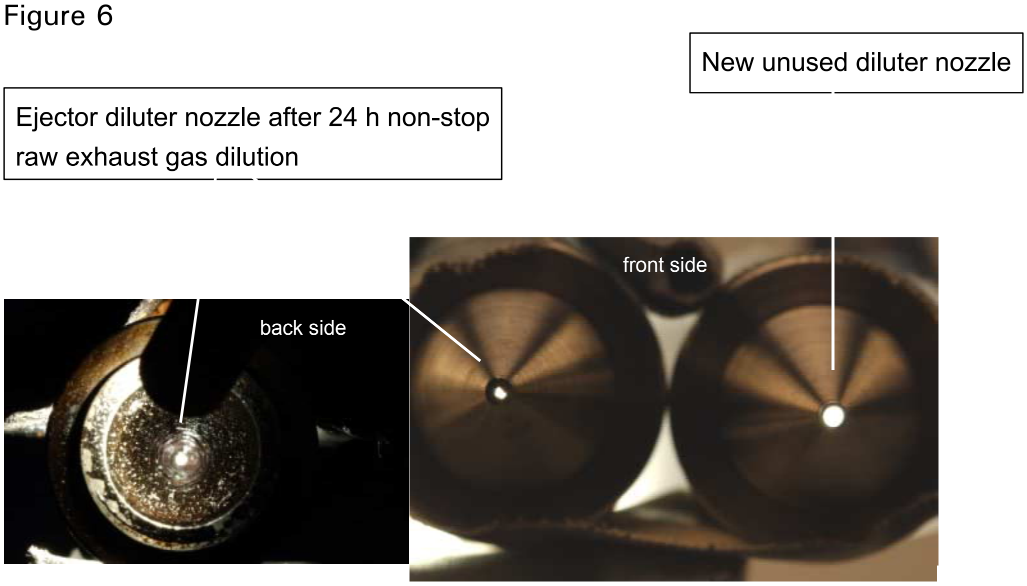
Commonly used dilution system for direct exhaust dilution is the two stage ejector diluter (first stage heated, dil. Ratio ≈ 1:100) directly mounted at the tailpipe. Principle: The compressed air creates a pressure drop at the nozzle and this way exhaust is sucked through the nozzle into the mixing chamber.

Figure 5: Ejector diluter principle (direct exhaust dilution)



As can be seen from the figure 6 that there is the danger of high dilution errors by nozzle fouling.

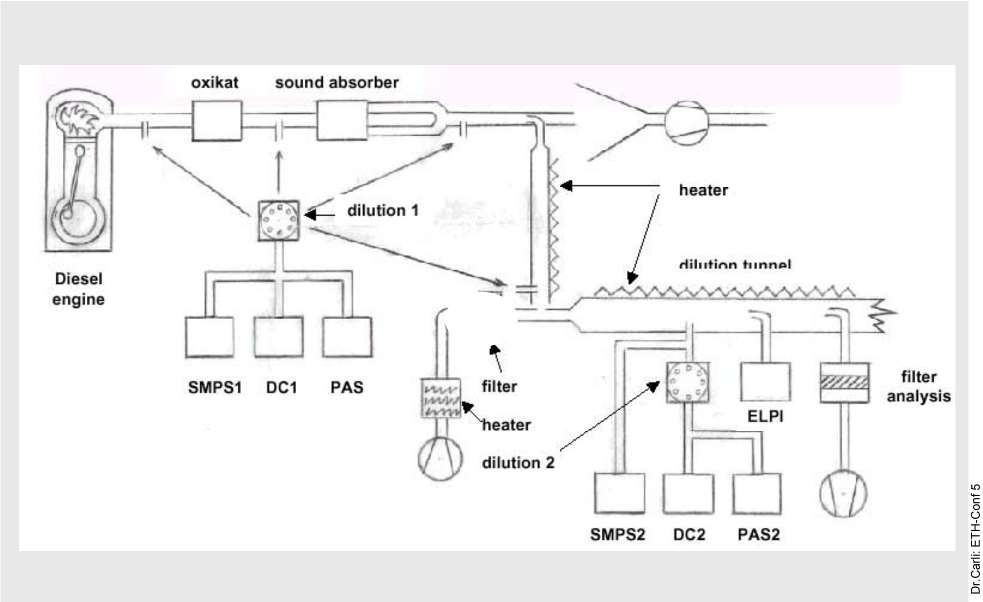
Figure 6



Better experience we have with a partial flow dilution tunnel mounted with a short heated connection line to the tailpipe.

- Variable dilution ration from 1:6 to 1:50
- Diluted exhaust flow of 400 i/min

Figure 7: Diesel engine test bench with partial flow dilution



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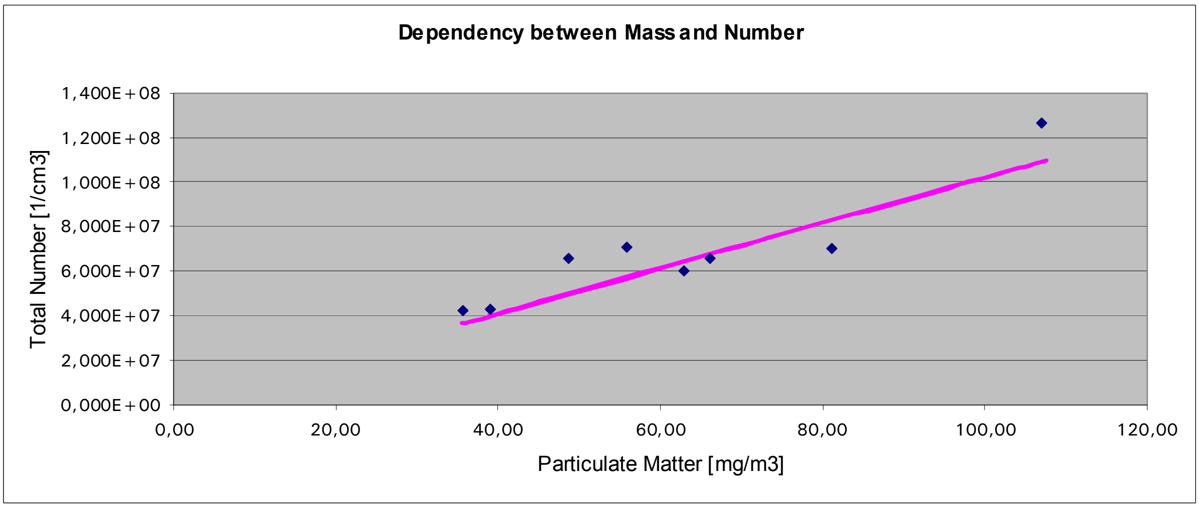
We experienced that it was sufficient to raise the dilution rate to 1:50 to let the nucleation particle mode disappear even at high load and high sulphur fuel conditions.

Result was a quite good correlation between mass measurement and number (SMPS) for different engine loads (50/100/120 km/h; TDI 85 kW engine) and fuel sulphur content (300, 25 ppm).

Figure 8



Summary/Conclusions

It was shown, how parameters such as material (connecting / sealing material), temperatures and the measurement history of connecting tubes influence the measured quantities. It was investigated to use an one step high dilution (partial stream dilution tunnel) instead of two stage ejector diluter to avoid unstable dilution conditions because of nozzle fouling. A one step dilution of 1:50 was sufficient to avoid nucleation resulting into good correlation between mass measurement and number even for under high load and high fuel sulphur conditions.

The new particle measurement instruments can as yet and in future only be applied for the qualitative assessment of particle number and size distribution as a relative comparison because of the nature of particle number behaviour and the various possibilities of measurement influences.

Acknowledgement
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