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Calibration of Particle Counter:
A Connection between Counts and Mole

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Metrological problem and solution through present work

First time we have shown a connection between particle counts and mole. This method can be used for a wide particle size range needed for the calibration of a particle counter (PC). This is an advantage over calibration of PCs by electrometer method. In this method, PC calibration check is based on the comparison between particle mass calculated from PC counts and mass derived simultaneously from particle filter sample by chemical analysis.

Methodology used

Briefly, a particle generation system was used wherein a solution of certified reference material, i.e. inorganic salt prepared in particle free water of a defined concentration was aerosolized with the particle free nitrogen gas. Generated particles were dried using diffusion dryers, and then allowed them to pass through the impactor, neutralizer, and a differential mobility analyser (DMA) for getting size selected particles. Then this particle stream was divided into two equal flow sub-streams, where one stream was sent to PC for number count measurement, and other one in parallel to the filter unit for corresponding mass measurement. Alternatively, this filter unit is also replaced with quartz crystal microbalance (QCM) to get particle mass directly.

Figure 1. Experimental setup

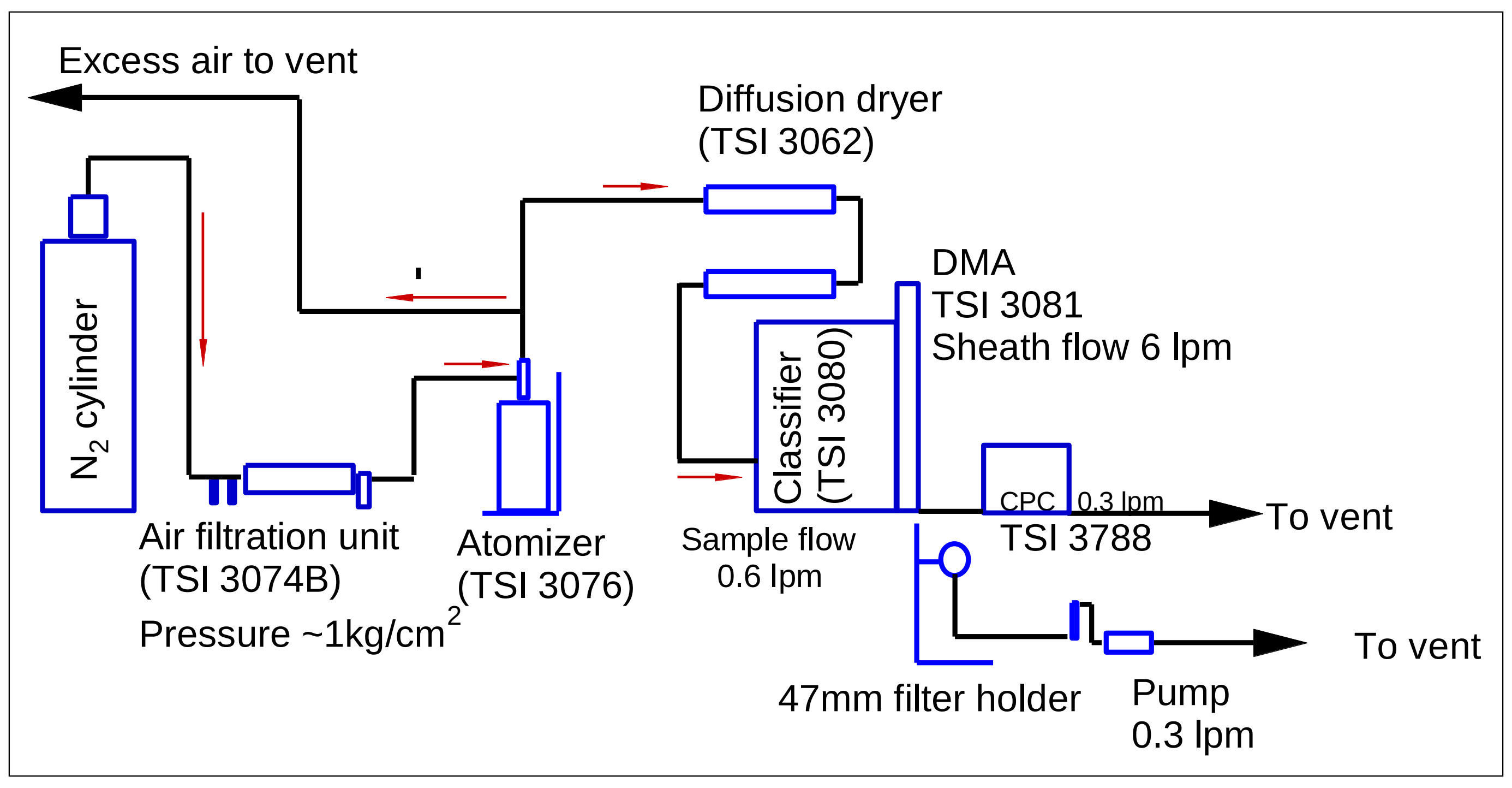

Figure 2. Schematic of the experimental setup

We used two approaches. (i) First, using PC particle count data, PC derived particle volume can be calculated. On the other hand, if particle effective density is known then particle mass collected on the filter/measured by QCM, volume of particles can be calculated.

(ii) Secondly, particle mass from the PC was calculated based on size (volume) and effective density (as above) and can be compared with the particle mass which was derived from filter analysis (molar mass determination).

First approach:

Using PC particle count data, PC derived particle volume and mass can be calculated as:

$$V = v \times \frac{\pi}{6} \sum_{i=14}^{600} d_{pi}^{3} \times n_i \qquad (1)$$

where, V is the total volume of the size distribution in cm^3, v is the flow volume (calculated from PC inlet flow and the time of flow) enters to PC, d_{pi} and n_i are the particle size and number concentration in bin i. If particle density is known then mass can be calculated.

Based on the particle mass collected on the filter/measured by QCM, and using density of particle material (e.g., ammonium sulfate), we have calculated the volume of particles as:

$$V = \frac{m}{\rho} \qquad (2)$$

where, ρ is the density of particle material (e.g., in case of ammonium sulfate, 1.769 g/cm^3), m is the mass of the particles collected on the filter.

Second approach:

Using particle effective density, equation 1 can yield PC derived particle mass. Similarly in equation 2, particle mass can be determined by analysis of particle material collected on the filter using analytical techniques, e.g. ion chromatography (IC), inductively coupled plasma – optical emission spectrometry (ICP-OES), etc.

$$C = \frac{m_c}{v_c} \Rightarrow \frac{m_c}{v_c} \times v_T = m_a \Rightarrow m_a \frac{A_T}{A_t} = m \qquad (3)$$

where, C is the concentration determined by an analytical technique in terms of (mole) m_c by v_c ($\mu g/ml$ or $\mu g/g$), v_T is the total volume of Milli-Q water in which a part of the particle filter was ultra-sonicated, m_a is the particle mass from analysis, A_T and A_t are the total filter area and the filter area taken for analysis, respectively. Finally, m is the particle mass collected on filter which determined using an analytical technique.

Results

Table 1: PC derived volume versus filter based volume

PC based particle volume, cm^3 × 10^{-5}	Filter based particle volume, cm^3 × 10^{-5}
1.38	1.37
1.39	1.33
1.39	1.39
1.39	1.34
1.38	1.35
1.37	1.38
1.39	1.33
1.38	1.41
1.39	1.41
1.38±0.007	1.37±0.031

We also tested this approach using QCM instead of mass measured using filter.

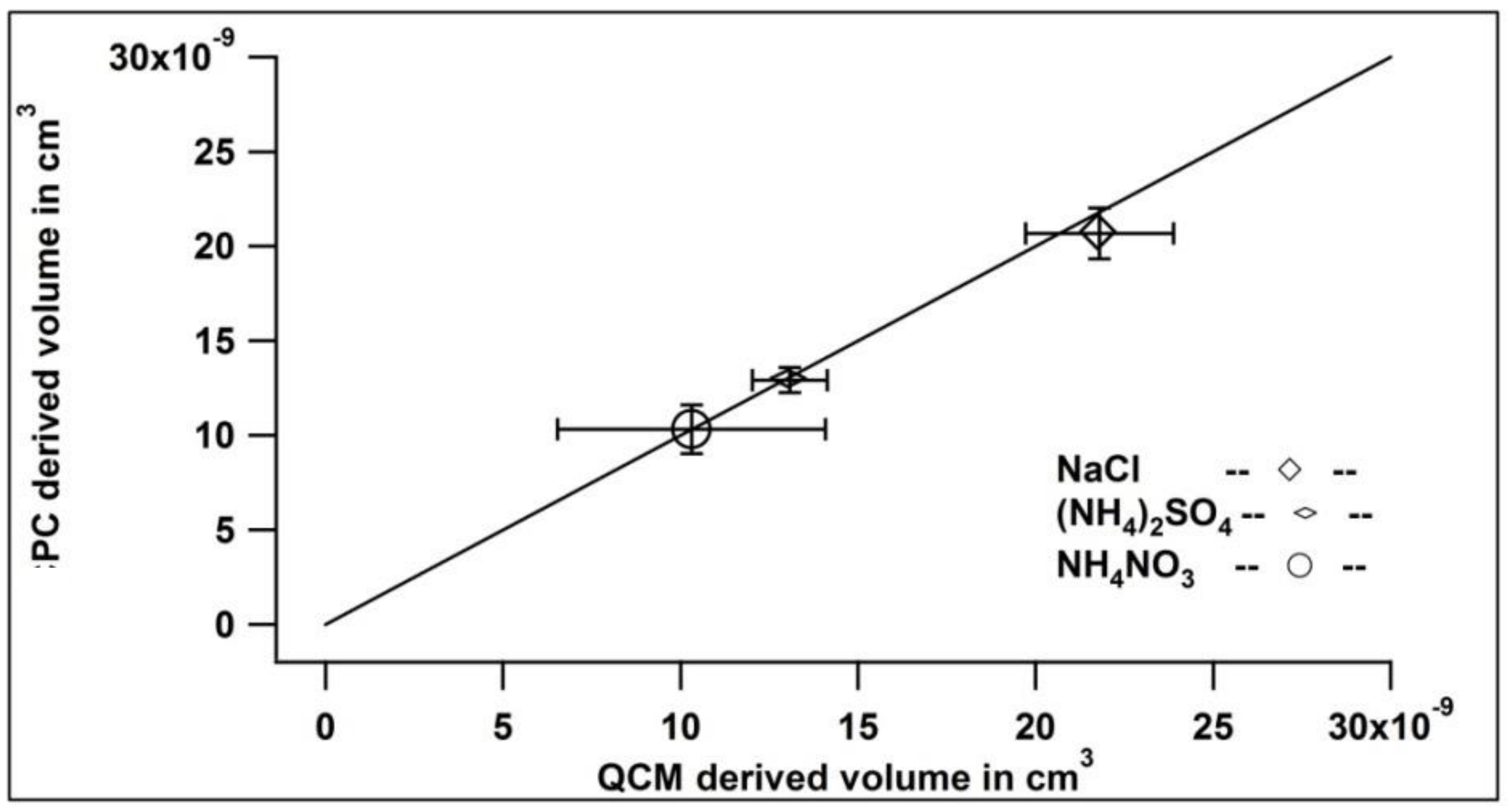

Figure 3. PC derived volume versus QCM derived volume using different salt particles

In the second approach, mass of the salt particles (e.g., ammonium sulfate, ferrous ammonium sulfate) was also determined using an analytical technique as per equation 3, and compared with PC derived mass as in equation 1-2. Our results show that this mole to count approach can be used to check the PC calibration at laboratory level as most of the particle laboratories have the required instrumentation.

Conclusion

Our preliminary comparison results of particle mass derived from PC counts and filter moles show an excellent agreement with below 1% relative difference. However, more data and a detailed uncertainty study is in progress to further quantify this approach.