CALIBRATION ET IMPACT DE LA PARAMÉTRISATION DE LA TEMPERATURE SUR LE DIAMÈTRE DE DECOUPAGE DU CPC A20 D'AIRMODUS

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TITLE

Calibration of A20 Airmodus CPC and impact of temperature settings on cutoff diameter

RESUME

La mesure de particules nanométrique dans l´atmosphère est devenu un sujet crucial pour la compréhension du mécanisme climatique de la Terre. Nous utilisons couramment des compteurs à particules condensées (CPC) dans ce but. De récentes recherches ont montré l'impact du réglage des températures sur le diamètre de découpage de CPC TSI (eau ou n-butanol). Pourtant il existe d'autres entreprises qui produisent des instruments de mesure (i.e. Airmodus). Dans cette étude, nous nous intéresserons à l'impact de différents réglages de température sur le diamètre de découpage du CPC à n-butanol A20 d'Airmodus, ainsi que de l'impact sur l'efficacité de détection de cet instrument.

ABSTRACT

The measurement of nano-metric particles in the atmosphere is more and more crucial to understand the Earth´s climate mechanism. Condensation particle counters (CPC) are commonly used. In recent studies the impact of the temperature settings on the cut-off diameter of TSI CPCs (water or n-butanol CPC) was shown, however, comparable instruments from other companies (i.e. Airmodus) need to be tested. In this study, we will be focus on the impact of the temperature settings on the cut-off diameter of the n-butanol A20 CPC of Airmodus, and how it impacts the maximum detection efficiency of the instrument.

MOTS-CLÉS : CPC à butanol, calibration, diamètre de coupure, efficacité de détection, paramétrisations de température / **KEYWORDS :** Butanol CPC, calibration, cut-off diameter, detection efficiency, temperature settings.

1. INTRODUCTION

Recent studies have shown that the cut-off diameter of butanol Condensation Particle Counters (CPC) is highly sensitive to the actual temperature settings, even if the temperature difference between saturator and condenser is kept constant (Barmpounis et al., 2018; Tauber et al., 2019). By reducing the temperature both in the saturator and condenser, the cut-off diameter can easily be shifted towards smaller sizes. Improving existing instruments is more and more studied to increase the possibility to use a same instrument for different research fields (Wlasits et al., 2020). Most of the studies are based on TSI CPCs (water CPC 3788, n-butanol 3776, etc.). In this study, we investigated the impact of the temperature settings on the detection efficiency and the cut-off diameter of the A20 butanol CPC of Airmodus Ltd. To this end we used sodium chloride (NaCl) and Silver (Ag) seeds which were size selected in a Vienna type DMA. Monodisperse particles were then counted in the A20 test CPC and a Faraday cup electrometer (FCE) for comparison.

2. MEASUREMENT SETUP

The Figure 1 shows a schematic draw of the setup used during the measurement. We used a high temperature furnace to produce nanoparticles of silver and sodium chloride (Scheibel & Porstendörfer, 1986). An ultrapure air flow of di-nitrogen was used as carrier flow. We used an Am241 radioactive source (60MBq) to charge the particle. The size selection was done with a U-Vienna type nano-DMA. An FCE was used as reference instrument for cut-off diameter measurement, and a reference A20 CPC operating at standard temperature settings (T(saturator) = 35°C, T(condenser) = 20°C and T(optics) = 40°C) with a cut-off diameter at 10nm for the concentration calibration and cut-off is calibrated against an FCAE.

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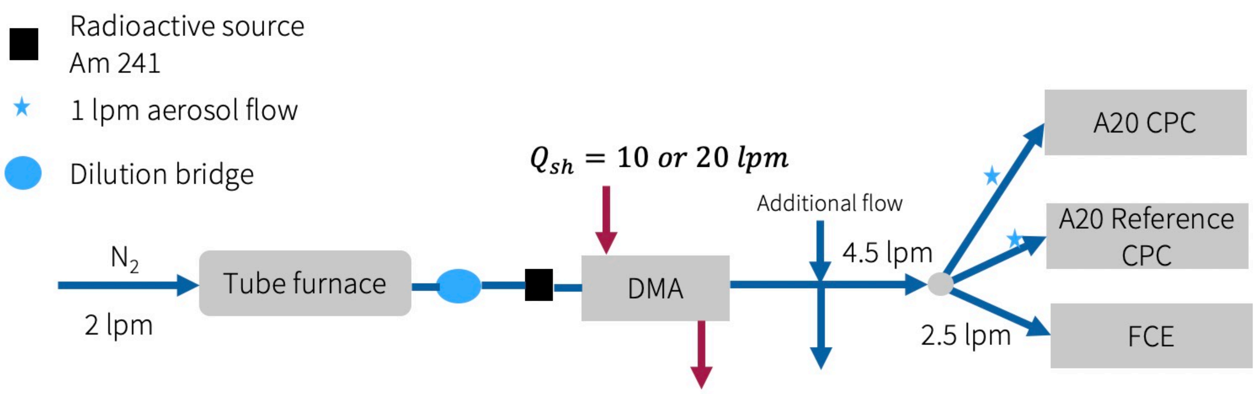

Figure 1. Schematic Setup used for the cut-off diameter and concentration calibration

The dilution bridge was controlled by an electronic needle valve. The sheath flows were set at 10 L.min^{-1} for the concentration calibration and 20 L.min^{-1} for cut-off calibration. In the next section, we will present some results from the measurement (i.e. concentration calibration and cut-off diameter measurement).

3. RESULTS

3.1. Concentration calibration of the CPC

Our first motivation was to know the response of the CPC with different temperature settings to a concentration calibration. To guarantee full particle activation we set the DMA to select particles at 90 nm. One of the limits of each CPCs is the multiple particles coincidences detection. In the case of the Airmodus A20, the single particle counting limit is 30 000 cm^{-3}. Below this limit the coincidence probability is below 10%, but about an additional cloud correction is applied to the concentration data (based on calibration). The dead time (τ in seconds) is the time when the counted signal is higher than the trigger threshold and is it subtracted to the sampling time to correct the concentration data:

$$C = \frac{N}{Q * (t - \tau)}$$

where C is the measured particles concentration in cm^{-3}, Q is the sampling flow in cm^{3}.s^{-1} and t is the sampling time in seconds. Figure 2 present the results of two concentration calibrations at two different temperature settings.

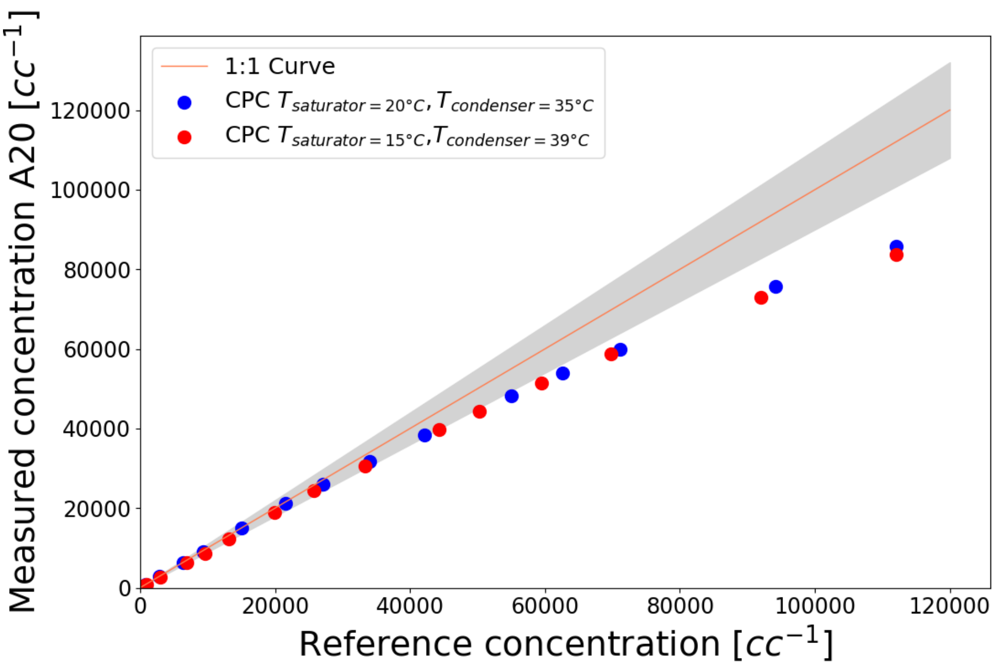

Figure 2. Concentration calibration curves of different settings at 90nm.

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The gray area corresponds to the 10% error of deviation. In the previous figure (Figure 2) we compare the response of the CPC with the standard settings of Airmodus (i.e. T(saturator) = 15°C, T(condenser) = 39°C) with a modify settings (T(saturator) = 20°C and T(condenser) = 35°C). As predicted, we observe a deviation of the measured particle concentration around 40 000 particles.cm^{-3} but the figure clearly shows that the temperature settings don't affect the concentration response of the instrument.

3.2. Impact on the cut-off diameter and detection efficiency

Here we present two characteristic results of our experiment. In the first case, the A20 CPC was operated with the following default values ($T_{condenser}$ = 39°C and $T_{saturator}$ = 15°C) and then we changed the temperatures to $T_{condenser}$ = 35°C and $T_{saturator}$ = 20°C. Figure 2 represents the normalized detection efficiency of the A20 CPC with the two settings. We used the Wiedensohler fit function (Wiedensohler et al., 2018), define by:

$$\eta_{CPC} = A\left(1 - e^{\left(\frac{Dp_0 - Dp}{Dp_{50} - Dp_0}\ln 2\right)}\right),$$

where A is the plateau height, Dp_0 is the lowest diameter detected in nm.
We also define Dp_{50} as the diameter where we have 50% of detection efficiency, function of the maximum detection efficiency plateau. Figure 3 clearly shows a shift of the cut-off diameter, just by changing the temperature settings of the A20 CPC.

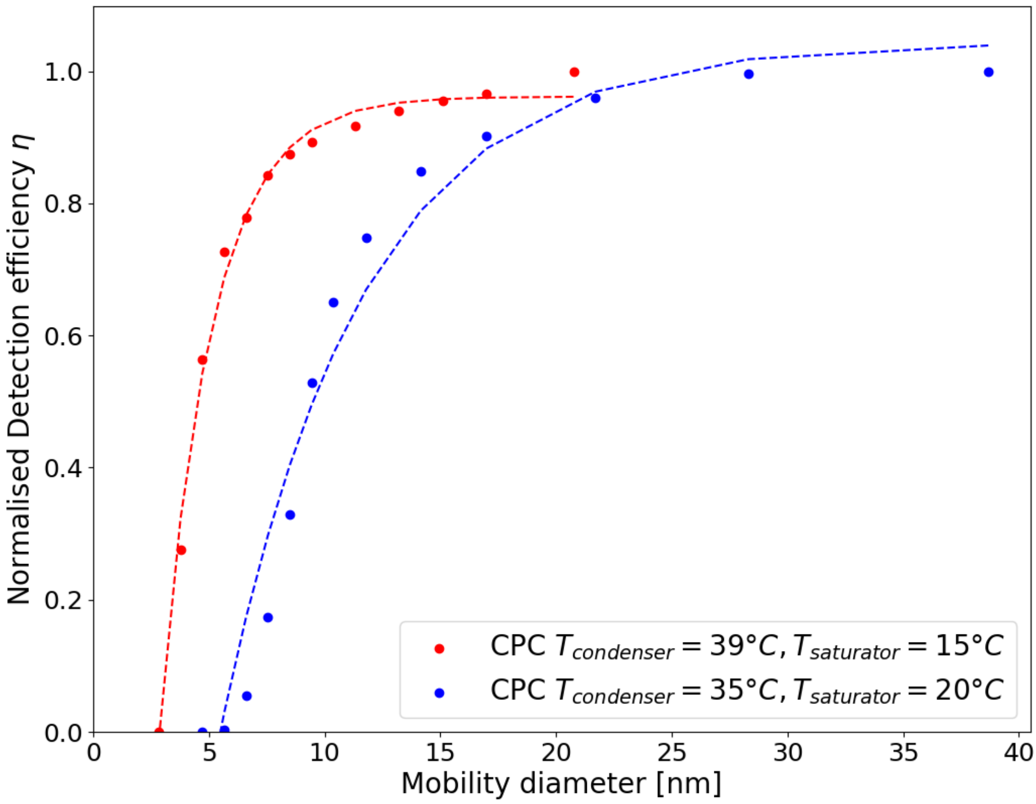

Figure 3. Detection efficiency response of A20 butanol CPC for two different temperature settings and for dry air condition (i.e. RH = 0%).

The dashed line is the Wiedensohler fit function defined previously. In the figure (Figure 3) we represented the detection efficiency of two different temperature settings in dry air condition (RH at 0%). We can see the good correlation between the fit and the data. Furthermore, we also see a shift of the cut-off diameter between the two temperature settings and correspond to an expected results like for Tauber et al. (2019). It was shown that a delta of ± 8°C of the condenser and saturator temperatures impacted the cut-off diameter of the TSI CPC 3776 that also using n-butanol as a working fluid (Figure 4). Table 1 summarizes the low, standard and high temperature settings used by Tauber et al. (2019). Further investigation will be done with other temperature settings.

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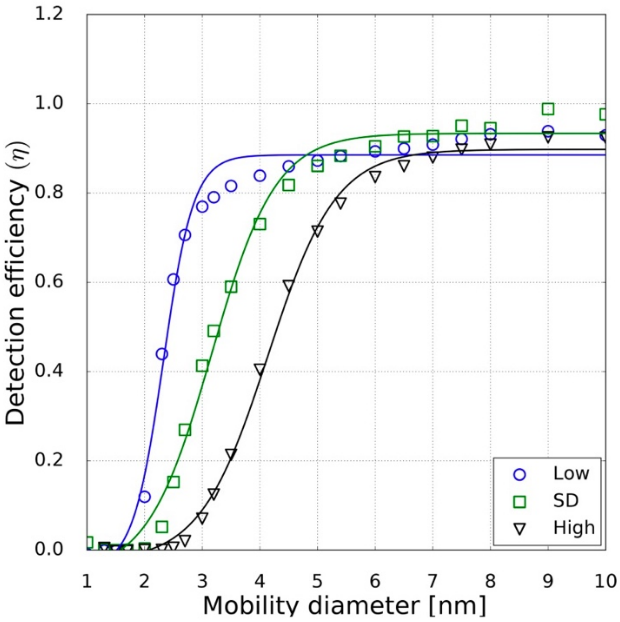

Figure 4: Detection efficiency as function of the mobility diameter for neutral sodium chloride at 10 % RH (Tauber et al., 2019)

Table 1: Temperature settings of the three TSI 3776 UCPCs used in Tauber et al. (2019)

Settings	Low T (°C)	Standard T (°C)	High T (°C)
Condenser	1.1	10.0	18.9
Saturator	30.1	39.0	47.9
Optics	31.1	40.0	48.9

The table below (Table 2) summarizes all the parameters calculated for two of the investigated settings in this study presented in the Figure 3.

Table 2. Results for two different temperature settings

Tcondenser (°C)	**Tsaturator (°C)**	**A**	**Dp_0 (nm)**	**Dp_{50} (nm)**
39	**15**	**1.044**	**2.862**	**4.409**
35	**20**	**0.962**	**5.489**	**10.9749**

4. CONCLUSION

The measurements demonstrate a clear dependence of the cut-off diameter on the temperature settings of the saturator and condenser of the CPC A20. Other investigations will be done to estimate the impact of other variables like the relative humidity and the response to biogenic particles. These preliminary results show similar impact of the temperature settings on the cut-off diameter of the CPC, as described in previous studies with TSI CPCs. Accordingly, the cut-off diameter of the A20 can be easily tuned and optimized depending on the field of application.

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