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Filter Systems in Enclosure Climate Control

White Paper

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Authors: Christine Ronzheimer, Carina Schmidt, Felix Halfmann and Maximilian Göttig

Which criteria tend to apply when users select the filters for a cooling unit or a fan-and-filter unit for their enclosure climate control application? In many cases, cost is the decisive factor; where apparently equivalent products can be found on the market at lower prices, it is tempting to forego purchasing an original filter from the manufacturer. But does a lower purchase price always mean lower overall costs? And how does filter selection affect the service life of the enclosure components and thus also overall system availability?

How can appropriate filter selection and maintenance contribute to making enclosure climate control even more efficient, reliable, and cost-effective? This white paper answers the most important questions asked by users of fan-and-filter units or cooling systems when it comes to selecting the best filter system for enclosure climate control.

Contents

Introduction

Extending the service life of components

The true relevance of filters in enclosure climate control is often underestimated in practice. From hopelessly clogged systems to incorrectly selected or even completely missing filters, there is no shortage of examples to be found throughout industry. Only through correct filter selection and timely filter replacement is it possible to maximize the service life of the installed components and thus also directly safeguard system availability.

Correct filter selection raises overall system availability.

> When selecting a filter, it is also important to be aware of the correlation between temperature and enclosure component lifetime.

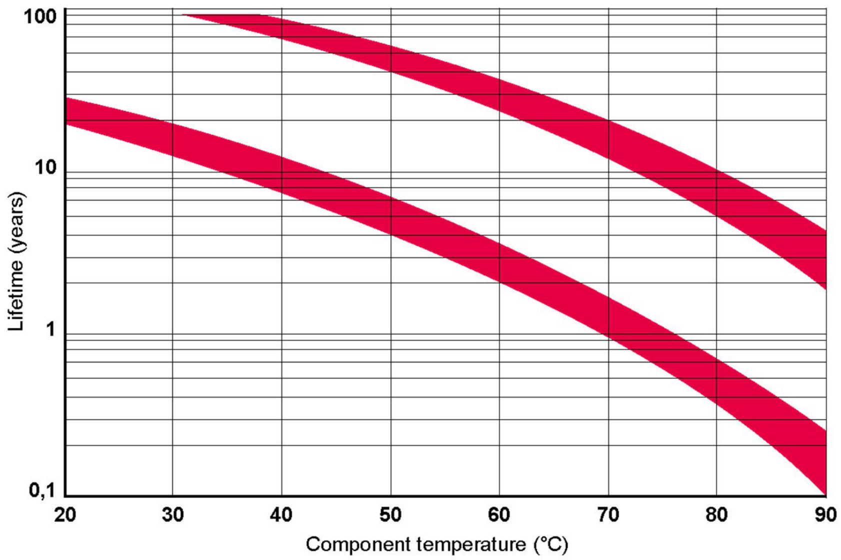


Fig. 1
Arrhenius plot

The Arrhenius plot depicted in *Fig. 1* shows that an increase in component temperature by 10 °C already shortens its lifetime by half. Accordingly, the probability of failure of a machine is doubled by such a temperature rise. Component-oriented enclosure climate control is thus imperative for proper long-term functioning. The role played by the use of original filter mats, and how the efficiency of enclosure climate control can be increased while at the same time reducing costs, will be explained in more detail in the following pages.

An increase in operating temperature by 10 °C shortens component lifetime by half.

Selection of an Appropriate Filter

How to determine the correct filter

It is not always easy to select the correct filter for an individual local environment, and there is sometimes no obvious choice. It is therefore important to know the selection criteria and the benefits of different types of filter. Only in this way can you be sure to protect the enclosure components effectively against all ambient influences and safeguard the efficiency of climate control.

Initially, selection of a filter type is dependent on the type of system used for climate control, as the filter is required to accomplish different tasks in different systems. The filter in a roof-mounted fan or fan-and-filter unit, for example, must guarantee very effective filtering, as the ambient air is transported directly into the enclosure and the filter thus constitutes the sole protection between the contaminated ambient air and the interior of the enclosure. Particular attention must be paid to the filter in such applications, and this will be a key focus of this white paper.

Save costs with the correct filter.

In the case of filters for use in cooling units, heat exchangers, or chillers, the filter serves merely as protection for the climate control system itself, as there is no direct exchange between the ambient air and the enclosure interior due to the hermetically separated cooling circuits. The sensitive system components are generally incorporated into the inner circuit and are thus protected against external influences. This means that open-pored filters are already adequate, as they must only protect the system against very coarse dust particles and do not become clogged so quickly. A chopped-fiber mat of the kind used in a fan-and-filter unit is therefore unsuitable for cooling units, as it would also filter very fine particles and become clogged much too quickly. This, in turn, would reduce the cooling performance and lead to higher energy consumption and service costs.

A metal filter is used in oil-laden atmospheres. When air or vapor condenses on the metal surface, any particles in the air adhere to the surface. This is the same function principle as for a kitchen extractor hood. The filter can then simply be washed out using a grease-dissolving cleaning agent. In enclosure climate control, metal filters are used in the immediate vicinity of CNC machine tools, for example. As the oil content of the ambient air increases during operation of such a machine tool, an effective filter is imperative to guarantee trouble-free operation. Due to their low filtration performance in terms of dry solid matter, however, metal filters are not suitable for dust filtering.

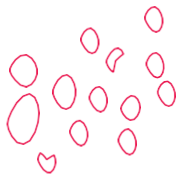
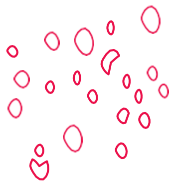
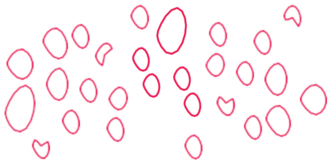
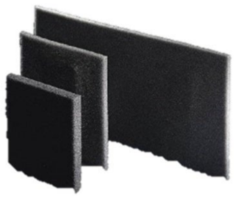
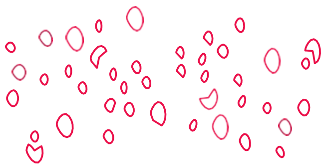
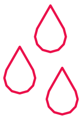
Degree of contamination of the ambient air	Type of enclosure climate control	Required filter
 **Coarse dust particles** *(> 10 µm)* low–medium	✓ **Roof-mounted fan** ✓ **Fan-and-filter unit**	  **Coarse chopped-fiber filter** **Pleated filter**
 **Fine dust particles** *(1–10 µm)* low–medium		  **Pleated filter** **Pleated filter + absorber mat**
 **Coarse dust particles** high	✓ **Air/air heat exchanger** ✓ **Cooling unit** ✓ **Chiller**	 **PU filter**
 **Fine dust particles** high		
 **Oil-laden atmospheres**	✓ **Air/air heat exchanger** ✓ **Cooling unit** ✓ **Chiller**	 **Metal filter**

Table 1
Overview of filter mats

As can be seen from *Table 1*, it is a relative simple matter to select the correct filter for cooling units, chillers, and heat exchangers on the basis of the dominant local ambient conditions.

When it comes to fan-and-filter units, however, most manufacturers offer filters in different filter classes. *Figure 2* is intended to provide a general overview of the most common aerosols and their particle sizes, as well as the filter classes suitable for retention in each case.

Pleated filters are especially effective with fine dusts and medium dust loads.

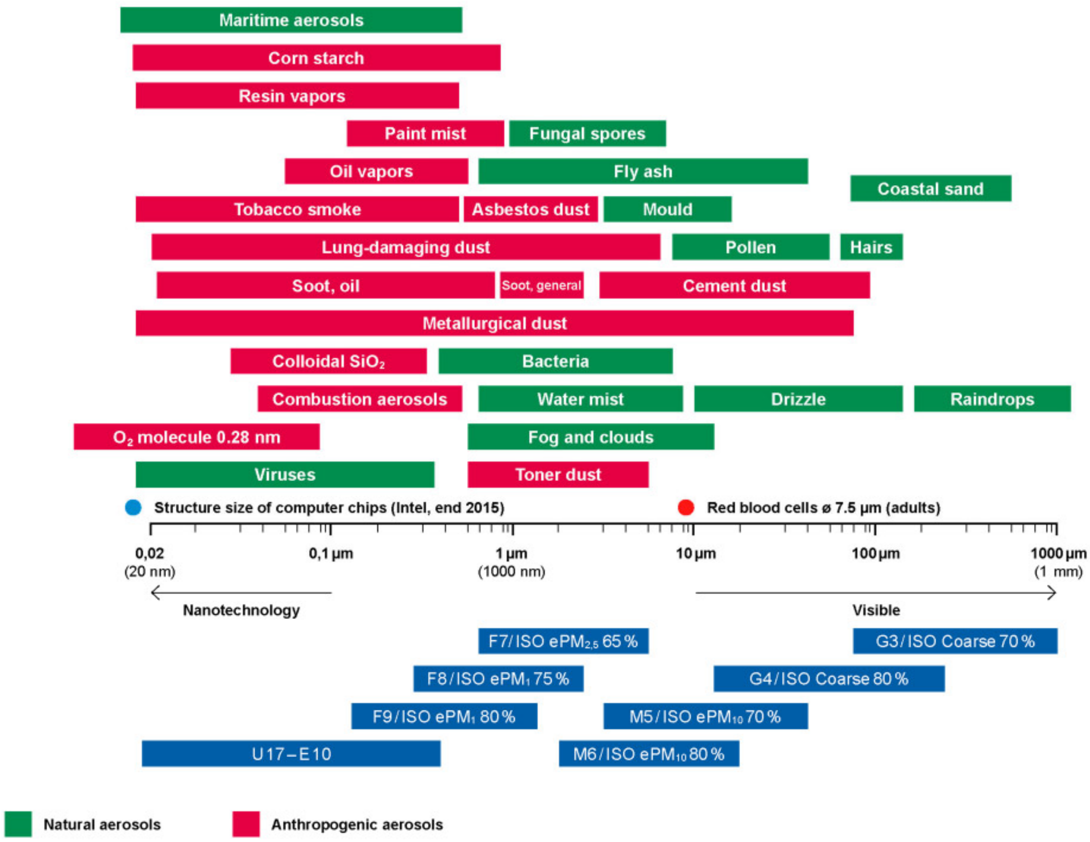


Fig. 2
Overview of aerosols

To gain a better idea of the significance of particle size, it is useful to know how different particles enter the human body. Coarse dust (> 10 µm) is retained effectively in the nasal cavity and throat, whereas fine dust and suspended matter (< 10 µm) pass with relative ease. Particles smaller than 0.1 µm – so-called nanoparticles – are able to penetrate cell membranes in the lungs and enter the blood stream directly.

The filter classes offered for fan-and-filter units usually lie between G2 and M5 (to EN 779). Many dust particles which arise in industrial environments lie below this filter range. Practice has shown, however, that these filter classes are adequate for most enclosure climate control applications. Each higher filter class leads to a reduction in air throughput and cooling output, as well as a shorter replacement interval, and thus higher operating costs. The motto here should be: As coarse as possible and only as fine as necessary.

The filter classes specified in *Figure 2* refer to two different standards. The specifications based on DIN EN 779 (e.g. G3 or M5) were applicable for many years and are thus widely known. Since 2018, however, the standard DIN EN ISO 16890 has been the sole valid reference, having gradually superseded DIN EN 779 from mid-2016 onwards.

The filter class definitions, in particular, have been reorganized and direct 1:1 comparisons are not possible. Fundamental differences and the most significant changes are listed in the table below:

Table 2
New standard DIN EN ISO 16890

DIN EN ISO 16890	DIN EN 779
Relevant filter characteristics	
▪ Coarse dust filter: Initial gravimetric arrestance of A2 dust ▪ Fine dust filter: Fractional arrestance for ePM_x (0.3 µm–10 µm)	▪ Coarse dust filter: Average gravimetric arrestance of ASHRAE dust ▪ Fine dust filter: Average efficiency for particles 0.4 µm in diameter
Test objective	
Assignment to an ISO ePM group	Classification into filter classes G, M and F
Test aerosol	
DEHS and KCl aerosols	DEHS aerosol
IPA treatment method	
▪ Entire filter element ▪ Conditioning with IPA vapor	▪ Sample taken from the filter medium ▪ Immersion in liquid IPA
Filter condition to be assessed	
▪ New ▪ New, after IPA treatment	▪ New and dust-laden condition ▪ New, after IPA treatment
Pressure drop, final	
▪ ISO Coarse: 200 Pa ▪ ISO ePM_1 to ePM_{10}: 300 Pa	▪ G1–G4: 250 Pa ▪ M5–F9: 450 Pa
Dust retention capability	
Exposure to A2 test dust (quartz dust)	Exposure to ASHRAE test dust (quartz dust, soot, cotton fibers)

Source: VDMA Luftfilterinformation (2018-06) DIN EN ISO 16890:2017: Ein Schritt zu mehr Praxisnähe

With regard to the relevant filter characteristics, DIN EN ISO 16890 defines a new basis for classification. The decisive factor in classification is the so-called arrestance, which increases with the amount of dust retained by the filter.

For coarse dust filters, which serve to remove dusts with particle sizes from 10 µm, the applicable classification is the ISO Coarse filter group (e.g. ISO Coarse 70%). Filters for fine dusts – termed **P**articulate **M**atter (PM) in the international nomenclature – are classified according to their ability to retain fractions of different particle sizes:

ISO ePM_{10}	Particle size 0–10 µm	(coarse dust)
ISO $ePM_{2.5}$	Particle size 0–2.5 µm	(fine dust)
ISO ePM_{1}	Particle size 0–0.1 µm	(suspended matter)

These fractional arrestance classes can then be further subdivided according to the percentage of the dust particles present in the surrounding environment, which is actually retained by the filter. An ePM_1 70% filter, for example, will remove around 70% of the fine dust particles between 0.3 µm and 1 µm from the air flow.

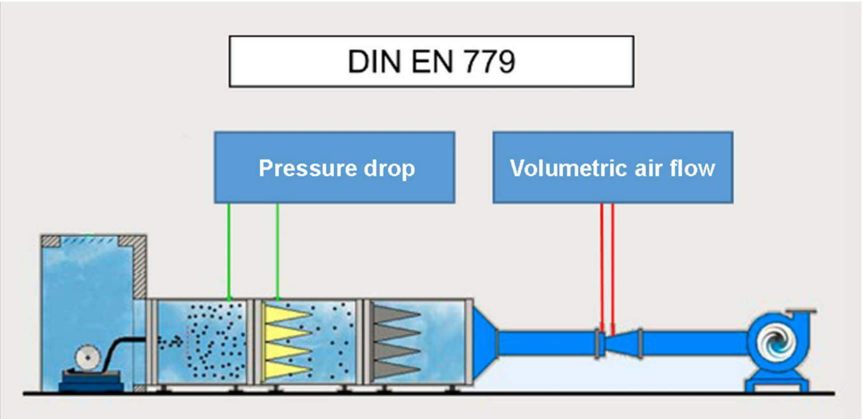
One of the greatest challenges of the transition from DIN EN 779 to DIN EN ISO 16890 is conversion of the classifications between the old filter classes and the new filter groups. The following table offers guidance for appropriate conversion:

Table 3
Conversion of classifications

DIN EN 779	**DIN EN ISO 16890**			
	Coarse	**ePM_{10}**	**$ePM_{2.5}$**	**ePM_{1}**
G1	-	-	-	-
G2	**30–50%**	-	-	-
G3	**45–65%**	-	-	-
G4	**60–85%**	-	-	-
M5	**80–95%**	**40–70%**	10–45%	5–35%
M6	> 90%	**45–80%**	**20–50%**	10–40%
F7	> 95%	80–90%	**50–75%**	**40–65%**
F8	> 95%	90–100%	75–95%	**65–90%**
F9	> 95%	90–100%	85–95%	**80–90%**

Source: Cf. J. Drzymalla, S. Theißen, J. Höper, D. Kalathoor, A. Henne: Partikelfilter in Raumlufttechnischen Anlagen – Methode zur Filterwahl nach DIN EN ISO 16890

A further change introduced by DIN EN ISO 16890 is a modified test set-up to determine the arrestance of the test aerosols (gases or particles suspended in the air).



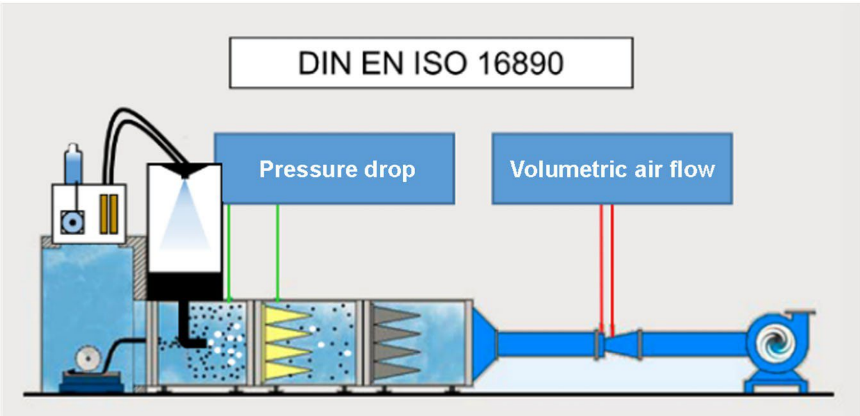


Fig. 3
Test set-up

For particle sizes below 1 µm, testing according to DIN EN ISO 16890 uses the same methodology as testing to DIN EN 779, whereas an additional assessment with KCl aerosols is required for the fraction ranges $PM_{2.5}$ and PM_{10}. Corresponding measurements are less complex but never- theless supply representative results due to the coarser nature of the measurement ranges.

The new regime of DIN EN ISO 16890 permits the conclusion that a few changes to the methodology have made the filter selection process simpler and more precise. The switch may appear onerous at first sight, but it is by all means a reasonable development when the added value of the outcome is taken into account.

Why use Original Filter Mats?

Avoid far-reaching consequences

Especially in the case of chopped-fiber filters, many customers turn to third-party products to save costs. They are often unaware, however, that this may have far-reaching consequences. It is important to use original filter mats from the manufacturer. They are cut exactly to size and observe all general specifications of the application in hand, e.g. required dimensions or material properties. Users should avoid cutting filters to size themselves. The scale of the problems which may be caused by using third-party filters is frequently underestimated.

The key risks are described in the following:

Performance data: A deviating air throughput may mean that the enclosure is no longer cooled adequately. If the interior temperature increases, this will shorten the lifetime of various components and even the derating or complete shutdown of certain components cannot be excluded.

IP protection rating: The IP protection rating according to DIN EN 60529 defines the ambient conditions for which a fan-and-filter unit is suitable. Use of a third-party filter may result in the conditions for the specified IP rating of the unit no longer being observed. Excessive dimensional tolerances or an imprecisely fitting filter mat can already lead to leakages which permit contamination (dusts, oils, etc.) or water to enter the interior of the enclosure unhindered and cause damage to installed components. Furthermore, it is possible that the third-party filter differs from an original filter in certain details, despite their apparently identical technical product data. The ability of a filter to retain or absorb water, for example, cannot be derived from the technical data.

Approvals: Product approvals always assume use of the original filter mats supplied by the manufacturer. If other filter mats are used, the approvals become null and void.

Fire safety: Original filter mats (e.g. from Rittal) are tested against currently applicable standards (UL 746C) to determine their fire safety performance in combination with the final product (fan-and-filter unit). By contrast, it is possible that a third-party filter is made from a different material and therefore reacts differently. In case of an accidental arc or short-circuit, this may result in the filter catching fire.

Warranty: Product warranties are given subject to the use of original spare parts. If other spare parts are used, e.g. third-party filters, the warranty becomes null and void.

Performance data, protection ratings, and device approvals are only guaranteed when using original filter mats.

Saving Money with the Correct Filter and Correct Maintenance

Many people view regular filter mat replacement as some kind of necessary evil and it is thus often neglected. A closer look, however, reveals that regularly maintained or higher-quality filter systems save money in the long run, while at the same time improving system availability and sparing the environment.

The impact of a poorly maintained filter system is demonstrated by considering a test installation with cooling units, where a contaminated filter not only reduced the cooling output of a 1.5 kW unit by 30%, but also resulted in 18% higher power consumption.

Assuming two-shift operation on five days a week, this leads to additional energy costs of 154 € ($160 USD) per cooling unit per year.

> For comparison, the fitting of original replacement filters at the ideal interval of every two weeks would cost only 88 € ($91 USD) per unit per year.

Pleated filters for more efficient filtering

Regular maintenance is not the only way to save money. Similar benefits are achieved by switching to a more efficient filter type where this is offered by the manufacturer.

Fig. 4
Field test with a chopped-fiber filter

Pleated filters are included as standard, but users are still able to choose between chopped-fiber and pleated filters. Generally speaking, chopped-fiber filters are the less expensive solution in terms of purchase costs. A broader assessment, however, indicates that the longer-term costs are actually higher.

A pleated filter is similar in design to the air filters which are used in motor vehicles. Pleating of the filter material results in an approximately six-fold increase in the surface area.

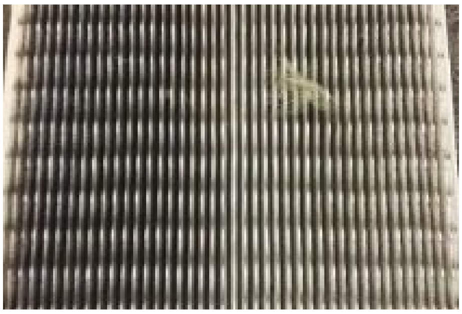


Fig. 5
Field test with a pleated filter

To illustrate the benefits of pleated filters, laboratory studies were supplemented by a series of field tests in which the two filter types were evaluated under real production conditions at customers from the most varied branches of industry.

To this end, the filters were fitted in two identical surface-mounted units *(see Figs. 4 and 5)*, and the relevant operating hours and temperatures were documented. Subsequent analyses produced the following results:

Higher air throughput:
The larger surface of the pleated filter results in a lower pressure drop, which in turn means that the air throughput of the fan is higher *(see Fig. 6).* The tests demonstrated this in that the fans ran for 32% fewer hours on average to achieve and maintain the desired temperature in the enclosure. This brings several benefits: The energy costs for fan operation are 32% lower, and both the service lifetime of the fans and the filter replacement intervals are extended.

Improved filter performance:
For small dust particles (0.3–1 μm), in particular, a pleated filter is significantly more efficient *(see Fig. 7).* The test installations confirmed that only half as many dust particles were detected on the air outlet side compared to a chopped-fiber filter. This means that the quantity of dust which escapes the filter and penetrates into the enclosure is reduced by half. Furthermore, the retention performance – here understood to mean the amount of dust which is retained by the filter over a given time – was increased by an average of 98% when using pleated filters with a protection rating of IP54.

Longer replacement intervals:
Another test observation was that filter replacement intervals were 2 to 3 times longer with pleated filters. This is attributable to the 2.5-times higher dust retention capacity previously determined in the laboratory *(see Fig. 8).* The higher capacity means that the replacement intervals can be extended and service costs are lower.

On the basis of the test results, the energy cost savings and longer replacement intervals add up to the following savings per fan-and-filter unit/outlet filter combination:

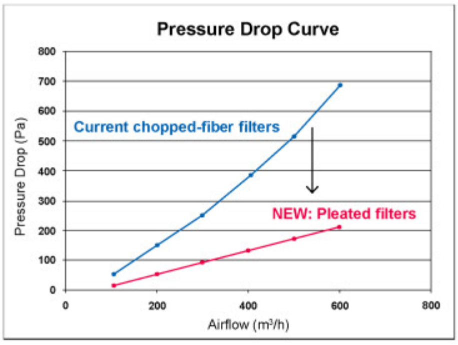


Fig. 6
Higher air throughout

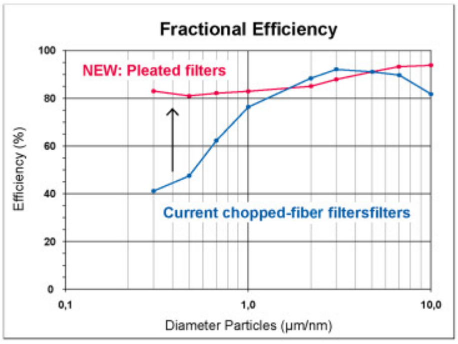


Fig. 7
Higher filter efficiency

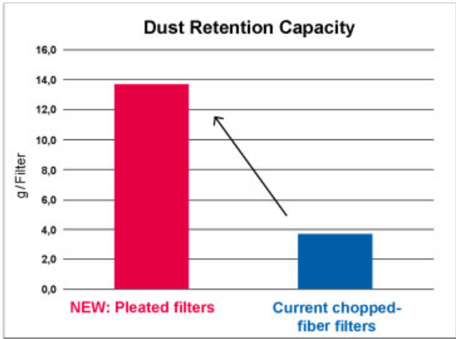


Fig. 8
Longer replacement intervals

Annual savings

Energy costs	6.34 € ($6.61 USD)
Service costs	42.94 € ($44.74 USD)
Total:	**49.28 € ($51.35 USD)**

Assumptions

Electricity price:	0.17 € ($0.18 USD)/kWh
Frequency of maintenance:	5 interventions instead of 12
Labor cost (service):	40 € ($41.68)/hour

Some manufacturers provide their own efficiency calculation tools to enable individual calculation of the potential savings for a particular application.

Further savings potential

The diverse control options of the fan are further possibilities to extend the maintenance intervals of a fan-and-filter unit. Manufacturers generally offer a comprehensive portfolio, ranging from simple thermostats and hygrostats to speed control functions and intelligent EC fans which can be integrated directly with the PLCs or other monitoring systems.

In most cases, the selected climate control components are overdimensioned in order to be able to cover summer temperature peaks. Accordingly, such measures alone suffice to save additional energy costs, and it is not unusual to be able to double the filter replacement intervals.

Demand-based maintenance

One question which often arises in this connection concerns the optimum maintenance interval. There is no single answer to this question, however, as the fields of application for fan-and-filter units, cooling units, and other climate control solutions are so diverse. They range from the food and beverage sector to textiles, chemicals, and the manufacturing of wind turbines and automobiles. Airborne dust loads and particle compositions may also vary significantly within a single production hall. It is an important difference, for example, whether the enclosure is standing directly alongside a grinding machine or in a more remote storage area. Maintenance intervals may vary from weekly to half-yearly or even annually.

The most common method to assess the filter condition remains a visual check. In the case of fan-and-filter units, the condition of the air outlet filter is an especially relevant indicator, because any particles which have found their way into the enclosure via the intake filter will have collected on the inner side of the outlet filter. If significant dust deposits are found there, either the chosen filter is not suitable for the purpose or else the appropriate maintenance interval has been exceeded. At the same time, it must be noted that some filter types no longer function reliably from a certain level of contamination and instead allow more and more particles to pass through. For this reason, it is not necessarily meaningful to base assessment of the filter condition on the inside temperature of the enclosure. If the climate control solution is dimensioned adequately, the air throughput will not be hindered to the extent that thermal problems arise. This is positive, on the one hand, because the electrical components are not at risk of overheating, but they still no longer benefit from effective protection against dust – a circumstance which could similarly lead to failures over a longer period of time.

Another possibility when using fan-and-filter units is to measure the air flow behind the filter, and in this way to gain information on the degree of contamination. Practical tests have shown, however, that the values obtained are highly dependent on the position of the sensor.

Modern cooling units, on the other hand, possess internal sensors. They measure the temperature before and after the condenser in the external circuit and can then calculate the degree of contamination of the filter mat. Different “filter tolerance levels” can be selected as the trigger for a filter replacement alarm, depending on the reduction in cooling output which is acceptable or permissible for a given application *(see Fig. 9).* On this basis, a reliable interval can be determined for replacement of the filter mats.

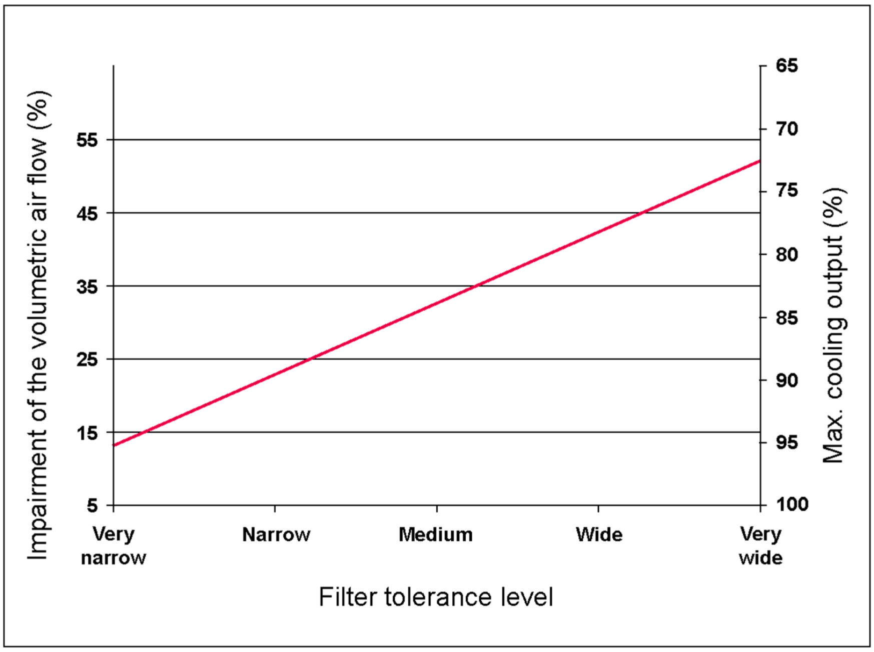


Fig. 9
Example of a cooling output characteristic

Source: Blue e+ cooling unit - Assembly and operating instructions, p. 28 (dri1813000en)

It can be seen, therefore, that selection of an ideal filter system yields considerable potential for cost savings and improved resource efficiency. The solution which appears least expensive at first sight is not necessarily the most sustainable or most cost-effective when the subsequent costs for operation and service are also taken into account.

The following points should thus be kept in mind:

- Use only original filter mats in order to safeguard the technical product specifications, approvals, and warranty entitlements
- Control accessories prevent the fans from running unnecessarily and extend the filter replacement interval
- Use pleated filters instead of chopped-fiber filters for greater efficiency and lower maintenance costs
- Adapt replacement intervals to match the ambient conditions in order to ensure effective protection of the installed components

Appendix

Terminology, abbreviations

CNC:	Computerized Numerical Control
DEHS aerosol:	Di-ethylhexyl sebacate (DEHS) is a colorless and odorless liquid which is insoluble in water and ideally suitable for the generation of stable aerosols
Derating:	Derating describes controlled reduction of the output of a device, e.g. an inverter, when operating in higher ambient temperatures. This serves to avoid damage to a component or device due to overheating.
DIN EN:	Deutsches Institut für Normung / EN: European standardisation
EC fans:	Fans which are driven by an EC motor. The intelligent EC electronics (EC = electronically commutated) permit a very good control response and high energy efficiency.
IP:	The IP protection rating according to DIN EN 60529 describes the suitability of electrical devices for operation under various ambient conditions, and additionally the protection offered to personnel against potential hazards arising during operation
IPA:	Isopropanol
ISO:	International Organization for Standardization
KCl aerosol:	Potassium chloride aerosol
kW:	Kilowatt
kWh:	Kilowatt-hour
Pa:	Pascal is the international standard unit of measure for pressure and mechanical stress
PLC:	Programmable logic controller
PM:	Particulate matter
PU filter:	Polyurethane filter
UL:	Underwriters Laboratories is an independent organization which tests and certifies products with regard to their safety
µm:	Micrometer

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