Calibration of Condensation Particle Counters for Reduced Pressure Applications

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Condensation Particle Counters (CPCs) are commonly used to measure the number concentration (PN) of airborne particles, ranging from the smallest nanoparticles to those in the accumulation mode. In the past four decades, CPCs have also been used increasingly to determine PN concentrations at non-standard atmospheric pressure in both scientific research as well as for regulatory purposes. Examples include airborne measurements (Petzold et al., 2015), mountain-top aerosol research but also vehicle exhaust emission certifications done at high altitude locations.

In this work, the performance of CPCs is studied at various levels of low pressure in extensive laboratory experiments. An overview of an optimized experimental set-up that was originally introduced by Bundke et al. (2015) will be given; see Fig. 1. Moreover, the methodology and best practices to calibrate CPCs for use under reduced pressure conditions will be explained.

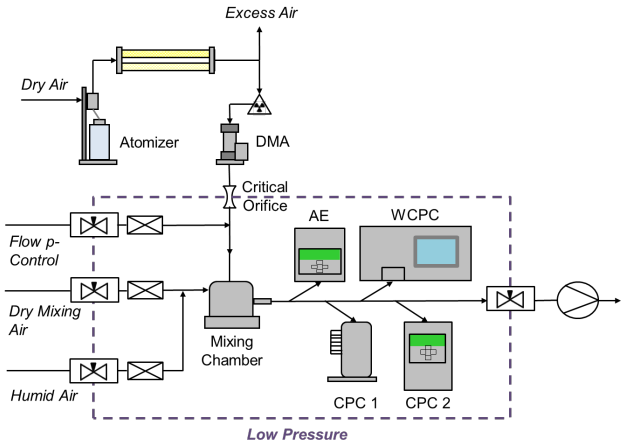

Figure 1. Schematic of the experimental setup for CPC calibration at low pressure, using an atomizer aerosol.

In addition to the different low-pressure stages, all experiments were done with the relative humidity of the calibration aerosol varied from almost dry conditions to moderate levels of up to 40% RH. This aspect was included to consider that humidity might play a role in the activation of the smallest particles in a CPC. Comprehensive results that consider the impact of ambient RH on the performance of CPCs at reduced pressure will be shown for two butanol-CPCs, the CPC model 3772-CEN (TSI Inc., Shoreview, USA) and the Sky-CPC 5.411 (Grimm Aerosol Technik, Ainring, Germany).

The calibrations were performed with two very different test aerosols. The first was an atomized and dried ammonium sulphate (AS) aerosol that is representative of inorganic particles in ambient air. The other calibration aerosol was a proxy for combustion emissions that can typically be found in urban environments. For this purpose, a Miniature Inverted Soot Generator (Argonaut Scientific Corp., Edmonton, Canada) was first characterized for operating conditions that allow the generation of sufficient particle concentrations also below 20 nm (Bischof et al., 2019).

The outcome of this work is a detailed analysis of the performance of these CPC models at pressures ranging from ambient 1,013 hPa down to 200 hPa as expressed by high-resolution counting efficiency curves, their smallest particle size detection limit, and concentration linearity at low-pressures in a range. It will be shown that that the counting efficiency of these full-flow CPC models is largely independent of ambient pressure between standard conditions and 500 hPa, and that they can be used even somewhat below that with acceptable corrections. At very low pressures, a very significant impact on the overall measurement performance can occur, which depends on the exact measurement conditions and the specific CPC design. The influence of moderate levels of relative humidity as well as of the two particle calibration materials on key performance characteristics of these CPCs under reduced pressure conditions will also be shown.

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Bundke, U., Berg, M., Houben, N., et al. (2015) The IAGOS-CORE aerosol package: instrument design, operation and performance for continuous measurement aboard in-service aircraft. *Tellus B: Chem. Phys. Meteorol.*, 67(1), 28339.

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