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Atmospheric Measurement Techniques Discussions

Interactive comment on "Characterization of an aerodynamic lens for transmitting particles > 1 micrometer in diameter into the Aerodyne aerosol mass spectrometer" *by* L. R. Williams et al.

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Atmos. Meas. Tech. Discuss., 6, C1952–C1953, 2013 Response to Anonymous Referee #1:

We thank Referee #1 for their careful reading of the manuscript and their many helpful comments. Our responses and the corresponding changes in the manuscript are detailed below:

Comment 1: Therefore it would be desirable that the authors present data that show that "good" lenses (i.e. the two out of the five) are able to reproduce the transmission

properties as shown in Figure 5 for one single copy of the lens.

We have clarified in the text and in Figure 5 (now Figure 4) that we have experimental data for both SN12 and SN13 showing transmission > 50% between dva= 80 nm and 3 micrometers. Figure 5 included data for both SN12 and SN13 on the small particle side (NH_4NO_3 mass method). We have added data for SN13 for NH_4NO_3 MS counts and for $NaNO_3$ LS counts to the figure, and rearranged the figure legend to make it clearer that data for both lenses are included. We also have added transmission efficiency data for SN10 that shows > 50% transmission between 100 nm and 3 micrometers, but used a single symbol without error bars in order to not clutter the figure too much.

"…in Fig. 4 (closed squares SN12, open squares SN13)."

"…in Fig. 4 (closed circles SN12, open circles SN13)."

"Similar transmission efficiencies (EL > 50% for dva between 100 nm and 3 micrometers) were measured for a third high pressure lens (SN10) and are shown in Fig. 4 without error bars and with a single symbol for all three methods (grey stars) in order to simplify the figure.."

"Figure 4. Experimental transmission efficiency (EL) as a function of particle size for three examples of the HPL (SN10, SN12 and SN13), using the mass method (triangles) and the count method (other symbols). "

Specific comments: P5035L3/4: ". . . that transmits particles between 80 nm and more than 3 μm in diameter." This was also true for the standard AMS lens, however with very little efficiency. It would be desirable if a statement would be added how well particles were transmitted.

We added a sentence in the introduction with more details about the transmission efficiency of the standard lens. "The transmission efficiency of the standard lens is 1 between approximately 90 nm and 700 nm in vacuum aerodynamic diameter (dva) and decreases to 0.3 at 1000 nm (Liu et al., 2007)."

P5035L15: Here are several references to papers from the same or almost the same group. The Canagaratna et al. 2007 paper would be sufficient to cite as it includes all the other references as a review paper.

We changed the references for the AMS to only Canagaratna et al. 2007.

P5035L22-25: The logic of the sentence is not completely correct. The collection "efficiency" cannot be a "combination" of the transmission "efficiency", particle "loss" and beam "spreading". Please reword.

We have reworded this sentence as "The overall collection efficiency (CE) for the AMS is EL $\times$ EB $\times$ ES, where EL is the lens transmission efficiency, EB represents reduced collection efficiency due to particle bounce off the vaporizer, and ES represents reduced collection efficiency due to particle beam spreading for very small or very non-spherical particles (Huffman et al., 2005)."

P5036L3: Indicate how efficient the standard lens transmits particles in this size range.

We added a sentence in the introduction with more details about the transmission efficiency of the standard lens.

P5036L18: "microns": slang

We changed "microns" to "micrometers."

P5036L1921: The introduction of a relaxation chamber behind the critical orifice was already described by Gaie-Levrel in his PhD thesis (2009) and in Gaie-Levrel, et al., AMT 2012.

The use of a relaxation chamber between the critical orifice and the lens was described in Wang et al. (2006) and we have included that reference in the introduction and in the discussion.

P5035/36: It would be desirable if a broader overview over the current state of the art in aerodynamic lens design and knowledge would be provided here. See also e.g. Lee

et al., AST 2013 and discussion therein as well as the papers from the McMurry group.

We added the following paragraph to the introduction: Several previous studies have addressed broadening the transmission size range of aerodynamic lenses. Wang and McMurry (2006) proposed using helium as the carrier gas to improve transmission of small particles. Lee et al. (2009) invented a converging-diverging orifice to stabilize the fluid flow and transmit 5-50 nm particles better in air. The same group also developed an orifice configuration with descending-ascending diameters to achieve better transmission of large particles (Lee et al., 2013). Schreiner et al. (1999) experimentally demonstrated that a 7-stage high pressure lens could focus micrometer-sized particles.

P5037L4/5: The Stokes number is the ratio of particle stopping distance to a characteristic dimension of an obstacle.

We changed the definition of stokes number in the text and included a reference: "The Stokes number is the ratio of the particle stopping distance to a characteristic dimension of an obstacle (Hinds, 1999),"

P5038L3ff: It would be desirable if the process how the authors came to the current aerodynamic lens design would be described before the evaluation of this lens using the CFD modeling is described.

We rearranged Section 2 (Modeling of high pressure lens) so that the process used to arrive at the lens design is described before the results of the CFD calculation are presented.

P5039L2: "This inlet distribution . . .": please be more specific of which variable is distributed.

We changed the wording to "This radial position distribution. . ."

P5040L7/8: "A significant fraction of the particles impact the back of the critical orifice or the walls and are lost." This cannot be seen in Figure 2.

We agree with the reviewer that Figure 2 is very difficult to interpret. Unfortunately, we have no way to regenerate the figure more legibly because we no longer have access to Fluent. Therefore, we have removed Figure 2 from the manuscript. The paragraph on P5039L28 to P5040/L18 describing the introduction of the relaxation chamber, now reads: "CFD simulations on the HPL lens with the constant bore valve predicted that an eddy would form downstream of the critical orifice holder and that this eddy could increase particle loss by impaction on the low-pressure side of the critical orifice or on the walls. Experimental observations of particle deposition on the back of the critical orifice confirmed this loss. A relaxation chamber was therefore introduced between the critical orifice and the valve as suggested by Wang and McMurry (2006). The purpose of the relaxation chamber is to slow the larger particles and allow them to be entrained in the gas flow eddy behind the critical orifice. The optimal ID and length of the relaxation chamber were determined by examining calculated particle trajectories; the ID and length were increased until less than 5% of the particle trajectories impacted the back of the critical orifice or the walls of the relaxation chamber. A larger than necessary relaxation chamber is not desirable because it increases the residence time for particles in the lens system, possibly increasing evaporation of volatile components. The relaxation chamber in the current design increases the residence time in the lens system by roughly 50%, from on the order of 0.04 s to 0.06 s. Experimentally, no deposition of particles on the back of the critical orifice was observed with the relaxation chamber."

P5040L17: ". . . residence time in lens system . . ." ! ". . . residence time in the lens system . . ."

Corrected.

P5041L8/9: Are the continuum assumptions implicit in the CFD software not "strictly valid" anymore in the vacuum or are they "not valid at all"?

We removed the word "strictly."

P5042L23: Shouldn't it be "effective particle density" instead of "material density"?

The effective particle density is incorporated in the Jayne shape factor. We added the phrase "which incorporates the effective particle density" to clarify this.

P5043L18: The lower limit of 100 nm for particles to be detectable with an ion burst in the MS should be dependent on the particle composition. While some components generate signal at only a few m/z for other components the signal might be spread over many m/z, easily causing this limit to increase by a factor of two.

We have clarified that the lower limit of 100 nm is for these laboratory experiments with single component NH4NO3 or NaNO3 particles. The text now reads: "For NH4NO3 particles detected at m/z 46 (or NaNO3 particles detected at m/z 30), the ion signal for particles with dm > 100 nm will cross a threshold set just above the background noise and will be counted as individual particles."

P5045L7: I suggest using "good" instead of "well" to avoid a potential misunderstanding.

We have rearranged this sentence to read "Aerodynamic lenses focus larger particles more tightly than smaller particles. For very small particles,. . ."

P5046L2: Why was the count method not used for smaller particles than 300 nm if already 100 nm particles generate sufficient signal for counting? This could provide some overlap and thus increased confidence in the measurement results.

We always use both the count method and the mass method for particles between dm = 100 nm and dm = 300 nm. We were trying to make Fig. 4 not too cluttered so we did not include the overlapping data. We have added some additional points to Fig. 4 to indicate the overlap. We have also updated the text to match the points in the figure.

P5046L21: ". . . can select larger dm's than . . .": Laboratory slang

We have changed the text to read, ". . .because it can select larger mobility diameters than the TSI DMA."

P5046L28: Why is the uncertainty of the AMS ion count (+/- 500 Hz) a constant number and does not depend on the number of ions counted?

The (+/- 500 Hz) is the detection limit for NO3 at m/z 46 and should not have been included. The error associated with ion counting statistics is negligible compared to the other sources of error in determining EL. We have rephrased the description of the error as: "The error bars on the experimental points determined by the mass method are estimated from the uncertainty in EMI ($\pm$ 15%), CPC counts ($\pm$ 5%), and dm ($\pm$ 5 nm). The error due to ion counting statistics in the mass spectrometer was negligible."

P5047L7: "Experimental particle velocities were determined . . .": Laboratory slang (also in caption for Figure 4)

We substituted the word "calculated" for "determined."

P5047L10: If there are measurement results for two different copies of the new lens, why is the reproducibility of the transmission efficiency not presented and discussed?

We have included data for three examples of the lens in Figure 4 and have added the following sentence to the text: "Figure 4 shows that the lens transmission efficiency measured for three different examples of the HPL (SN10, SN12 and SN13) are in good agreement and demonstrate EL > 50% between approximately dva = 80 nm and dva > 3 micrometers."

P5048L3: ". . . CFD model by recording . . .": This sounds like a measurement.

We have reworded this sentence as: "The measured values are in good agreement with the beamwidth determined from the CFD model by calculating the arrival positions at the target (vaporizer) of 100 particles at each size."

P5048L13-22: The order the information is presented in this paragraph is somewhat confusing. Please reorder.

We have rearranged this paragraph.

P5049L11: It would be helpful in this context if at any place the SN of the lens which was used for the measurements presented in Fig. 5 would be provided.

The SN was in the figure legend. We have rearranged the legend and updated the text to make this clearer.

P5049L24: Was the SN10 Lens re-aimed for every particle size individually or was it necessary to re-aim it just once? Please be more specific.

We have added the information about re-aiming of SN10 as follows: "The measured EL for SN10 for larger particles (200 nm to 3 ïĄ■m) was the same as SN12 as long as the lens was re-aimed twice (at dva = 700 nm and dva = 1.5 micrometer) so that the particles reached the detector."

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 5033, 2013.