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ISO 21083 – new international standard for determination of nanoparticles filtration efficiency[1]

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Abstract

The new international standard ISO 21083 provides a method of testing filter media during the filtration of spherical shaped nanoparticles. The described procedure can be used to determine operating parameters of filtration materials of any classes. The filtration efficiency is determined on the basis of averaged results obtained for samples of the tested material in the initial state and after neutralization of the charge in the 2-propanol vapour. The standard does not introduce a division into filter classes, and in the final report of the tests, fractional particle retention efficiencies are given. This article discusses the problems of occupational safety and health, which are covered by health sciences and environmental engineering.

Keywords: filter media, nanoparticles, health sciences, environmental engineering.

INTRODUCTION

A large number of standards for testing air filters exist such as the most widely applied ISO 29463 *High-efficiency filters and filter media for removing particles in air* series and ISO 16890 *Air filters for general ventilation* series (in Poland PN-EN ISO 29463 and PN-EN ISO 16890 standards respectively), (*Jankowski*, *Jakubiak* 2018). The new international standard ISO 21083 aims to standardize the methods of determining the efficiencies of filter media against spherical nanoparticles. Unlike the above-mentioned standard series, ISO 21083 imposes no limitations with regard to the minimum retention efficiency or the intended use of filter media that can be subject to testing. The nanoparticle retention efficiency of a filter medium is determined based on its initial efficiency in a clean filter. The proposed procedure minimizes the impact of the mechanism of electrostatic retention of particles, which was achieved by applying charge neutralization to both the test aerosol and the filter fibres. It can be assumed that the obtained filtration efficiency results correspond to the most demanding process operating conditions of the tested media.

The selection of the right structure of the filter material for a specific application can be essential for nanoparticles retention efficiency, energy consumption and filter longevity in industrial applications such as general air ventilation systems (*Brochot et al.* 2019) and in analytics (*Sobiech et al.* 2018). This area seems to be the most important field of application of the ISO 21083 standard. The short testing procedure and the possibility of using filter media samples with a small area (instead of ready-made filters defined in ISO 29463 and ISO 16890 standards) enables designing or choosing an optimal filter structure for a specific application. It must be also noted that the obtained results of the

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retention efficiency of nanoparticles relate only to the testing setting and cannot be used to determine operating parameters of various filter media in real-life conditions.

The ISO 21083 standard consists of two parts that describe the procedures for testing filter media during the filtration of nanoparticles with different particle size ranges. The first part, whose recommendations are presented in this article, concerns the filtration of nanoparticles in the size range of 20 to 500 nm. The second part concerning the filtration of nanoparticles in the size range of 3 to 30 nm had not been published by the Polish Committee for Standardization when this article was prepared.

This article discusses the problems of occupational safety and health dealt with by health sciences and environmental engineering.

TEST SETUP

The test setup can be symbolically divided into three sections responsible for generating, conditioning and measuring the concentration of the test aerosol. The standard contains diagrams of two test setup variants, both presented in fig. 1. They differ in the place of the installation of an electrostatic classifier in the system layout. The installation of the classifier between the diffusion dryer and the charge neutralizer enables loading the tested filter with aerosols with a monodisperse particle size distribution. For testing aerosols with a polydisperse particle size distribution, the classifier is installed before the particle counter.

Recommendations regarding individual components of the test setup are presented in a subsequent part of this article.

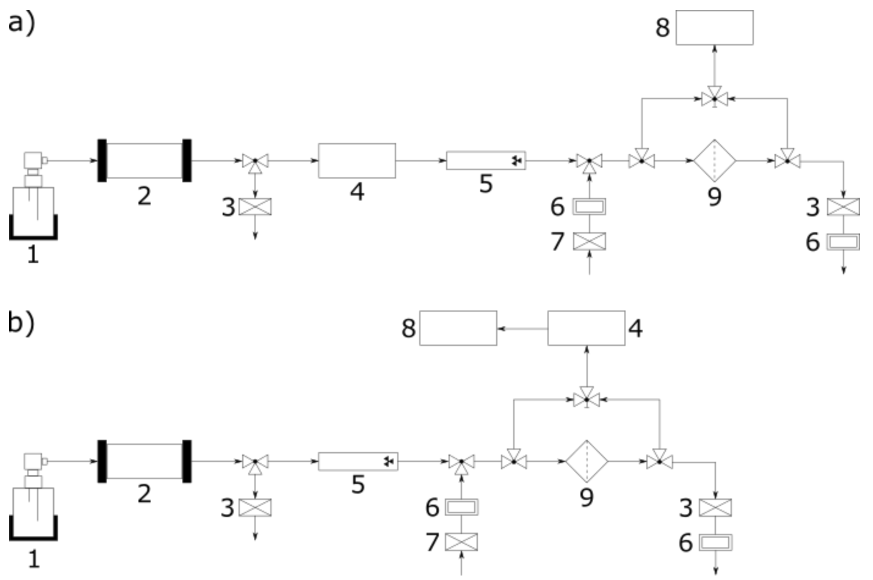

Fig. 1. Diagrams of the test setting for testing nonwoven materials during loading with monodisperse aerosol (a) and polydisperse aerosol (b) particle size distribution: 1 – aerosol generator; 2 – diffusion dryer; 3 – high-efficiency filter; 4 – electrostatic classifier; 5 – charge neutraliser; 6 – flow regulator; 7 – air conditioning unit; 8 – condensation particle counter; 9 – filter media sample holder

TEST AEROSOL

The filtration efficiency test is carried out using aerosol consisting of spherical or nearly-spherical particles. This requirement concerning the particle shape is intended to eliminate the influence of the morphology of particles on the results of particle retention efficiency measurements. To meet this requirement, using liquid atomization aerosol generators is recommended. DEHS (di-ethylhexyl sebacate) oil in a suitable organic solvent (typically 2-propanol is used to modify the surface tension of DEHS oil) or another substance allowed by the generator manufacturer's specification is recommended to generate the test aerosol. The annexes to the standard include a list of 11 generators of test aerosol compatible with the requirements of the standard, offered by leading manufacturers of equipment for testing filter media (Collison, TSI, Topas and Palas), however any other generator capable of producing droplets with a minimum concentration of over 1,000 particles per cubic centimetre in the particle size range of 20 to 500 nm can be used.

The test aerosol from the aerosol generator is conditioned in two stages. In the first stage, the organic solvent is neutralized in a diffusion dryer with a suitable absorbing bed (e.g. for 2-propanol with silica gel). In the second stage, the aerosol charge is brought to the equilibrium state corresponding to the Boltzmann distribution. It must be emphasized here that the intention is not to neutralize the charge of individual particles, but to sustain the charge of individual particles in a state of equilibrium, which results in obtaining neutralized aerosol as a collection of particles.

Aerosol concentration is also an important issue, as it must be high enough to be statistically significant, but at the same time low enough not to exceed the upper measuring range of the particle counter and not to increase the efficiency of retention and flow resistance due to the deposition of particles on the filter. At the conclusion of the test, the focus is on the measurement of the correlation ratio for the loading of the filter and its retention efficiency against the most penetrating particles. If a higher efficiency of the retention of these particles compared to a clean filter media is observed, the collected measurement data for the clean media is rejected and another test is carried out using lower concentration aerosol. In addition to operating parameters of the generator, the aerosol concentration can be controlled by removing part of the stream coming out of the diffusion dryer and diluting the neutralized aerosol with a stream of filtered air. The recommended minimum aerosol concentration is 1,000 particles per cubic centimetre in the particle size range of 20 to 500 nm.

PARTICLE COUNTER

A condensation particle counter (CPC) is used to measure the particle concentration upstream and downstream of the filter. The counter must be capable of counting particles in the size range of 20 to 500 nm, however no specific requirements have been established for measurement resolution. The counter, that must be calibrated once a year, should be also used in concentration mode.

As the flow rate of the aerosol through the counter can significantly affect the measurement results, it is then necessary to perform an air flow rate stability test upstream (before) and downstream (after) of the filter. This test is performed using a high-resistance filter medium or a perforated plate installed in a holder to produce pressure difference before and after the barrier. A higher upstream pressure will force a higher flow rate of the aerosol upstream of the filter, which should be adjusted by the counter pump controller. The difference in the flow rate values in either line should not exceed 5% in relation to the nominal flow rate of the counter and be below 2% in relation to each other.

In order to confirm the measurement accuracy of the counter, a zero test should also be carried out. It is performed using a high-efficiency filter (at least a HEPA-grade filter) installed in the aerosol feeding line to determine the number of counted particles during a one-minute scanning interval. A properly calibrated counter should detect below two particles.

Filtration efficiency can be tested using one or two counters. If one counter is used, it is important not to measure the particle concentration immediately after switching the aerosol intake line. Regardless of whether one or two counters are used, the measurement correlation ratio must be measured each time to determine the decrease in the aerosol concentration due to the deposition of particles in the ducts between the aerosol intake points to the counter, if one counter is used, or to take into account different readings from two counters sampling the same aerosol.

MEDIA SAMPLE PREPARATION

The test is carried out on samples of filter media with an active surface area of at least 100 cm^2. It should be noted that for samples with an area larger than 100 cm^2, it is necessary to test the uniformity of the test aerosol concentration inside the chamber where the filter is installed. The aerosol concentration test is carried out in the central point of the chamber and in the centres of four fields of equal area marked out on the tested filter media, at flow rates of 0.02; 0.05 and 0.1 m/s. The differences between the test aerosol concentration at each point and the average value determined for each flow rate cannot exceed 15%.

In the section on the media sample preparation method of the standard text, it is recommended that at least three samples of filter media with an active surface area of at least 0.01 m^2 each should be tested, but the total active surface area should be at least 0.06 m^2. Thus, at least six filter media samples with surface area of 0.01 m^2 (e.g., in the form of discs with a diameter of approximately 11.3 cm) should be tested. However, in the section on the analysis of test results of the standard text it is pointed out that the total number of filter media samples is dependent on the value of the minimum retention efficiency determined for the first tested sample. If this value is below 85%, it is recommended to repeat the measurements on five consecutive samples, and if the value is 85% or higher, it is recommended to repeat the test cycle on two consecutive samples.

Test procedure

The procedure for testing filter media is divided into several stages. In the first two stages the testing system is checked for air leaks and a zero count test on filtered air is carried out. Then a pressure drop across the sample at the nominal flow is determined. In the next stage, the measurement correlation ratio is determined at the nominal flow rate and the particle generator switched on, but without the sample filter medium installed in the filter medium holder. The method of determining the correlation ratio is analogous to that described in the PN-EN ISO 16890-2 standard, but the ratio is determined based on at least three measurements taken on both particulate intake lines, lasting at least one minute each. In the next stage, the same method is applied to measure the retention efficiency of media samples installed in the filter media holder.

Then the filter media charge neutralization according to the PN-EN ISO 29461-1 standard is performed. A nonwoven fabric sample is placed on an openwork base in a sealed container filled with 2-propanol to the level of 10 mm liquid column measured from the bottom. After 24 hours the sample is removed from the container, placed on an openwork base and left in a fume hood for 15 minutes to dry. Next, the sample is installed in the filter media holder and blown through by a stream of dry, clean air for 30 minutes and then used to measure its flow resistance and particle retention efficiency. If the difference in the measured values exceeds 3% for filtering efficiency and 5 Pa for flow resistance when compared to the values determined prior to neutralization, the sample must be once again blown through by a stream of dry, clean air.

Results analysis

The ISO 21083 standard does not introduce a division into filter classes depending on test results. The final report must contain fractional particle retention efficiencies presented in a table with measurement results for each of the tested filter media samples. The averaged values must be presented in another table and a graph. However, no averaged effectiveness value is determined that would be directly dependent on the shape of the distribution of the number of dust particles in each particle size range. The report must also include the results of flow resistance measurements presented in a table and a graph. Guidelines for statistical analysis of the obtained results are provided in the annexes to the standard text.

CONCLUSION

This article presents the most important recommendations regarding the method of testing filter media during filtration of nanoparticles described by the ISO 21083-1 standard. The new standard can be of great practical importance for manufacturers and users of filter media intended for filtration of nanoparticles, because it enables them to compare the performance parameters of filtering products available on the international market. The standard can also be applied in research and development activities focused on designing the optimal structure of filter media in diverse applications. It is worth noting that filter media are tested at the CIOP-PIB Aerosols, Filtration and Ventilation Laboratory in accordance with the requirements of the standard.

BIBLIOGRAPHY

Brochot C., Abdolghader P., Haghighat F., Bahloul A. (2019). Filtration of nanoparticles applied in general ventilation. Science and Technology for the Built Environment 25-2, 114–127.

Jankowski T., Jakubiak S. (2018). Parametry użytkowe filtrów powietrza w ogólnej wentylacji i klimatyzacji – nowe wymagania norm i wyniki badań własnych [Utility parameters of air filters used in general ventilation and air conditioning systems – new requirements of standards and results of own research]. Bezpieczeństwo Pracy – Nauka i Praktyka [Occupational Safety] 6, 16–21.

PN-EN ISO 16890-2:2017 Przeciwpyłowe filtry powietrza do wentylacji ogólnej - Część 2: Pomiar skuteczności filtracji w funkcji wymiaru cząstek oraz oporu przepływu powietrza [Air filters for general ventilation – Part 2: Measurement of fractional efficiency and air flow resistance].

PN-EN ISO 29461-1:2013 Systemy filtracji powietrza wlotowego do maszyn rotacyjnych – Metody badań – Część 1: Statyczne elementy filtracji [Air intake filter systems for rotary machinery – Test methods – Part 1: Static filter elements].

Sobiech P., Jakubiak S., Oberbek P., Kozikowski P., Jankowski T. (2018). Wpływ struktury i porowatości wybranych materiałów filtracyjnych stosowanych w analizie grawimetrycznej na skuteczność zatrzymywania nanocząstek [Influence of Structure and Porosity of Selected Filtration Materials Used in Gravimetric Analysis on the Retention Efficiency of Nanoparticles]. Rocznik Ochrona Środowiska [Annual Set The Environment Protection] 20, 1402–1417.

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