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Report

Calibration of an HSY CPC (Grimm) using SCAR

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Content in short

This report describes the calibration of a Grimm condensation particle counter (CPC) owned by HSY and presents the calibration results. The calibration experiments were conducted using the Singly Charged Aerosol Reference (SCAR), which has partly been developed under the Measurement, Monitoring and Environmental Assessment research program of Cluster for Energy and Environment (CLEEN Ltd., MMEA, WP 4.5.1). The CPC of HSY is constantly used for air quality monitoring in metropolitan area. Therefore, a traceable and accurate calibration of the instrument is vital in terms of quality assurance of the measurements.

1. Objectives

- To study the particle size response of a Grimm CPC between 10 nm and 1 µm.
- To provide traceability to SI-units for the calibrated instrument

2. Calibration of the instruments

All of the experiments were conducted during February 2013 at the facilities of Aerosol Physics Laboratory in Tampere University of Technology (Tampere, Finland). In the experiments, both the device that was being calibrated and the reference instrument sampled the aerosol simultaneously at ambient inlet conditions (temperature ~23 °C and pressure 980–1003 mbar). The measurements were conducted Dr. Jaakko Yli-Ojanperä (jaakko.yli-ojanpera@tut.fi). Jaakko Yli-Ojanperä was also responsible for the calculation of the detection efficiencies and for evaluating the uncertainty values of the detection efficiencies and particle sizes. The results are applicable to calibrated instrument at conditions specified above.

2.1. Size response

The size response of a Grimm CPC was evaluated using di-octyl sebacate (DOS) particles generated using the Singly Charged Aerosol Reference (SCAR) (Yli-Ojanperä et al., 2010). The SCAR consists of a particle generator and a traceable Faraday cup Aerosol electrometer (FCAE). The key feature of the particle generator is its ability to generate singly charged, fairly narrow size distributions for calibration purposes in a wide particle size range: between 10 nm and 1 µm. Fig. 1 shows the experimental setup that was used in the calibration measurements up to 500 nm. With this setup the whole output aerosol size distribution was used as a calibration aerosol and the mode of the output particle size distribution was used as the particle size of a calibration. The output particle size distribution just downstream of the particle generator (i.e. the particle size of the calibration) was measured using an SMPS (DMA 3071 and CPC 3775/3025, TSI Inc.). The particle size measurement was conducted simultaneously with the CPC and FCAE number concentration measurements.

The flow rate at the output of the SCAR is always 2 L min^{-1}. The particle number concentration was controlled by changing the flow rate of the dilution nitrogen, which controls that fraction of the 2 L min^{-1} aerosol flow which escapes to the excess port. Inlet conditions, i.e. the temperature, pressure and humidity, were measured using a combined temperature, pressure and humidity sensor (PTU 300, Vaisala Inc.). A static mixer located just before the instruments guaranteed the homogeneity of the particle flow before the flow splitter.

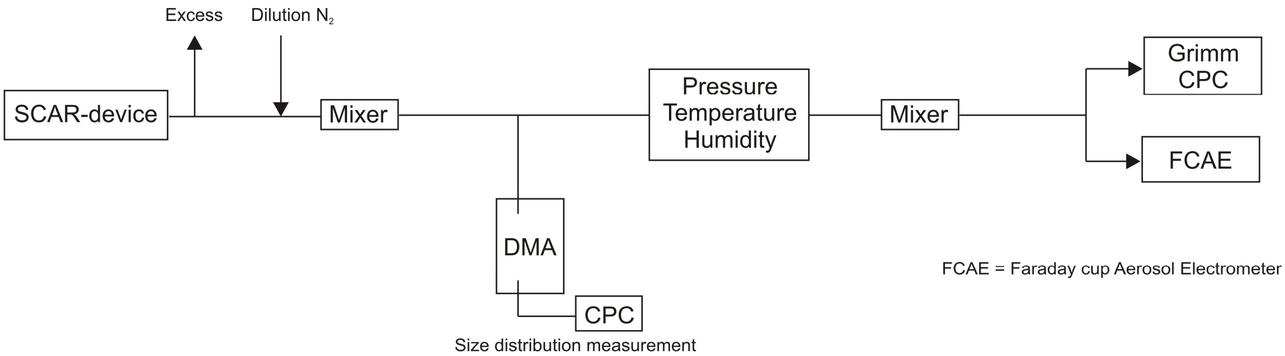

Figure 1. Measurement setup used in the size response calibrations.

The CPCs and the home-built Faraday cup sampled the aerosol simultaneously downstream the flow splitter. The flow rate of the Grimm CPC was 0.3 L/min and the nominal volumetric flow rate of the FCAE was 1 L/min. The inlet flow rate of the Faraday cup was controlled with a mass flow controller (MC-2SLPM-D/5M, Alicat Scientific). The electric current from the Faraday cup was measured using a Keithley 6430 sub-femtoamp remote sourcemeter. At particle sizes between 500 nm and 1 µm a DMA 3071 (TSI Inc.) was connected to the output of the SCAR in order to ensure singly charged calibration aerosol up to 1 µm.

The measurement period for each particle size was 21 minutes. During each measurement period the Faraday cup aerosol electrometer and CPCs sampled 11, one minute long periods of zero concentration and 10, one minute long periods of nominal calibration concentration (e.g. 10 000 #/cm^3). This is demonstrated in Fig. 2.

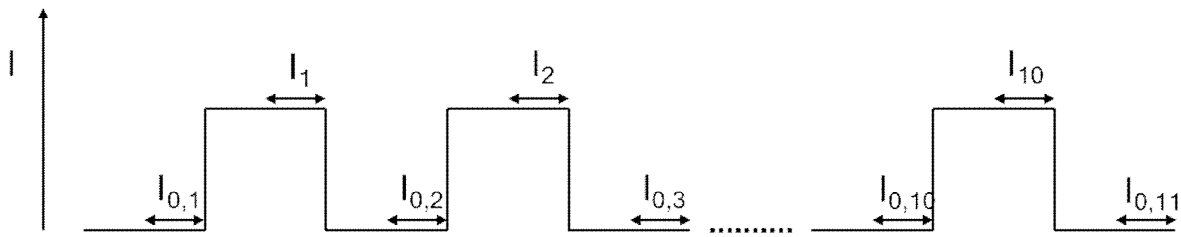

Figure 2. Actual measurement cycle as seen by the FCAE.

As the average charge of the particles (singly charged) and the volumetric flow rate at the inlet are known, the FCAE number concentration reduces to

$$C_{FCAE} = \frac{\Delta I}{Qne\eta_{\mathrm{FCAE}}\gamma}, \tag{1}$$

where ΔI is offset corrected electric current, Q is the volumetric flow rate of the cup, n is the average charge of the particles, e is the elementary charge, η_{FCAE} is the detection efficiency of the FCAE and γ is the calibration factor of the electrometer. In Eq. 1, the offset corrected current is calculated as an average value from the ten repetitions

$$\Delta I = \frac{\sum_{k=1}^{10}\left(I_k - \frac{I_{0,k} + I_{0,k+1}}{2}\right)}{10}. \tag{2}$$

After each sudden concentration change, the instruments needed some time to stabilize. Therefore, in each of the 60 s periods, the average values were calculated by using data only from the last 30 s.

3. Calculation of the detection efficiencies

In this report, the performance of the calibrated CPC are evaluated and presented in terms of their detection efficiency. In general, the detection efficiency is defined as a ratio of the number concentration measured by the CPC to that measured by a reference instrument.

$$\eta_{CPC} = \frac{C_{CPC}}{C_{reference}}, \tag{3}$$

where C_{CPC} and $C_{reference}$ are the average concentrations measured by the instruments. The reference instrument in this study was a Faraday cup Aerosol Electrometer (FCAE).

The results that are presented in the next section include an uncertainty evaluation both for the particle sizes and for the detection efficiencies. The uncertainty of the particle size includes the following component uncertainties: Uncertainty of the SMPS calibration meaning its size accuracy, stability of the particle size during the experiments and an additional uncertainty component, which takes into account the uncertainty of the flow rates, pressure, temperature etc.

The uncertainty of the detection efficiency includes the following component uncertainties when applicable: Component uncertainties of the quantities presented in Eq. 1, which were used in calculating the reference concentration. Deviation of the detection efficiency in repetitive measurements and the uncertainty of the bias between the sampling ports to which a reference instrument the calibrated instruments were connected. All the uncertainty bars presented in the next section delimit the range within which the true values of the quantities are located at 95 % probability.

4. Results

4.1. Size response

Size response of the calibrated Grimm CPC is presented in Fig. 3.

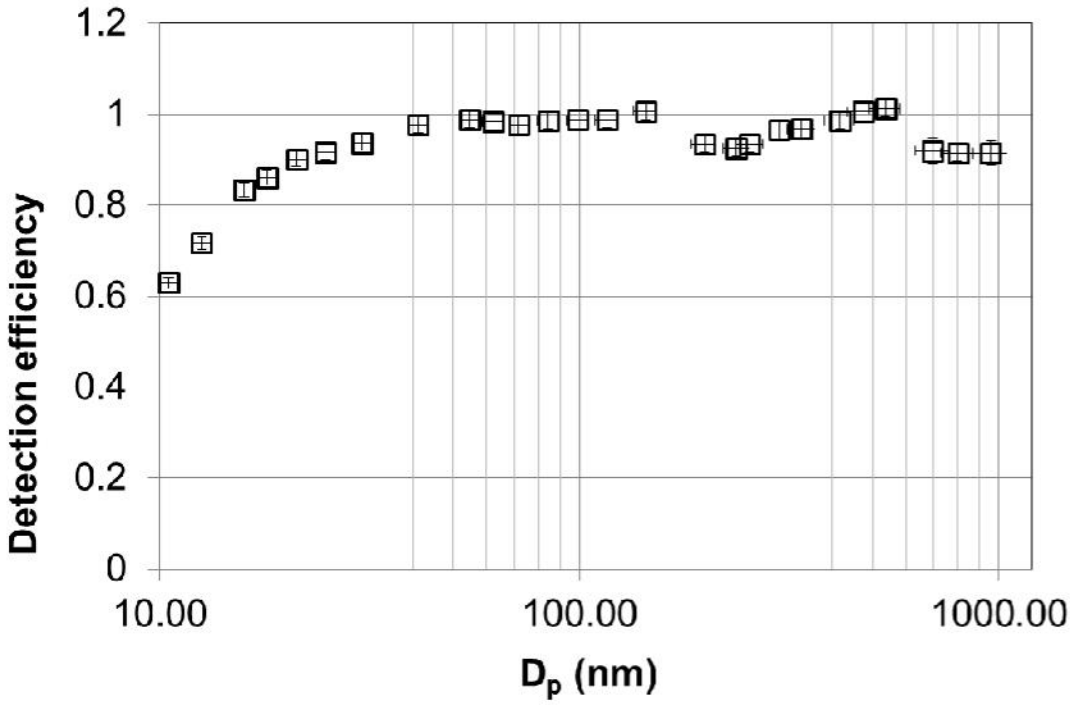

Figure 3. Size response of the Grimm CPC.

Before the calibration experiments conducted at TUT, the CPC was calibrated and maintenance by the manufacturer. Based on the results, the detection efficiency of the CPC reaches its plateau efficiency (close to 100 %) at about 50 nm. However, there are few concerns related to conducting measurements with this particular CPC. By taking a closer look at the calibration results (Fig. 4) we see that the detection efficiency seems to drop two times by 10 per cent as the particle size gets larger. This in fact is caused by a break (30-60 min) before the measurements were continued. So even though the instrument reports that it is ready to measure, every time the break occur the measurement results should be omitted from the first 30 minutes. This is an important piece of information and should be taken into account every time the instrument is used for doing experiments.

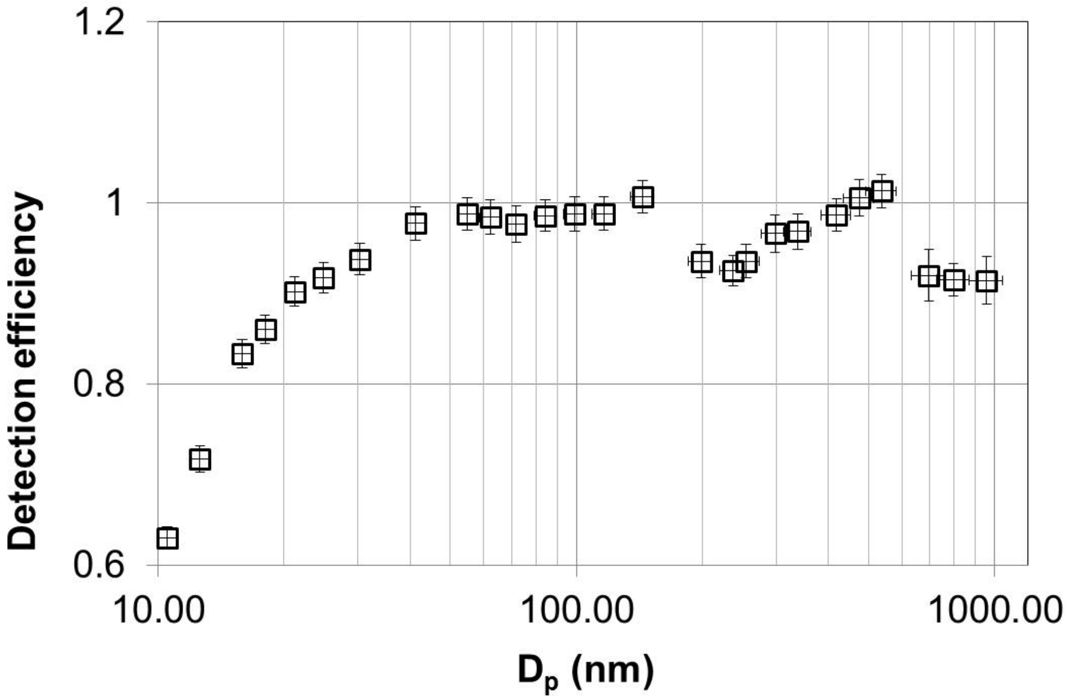

Figure 4. Close view of the size response of the Grimm CPC.

5. References

Yli-Ojanperä, J., Mäkelä, J. M., Marjamäki, M., Rostedt, A. and Keskinen, J. (2010) Towards traceable particle number concentration standard: Single charged aerosol reference (SCAR). *J. Aerosol Sci.*, **41**, 719–28.