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IUTA report UN2-210225-T5599900-036B

Measurement of the deposition efficiency of GJ type filter for 0.003 µm NaCl particles

Customer:	IUTA, Managing Director
Winix Sangdeuk Son (Cris) 6, Haogae-ro 344 beon-gil, Bundangu-gu, Seongnam-si, Gyeonggi-do, 13455 Korea	Dr.-Ing. Stefan Haep Institut für Energie- und Umwelttechnik e.V. (IUTA) Bliersheimer Straße 60 47229 Duisburg Duisburg, April 21st, 2021

IUTA – Data report

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1. Table of content

2. List of figures

3. List of tables

4. Introduction

Three filters of the type GJ were delivered by Winix to be tested at IUTA. The requirement set by the customer was that the deposition efficiency for 0.003 µm NaCl particles of one filter, at a face velocity corresponding to a flow rate of 6.5 CMM through the whole filter, should be determined.

5. Experimental set up

Figure 1 and *Figure 2* show the experimental set up used to generate the test aerosol and determine the deposition efficiency of the filter for 0.003 µm NaCl particles. A nanoparticle generator (model FG2, MoTec Konzepte, Bochum, Germany, no. 1361) with flame-based dissociation of an aqueous NaCl precursor solution was used to generate the desired NaCl aerosol. A 0.5 g/L NaCl precursor solution was fed with a syringe pump into the generator with a feed rate of 50 ml/h. The generated NaCl aerosol was fed into a large filter test rig according to ISO 16890, where it was mixed with 4000 m^3/h dilution air. The immediate strong dilution quenches the aerosol formation process and avoids further particle growth. The test rig is equipped with a conditioning system, which keeps the temperature and relative humidity of the test aerosol constant. During the measurement the temperature in the ISO 16890 test rig was kept around 23 °C, while the relative humidity was kept under 40 % and therefore below the deliquescence point for NaCl to avoid water uptake by the NaCl particles. Also the aerosol flow in the ISO 16890 test rig was kept constant, thus ensuring a constant particle size and number concentration of the aerosol during the filter test. The necessary test aerosol was withdrawn from the ISO 16890 test rig at the required flow rate and introduced into the second test rig, designed for testing cabin air filters according to DIN 71460-1/ ISO/TS 11155-1, containing the filter to be tested. The particle size distribution of the test aerosol was measured with an Electrostatic Classifier (TSI model 3080, no. 1346) coupled with an Ultrafine Condensation Particle Counter (UCPC, TSI model 3776, no. 1354). The Electrostatic Classifier uses a Nanometer Differential Mobility Analyzer (nanoDMA TSI, model 3085, no. 1355) to classify the particles according to their electrical mobility, which is related to the particle size. Before performing the measurement, the filter was static conditioned for 48 h at rh = 50 % and T = 23° C.

The size of the filter was adapted to the size of the test rig and correspondingly the test flow rate was decreased to 5.35 CMM, in order to have the same face velocity as with a flow rate of 6.5 CMM through the whole filter.

In order to determine the deposition efficiency of the investigated filter for 0.003 µm NaCl particles, only the concentration of the particles with this size was measured both in raw and

clean gas. To do so, the Electrostatic Classifier was set to a fixed size mode to classify only the particles with an electrical mobility diameter of 0.003 µm. The nanoDMA was operated at 1.5 L/min aerosol flow and 10.5 L/min sheath flow rate. The number of the classified 0.003 µm particles was measured with the UCPC downstream of the nanoDMA. Three consecutive measurements raw gas/clean gas/raw gas were performed. Each clean gas measurement lasted ~20 min.

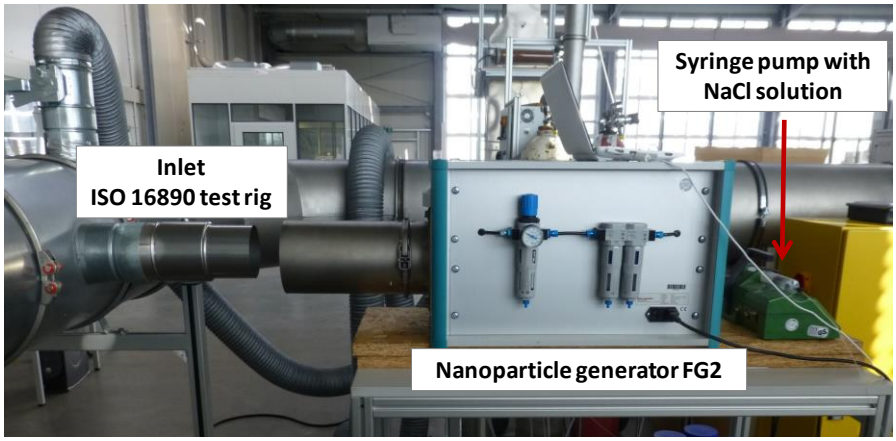

Figure 1: Experimental set up used to generate the NaCl test aerosol.

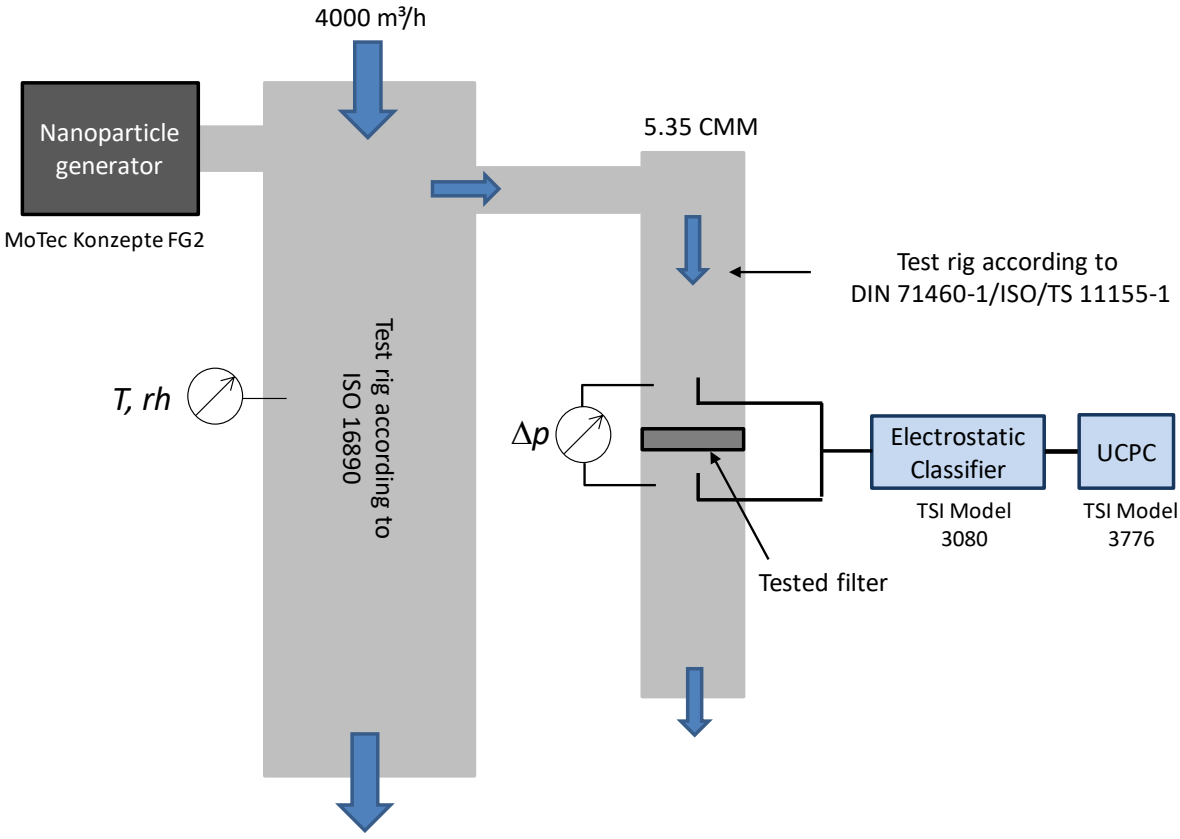

Figure 2: Schematic of the experimental set up used to determine the deposition efficiency of the tested filter for 0.003 µm NaCl particles.

Before the filter test the UCPC was zero checked with a HEPA filter (>99.97 % efficiency @ 0.3 µm). Prior to the measurement with NaCl particles, the filter was stabilized to temperature and humidity test conditions for 20 min, by flushing the filter only with dilution air. During these 20 minutes the 0.003 µm particles concentration was measured in the clean gas. This measurement would identify any leakages in the measurement system and clean gas sampling train, as expected raw gas 0.003 µm particles concentrations are < 1#/cm^3. Thus, depending on the efficiency of the tested filter, only few particles should be counted in the clean gas. During the 20 min clean gas measurement, one particle was counted by the UCPC.

6. Results

To test the filter's deposition efficiency for 0.003 µm NaCl particles, a polydisperse aerosol with a modal diameter of 3.6 nm and a geometric standard deviation of 1.3 was used (see *Figure 3*). Although the majority of the particles is larger, this distribution provided a sufficient concentration of 0.003 µm particles (see *Table 1*) to determine the deposition efficiency of the investigated filter for the abovementioned particle size.

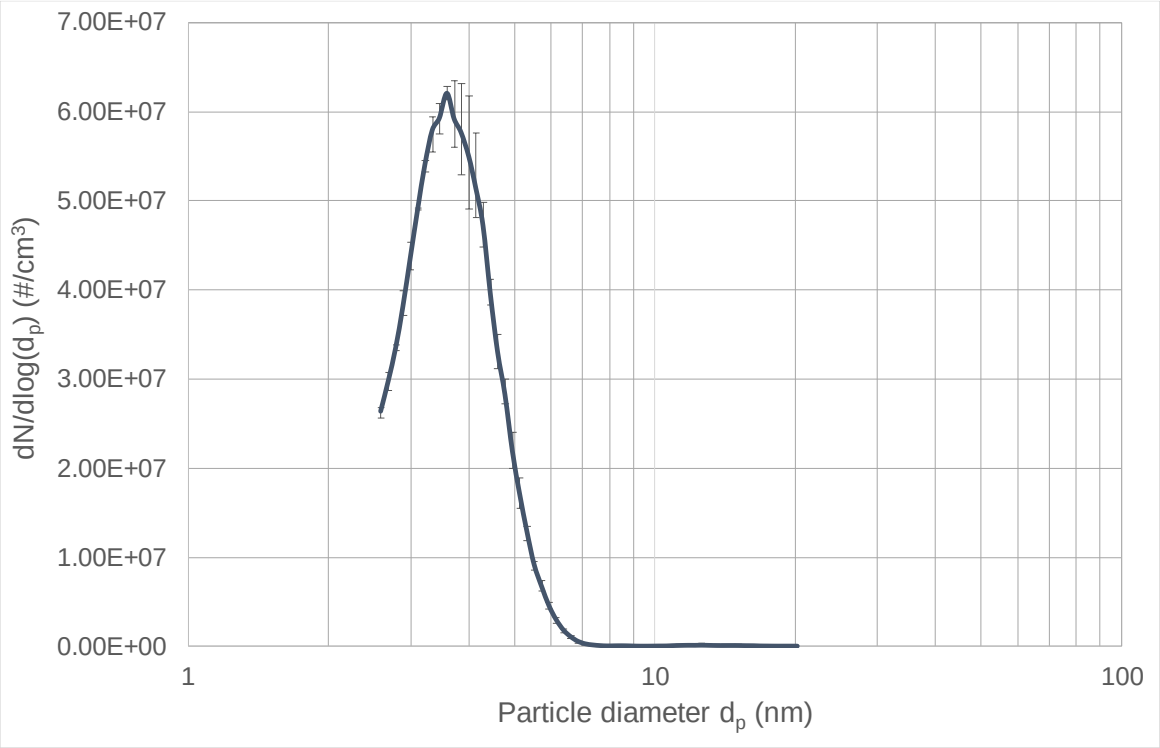

Figure 3: Particle size distribution of the NaCl test aerosol used to determine the deposition efficiency of the GJ type filter for 0.003 µm NaCl particles.

Table 1 lists the particle number concentrations in raw and clean gas and the particle counts in clean gas, respectively, of the 0.003 µm NaCl particles measured by the UCPC downstream

of the nanoDMA during the test with the GJ type filter. As the nanoDMA classifies only the monomobile positively charged particles, the concentration measured by the UCPC was divided by the charging probability of 0.003 µm particles (~ 1.1 %) to determine the total number of 0.003 µm particles present in raw and clean gas. These values, together with the deposition efficiency of the tested filter for this particle size can be found in *Table 1.*

Table 1 gives two values for the efficiency, i.e. one calculated from the measured particle counts (denominated “calculated”) and a second one taking into account the least favorable limit value of the 95 % two-sided confidence interval (denominated “minimum”) based on Poisson statistics, due to the low number of particles counted downstream of the filter. The calculation is carried out taking into account the particle counting statistics specified in DIN EN ISO 29463-2:2019-05 and is based only on pure counting data. The downstream concentration is based on the upper limit of the 95 % confidence range of the counted particles, while the upstream concentration is based on the lower limit of the 95 % confidence range of the counted particles.

The numbers of particles counted by the UCPC during each ~20 min clean gas measurement can be summed up for the tested filter and a deposition efficiency based on roughly one hour measurement can be calculated. This would correspond to 9 counts and a deposition efficiency of 99.9997 % ($E_{95\%}$ = 99.9992 %).

From *Table 1* it can be seen that the tested filter showed efficiencies >99.999 % (lower end of the 95 % confidence interval) for the 0.003 µm NaCl particles.

Table 1: Overview of the number concentration and counts of monomobile 0.003 µm NaCl particles classified by the nanoDMA and measured by the UCPC, of the total particle number in raw and clean gas and of the deposition efficiency determined for the tested GJ type filter for 0.003 µm NaCl particles.

Filter denomination customer/ Filter number IUTA	Raw gas		Clean gas				Efficiency	
	Concentration[1] (#/cm^3)*10^3	Particle number (#)*10^{13}	Time (s)	Counts UCPC[1] (#)	Concentration[1] (#/cm^3)*10^{-3}	Particle number (#)*10^7	Calculated (%)	Minimum[2] (%)
GJ M210315/010	1.13	1.09	1200	3	2.98	2.88	99.9997	99.9992
	1.15	1.11	1200	2	2.00	1.94	99.9998	99.9994
	1.11	1.08	1200	4	3.98	3.85	99.9996	99.9991

[1]The values refer only to the monomobile positively charged fraction of 0.003 µm particles behind the DMA
[2]The minimum value of the 95 % confidence interval

7. Summary

A single GJ type filter was tested with 0.003 µm NaCl particles. The filter was installed in a test rig according to DIN 71460-1/ISO/TS 11155-1. The size of the filter was adapted to the size of the test rig and the test flow rate was set in order to have the same face velocity as with a flow rate of 6.5 CMM through the whole filter.

A polydisperse aerosol with a geometric mean diameter of 3.6 nm and a geometric standard deviation of 1.3 was produced and the number of 0.003 µm particles both in raw and clean gas classified with a nanoDMA and counted with an UCPC.

The 0.003 µm NaCl particles removal efficiency of the tested filter GJ was >99.999 %.

Remark:

The test was conducted with one of the specimens of the Winix filter GJ type. According to the information provided by Winix, this filter type is installed in the Winix AUS-1250AZPU and AZPU370-HWT Air purifier models.

According to the information provided by Winix, which relies on the quality control and consistency of Winix's supply chain, each filter model mentioned in the following table corresponds to the same filter type (same fabric, geometry, size and pleating). The table also mentions the air purifier models in which the filters are installed and the corresponding maximum flow rate of the air purifier.

Filter model	Filter dimensions: length x width x height (mm^3)	Max. air-flow of product (CMM)	Filter geometry	Air purifier model
T	409 x 308 x 43	6.5	Rectangular	HR900 WINIX ZERO Pro
CAF-COS6				APEE443-HWK

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Remarks according DIN EN ISO/IEC 17025:2018 (general criteria for the operation of testing laboratories):

1. The results are only valid for the tested filter samples.
2. Extracts of this measurement report and the method description are not allowed to be forwarded to a third party without permission of IUTA.
3. Retained filter samples are stored for one year.