17th ETH-Conference on Combustion Generated Nanoparticles, 23th – 26th June, 2013, Zürich, Switzerland

Development of a German national aerosol standard for validation and calibration of particle measurement instruments

Physikalisch-Technische Bundesanstalt

TECHNISCHE UNIVERSITÄT DARMSTADT

Center of Smart Interfaces

Margit Hildebrandt[1], Andreas Nowak[1], Gert Lindner[1], Anke Jordan-Gerkens[1], Arne Kuntze[1], Norbert Böse[1], Volker Ebert[1,2]

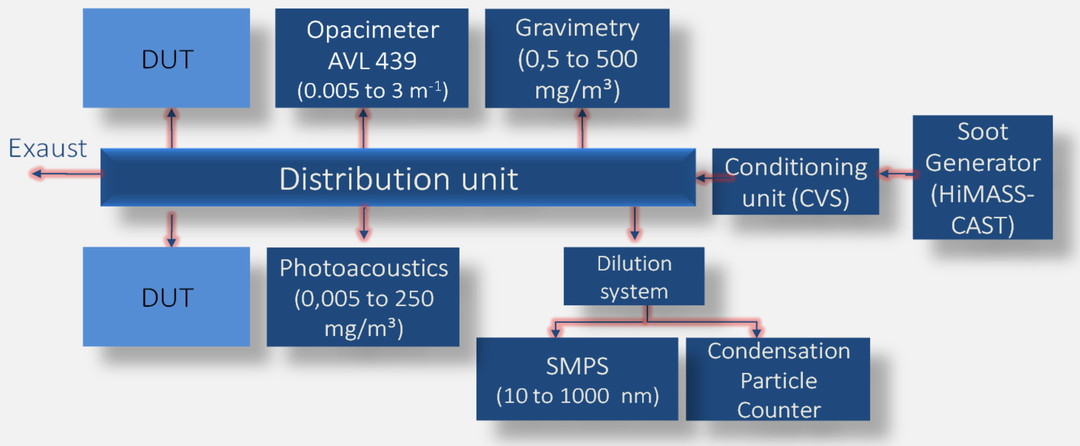
corresponding author: margit.hildebrandt@ptb.de

[1] Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany ; [2] Center of Smart Interfaces, TU Darmstadt, Petersenstraße 32, 64287 Darmstadt, Germany

Introduction and Motivation

Emissions of soot particles from combustion processes and notably from motor vehicles can influence air quality and thus the environment and human health in a serious way. Therefore, the European Community covenanted to a significant reduction of the soot particle emission limits stated as mass and particle number concentrations. Compliance with current EURO 5b and future EURO 6 emission standards is only possible with improvements in motor technology. Along with cleaner engines comes the need for improvements in particle measurement and monitoring devices. But before capturing the market, recently developed instruments with different measurement techniques for different particle parameters require means of independent validation and calibration. At the German National Metrology Institute PTB a new standard soot aerosol source was established, which is based on a propane fired soot generator of high stability. Further components of the setup are an aerosol conditioning system, that comprises a new specifically designed mixing chamber and a sample gas distributor, as well as a set of particle measuring instruments to characterize certain key parameters of the soot aerosol. With this setup, measurements were taken as part of the ENV02 PartEmission project and a test campaign in cooperation with the German Garage Equipment Association (ASA).

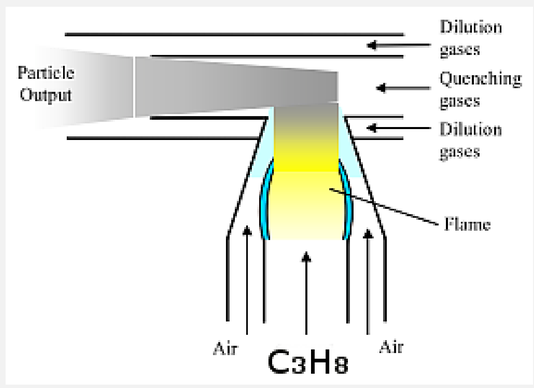
Setup



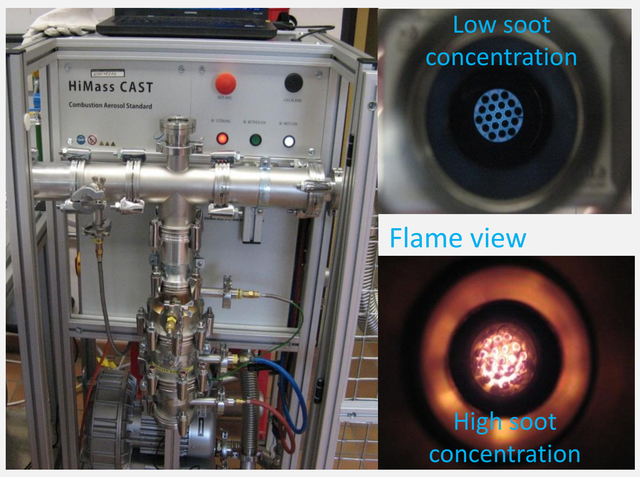
Implemented diagnostic devices for chacterizations of the soot aerosol:
Opacimeter (AVL 439) as reference system,
Scanning mobility particle spectrometer (non-commercial SMPS) for selecting of monodisperse particles,
Engine exhaust condensation particle counter (3790 EECPC, TSI),
Photoacoustic sensor (AVL 483),
Unit for loading of filters (gravimetrical mass)

Generation of soot aerosol

- Installed a commercially available HiMass-CAST (Jing Ltd) to generate soot aerosols in size range from 50 nm to 300 nm.
- Extensive modifications: electric ignition, additional N_2 injection, alteration of the mass flow scheme within the generator´s burning chamber.



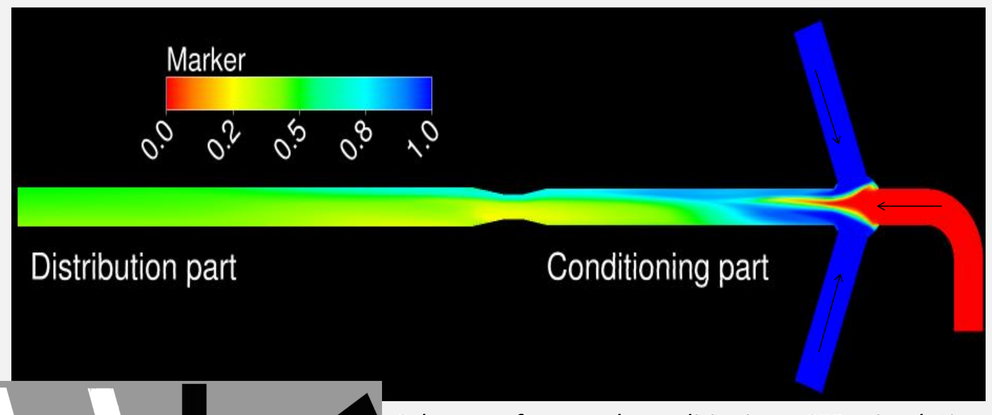
Process scheme of a single flame

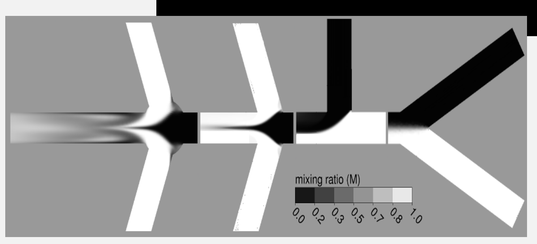


HiMass-CAST in different operating modes

Conditioning of soot aerosol

Novel conditioning unit (counter flow mixer) for dilution was developed and investigated in an internal PTB cooperation → providing a stable and homogeneous mixture of soot aerosol and dilution air



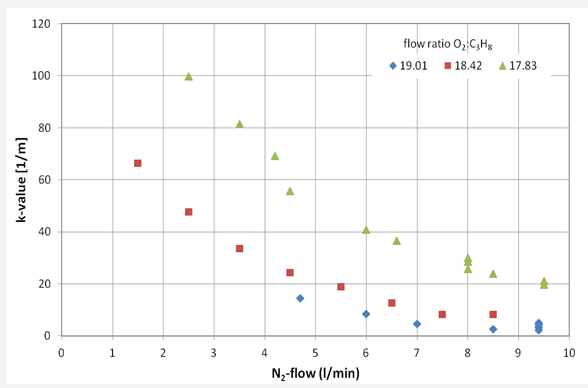


Scheme of aerosol conditioning: CFD simulation of mixing between dilution air (blue) and soot aerosols (red), green indicates homogeneous soot dilution

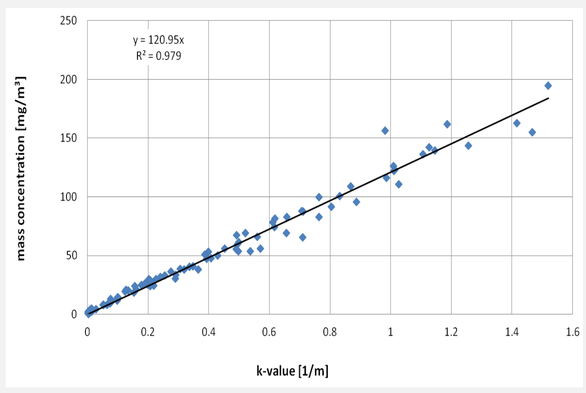
Four possibilities for mixing of two gas streams

Operation of setup

Recently, two campaigns were performed to analyze the dependancy of k-value and mass concentration (m) in the range from 0.01 (1 mg/m³) to 3.0 m^{-1} (500 mg/m³)

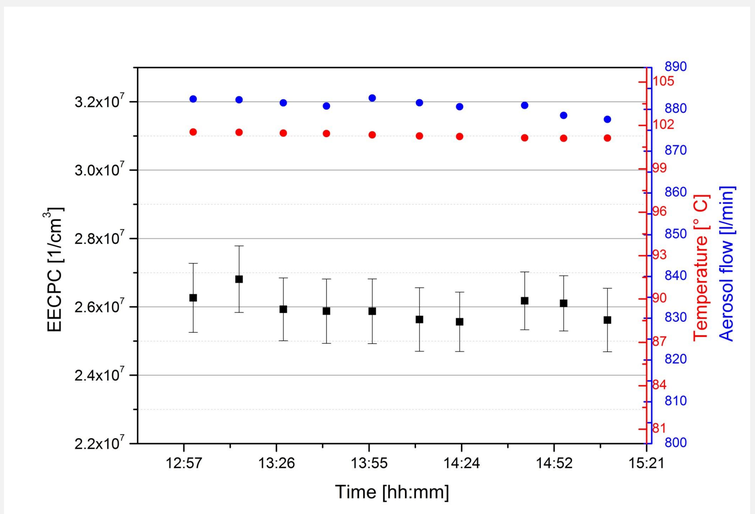


k-value (light extinction coefficient) depending on the gas flows of burning, quenching and dilution gas inside the generator

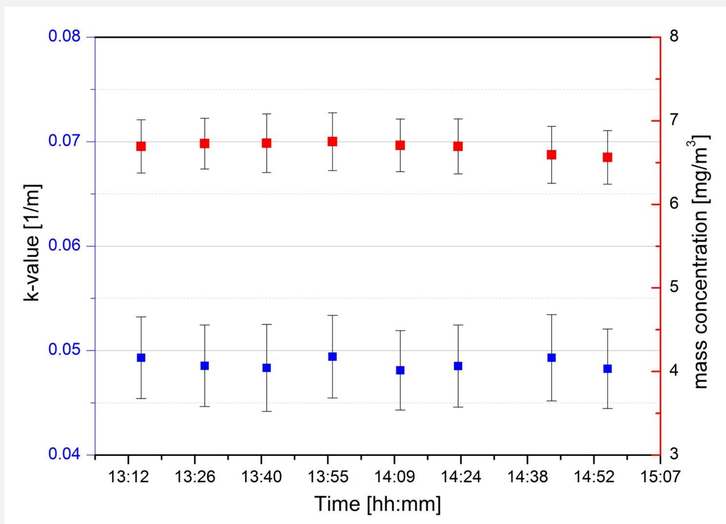


Correlation between k-value (1/m) (reference opacimeter, AVL 439) and gravimetrical mass concentration (mg/m³)

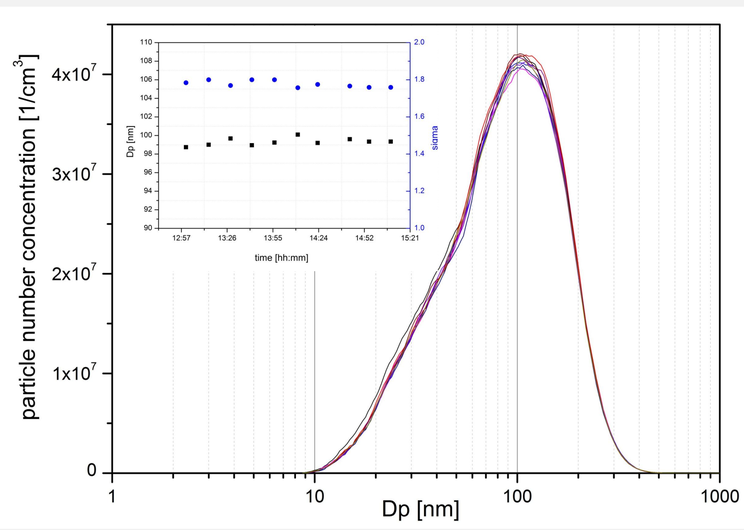
Measurements of stability



Testing of stable conditions at ten different ports of the distribution unit. Particle number concentration (1/cm³), tunnel temperature (° C) and aerosol flow (l/min) during measuring time



Stability of k-value (1/m) (reference opacimeter AVL 439, blue) and mass concentration (mg/m³) (photoacoustic mass sensor, AVL 483, red) during measuring time



Monodisperse particle number size distributions (PNSD) of the HiMass CAST generator with Gaussian Fit parameter of PNSD for mode diameter and sigma during measuring time

Conclusion and Outlook

- The PTB infrastructure which is currently setup is based on a combustion based soot generator (modified HiMass CAST) running on propane, which is able to generate soot with diffusion flames. The infrastructure is intended to ensure at PTB a highly stable, accurately characterized soot generator that allows well defined soot aerosols and particle parameter variations.
- Calibration and standardization procedures are developed to allow valid comparisons between different techniques, and to determine uncertainties reliably.
- The final step will be transferring the current standard into a national standard in terms of uncertainty budget for mass and number concentration.

Parts of this work have been funded by German Garage Equipment Association (ASA) and the European Metrology Research Programme (EMRP) in “ENV02 PartEmission” (WP2)