ACTRIS Recommendation for measurements with mobility particle size spectrometers - Part II recommended particle loss correction

Alfred Wiedensohler and Wolfram Birmili

Leibniz Institute for Tropospheric Research

Correction of Particle Losses

This recommendation is based on the article of Wiedensohler et al. (2012).

Particle losses may practically occur in any part of a mobility particle size spectrometer. An important mechanism is particle diffusion to walls e.g. inside of pipes, the DMA, aerosol dryer and bipolar charger, especially for particles smaller than 100 nm in size. If particle losses in a particularly device are known as a function of particle size, they can be corrected during the data post-processing. A useful parameter to describe particle losses in any component of the mobility particle size spectrometer is the method of “equivalent pipe length”. Particle losses by diffusion of different components of the mobility particle size spectrometers are described by a straight pipe, which has the same particle penetration (equivalent pipe length, see Table 1). The losses can thus be easily computed for any particle size and flow rate from such an equivalent pipe length. Equivalent pipe lengths of different devices and plumbing elements aligned in sequence can be simply added if they are traversed by the same rate of aerosol flow. To ensure traceability of the data, any such corrections need to be documented when submitting data to a data base.

Plumbing

Particle losses by diffusion in a straight pipe can be described by analytical formulas derived for the laminar flow regime. For a developed laminar flow, these losses depend only on the pipe length, the flow rate through the pipe, and the particle size. When designing a mobility particle size spectrometer, it is advisable to use connecting pipes as short as possible, and as straight as possible. Enhanced diffusional particle losses may occur in sampling pipes containing bends or elbows. These enhanced particle losses increase with a decreasing radius of the bend or elbow. We estimated the equivalent pipe length of a 90° bend based on the investigation of Wang et al. (2002). Using curves with smooth radii instead of elbow joints will also reduce the opportunity for particle losses. It is very essential that the plumbing consists of electrical conducting material, preferably stainless steel. Experience has shown that non-conductive tubing (e.g. plastics) may remove a considerable fraction of any charged particles by electrostatic forces.

Bipolar Diffusion Charger

Particle losses also occur inside bipolar diffusion chargers. The loss correction can be directly applied based on the experimentally determined penetration efficiency. Alternatively, any experimental penetration efficiency under a specific flow can be converted to an equivalent pipe length using the diffusional deposition formula for laminar flow. Particle losses for sub-10 nm particles across 85Kr bipolar diffusion chargers were measured for a TROPOS custom-made bipolar charger.

Differential Mobility Analyzer

Different DMA types exhibit different particle losses due to Brownian diffusion. The probability of a particle penetrating through a DMA depends on the losses in the DMA inlet and outlet region as well as on the transfer function in the DMA classification region. Short column lengths and high aerosol and sheath air flows are general design features that minimize particle losses. Particle losses can be either simulated by diffusional deposition models, or estimated experimentally. As with the bipolar diffusion charger, the diffusional losses across different DMAs have been simulated by an equivalent pipe length as given in Table 1.

Condensation Particle Counter

Each CPC may have a rather individual particle counting efficiency, which can be determined experimentally. The size-dependent counting efficiency of an individual CPC depends on many specific factors, such as CPC geometry, or the actual supersaturation profile inside the condenser. If experimental data on the counting efficiency of a particular CPC are not available, the manufacturer's calibration curve can be applied with caution. Our recommendation is, however, to calibrate CPCs individually against a reference instrument. Experience suggests that the performance of CPC degrades typically after one year of continuous ambient measurements due to laser power deterioration or contamination of the optics. When calibrating a CPC, particle losses inside the CPCs are implicitly included in the measured counting efficiency.

Device	Equivalent pipe length	
Hauke-type medium-DMA (28 cm effective length)	4.6m	Karlsson and Martinsson (2003)
Hauke-type short-DMA (11 cm effective length)	4.6m	IFT internal calibration
TSI long-DMA (444mm effective length)	7.1m	Karlsson and Martinsson(2003)
TSI nano-DMA (49.9mm effective length)	3.64m	Jiang et al. (2011)
Permapure Nafion dryer SS2400	2.5m	Dick et al. (1995)
Permapure Nafion dryer SS1200	1.25m	Dick et al. (1995)
Diffusion dryer (e.g. TOPAS)	5m	estimated from Tuch et al. (2009)
90 bend (less than 5 cm radius)	0.15m	estimated from Wang et al. (2002)
Bipolar diffusion charger (IFT custom-made)	1m	Covert et al. (1997)

Table 1: Recommended equivalent lengths taken from Wiedensohler et al. 2012

References

Covert D.S., Wiedensohler A., Russell L.M. (1997). Charging and transmission efficiencies of aerosol charge neutralizers. Aerosol Sci. Technol. 27, 206-214.

Dick, W., Huang, P.F., McMurry, P.H. (1995). Characterization of 0.02 to 1.0 µm particle losses in Perma Pure dryers: dependency on size, charge and relative humidity. PTL Publication No. 936: Particle Technologogy Laboratory, Department of Mechanical Engineering, University of Minnesota, Minneapolis, MN 55455.

Jiang, J., Attoui, M., Heim, M., Brunell, N. A., McMurry, P. H., Kasper, G., Flagan, R. C., Giapis, K. and Mouret, G. (2011). Transfer Functions and Penetrations of Five Differential Mobility Analyzers for Sub-2 nm Particle Classification. Aerosol Sci. Technol. 45, 480-492.

Karlsson, M.N.A., Martinsson, B.G. (2003). Methods to measure and predict the transfer function size dependence of individual DMAs. J. Aerosol Sci. 34, 603-625.

Tuch, T. M., A. Haudek, T. Müller, A. Nowak, A. Wex and A. Wiedensohler (2009). Design and performance of an automatic regenerating adsorption aerosol dryer for continuous operation at monitoring sites. AMT 2, 417-422.

Wang, J., Flagan, R., and Seinfeld, J. (2002). Diffusional losses in particle sampling systems containing bends and elbows. Aerosol Sci. Technol. 33, 843-857.

Wiedensohler, A., W. Birmili, A. Nowak, A. Sonntag, K. Weinhold, M. Merkel, B. Wehner, T. Tuch, S. Pfeifer, M. Fiebig, A. M. Fjäraa, E. Asmi, K. Sellegri, H. Venzac, P. Villani, P. Laj, P. Aalto, J. A. Ogren, E. Swietlicki, P. Roldin, P. Williams, P. Quincey, C. Hüglin, R. Fierz-Schmidhauser, M. Gysel, E. Weingartner, F. Riccobono, S.Santos, C. Grüning, K. Faloon, D. Beddows, R. Harrison, C. Monahan, S. G. Jennings, C.D.O'Dowd, A. Marioni, H.-G. Horn, L. Keck, J. Jiang, J. Scheckman, P. H. McMurry, Z. Deng, C. S. Zhao, M. Moerman, B. Henzing, G. d. Leeuw, G. Löschau and S. Bastian (2012). Mobility Particle Size Spectrometers: Harmonization of Technical Standards and Data Structure to Facilitate High Quality Long-term Observations of Atmospheric Particle Number Size Distributions. AMT 5, 657–685.