Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2017-480-AC2, 2018


Atmospheric Measurement Techniques Discussions

# *Interactive comment on* "Effects of Temperature, Pressure, and Carrier Gases on the Performance of an Aerosol Particle Mass Analyser" *by* Ta-Chih Hsiao et al.

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Received and published: 21 June 2018

The authors would like to thank the positive feedbacks to our work and appreciate the reviewers' valuable comments for helping to significantly improve the manuscript. We agreed with most of the comments and have revised the manuscript accordingly. Following are our point-by-point response to each of the comments made by the reviewers.

Reviewer 2 Comments

This manuscript by Hsiao et al. entitled as 'Effects of Temperature, Pressure, and Car-



rier Gases on the Performance of an Aerosol Particle Mass Analyser' discusses the influence of carrier gas on the operation of the APM. As far as I know, most of previous work on the APM has been focusing on operations under a normal atmospheric condition. The experimental result of the present study will help interpreting experimental data of the APM (or DMA-APM system) in the future, especially when the instrument is operated under unusual conditions. My major concern about the manuscript is that the experimental part of the study focuses on the operation of the APM under different types of gases (air, CO2, and O2). No experiment seems to have been conducted to investigate the influence of temperature and pressure on the APM, even though the title mentions them. It is not clear to me when CO2 or O2 could be the major carrier gas of aerosol particles during atmospheric measurement. In that sense, I am not sure if the manuscript really fits well with the scope of the journal. I leave this question to the handling editor of the manuscript. My comments in this review focuses on scientific/technical components of the manuscript.

We appreciate these valuable comments on our work. The abstract was rewrote to explicitly express that the effects of pressure and temperature were theoretically analysed, while the effect of carrier gas was evaluated experimentally. Using gases other than air, such as CO2 and O2, as carrier gas for APM are just trying to test whether or not the APM performance would change significantly under various conditions, which may be the case for ambient monitoring or characterizing atmospheric aerosols. For example, argon would be required as the carrier gas if the APM was used as an aerosol particle classifier coupled with inductively coupled plasma mass spectrometry (ICP-MS; in a similar manner to the DMA–ICP-MS system). Tandem APM-ICP-MS could be employed for realtime characterization of trace elements in atmospheric aerosols. In addition, the theoretical calculation and numerical simulation were conduct for explaining the experimental results.

1. P5L11 Detailed information about the standard PSL particles is important for papers characterizing instruments. Please provide further detailed information about the PSL

particles (e.g. manufacturer, model number, standard deviation of the distribution). Also, please provide more detailed information about the generation and desiccation processes of the PSL particles. Thanks for the suggestion. The information of PSL and the generation processes were added in the revised manuscript.

P5.L11-16: "Fig. 4 depicts the experimental evaluation system. The particles were generated by an aerosol atomizer (TSI, Model 3076) and dehumidified by two desiccant dyers connected in series to remove excess water content. To experimentally evaluate the classification accuracy, 50-nm and 100-nm polystyrene latex (PSL) spheres certified by National Institute of Standards and Technology (ThermoFisher SCIENTIFIC, Cat. No. 3050A and 3100A) were used here. The mean diameters of the size distributions of the 50-nm and 100-nm PSL given by the manufacturers are 46$\pm$2 nm and 100$\pm$3 nm. These PSL particles were classified using the DMA (TSI 3081) and then delivered to the APM (Kanomax modelâĂą-3601) to determine particle mass." https://www.thermofisher.com/order/catalog/product/3050A

2. P5L12 It was not clear to me how the DMA voltage has been set. Both the transfer function of the DMA and size-distribution of the PSL particles have relatively sharp distributions. Thus, it is important set the DMA voltage so that the center of the DMA transfer function matches with that of the size-distribution of the PSL particles.

The following description were added in P6.L5-8: "…The operation of DMA-APM is identical to Kuwata and Kondo (2009) and Kuwata et al. (2011), in which the DMA selects particles with +1 charge and predetermined mobility diameters and then subjects them to the APM. Following, the APM was set to scan across a range of voltage (V) while the number concentration (CN) of the passing particles was measured by a CPC…."

3. P5L21 The authors found 6% of differences in the size of PSL particles when they were measured under different types of gas. Although the authors mention that it is not significant, I do not think that the difference is small. I wonder if they have any



explanations on it.

The differences were not considered significant because of (1) the NIST-certified PSL mean diameters (50, 100 nm) have an expanded uncertainty of ïĆś2 to ïĆś3 nm, corresponding to coefficients of variation of ïĆś3-ïĆś4.3%, (2) repeated measurements of PSLs show that the DMA has a precision of 1.7-8.9%, (3) the TSI DMA has sizing uncertainties of 3-3.5%, and (4) the 6% differences yield about 3-6 nm, which may not be of practical significances in field studies.

4. P6L20 'The results revealed that particle mass was generally underestimated for cases where $CO_2$ was used as a carrier gas. In particular, underestimation was 23%-25% for a 50-nm PSL sphere. By contrast, when $O_2$ was used as the carrier gas, an overestimation of mass measurements was observed, with an error within 9%.' I wonder how the authors explain it.

As shown in Table 1, the viscosity of $CO_2$ was lower than that of air, whereas the viscosity of $O_2$ was higher than that of air. These findings exhibit qualitative agreement with observations of under- or over-estimations of PSL spheres. Therefore, we suspect that the fluid field in the APM classification zone is influenced by gas-specific properties such as $\mu$ and . Based on the numerical simulation of the flow field and using the flow velocity of air as a reference, the velocity differences in an angular direction at the APM's inlet and outlet under various $\omega$ values are plotted in Fig. 7. The velocity was generally lower in the classification zone of the APM when $CO_2$ was used as the carrier gas, and an increase in the distinct differences between $CO_2$ and air with an increase in the rotation speed was observed. Therefore, a lower viscosity and higher gas density likely intensify the shear force required to create rotating flow inside the APM. Because of the lower rotating flow velocity, significant deviations were observed in the measured results under normal conditions in the case of $CO_2$; this phenomenon is intensified with higher values of $\omega$ and is more significant for small particles, which are even more prone to influence from the flow field. (P7.L13-24)

5. P6L25 '(convoluted with the known size distribution classified by DMA)' It might also be needed to consider the size-distribution of particles entering the DMA when they have a narrow distribution. I wonder if the authors could add any comments on it.

Thanks for the comments, and we have add some comments on P6.L29-31. "As reported by Lall et al. (2009) and Lall et al. (2008), the particle concentration measured as a function of APM voltage is wider than the APM transfer function even through the particle can be considered as "mono-disperse" in size. This is mainly due the spread in calibration particle sizes or the transfer function of the DMA." Therefore, to further eliminate the spread propagated from DMA classification, the transfer function of the APM was calculated using software developed by the AIST of Japan. The transfer function predicted based on the known size distribution of the DMA outlet (convoluted with the known size distribution classified by DMA).

6. P7L5 'Therefore, we suspect that the fluid field in the APM classification zone, also known as Taylor–Couette flow, is influenced by gas-specific properties such as $\mu$ and .' I am not sure if the APM only relies on the viscosity to rotate gas between the two rotating cylinders. There might be some kinds of internal structures to force the gas to rotate at the same angular velocity as the rotating cylinders. I suggest the authors to contact the manufacturer for it.

We have consulted the manufacturer, Kanomax, and confirmed that there is a partition inside electrodes to force the gas to rotate at the same angular velocity, as suggested by the reviewer. Therefore, we re-run the numerical simulation again with this internal structure and update the figures. Qualitatively, the influence of gas properties was still observed, while the quantitative effect is lessened. Therefore, the conclusion is remained unchanged and the sentence was rewrote without mentioning Tayor-Couette flow.

7. Figure 6: Are the y-axis of the figure the APM transfer functions, or are they the number concentration of particles measured by the CPC?



The y-axis of the figure should be APM transfer function.

Kuwata, M. and Kondo, Y.: Measurements of particle masses of inorganic salt particles for calibration of cloud condensation nuclei counters, Atmos. Chem. Phys., 9, 5921-5932, 2009.

Kuwata, M., Zorn, S. R., and Martin, S. T.: Using elemental ratios to predict the density of organic material composed of carbon, hydrogen, and oxygen, Environ Sci Technol, 46, 787-794, 2011.

Lall, A. A., Ma, X., Guha, S., Mulholland, G. W., and Zachariah, M. R.: Online Nanoparticle Mass Measurement by Combined Aerosol Particle Mass Analyzer and Differential Mobility Analyzer: Comparison of Theory and Measurements, Aerosol Science and Technology, 43, 1075-1083, 2009.

Lall, A. A., Rong, W., Mädler, L., and Friedlander, S. K.: Nanoparticle aggregate volume determination by electrical mobility analysis: Test of idealized aggregate theory using aerosol particle mass analyzer measurements, Journal of Aerosol Science, 39, 403-417, 2008.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2017-480/amt-2017-480-AC2-supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2017-480, 2018.