Determination of the filtration efficiency for HVAC, HEPA and ULPA filters for nanoparticles ≥5 nm

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Keywords: filtration, nanoparticles, HVAC, ULPA, HEPA
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Airborne nanoparticles can cause adverse effects both in human health as well as in the clean production of e.g. computer chips. Humans and cleanrooms therefore need to be protected from exposure to airborne nanoparticles by the use of dedicated filters.
Especially in urban areas, a large fraction of nanoparticles stem from industry and traffic exhaust and may enter indoor environments through HVAC systems. Typically, the number concentration of nanoparticles in the (urban) air is orders of magnitude higher than the concentration of micron sized particles. Still, current standards for the evaluation of HVAC filters (e. g. EN 779) only prescribe the determination of the filtration efficiency at a particle size of 400 nm. It is known that the filtration efficiency increases for particle sizes below the most penetrating particle size (MPPS), which typically is between around 100 and 300 nm. High upstream nanoparticle concentrations are therefore required in order to produce statistically secured data downstream of the filter.

In the present work, we investigated the efficiency of both the filter media as well as the assembled full size HVAC, HEPA and ULPA filter cassettes. Due to the high efficiency for nanoparticles, the tests require both a very high degree of cleanliness and accuracy as well as (nearly) monodisperse particles with a sufficiently high concentration to still be able to determine a statistically significant number of particles in the clean gas. Both can be realized with the described methods. While the flat sheet media are tested in small scale test rigs, similar to DIN EN 1822, the full scale filters are tested with the rated flow rate in a test rig according to DIN EN 779. For testing flat sheet media, a NaCl, Ag or DEHS aerosol is produced with an atomizer and size classified by a differential mobility analyzer. The number concentration is measured simultaneously upstream and downstream of the filter with a condensation particle counter. For testing full size cassettes with a typical cross section of 600 mm x 600 mm and flow rates of several thousands of cubic meters per hour, the use of DMA for size classification is impossible. Instead, quasi-monodisperse NaCl particles with adjustable modal diameters between 5 nm and >50 nm and very high concentrations $>10^7$ 1/cm³ (even at operating flow rates of up to 4700 m³/h) are produced with a flame spray generator. Polydisperse aerosols with modal diameters around the MPPS are used for larger particles.

An example for the fractional deposition efficiency measured with this method is shown in Figure 1. One of the goals of the research is to point out whether cross-reading from media tests to the performance of filter cartridges is valid.

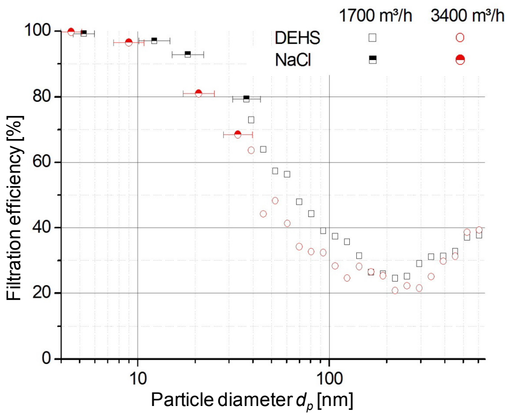

Fig. 1: Example for the fractional collection efficiency of a full scale HVAC filter for particle sizes between 5 nm and 600 nm

The developed methods allow for an accurate determination of the fractional deposition efficiency of flat sheet filters and filter cartridges for the particle size range from 5 nm at least up to the MPPS. The filter classes that can be tested range from low (e.g. M5) to very high efficiency filters (e.g. H14). Potential applications of these filters comprise air supply households or offices as well as for more critical environments such as clean rooms or operation theatres.

The experimental procedure, measurement strategy and experimental results for the fractional collection efficiency down to 5 nm will be presented.

ACKNOWLEDGEMENT
The IGF-project 18314N of the research association “Umwelttechnik“ is funded by the German Federal Ministry for Economy and Energy (BMWi) via AiF within the framework of the program for the promotion of industrial cooperative research and development (IGF) based on a decision by the German Bundestag.