Energy performance of active polarization filters vs. conventional filters in HVAC systems

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ABSTRACT

Pressure drop due to filters embedded in HVAC systems is one of the energy loss causes in building air conditioning systems, which can become important in large all-air systems with highly demanding filtering needs, such as hospitals, clean rooms, laboratories or pharmaceutical environments. This pressure drop increases with filter use, since grid spacing diminishes with filtering effect, due to accumulation of particles in the grid.

This energy loss can be partially avoided with the use of special filters, with the same filtering effect but that, based in a different filtering technology, lead to a lesser head loss. In this work we consider active polarization filters, which use an active electrostatic field to polarize both the fibers of a media pad and the particles to be removed. The polarized particles are drawn to the polarized media fibers and to each other, form bigger clusters that are more easily captured in the grid. This way, with a coarse filter (and consequently a lesser pressure drop) an equivalent filtering effect is achieved.

The aim of this work is to assess the effect in final energy use of a building of this kind of filters compared to conventional ones, during a filter life period between two substitution/cleaning of the filters.

A 7,500 m^2 non-residential building (office building) with a ventilation system has been chosen to perform a simulation with each one of the mentioned types of filters, which allows evaluating the energy consumption difference and the corresponding economic savings. This case has been considered as an average case, being the influence of the filters over the total energy consumed restricted, since filtering level is not very demanding and HVAC system considered is not an all-air system (VRV systems are considered for HVAC), where air flow levels are usually higher and so is consumed fan energy. However, an annual saving of more than a 7% and a cumulated saving in a 5 year life period of a 6% over the final energy consumption is achieved considering unused filters for case former mentioned.

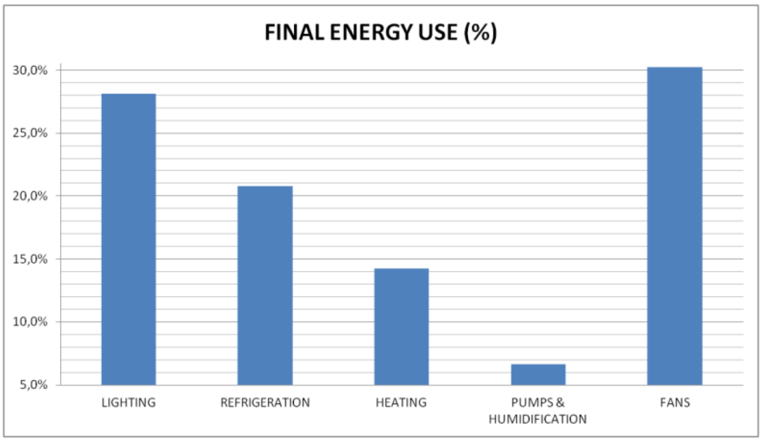
KEYWORDS

Energy efficiency, polarized filters, building energy savings.

1 INTRODUCTION

Nowadays, air transport is one of the most important sources of energy consumption in building's energy performance, thus a reduction in energy consumption in ventilation leads to an important reduction in building final energy consumption. In figure 1, a standard consumption distribution corresponding to a typical office building fulfilling Spanish energy Standards is shown.

Figure 1: Building final energy consumption in an office fulfilling Spanish Standards.



Many studies, among others, those performed by Brothers (Brothers et al., 1986), Wang (Wang et al., 1999), Webster (Webster et al., 2002), and Yang (Yang et al.,2011) have been made about fan energy consumption in air systems, mainly regarded to the importance of control over the flow amount in variable air volume systems (VAV).

Fan energy demand depends not only on the demanded air flow, but also in the pressure drop that must be overcome along the ductwork. Within this ductwork, were are going to focus in an important element, the filters, for two reasons: in one hand, their use is compulsory, and though they must be present in every single HVAC air system, and on the other hand, their pressure drop is significant in all cases, above all in those where sanitary facilities are involved.

The use of air filters which allow reducing the pressure drop inside the air handling units lowers the energy demanded by air handling units' fans improving the building energy performance and reducing consumptions of final energy, primary energy and CO_2 emissions.

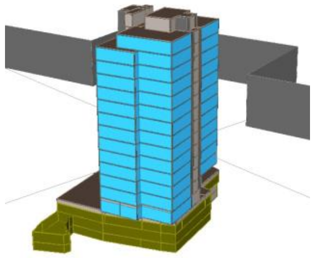
In this context, polarized filters use electricity in order to attract dust allowing the use of coarse grids that ease air pass reducing pressure drop and consequently reducing air handling units' fan power.

In this work, energy performance of polarized filters and conventional filters is assessed in a ventilation system of a standard office building in Madrid.

2 BASELINE DATA

A thirteen floor height office of 7,500 square meters located in Madrid with three underground floors (see figure 2) has been modelled to perform this study.

Figure 2: Building simulation model



Fan-coils and air handling units were considered for building's HVAC equipment, and ventilation system is driven by two CAV AHUs of 22.050m^3/h each. Airflow moved by the building air handling units was dimensioned according to Spanish regulations.

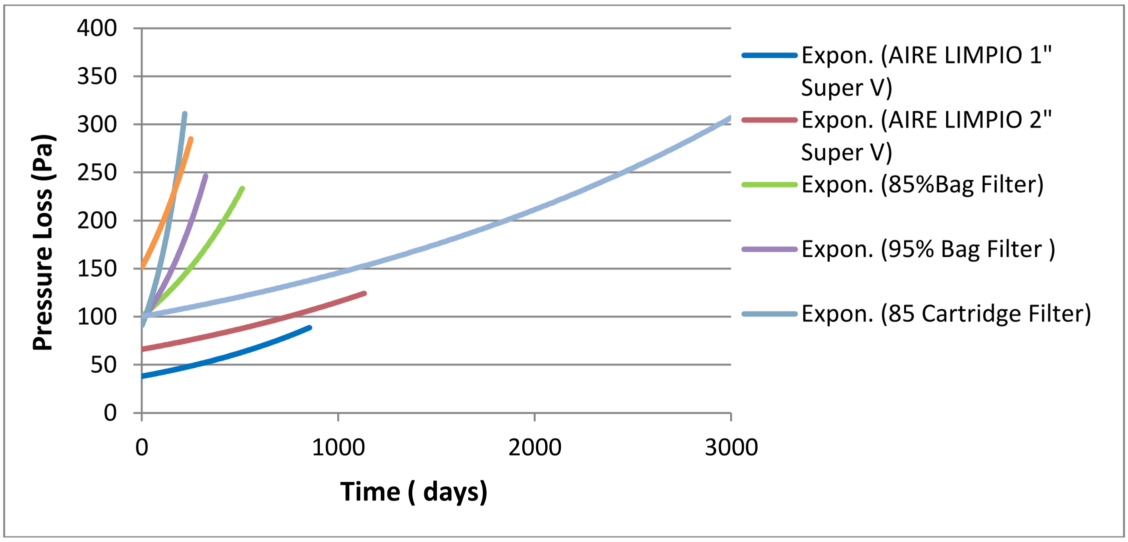
This case of study has been considered as an average case, being the influence of the filters over the total energy consumed restricted, since filtering level is not very demanding and HVAC system considered is not an all-air system (VRV systems are considered for HVAC), where air flow levels are usually higher and so is consumed fan energy.

3 METHODOLOGY

Simulations have been performed for a period of five years (usual polarization filtering substitution lapse), considering the increases of pressure drop caused by the accumulation of dust in the filters. Compliying with Spanidh regulation, in the supply side of the AHU, two filters in series are considered: F7 y F9 type. In the return side, a F7 filter is considered. For the comparison, two cases have been studied: Bag and Polarized filters.

The pressure drop due to the filters has been measured experimentally. These measures indicate that the pressure drop has an exponential evolution (figure 3).

Figure 3: Pressure drop evolution for different kind of filters (data courtesy of Aire Limpio)



Since energy consumption is proportional to pressure drop for a constant flow, in order to have a unique value representative of pressure drop along all the year, the following process has been made:

- Area under the exponential has been calculated integrating the exponential function along all measured days.
- Equivalent pressure drop has been calculated so that the area contained in the rectangular surface formed by this equivalent pressure and the measured days is the same as the calculated in the first step.

3.1 Pressure Drop due to the Use of Bag Filters

Measured pressure drop in a F7 bag filter and a F9 bag filter along the first year of use is shown in the next table:

Table 1: F7 bag filter and F9 bag filter pressure drop

Days	F7 Bag Filter	F9 Bag Filter
0	105,82 Pa	108,31 Pa
365	192,20 Pa	275,98 Pa

Next table indicates the equivalent pressure drop for these two filters:

Table 2: F7 bag filter and F9 bag filter pressure drop

Days	F7 Bag Filter	F9 Bag Filter
0 - 365	144,74 Pa	179,26 Pa

3.2 Pressure Drop due to the Use of Polarized Filters

Next figure shows the pressure drop in a F7 polarized filter and a F9 polarized filter:

Table 3: F7 bag filter and F9 bag filter pressure drop

Days	F7 Polarized Filter	F9 Polarized Filter
0	38,59 Pa	104,58 Pa
365	55,32 Pa	119,55 Pa
730	79,31 Pa	136,66 Pa
1,095	---	156,22 Pa
1,460	---	178,58 Pa
1,825	---	204,14 Pa

Equivalent pressure drop for these two filters is shown in the next figure:

Table 4: F7 bag filter and F9 bag filter pressure drop

Days	F7 Polarized Filter	F9 Polarized Filter
0 - 365	46,45 Pa	111,90 Pa
365 - 730	66,60 Pa	127,91 Pa
730 - 1,095	---	146,22 Pa
1,095 - 1,460	---	167,15 Pa
1,460 - 1,825	---	191,08 Pa

3.3 Simulation Cases

In order to study building energy performance the following combinations of filters has been simulated:

Table 5: Bag filter and polarized filter combinations simulated

Days	F7 Bag Filter	F9 Bag Filter	F7 Polarized Filter	F9 Polarized Filter
0 - 365	144,74 Pa	179,26 Pa	46,45 Pa	111,90 Pa
365 - 730	144,74 Pa	179,26 Pa	66,60 Pa	127,91 Pa
730 - 1,095	144,74 Pa	179,26 Pa	46,45 Pa	146,22 Pa
1,095 - 1,460	144,74 Pa	179,26 Pa	66,60 Pa	167,15 Pa
1,460 - 1,825	144,74 Pa	179,26 Pa	46,45 Pa	191,08 Pa

These combinations of pressure drops were introduced in an air handling unit commercial selection program where the fan supply and the fan return power was calculated.

Calculated fan power is shown in the next table:

Table 6: Bag filter and polarized filter combinations simulated

Days	Bag Filter		Polarized Filter	
	Supply Fan	Return Fan	Supply Fan	Return Fan
0 - 365	8,65 kW	6,68 kW	7,36 kW	6,04 kW
365 - 730	8,65 kW	6,68 kW	7,66 kW	6,18 kW
730 - 1,095	8,65 kW	6,68 kW	7,63 kW	6,04 kW
1,095 - 1,460	8,65 kW	6,68 kW	7,92 kW	6,18 kW
1,460 - 1,825	8,65 kW	6,68 kW	8,00 kW	6,04 kW

4 RESULTS

4.1 Fans Energy Performance evolution using Bag Filters

Simulations have been made to calculate fans' final energy consumption taking into account fan powers using bag filters mentioned in table 6. Values shown in table 7 include terminal units' fans:

Table 7: Fan final energy consumption using bag filters

Days	Fans' Final Energy Consumption
0 - 365	219,880 kWh
365 - 730	219,880 kWh
730 - 1,095	219,880 kWh
1,095 - 1,460	219,880 kWh
1,460 - 1,825	219,880 kWh

4.2 Fans Energy Performance evolution using Polarized Filters

Simulations have been made to calculate fans' final energy consumption taking into account fan powers using polarized filters mentioned in table 6:

Table 8: Fan final energy consumption using polarized filters

Days	Fans' Final Energy Consumption	Polarization Final Energy Consumption	Total Final Energy Consumption
0 - 365	203,104 kWh	54 kWh	203,158 kWh
365 - 730	206,930 kWh	54 kWh	206,984 kWh
730 - 1,095	205,451 kWh	54 kWh	205,505 kWh
1,095 - 1,460	209,188 kWh	54 kWh	209,242 kWh
1,460 - 1,825	208,667 kWh	54 kWh	208,721 kWh

Polarization process has an electric power consumption of 12 W during an estimate operation time of 4.500 hours per year.

4.3 5-year performance comparison

Table 9 shows fans' final energy consumption comparison:

Table 9: Fan final energy consumption comparison

Days	Fans' Final Energy Consumption (Bag Filters)	Fans' Final Energy Consumption (Polarization Filters)
0 - 365	219,880 kWh	203,158 kWh
365 - 730	219,880 kWh	206,984 kWh
730 - 1,095	219,880 kWh	205,505 kWh
1,095 - 1,460	219,880 kWh	209,242 kWh
1,460 - 1,825	219,880 kWh	208,721 kWh
TOTAL	**1,099,400 kWh**	**1,033,610 kWh**

The percentages of final energy savings are shown in table 10:

Table 10: Percentages of final energy savings using polarization filters

Days	Final Energy Savings using Polarization Filters (%)
0 - 365	7,6%
365 - 730	5,9%
730 - 1,095	6,5%
1,095 - 1,460	4,8%
1,460 - 1,825	5,1%
TOTAL	**6,0%**

As can be seen in the former table, the use of polarization filters represents a saving of approximately a 6% in electric energy consumption along a period of life of 5 years.

It is important to remember that this case study has been considered as an average case, being the influence of the filters over the total energy consumed restricted, since filtering level is not very demanding and HVAC system considered is not an all-air system (VRV systems are considered for HVAC), where airflow levels are usually higher and so is consumed fan energy.

5 CONCLUSIONS

As shown before, a study on the impact of differences in building energy performance using bag filters or using polarized filters has been performed, being the main conclusions:

- Fan use derived from HVAC systems is one of the most important consumptions in non-residential building energy performance.
- Fan energy use can be reduced diminishing pressure drop throughout the ductwork.
- Air handling units' fan pressure drop must be carefully studied in order to improve building energy performance.
- Polarization filter usage reduces significantly the pressure drop inside air handling units.
- Savings of a 6% of fans' final energy consumption can be achieved in average office buildings using polarized filters instead of traditional bag filters.

6 ACKNOWLEDGEMENTS

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