Comparison of Aerosol Electrometers using soot particles

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Introduction

Particulate emissions are a major hazard for human health and the environment [1, 2]. Nanometre-sized particles have been found especially harmful, as they penetrate deep into the lungs [3]. In urban areas, vehicles are the main source of these particles. Therefore, increasingly stringent regulations have been introduced to reduce particulate emissions from vehicles. Recently, particle number concentration limits for passenger vehicles have been introduced into legislation, e.g. EURO 5b and EURO 6 emission standards [4]. As a result of the particle measurement programme (PMP), a measurement system for measuring exhaust particle number concentration was defined. A vital part of this system is the particle counter. According to the UNECE regulation no. 83 [5], the particle counter needs to be traceably calibrated by reference to an aerosol electrometer (AE) or a reference condensation particle counter (CPC) which is calibrated against an AE.

In order to achieve accurate, reliable and comparable results, particle counters need to be calibrated using a traceable measurement standard, e.g. an AE. The AE measures particle charge concentration and it can be made traceable to the SI system of units through traceable measurements of electrical current and volume flow. National metrology institutes (NMI) provide traceability for particle number concentration through primary measurement standards. Comparison measurements between NMIs are necessary in order to assess the equivalence of the measurement standards and to find out the best attainable measurement capability. Up to now, no extensive comparison study between NMIs has been performed. In this paper we report results from a comprehensive comparison study involving eight primary AEs from NMIs and expert laboratories around the world.

Aerosol electrometers

All eight AEs in the comparison study had SI traceability for particle charge concentration, either directly (primary standards) or by reference to a primary standard (secondary standards). Different types of AE, self-made, commercial, and commercial AEs with external measuring instruments (Table 1), were present in the comparison. Therefore, it is possible to detect instrument-type-dependent errors, such as internal particle losses, in the determination of particle charge concentration.

Table 1. Properties of participating laboratories AEs.

Participant	AE model	Status of standard	External flow/current measurement
NPL	GRIMM 5.705	primary	flow: yes / current: no
MIKES - TUT [1]	Self-made FCUP	primary	flow: yes / current: yes
METAS	TSI 3068B	primary	flow: yes / current: no
PTB	TSI 3068B	primary	none
AIST	TSI 3068B	secondary	none
JRC	Ioner EL-5030	primary	flow: yes / current: no
TROPOS	TSI 3068B	primary	none
APSL	TSI 3068B	primary	flow: yes / current: no

[1]MIKES and TUT cooperated and participated with one instrument.

Experimental setup

Aerosol particles used for the comparison study were generated with an acetylene fuelled flat flame burner with radial dilution and quenching using nitrogen. The generated soot particles were further conditioned by diluting with nitrogen, followed by aging in a mixing chamber and removal of volatile compounds in a thermodenuder. Using this type of soot generator a narrow log-normal particle size distribution with particle size of 30 nm was generated.

The soot particle concentration entering the AE was adjusted using a dilution bridge (Figure 1). Make-up nitrogen flow was used for achieving a flow rate of 8 L min^{-1}, i.e. 1 L min^{-1} flow rate through each AE. Special care was taken in order to ensure equal particle concentration to the AEs. Symmetric flow splitting was achieved by using a static mixer before the 4-port flow splitter (TSI) and by using rigid sampling lines of equal length symmetrically placed in relation to each other (Figure 1). Preparatory experiments confirmed that the particle concentration at the AE sampling ports were equal within measurement uncertainties.

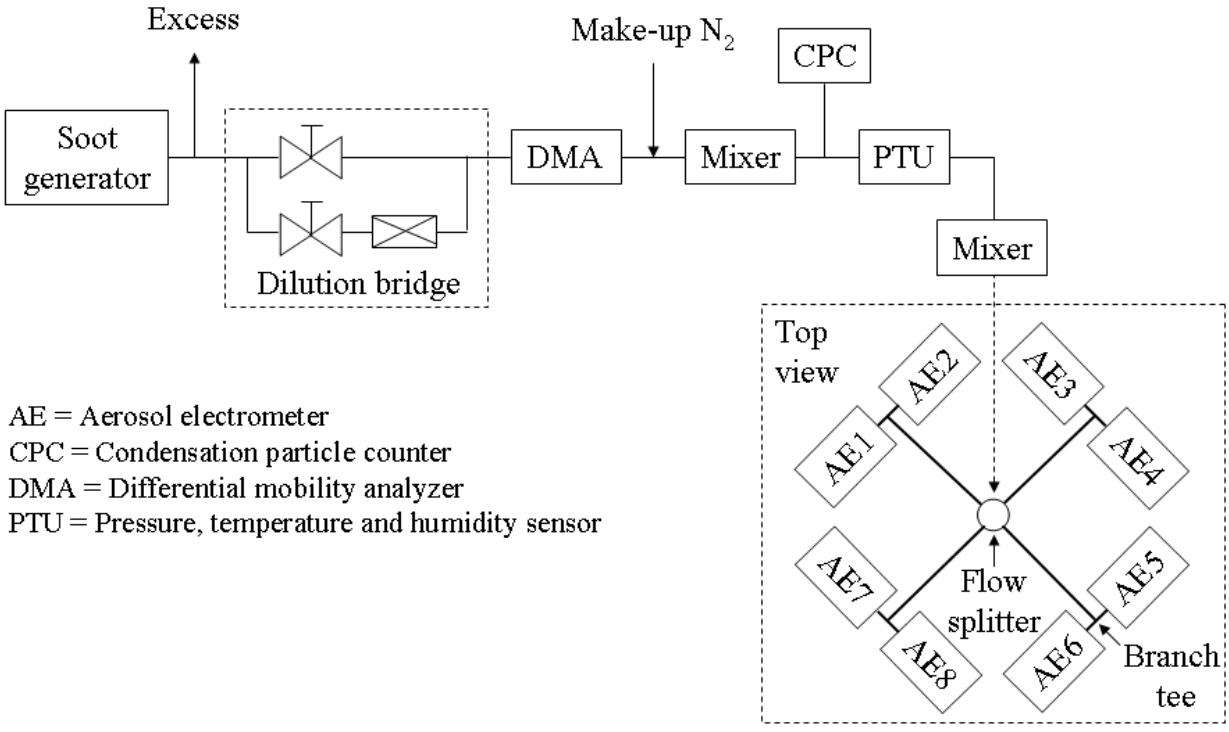

Figure 1. Experimental setup used for the comparison study. A CPC was used to monitor the output concentration.

Results

Figure 2 shows the comparison results for 30 nm soot particles with a nominal particle charge concentration of 10 fC cm^{-3} (corresponding 3800 cm^{-3} singly charged particles). The results agree within stated uncertainties ($k = 2$) except for the JRC results. Further investigations revealed that the construction of the JRC AE should be improved in order reduce particle losses within the instrument and thus obtain the same accuracy level as the other AEs. Results obtained using Di-Octyl Sebacate (DOS) particles from the SCAR generator [6, 7] (not presented here) show that the relative differences between the AEs are to a large extent insensitive to particle size and concentration. This may indicate that the observed differences are related to calibration of flow and/or current measurement of the AEs.

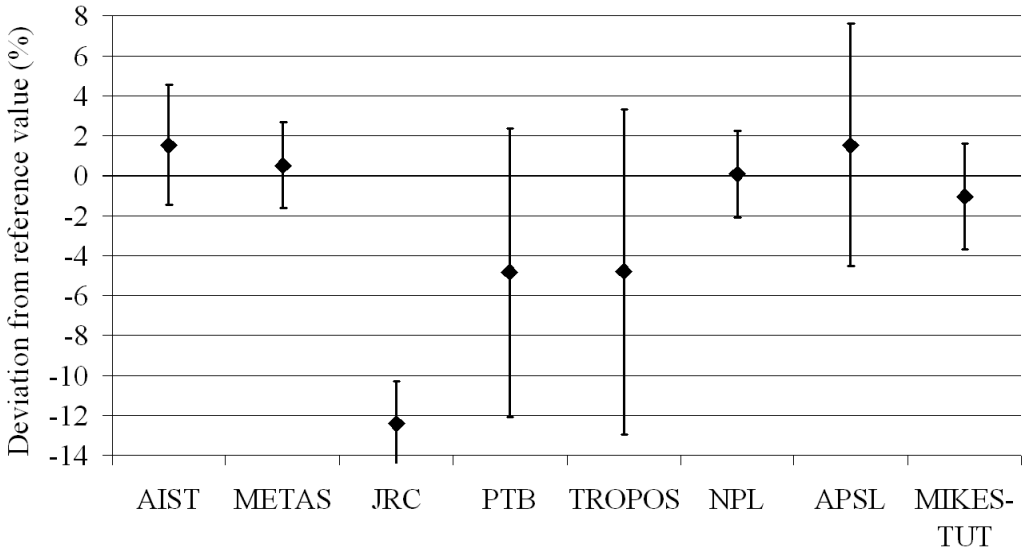

Figure 2. Comparison results showing the deviation from the reference value (the uncertainty weighted mean of all participants except for JRC) for each participant.

Conclusions

The comparison results show that the charge concentration measurements are consistent within stated uncertainties. This is a prerequisite for achieving reliable and accurate measurements of engine exhaust particle number concentration.

Acknowledgements

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INTRODUCTION

Particle counters used for emission tests in type-approval of vehicles (EURO 5b, EURO 6, [1]) needs to be traceably calibrated e.g. by reference to an aerosol electrometer (AE) [2]. An AE can be made traceable to the SI system of units through traceable measurements of electrical current and volume flow. National metrology institutes (NMI) provide traceability through primary standards. Comparison measurements between NMIs are necessary in order to assess the equivalence of the measurement standards and to find out the best attainable measurement capability. Up to now, no extensive comparison study between NMIs has been performed

AEROSOL ELECTROMETERS

Different types of AEs were present (table 1), which made it possible to detect instrument type dependent errors.

Table 1. Properties of participants AEs.

Participant	AE model	External flow/current measurement
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TROPOS	TSI 3068B	none
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[1]MIKES and TUT cooperated and participated with one instrument.

EXPERIMENTAL SETUP

Aerosol particles were generated with an acetylene fuelled flat flame burner. Preparatory experiments confirmed that the particle concentration at the AE sampling ports were equal within measurement uncertainties.

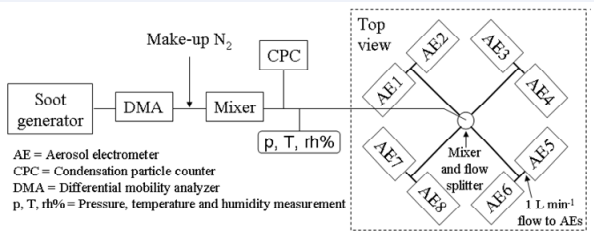

Figure 1. Setup used for the comparison study

RESULTS

The results agree within stated uncertainties (k = 2) except for the JRC result (figure 2), which was excluded from the calculation of the reference value (uncertainty weighted mean). It was found that particle losses within the JRC AE caused the discrepancy. Results obtained using Di-Octyl Sebacate (DOS) particles from the SCAR generator [3, 4] (not presented here) show that the **relative differences between the AEs are to a large extent insensitive to particle size and concentration**. This may indicate that the observed differences are related to calibration of flow and/or current measurement of the AEs.

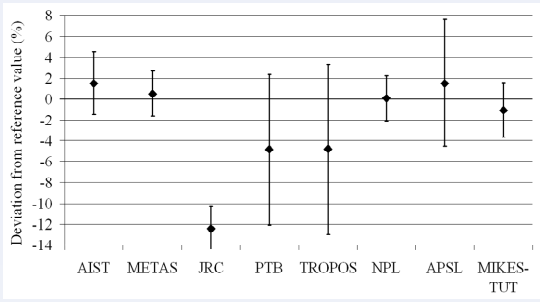

Figure 2. Comparison results for 30 nm soot particles and 10 fC cm^{-3} charge concentration (i.e. 3800 cm^{-3} singly charged particles).

CONCLUSIONS

The comparison results show good agreement. This is an important step towards achieving traceable and accurate measurements of engine exhaust particle number concentration.

ACKNOWLEDGEMENTS

This work was supported by European Metrology Research Programme (EMRP) jointly funded by the EMRP participating countries within EURAMET and the European Union and by the Cluster for Energy and Environment (CLEEN Ltd., MMEA, WP 4.5.1).

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