PARTICLE EMISSIONS OF SPARK-IGNITION ENGINES

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In the presented work particle emissions of four SI engines have been investigated. In the scope of this project the same four cars were tested on the road by chasing experiments and on a chassis dynamometer. In both cases steady state and transient conditions were performed. As the chassis dynamometer provided simulation of ambient air temperature the particle emissions were measured at simulated 0°C ambient air and transient condition (unified driving cycle).

The panel presentation focused on the measurements performed on the chassis dynamometer.

The objectives of the project were the measurement of representative number concentrations and surfaces and the characterization of the chemical composition of the particulate matter.
All experiments were accomplished with the same configuration of measuring equipment, namely the one of the Mobile Emission Laboratory (MEL) of the University of Minnesota, Minneapolis (D.B. Kittelson, et al, SAE Technical Paper No 2000-01-0515).

Slide 5 with the setup shows how the vehicle connected to the CVS-tunnel. The air taken for dilution was furnace-filtered air with a temperature of 45°C. This temperature was maintained in the CVS-tunnel. From thereon two exhaust sample lines were installed. One, to take filter samples with a Nano-MOUDI and another one for the particle and exhaust gas measurement. The particle emissions were monitored with ELPI (size distribution and total number concentration), SMPS (size distribution, CPC Model 3022A), stand-alone CPC (total number concentration, Model 3025A), PAS (photoelectric activity) and DC (active surface).

The two photographs give an overview of the real-world setup. Slide 6 shows the room with the chassis dynamometer. This room is equipped to simulate various climate conditions. Slide 7 shows how the Windstar is connected to the CVS-tunnel.
Slide 8 exhibits all number size distributions measured for the Ford Windstar (mini-van) while running all steady state tests. These were performed at 35mph and 65mph during one hour. The size distributions exhibit exemplarily the low number concentrations measured for three of the four vehicles. There is neither a distinct accumulation mode nor a pronounced nucleation mode to be seen.
Slide 9 shows the same operating conditions for the Ford Escort (passenger car), which exhibits the same characteristics for the accumulation mode but differently from the other vehicles emits a pronounced nucleation mode.
The nucleation mode particles show on the filter sample presented on slide 10. It shows two filters: a blank one (left) and the one after the 65mph steady state testing of the Escort. The color of the filter (yellow-brownish) indicates a high content of ammonia in the nucleation mode particles.

Slides 11 and 12 depict the influence of the ambient temperature on the particle emissions.
Running a cold unified driving cycle means that the vehicle in the test cell has been cold-soaked over night down to 0°C. The measurement starts simultaneously with the engine. The PAS saturates at the hard accelerations up to 65mph and 70mph, respectively. During the first five minutes the sensor

saturates even for moderate accelerations (up to 40mph) too. Once the vehicle warms up the sensor does not saturate for similar operating conditions.
When comparing this result to the one measured with the vehicle being fully warmed up one states that the PAS-signal does not saturate at all and even for the hardest acceleration the signal measured is only half the value than the one measured under 0°C condition.

The correlation of the PAS-signal with the elemental carbon (EC) from the filter sample is good, see slide 13. It is almost better than the one known from the same correlations observed with diesel engines. The values originating from the cold cycle are wider spread then the ones from the warm cycles and the slope stemming from the measurements at 0°C is correspondingly steeper. The factor of 4 between these two clearly underestimates the real condition because of the saturation of the PAS-signal while the vehicle is still cold.

The concluding statements are the following: generally, the particle number concentrations are quite low. Some vehicles show a high nucleation mode at steady state conditions. PAS, DC and number concentrations show strong dependence on ambient temperature. High emissions occur after cold start and during fast acceleration.

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Particle Emissions from SI-Engines

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Slide 1

Overview

- Objectives
- On-road Chasing Tests
  - Background sampling
  - Steady state conditions
  - Accelerations
- Chassis Dyno Tests
  - Steady state conditions
  - Transient conditions (Unified Driving Cycles)
  - Influence of ambient temperature
- Results
- Conclusions

Slide 2

Objectives

- Measurement of representative number concentrations and surfaces.
- Characterisation of the chemical composition of the particulate matter.

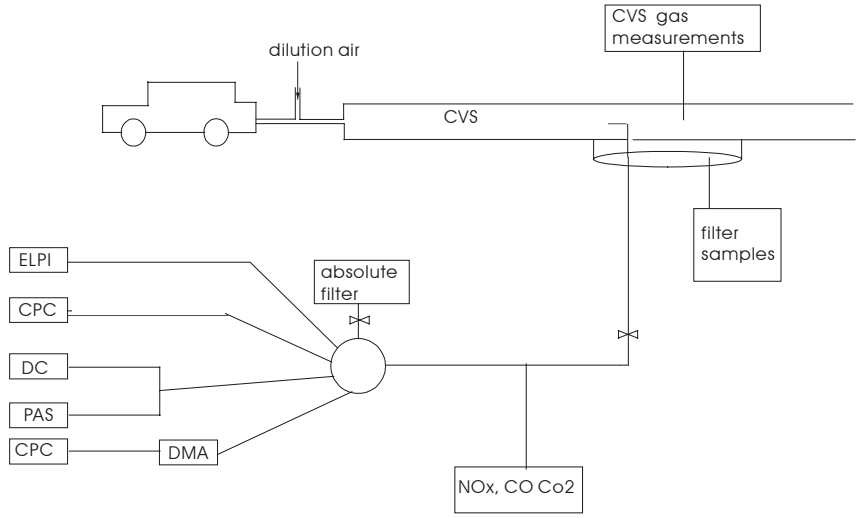
Slide 3

The DOE-Project

- Projectpartners: University of Minnesota, Minneapolis, PSI, FH-Aargau
- Funding: Department of Energy (DOE), PSI, FH-Aargau
- Performance:
  - Chasing experiments with the MEL: U of MN
  - Chassis Dyno testing: U of MN, FH-Aargau

Slide 4

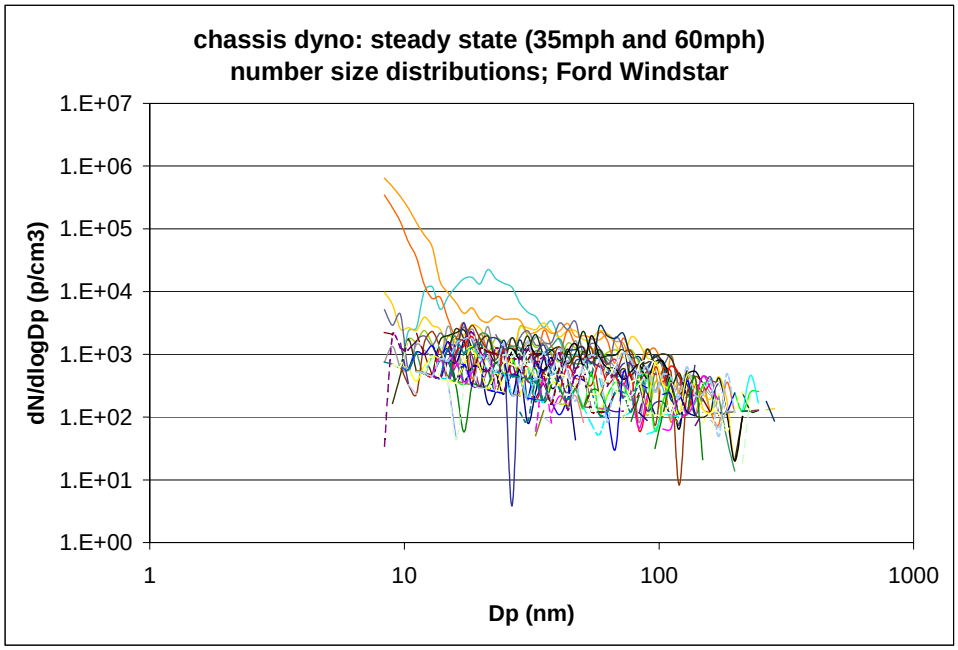
Setup



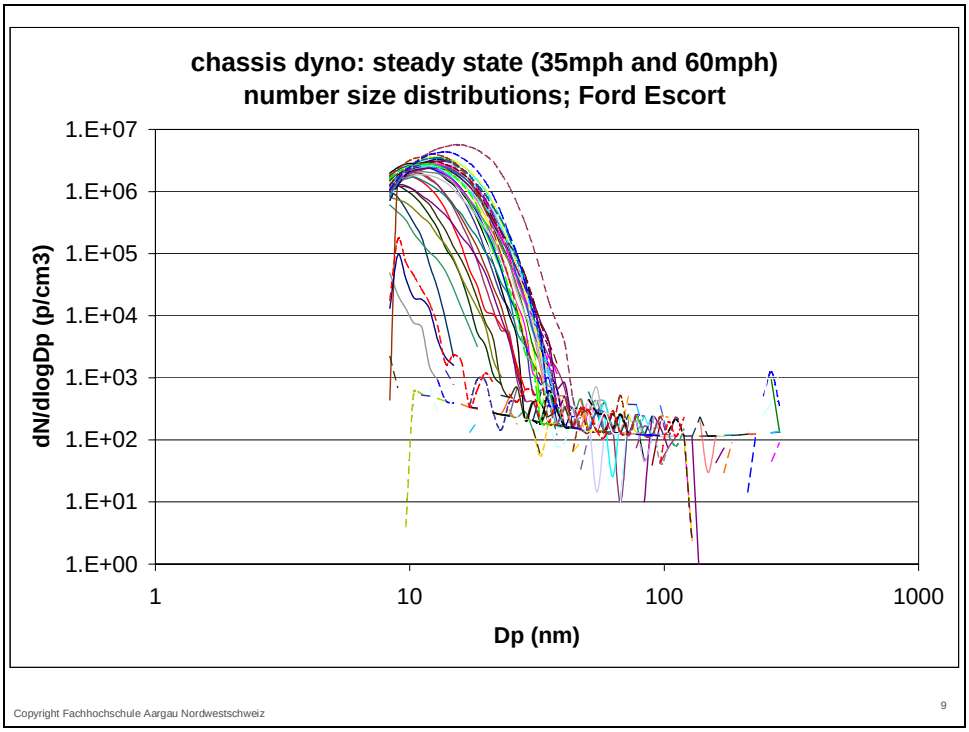
Slide 5

Slide 6

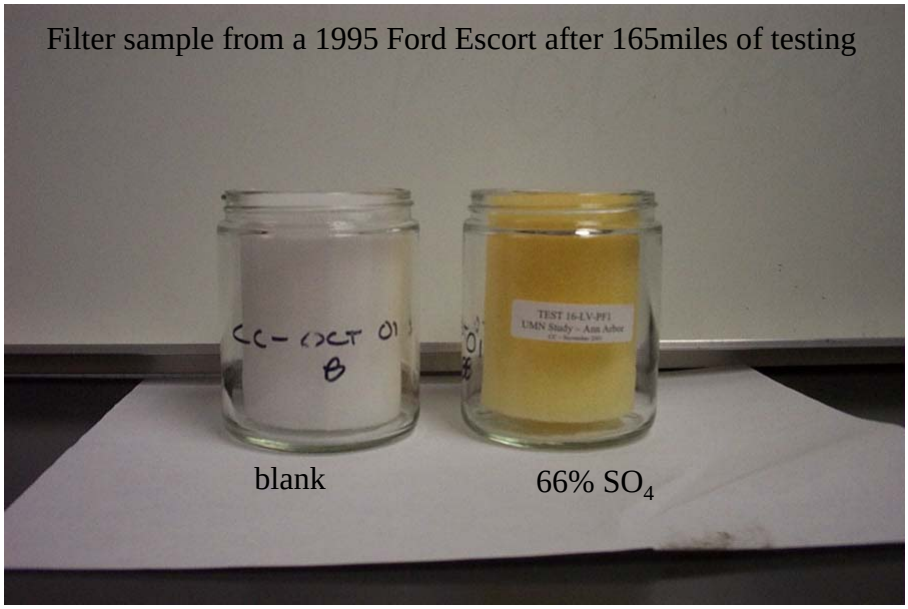
Slide 7



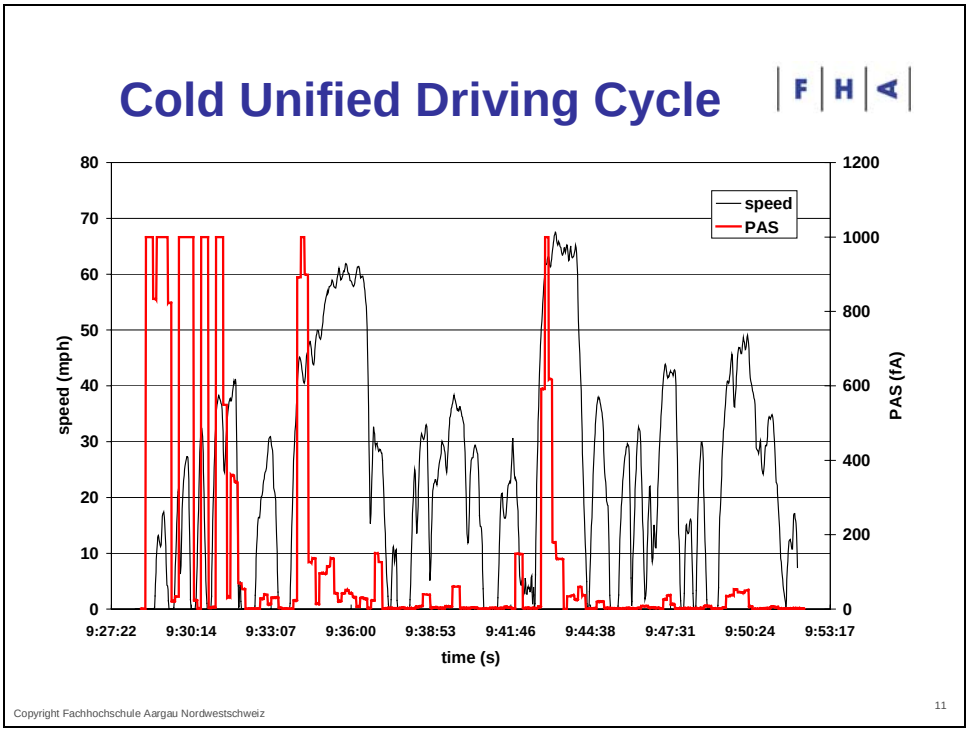
Slide 8



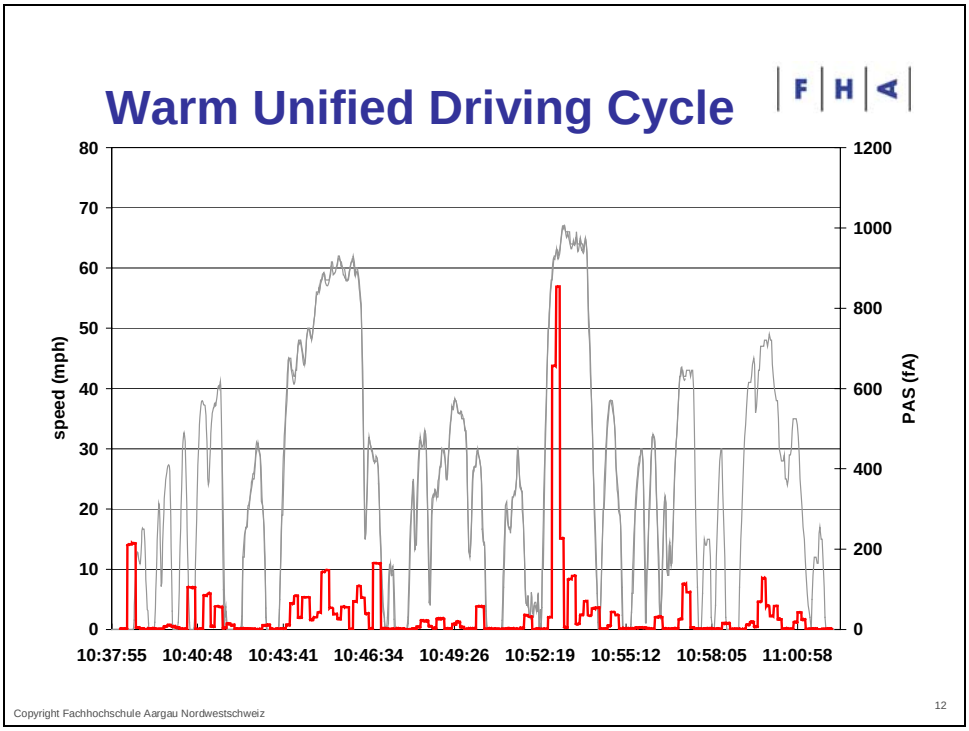
Slide 9



Slide 10

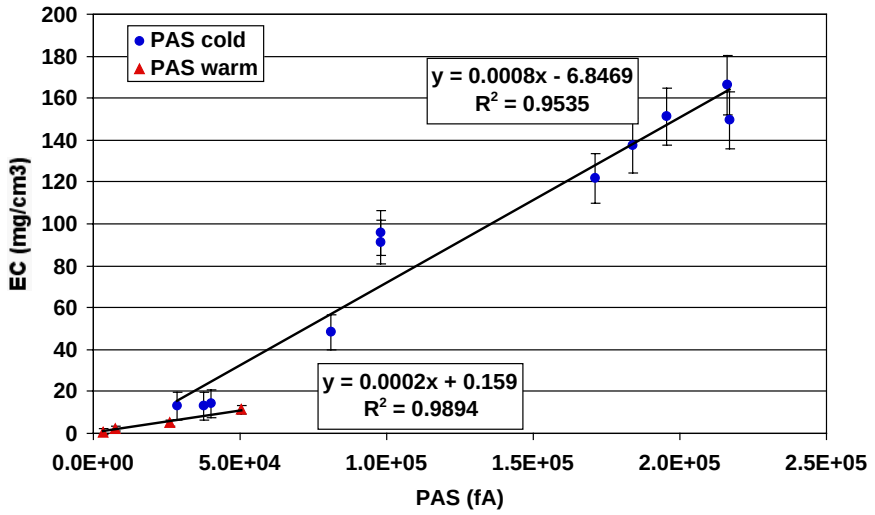


Slide 11



Slide 12

Correlation EC with PAS



Slide 13

Conclusions

- Generally, the particle number concentrations are quite low.
- Some vehicles show a high nucleation mode at steady state conditions.
- PAS, DC and number concentrations show strong dependence on ambient temperature.
- High emissions occur after cold start and during fast acceleration.

Slide 14