EUROVENT

EUROVENT 4/11

ENERGY EFFICIENCY CLASSIFICATION OF AIR FILTERS FOR GENERAL VENTILATION PURPOSES

EUROVENT 4/11

First Edition – 2011

Published by EUROVENT

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1. INTRODUCTION

In the context of increasing energy prices and the imperative of reducing CO_2 emissions, the energy consumption related to air filters has become the focus of attention. Currently, air filters are classified only by their average particle collection efficiency according to the European standard EN 779. The aim of this guideline is to define a method of air filter classification with regard to energy-efficient operation.

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. As a laboratory test method, the average pressure drop is determined from an ASHRAE dust loading of the filter as defined in EN 779.

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.

To define an energy efficiency classification system for air filters, we consider only the portion of the total energy consumption which is related to the filters' pressure drop. This can be calculated using Eq. (1):

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

Where: q_V = 0.944 m³/s ; t = 6000 h and η = 0.50

Furthermore, we consider the volume flow rate 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 be fixed at 0.50, which can be considered as a typical average efficiency of a fan in an air handling unit.

3. ENERGY EFFICIENCY EVALUATION AND CLASSIFICATION

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

1.) Carry out a full test to EN 779 at a flow rate q_V = 0.944 m³/s. As part of this test, the air filter is loaded with ASHRAE dust to the final pressure drop (250 Pa in case of a course dust filter and of 450 Pa in case of a fine dust filter). During the course of dust loading, the pressure drop curve shall be recorded with at least five data points.

2.) Use the polynomial of 4th order $\Delta p = a \cdot m^4 + b \cdot m^3 + c \cdot m^2 + d \cdot m + \Delta p_i$ and curve fit the parameter a, b, c and d to the measured pressure drop data as a function of the dust loading, where Δp_i is the initial pressure drop of the filter at the flow rate q_V = 0.944 m³/s with no dust loading.

3.) Calculate the average pressure drop using Eq. (2):

$$\overline{\Delta p} = \frac{1}{M_x} \int_0^{M_x} \Delta p(m) \cdot \mathrm{d}m = \tfrac{1}{5} a \cdot M_x^4 + \tfrac{1}{4} b \cdot M_x^3 + \tfrac{1}{3} c \cdot M_x^2 + \tfrac{1}{2} d \cdot M_x + \Delta p_i \quad (2)$$

Where M_x represents a fixed amount of dust simulating the dust loading of a filter after one year of operation. It depends on the group x = M, G or F where the filter under concern belongs to. For filters of group G (coarse dust filters) M_G = 350 g, for filter of group M (medium grade filters) M_M = 250 g and for filters of group F (fine dust filters) M_F = 100 g of ASHRAE dust.

If the dust holding capacity of the filter – the amount of dust loaded to the filter to reach the final pressure drop to EN 779 – is lower than M_x, the filter shall be classified to the energy efficiency class G and the classification procedure can be stopped.

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

The value W shall be compared to the class limits defined in the Table 1 for different energy efficiency classes to classify the filter under concern, depending of its filter class to EN 779.

Filter class	G4	M5	M6	F7	F8	F9
MTE	—	—	—	MTE ≥ 35%	MTE ≥ 55%	MTE ≥ 70%
	M_G = 350 g ASHRAE	M_M = 250 g ASHRAE		M_F = 100 g ASHRAE		
A	0 – 600 kWh	0 – 650 kWh	0 – 800 kWh	0 – 1200 kWh	0 – 1600 kWh	0 – 2000 kWh
B	> 600 kWh – 700 kWh	> 650 kWh – 780 kWh	> 800 kWh – 950 kWh	> 1200 kWh – 1450 kWh	> 1600 kWh – 1950 kWh	> 2000 kWh – 2500 kWh
C	> 700 kWh – 800 kWh	> 780 kWh – 910 kWh	> 950 kWh – 1100 kWh	> 1450 kWh – 1700 kWh	> 1950 kWh – 2300 kWh	> 2500 kWh – 3000 kWh
D	> 800 kWh – 900 kWh	> 910 kWh – 1040 kWh	> 1100 kWh – 1250 kWh	> 1700 kWh – 1950 kWh	> 2300 kWh – 2650 kWh	> 3000 kWh – 3500 kWh
E	> 900 kWh – 1000 kWh	> 1040 kWh – 1170 kWh	> 1250 kWh – 1400 kWh	> 1950 kWh – 2200 kWh	> 2650 kWh – 3000 kWh	> 3500 kWh – 4000 kWh
F	> 1000 kWh – 1100 kWh	> 1170 kWh – 1300 kWh	> 1400 kWh – 1550 kWh	> 2200 kWh – 2450 kWh	> 3000 kWh – 3350 kWh	> 4000 kWh – 4500 kWh
G	> 1100 kWh	> 1300 kWh	> 1550 kWh	> 2450 kWh	> 3350 kWh	> 4500 kWh

Table 1: Energy efficiency class limits for each filter class to EN 779 measured at 0.944 m^3/s

All data used for the energy efficiency classification (filter class, pressure drop curve, MTE) shall result from the same EN 779 test carried out at 0.944 m^3/s.

The minimum test efficiency (MTE) is the lowest particle collection efficiency for 0.4 µm particles among the initial efficiency, conditioned efficiency and the lowest efficiency measured throughout the dust loading procedure of the test according to EN 779.

4. ENERGY EFFICIENCY LABEL

An energy efficiency label based on the energy efficiency evaluation method described here shall, as minimum requirement, contain information on the energy efficiency class according to Table 1, the yearly energy consumption W to Eq. (1), the filter class to EN 779, and the volume flow rate q_V at which the test was conducted.

5. SYMBOLS

a, b, c, d	Parameters of a polynomial of 4th order to be fitted to the pressure drop curve.
η	Efficiency of a fan for the transmission of electrical energy into energy content of the air flow field. As an representative average value for the different installations and operating conditions η is assumed 0.50
MTE	Minimum Test Efficiency. Lowest efficiency for 0.4 µm particles among the initial efficiency, conditioned efficiency and the lowest efficiency measured throughout the dust loading procedure of the test to EN 779
M_x	Amount of ASHRAE dust in g used to calculate the average pressure drop. M_x represents one of the three values M_G = 350 g for group G filters, M_M = 250 g for group M filters, or M_F = 100 g for group F filters.
Δp_i	Initial pressure drop of an air filter, Pa
$\overline{\Delta p}$	Average pressure drop of an air filter, Pa
q_V	Air volume flow rate at filter, m³/s
t	Time of operation in h. For an air filter during a period of one year, a total operating time of 6000 h is assumed.
W	Yearly energy consumption, kWh

6. EXAMPLE

As an example, the calculation method is shown based on the EN 779 test results for a F8 rigid filter tested at 0.944 m³/s.

EN 779 - Air filter test results (Abstract)				
General				
Test no.: Report no.:	XYZ	Date of test:		Testing organisation: XYZ laboratories
Device tested				
Model: Construction:	ABC rigid filter 8x V-banks	Manufacturer: Net effective filter area:	Sample Filter Ltd. 18 m²	Weight 5063.2 g Dim.: 592x592x292 mm
Test data				
Test air flow rate: 0.944 m³/s	Test air temperature: 21 °C	Test air relative humidity: 34 %	Test aerosol: DEHS	Loading dust: ASHRAE
Results				
Initial pressure drop: 75 Pa	Initial arrestance: 100 %	Initial efficiency: 58 %	Dust holding capacity: 535 g	Efficiency (0.4 µm) of media (Annex A), Untreated: 61 % IPA treated: 57 %
Final pressure drop: 449 Pa	Average arrestance: 99 %	Average efficiency: 92 %	Filter class: **F8**	
Remarks				

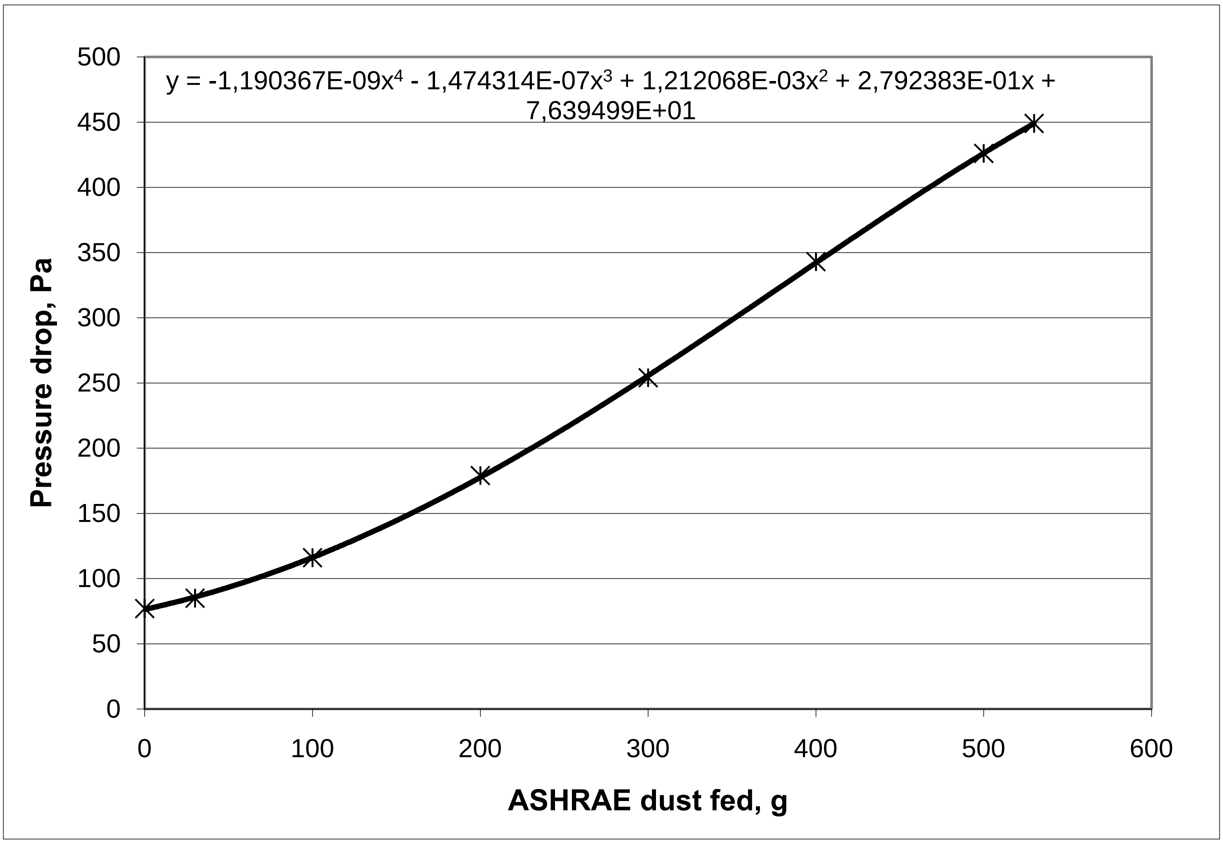

Figure 1: Pressure drop as a function of the dust loading as result of the EN 779 test at 0.944 m³/s. The function plotted on the top of the diagram shows the parameters a, b, c and d of Eq. (2) resulting from a curve fit of a polynomial of 4th order to the test data

Table 2: Test data for the pressure drop as a function of the ASHRAE dust fed

Dust fed g	*Δp*@0.944m³/s Pa
0	77
30	85
100	116
200	179
300	254
400	343
500	426
530	449

The initial pressure drop of the filter at 0.944 m³/s is $\Delta p_{\mathrm{i}} = 77$ Pa. Based on the curve fit to the data shown in the table on the left, the parameters for Eq. (2) calculate to:

a = - 1.190367 x 10^{-9} Pa.g^{-4}

b = - 1.47431 x 10^{-7} Pa.g^{-3}

c = 1.212068 x 10^{-3} Pa.g^{-2}

d = 0.2792383 x Pa.g^{-1}

With $M_x = M_{\mathrm{F}} = 100$ g using Eq. (2) the average pressure drop computes in this example to $\overline{\Delta p} = 95$ Pa.
Hence, using Eq. (1) the yearly energy consumption gives: *W* = 1074 kWh.

From the EN 779 test in this example, the average filter efficiency measures to 92%, and the MTE to 57%. Hence, the filter is classified F8 to EN 779 at 0.944 m^3/s. With these data the energy efficiency class A reads from Table 1.