Eurovent Industry Recommendation / Code of Good Practice

Eurovent 4/24 - 2023

Energy consumption evaluation of air filters for general ventilation purposes

First Edition (Update 1)

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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
1st edition	Correction of errors in Section 4 and minor editorial amendments
1st edition (update 1)	Present document

Preface

In a nutshell

The purpose of this Recommendation is to provide a generic methodology for estimating energy consumption of air filters for general ventilation under actual operating conditions, taking into consideration:

- **Wide range of airflow rate**
- **Actual filter dimensions**
- **Approach to the filter change (condition based and time based method)**
- **Actual operating time**
- **Actual fan efficiency**

The document is built on the methodology defined in Eurovent 4/21 and implements the ISO 16890 classification, as well as its testing methods. This Recommendation, together with Eurovent 4/21 and Eurovent 4/25, forms a set of Eurovent documents for evaluation of energy consumption and energy efficiency of air filters. The differences between the scope of respective Recommendations are the following:

- **Eurovent 4/21 is an integral Recommendation for energy rating and filter performance comparison at standard reference conditions as a basis for the certification programme**
- **Eurovent 4/25 is a simplified version of this Recommendation to propose a consistent evaluation of energy consumption of air filters in the revised Regulation (EU) 1253/2014**

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.

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Important remarks

Eurovent 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

1. Introduction

The present document describes a procedure to estimate the energy consumption of air filters for general ventilation. The focus is on estimation under different operating conditions, including actual air flow rate, filter size, operating time and fan efficiency. Due to the large number of variables, comparing the energy performance of filters under different conditions is complex. For filter comparison, the dedicated Eurovent 4/21 is recommended.

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 is increasing. The related energy consumption during a certain period of time can be calculated from the integral average of the pressure drop over this period of time.

Typically, air filters are replaced when reaching a predefined final pressure drop (condition based method). Alternatively, based on hygiene considerations, air filters are changed based on a fixed time schedule (time based method). For example, in Germany, the VDI Recommendation 6022 recommends changing filters on a yearly base (first filter stage) or every two years (second filter stage). The time based method typically applies when the final pressure drop is not reached before the predefined change time is reached.

The aim of this document is to assess the average yearly energy consumption based on a laboratory test procedure, which can be the basis to give the user of an air filter an in-depth guidance for 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 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 methods provided in this document are based on laboratory test data with standardised test conditions, which may differ significantly from the individual application in a building ventilation unit. Hence, the average yearly energy consumption calculated in this document can be used as a rough estimation and relates only to the contribution of the air filters involved.

Fine dust filters with an efficiency $e\mathrm{PM}_{10} \geq 50\%$ and a respective face velocity higher than 1,2 m/s (1.500 m^3/h for 592 mm x 592 mm filter size) are rated according to this guideline.

2. 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. (1):

$$W = \frac{q_V \cdot \overline{\Delta p} \cdot t}{\eta \cdot 1000} \tag{1}$$

As given above, there are four variables to determine before calculating: The air volume flow rate q_V, the average pressure drop $\overline{\Delta p}$, the operating time t and the fan efficiency η. If fan efficiency and/or operating time are not known, the default values of Eurovent 4/21 can be used as a substitute:

t = 6.000 h/a

η = 0,5

Equation (1) is common for both the time based and condition based method. However, in case the yearly energy consumption is calculated using the time based method, $\overline{\Delta p}$ calculated according to Eq. (2) shall be used as the average filter pressure drop. For the condition base method, $\overline{\Delta p}$ calculated according to Eq. (3), (3a) or (3b) is substituted as the average filter pressure drop.

2.1 Time based method

In case filters are changed according to a fixed time schedule, the operating time of the filters is known, and the pressure drop curve and the final pressure drop have to be determined to calculate the average pressure drop. 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).

The average pressure drop can be estimated in laboratory with the following method. This has to be done with the volume flow rate of the actual application. To compare different filters for one application, q_V, t, η and dimensions must be the same for all filters.

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. See Annex 1 on how to deal with different face dimensions of the filter. The filter face velocity has to be above 1,2 m/s.

1. Carry out a full test according to the ISO 16890 series of standards at nominal volume flow rate and determine the *e*PM$_x$ efficiencies and the ISO *e*PM$_x$ 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 (rounded up to 10 g) 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, Δp_i) including the initial data point (m_0 = 0 g, Δp_0) (minimum of eight loading steps). 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 M_x given in Table 1. If the last loading step results in a total amount of dust that is slightly higher than M_x, linear interpolation can be used to define the values at the exact M_x. The 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 *e*PM$_1$	ISO *e*PM$_{2,5}$	ISO *e*PM$_{10}$
Amount of dust fed M_x for the flow rate q_V (m^3/s)*	$\frac{q_V}{0.944} \cdot 200$ g	$\frac{q_V}{0.944} \cdot 250$ g	$\frac{q_V}{0.944} \cdot 400$ g

Table 1: Dust amount used for Eq. (2)

*The amount of dust is based on estimated dust concentrations in real life: ePM$_1$: ~10 µg/m^3, ePM$_{2.5}$: ~12 µg/m^3, ePM$_{10}$: ~20 µg/m^3

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

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

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

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

(2) $$\overline{\Delta p} = \frac{1}{M_x} * \sum_{i=1}^{n} \overline{\Delta p_i} * \Delta m_i$$

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

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

2.2 Condition based method

In case filters are changed when they have reached the final pressure drop, the average pressure drop is not time dependent (as long as the time interval for calculating the average pressure drop always considers full filter lifetime intervals), and the only variable to determine the average pressure drop is the shape of the pressure drop curve as a function of the time. In this case, the average pressure drop can be estimated by using Eq. (3):

(3) $$\overline{\Delta p} = \frac{2}{3}\Delta p_0 + \frac{1}{3}\Delta p_{\text{final}}$$

where Δp_{final} is the predefined final pressure drop at which filters are changed.

In case the final pressure drop is defined as a multiple x of the initial pressure drop Eq. (3) can be also written as Eq. (3a):

(3a) $\Delta p_{\text{final}} = x \cdot \Delta p_0$ and $\overline{\Delta p} = \Delta p_0 \left(\frac{2}{3} + \frac{1}{3} x\right)$

assuming, after EN 13053, that the multiplier x equals 3, the equation becomes $\overline{\Delta p} = 1.67 \cdot \Delta p_0$

In case the final pressure is defined as the initial pressure drop increased by a certain value Δp, Eq. (3) can be also written as Eq. (3b):

(3b) $\Delta p_{\text{final}} = \Delta p_0 + \Delta p$ and $\overline{\Delta p} = \Delta p_0 + \frac{\Delta p}{3}$

assuming, after EN 13053, that Δp equals 100 Pa, the equation becomes $\overline{\Delta p} = \Delta p_0 + 33.3$

Calculate the yearly energy consumption W related to the filter using Eq. (1) and $\overline{\Delta p}$ determined according to (3), (3a) or (3b).

3. Symbols

$e\text{PM}_x$	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	
	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	[g]
	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	
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]
Δp_{final}	Predefined final pressure drop at which filters are changed	[Pa]
q_V	Air volume flow rate at filter	[m³/s]
$q_V(act)$	Air volume flow rate at filter with face dimension other than 592 x 592 mm used to calculate $W(act)$ according to Annex 1	[m³/s]
t	Time of operation	[h]
W	Yearly energy consumption	[kWh]
$W(act)$	Yearly energy consumption of a filter with face dimensions other than 592 x 592 mm calculated according to Annex 1	[kWh]

4. Example

As an example, the calculation method is shown based on test results for a panel filter rated as ISO *e*PM$_1$ 50% at 0,277 m^3/s according to EN ISO 16890.

The Dimensions of the filter for width x height x depth are 592 mm x 287 mm x 50 mm. According to Annex 1, this filter could be calculated with a test filter in the same filter family. In this case, a filter with dimensions 592 mm x 592 mm x 50 mm and an accordingly fitted volume flow rate of 0,556 m^3/s.

At this flow rate, 117,8 g test dust are required in total according to Table 1.

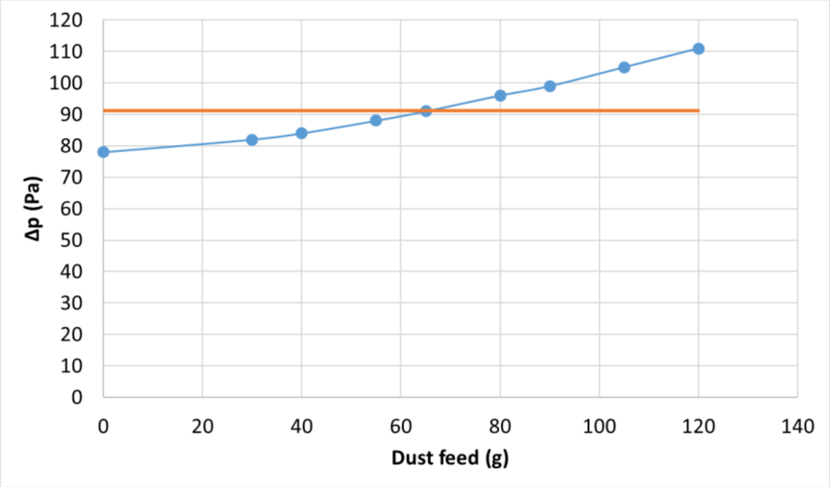

Figure 1: Pressure drop as a function of the dust loading at 0,944 m^3/s according to EN ISO 16890-3. The straight orange line marks the average pressure drop.

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	78		
1	30	82	30	80,0
2	40	84	10	83,0
3	55	88	15	86,0
4	65	91	10	89,5
5	80	96	15	93,5
6	90	99	10	97,5
7	105	105	15	102,0
8	120	111	15	107,6

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

Linear interpolation between steps 7 and 8 results in an average pressure drop of 107.56 Pa for the last step up to 117.8 g test dust. By using Eq. (3) with the data given in Table 2, the average pressure drop calculates to $\overline{\Delta p}$ = 90,8 Pa and the yearly energy consumption to W = 301,9 kWh/a for the 592 mm x 287 mm x 50 mm filter.

5. 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. Standardised 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

[7] EN 13053:2019: Ventilation for buildings - Air handling units - Rating and performance for units, components and sections, 2019

Annex 1

Filter with face dimensions different than the standard size 592 mm x 592 mm can still be estimated with a standard sized filter of the same filter family. After carrying out a test with a standard sized filter, the energy consumption of the nonstandard filter in the same filter family is calculated with the following formula:

$$W(act) = W \cdot \frac{q_v(act)}{q_V}$$

where W(act) is the energy consumption and q_v(act) the volume flow rate of the nonstandard sized filter under consideration. W is the energy consumption and q_v the volume flow rate of the tested 592 mm x 592 mm filter.

Filter family

Filters are part of the same filter family under the following conditions drawn on EPC 11 FIL – 04-2020 'Technical certification rules of the Eurovent Certified Performance Mark – Air Filters':

1. The same filter material
2. The same basic construction (e.g. bag, V-type, etc.)
3. The same face velocity: Rated airflow / min. net filter area (does not have to be published); the airflow rate shall be adapted to the face area with acceptance criteria of +/- 10%
4. The same length/depth of the overall filter element with acceptance criteria of +/- 10% or 50 mm whatever is the smaller
5. For Bag and V-Type filters, the same ratio of filter medium area to front face area with acceptance criteria of +/- 10%
6. Same initial pressure drop with acceptance criteria of +/- 10%
7. The same ePMx group
8. The same ISO efficiency rating
9. Published data available about: Basic construction, filter media, filter class available via internet or other published sales brochures

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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.

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