STUDY OF USED VENTILATION FILTERS UNDER DRY AND WET CONDITIONS

F Frydenlund[1], E Haugen[2], O Kristiansen[3], H N Lysne[1] , C Ahlén[2] and S O Hanssen[3]

[1] SINTEF Energy Research, Norway
[2] SINTEF Unimed, Norway
[3] Norwegian University of Science and Technology, Trondheim, Norway.

ABSTRACT

It is recommended to keep the ventilation filters dry. However there are many ventilating systems that cannot fulfil this requirement all the time. It is then interesting to know the state of filters in use, and how they perform during extreme wet conditions, especially at the end of their lifetime.
This investigation includes used filters collected at the time of normal change of filters.

The used filters absorbed a different amount of humidity. The particle filtration efficiency was nearly the same as for unused filters (comparing only filter class F7/EU7). The efficiency of the filters was slightly decreased during the wet conditions compared with the dry conditions. The amount of contaminants in the filters was probably a result of the external conditions.
There was found thermotolerant moulds in **all** the filters. This is very different from the natural composition of moulds in this region.

INTRODUCTION

Most modern buildings have ventilation systems that include air filtration. The filter unit should protect the system components and the users against outdoor air contaminants. It is recommended to keep the filters dry, but many ventilating systems cannot fulfil this requirement all the time. It is then interesting to know the state of some used filters, and how they perform during extreme wet conditions.
A field study of the ventilation systems of several "non problem" buildings was carried out [1]. The buildings were office and school buildings in the city of Trondheim.
Subsequently a detailed study of used filters in some of these ventilation systems was performed [2].

METHODS

The filters were collected at the time of the normal change of the filters. The 19 ventilating systems were in advance classified as either dry or periodic humid. All the 36 filters were sampled for microbiological analysis. One filter pr. system was selected for additional tests.

- the mass weight of the collected contaminants (19 filters)
- the capacity to absorb humidity (17 filters)
- the particle filtration efficiency under dry and wet conditions (17 filters)

Method to quantify the contaminants

The weight of the used filters were determined and compared with the weight of new and clean filters given from the supplier. We did not know the exact start weight of the individual filters we investigated. This gives some uncertainty to the weight of the contaminants.

Method for determination of absorption of humidity

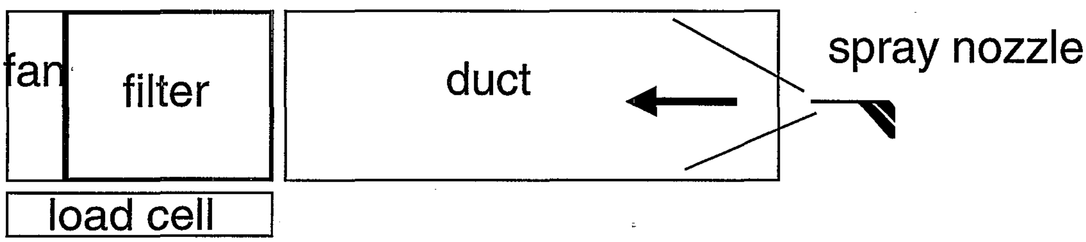

Figure 1. Humidifying the filter

Figure 1 show how the filters are humidified in the laboratory. The filter was mounted in a rack (60x60 cm^2). A duct and a spray nozzle were mounted straight in front of the filter. A fan sucked the air, with atomised water, trough the filter. The fan and the rack (with the filter) were placed on a load cell. The humidification proceeds until the weight has increased with 3.0 kg. Then the distribution of the water was investigated:

- in front of the filter
- passed trough the filter
- absorbed by the filter (the rest)

Method of particle filtration efficiency

We added artificial particles (DOS) and counted the number of particles, while alternating between the upstream and downstream flow. After 12 count cycles the average particle filtration efficiency was calculated. This method is based on a procedure described in EUROVENT 4/9 [3], but there are some differences:

- the air flow rate used in our method was equal to the designed air flow in each ventilation plant. The EUROVENT 4/9 describes a nominal flow recommended by the filter manufacturer.
- the pressure drop was only measured at this designed air flow

Method of microbiological samples

Two filters were collected from each ventilation plant. Three swab samples and three snatch samples were made at the front of the first filter (without damaging the filter). Three snatch samples were made at the second filter, one in the front and two deep inside the filter bags (this punctured the filter bags).
Afterwards the samples were grown at two temperatures 22°C and 37°C for 2-3 weeks, and analysed afterwards.

RESULTS

Description of the ventilation plants and the filters

Table 1. Data about the ventilation plants and the filters

Ventilation plant id	Filter class	Filter material	Time in plant [h]	Operating time [h]	Air flow rate pr filter[m^3/h]	Frontal velocity [m/s]	Area of filter bags [m^2]	Total air passed filter during the lifetime [m^3]	Contaminants [g]	Absorbed water [g]	Humidity conditions
S1-1	EU4	Synt.	9672	2070	4400	3.4	2.45	9.11E+06	283	638	Dry
S1-2	EU4	Synt.	9696	2076	4283	3.3	2.45	8.89E+06	197	640	Dry
S2-1	EU6	G.F.	9432	2948	3166	2.4	8.93	9.33E+06	513	1270	P.H.
S2-2	EU6	G.F.	9432	2948	3647	2.8	8.93	1.07E+07	439	1396	P.H.
S2-3	EU5	Synt.	9600	5829	2500	1.9	0.64	1.46E+07	506	692	Dry
S3-3	EU7	G.F.	7704	2064	3665	2.8	6.00	7.56E+06	286	1436	P.H.
S4-1	EU7	Synt.	8256	2457	4750	3.7	7.80	1.17E+07	1662	1058*	P.H.
S4-2	EU7	Synt.	8256	1846	7130	3.7	7.80	1.32E+07	1569	2051	P.H.
S4-3	EU7	Synt.	3744	1560	5175	4.0	7.80	8.07E+06	1418	1381	Dry
S5-1	EU7	G.F.	2616	1090	3475	2.7	8.78	3.79E+06	519	2067	Dry
S5-2	EU7	G.F.	2256	1034	2748	2.1	7.32	2.84E+06	64	1762	Dry
S5-3	EU7	G.F.	2688	1200	5060	2.6	8.93	6.07E+06	184	-	P.H.
O2-1	EU7	G.F.	9504	9504	5000	3.9	8.78	4.75E+07	1102	2298	P.H.
O2-2	EU7	G.F.	9912	9912	2600	2.0	6.00	2.58E+07	1061	2073	P.H.
O2-4	EU7	G.F.	9792	9792	3440	2.7	9.22	3.37E+07	622	2114	P.H.
O3-1	EU7	G.F.	6984	6984	4000	3.1	8.93	2.79E+07	274	1792	Hot/D
O3-3	EU7	G.F.	7152	2810	3900	3.0	9.22	1.10E+07	614	1877	P.H.
O4-1	EU7	G.F.	4536	1620	5750	3.0	13.39	9.32E+06	1637	-	Dry
O4-2	EU7	G.F.	6240	2229	3888	3.0	8.78	8.66E+06	1218	2309	Dry

*) this filtrer was humidified twice - in the second run the absorbed water was: 1518 g

Ventilation plant id: "S.." = school, "O.." = office
Filter material: "G.F". = glass fibre, "Synt." = organic synthetical
Time in plant: The total time mounted in the plant
Operating time: The total time the plant has been operating with this filter
Air flow rate pr. filter: The air flow rate trough this filter
Frontal velocity: The average air velocity at the front of the filter
Area of filter bags: The area of the filter bags
Total air passed filter during the lifetime: The total amount of air which have passed the filter during the lifetime
Contaminants: The amount of contaminants found in the filter
Absorbed water: The amount of water absorbed by the filter during humidifying

Humidity conditions: of the filters as we expected after the visual inspection: "Dry" = mostly dry, "P.H." = periodic humid, "Hot/D" = hot and mostly dry

Particle filtration efficiency

In this paper we limit the presentation only to the 12 filters of EU7 filter class (excluding the other 5 filters).

Figure 2. Particle filtration efficiency of dry EU7 filters

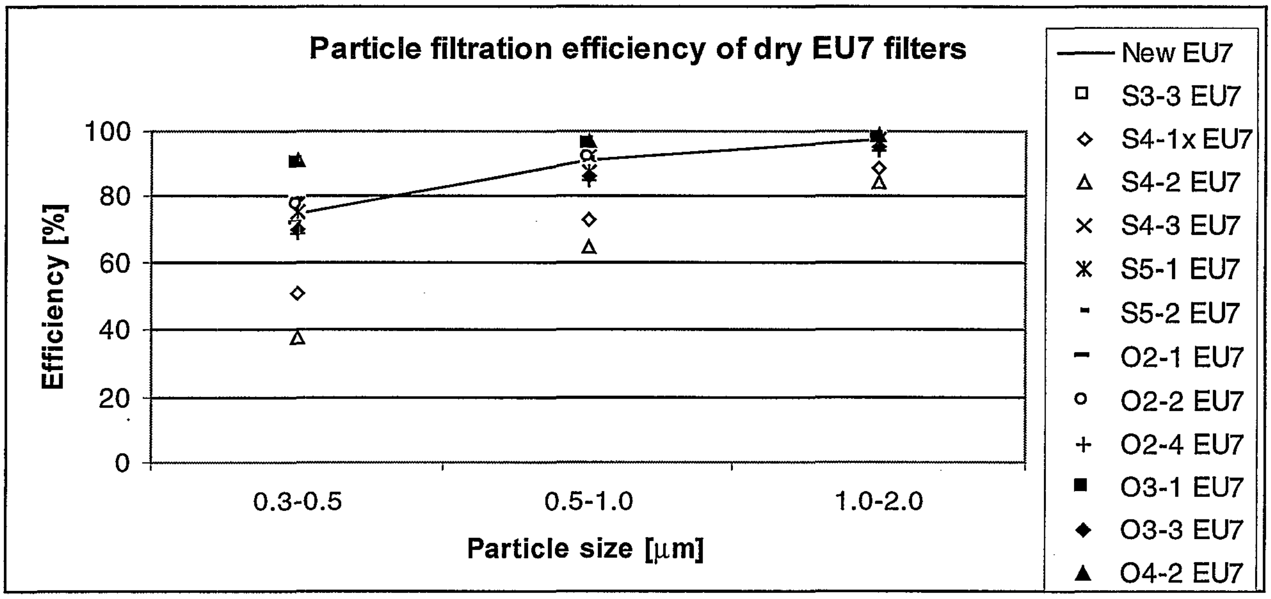

Figure 3. Particle filtration efficiency of wet EU7 filters

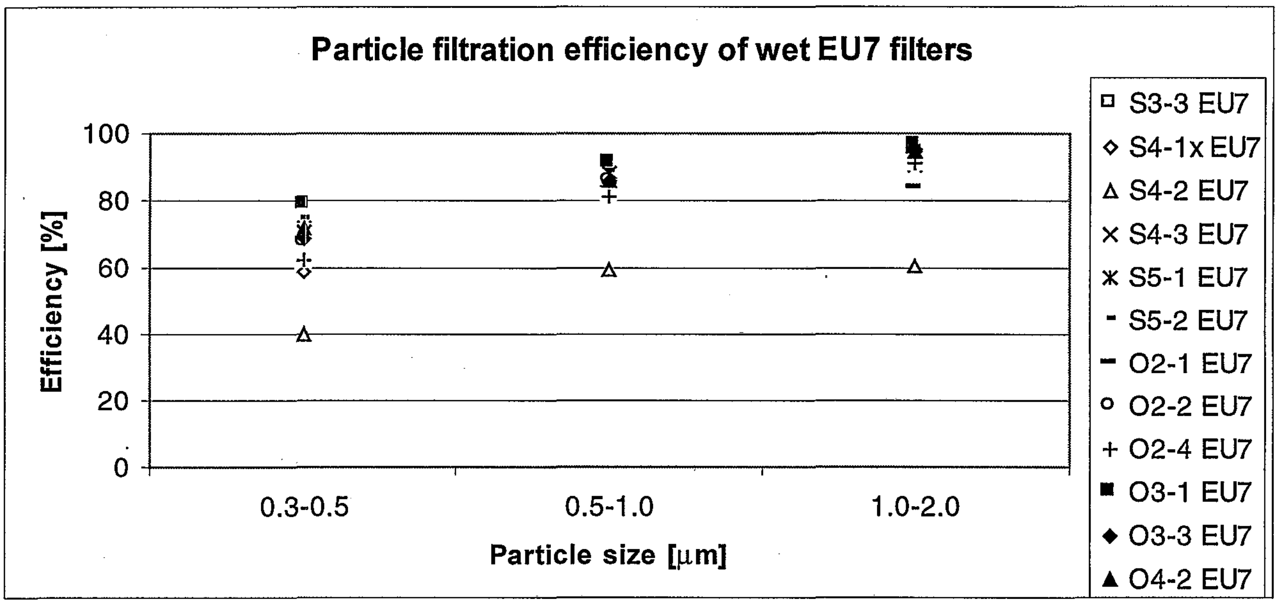

Figure 2 and 3 shows the measured particle filtration efficiency of the investigated EU7 filters.

Microbiological samples

36 filters from 19 ventilation plants were investigated. The samples from all the filters, grown at 22°C, showed plentiful growth of assorted moulds - i.e. normal flora. The results were very similar and independent of the sample position in the filter. All the sampled filters showed thermotolerant moulds.

DISCUSSION

Quantifying the contaminants

The results in Table 1 showed big differences in the amount of contaminants collected by the filters. We tried to present the contaminant load in 3 specific ways:

- contaminants per hour of operation
- contaminants per accumulated air volume
- contaminants per area of filter bags

We could not observe any close relation with the accumulated contaminants. Some of the filters came from the same building. When comparing such filter neighbours we found much smaller differences than comparing with some other filter. This indicates that the surroundings and the contaminant load around the buildings are a major factor.

Absorption of humidity

The measuring procedure was developed for this special purpose. The results from this method, in Table 1, showed big differences between the filters ability to absorb water. We tried to find a relation between the total area of the filter bags, the amount of contaminants and the absorbed humidity. We found some correlation between these parameters but the big element of uncertainty is probably related to the composition of the contaminants.
This test was run twice for one single filter. This extra run also showed major differences in the absorption of humidity.

Particle filtration efficiency

The results, showed in Figure 2 and 3, are mostly gathered in a cluster, but some synthetic filters showed a considerably lower performance (S4-1x & S4-2 in Figure 2 and S4-2 in Figure 3).
The average performance of wet filters decreases with approximately 5 percentage points compared with dry filters.

Microbiological samples

Thermotolerant moulds are not assumed to be normal flora in outdoor air in Norway. Micro composting in ventilation filters has been suggested as a possible source and /or reservoir to frequent findings of thermotolerant moulds in HVAC-generated indoor air [4].
It's then even more important that the filter barrier is able to stop the moulds and the spores.

The design, operation and maintenance of ventilation systems is very important. A good design gives possibilities to maintain the ventilation system and keep the ventilation filters dry. A good maintenance gives possibilities to keep the ventilation systems clean and well functioning.

ACKNOWLEDGEMENTS

The Research Council of Norway is highly acknowledged for financial support of the presented work.

REFERENCES

1. Lysne H N., Kristiansen O., Witsø E et al. 1997. Ventilation systems as a potential health risk – a field study. (in Norwegian) *SINTEF report STF84 A97208.*
2. Frydenlund F., Kristiansen O., Haugen E. et al. 1998. Ventilation systems as a potential health risk – a study of used filters in laboratory. (in Norwegian) *SINTEF report TRA4704*
3. *EUROVENT 4/9* 1992: Method of testing air filters used in general ventilation for determination of fractional efficiency.
4. Ahlén C., Haugen E.N., Frydenlund F. et al 1999. Composting in ventilation filters? – a possible key to altered thermotolerance in microbial flora of indoor air. *In these proceedings.*