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Influence of water emulsions on nanoparticle emission characteristics

Influence of AQUAZOLE,

a Water in Diesel Fuel Emulsion on Nanoparticles Emission Characteristics

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4th - Conference on Nanoparticles Measurement

7-9 August 2000

Zürich

OBJECTIVES

- Investigate the influence of AQUAZOLE a Water in Diesel Fuel Emulsion on Nanoparticles emission using this fuel in a DI-diesel engine.
- Comparison of Particles Size Distribution of AQUAZOLE with EN590 Diesel Fuel.
- Study the influence of minerals present in Water in Diesel Fuel Emulsion on Nanoparticles size distribution and composition.

TEST PROGRAM

- **EAF has mandated TTM to perform the measurement according to the VERT test program.**

- **Participating Laboratories and responsible persons**
  - ➜ **Exhaust gas test center of the School of Engineering Biel (Measurements on engine test rig, leading the test program) : Prof. Dr. Jan Czerwinski, Dipl. Ing. S. Napoli**
  - ➜ **Laboratory for Solid State Physics of the ETH (Federal Institute of Technology) Zurich, (aerosol Measurement technique) : Prof. Dr. H.C. Siegman, Dr. U. Matter,**
  - ➜ **Matter Engineering : Dr. U. Matter, Dr. Kasper; DiplIng. Th. Mosimann.**
  - ➜ **TTM Technik Thermische Maschinen, Niederrohrdorf; (project Management) : Dipl. Ing. A. Mayer**

TEST PROGRAM

- **Fuels investigated :**
  - → Standard Diesel fuel EN590 (350 ppm S)
  - → AQUAZOLE Standard (13% water in EN590 diesel fuel)
  - → AQUAZOLE new formulation
  - → AQUAZOLE new formulation with demineralized water
- **Analysis of PSD and on-line characterisation has been performed at 6 operating points**

TEST PROGRAM

- **Tested Engine :**
  - → Liebherr I (Construction type engine - Euro 0)
  - → Type : D914 T
  - → Cylinder volume : 6.11 liters
  - → Rated RPM : 2000 min-1
  - → Rated power : 105 kW
  - → Model : 4 cylinder in line
  - → Combustion process : Direct injection
  - → Injection pump : Bosch in-line pump
  - → Supercharging : Turbocharger without intercooling.
  - → Development period : 1986

TEST PROGRAM

Test procedure

- **6 operating points have been performed and fixed on the basis of the cycle according to ISO 8178 C1 and D2 prescribed for off-road engines :**
  - point 1 : full load, rated RPM
  - point 2 : full load, mean RPM
  - point 5 : rated RPM 50%
  - point 6 : mean RPM 50%
  - point 8 : mean RPM 25%
  - point 10 : mean RPM 10%
- **test concentrated on specific point considered representative.**
- **detailed measurements were made at each choosen operating point**
- **Sequence of operating points : 10-8-6-2-1-5-2 repeat 2 (similar to ECE R49)**

PARTICLES ANALYSIS

Particle Size Distribution Analysis

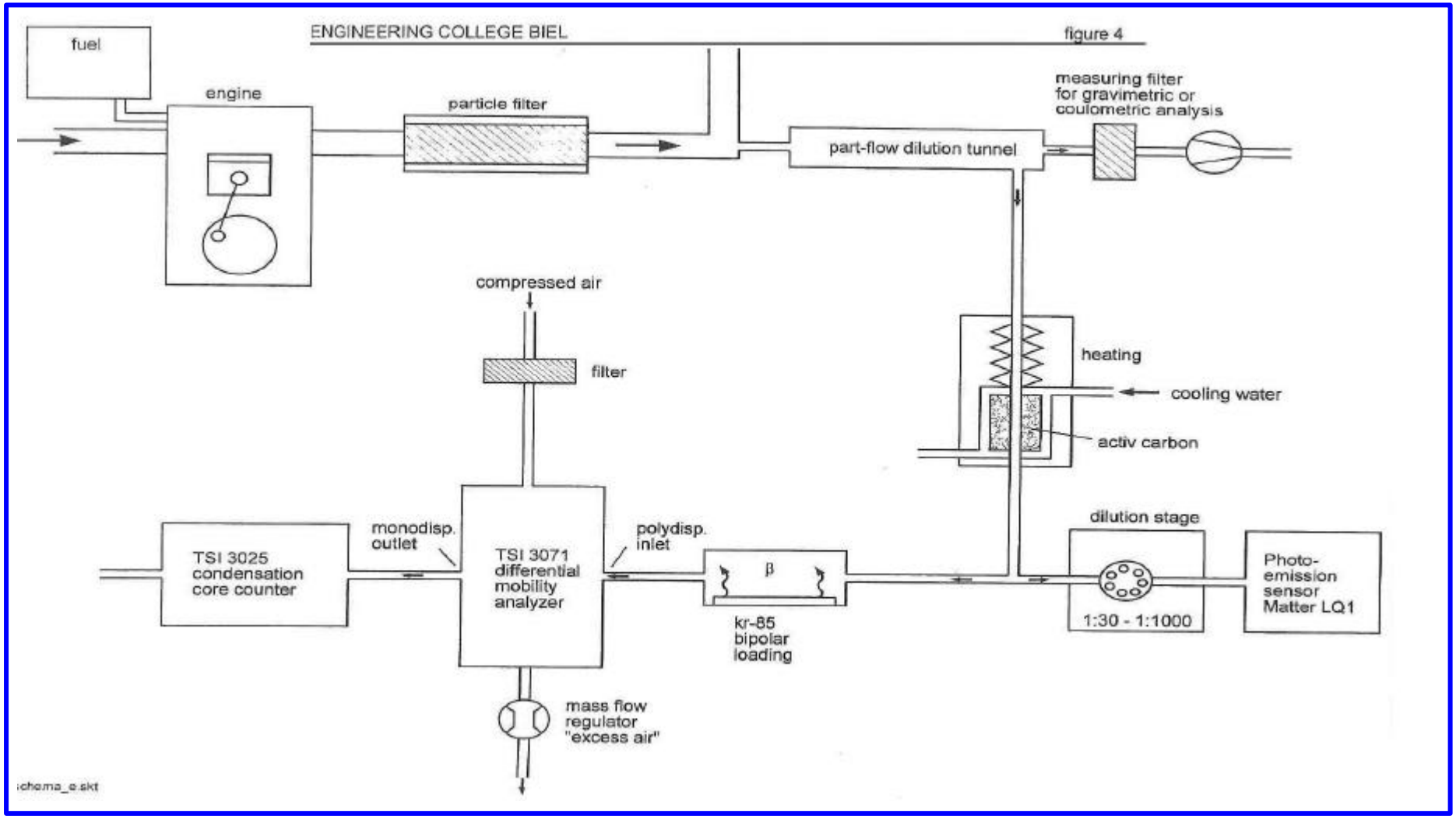
- **SMPS (Scanning mobility Particle Sizing) manufactured by TSI, model 3934.**
- **CNC (Condensation Nucleus Counter) TSI model 3025A**
- **Distinction between solid and volatiles particles using an activated charcoal trap developed at the ETH.**
  - First the gas is heated to a well-defined temperature which may be increased stepwise. In the water cooled second stage the gas is guided through activated charcoal with a very large surface which adsorbs the major part of the re-condensing volatiles.
  - Technique allows a phase separated analysis of the particles.

PARTICLES ANALYSIS

On-line measurements : PAS and DC

- ➜ particles are electrically charged and subsequently precipitated on a measurement filter with current amplifier
- ➜ measured current is proportional to the charging probability of particles
- ➜ In the diffusion charger (DC) positive ions from a corona discharge diffuse onto the particles. The electric charge acquired by a particle depends on the collision probability with the ions and is called Active Surface.
- ➜ In the Photoelectric Aerosol sensor (PAS) aerosol particles are illuminated by UV light and photoelectrically charged. As photoemission involves absorption of a photon by a particle bulk material and emission of an electron through the particle surface the resulting charge on the particles is proportional to the active surface and a material coefficient. PAS is then a selective soot sensor.

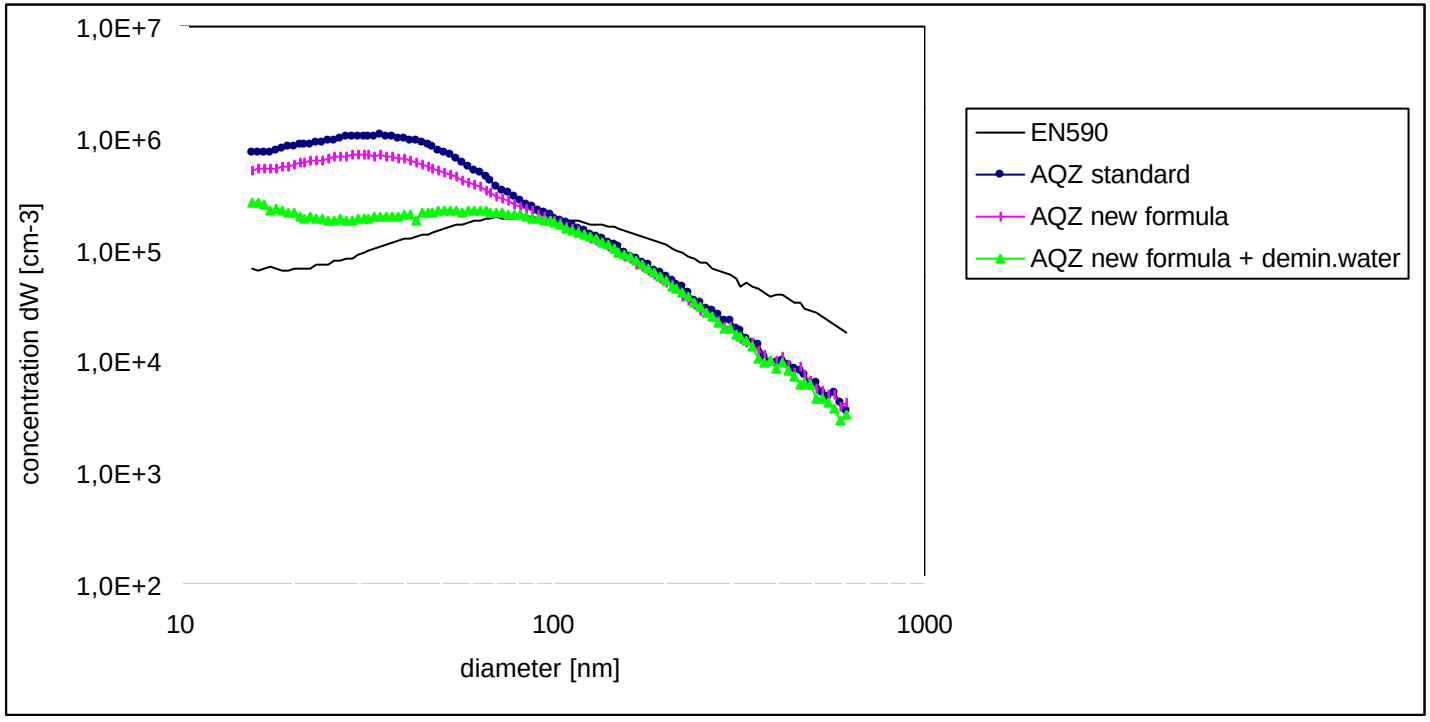
MEASUREMENT SCHEME



SMPS SIZE DISTRIBUTION

Engine: Liebherr D914T

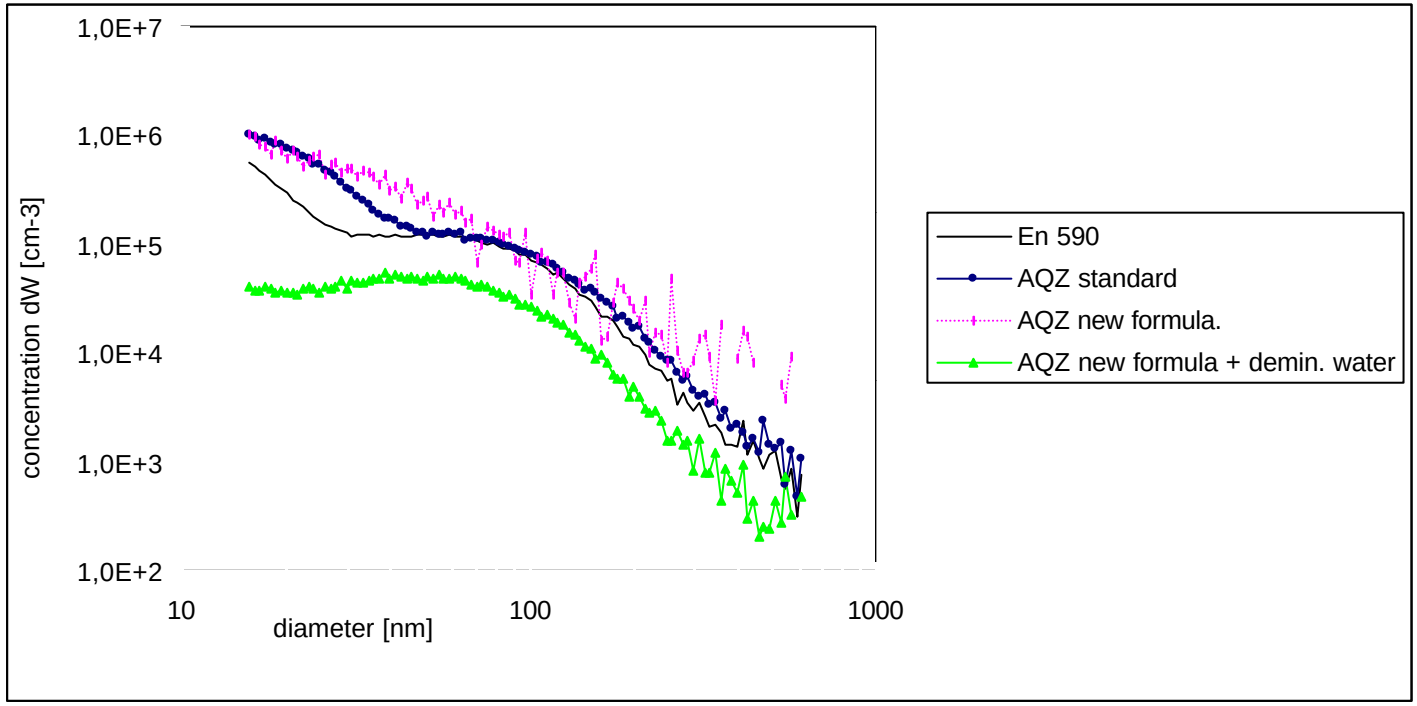
- **measuring point 1 : 2000min^{-1} / full load - mean of 3 samples**



SMPS SIZE DISTRIBUTION

Engine: Liebherr D914T

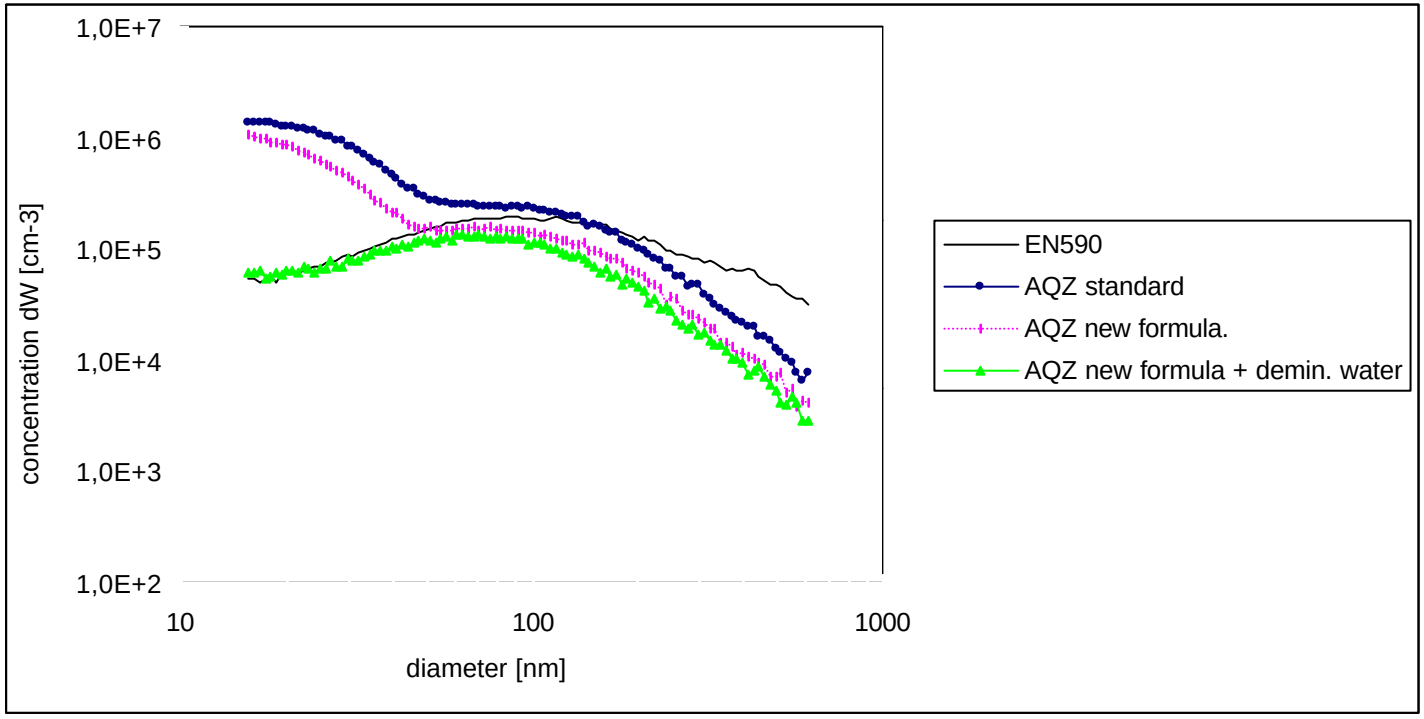
- **measuring point 10 : 1400min^{-1} / 10% load - mean of 3 samples**



SMPS SIZE DISTRIBUTION

Engine: Liebherr D914T

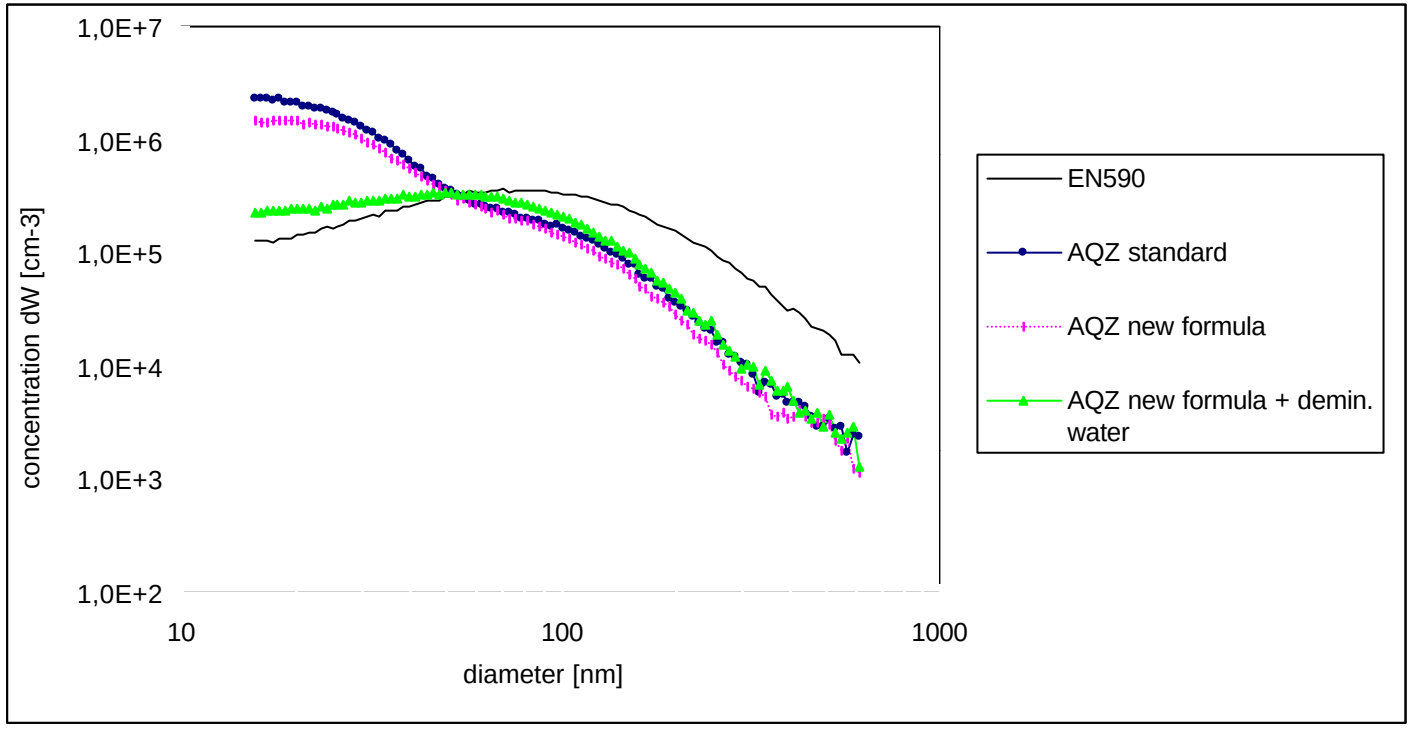
- **measuring point 2 : 1400min^{-1} / full load - mean of 3 samples**



SMPS SIZE DISTRIBUTION

Engine: Liebherr D914T

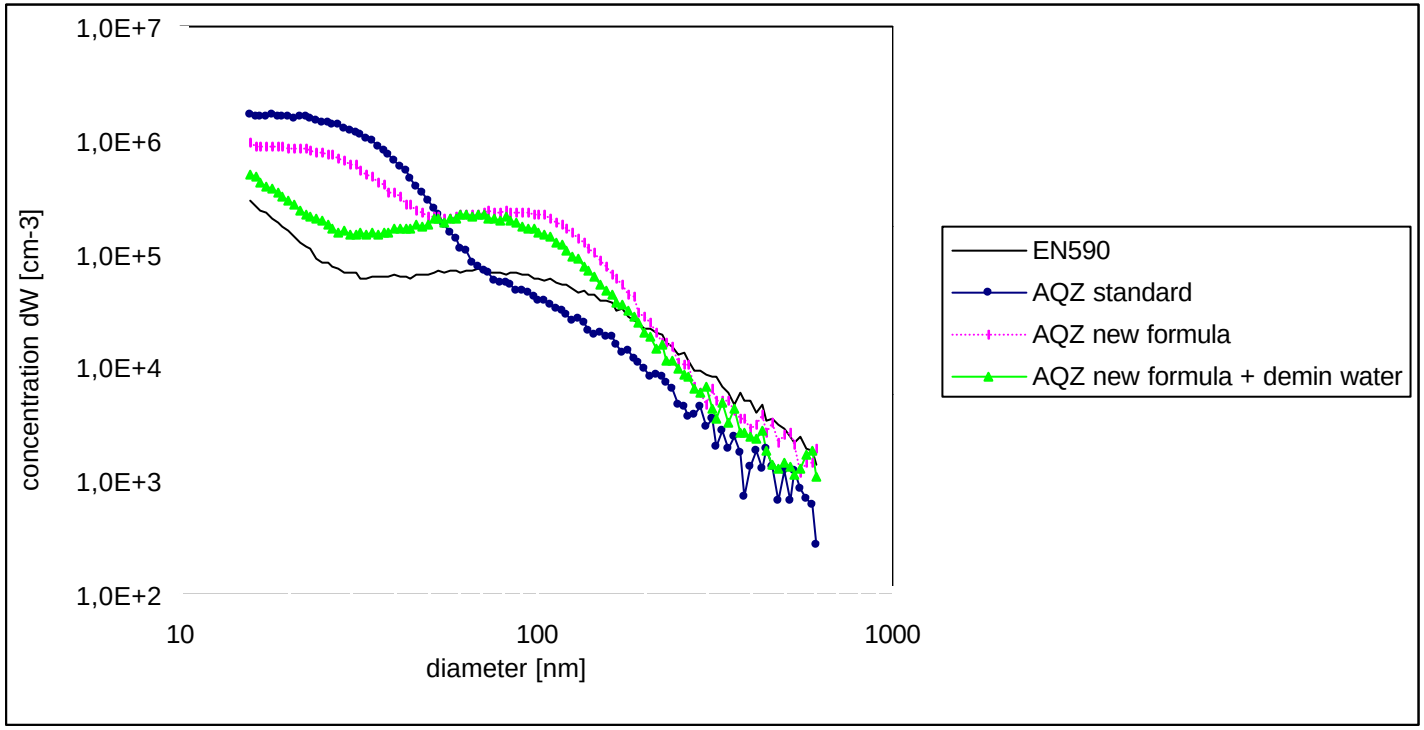
- **measuring point 5 : 2000min^{-1} / 50% load - mean of 3 samples**



SMPS SIZE DISTRIBUTION

Engine: Liebherr D914T

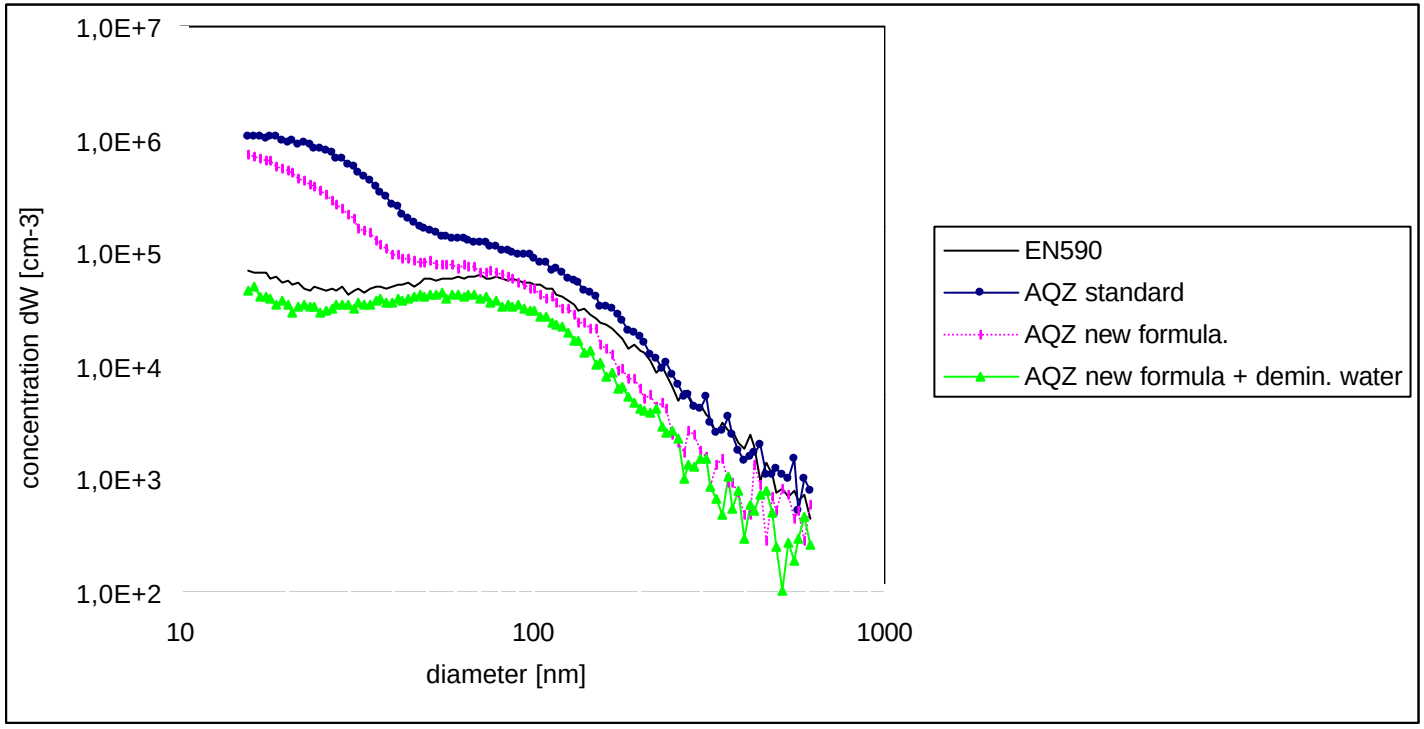
- **measuring point 6 : 1400min^{-1} / 50% load - mean of 3 samples**



SMPS SIZE DISTRIBUTION

Engine: Liebherr D914T

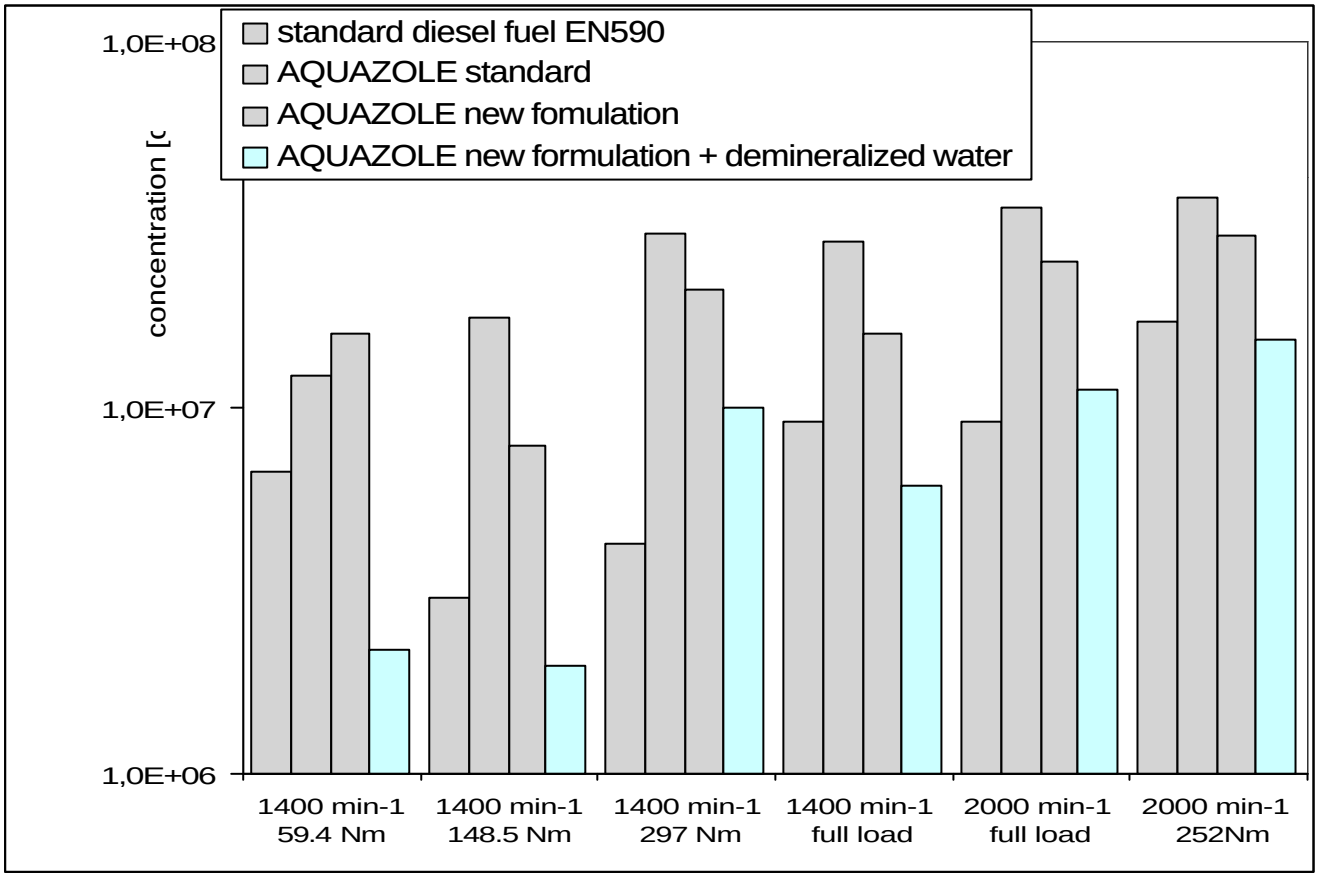
- **measuring point 8 : 1400min^{-1} / 25% load - mean of 3 samples**



SMPS SIZE DISTRIBUTION

Engine: Liebherr D914T

- **Integrated number of particles in the size spectrum 20-200nm**



CONCLUSIONS

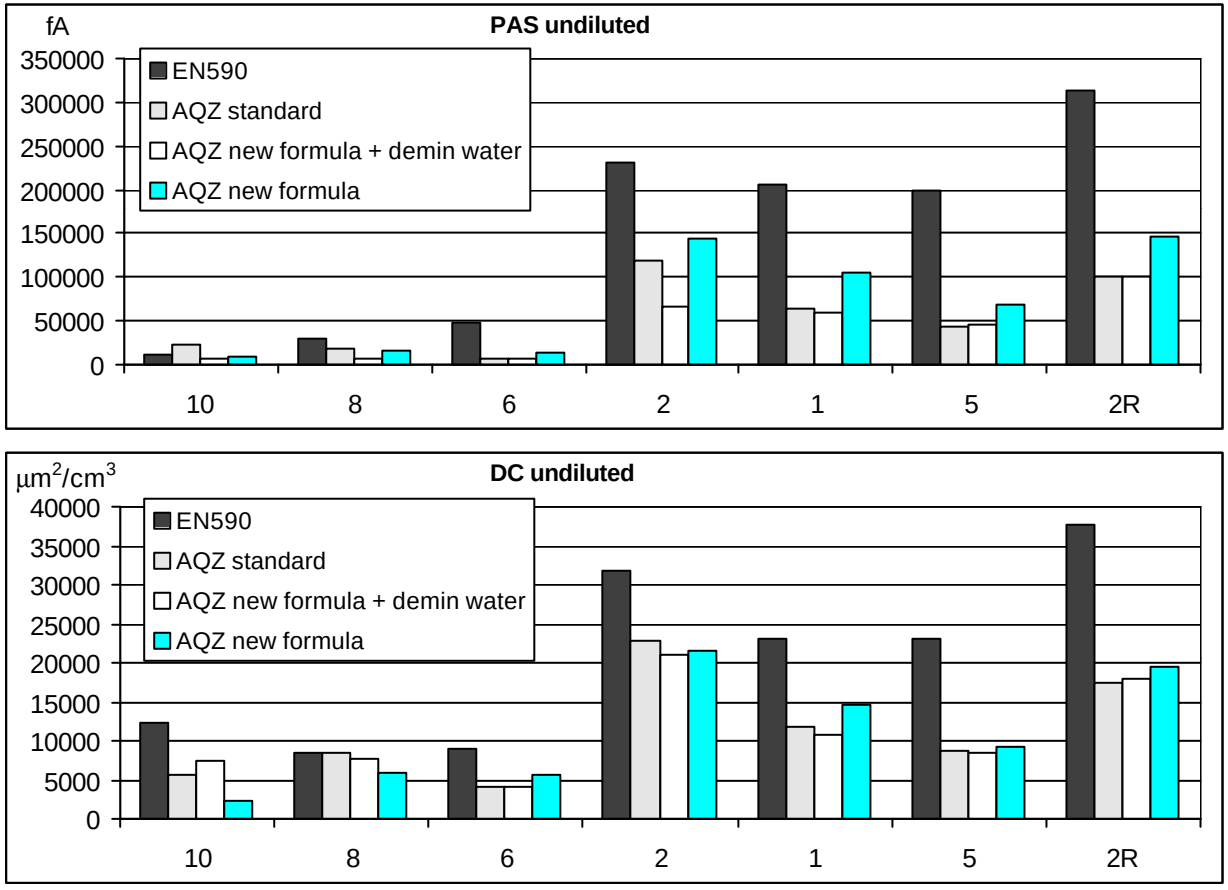
SMPS measurements :

- there is a bimodality of PSD with fuel emulsions which causes an increase of particulate counts in the lower size range (20-50nm).
- minerals present in water are the source of the particles number increase in the lower size range (20-50nm).
- the integrated particle number with AQUAZOLE new formulation and AQUAZOLE new formulation + demineralized water are lower than with AQUAZOLE standard.
- the integrated particle numbers with AQUAZOLE new formulation + demineralized water are to the level or are significantly lower than with standard Diesel fuel. (excepted on point 6 and decrease up to 66%on point 10)

PARTICLE ON-LINE MEASUREMENT

Engine: Liebherr D914T

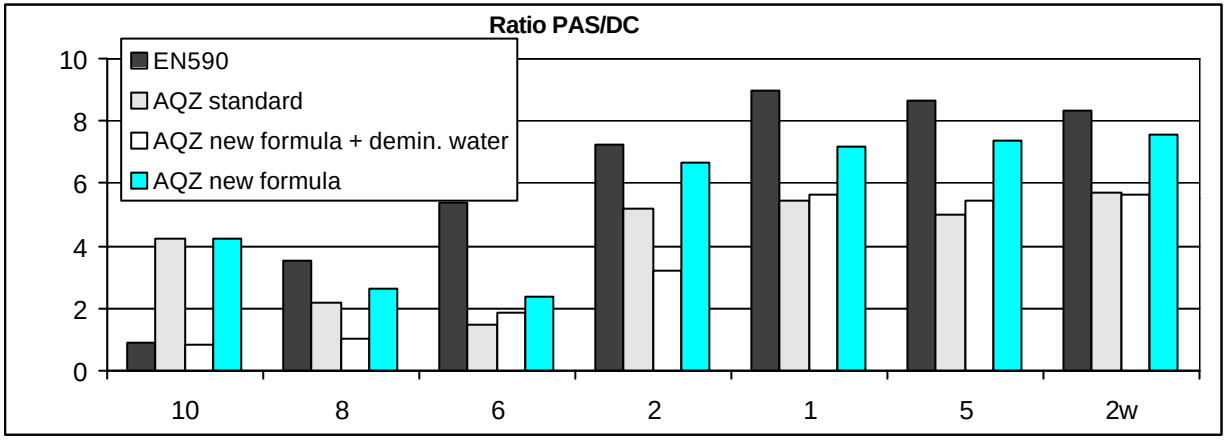
Comparison of PAS and DC sensors



PARTICLE ON-LINE MEASUREMENT

Engine: Liebherr D914T

- **Comparison of PAS and DC sensors**



CONCLUSIONS

- **On line measuring method : Photoelectric Aerosol Sensor (PAS) and Diffusion Charger (DC)**

  → **The PAS signal indicate a reduction of carbonaceus particles with the 3 AQUAZOLE fuels.**

  → **The DC signal shows a decrease of the total particle surface with the 3 AQUAZOLE fuels when compare to Standard Diesel Fuel.**

GENERAL CONCLUSIONS

- There is a bimodality of PSD with Water in Diesel Fuel emulsion which causes an increase of particulate counts in the lower size range (20-50nm).
- Traces of minerals present in water are at the origin of the increase of the lowest size nanoparticles emitted by fuel emulsions.
- AQUAZOLE + demineralized water produce a number of particle to the level or significantly lower than with standard Diesel fuel. (excepted on point 6)

GENERAL CONCLUSIONS

- The 3 AQUAZOLE fuels produce a lower number of soot particles than standard Diesel Fuel (PAS).
- The 3 AQUAZOLE fuels reduce the total particle surface compare to standard Diesel Fuel (DC).

AKNOWLEGMENT

- Exhaust gas test center of the School of Engineering Biel (Measurements on engine test rig, leading the test program) : Prof. Dr. Jan Czerwinski, Dipl. Ing. S. Napoli

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