



Eurovent 4/21 - 2019

Energy Efficiency Evaluation of Air Filters for General Ventilation Purposes

Fourth Edition

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Document history

This Eurovent Industry Recommendation / Code of Good Practice supersedes all of its previous editions, which automatically become obsolete with the publication of this document.

Modifications

This Eurovent publication was modified as against previous editions in the following manner:

Modifications as against	Key changes
1 st edition	Implementation of ISO 16890 classification and testing methods in place of EN 779.
2 nd edition	Modification of the total amount of dust fed for rating. Withdrawal of key energy performance number (kep) for energy efficiency evaluation.
3 rd edition	Annex 1 concerning calculation of annual energy consumption at the flow rate other than 0.944 m ³ /s.
4 th edition	Present document

Preface

In a nutshell

The purpose of this Recommendation is to:

- **Define energy efficiency of air filters for general ventilation purposes**
- **Define energy efficiency evaluation methods**
- **Implement the ISO 16890 classification and testing methods**

Authors

This document was published by the Eurovent Association and was prepared in a joint effort by participants of the Product Group 'Air Filters' (PG-FIL), which represents a vast majority of all manufacturers of these products active on the EMEA market.

Adoption

It has been approved and adopted through a formal voting procedure by Europe's national Member Associations from 20+ European countries, which ensures a wide-ranging representativeness based on democratic decision-making procedures. More information on these members can be found at www.eurovent.eu.

Important remarks

The Eurovent Association does not grant any certification based on this document. All certification-related issues are managed by the association's independent subunit Eurovent Certita Certification in Paris. For more information, visit www.eurovent-certification.com.

Contents

Eurovent 4/21 - 2019	1
Document history	2
Modifications	2
Preface	2
In a nutshell	2
Authors	2
Adoption	2
Important remarks	2
Background	4
Energy consumption related to air filters	4
Symbols	6
Example	7
Literature	8
Annex 1	9
About Eurovent	10
Our Member Associations	10

Background

In the context of increasing energy prices and the imperative of reducing CO₂ emissions, the energy consumption related to air filters is in the focus of attention. Air filters used for general ventilation are tested and classified according to their particle efficiencies, especially with respect to the removal of particulate matter, in accordance with the ISO 16890 series of standards.

The aim of this guideline is to assess the yearly energy consumption based on a laboratory test procedure which can be the basis for an energy efficiency classification, to give the user of air filters guidance for the filter selection. It has to be noted that to reduce the energy consumption by using more energy efficient filters requires that the speed of the fan can be adjusted to supply a constant air volume flow rate. If the fan is operated at a fixed speed, lowering the (average) pressure drop of the air filters will result in an increased air volume flow rate. In the worst case, this may even result in a situation where the fan is operated in a region with lower efficiency resulting in an increased overall energy consumption.

It also has to be noted that the method provided in this document is based on laboratory test data with standardised test conditions, which may differ significantly from the individual application in a building ventilation unit. Hence, the yearly energy consumption calculated in this document can only be used as an indicator for the classification system and relates only to the contribution of the air filters involved. The yearly energy consumption in an individual, actual application may differ from this significantly.

The energy consumption of air filters can be determined as a function of the volume flow rate, the fan efficiency, the operation time, and the average pressure drop. Due to the dust loading during operation, the pressure drop of an air filter increases over time. The related energy consumption over a certain duration can be calculated from the integral average of the pressure drop over this period of time. As a laboratory test method, the average pressure drop is determined from a loading of the filter according to ISO 16890-3 using a synthetic test dust specified in ISO 15957 as L2 (AC Fine).

According to this guideline fine dust filters are rated with an efficiency $ePM_{10} \geq 50\%$.

Energy consumption related to air filters

The energy consumption of a fan in an air handling unit can be evaluated as a function of the volume flow rate supplied by the fan, the fan efficiency, the operation time, and the difference of the total pressure (static plus dynamic pressure) after the fan and the static pressure of the ambient air (assuming that the fan sucks in air from a static reservoir). Typically, the volume flow rate supplied by the fan and the pressure difference the fan has to overcome are related to each other by the characteristic fan curve. The efficiency of the fan is a function of the fan speed. The actual fan efficiency also strongly depends on the design and the layout of the fan and can be in the best case as high as 0.80 or even higher, and in the worst case as low as 0.25 or even lower.

The portion of the total yearly energy consumption which is related to the filters' pressure drop can be calculated using Eq. (1a):

$$(1a) \quad W = \frac{q_v \cdot \overline{\Delta p} \cdot t}{\eta \cdot 1000}$$

Where we define: $q_v = 0.944 \text{ m}^3/\text{s}$, $t = 6000 \text{ h/a}$ and $\eta = 0.5$

As given above, the volume flow rate is considered to be fixed at 0.944 m³/s [3400 m³/h]. This corresponds in a real air handling unit to a fan with variable speed drive controlled to run at fixed volume flow. Additionally, the fan efficiency is defined to 0.50, which can be considered as a typical average efficiency of a fan in an air handling unit.

With the constant values given above, the only variable in Eq. (1a) is the average pressure drop and hence, it can be written as Eq. (1b):

$$(1b) \quad W = 11.33 \frac{\text{kWh} / \text{a}}{\text{Pa}} \cdot \overline{\Delta p}$$

The rating shall be carried out for a full-size filter element (face dimension 592 mm x 592 mm according to EN 15805) as described below.

1. Carry out a full test according to the ISO 16890 series of standards at a flow rate $q_V = 0,944 \text{ m}^3/\text{s}$ and determine the ePM_x efficiencies and the ISO ePM_x group as described in ISO 16890-1.
2. Load the filter with ISO L2 dust (AC Fine) according to the procedure described in ISO 16890-3, feeding the total amount of dust given in Table 1 or to the final pressure drop (300 Pa), whichever comes first. During the course of dust loading, the pressure drop curve versus dust fed shall be recorded with at least nine data points ($m_i, \Delta p_i$) including the initial data point ($m_0 = 0 \text{ g}, \Delta p_0$) (minimum of eight loading steps). In the first step, 30 g of dust shall be fed to the filter or an amount of dust that results in 10 Pa pressure drop increase, whichever comes first. For the last loading step, the total amount of dust fed m_n ($n \geq 8$) shall be equal or slightly larger than the amount of dust given in Table 1. The additional dust loading increments should give a smooth curve pressure drop versus dust fed. The total amount of dust that shall be fed to the filter is defined in Table 1, depending on the ISO classification.

ISO group	ISO ePM_1	ISO $ePM_{2,5}$	ISO ePM_{10}
Amount of dust fed M_x	200 g	250 g	400 g

Table 1: Total amount of dust fed

If the final pressure drop of 300 Pa is reached at a lower amount of dust than specified in Table 1, the filter's energy efficiency cannot be evaluated, and the procedure can be stopped.

ISO 16890-3 defines to load the test filter up to the final pressure drop (300 Pa). In case the final pressure drop is not reached before the total amount of dust M_x given in Table 1 is fed to the test filter, the loading procedure can be continued to achieve a full ISO 16890-3 test, but the additional dust loading data are not used in this Eurovent document.

3. Calculate the average pressure drop by using Eq. (2) from the $n+1$ data points pressure drop versus mass of dust fed.

$$\overline{\Delta p}_i = 0,5 \cdot (\Delta p_i + \Delta p_{i-1}) \text{ where } i = 1 \dots n - 1$$

$$\overline{\Delta p}_n = \Delta p_{n-1} + 0,5 \cdot \frac{\Delta p_n - \Delta p_{n-1}}{m_n - m_{n-1}} \cdot (M_x - m_{n-1}) \text{ where } m_{n-1} < M_x \text{ and } m_n \geq M_x$$

$$\Delta m_i = m_i - m_{i-1} \text{ and } \Delta m_n = M_x - m_{n-1}$$

$$\overline{\Delta p} = \frac{1}{M_x} \cdot \sum_{i=1}^n \overline{\Delta p_i} \cdot \Delta m_i$$

4. Calculate the yearly energy consumption W related to the filter using Eq. (1b).

All data used for the energy efficiency evaluation (ePM_x efficiency, ISO ePM_x rating, and pressure drop curve) shall result from the same filter specimen.

Symbols

ePM_x	Rated efficiency as defined in ISO 16890-1 (values rounded downwards to the nearest multiple of 5% points)	
η	Efficiency of a fan for the transmission of electrical energy into energy content of the air flow field As a representative average value for the different installations and operating conditions η is assumed to equal to 0.50 The total fan efficiency used in this document corresponds to η_{tot} as defined in EN 16798-3:2017, chapter 9.5	
i	Number of the dust loading steps	
m_i	Total amount of dust fed to an air filter after the dust loading step i	[g]
Δm_i	Dust increment fed to an air filter during loading step i	[g]
M_x	Amount of L2 dust fed to the test filter in accordance with ISO 16890-3 Used to calculate the average pressure drop M_x represents one of the three values M_{10} , $M_{2,5}$, and M_1 defined in Table 1	[g]
n	Total number of dust loading steps used to feed the amount of test dust M_x to the air filter ($n \geq 8$)	
Δp_0	Initial pressure drop of an air filter	[Pa]
Δp_i	Pressure drop of an air filter after dust loading step i	[Pa]
$\overline{\Delta p_i}$	Average of the pressure drops of an air filter measured before and after the dust loading step i	
$\overline{\Delta p}$	Average pressure drop of an air filter	[Pa]
q_v	Air volume flow rate at filter	[m ³ /s]
t	Time of operation For an air filter during a period of one year, a total operating time of 6000h is assumed	[h]
W	Yearly energy consumption	[kWh]

Example

As an example, the calculation method is shown based on test results for a pocket filter rated as ISO ePM_{2,5} 60% at 0.944 m³/s according to EN ISO 16890.

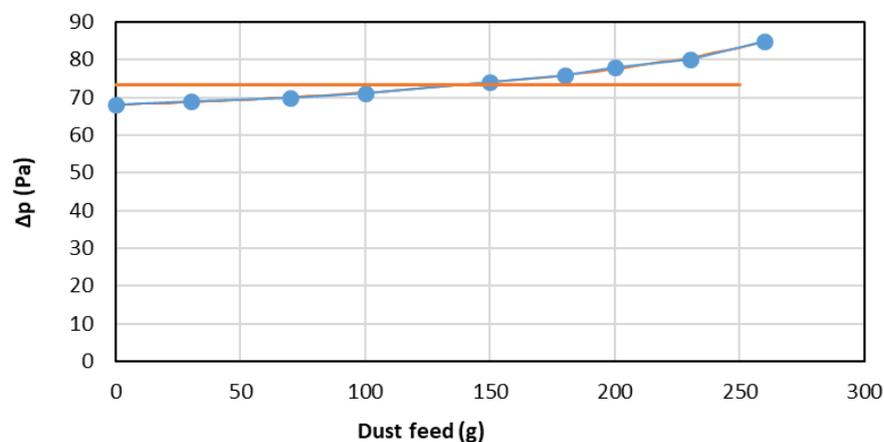


Figure 1: Pressure drop as a function of the dust loading at 0.944 m³/s according to EN ISO 16890-3

The red line marks the average pressure drop.

Step	Dust feed m_i [g]	Pressure drop Δp_i [Pa]	Dust increment Δm_i [g]	Av. Pressure drop $\overline{\Delta p_i}$ [Pa]
0	0	68		
1	30	69	30	68,5
2	70	70	40	69,5
3	100	71	30	70,5
4	150	74	50	72,5
5	180	76	30	75,0
6	200	78	20	77,0
7	230	80	30	79,0
8	260	85	20	82,0

Table 2: Test data for the pressure drop according to EN ISO 16890-3 as a function of the AC Fine dust feed

According to Table 1, the total amount of dust $M_{2,5} = 250$ g and by using Eq. (2) with the data given in Table 2, the average pressure drop calculates to $\overline{\Delta p} = 73.4$ Pa and the yearly energy consumption to $W = 833$ kWh/a.

Literature

- [1] Goodfellow, H.; Tähti, E.: Industrial Ventilation, Academic Press, 2001.
- [2] EN ISO 16890-1:2017: Air filters for general ventilation — Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM), 2017.
- [3] EN ISO 16890-3:2017: Air filters for general ventilation — Part 3: Determination of the gravimetric efficiency and the airflow resistance versus the mass of test dust captured, 2017.
- [4] Mayer, M.; Caesar, T.; Klaus, J.: Energy efficiency classification of air filters, Proc. 10th World Filt. Cong., Vol. 3, p. 313 – 317, April 14 – 18, 2008, Leipzig, Germany.
- [5] EN 15805:2009: Particulate air filters for general ventilation. Standardized dimensions, 2009.
- [6] EN 16798-3:2017: Energy performance of buildings - Part 3: Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems, 2017

Annex 1

The yearly energy consumption W according to this guideline is determined at a flow rate $q_v = 0.944$ m³/s. However, in an actual application the air flow rate might be higher or lower. To estimate the yearly energy consumption of an air filter at a given flow rate q_{act} other than 0.944 m³/s, the energy consumption W_{act} can be calculate by using the following formula:

$$W_{act} = W \cdot \frac{\Delta p_0(q_{act})}{\Delta p_0(q_v)} \cdot \frac{q_{act}}{q_v}$$

Where $\Delta p_0(q_{act})$ is the measured initial pressure drop of the unloaded filter at the actual flow rate q_{act} and $\Delta p_0(q_v)$ the measured initial pressure drop of the unloaded filter at the flow rate $q_v = 0.944$ m³/s.

The larger the difference between q_{act} and q_v , the more inaccurate the estimation gets.

The pressure drop at the alternative airflow should be extracted from the same ISO 16890 test report that was the basis for the kWh value at the nominal airflow (0.944 m³/s). This ISO 16890 test report should be provided together with the calculated energy consumption at the alternative airflow.

About Eurovent

Eurovent is Europe's Industry Association for Indoor Climate (HVAC), Process Cooling, and Food Cold Chain Technologies. Its members from throughout Europe represent more than 1.000 organisations, the majority small and medium-sized manufacturers. Based on objective and verifiable data, these account for a combined annual turnover of more than 30bn Euros, employing around 150.000 people within the association's geographic area. This makes Eurovent one of the largest cross-regional industry committees of its kind. The organisation's activities are based on highly valued democratic decision-making principles, ensuring a level playing field for the entire industry independent from organisation sizes or membership fees.

Our Member Associations

Our Member Associations are major national sector associations from Europe that represent manufacturers in the area of Indoor Climate (HVAC), Process Cooling, Food Cold Chain, and Industrial Ventilation technologies.

The more than 1.000 manufacturers within our network (Eurovent 'Affiliated Manufacturers' and 'Corresponding Members') are represented in Eurovent activities in a democratic and transparent manner.

→ For in-depth information and a list of all our members, visit www.eurovent.eu