1 SCOPE

This Nordtest method is intended to be used in the testing of fibrous filter materials. The purpose of the test is to determine whether the efficiency of a filter material is dependent on the electrostatic removal mechanism and to provide quantitative information about the importance of the electrostatic removal mechanism.

2 FIELD OF APPLICATION

The method is primarily intended to be used in the testing of filter materials used in general ventilation filters. The method can be applied to any fibrous filter material which is known or suspected to be made of electrostatically charged fibers.

3 REFERENCES

4 DEFINITIONS

Electret filter
Electret filter (or electrostatically charged fibrous filter) is defined as a filter made of fibers which are electrostatically charged or polarised. The purpose of fiber charging or polarisation is to enhance the removal efficiency of the filter material.

Aerosol
An assembly of liquid or solid particles suspended in a gaseous medium long enough to enable observation or measurement.

Aerosol particle
A small discrete object suspended in gaseous media.

Particle size
For spherical particles the size of a particle is defined as the diameter of the spherical object. When an optical particle counter is used, the equivalent PSL (polystyrene latex particles) particle size is used. This is the particle size indicated by the particle counter calibrated with monodispersed PSL particles.

Aerodynamic particle size is an equivalent particle size defined as a diameter of a unit density sphere having the same aerodynamic properties as the particle in question. Aerodynamic particle size is used e.g. when measuring the particle size distribution with a cascade impactor.

Particle concentration
The number of particles in a specified volume of air. Particle number concentration is defined as the number of particles in a unit volume of air. Number concentration is typically used e.g. when making measurements with an optical particle counter.

Particle mass concentration is defined as the particle mass in unit volume of air. Mass concentration is normally used when measuring particle concentration with filter sample or gravimetric method.

Particle size distribution
A relationship expressing the quantity of a particle property (number or mass) associated with particles in a given size range. Optical particle size analyser is typically used to measure particle number size distribution while cascade impactor is used when particle mass size distribution is to be measured.

Filter efficiency
Filter efficiency or removal efficiency is expressed in terms of an efficiency of collection, the fraction of entering particles that are retained by the filter. Filter efficiency can be calculated by

\[ E = 100 \left( 1 - \frac{N_{\text{out}}}{N_{\text{in}}} \right) \]  

where \( N_{\text{in}} \) and \( N_{\text{out}} \) refer to the concentration of particles entering and leaving the filter.

Filtering area
Filtering area \( A \) is the area of the filter media exposed to the air stream.

Flow rate
Filter flow rate \( q_v \) is the volumetric flow through the filter.

Filter media velocity
Filter media velocity \( v_A \) is the velocity of the air at the surface of the filter media just prior to entering it. Media velocity is calculated by

\[ v_A = \frac{q_v}{A} \]  

where \( q_v \) is the volumetric flow through the filter and \( A \) is the filtering area.

Pressure drop
Pressure drop is the pressure difference across the filter caused by the filter material’s resistance to air flowing through it.

Test aerosol exposure
The mass of test aerosol entering the filter divided by the filtering area. Filter exposure \( m_A \) after \( n \) loading periods is given by

\[ m_A = v_A \left( \sum_{i=1}^{n} c_{m,i} \Delta t_i \right) \]  

where \( v_A \) is the filter media velocity and \( c_{m,i} \) is the particle mass concentration during the \( i \)th loading period and \( \Delta t_i \) is the length of the \( i \)th loading period.

5 SAMPLING

5.1 Filter samples
Minimum of five filter samples must be tested. Filter samples must be selected (e.g. by cutting) in such a way that they represent the complete filter material under test. The locations where filter samples are to be cut must be randomised.

When testing material samples from a complete bag filter unit, the samples must be taken from different filter bags and
the locations where the samples are to be cut must be randomised.

5.2 Isopropanol

Either reagent grade or technical grade isopropanol should be used in the isopropanol test.

5.3 Test aerosols

When measuring the filter efficiency with an optical particle size analyser, either DEHS (di-ethyl-hexyl-sebacate) aerosol or latex test aerosol can be used (see Eurovent 4/9). If some other test aerosol (e.g. Potassium Chloride test aerosol) is used it must be experimentally verified that it produces comparable results with the "standard test aerosols".

In the combustion aerosol test, diesel fume aerosol should be used. If another test aerosol is to be used, it must be experimentally verified that the effect of the aerosol on the performance of electret filter materials is comparable with that of diesel fume.

6 METHOD OF TEST

6.1 Principle

The principle of the test is to determine whether the efficiency of the filter material is based on the electrostatic removal mechanism and to provide quantitative information about the influence of the electrostatic effect. This is accomplished by measuring the removal efficiency of an untreated filter material and the corresponding efficiency after the effect of the electrostatic removal mechanism has been eliminated. This is illustrated in Figure 1 which shows examples of efficiency curves corresponding to an untreated filter and the corresponding efficiency after the electrostatic effect has been eliminated.

The decrease in the efficiency caused by the elimination of the electrostatic mechanism is used to quantify the importance of the electrostatic mechanism. This is accomplished by means of an index $X$ which illustrates the influence of the electrostatic removal mechanism.

The value of index $X$ is calculated by

$$X = 100 \left( 1 - \frac{E_0}{E_1} \right)$$

where $E_0$ is the efficiency of an untreated filter sample and $E_1$ is the corresponding efficiency after the effect of the electrostatic effect has been eliminated. It is worth noticing that the value of index $X$ is a function of particle size. In this test method, however, only the values measured at the particle size of 0.4 µm are used.

Two alternative test procedures can be used. The simpler one, called isopropanol test, is based on the elimination of the electrostatic removal mechanism by means of chemical treatment. In the second alternative, called combustion aerosol test, the electrostatic effect is removed by exposing the filter material to a fine diesel fume aerosol.

The isopropanol test is made by first measuring the filter efficiency of untreated filter samples. Next, the filter samples are immersed into isopropanol (100 % solution). After filter samples have been wetted by the isopropanol they are placed on a flat inert surface in a fume cupboard for drying. After the drying period of 24 hours the filter efficiency measurements are repeated.

The combustion aerosol test is made by first measuring the filter efficiencies of clean filter samples. Next, the filter samples are exposed to the diesel fume aerosol in such a way that the amount of test aerosol fed to each filter sample is 5 g/m². This is followed by the filter efficiency measurements. Filter loading and efficiency measurement procedure is repeated until the minimum of the efficiency is reached. Then, the minimum efficiency values are used to calculate the index $X$.

6.2 Apparatus

The test system consists of the following parts:
- test rig for filter efficiency measurements
- filter material test equipment
- equipment for isopropanol treatment
- equipment for controlled aerosol exposure.

Figure 2 illustrates the principle of the filter efficiency measurement system. The purpose of this system is to provide controlled conditions (flow rates, aerosol concentration) for the filter efficiency measurement. Thus, the filter efficiency systems based on Eurovent 4/9 are suited ideally for the measurements. The system shown in Figure 2 consists of a supply of HEPA filtered air, test aerosol generator, mixing chamber, test duct, filter material test equipment and an optical particle size analyser. The system also includes fans, flow measurement devices and control instruments which are not shown.

Figure 1. Efficiency vs. particle size. Efficiency values before and after the effect of the electrostatic removal mechanism has been eliminated.
Filter material test equipment

The principle of the filter material test equipment is shown in Figure 3. This system consists of a test tube, a flow meter, a flow control valve, a (downstream) sampling tube and a manometer. The filter sample to be tested is fixed to the test tube by means of a flange. The test tube also includes a mixing section which guarantees a representative sampling downstream the filter. Sampling tube is connected to the downstream sampling line of the particle size analyser. The manometer is used to measure the pressure drop across the filter sample.

Equipment for isopropanol treatment

The isopropanol treatment is made using the system shown in Figure 4. This system includes a vessel for the technical grade isopropanol. The system also includes flat surfaces on which filter samples are placed for drying. The drying of the filter samples should take place in a laboratory fume cupboard.

Equipment for controlled aerosol exposure

Filter loading with the diesel fume aerosol is made using the system shown in Figure 5. This system consists of a test chamber, the filter material test equipment, diesel engine and equipment for the measurement of the particle mass concentration and size distribution. A convenient alternative is to use the same test duct part as is used in the efficiency measurement system. The system also includes a duct which is used to draw a fraction of the exhaust gas from the diesel engine to the test chamber.

The concentration of the combustion aerosol in the test chamber is measured using a standard gravimetric method. Aerosol is sampled into a membrane filter and the aerosol mass collected from the known volume of air is determined gravimetrically. The particle mass concentration is then calculated as the ratio of aerosol mass to the volume of the sampled air.

The mass size distribution of the test aerosol is measured using a cascade impactor. Diesel fume aerosol consists of very small particles which makes it necessary to use a cascade impactor which is capable of classifying particles in the fine particle size range (down to 0.05 µm). The size distribution of the diesel fume aerosol is assumed to be relatively stable. Thus, it is not necessary to measure the size distribution during each loading period.
6.3 Preparation of Test Samples

Filter samples are cut from the material to be tested. The diameter of the effective filter area should be ≥150 mm. At least five filter samples should be cut from randomised locations of the filter material to be tested.

6.4 Procedure

Measurement of the filter efficiency

The test is started by placing a filter sample in the test equipment. The volumetric flow rate through the filter sample is adjusted to the desired value. When material samples cut from complete bag filter units are tested, the flow velocity is adjusted to the nominal media velocity. The filter pressure drop is measured with a micromanometer.

The concentration of the polydisperse test aerosol generated with an aerosol nebuliser is adjusted to a level which is within the measurement range of the optical particle counter. Test aerosol must be neutralised with an aerosol neutraliser. When latex aerosol or Potassium Chloride aerosol is used, care must be taken to ensure a complete drying of particles before they enter the aerosol neutraliser.

The filter efficiency for 0.4 μm particles is determined by measuring the particle concentrations from upstream and downstream of the filter sample. The efficiency measurement and the data analysis are made according to the instructions presented in Eurovent 4/9.

Isopropanol test

The isopropanol test is made as follows:
- initial efficiency and pressure drop values of the filter samples are measured
- filter samples are immersed into technical grade isopropanol
- filter samples are placed on a flat inert surface for drying (this should take place in a laboratory fume cupboard)
- after drying period of 24 hours the efficiency and pressure drop measurements are repeated
- the measured efficiency values are used to calculate the values of index X for each filter sample (particle size, 0.4 μm)
- the mean value of the index X is calculated by

\[
X_{ave} = \frac{1}{n} \sum_{i=1}^{n} X_i
\]  

(5)

where \( X_i \) refers to the values of index X measured with individual filter samples
- the standard deviation \( \sigma_x \) of the index X is given by

\[
\sigma_x = \frac{1}{n} \left[ \sum_{i=1}^{n} (X_i - X_{ave})^2 \right]^{1/2}
\]  

(6)

- the uncertainty \( \Delta X \) is expressed as

\[
\Delta X = k_n \frac{\sigma_x}{\sqrt{n}}
\]  

(7)

where the coefficient \( k_n \) depends on the number \( n \) of filter samples and the confidence level (at 95 % confidence the following values can be used: \( k_2 = 2.13, k_5 = 2.02, k_7 = 1.94, k_9 = 1.90, k_{10} = 1.86, k_{15} = 1.83 \))
- the final result is expressed in the form

\[
X = X_{ave} \pm \Delta X
\]  

(8)

Combustion aerosol test

The principle of the combustion aerosol test resembles the isopropanol test. However, instead of isopropanol treatment, filter samples are exposed to controlled amounts of diesel fume. The test procedure includes the following steps:
- initial efficiency and pressure drop of the filter samples are measured
- filter samples are exposed to diesel fume aerosol in three successive loading tests (filter exposure in each test \( m_A = 5 \text{ g/m}^2 \))
- the efficiencies and the pressure drops are measured after each loading test
- if the efficiency value after the third loading test (\( m_A = 15 \text{ g/m}^2 \)) is lower than the corresponding value after the second test (\( m_A = 10 \text{ g/m}^2 \)) the filter exposure and measurement procedure is repeated until an increase in the efficiency is observed
- the minimum efficiency values are used to calculate the values of index X for 0.4 μm particles
- the data analysis is performed as described in the isopropanol test.

6.5 Expression of Results

Isopropanol test

The following test results should be given:
- filter media velocity of the filter samples
- efficiency of each untreated filter sample (particle size, 0.4 μm)
- efficiency of each filter sample after the isopropanol treatment (0.4 μm particle size)
- the value of index X for 0.4 μm particles
- mean pressure drop of the untreated and treated filter samples.

Combustion aerosol test

The following test results should be given:
- filter media velocity of the filter samples
- efficiencies of the clean filter samples (particle size 0.4 μm)
- particle mass concentration and the corresponding filter exposure \( m_A \) after each loading test
- efficiencies of the filter samples after each loading period (0.4 μm particle)
- the value of index X for 0.4 μm particles
- mean pressure drop of the clean filter samples as well as the corresponding pressure values after each loading test.
6.6 **Accuracy**
According to Eurovent 4/9

6.7 **Test Report**
The test report should include the following information:

a) Name and address of the testing laboratory
b) Identification number of the test report
c) Name and address of the organisation or the person who ordered the test
d) Purpose of the test
e) Method of sampling and other circumstances (date and person responsible for the sampling)
f) Name and address of manufacturer or supplier of the tested object
g) Name or other identification marks of the tested object
h) Description of the tested object
i) Date of supply of the tested object
j) Date of the test
k) Test method
l) Conditioning of the test specimens, environmental data during the test (temperature, pressure, RH, etc.)
m) Identification of the test equipment and instruments used
n) Any deviation from the test method
o) Test results
p) Inaccuracy or uncertainty of the test result
q) Date and signature.