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Technical note

Counting efficiency measurements for a new condensation particle counter

S. Baltzer [a], S. Onel [a], M. Weiss [b,1], M. Seipenbusch [a,*]

[a] Karlsruhe Institute of Technology KIT, Institute for Mechanical Process Engineering and Mechanics, Straße am Forum 8, 76131 Karlsruhe, Germany
[b] Palas GmbH, Greschbachstraße 3b, 76229 Karlsruhe I Deutschland, Germany

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ABSTRACT

The counting efficiency of a new condensation particle counter (Palas UF-CPC) was tested and the lower detection limit regarding the diameter of graphite particles was determined. The influence of the supersaturation of the working fluid butanol was investigated which was varied by adjusting the condenser temperature at a fixed saturator temperature. As expected, the lower detection limit decreased strongly with decreasing saturator temperature. However, a limitation was reached at a particle size of 5 nm which can be explained by a limitation in the growth kinetics for droplets growing on small condensation kernels and an insufficient residence time in the condenser for these particles to grow beyond the detection limit of the optical counter.

1. Introduction

Condensation particle counters (CPCs) allow the determination of number concentrations of particles too small for a direct detection via light scattering by size magnification by condensing vapors, so called working fluids, such as butanol or water (Keller et al., 2013; Liu & Pui, 1974; Stolzenburg & McMurry, 1991). The ability of the condensable vapor to adsorb on the particle surface depends on the physicochemical properties of the vapor and the particle material. The lower detection limit in terms of particle diameter however is determined by a purely physical effect. Once a monolayer is formed on a particle the surface curvature and therefore particle size determines the vapor pressure according to the Kelvin equation which defines the rate of desorption from the surface. Additionally kinetic effects come into play which may limit the measurable particle size range. A limitation arises when the time for condensational growth in the condenser section is insufficient for the establishment of an equilibrium between the condensed phase and the vapor.

The Palas UF-CPC is a newly developed condensation particle counter with a few changes to the established system regarding the saturator design and the optical counter. One of these changes is the design of the saturator, which is set vertically in line with the condenser (see Fig. 1). A special feature is the introduction of the working fluid not employing a soaked felt as commonly done but by continuously cycling it through a helical groove in the heated steel cylinder. The change of working fluids is possible in the running system. The particle counter used has an optically defined measuring volume similar to an optical particle counter. It is therefore possible to monitor the droplet size which gives additional

* Corresponding author. Tel.: +49 721 608 42416; fax: +49 721 608 46563.
E-mail addresses: mail@palas.de (M. Weiss), martin.seipenbusch@kit.edu (M. Seipenbusch).
[1] Tel.: +49 721 96213 0; fax: +49 721 96213 33.

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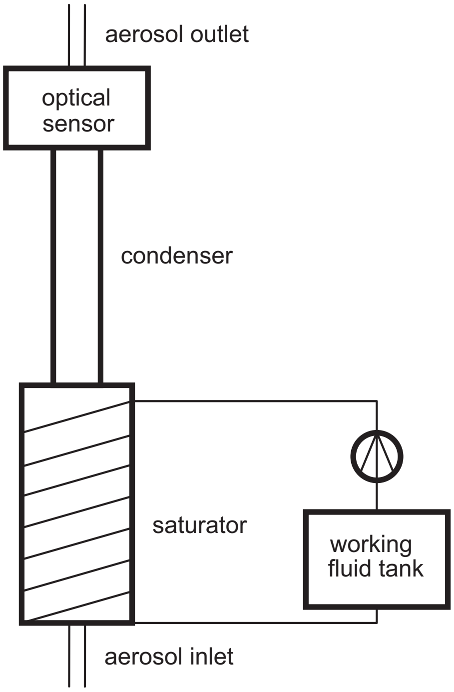

Fig. 1. Schematic diagram of the functional principle of the Palas UF-CPC.

information on the condensation process. The aim of this work was to determine the counting efficiency of this new device as a function of particle size and droplet growth conditions, which were varied by adjusting the condenser temperature.

2. Material and methods

2.1. Test aerosol generation

A test aerosol of graphite agglomerates was generated using a commercial spark discharge generator (Palas DNP 3000), which produces nanoscale particles by sublimation of graphite electrodes in a spark plasma (Schwyn et al., 1988). Agglomeration of particles formed in nitrogen by desublimation of the carbon vapor was reduced by subsequent dilution with air. The characteristics of the particle generator and diffusional losses in the entire setup (see Fig. 2) limited the size range to particles with a mobility diameter d_p larger than 3 nm (see Fig. 3). Before entering a dilution stage (Palas VKL-10) a filter allowed for the decoupling of the flows and prevented pressure build up (see Fig. 2). The aerosol was then diluted with filtered air by a factor of ten and passed a ^{85}Kr radioactive source producing bipolar ions, which led to electrostatic neutralization of the aerosol. Electrostatic classification of these particles possessing a defined charge state was then conducted using a differential electro mobility classifier (Palas DEMC 1000) (Knutson & Whitby, 1975). The aerosol flow was set to 1.5 lpm for all experiments.

2.2. Methodology for the determination of the counting efficiency

The determination of the counting efficiency was done according to the procedure described by Stolzenburg & McMurry (1991) and the setup is shown in Fig. 2. As a reference device a Faraday cup electrometer FCE (Palas CHARME) was used in parallel to the CPC since its counting performance is not limited for small particle sizes based on its working principle. The effect of multiple charging would affect the two devices differently, and could thus lead to lower apparent counting efficiencies. However, below 50 nm and particularly close to the cutoff size in the single digit nanometer range the likelihood of multiple charging is negligible (Friedlander, 1977). Therefore no correction of the data was made to that effect.

The classified aerosol was split into two flows (1000 ml/min for the FCE and 500 ml/min for the CPC). The lengths of the lines leading to the two instruments were adjusted to equalize the lag times between the exit of the classifier and the entry into the instruments and also to equilibrate the diffusional losses occurring in the two lines. Thus a time lag between the signals of the two devices was avoided and it was ascertained that both received an identical aerosol. The parallel measurement further excluded influences of temporal variations in the particle size distribution. The UF-CPC was operated with butanol as working fluid.