EUROVENT

EUROVENT GUIDEBOOK

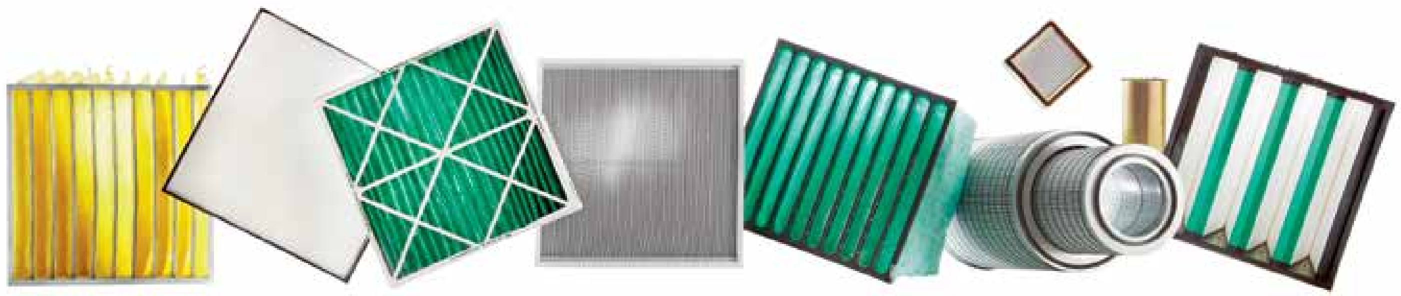
AIR FILTERS FOR GENERAL VENTILATION

#IAQmatters

PRODUCT GROUP 'AIR FILTERS'

MARCH 2017

CONTENTS



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1. INTRODUCTION

Air filters play an essential role in all kinds of indoor climate areas. Not only are they essential for a good and healthy indoor climate, but they can also have a strong impact on the energy performance of buildings as well as air handling equipment. The use of ineffective air filters or a lack of filter maintenance and replacements can even nullify the efficiency gains of the entire product in which filters are incorporated.

While the above-mentioned might be common knowledge among air filter manufacturers, this is not the case with many of their customers, end users, and (especially) legislators. While for the latter the primary focus lies mostly with the products (e.g. an Air Handling Unit), the essential components of this product are often of secondary importance and tend to receive limited attention.

This Eurovent Guidebook aims to fill this gap and raise awareness on the importance of air filters in general, air pollution and its impact on health, and the correct filter application in equipment.

PURPOSE OF THIS GUIDEBOOK

The main objective of this document and its various authors is to brief air handling equipment manufacturers and end users on correct air filtration. Within this Guidebook, attention will be given to:

- Importance of filtration,
- Benefits of using air filters,
- Fundamentals of air filtration,
- Standards in place,
- Correct filter design,
- Energy efficiency of air filters,
- Key applications for air filters,
- Correct assembling, maintenance and disposal of used filters.

2. WHY AIR FILTERS?

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2.1 THE IMPORTANCE OF AIR FILTRATION

Controlled air quality is crucial in many processes today. Besides many technical applications, building ventilation is a key area. Here, air filters ensure healthy indoor air by removing harmful fine dust including pollen, bacteria, yeast and moulds along with other organic and inorganic material. Air filters also serve to keep the air handling equipment itself clean. By doing so, they ensure its hygienic and efficient operation.

Air purity requirements are continuously increasing. This is due to increasingly sophisticated and sensitive industrial processes, stricter environmental legislation and rising comfort and health conscious attitudes. At the same time, the need to reduce energy consumption and carbon dioxide emissions is increasing, along with the pressure on costs. Thus, buildings are more and more restricted from natural ventilation. Energy-efficient mechanical air handling and, in particular, air filtration solutions, are more in demand than ever.

2.2 THE COMPOSITION OF AIR

Air is defined as the gas mixture of the earth's atmosphere. The exact composition of gaseous, solid and liquid components (particles) dispersed in the air varies greatly depending on time and location. Dry, particle-free air is mainly composed of two gases: nitrogen (around 78%) and oxygen (around 21%). There are also traces of argon, carbon dioxide and other gases, as well as varying amounts of water vapour, which is typically in the range of several grams per cubic meter of air.

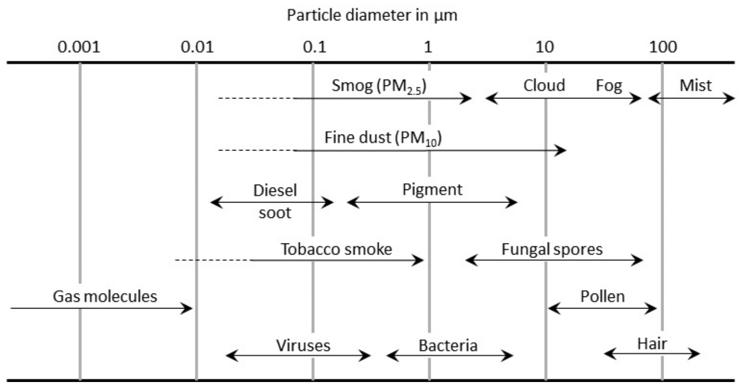

Figure 1: General guide to particle size distribution of common atmospheric contaminants

Figure 1 compares different types of air contamination with the respective particle size ranges. The scale shows that the various contaminants cover a size range of several orders of magnitude. This is a major reason why so many different filters are used in a wide variety of classes and designs.

The common technical classification of fine dust fractions is also based on the classification of particle sizes according to the areas they are deposited in the human respiratory system. The classes are PM10 (particles with an aerodynamic diameter of ‹ 10 µm), PM2.5 (‹ 2.5 µm) and PM1 (‹ 1 µm).

PM stands for particulate matter. There has been a recent addition to the established particle size classes: particle fractions with a diameter of ‹ 100 nm. Particles of this size are referred to as ultrafine particles (UFP) or nanoparticles.

The mechanisms for the separation of particles and gaseous contaminants from the air are fundamentally different. Particles are separated by mechanical or electromechanical effects whereas gases are generally separated by adsorption or absorption.

3. BENEFITS FROM USING AIR FILTERS

The aim of using air filters is to protect people's health by maintaining a good hygiene level in the ventilation system and clean indoor air quality (IAQ). It is commonly known that air pollution is unhealthy, but it is not so well known that the smallest particles are the most dangerous. The aspects could be different depending on the outdoor air quality and the indoor activities.

The urban air quality is nowadays polluted by small PM_1 particles and gases coming from combustion and diesel engines (Figure 1), which city centres are crowded with. Additionally, for hygiene reasons, bacterial and fungal spores must be removed from the air stream, which are typically in a size range between 1 and 10 µm (see Figure 1). Therefore, for the human health and indoor hygiene, it is important to clean the inlet air with sufficient air filters.

The most common air filters in comfort ventilation are ePM_1, $ePM_{2,5}$ and ePM_{10}. ePM_1 is recommended in buildings such as schools, hospitals, office buildings, apartments and residential facilities.

4. FUNDAMENTALS OF AIR FILTRATION

4.1 PARTICLE SEPARATION

The most common method of separating particles from gas streams in HVAC systems and in industrial applications is through fibre filters. Other processes for particle separation such as cyclones, scrubbers or electrostatic precipitators are generally more complex and are therefore only used in specific industrial areas. The following section examines fibre filtration in detail.

The efficiency of a filter for separating particles is usually described using separation efficiency, also referred to as fractional efficiency. This is defined as the ratio of the number of particles of a particular size that have been deposited in the filter to the total number of particles of this size upstream of the filter. Filter efficiency can be defined both in terms of quantity and mass (the mass of arrested dust in relation to the total dust mass fed to the filter is named gravimetric arrestance). When specifying filter performance, it is therefore important to always be sure about the particle size on which the data is based and whether it is defined in terms of quantity or mass. Values can only be compared that have been measured according to the same standard. This is because different standards are usually based on different measurement methods and are therefore not directly comparable.

Typically, in building ventilation and HVAC applications, fibre filter media is used, where the average pore size is significantly larger than the size of particle to be arrested. Particles can enter the filter medium and could pass through it, if they could follow the air streamlines perfectly. Since this is not the case, there is a certain probability that on their way through the filter media, particles will hit a fibre, where they will be deposited and remain.

Figures 2a to 2d show the mechanisms that lead to a particle hitting a fibre. The mechanisms are: **a) Interception, b) Inertia, c) Diffusion and d) Electrostatics**

INTERCEPTION: This principle means that the path on which a particle's center of gravity moves passes the fiber at a distance of less than half the particle diameter. The particle therefore hits the fibre and is deposited there. The probability of a particle hitting a fibre due to interception increases with the particle size. Interception dominates arrestance for particles with diameters between 0.5 and 1 µm.

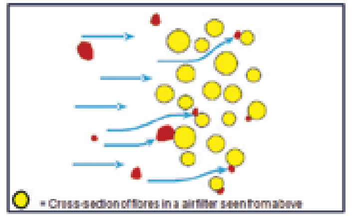

Figure 2a: Transport mechanisms in particle separation on fibres – Interception

INERTIA: Due to inertia forces, particles cannot fully follow the air streamlines that flows around a fibre. Instead, they hit the fibres at a certain proximity on a less curved path. The importance of inertia for particle collection increases with increasing particle mass (i.e. particle diameter) and increasing particle velocity. In the case of the typical air velocity in air filtration, the inertia effect becomes dominant from a particle diameter of › 1 µm.

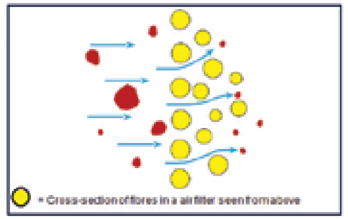

Figure 2b: Transport mechanisms in particle separation on fibres – Inertia effect

DIFFUSION: Due to the irregular thermal movement known as Brownian motion, the particles oscillate. This means that some very small particles that would otherwise pass a fibre hit them and are deposited there. Diffusion-based particle collection increases with decreasing particle size and decreasing air velocity. Assuming there is no predominant electrostatic interaction, nanoparticles (i.e. particles with a diameter of ‹ 100 nm) are deposited almost exclusively by diffusion.

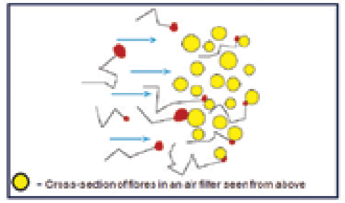

Figure 2c: Transport mechanisms in particle separation on fibres – Diffusion

ELECTROSTATICS: Electrostatic interaction causes particles to be attracted to the fibres. If the particles and fibres have opposite electrostatic charges, they will attract each other. However, if only the fibre or particle is electrostatically charged, it is also sufficient to polarize the respective counterpart to generate a force of attraction.

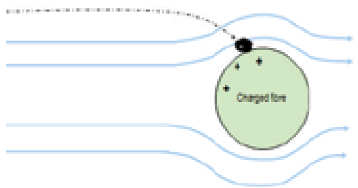

Figure 2d: Transport mechanisms in particle separation on fibres – Electrostatics

Electrostatic interaction-based particle collection decreases with increasing air velocity. In industrial air filtration, this effect is used in electret media, in which the fibres are selectively electrostatically charged in the production process. Because electrostatic fields increase the filtration efficiency of filter media without increasing flow resistance, and hence pressure drop, such filter media are particularly energy-efficient. However, there is a possibility that under certain conditions (e.g. very high humidity or a very high proportion of submicron particles in the air to be filtered) the electrostatic charge could be reduced during the filtration operation. This could ultimately lead to a decrease in the filtration efficiency of the filter.

It is therefore necessary to ensure a certain minimum filtration efficiency, based purely on mechanical particle collection mechanisms and which remains effective even after complete removal of all electrostatic charges. It is important to find an optimum balance between energy-efficient electrostatic particle collection and purely mechanical collection. In practice, however, any loss of filtration efficiency caused by the reduction of the charge can be at least partly compensated by the increase in filtration efficiency associated with the higher dust loading of the filter.

4. FUNDAMENTALS OF AIR FILTRATION

The phenomena of increased filter efficiency due to the electrostatic charge is illustrated in Figure 3.

Curve 1 shows the efficiency of the filter not depending on the electrostatic charge, whereas the Curve 2 corresponds to the filter with a charge decreasing after short period of time.

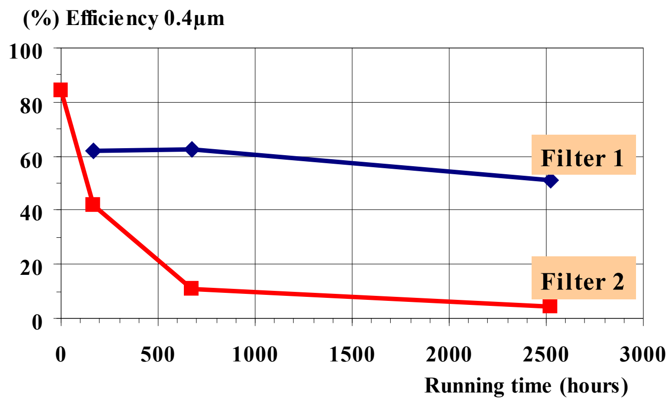

Figure 3: Increase of efficiency due to electrostatic charge

In practice, the particle collection mechanisms described above all occur simultaneously and superpose accordingly. This results in total in a dependency for the fractional efficiency as a function of particle size as shown in Figure 4. The curve with a distinct minimum in the particle size range between 0.1 and 0.5 µm is typical of depth-loading filtration with fibre filter media. Smaller particles can be arrested very efficiently due to diffusion. For larger particles, high levels of particle collection are achieved due to inertia and interception. The particle size with the lowest arrestance and the greatest penetration is usually referred to by the abbreviation MPPS (Most Penetrating Particle Size). With increasing air velocity, minimum fractional efficiency is decreased and shifts toward smaller particles.

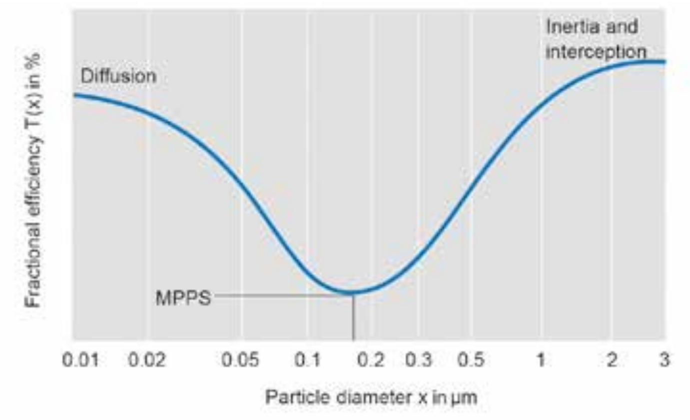

Figure 4: Transport mechanisms in particle separation on fibres

4.2 REMOVAL OF GASEOUS CONTAMINANTS

In addition to particles, a wide variety of types and concentrations of contaminant gases can be found in the air.

4.2.1 ADSORPTION AND ABSORPTION

Technically speaking, these are largely removed from the air by sorption, i.e. adsorption or absorption. Adsorption refers to the accumulation of substances from the gas phase (adsorbate) on the surface of a solid (adsorbent). This is different from absorption, in which substances penetrate the interior of a solid or a liquid and dissolve therein.

Adsorption is generally a physical process, in which atoms or molecules attach themselves to the surface of a solid via van der Waals forces. In this case, we talk of physisorption. The strength of this adhesive force depends on the material combination.

The rate of sorption (i.e. the quantity of contaminant gas deposited or released per time unit) depends on temperature, contaminant gas concentration, rate of diffusion from the gas phase to or away from the surface of the adsorbent.

4.2.2 COMMON ABSORBENTS

The most commonly used adsorbent in technical applications is activated carbon, which usually adsorbs a large, very non-specific number of different gases, such as aliphatic or cyclic hydrocarbons (VOC) and alcohols. For this reason, it is often used to arrest odors in industrial air handling and building HVAC systems. In practical use, the high affinity of water vapour (humidity) to activated carbon is problematic as, in the case of pure physisorption, water can displace (desorb) many other substances and decrease the adsorption efficiency of the activated carbon.

5. STANDARDS

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5.1 FILTRATION PERFORMANCE

At the present time, there are two valid European standards defining the filtration performance of filters for general ventilation - the well known EN 779:2012 and the new global standard EN ISO 16890:2016. The coexistence period for both standards is expected to end in 2018 and afterwards EN 779:2012 will become obsolete.

Both standards deal with the evaluation of the filtration effect of coarse and fine dust filters used in general ventilation. Yet, in EN 779:2012, the efficiency classification for medium and fine filters is based on 0,4 µm particles, while the new EN ISO 16890 defines the efficiency for various fractions of particle size: PM10, PM2.5 and PM1.

Although the methods of measurement and testing rigs for both standards are similar, some important differences are indicated in Table 1.

<table>
<tr><th>EN 779:2012</th><th>EN ISO 16890:2016</th></tr>
<tr><td>0,4 µm particle by classification of fine filters</td><td>Particulate matter efficiency (ePM)

ePM$_x$ – mass concentration of particles with an optical diameter of > 0,3 µm and x µm

<table>
<tr><th>Efficiency</th><th>Size range, µm</th></tr>
<tr><td>ePM$_{10}$</td><td>$0{,}3 \leq x \leq 10$</td></tr>
<tr><td>ePM$_{2.5}$</td><td>$0{,}3 \leq x \leq 2.5$</td></tr>
<tr><td>ePM$_1$</td><td>$0{,}3 \leq x \leq 1$</td></tr>
</table></td></tr>
<tr><td>Dust feeding and particle efficiency measure – in steps up to 450 Pa final pressure drop - average efficiency</td><td>Average efficiency = Mean value of initial eff and conditioned efficiency

Final pressure drop: 200 Pa (Coarse) 300 Pa (PM$_x$)</td></tr>
<tr><td>Conditioning (discharging) of a piece of media (F7 – F9) in Isopropanol liquid</td><td>Conditioning (discharching) of a complete filter in IPA vapour chamber</td></tr>
<tr><td>Test dust: ASHRAE</td><td>Test dust: ISO A2 / AC Fine</td></tr>
</table>

Table 1. Main differences in test method between EN 779:2012 and EN ISO 16890:2016

EN 779:2012 STANDARD

The quality of any filter essentially depends on the percentage of dust transported through the filter that is actually collected.

For coarse filters, the filter effect is evaluated by measuring the initial gravimetric arrestance when challenging the filter with synthetic test dust using ASHRAE-test dust.

For fine filters, the filter effect is evaluated by measuring the efficiency against 0.4 micron DEHS droplets.

The classification of classes defined in EN779:2012 is shown in Table 2.

Filter Type	EN 779 Class	Average Arrestance (Am) (%)	Average Efficiency (Em), 0,4 µm (%)	Final Test Pressure Drop (Pa)	Minimum Efficiency 0,4 µm (%)
Coarse filter	G1	$50 \leq Am < 65$	-	250	-
	G2	$65 \leq Am < 80$	-	250	-
	G3	$80 \leq Am < 90$	-	250	-
	G4	$90 \leq Am$	-	250	-
Medium filter	M5		$40 \leq Em < 60$	450	-
	M6		$60 \leq Em < 80$	450	-
Fine filter	F7	-	$80 \leq Em < 90$	450	35
	F8	-	$90 \leq Em < 95$	450	55
	F9	-	$95 \leq Em$	450	70

Table 2: Filters classification according to EN 779:2012

EN ISO 16890:2016 STANDARD

Similar to EN779:2012, the EN ISO 16890:2016 testing method of filters also considers the percentage of dust collected in a filter in order to classify the filter. Yet, this method no longer considers one particle size diameter, but reflects the overall dust classification system recommended by the World Health Organization (WHO).

For coarse filters, the filter effect is evaluated by measuring the initial gravimetric arrestance when challenging the filter with synthetic test dust using AC-fine test dust.

For fine filters, the fractional efficiency is measured in the range of 0.3 to 10-micron particle diameter. This measurement is performed on a new filter and on the same filter after discharging. These measured fractional efficiencies are used to calculate the average efficiency against typical aerosol distributions.

The initial gravimetric arrestance and the three efficiency values *e*PM1, *e*PM2,5 and *e*PM10 as well as the minimum efficiency values *e*PM1, min and *e*PM2,5, min are used to classify a filter in one of the four groups given in Table 3.

Group desig-nation	Requirement			Class reporting value
	ePM$_{1,min}$	ePM$_{2,5,min}$	ePM$_{10}$	
ISO Coarse	-	-	50%	Intial grav. arrestance
ISO ePM10	-	-	50%	ePM$_{10}$
ISO ePM2,5	-	50%	-	ePM$_{2,5}$
ISO ePM1	50%	-	-	ePM$_1$

Table 3: Group designation and min. requirements for filter classification

5. STANDARDS

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Filters with initial efficiency and discharged efficiency below 50% automatically drop to the inferior group. Fine filter efficiencies are reported in steps of 5%.

The filter classification according to EN ISO 16890 is shown in Table 4.

PM1 classification	PM2,5 classification	PM10 classification	Coarse
ePM1[95%]	ePM2.5[95%]	ePM10[95%]	Arrestance reported in full 5%
ePM1[90%]	ePM2.5[90%]	ePM10[90%]	
ePM1[85%]	ePM2.5[85%]	ePM10[85%]	
ePM1[80%]	ePM2.5[80%]	ePM10[80%]	
ePM1[75%]	ePM2.5[75%]	ePM10[75%]	
ePM1[70%]	ePM2.5[70%]	ePM10[70%]	
ePM1[65%]	ePM2.5[65%]	ePM10[65%]	
ePM1[60%]	ePM2.5[60%]	ePM10[60%]	
ePM1[55%]	ePM2.5[55%]	ePM10[55%]	
ePM1[50%]	ePM2.5[50%]	ePM10[50%]	
Requirement > 50% initial eff > 50% discharged eff	**Requirement** > 50% initial eff > 50% discharged eff	**Requirement** > 50% initial eff No minimum discharge efficiency	**No discharge requirement**

Table 4: The filter classification according to EN ISO 16890-1:2016

5.2 RECOMMENDATIONS ON FILTER CLASS SELECTION

The new EN 16798-3:2017 standard, which supersedes the globally known EN 13779, recommends minimum combined filtration efficiency depending on required supply air class and outdoor air quality classified for particle pollutants (P). However, it must be stated that the efficiency is still defined according to EN 779 standard. This has been summarised in Table 5 below:

Outdoor air quality	Supply air class				
	SUP1 (Highest)	SUP2	SUP3	SUP4	SUP5 (lowest)
ODA (P) 1	88%	80%	80%	80%	Not specified
ODA (P) 2	96%	88%	80%	80%	60%
ODA (P) 3	99%	96%	92%	80%	80%

Table 5: Recommended minimum combined efficiency depending on supply air class and outdoor air quality acc. to EN16798-3:2017

The combined filtration efficiency is calculated according to following formula:

$$E_t = 100 \cdot \left(1 - \left(\left(1 - \frac{E_{s1}}{100}\right) \cdot \left(1 - \frac{E_{s2}}{100}\right) \cdot \ldots \cdot \left(1 - \frac{E_{sn+1}}{100}\right)\right)\right)$$

Where:
E_t is the total filtration efficiency
E_{sn+1} is the efficiency of each filter step

The minimum combined efficiencies refer to the following filter classes (acc. to EN 779:2012) showed in Annex B of the EN 16798-3:2017 standard with default design data:

Outdoor air quality	Supply air class				
	SUP1 (Highest)	SUP2	SUP3	SUP4	SUP5 (lowest)
ODA 1	M5 + F7	F7	F7	F7	-
ODA 2	F7 + F7	M5 + F7	F7	F7	G3,M5
ODA 3	F7 + F9	F7 + F7	M6 + F7	F7	F7

Table 6: Recommended minimum filter classes per filter selection depending on supply air class and outdoor air quality acc. to EN16798-3:2017

Since the new EN 16798-3:2017 standard refers to EN 779, it gives no recommendation for filter selection classified according to EN ISO 16890-1. At the time of publication of this document, some recommendations on how to convert the new classification to the old ones can be found in the upcoming revisions of VDI 3803-4 and SWKI VA 101-01 guidelines. These are summarised in Table 7.

Filter class		Remarks
EN 779:2012	EN ISO 16890-1:2016	
M5	ePM10 ≥ 50	
F7	ePM2.5 ≥ 65	If not the last filter stage
F7	ePM1 ≥ 50	If the last filter stage
F9	ePM1 ≥ 80	

Table 7 – Filter class replacement acc. to VDI 3803-4 and SWKI VA 101-01

6. FILTER DESIGN

6.1 FILTER DESIGN

A good filter in an air handling unit creates a clean and healthy environment. At the same time, it keeps the air handling unit and its important components free from contamination so the heat exchanging equipment in the unit can maintain its efficiency over time.

When considering general ventilation systems, the most important factor for the end user is the filter performance. This includes filtration efficiency, designed air flow rate, initial and average pressure drop – affecting directly energy consumption, expected service life, and in some cases resistance to temperature.

Other important issues are related to recycling and environmental protection

Looking at the basics of today's most common air filters, three major contributors to the performance of air filters can be determined:

- Filter media, characteristic and m² inside a filter, required filter class and dust holding capacity.
- Filter construction, flow pattern through the filter.
- Cell side material.

6.2 FILTER MEDIA

Filter media can be selected for many filter classes. In general, the amount of fibres and size of the fibre determine the efficiency. The higher the efficiency, the higher the pressure drop.

For filters that require a high dust holding capacity, a media surface needs to be created that can hold the dust while maintaining the possibility for air to move through the media and filter. These filters are often the pocket filters as installed in air handling units.

If less dust holding capacity is required (often the second stage filters in an air handling unit), so called compact filters are normally used. This media is different from the pocket filter media and has lower dirt holding capacity.

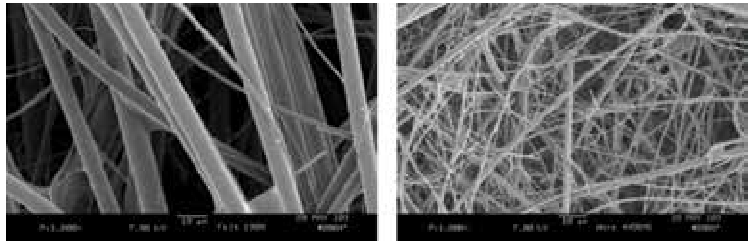

Figure 5: Fibres in a filter media

6.3 FILTER CONSTRUCTION

The shape and the construction details of the filter have essential influence on the pressure drop.

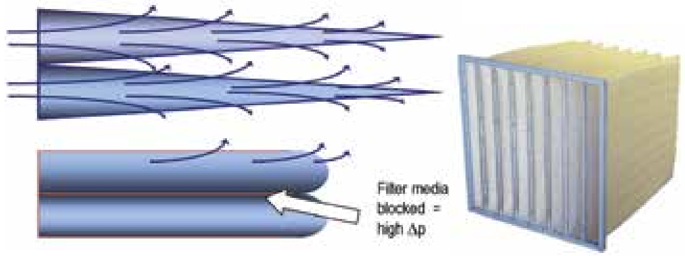

Figure 6: Schematic air flow in correctly designed and poor quality bag filter

To reduce the pressure drop over the filter, it is important that the design of the filter is such that the air velocity through the media is as equal as possible. The characteristics of the media, the media amount, thickness and shape determine the performance of the filter. The same theory is applicable for the pleat shape of a compact filter. The influence on the pressure drop is significant and an incorrect pleat shape will increase the resistance.

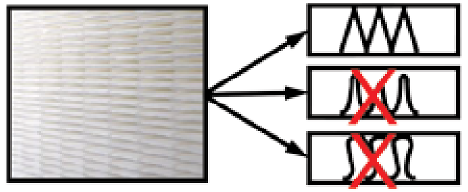

Figure 7: Correct and incorrect pleat shape configuration

As for the pocket filters, the air flow velocity should be even over the complete media surface. This is required to have the lowest resistance possible on the selected media. Looking at the velocity through a V-shape mini pleat filter, the face velocity is the incoming velocity on a filter. This velocity changes through the filter.

Figure 8: V-shape mini pleat filter

For example, a V-shape mini pleat filter as pictured in Figure 8 has a media surface of 19 m². An M7 media has a resistance of 12 Pa while the total filter has a resistance of 75 Pa @ 0.94 m³/s. 10% resistance reduction of the media will have a minor influence on the resistance of the total filter. For these type of filters, the configuration and shape of the filters play an important role on the performance.

For filter cell sides, most common materials used are:

- Plastic,
- Metal (galvanised steel, stainless steel),
- Wood (MDF – particle board, Ply wood, beech wood).

The wooden cell sides are often selected out of environmental reasoning (low CO_2 foot print, renewable source) or for filters that need to be fully incinerable.

Plastic cell sides have, especially when casted, a lot of freedom in geometry. This enables the designer to fully optimise the geometry with the selected filter media.

Metal is often used for filters that are installed in higher temperature application. A metal filter is very robust. Stainless steel is often selected when installed in a corrosive environment or when cleaning or shedding might be of concern.

7. ENERGY EFFICIENCY OF FILTERS

When placing filters into an airstream, the filters will cause a flow resistance. This resistance can be measured as a pressure drop between the inlet and outlet side of the filter. Pressure drop therefore defines the energy demand for the specific filter, because the fan that provides the airflow must supply the required pressure.

The described pressure drop is on its minimum when the filter is clean and used for the first time. As soon as dust is in the air and eliminated by the filter, this pressure drop increases. Hence, also the energy demand for the use of the filter increases. The more dust is in the filter, the higher the pressure drop, the higher the energy demand, and finally the higher the power consumption of the fan.

Beside a low initial pressure drop, an energy efficient filter has the property that its pressure increase, in case of dust in the filter, is low. That extends the efficient lifetime and reduces the operational costs. The dust loading capacity and the related increase of the pressure drop depends significantly on the filter area.

The procedure for energy efficiency evaluation for filters classified according to EN 779 is defined in Recommendation Eurovent 4/21-2014, whereas for filters classified according to EN ISO 16890 in the second edition of this document, Eurovent 4/21–2016. Both documents can be downloaded at www.eurovent.eu.

An indication of the efficiency and energy consumption of a filter is the Eurovent Energy Efficiency Class. Depending on the average pressure drop and the filter class, filters are rated from A+ to E – a so far unique approach that sets global benchmarks in the air filtration area.

Only participants of the 'Eurovent Certified Performance' programme for Air Filters can use the Eurovent Energy Efficiency class. The list of certified manufacturers, their filters and the related technical information is publically available and can be found on the 'Eurovent Certified Performance' website www.eurovent-certification.com.

8. KEY APPLICATIONS FOR AIR FILTERS

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There are plenty of air filtration solutions for a wide range of industries. The key applications of air filters covered in this guidebook are described in the following.

8.1 COMFORT (GENERAL HVAC)

HVAC stands for Heating, Ventilation and Air Conditioning. These are some concepts designed to improve our comfort of living. The indoor air temperature can be set to our preferences. When there is hot weather, the indoor temperature can be lowered through air conditioning. When there is cold weather, the complete opposite can be done, and the indoor temperature can be increased through heating.

This is very often combined with ventilation, which involves bringing fresh outside air into the building. Outdoor air must be filtered to achieve the desired indoor air quality and to protect the people against particulate matter. This is very important, given that a poor indoor air quality is known to significantly affect the attitude, concentration, productivity and health of people.

8.2 RESIDENTIAL

The need for good filtration and high quality commercial air filters is becoming more and more obvious to most people around the world. People perform better with clean air and a healthy indoor climate. Research proves that high-efficiency commercial air filters reduce the problems that small particles can cause for sensitive people.

It goes without saying that the protection against particulate matter is a very important factor for commercial and office buildings. But it is not limited to these types of buildings.

Residential air cleaners designed for home usage (in bedrooms and living rooms for example) are becoming more common and accepted nowadays.

8.3 MEDICAL

Air filtration is very important in healthcare facilities. The level of airborne infectious contaminants increases proportionately with the increased population density of infected individuals. Infections are a concern, especially in surgery rooms but not limited to hospitals only. Nursing homes and dental offices or clinics also need efficient filtration to prevent bacterial infections.

Other important fields of application for air filters, but basically of different construction than used in general ventilation, are industries such as automotive, paint booths, optical, microelectronics or power generation.

9. PRACTICAL ISSUES

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9.1 MAINTENANCE OF AIR FILTERS

The filter service life is defined as the operating period between filter installation and filter replacement. It is determined by the following factors:

- Hygiene issues (e.g. microorganisms, fungal spores, odours),
- Optimisation of economic efficiency,
- Reaching of the final pressure drop specified for the filter system in the ventilation system,
- Defective filter.

Filters should be changed considering the above-mentioned factors and the supplier's maintenance plan. When replacing filters, it needs to be ensured that all filters across the entire duct cross-section are changed at the same time. Filters may only be changed with the system at standstill and by using personal protection equipment (clothing, gloves, class-P2 respirators). The used filters should be transported in big plastic bags.

Figure 9: Personal protection equipment for filter replacement

Particularly when mounting new filters, utmost care shall be taken to prevent filter damage due mostly to the sharp edges of the slot. Contaminated filters should be handled with care, transported in a suitable, lockable package and disposed according to local legislation. The connections between filter frames and partitions shall be cleaned, checked and repaired, where required. The filter frames or the filter housing of the new filter as well as the sealing faces should be cleaned carefully prior to assembly. The new filter should be careful assembled as per assembly instructions.

Visual inspections of coarse and fine dust filters and particle measurements on particulate air filters of classes H and U must be performed at regular intervals to detect such defects. During maintenance, optical and/or electrical differential pressure gauges and indicators shall be checked for proper functioning. If testing a filter is impossible, it should be replaced after the period specified by the manufacturer.

9.2 TRANSPORT AND STORAGE

To protect filters from contamination, they should be transported and stored only in their original packaging, preferably on pallets. Transportation should be done with care, avoiding any abrupt movement. Filter storage must be indoors according manufacturer's instructions (not outdoors), protected against rain and moisture, and at temperatures above the freezing point. The filters should be brought to the assembly site in their original packaging and should not be unpacked until immediately before assembly. The packaging must not be pierced with sharp objects. When removing a filter from its packaging, avoid touching the delicate filter medium. Prior to assembly, each filter should be checked visually for any transport damage. Damaged filters should not be used. each filter should be checked visually for any transport damage. Do not use damaged filters.

9.3 DISPOSAL

Air filter products must not be assessed by technical/ economic criteria alone. They also need to satisfy ecological requirements.

To obtain a reliable assessment of the ecological criteria, material and production must be assessed and balanced with regard to energy, influencing substances and emissions over the entire life cycle.

Composite materials, e.g. mixtures of aluminium, steel and plastics, are not recommended as they involve a higher expense of disposal. Filter systems for the separation of hazardous substances should have the smallest possible number of stages (unless otherwise required for application-specific reasons) as the replacement and disposal of several contaminated filters is more expensive due to the extra time required for contamination-free filter change and due to the higher disposal costs involved (hazardous waste).

Recycled or recyclable, low-emission materials shall be preferred for filter frames.

10. EUROPE'S AIR FILTERS INDUSTRY

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The manufacturers that have developed this guidebook produce state-of-the-art air filters that set the global standard in terms of quality, energy efficiency and indoor air quality aspects.

They are members of the Eurovent Product Group 'Air Filters' (PG-FIL) and have developed this set of informative guidelines to raise awareness of their products and the potential of their technologies.

The Eurovent Product Group 'Air Filters' is the only European-wide committee on air filters. Its participants hold a joint market share of more than 85% in the general ventilation area. Over the past decades, it has developed various industry recommendations that have become part of EN or ISO standards later on.

10.1 LIST OF IMPORTANT PUBLICATIONS OF THE EUROVENT PRODUCT GROUP 'AIR FILTERS'

- Eurovent 4/21 - 2016: Energy Efficiency Evaluation of Air Filters for General Ventilation Purposes
- Eurovent 4/19 - 2015: Updated Industry Recommendation concerning Public Enquiries for Air Filters
- Eurovent 4/22 - 2015: Industry Recommendation for Residential Air Filter Performance Measurements
- Eurovent 4/21 - 2014: Calculation method for the energy use related to air filters in general ventilation systems
- Eurovent 4/20 - 2012: Recommendation concerning classification of air filters
- Eurovent 4/6 - 2009: Recommendation concerning Air Filters for better Indoor Air Quality
- Eurovent 4/18 -2009: Recommendation concerning Diesel Fume: Discharging Test of Air Filters
- Eurovent 4/5 - 1992: Method of testing air filters used in general ventilation and recommended classification
- Eurovent 4/9 - 1991: Recommendation concerning Standard front dimensions or air filters

All publications can be obtained at www.eurovent.eu.

10.2 PRODUCT GROUP PARTICIPANTS CONTRIBUTING TO THIS GUIDEBOOK

AAF INTERNATIONAL; AFPRO FILTERS; alnor systemy wentylacji; camfil

CETIAT ensemble, innover et valider; DencoHappel; Dinair Balanced clean air solutions; DMT

filtech to enjoy clean air; FREUDENBERG INNOVATING TOGETHER; INTERFIL; JASUN ENVIROCARE PLC

MANN+HUMMEL; SagiCofim; SALDA; TROX TECHNIK

ultramare; Uniclima; UNIFIL AG FILTERTECHNIK; venfilter

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The brochure includes photos of the companies DENCO HAPPEL, FILTECH and TROX.

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