Automotive combustion particle metrics: Metrological implementation within EMRP

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Introduction

The European Metrology Research Programme EMRP is an initiative of the European Commission and the member states of the European Association of National Metrology Institutes EURAMET. The project ENV02 "PartEmission" (http://www.ptb.de/emrp/partemission-home.html) started in June 2011 and comprises several Work Packages (WP). They are dealing with combustion particles, instruments for periodic emission control, measurement of the platinum-group elements in the exhaust, and mercury vapor measurement. WP 1 is called "Automotive combustion particle metrics" and is a corporation of following national metrology institutes (NMI): METAS (CH, WP lead), PTB (DE), NPL (UK), JRC-IE (EU), DFM (DK), MIKES (FI), and with a Researcher Excellent Grant for IfT (DE).

The motivation of WP 1 is the demand for traceable standards for the measurement of particle emissions from diesel engines according to ECE R83 and ECE R49. WP 1 will therefore establish the necessary common standard in Europe for the particle number concentration. This comprises also the knowledge of the particle size and the chemical and physical suitability of the calibration particles.

First Task: Generation of suitable aerosols

The consortium started the first step in this task with establishing the standards for particle diameter in the range between 20 nm and 200 nm. This work is following two different approaches for the calibration of sizing instruments (e.g DMAS). First certified Gold, silver and polystyrene (PSL) particles in suspensions and second Ag particles nucleated from the vapor phase were evaluated as reference material with TSEM (Transmission Scanning Electron Microscopy) and AFM (Atomic Force Microscopy). The research includes the procedure for aerosolisation and the determination of particle shape (e.g. roundness), size distribution width, and geometrical diameter. As a result the institutes start to provide calibration services for particles in suspensions and for aerosol particle sizers.

The findings are presented in several contributions to this conference:

- Lüönd F. / METAS, Bern, Switzerland: Aerosolization of Monodisperse Spherical Gold Particles as Aerosol Size Standards
- Nicolet A. / METAS, Switzerland: Nanoparticles Trajectories in an Electrostatic Precipitator: Simulation and Experimental Validation
- Klein T. / PTB, Germany: Generation and Traceable Electron-Microscopic Characterization of Monodisperse Aerosols.

Next step will be a protocol for the generation of aerosols with temperature resistant particles between 30 nm and 100 nm for the dilution factor for the calibration of the "Volatile Particle Remover" (VPR) according to http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/pmpfcp.html.html. The dilution is represented by the "particle number reduction factor" PNRF. This VPR calibration allows only minimal modifications of the particles in the VPR, which heats the aerosol to temperatures above 300 °C. Therefore the stability of the aerosol will be a key issue. Several approaches will be prepared and assessed. These will be aerosols with spark carbon generator, combustion aerosol generator and Ag-aerosol. This project step will be finished with a report describing the procedures for aerosol generation and comparing the various methods until end of 2012.

The third step will start end of 2012 and deals with the generation of a soot-like aerosol for the measurement of the CPC-cutoff curve and the CPC linearity. This aerosol shall be "soot-like" that means it shall lead to the same counting efficiency as real combustion aerosol from diesel engines. The challenge in this work will be to find criteria for the evaluation of "sootlikeness". Already discussed in the certification community are the aerosols with emery-oil, CAST (combustion aerosol standard), silver and spark carbon. At this stage the focus will lay on CPC run with butanol, but the consortium is aware that other CPC liquids will be introduced. This step will be finished by May 2013.

Second Task: Number traceability

The second task consists in three steps as well. Within this task the calibration services for Condensation Particle Counters (CPC) and Aerosol Electrometers (AE) of the national metrology institutes shall be established and validated, also the validation of commercial calibration services shall be initiated. The calibration service shall cover the number concentration for certified particle sizes between 23 nm and 100 nm and concentrations up to 10^4 cm^{-3}.

The first two steps last until November 2013. The NMIs establish their independent national standard for particle concentration for the mentioned particle size range. The uncertainty is aimed to be below 10 %. Then the validation of their standard will take place by intercomparison among the NMIs. Thus the NMIs provide a transfer standard: In the first comparison the focus will be on AEs and in the second on CPCs. The calibration services, the protocols and the results will be summarized in a project report.

The third step is the initiation of an assessment of the calibration services for other institutions. Within the project the protocol of this assessment shall be fixed and the experimental work shall be announced. This announcement will be before Mai 2014.

Project impact

The EMRP project is initiated in order to support the enforcement of the regulations ECE R83 and R49. Periodic contacts and the reporting in the PMP group will give feedback to the scientific part of the regulation body. Presentations at the ETH particle conference and publications will show the project outcome to further interested parties.

Acknowledgment

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Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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New Swiss legislation on portable particle counters for construction machinery

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16th ETH-Conference on Combustion Generated Nanoparticles, June 24nd to 27th 2012

Motivation and objectives

The Swiss Ordinance on Air Pollution Control (OAPC[1]) specifies the particle emissions from construction machines with diesel engines by defining a limit value of 10^{12} particles per kWh. This limit makes high requirements on the instruments for the machine homologation and the periodic emission control on site. The regulations for homologation are going to be internationally harmonized (particle number concentration measurements for road vehicles in ECE-R49 and R83[2]). The current regulation for the periodic control of road vehicles is unpersuasive for construction machines with particle filters, because the sensitivity of opacimeters is too weak. Therefore FOEN and METAS evaluated new measuring instrument types based on the particle counting principle.

Since the feasibility for portable particle counters for exhaust measurements could be proven the Department of Justice and Police intends to define the requirements for «nanoparticle measuring instruments» in the existing Ordinance on Exhaust Measurement Instruments (VAMV[3]).

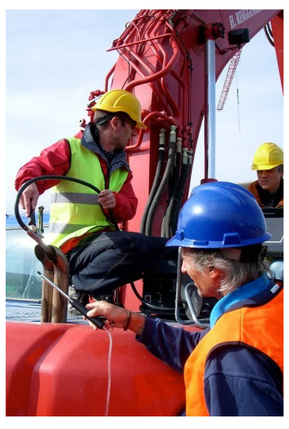
Emission control for construction machines

According to the best available technique only construction machines equipped with efficient i.e. closed particle filters fulfil the requirements of the Swiss Legislation. The clean air act defines in Annex 4 paragraph 32 the requirements for the filters to retain 97 % of all particles in the size range from 20 nm to 300 nm.

The control of the emission is made by the measurement of the particle number concentration. An initial control has to be passed during the homologation procedure of either the machine or the particle filter system. A periodic control of the machines on duty is executed every two years by fabricants, retailers or owners. Additional spot tests may made by the authorities.

Up to now opacimeters were used for the periodic control. Since the sensitivity of optical instruments is not sufficient for nanoparticles the new type of particle counters shall replace the opacimeters after a transition period.

With this new regulation instrument manufacturers are invited to develop instruments for this trendsetting engine control procedure.



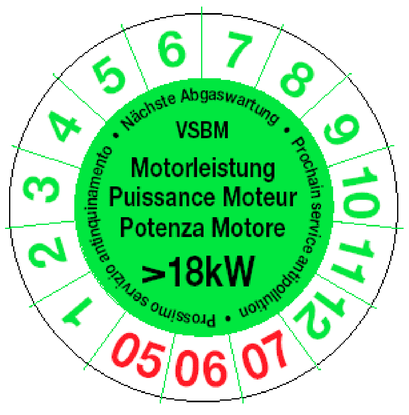


Figure 1: Exhaust measurements on construction machines and seal to declare the control

References

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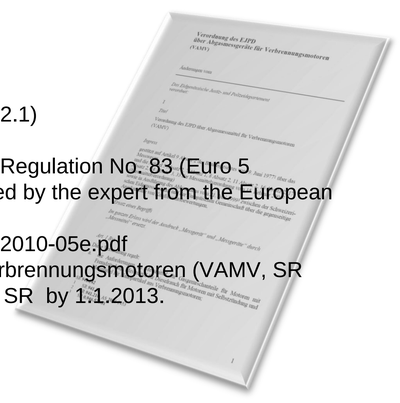
http://www.admin.ch/ch/d/sr/c814_318_142_1.html
2. HEAVY DUTY VEHICLE ENGINES, Alignment of Regulation No. 49 with Regulation No. 83 (Euro 5 requirements) Proposal for draft amendments to Regulation No. 49 Submitted by the expert from the European Commission;
http://www.unece.org/trans/doc/2010/wp29grpe/ECE-TRANS-WP29-GRPE-2010-05e.pdf
3. Verordnung des EJPD vom 19. März 2006 über Abgasmessgeräte für Verbrennungsmotoren (VAMV, SR 941.242). Presented changes will be decided shortly and will be available in SR by 1.1.2013.
http://www.admin.ch/ch/d/sr/c941_242.html
4. Messmittelverordnung vom 15. Februar 2006 (SR 941.210)
http://www.admin.ch/ch/d/sr/c941_210.html



Metrologigal requirements

Number concentration measurement

- The measuring range shall be from 5 x 10^4 cm^{-3} to 5 x 10^6 cm^{-3}.
- Values outside the measuring range shall be indicated as below or above the indicated concentration range.
- The reference conditions for the result shall be actual ambient conditions.

Error limits for number concentration measurement

As a function of particle size and particle composition the counting efficiency *E* shall be within following limits:

Particle (mobility) diameter	Permitted range for *E*
• 23 nm solid particles	*E* < 50 %
• 41 nm solid particles	50 % < *E*
• 80 nm solid particles	70 % < *E* < 130 %
• 200 nm solid particles	*E* < 200 %
• 30 nm tetracontane droplets	*E* < 5 %

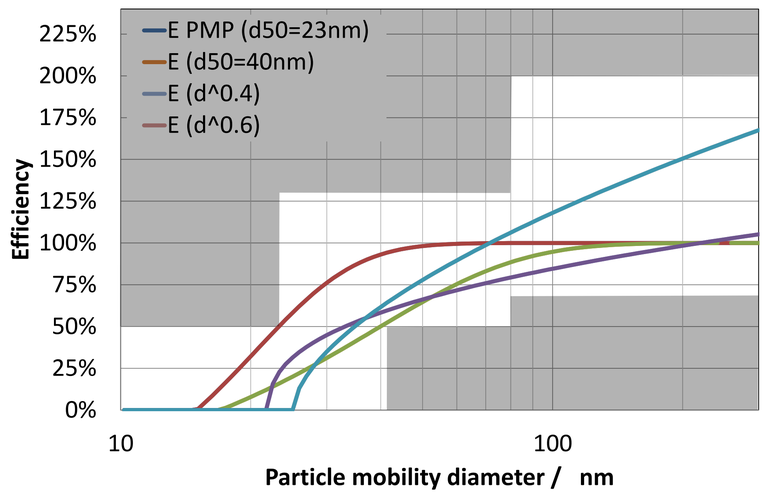


Figure 2: Schema of the limits for the number concentration efficiency curve (white area) and examples of efficiency curves conform to the requirements (curves)

Disturbances

The following disturbances shall not falsify the indication of results :

- Particles below 20 nm (e.g. particles from additives)
- Corrosive exhaust gas components and condensates
- High temperatures of exhaust gas
- High particle concentrations
- Deposition of particles or condensates in the instrument

Time constants

Response Time: During the official measurement the instruments response from 10 % to 90 % of an instantaneous change of the particle number concentration (up- and downwards) shall last between 4,5 s and 5,5 s.

Delay Time: The duration between the entry of aerosol at the sampling line and the 90 % indication of the number concentration shall be below 10 s.

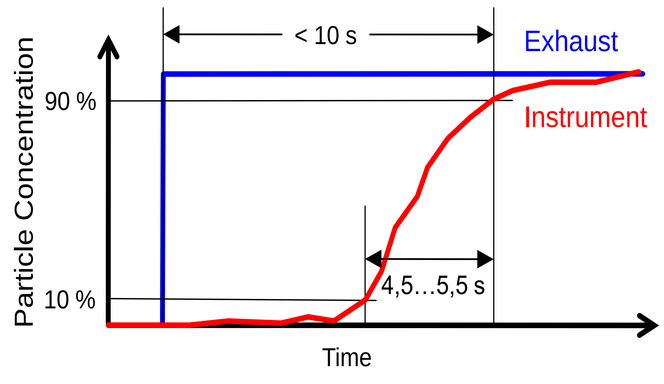


Figure 3: Definitions and requirements for the response time and the delay time

Verification and maintenance of the metrological performance

- Type approval «Module B» and conformity declaration «Module F» according the Ordinance on Measuring Instruments[4]
- Periodic instrument maintenance
- Annual verification by an authorized body