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Nanoparticles in the Exhaust Gas of all IC-Engines?

NANOPARTICLES
in the Exhaust Gas of all kind IC-Engines?

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by

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- Ambient conditions and dilution air
- Gasoline and Diesel cars
- Continuously Regeneration Trap
- Small 4-stroke gasoline engines
- Summary
- Acknowledgement

In the present paper some examples of results of the past year are represented.

Ambient air

The numbers of particles in the ambient air usually vary between 100 and 1000 per ccm, Fig. 1.
In the dilution tunnel of an CVS-installation the level of particle numbers (PN) is lower, because of the dilution air filter. A modern gasoline car produces a similar level of PN-emission as the values in the dilution tunnel, Fig. 2.
Other sources and particularly the smokers contribute also to the PN-emission. Fig. 3 compare it with the Liebherr construction machine DI-Diesel engine.

Gasoline and Diesel cars

Fig. 4 shows the comparison of the particles size spectra of a modern automotive DI-TC-diesel engine and a modern gasoline engine. The maximum for the diesel engine is by the diameter of 100 nm and its value exceeds even the usual value of 1 million particles per cm^3. The particulate counts of the gasoline engine are about three ranges of magnitude lower, than those of the diesel engine.

For the diesel engines it can be concluded, that due to the heterogeneous combustion the modern developments of the engine technology are unable to substantially suppress the formation and emission of nanoparticulates.

Additives can be used in the passenger cars as antiknock agents for gasoline-, or for the additiv supported particle trap regeneration for the Diesel engines.
As the Fig. 5 and Fig. 6 show on the example of ferrocen – the usually necessary concentrations don't have any influence on the nanoparticles.

CRT-Continuously Regeneration Trap

Particulate traps are very efficient exhaust gas aftertreatment systems to cut down the particles mass- and count emissions. During the last ETH-Nanoparticle Workshop the author reported about the experiences of the VERT-Building Machinery Field Test with very good results with particulate traps after in average 2375 hours of operation.

CRT is an innovative system, which utilizes an oxidation catalyst before the trap. Some results with CRT on the Liebherr engine are given in the Figures 7 and 8.

The results can be summarized as follows:

- the CRT has a very good filtration efficiency in all operating points and at transient conditions (free acceleration),
- the counts of nanoparticulates are reduced with CRT very efficiently to, or below the level of ambient air quality,
- the CRT- system acts also as an oxidation catalyst and reduces strongly CO and HC,
- there are no problems with increase of the back pressure- the continuous regeneration takes place.

A very low sulfur fuel is necessary, what can cause any problems today, but it shouldn't be a problem in view of the future perspective of the diesel sulfur content.

Small 4-stroke gasoline engines

There is a need of emission reduction of small machines for agriculture, or gardinery.

A simple and low cost post-equipment system of HJS using a bypass valve to control the rich operated carburetor to Lambda = 1, reduces engine out emissions and reduces fuel consumption even with simple carburetors.

At Lambda = 1 the 3-way catalyst is able to reduce CO, HC and NO_X with a high efficiency.

Another measure of improvement is a special sulfur- and aromats- free fuel Aspen.

Both of these possibilities were investigated on two Briggs & Stratton engines with the measurement of nanoparticles with SMPS.

Fig. 9 shows the integrated particles numbers for both engines at different operating points.

The 2-cylinder-engine represents a newer generation with lower basic emissions values. The 3-way-catalyst has on this engine a reduction potential also for the nanoparticulates.

Fig. 10 gives an example of size distributions: there is no big difference for different fuels, but a clear and repetitiv influence of the hydrocarbon trap (thermodenuder).

The emissions of naoparticulates of those engines consist by a higher amount of the VOC. These emissions depend of air excess factor λ and of the basic HC-level.

The investigated special fuel has no influence on the nanoparticles.

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Summary

- Nanoparticles concentration in the ambient air is in the range of magnitude 10-E3.

- Gasoline engines with recent technology have the nanoparticles emission in the range of ambient air.

- Gasoline engine
  - at rich operation (full load)
  - with older technology (higher oil consumption, higher HC-level)

  have a considerably higher nanoparticles emission level

- Particulate traps and CRT are very efficient to eliminate the nanoparticles

- The metal additives don't increase the nanoparticles, if used with catalyst, or trap.

Title: always ? → yes !
but we can do a lot against it !

Fig. 1

particulate counts in the ambient air

during the measurements on engine dynamometer

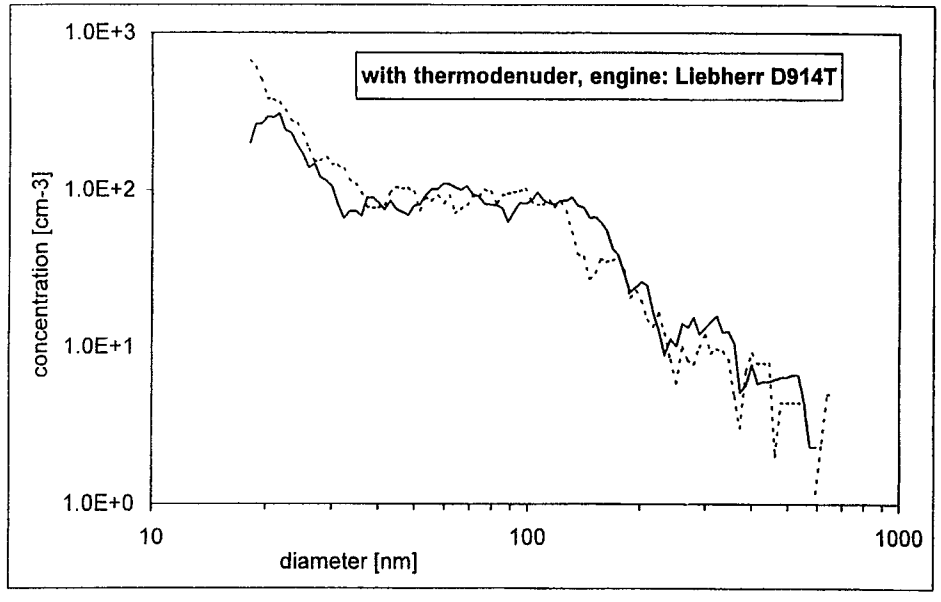


Fig. 2

Particles size spectra in the CVS-dilution tunnel

with and without exhaust gas

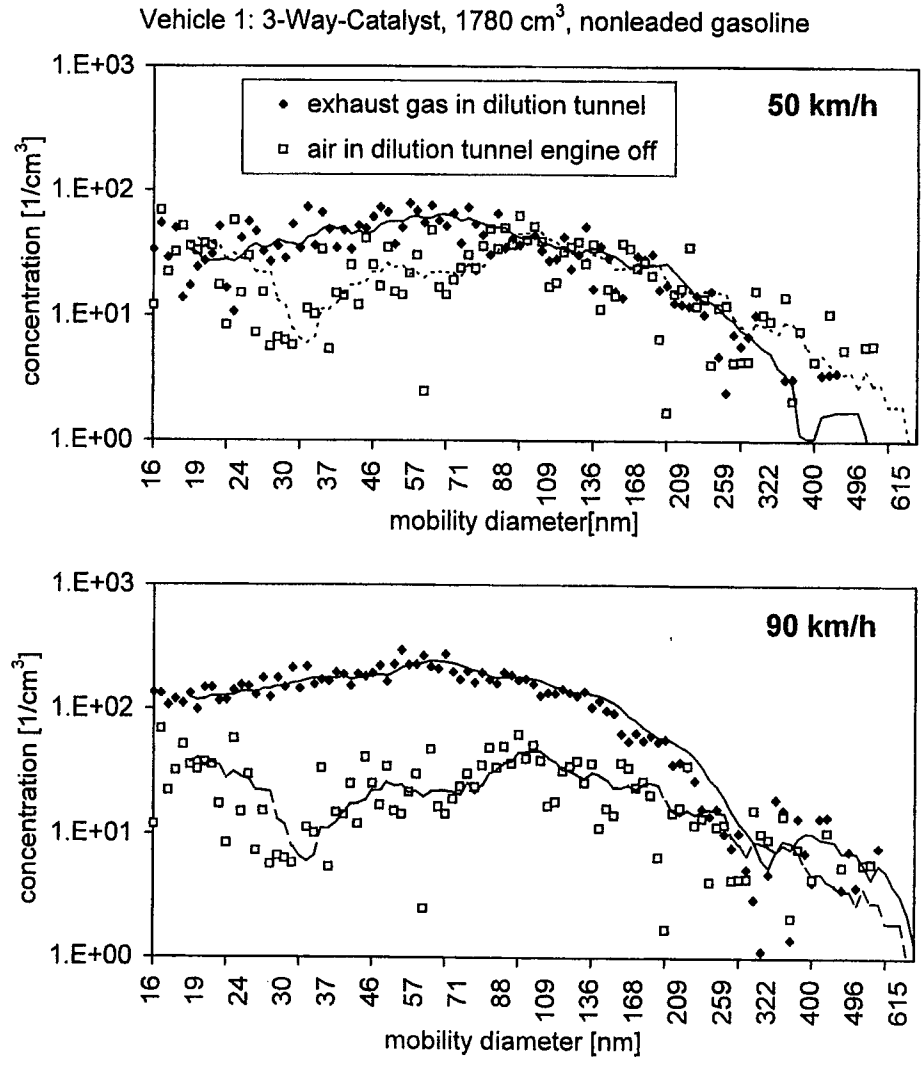
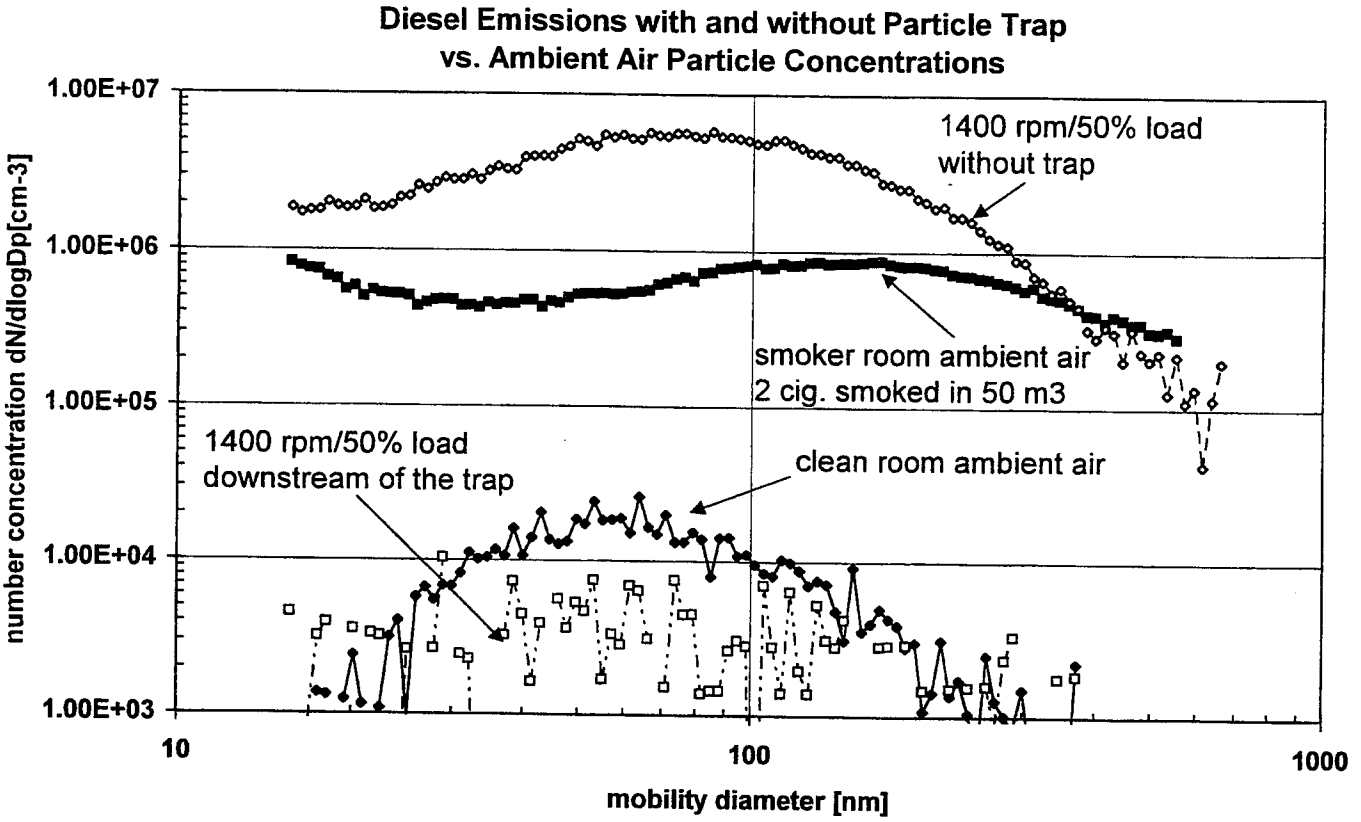
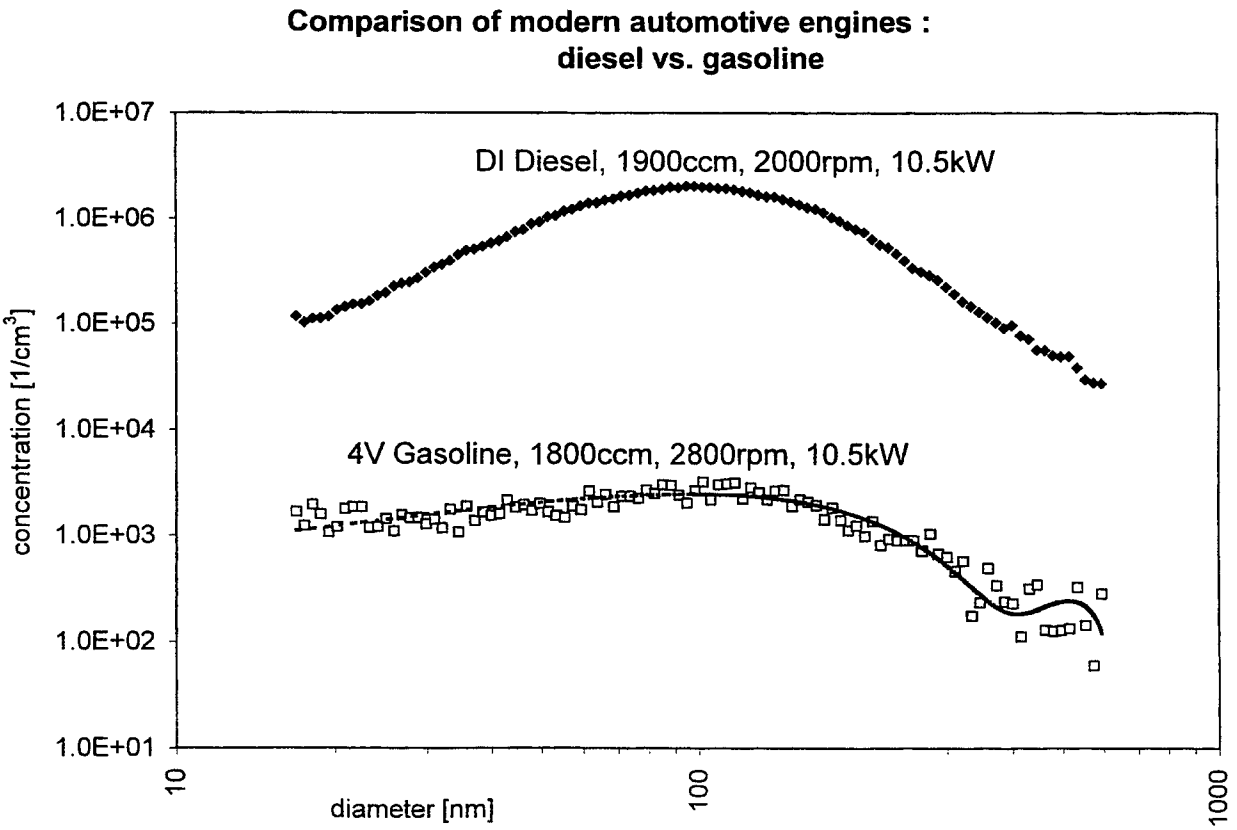


Fig. 3



Matter Engineering

Fig. 4

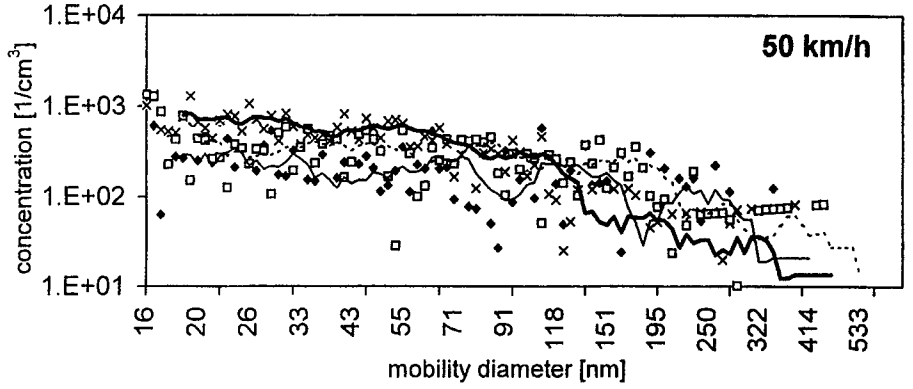


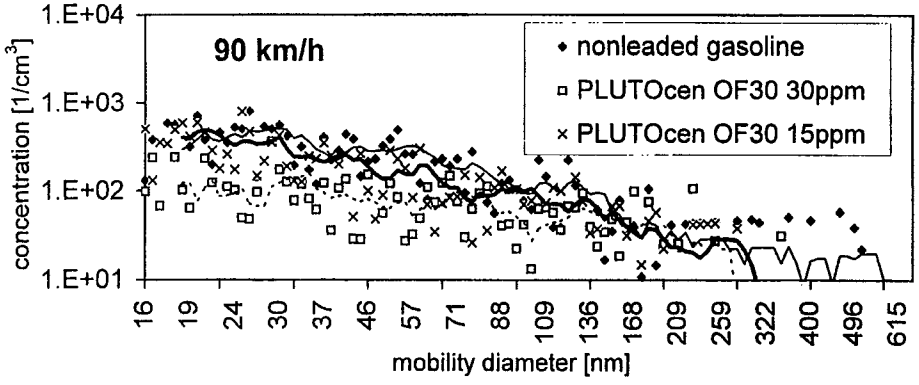
Ott_dies_E.xls

Fig. 5

Particles size spectra of a gasoline car with different concentrations of ferrocen

Vehicle 2: 3-Way-Catalyst, 1600 cm^3





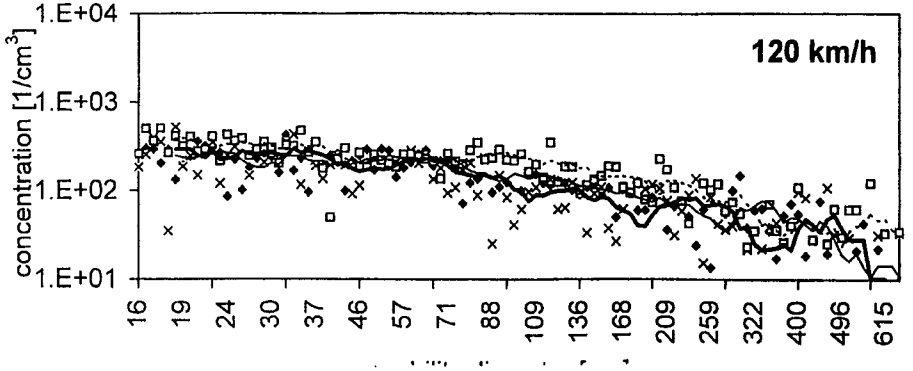
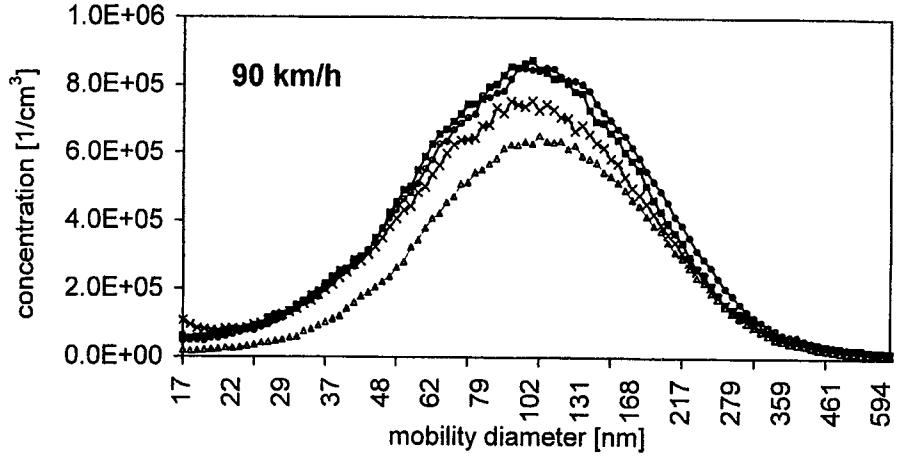


Fig. 6

Particles size spectra of Diesel cars with different concentrations of ferrocen

Vehicle 1: TCI-DI-Diesel , 1900 cm^3



Vehicle 1: TC-IDI-Diesel , 1770 cm^3

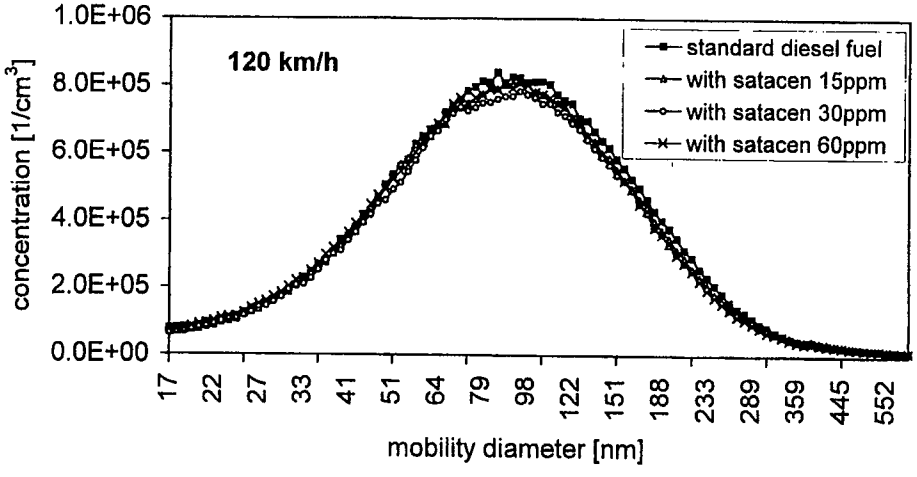
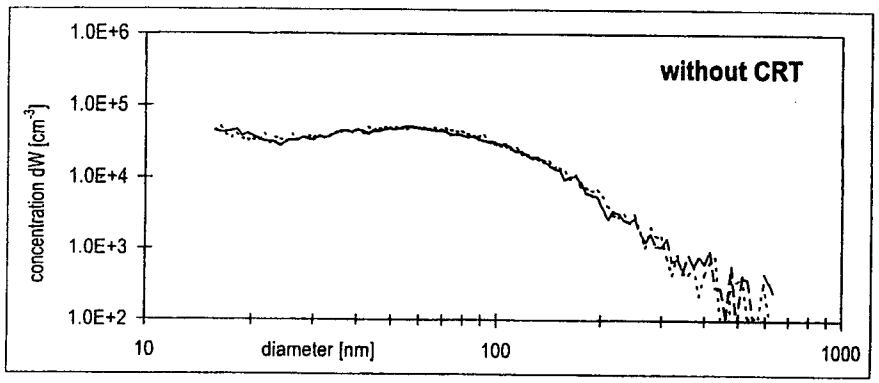
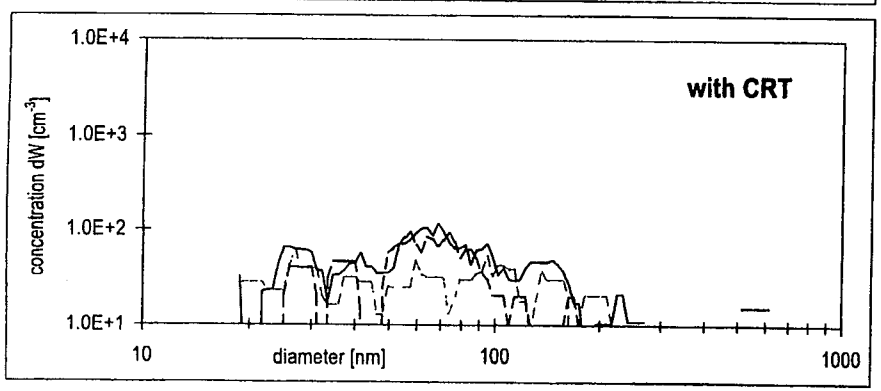
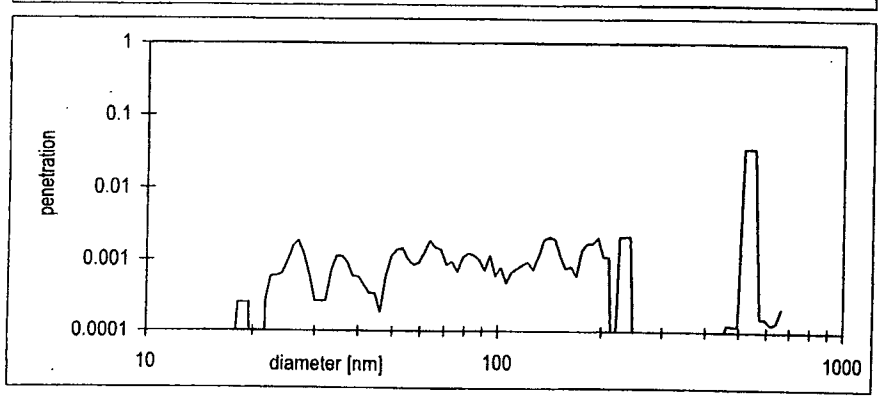


Fig. 7

CRT-filter, Greenergy fuel
engine: Liebherr D914T at 1400min^{-1} / 59.4Nm
with thermodenuder

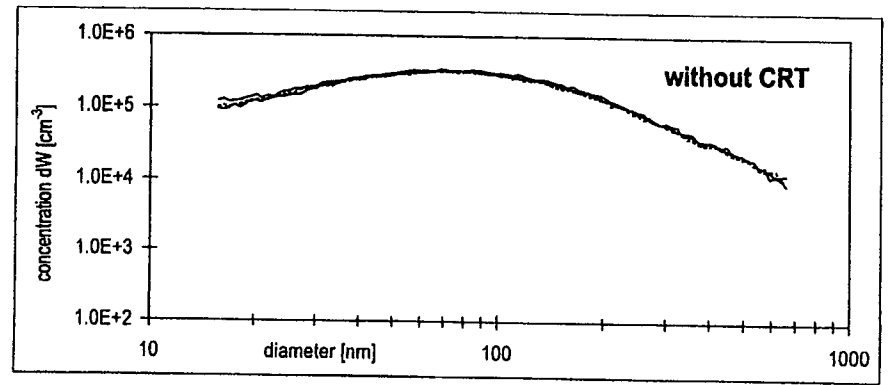


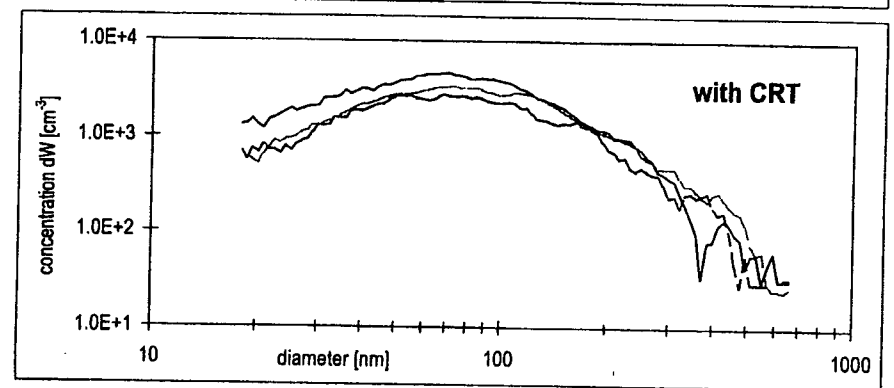


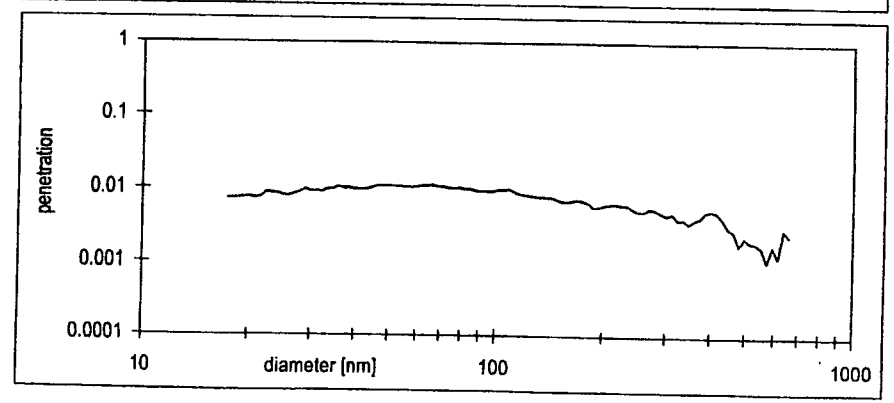


cg0.xls

CRT-filter, Greenergy fuel
engine: Liebherr D914T at 2000min^{-1} / full load
with thermodenuder



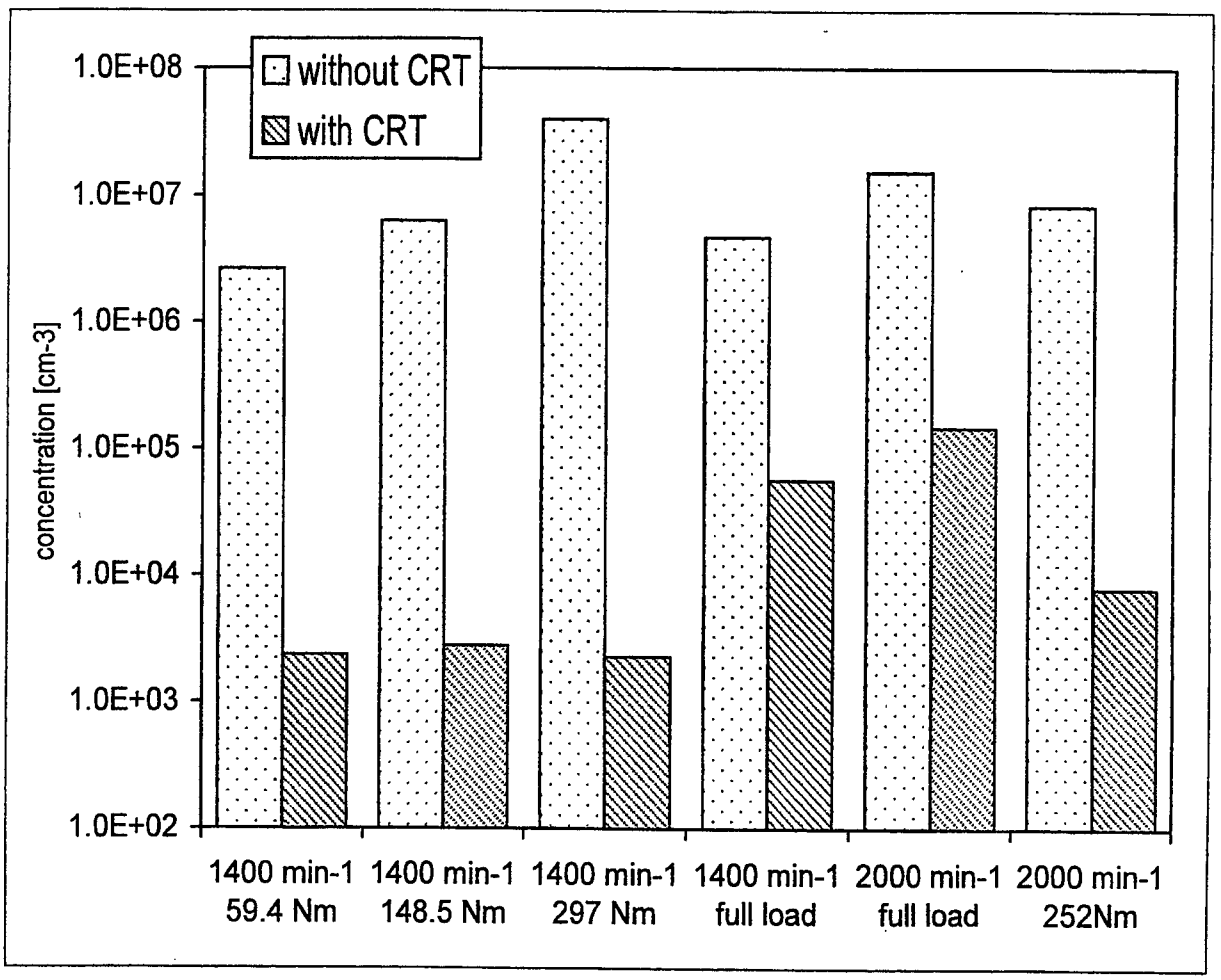




cg1.xls

Fig. 8

Integrated numbers of particles in the size spectrum 20-200nm with CRT-filter, engine: Liebherr D914T

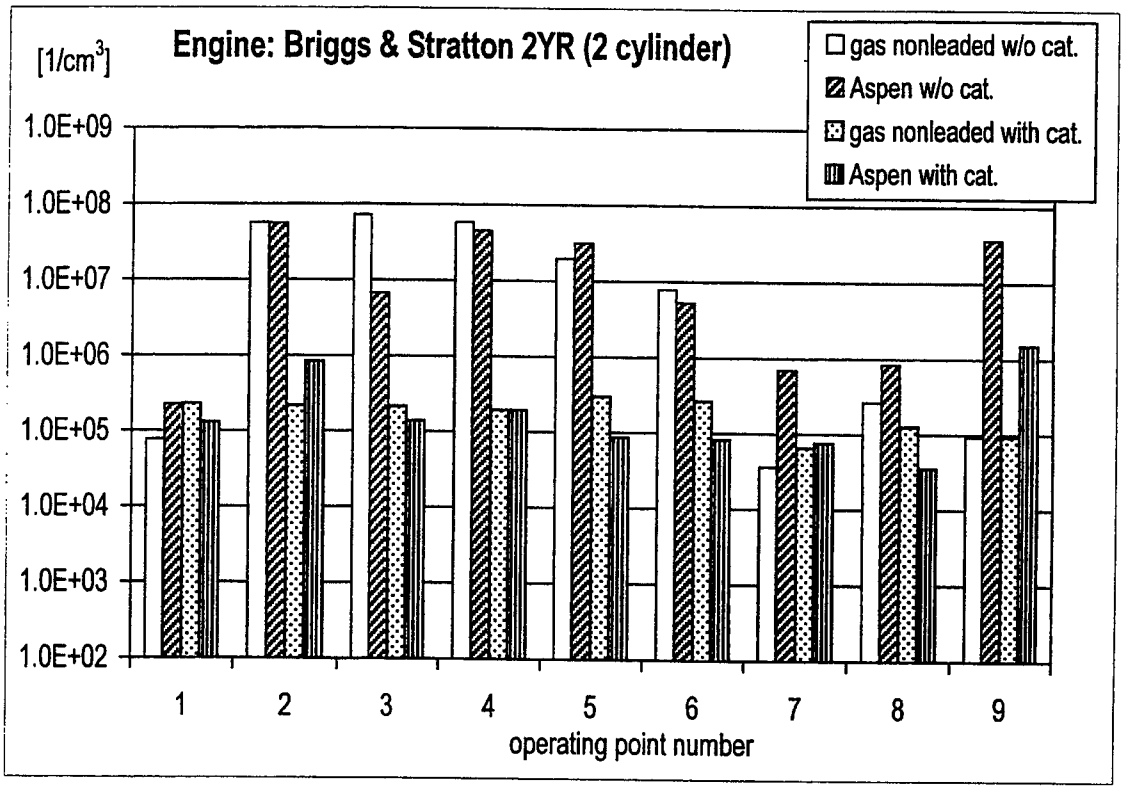


PZ.CRT.xls

Fig. 9

Integrated numbers of particles in the size spectrum 20-500 nm

with thermodenuder



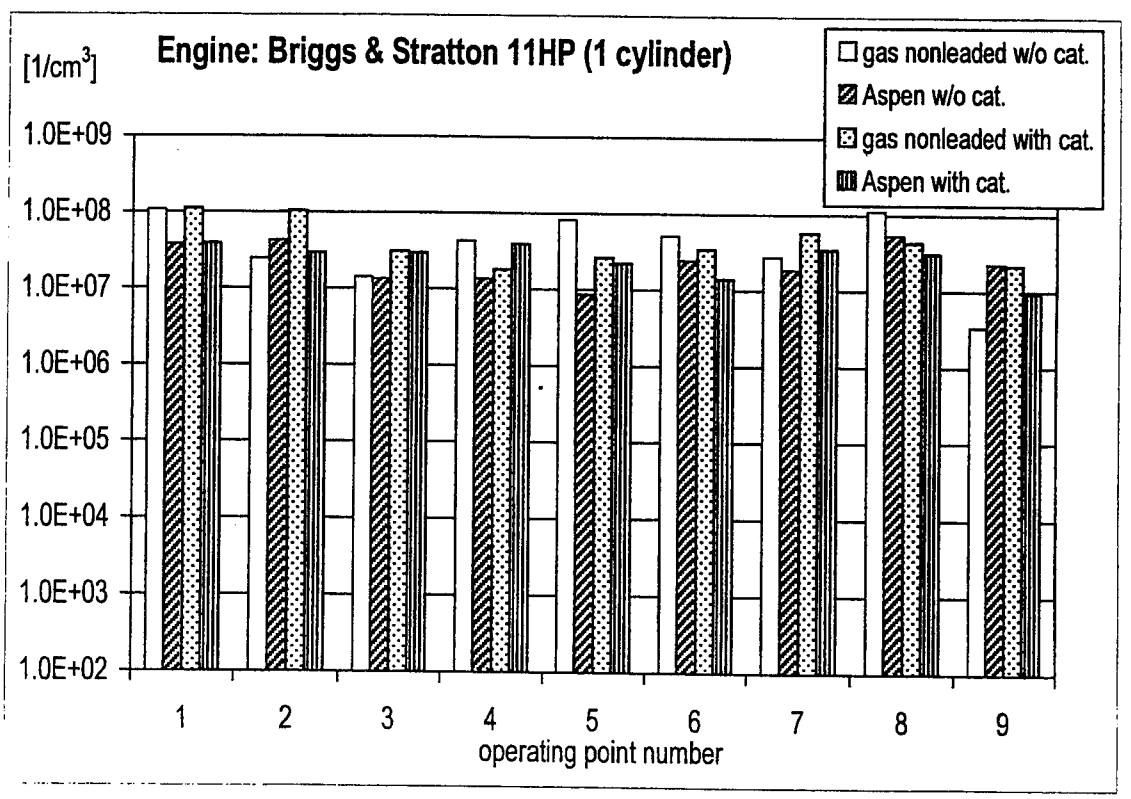
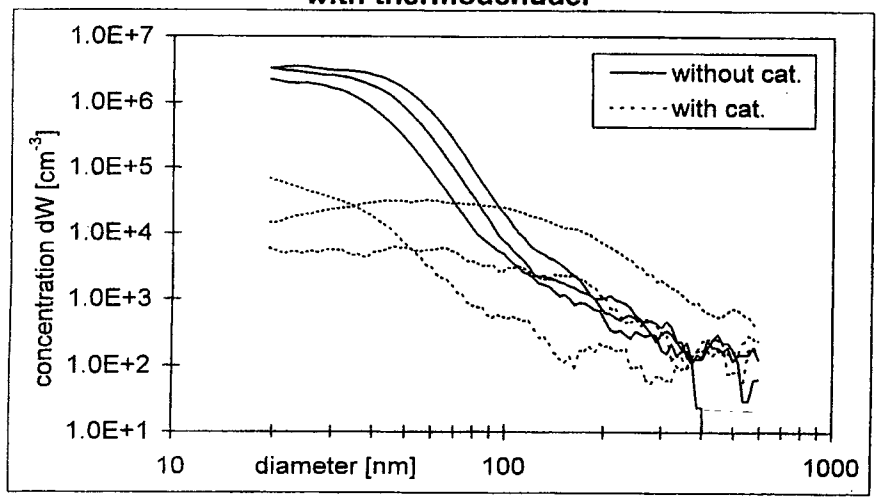


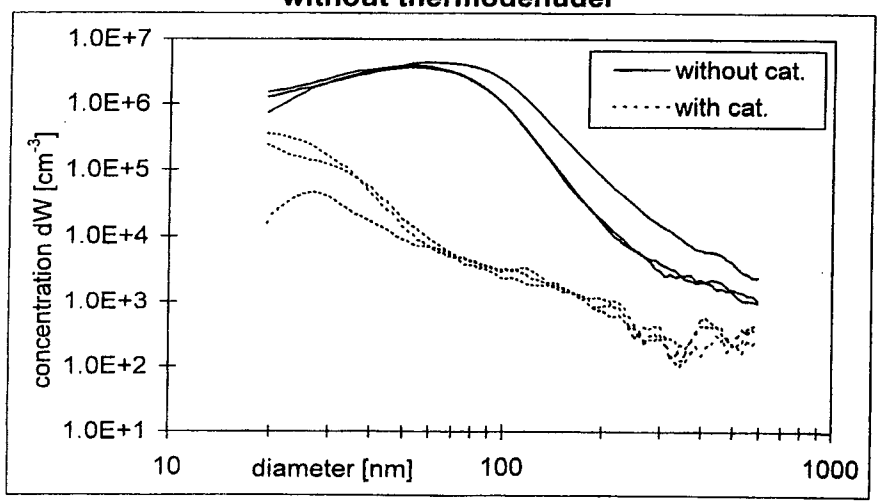
Fig. 10

Briggs&Stratton 2YR
nonleaded fuel RON 95, 2400min^{-1} / full load

with thermodenuder



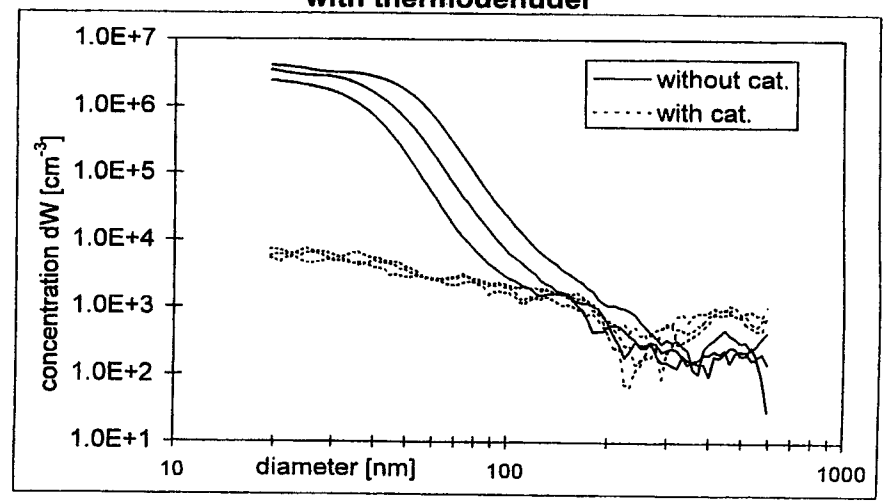
without thermodenuder



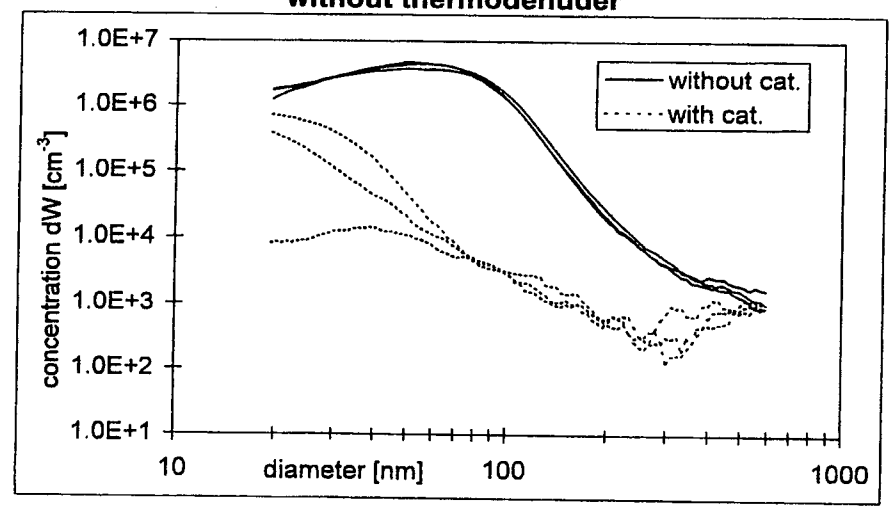
B+Sn2_E.xls

Briggs&Stratton 2YR
Aspen fuel, 2400min^{-1} / full load

with thermodenuder



without thermodenuder



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