FILTER PRESSURE DROP CONTROL IN BALANCED VENTILATION SYSTEMS FOR DWELLINGS

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ABSTRACT

As a consequence of the energy and environmental issues, it is necessary to reduce the energy consumption of buildings. So, the air tightness of building envelopes is being improved and the air change rate due to infiltration is decreasing. It is then even more important than in the past that the buildings are equipped with well designed and working ventilation systems in order that the air renewal within buildings is ensured. In this context, the market of balanced ventilation systems with heat recovery for dwellings is growing.

In order to maintain the air flows of the balanced ventilation systems and to control their electricity consumption (one fan on each air circuit), it is necessary to define a maximum pressure drop value for the filters above which they should be replaced.

The objective of our study was to determine the pressure drop increase of commercially available filters in balanced ventilation systems for dwellings as they are continuously used for long-term (1 year) with real outdoor air. The efficiency by particle size as well as the mass of dust collected were also reported.

A very popular filter for balanced ventilation systems for dwellings is the panel mini-pleated filter type and this is why it has been considered in our study. It has been decided to study G4, F5 and F7 panel mini-pleated filters. Some of the studied F7 filters have been tested with and without a prefilter (class G4) installed upstream.

Choosing a filter for balanced ventilation systems if not only a question of class. It has been shown that from the energy consumption point of view, it is better to use a F7 filter protected by a prefilter installed upstream instead of the same F7 filter alone because the increase of pressure drop is lower. A G4 prefilter appears suitable for the protection of the panel mini-pleated F7 filters but a more efficient prefilter can be necessary if the efficiency of the fine filter is high. Regarding the popular panel mini-pleated technique, the pleat width is an important parameter that has to be high enough to prevent fast surface loading of the filter. So a pleat width smaller than about 5 mm should be avoided.

Energy savings issues should not reduce indoor air quality. The efficiency of the filters has to be high enough to insure that the balanced ventilation systems will provide clean air to the building and its occupants (well being and health issues).

Finally, the results of our study are of a great interest for the design of filters for balanced ventilation systems in the context of low energy buildings.

KEYWORDS

Ventilation, Balanced ventilation, Air filtration, Filter pressure drop, Indoor air quality

1 INTRODUCTION

The European Commission (European Commission, 2013) claims that buildings consumed 41 % of the final energy in Europe in 2010. Moreover, the average energy consumption of the building sector (220 kWh/m^2 in 2009) has increased by around 1 % per year since 1990, with residential buildings (around 200 kWh/m^2 on average) representing a 0.6 % per year increase compared to 1.5 % per year for non-residential buildings (around 200 kWh/m^2 on average).

As a consequence of the energy and environmental issues, it is necessary to reduce the energy consumption of buildings. So, the air tightness of building envelopes is being improved and the air change rate due to infiltration is decreasing. It is then even more important than in the past that the buildings are equipped with well designed and working ventilation systems in order that the air renewal within buildings is ensured.

In this context, the stock of balanced ventilation systems with heat recovery in existing dwellings is still small (only 1.5 % of European residential one or two family houses and only 7 % of non-residential and collective residential buildings are equipped (European Commission, 2012)) but the market is growing. EVIA (the European Ventilation Industry Association) estimates that the 2012 market of balanced ventilation systems for residential buildings in Europe exceeded the 400 000 units, with an annual increase of 25 % from 2010 (EVIA, 2012).

Balanced ventilation systems with heat recovery include air filters used to protect the heat exchanger (both on the fresh air and exhaust air sides) and to enhance the quality of supplied air. The assessment of thermal, acoustic and airflow performances of balanced ventilation systems for dwellings relies on the European standard EN 13141-7 (2011). National labels provide additional requirements. For example, the French “NF” mark requires that the system provides the air flow required by the French regulation (French regulation, 1982) when used with a typical ductwork. This mark also requires that the filter classes according to EN 779 (2002) are at least F5 (since the revision of EN 779 in 2012, F5 class has been replaced by M5 class, all the performances being equal) on the outdoor air side and G4 on the exhaust air side. All the tests for certification are operated on new systems. One of the issues is the guarantee of those performances during their real use. In spite of the recent development of the balanced ventilation systems market, almost no information is available on the filters characteristics and performance changes along time when used in real life.

In order to maintain the air flows of the balanced ventilation systems and to control their electricity consumption (one fan on each air circuit), it is necessary to define a maximum pressure drop value for the filters above which they should be replaced. So, the initial pressure drop of the filters as well as the increase of their pressure drop as function of time have to be as low as possible.

The objective of our study was to determine the pressure drop increase of commercially available filters in balanced ventilation systems for dwellings as they are continuously used for long-term (1 year) with real outdoor air. The efficiency by particle size as well as the mass of dust collected were also reported.

2 AIR FILTERS FOR BALANCED VENTILATION SYSTEMS

A balanced ventilation system for dwellings is typically composed of one ductwork for supply of air from outside and one other ductwork for indoor air exhaust. In balanced ventilation systems with heat recovery, heat transfer between exhaust and outdoor air is made possible thanks to an air-to-air heat exchanger inserted in a ventilation box together with 2 fans. The ventilation box is placed at the crossing of the 2 ductworks. Heat transfer allows to heat supplied air during the cold season and to cool it during the warm season. The heat exchanger is protected upstream by 2 sets of filters, one on the outdoor air side and the other on the exhaust air side. There is a wide variety of filters on the market including different sizes, shapes, filter medium, medium configuration and class efficiency. A very popular filter for balanced ventilation systems for dwellings is the panel mini-pleated filter type and this is why it has been considered in our study.

3 EXPERIMENTAL METHOD

Two different balanced ventilation boxes with heat recovery were installed at CETIAT (Villeurbanne, France) for continuous long term running at more or less constant air flow rate (120 m³/h) in order to allow long time (1 year between May 2010-May 2011 or May 2011-May 2012 or May 2012-May 2013) filter testing with natural dust loading. The 2 circuits of each ventilation box that are normally used for respectively outdoor and exhaust air flows were connected to a same outdoor air inlet. Because of the symmetry of the systems with respect to outdoor vs. exhaust air circuits, this allows to test 4 different filtration configurations in parallel with the same outdoor air (typical of that of a large European city) without changing the way in which the filters are normally installed.

It has been decided to study G4 (equivalent to MERV7 or MERV8 class according to ANSI/ASHRAE Standard 52.2 (2012)), F5 (equivalent to MERV9 to MERV11 class) and F7 (equivalent to MERV13 class) panel mini-pleated filters. Some of the studied F7 filters have been tested with and without a prefilter (class G4) installed upstream. F7 filter class is widely used in balanced ventilation systems for dwellings and the prefilter is intended to prevent fast filter pressure drop increase due to the loading of the F7 filters by particles. In that case, for each ventilation box, the F7 filter is used alone in one circuit and protected by a G4 filter in the other circuit.

The main characteristics of the studied filters are reported in Table 1. Filtering medium of filters B and C is made of glass fibres while that of filter D, E and F is made of electrostatically charged synthetic fibres (electret). Filters E and F have approximately the same filtration area, are manufactured with the same filtering medium but have different pleat width and also different thickness.

F7 filters C and D have been studied with and without a G4 filter installed upstream (bag filter installed upstream of filter C and plan filter installed upstream of filter D).

The 2 balanced ventilation systems were regularly stopped (every 6 to 8 weeks) in order to remove the filters for performance measurements (pressure drop, mass of retained dust and efficiency by particle size). The amount of dust retained by the filters was determined by direct weighing of the filters. A test rig used for EN 779 filter testing was used for pressure drop and fractional efficiency (by particle size with DEHS aerosol in the particle size range 0.2 to 5 µm) measurements.

Table 1 : Main filter characteristics

Filter	A	B	C	D	E	F
Filtering medium	Unknown	Glass fibre	Glass fibre	Electret synthetic fibre	Electret synthetic fibre	Electret synthetic fibre
Class (EN 779)	G4	F5*	F7**	F7**	F7**	F7**
Filtration area (m²)	0.42	0.88	1.00	0.66	0.49	0.50
Thickness (mm)	10	42	44	18	20	48
Number of pleats	139	54	59	97	65	26
Pleat width (mm)	2.8	4.8	4.4	4.0	6.1	10.4
Initial pressure drop at 120 m³/h (Pa)	15	9	20	70	24	20

** Since the revision of EN 779 in 2012, F5 class has been replaced by M5 class, all the performances being equal*

*** Since the revision of EN 779 in 2012, F7 class takes into account not only the average efficiency but also the minimum efficiency at 0.4 µm*

4 RESULTS

The results of the measurements of the filter performances are shown in Figures 1 to 6.
The filtration efficiency (left ordinate axis) is plotted for 2 different particle sizes (0.4 µm for the 0.3-0.5 µm optical particle counter channel and 2.5 µm for the 2-3 µm optical particle counter channel) representative of the whole particle size range studied (0.2 to 5 µm) for a fine (0.4 µm) and a coarse (2.5 µm) fraction consideration.
The filter pressure drop increase (current pressure drop minus initial pressure drop) is shown on the right ordinate axis. Filtration efficiency and pressure drop increase are expressed as function of time (abscissa axis) over a 1 year period of time. It has to be noted that filter B (Figure 2) was not fed with air for about 2 weeks at the end of 2012 because of electrical failure of the motor of the fan.
Tests have been stopped after 9 months for filter D (Figure 4) because the pressure drop increase was too big (approximately 1000 Pa) for this kind of application.

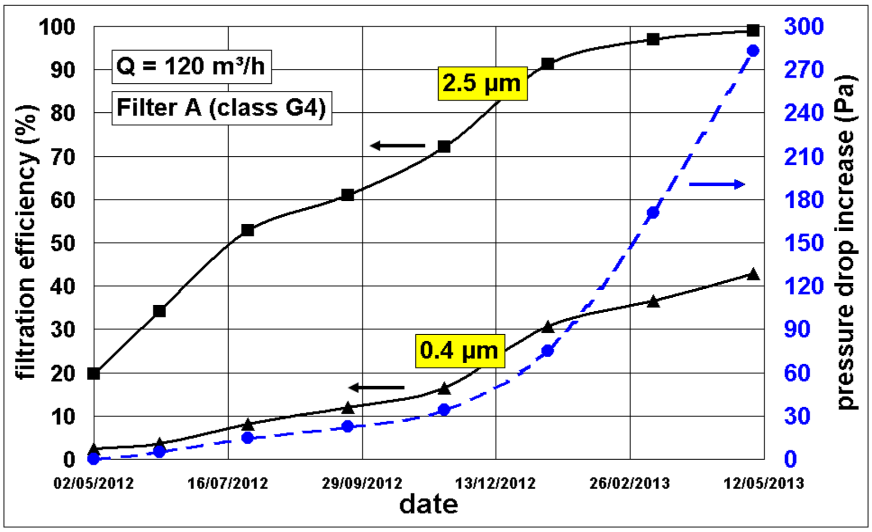

Figure 1 : Performances of filter A

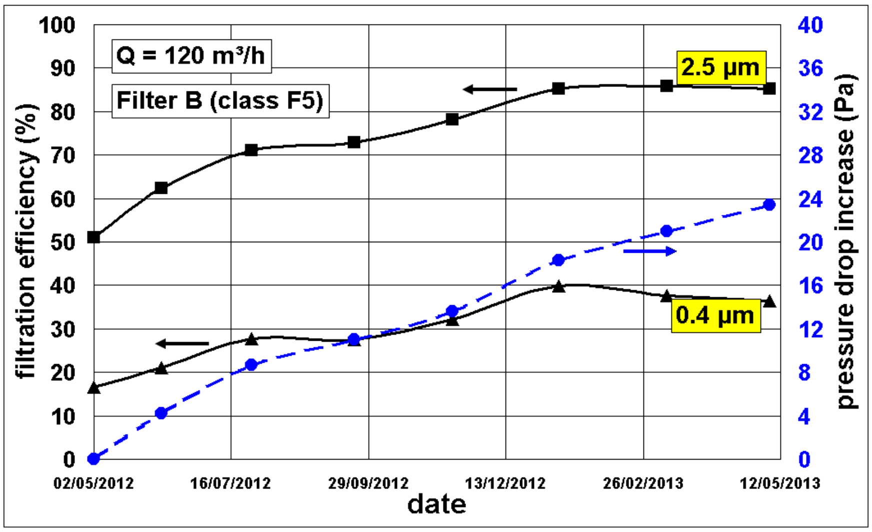

Figure 2 : Performances of filter B

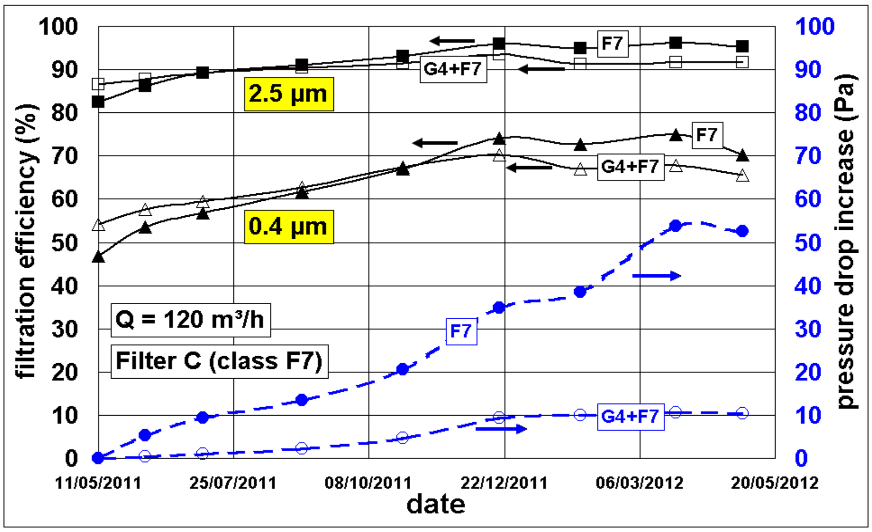

Figure 3 : Performances of filter C

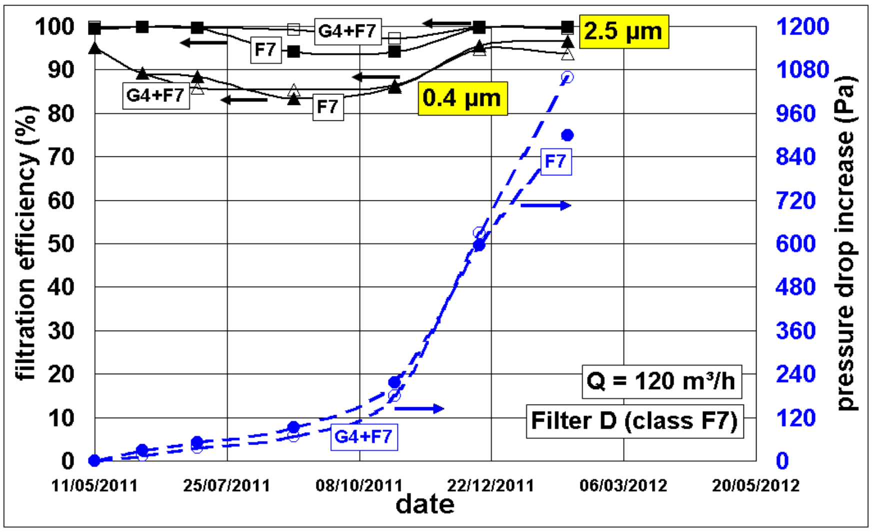

Figure 4 : Performances of filter D

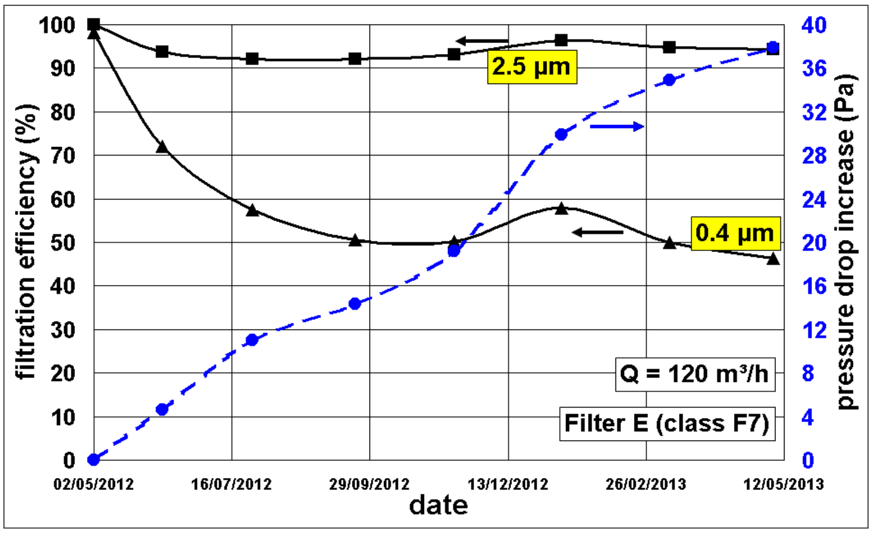

Figure 5 : Performances of filter E

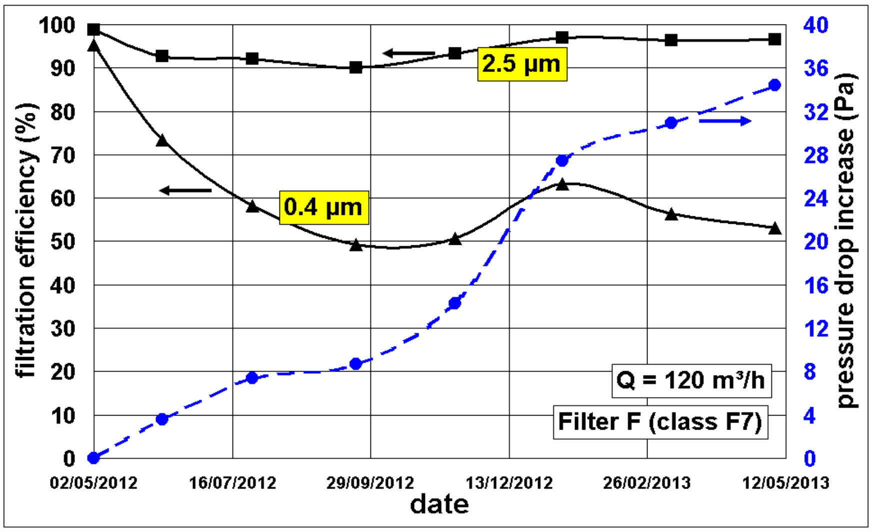

Figure 6 : Performances of filter F

5 DISCUSSION

5.1 Filter performances

The initial efficiency of the G4 filter (filter A, Figure 1) is the lowest of all the tested filters. Its initial efficiency at 0.4 µm was only a few percents (3.2 %) in line with was is expected for a G filter. Its efficiency has increased a lot after 1 year, reaching more than 40 % at 0.4 µm and 99 % at 2.5 µm. This especially high level is associated to a very high pressure drop increase, more than 280 Pa after 1 year, due to a very high loading by particles on the filter surface (Figure 7). The pressure drop has increased linearly for 6 months then has increased much more rapidly after a transition point between depth loading and surface loading.

The pressure drop increase of the F5 filter (filter B, Figure 2) has been controlled with a maximum value of 23 Pa reached after 1 year despite a high loading by particles (Figure 8). Its efficiency has increased linearly for about 8 months then it has remained more or less constant. The same phenomenon has been observed with filter C (class F7, Figure 3) made of the same material and using the same pleat technique ; its maximum pressure drop increase after 1 year was 54 Pa.

Figure 7 : Filter A after 1 year of use

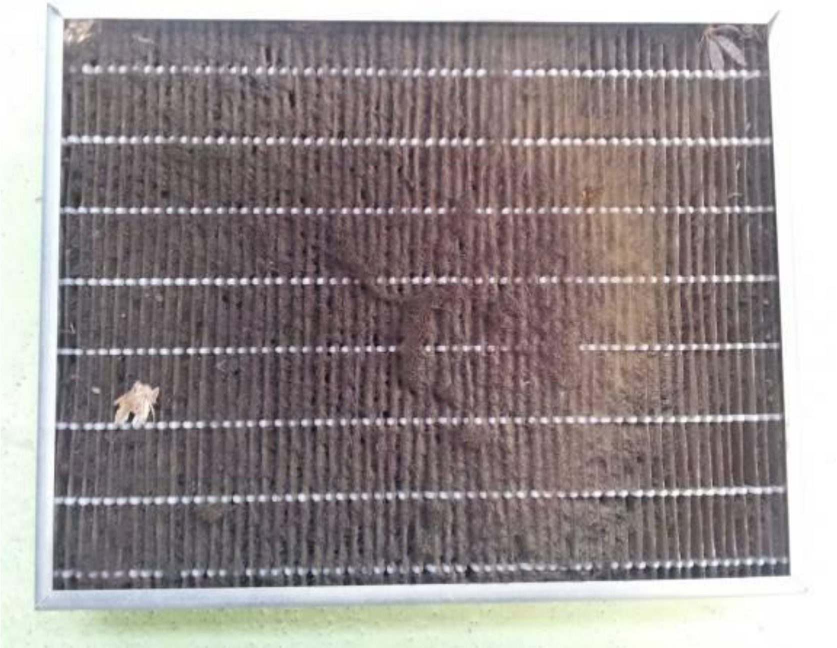

Figure 8 : Filter B after 1 year of use

The pressure drop of filter D (class F7, Figure 4) has increased linearly for 4 months then has increased much more quickly after a transition point between depth loading and surface loading. A lot of dust has deposited on the surface of the filter. Moreover, the pleat structure has been deformed (see next paragraph). Its efficiency has decreased a bit due to the loss of the electrostatic effects. This phenomenon has been met during testing of other type of electret filters whose results have been published in others papers (Ginestet et al, 2011 and 2013).

The 2 F7 electret filters (filters E and F, Figures 5 and 6) made of the same filtering medium and having the same filtration area behaved in the same way. Their pressure drop has increased more or less linearly while their efficiency has decreased due to the loss of the electrostatic effects. The pressure drop increase has been limited to respectively 38 Pa (filter E) and 34 Pa (filter F) after 1 year.

5.2 Influence of the use of a prefilter

The use of a G4 prefilter upstream of the F7 filter C has allowed to limit the pressure drop increase to 10 Pa instead of 54 Pa when no prefilter is used (Figure 3). 60 % to 80 % in mass of the particles challenging the filters have been retained by the G4 filter and thus loading of the F7 filter C is limited. When the F7 filter is not protected by the G4 prefilter, a thin layer of fibres and particles covers the front area of the filter (Figure 9) which is not observed when the prefilter is used (Figure 10). This phenomenon and this kind of results (less pressure drop increase with the use of a prefilter) have been observed during testing of other types of F7 filters whose results have been published in others papers (Ginestet et al, 2011 and 2013).

For F7 filter D, the pressure drop increase was not different with or without the use of a prefilter (Figure 4). The efficiency of this F7 filter is very high, as well as its initial pressure drop, and the amount of dust retained by the prefilter was not enough to slow down its loading and pressure drop increase. Nevertheless, the amount of dust covering the front surface of the F7 filter not protected by the prefilter (Figure 11) appears higher than that of the protected F7 filter (Figure 12) (the mass increase of the non protected filter D is higher than that of the protected filter D). For this F7 filter a more efficient prefilter would have been necessary.


Figure 9 : Filter C not protected by a prefilter, after 1 year of use

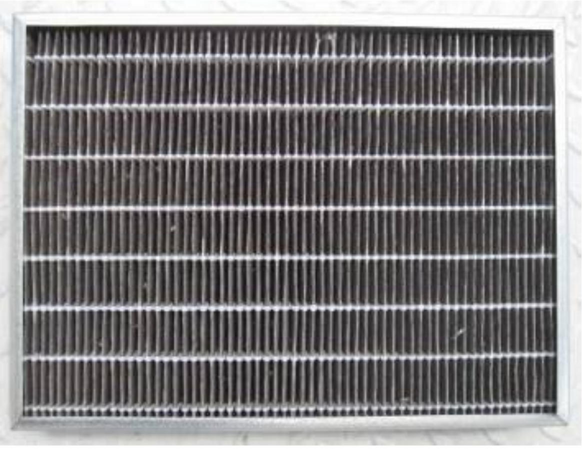
Figure 10 : Filter C protected by a prefilter, after 1 year of use


Figure 11 : Filter D not protected by a prefilter, after 9 months of use

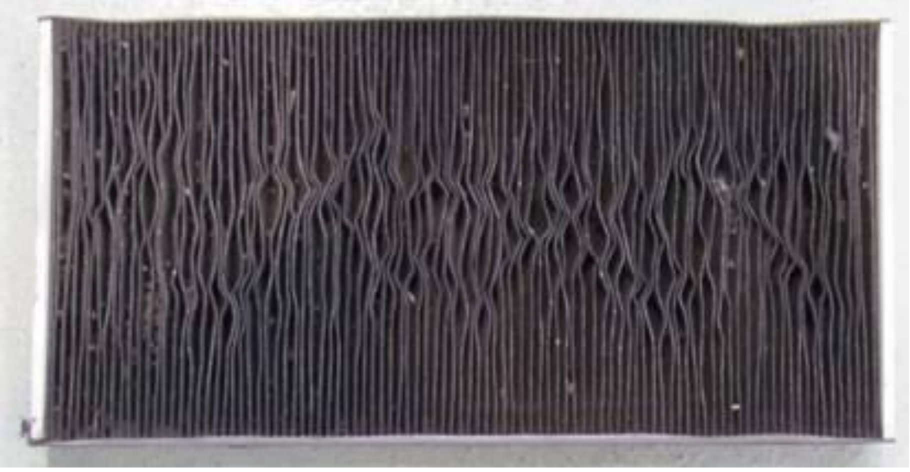
Figure 12 : Filter D protected by a prefilter, after 9 months of use

5.3 Influence of the pleat width

The results for filters E (Figure 5) and F (Figure 6) (these filters have the same filtration area and are made of the same filtering medium but have a different pleat width) show that a more opened pleat structure (10.4 mm pleat width for filter F and 6.1 mm pleat width for filter E), reduces by more than 10 % the pressure drop increase (34 Pa for filter F instead of 38 Pa for filter E) because of less risk to promote loading and blocking of pleat opening by particles (Figures 13 and 14). The initial pressure drop of the more opened filter is also lower (20 Pa for filter F instead of 24 Pa for filter E, see Table 1).

Figure 13 : Filter E after 1 year of use (pleat width 6.1 mm)

Figure 14 : Filter F after 1 year of use (pleat width 10.4 mm)

Despite its low efficiency, the pressure drop increase of G4 filter A (Figure 1) was particularly high because its pleat width is very small (2.8 mm) then many pleats were blocked and overloaded by particles (Figure 7). The low pleat depth (10 mm) can also explain fast loading of the pleats.

6 CONCLUSIONS

As the balanced ventilation with heat recovery is more and more used in dwellings and because it is necessary to reduce the energy consumption of the fans of these systems, the pressure drop increase of the filters along their life must be limited.

On the occasion of long term tests of filters typically used in balanced ventilation boxes (panel mini-pleated filters), it has been shown that from the energy consumption point of view, it is better to use a F7 filter protected by a prefilter installed upstream instead of the same F7 filter alone because the increase of pressure drop is lower. A G4 prefilter appears suitable for the protection of the panel mini-pleated F7 filters but a more efficient prefilter can be necessary if the efficiency of the fine filter is high. More generally, the filtration of the balanced ventilation systems has to be well designed in such a way that a prefilter and a fine filter are used in series (in separate units or in one unit), the efficiency of the prefilter being adapted to the efficiency of the fine filter in order to ensure lower pressure drop increase, reduced filter maintenance and lower energy consumption.

Choosing a filter for balanced ventilation systems with heat recovery is not only a question of class. Regarding the popular panel mini-pleated technique, the pleat width is an important parameter which has to be high enough to prevent fast surface loading of the filters. So a pleat width smaller than about 5 mm should be avoided.

Energy savings issues should not reduce indoor air quality. The efficiency of the filters has to be high enough to ensure that the balanced ventilation systems will provide clean air to the building and its occupants (well being and health issues). Engineers have to design filters with acceptable pressure drop increase together with high filtration efficiency : this compromise is still difficult to achieve.

7 ACKNOWLEDGEMENTS

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