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What Causes High Particle Emissions from Gasoline Vehicles?

A Study of Vehicle Effects

3rd ETH WORKSHOP ON NANOPARTICLE MEASUREMENT, ZURICH, August 9-10, 1999

What Causes High Particle Emissions From Gasoline Vehicles? A Study of Vehicle Effects

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Background: Early studies of particle size and number emissions showed some surprising results for gasoline vehicles. As an example, Esso data published as SAE961980, and presented at the 1st ETH workshop recorded very low particle number emissions for TWC gasoline vehicles at city speeds, but showed emissions at the same high level as diesel cars at 120km/h. Since these tests were performed, understanding of the measurement techniques has progressed, and substantial evidence points to the possibility of small particle formation in the dilution and sampling system. At the same time, there is evidence that very small particles do exist in the atmosphere, so our understanding is not complete. We carried out tests to investigate whether vehicle operating conditions or test procedures could help explain the high gasoline emissions at high speed, and these form the subject of this presentation.

Is the effect repeatable? The high gasoline particle number emissions at high speed were initially unexpected, however the effect has been reported in several other studies. As an illustration we show results for a number of vehicles tested by Esso and Concawe. All the tests reprorted here used the standard dilution tunnel used for filter paper PM mass measurement, coupled with SMPS measurements performed by AEA Technology.

Stabilisation Effects: In the tests reported in SAE961980 we obtained very good repeatability by careful attention to the test procedure, and particularly in ensuring that the schedule of tests followed for each fuel/vehicle combination was identical. We wondered what would be the effect of increasing the stabilisation time at each test speed and found that at 120km/h there was a steady change in emissions over a 20 minute stabilisation, with particle numbers recorded by the SMPS (16-800nm range) decreasing over time. Concurrently, there was a trend for mean particle size to decrease with time. We believe that the engine itself is stable during this time, but that the sampling system needs time to reach an equilibrium.

Lubricant blowby was suggested as a possible source of particles at high speed. To test this hypothesis we measures emissions with the crankcase ventilation pipe disconnected, bracketing the test with measurements with the pipe connected in the standard vehicle configuration. No systematic effect of crankcase ventilation gases was seen.

Air/Fuel Ratio is frequently suggested as a possible explanation of high PM numbers, since some vehicles run richer as they approach full load. However, tests on several TWC gasoline cars showed that at 120km/h they maintained stoichiometric operation, so AFR changes are not responsible for the high emissions recorded.

Sulphate formation is known as a potential source of fine particles, particularly in low-dilution tunnels as used for these tests. It is known that these fine sulphate particles can form as artefacts in the sampling system, although their relevance to real world emissions is still unclear. To test whether the measured particles at 120km/h could be explained by sulphate formation, we collected and analysed filter paper samples. The sulphate content was higher than normally seen in diesel particulate matter, but not high enough to explain the dramatic increase in measured particle numbers. However, it should be noted that the amount of mass collected on the filter was very small; not all the material seen by the SMPS seems to be collected on the filter.

Conclusion: High particulate numbers have been recorded from gasoline engines at high speed. The tests reported here show that there are no easily identifiable vehicle factors that can explain these results. We know that particles can form as artefacts in the sampling system, so a thorough understanding of how particles are emitted to the atmosphere and their subsequent evolution is important to guide future studies.

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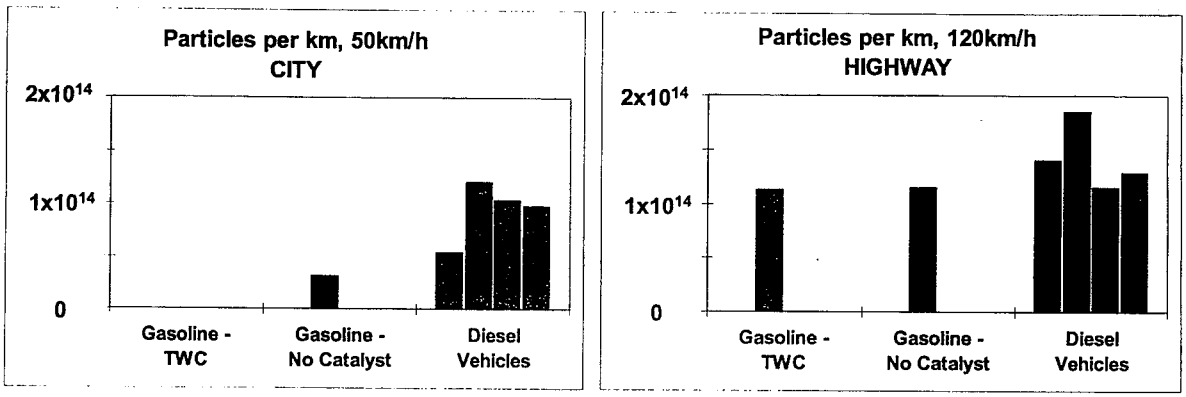
Background

- **Early studies of particulate size/number showed high gasoline emissions at high speed**



SOURCE: SAE 961980, ESSO/AEA
MEASUREMENT BY SMPS

- **Vehicle parameters studied to seek understanding**

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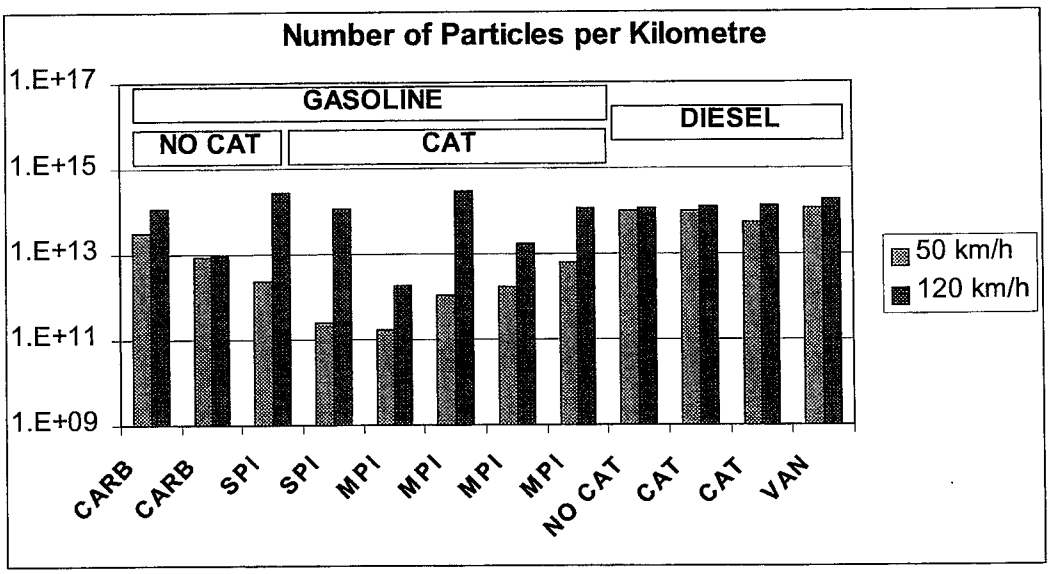
Result Confirmed on Other Vehicles



- **Data from Esso/Concawe studies**
  - SMPS measurements
- **Gasoline emissions up 10-100 times as speed increases**

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What Causes High Particle Numbers at High Speed?

Vehicle/Test Factors Examined:

- **Test stabilisation time, order of testing**
  - Hang up in dilution tunnel?
- **Effect of lubricant blowby**
  - PCV pipe on/off
- **Air/Fuel ratio at high speed**
  - does the vehicle maintain stoichiometry?
- **Contribution of sulphate**
  - % of sulphate on filter paper samples
- **All size measurements with SMPS**

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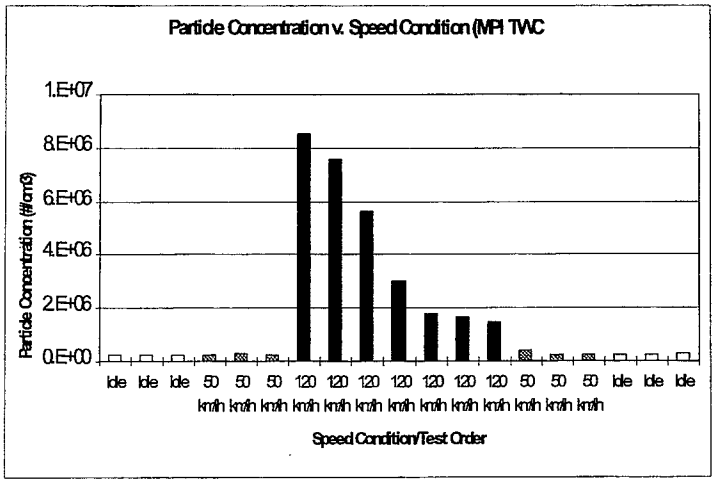
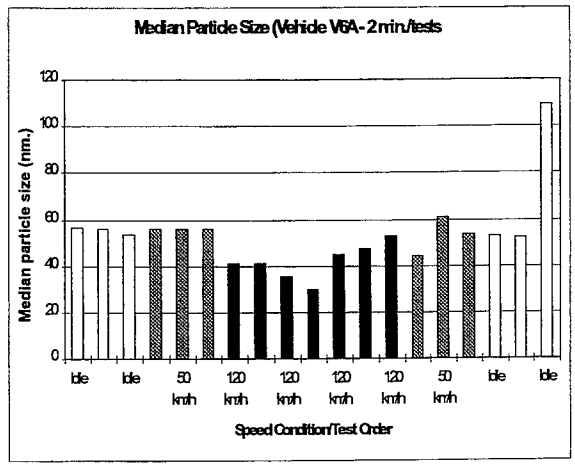
Stabilisation Effects





- **Particle concentration, linear scale**
  - Each test bar is 2 minutes operation
  - TWC car showed decrease in 120km/h emissions over time
- **Results varied to some extent between cars**
- **Evidence of more small particles at high speed**

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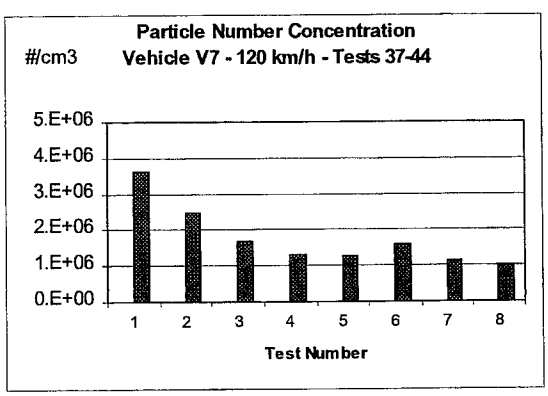
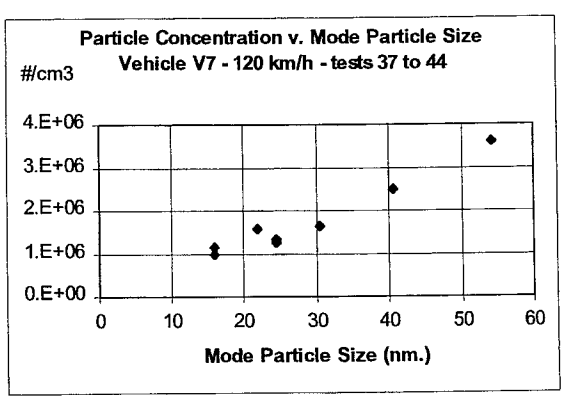
Changing particle Numbers Linked to Size

- **Particle numbers at 120km/h declined over time**
  - mode size increased over same period
  - TWC vehicle, SPI





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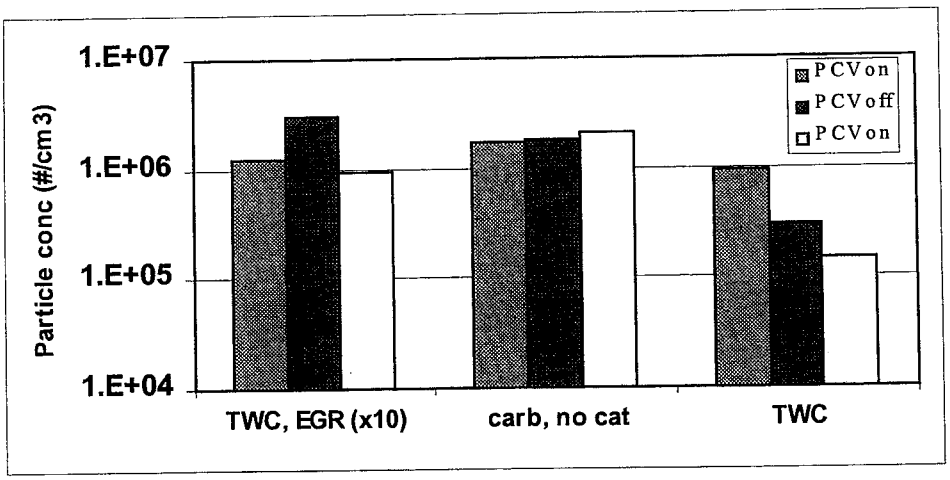
Lubricant Blowby

- **Blowby gases to crankcase increase at high speed**
  - Potential for lube carry-over through PCV system?
    - + **Idle (20 min), 50km/h (20min), 120km/h (20min)**
    - + **Disconnect PCV hose and repeat (no crankcase gas recirculation)**
    - + **Replace PCV hose and repeat**



- **No consistent effect of PCV gases**

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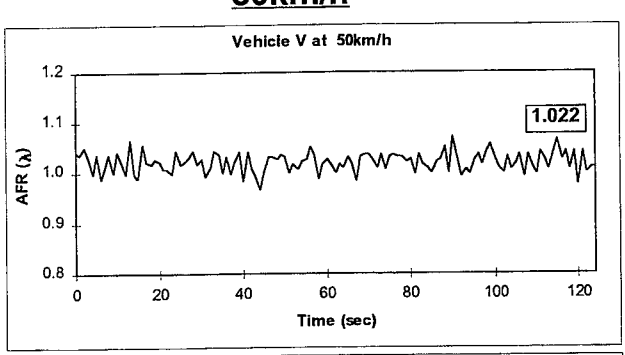
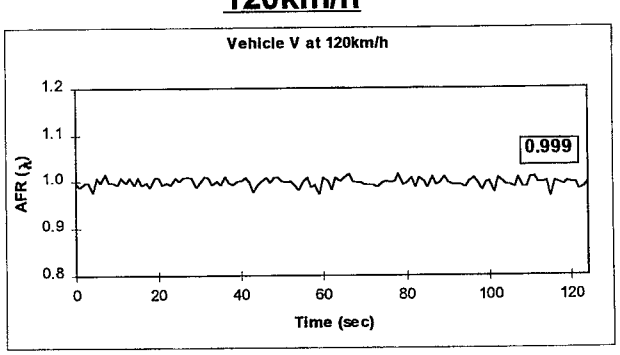
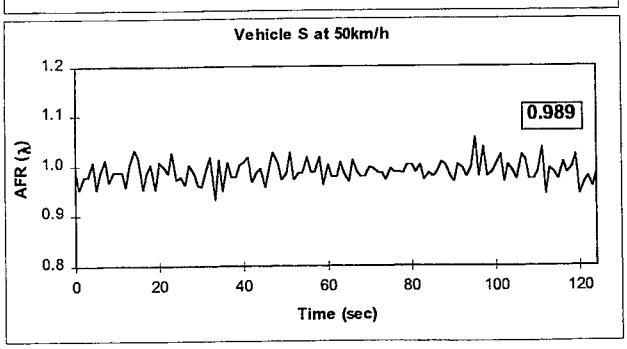
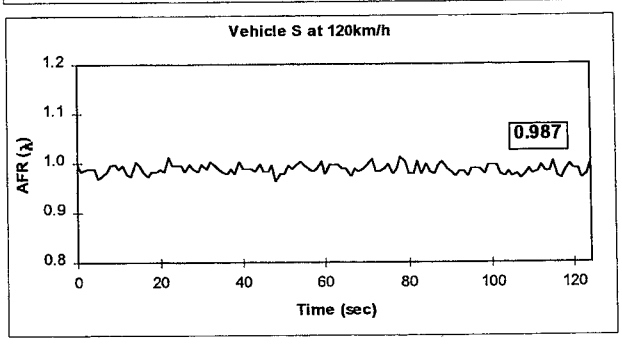
Does Air/Fuel Ratio Change at High Speed?

50km/h **120km/h**









- **AFR control maintained on two TWC cars**

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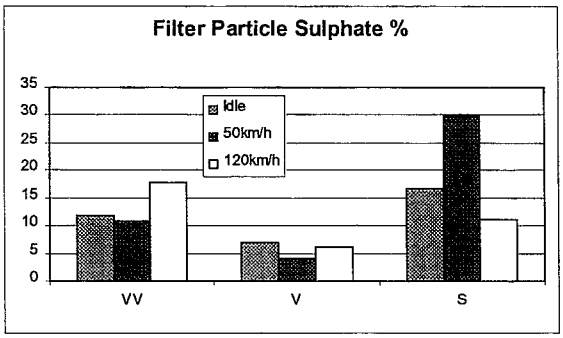
Sulphate Content of Filtered Particles

- **Filter paper samples collected over 20 minutes**
  - to allow adequate sample to be collected
  - typical sample mass <0.1mg
  - sulphate measured by IP436, extraction + ion chromatography



- **Sulphate % not correlated to vehicle speed**
  - overall levels quite high
  - diesel figures typically around 5%

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Conclusion

- **None of the investigated parameters explained the observed increase in particle numbers ar high speed**
- **Study of test conditions/protocol needed to obtain reliable results**

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