Formation of Nanoparticles in the Exhaust of Diesel Busses for Different Levels of Fuel Sulfur Content

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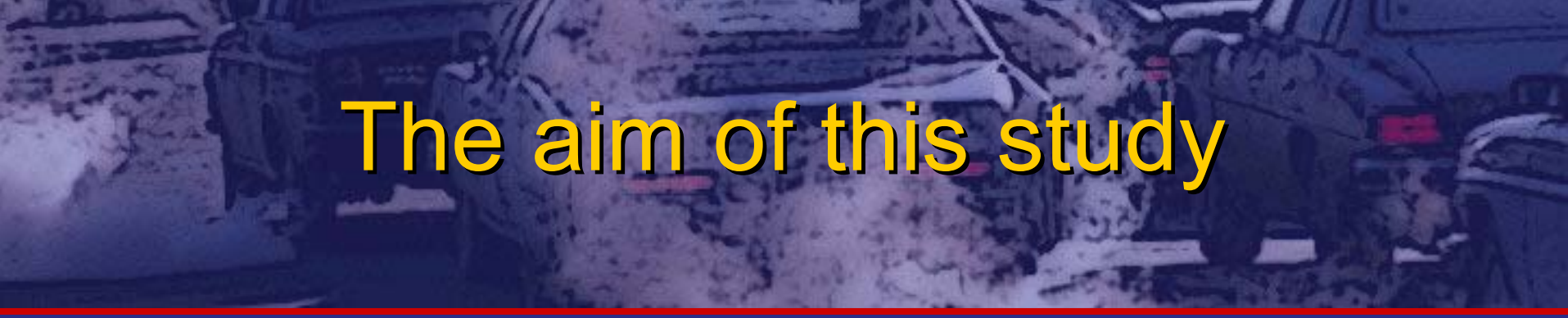


The aim of this study

AIM:

To estimate the influence of the reduction of fuel sulfur content from 500ppm to 50ppm on the emissions from a bus fleet consisting of pre EURO I, EURO I and EURO II buses.

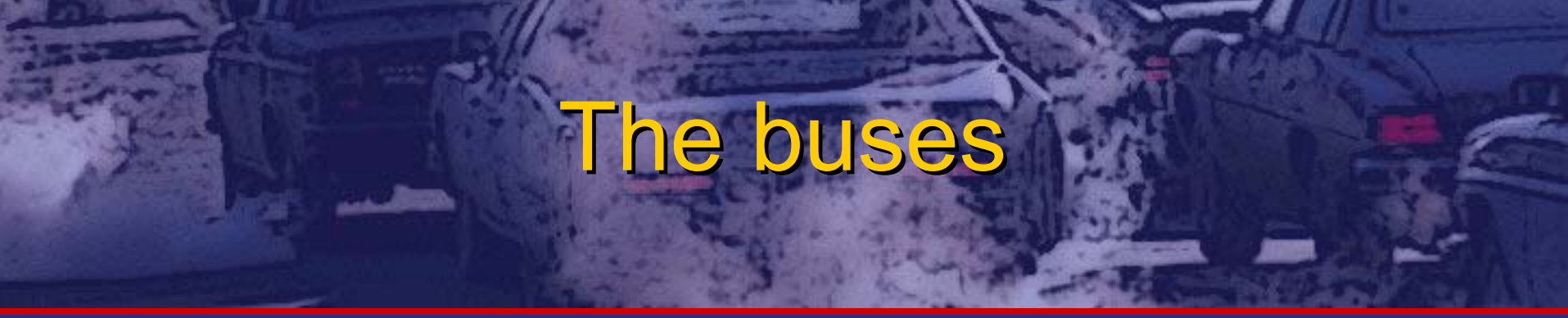
Current diesel fuel sulphur level in Queensland is set to 500 ppm - low sulphur (LS) and

Future fuel sulphur level in Queensland is set to be 50 ppm - ultralow sulphur (ULS)

- Eleven in-service Brisbane City Council buses operating alternatively on LS and ULS diesel fuel were tested on a chassis dynamometer.
- Initially the low sulfur (LS) diesel fuel emission measurements were carried out.
- Few weeks after the initial measurements the bus depot from which the busses were sourced had switched the supply of fuel to ULS.
- The second round of measurements on ULS fuel was carried out around 2 months after the supply of fuel was switched to ULS.

Experimental Materials And Methods

- Particle mass measurements
- Particle Size Distribution Measurements
- Gas Emission Measurements
- Chemical composition - Polycyclic aromatic hydrocarbons (PAH) measurements included the sixteen US EPA priority PAHs
  - Particle-bound (filters)
  - Vapor-phase (XAD – in series after the filters)



The buses

Bus Type	Number of Buses	Age of Buses
MAN SL200	2	19 years (pre EURO I)
Volvo B10M	6	6-12 years (EURO I)
B10L	3	1 (EURO II)

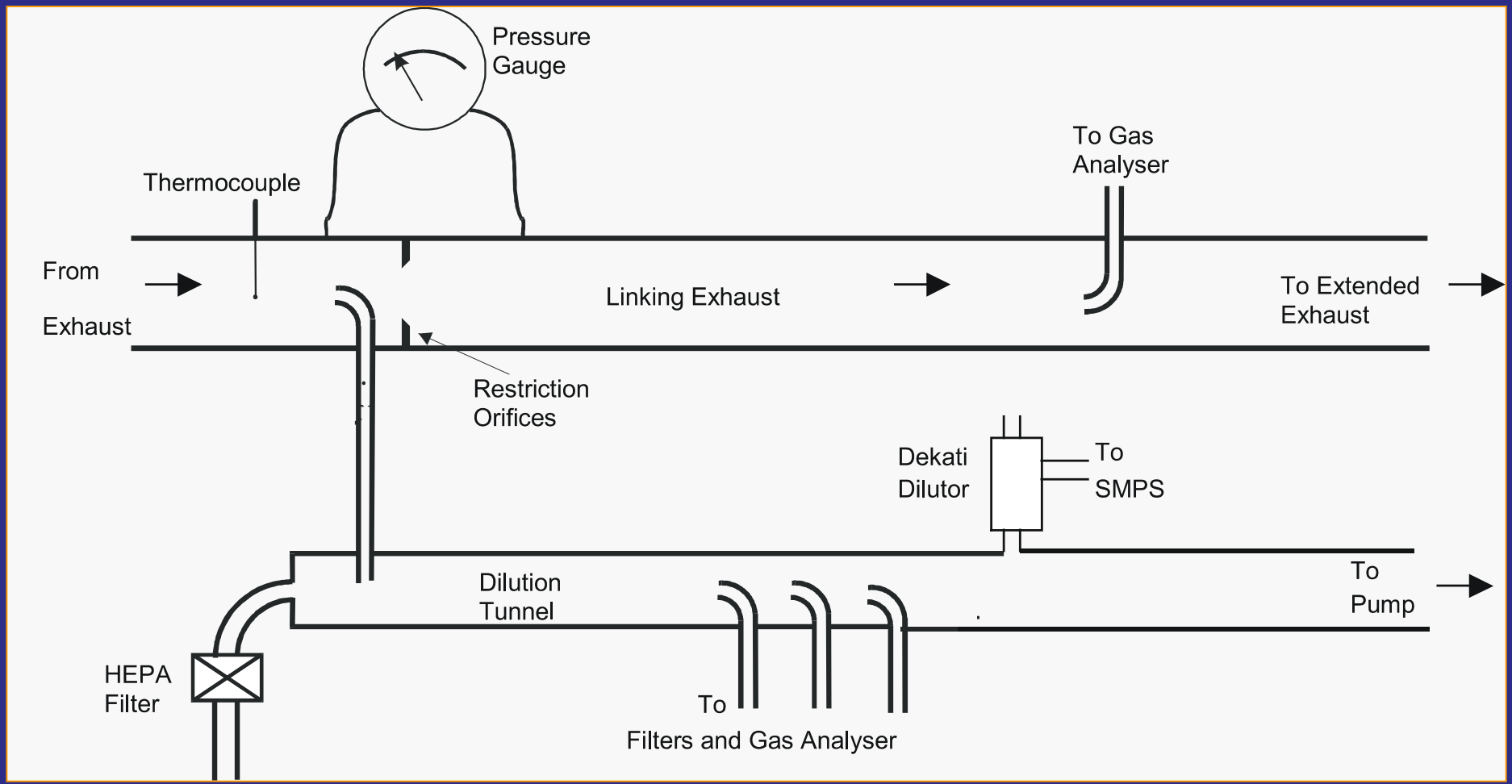
Bus operating modes

Mode	Engine Power %
Mode 7 (Idle)	0
Mode 11	25
Mode 10	50
Mode 8	100

Fuels Used

Property	Test Method	Unit	LS BP G32	ULS BP G50
Density (at 15ºC)	ASTM D4052	kg/L	0.82 - 0.86	0.830 - 0.855
Cetane Index (min)	ASTM D4737		46	51
Viscosity (at 40ºC)	ASTM D445	cSt	2.0 - 4.5	2.0 - 4.5
Distillation 95% recovered	ASTM D86	ºC	371	350
Sulfur Total (max)	ASTM D4294	mg/kg	500	50
Aromatics Total	IP 391	% mass	14	9

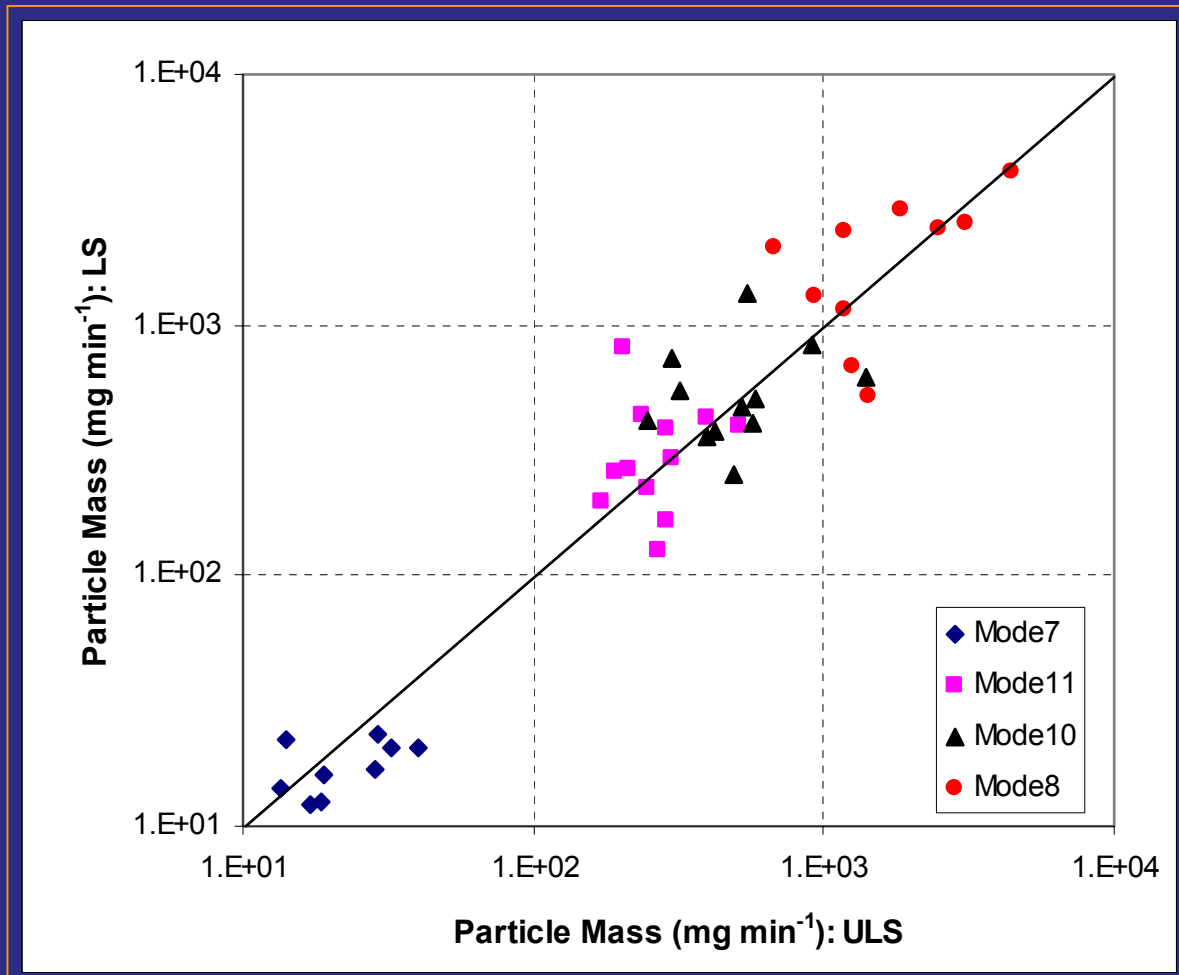
Measurement technique



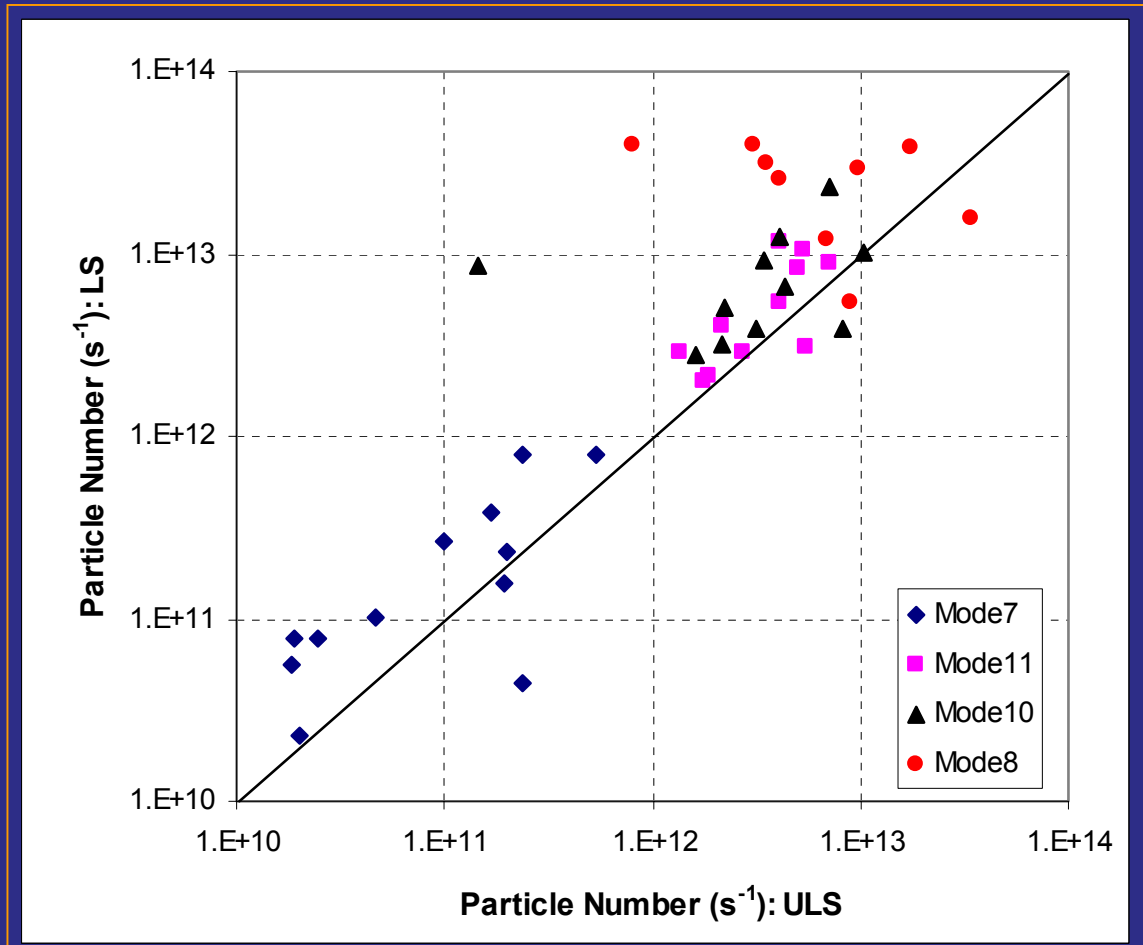
Experimental Conditions

- As the main aims of this study was to compare particle number emissions with the two fuels, care was taken to achieve the same dilution conditions for a given bus/mode.
- In each experiment, the engine was first allowed to run at the required rate for several minutes until the exhaust temperature and gas concentrations had attained steady state values.

Particle mass emission rates



Particle number emission rates



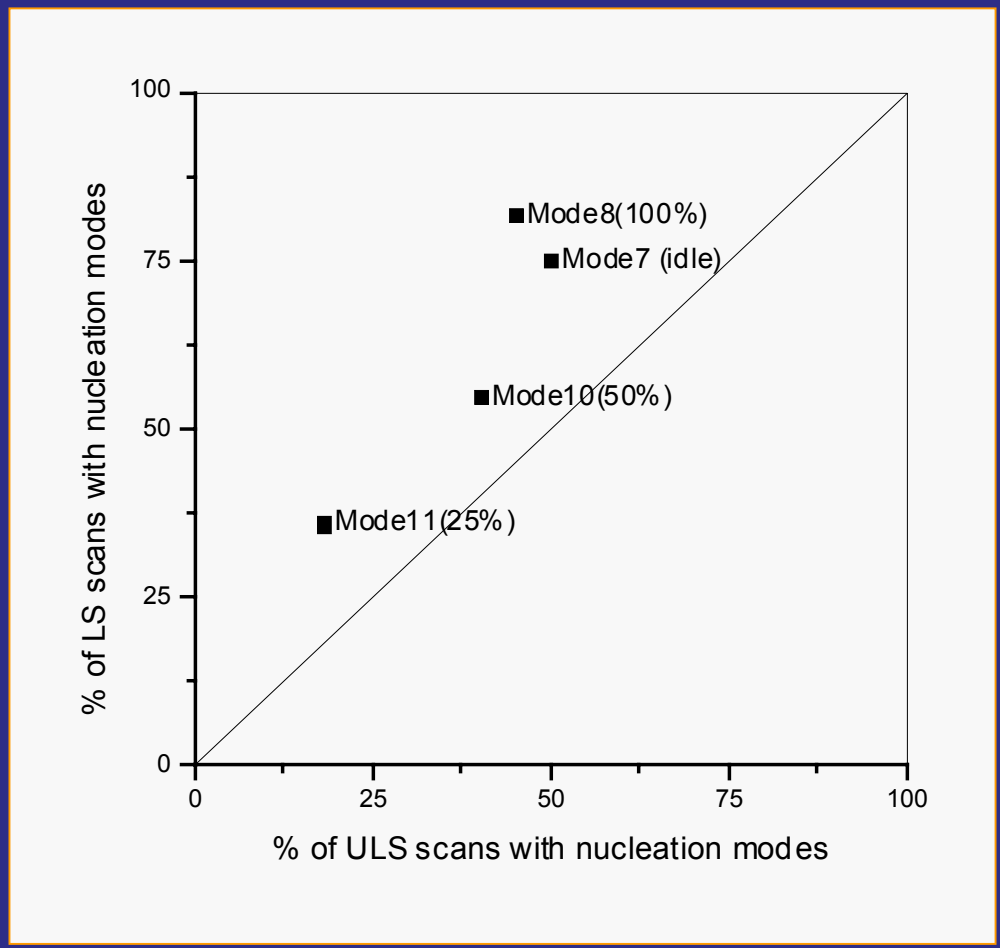
Comparison between LS and ULS fuel emissions

- Decrease in particle number emissions for ULS (statistically significant for all modes but idle)
- No difference in TSP emissions

Reduction in emissions: in which particle size range?

- In nucleation mode (< 0.05 μm)?
- In accumulation mode (> 0.05 μm)?
- Close to 300 SMPS particle number size distribution spectra were carefully examined to identify the presence of nucleation modes.
- Bimodal number size distributions usually exhibited a nucleation mode below 50 nm.
- The accumulation mode generally occurred between 50 nm and 120 nm.
- The percentage of SMPS scans which showed a distinctive nucleation mode was computed for each of the four driving modes, for each of the two fuel types.

Occurrence of nucleation mode



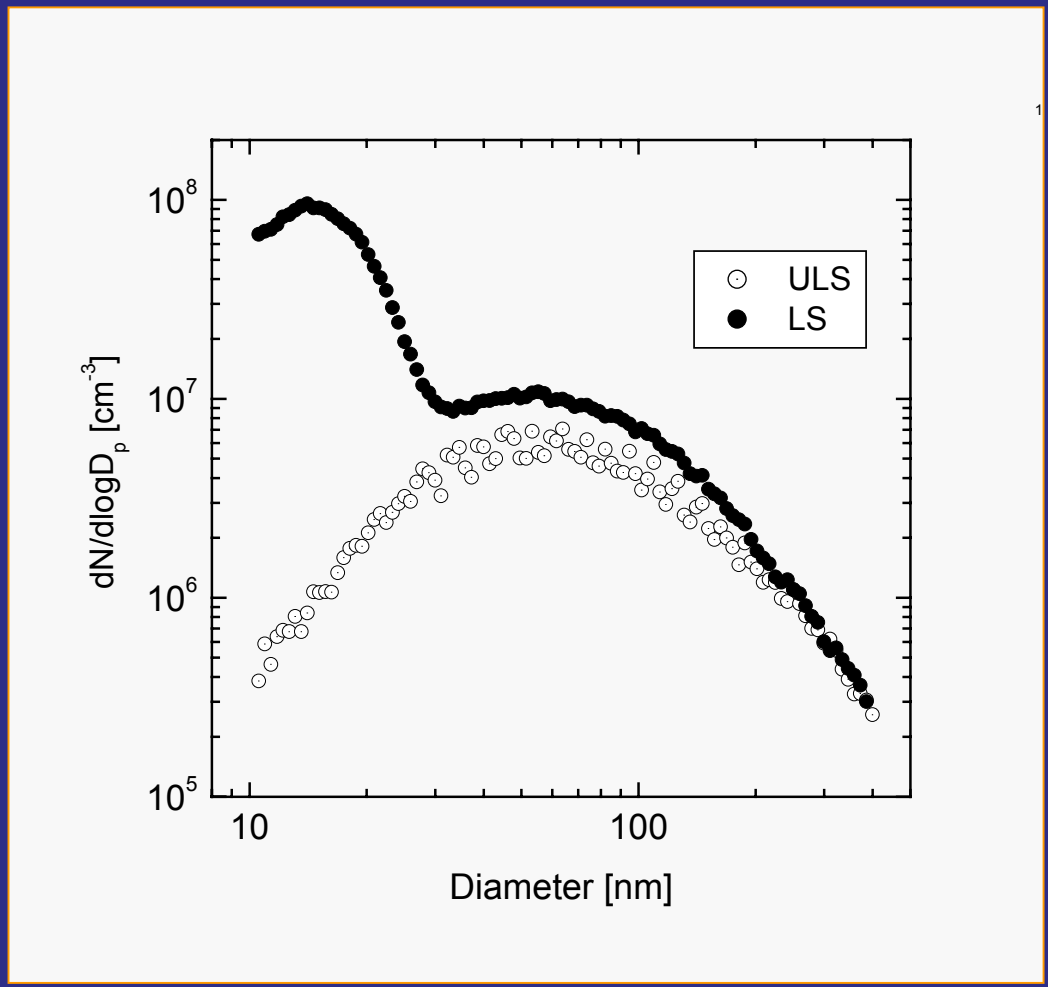
Occurrence of nucleation mode

- Where the formation of the nucleation mode was already suppressed with 500ppm (LS) fuel there was only a small reduction, if any, in the total particle number emission with 50ppm (ULS) fuel.
- In mode 11 - only 36% showed a distinct nucleation mode as opposed to mode 8 where 82% of cases exhibited a nucleation mode (LS).
- Only in 3 cases out of around 50 was the nucleation mode observed with ULS fuel but not with LS fuel.

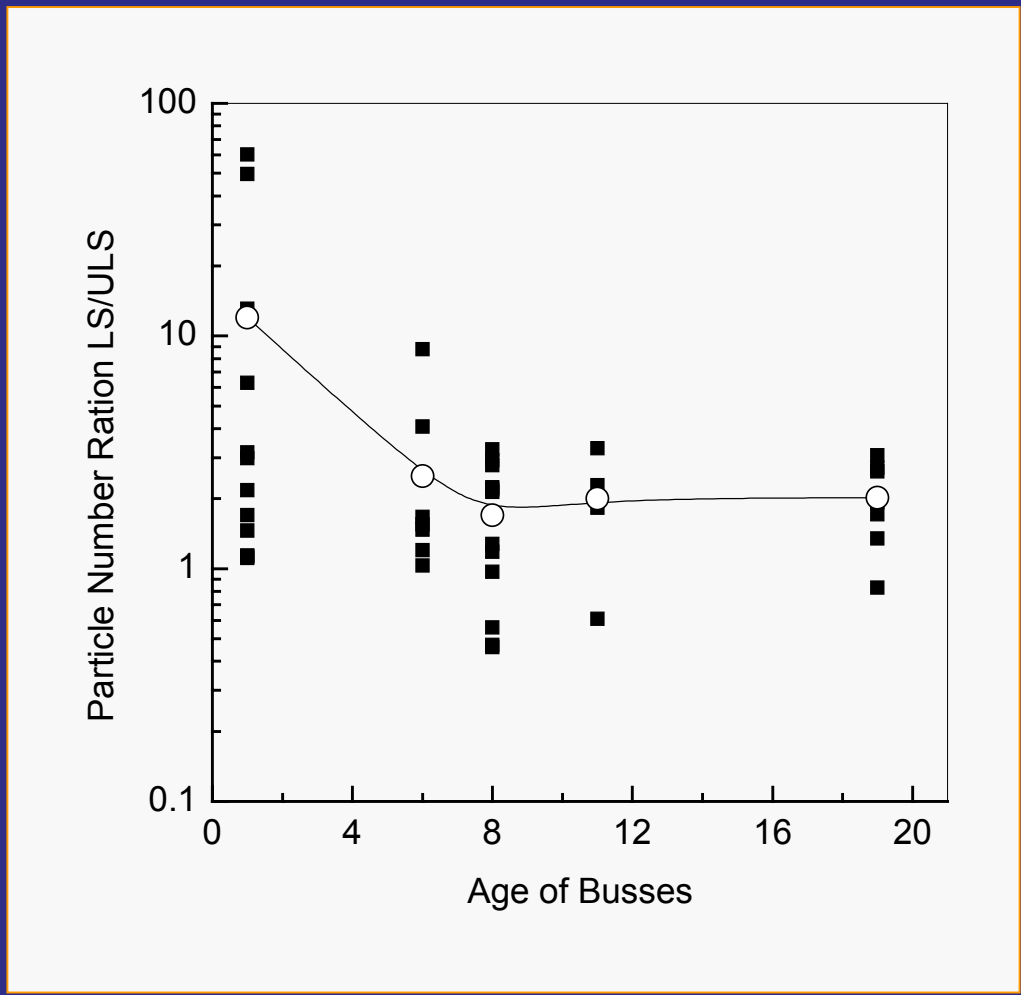
Occurrence of nucleation mode

- For around 10% of all cases the number size distribution was unimodal - between about 40 nm and 50 nm.
- Observed in modes 7, 10 and 11 with both types of fuel. No such cases were observed at the maximum power – mode 8.

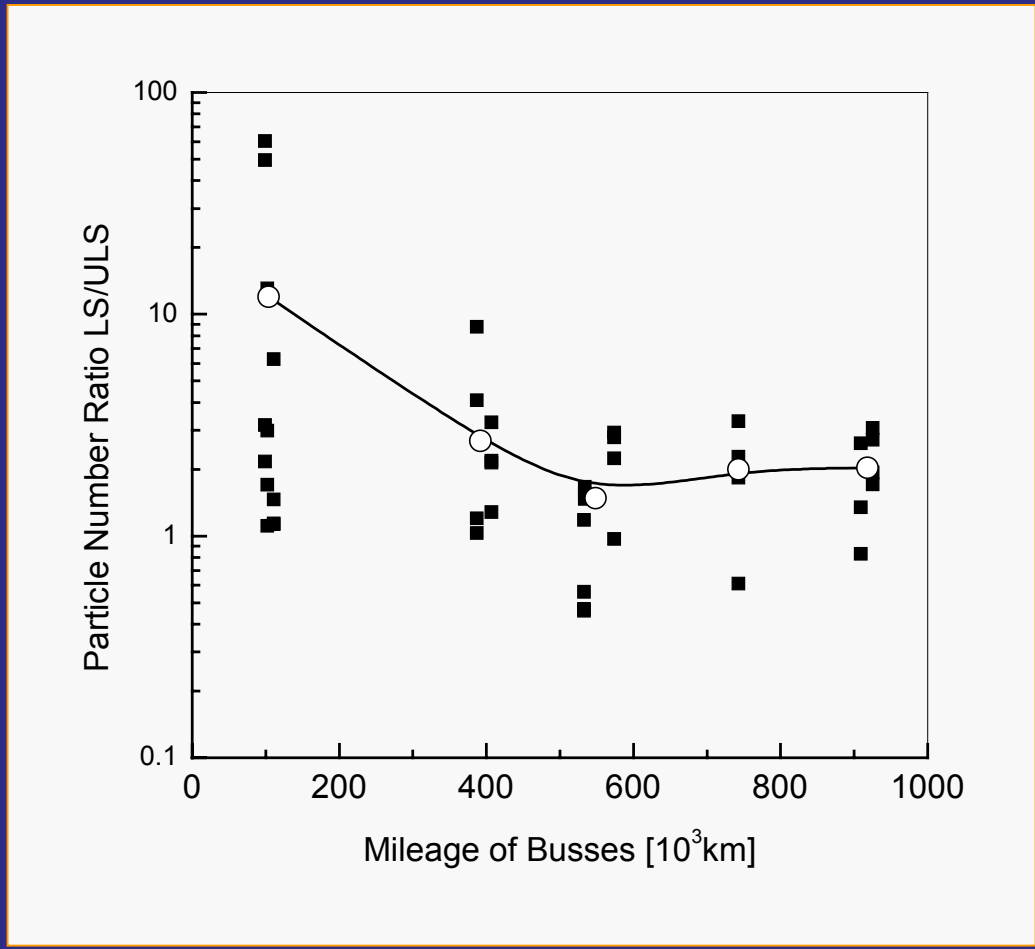
Size distribution of emitted particles

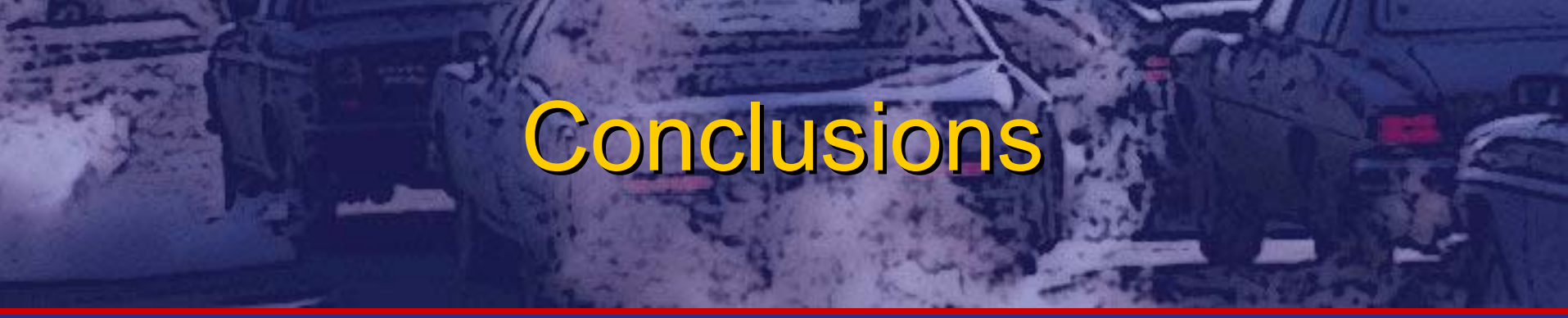


The relation between bus age and the emissions



The relation between bus mileage and the emissions

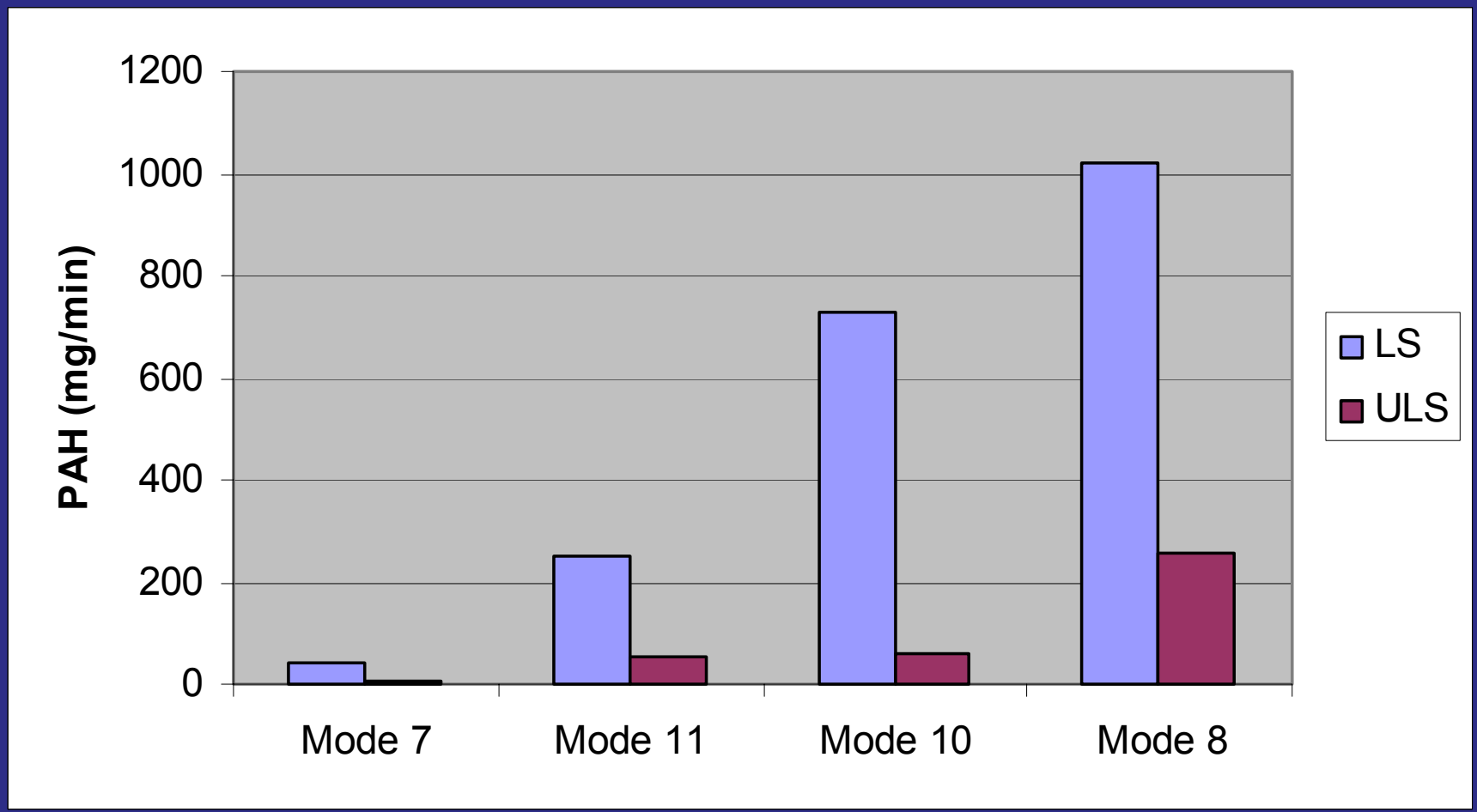




Conclusions

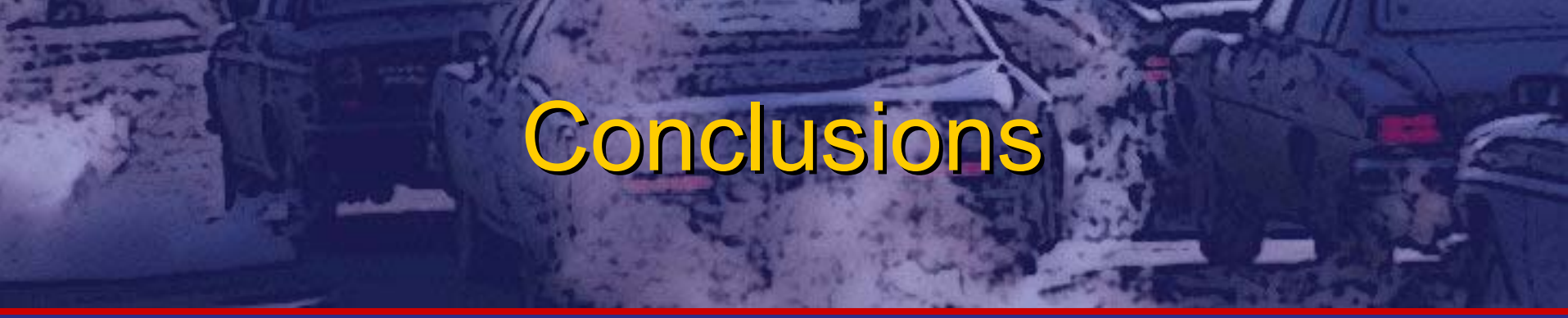
- The reduction of sulfur level from 500ppm to 50ppm results in the suppression of the nucleation mode which further results in significant reduction in particle number emission.
- The reduction of the particle number was much more prominent in the engines with lower particle mass – newer design, than with engines of the older design.

Total PAH


1200
1000
800
600
400
200
0
PAH (mg/min)
Mode 7
Mode 11
Mode 10
Mode 8
LS
ULS

PAH

- The reduction in PAH emissions observed with ULS was due to the reduction in vapor phase PAH.
- Particle bound PAH remained around the same levels.



Conclusions

- What fuel property is the cause of the reduction in vapour phase PAH?
- Aromatic content?
- What has caused the suppression of nucleation mode?
- Can the effect of fuel sulfur content be decoupled from the effect of aromatic content?
- Further work has to be done on the influence of the aromatic content on nanoparticle emissions.

Acknowledgement

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