VENTILATION TECHNOLOGIES IN URBAN AREAS

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EXPERIMENTAL IMPACT VALUATION OF FOULING ON EXTRACT AIR TERMINAL DEVICES PERFORMANCES: AN ACCELERATED ARTIFICIAL FOULING APPROACH

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ABSTRACT

A humidity controlled air flow terminal device works as a humidity sensor : its opening surface varies according to relative humidity inside a room in order to match air flow rate to pollution. These components are fouling up when used during several months.

In a laboratory, an air flow with a high rate of particules is fouling up five identical air devices in a few hours. Considering a constant relative humidity, the impacts on two devices are similar : it seems that artificial fouling tests can be reproduced. These first tests show a high sensitivity to fouling at low relative humidities (small openings devices) and nearly no sensitivity at high relative humidities (large openings devices).

The characteristic curve of a humidity controlled air flow device represents the air flow rate in function of the relative humidity at a set pressure loss. The curves of four devices are compared before and after the accelerated fouling : the most important absolute air flow reduction is about 3.1 l/s. This maximum is always reached near the point of RH = 60 %. The corresponding relative reduction varies from 14 % to 23 %. The nearly same relative reductions are measured at the point of RH = 60 % with two years old fouled up devices from real dwellings although the fouling is visually very different. Thus, the accelerated artificial fouling experiments seem to be representative of real cases.

SYMBOLS AND UNITS

Q	Air flow rate (in l/s)
ΔQ	Air flow rate reduction (in l/s)
m	Total mass of generated particules (in g)
C	Particules concentration (in mg/m^3)
T	Temperature (in deg C)
ΔP	Pressure loss of a device (in Pa)
RH	Relative humidity

1- INTRODUCTION

As generally known, the extract air terminal device which is the only visible component of a mechanical ventilation system is clearly fouling up when used during several months. The impact is a possible deterioration of its performance. Considering real dwellings, the valuation of this impact is still possible. But the generalization of the results is difficult because some basic parameters are out of control, such as the users behaviour on a long time period or the local pollution.

This paper studies an experimental method of accelerated fouling of air terminal devices in a laboratory. The method is similar to the one used to test filters performances : an air flow with a high rate of particules is fouling up the component in a few hours. The performance of a clean component is compared to the performance of the same component once fouled up. The main purpose is to reproduce the same results under similar experimental conditions. Furthermore, these results are qualitatively compared to the performance of dirty components from real dwellings in order to check the representativeness. If these tests are successfull, this method would allow the comparative valuation of the air terminal devices performances with standard fouling conditions.

2- TYPE OF TESTED AIR TERMINAL DEVICES

Two types of extract air terminal devices are generally used in France. An automatic controlled air flow device keeps a nearly constant air flow rate whatever the pressure loss. A humidity controlled air flow device adjusts its opening surface to the relative humidity inside the room where the device is set up. Therefore, the air flow rate is an increasing function of relative humidity.

Humidity controlled air flow device is supposed to be more sensitive to fouling because its average opening surface is lower than the one of an automatic controlled air flow device. So, only humidity controlled air flow devices are tested here.

3- EXPERIMENTAL SET UP

Figure 1 represents the accelerated fouling experimental bench. The air flow contains a high concentration of particules. The ASHRAE dust is used. Its composition is given by the standard EN 779 [1] used to test filters performances : silica, carbon and fibrous cotton.

Because of the low air flow rates (about 5 to 20 l/s), the duct is set up on a vertical position in order to avoid the particules sedimentation.

The pressure difference between the both sides of the device is maintained constant at $\Delta P = 100$ Pa (± 2 Pa). Air relative humidity, RH, is controlled by a steam generator upstream the experimental bench. The relative humidity precision is about ± 5 %. The air temperature near the tested components varies between 19 and 23 deg C. On this temperature range, the devices performance is not dependent on air temperature. The air flow rate measurement is performed downstream the experimental bench with a propeller flowmeter.

Five identical air terminal devices are tested (called A, B, C, D and E).

4- REPRODUCTIBILITY TESTS

The method must be reproductible. For two identical air terminal devices tested with the same experimental conditions, the results must be similar.

Each air terminal device is fouling up on the experimental bench at a constant relative humidity. The tests are done with two relative humidity values : RH = 30 % and RH = 70 %. Figure 2 shows the air flow rate, Q, in function of the total mass of particules generated, m. The dust generator allows to control the particules mass flow. At each measurement point, the particules mass flow is adjusted taking into consideration the air flow rate in order to achieve a particules concentration C = 200 mg/m^3. Then, the mass flow is maintained constant until the next measurement. At this new point, the mass flow is adjusted again in order to have C = 200 mg/m^3. Therefore, between two measurement points, the particules voluminal concentration is increasing as the air flow tends to decrease due to the fouling.

Tests seem to be reproductible : at each relative humidity value, the curves shapes of two identical air devices are comparable. The fouling reduces the air flow rate at RH = 30 % but not at RH = 70 %. Thus, air terminal devices seem to be more sensitive to fouling when relative humidity (or their opening surface or the air flow rate) is low. Nevertheless, the curve shape of the B device is unexpected. The first three points are suspect due to possible experimental problems : perhaps, the device was still adjusted its opening surface to the relative humidity during the fouling and its steadyness was not achieved. Even so, the B device was fouled up and used for the next test (cf. section 6).

5- HUMIDITY CONTROLLED AIR FLOW DEVICES PERFORMANCES

The humidity controlled air flow device performances are represented by the characteristic curve which shows the air flow rate in function of the relative humidity at a constant air temperature (for our tests : T = 20 deg C).

The experimental bench used for these tests is set up according to the standard ISO 5219 [2]. The pressure difference between the both sides of the device is maintained at ΔP = 100 Pa. It takes more than one hour and a half to reach the steadyness of the relative humidity in the room calorimeter at each measurement point. The air flow measurement error is less than 0.15 l/s. The relative humidity error is less than 1.3 %.

First, these tests were done considering an increasing humidity and then considering a decreasing one. The goal is to see a possible hysteresis. Both the characteristic curves were so similar that we decided to present only the increasing humidity curve.

6- ACCELERATED FOULING TESTS

Figures 3 to 6 represent the characteristic curves of the A, B, C, and D air terminal devices before and after the accelerated fouling, and after the cleaning (the E device was only used in the course of the reproductibility tests). A sensible air flow reduction is noticed on the whole humidity range once devices are fouled up. The maximum absolute air flow reduction is about 3.1 l/s. This maximum is always reached near the point of RH = 60 % (table 1). At this point, the relative reduction varies from 14 % to 23 %. We also note that the fouled up devices curves are nearly linear whereas the cleaned up devices curves are hardly concav. Besides, the performances of an air device once cleaned up are nearly as good as they were when the device was new.

At RH = 30 % and RH = 70 %, we note unexpected differences between these characteristic curves and the results of the reproductibility tests (figure 2). A sufficient explanation was not found. The only one is about humidity during the accelerated fouling experiment which were performed with no normative requirements : a proper steadyness of the relative humidity and its stability were not sure. Besides, The relative humidity precision was not as good as it was during the devices performances tests.

Device	Fouling conditions		Air flow rate reduction between a clean device and the same device once fouled up		
	RH	m (g)	Maximum ΔQ (l/s)	Corresponding RH	Corresponding $\Delta Q/Q$
A	70 %	31	3.3	58 %	19 %
B	70 %	23	2.3	60 %	14 %
C	30 %	10	3.2	60 %	19 %
D	30 %	12	3.6	60 %	23 %

Table 1 : Fouling conditions and air flow rate reduction between a clean device and the same device once fouled up

7- TESTS VALIDATION

The tests validation goal is to study the characteristic curves of fouled up air terminal devices used in real dwellings. We compare qualitatively these tests to the results of the accelerated fouling experiment.

Three devices called F, G and H which have been used for two years are taken from bathrooms of real dwellings. They are identical to the accelerated fouled up devices. Their fouling is fibrous and very different from the laboratory accelerated fouling which is finer. The characteristic curves of the F, G and H cleaned up devices cannot be compared to the ones of A, B, C and D new devices due to differences in initial calibration.

The figures 7 to 9 represent the characteristic curves of F, G and H devices when they are fouled up and again when they are cleaned up. Considering the three devices, the fouling impacts are similar although the three fouling aspects are not equivalent (table 2). The maximum air flow reduction is about 2.1 l/s. Contrary to the laboratory fouling tests, the reduction is nearly constant in the whole humidity range. At RH = 60 % (the laboratory fouling results show that the absolute air flow reduction achieves the maximum at this point), the relative air flow reduction varies from 15 % to 21 %. These relative reductions are comparable to the ones of the artificial fouling.

Considering all these components, the accelerated artificial fouling impact is similar to a real fouling impact. Nevertheless, the fouling aspects are visually different (fibrous fouling and finer one).

Device	Fouling visual diagnosis	Air flow rate reduction between the fouled up device and the same device once cleaned up		
		Maximum ΔQ (l/s)	Average ΔQ (l/s)	ΔQ/Q at RH = 60 %
F	Fibrous, high and homogeneous	2.1	1.7	19 %
G	Fibrous and low	2	1.6	15 %
H	Fibrous, high and confined (aggregates around the opening)	2.1	1.8	21 %

Table 2 : Fouling visual diagnosis and air flow rate reduction between the fouled up device and the same device once cleaned up

8- CONCLUSION

This study is a laboratory experimental approach of the impact valuation of the fouling on humidity controlled air flow devices performances. Considering the air terminal devices tested here, the representativeness is satisfactory. The reproductibility tests are also satisfactory but they need more control of the experimental conditions. This first work shows that the impact valuation of the fouling on air terminal devices performances is possible with standard (and possibly normative) experimental conditions. Nevertheless, we carrefully notice that only eight air terminal devices were tested here.

REFERENCES

[1] EN 779 - Particulate air filters for general ventilation - Requirements, testing, marking - December 1993

[2] ISO 5219 - Air distribution and air diffusion - Laboratory aerodynamic testing and rating of air terminal devices - 1984

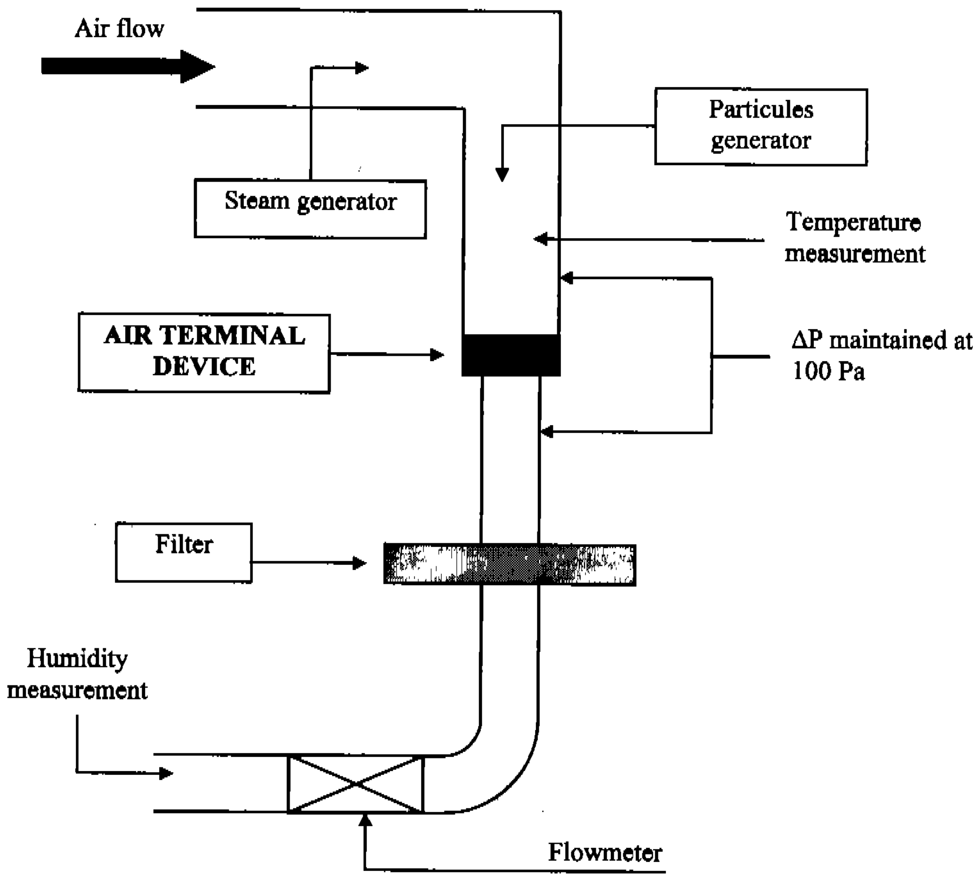

Figure 1 : Accelerated fouling experimental bench

Figure 2 : Reproductibility tests at ΔP=100 Pa and a constant relative humidity : air flow rate in function of the total mass of generated particules

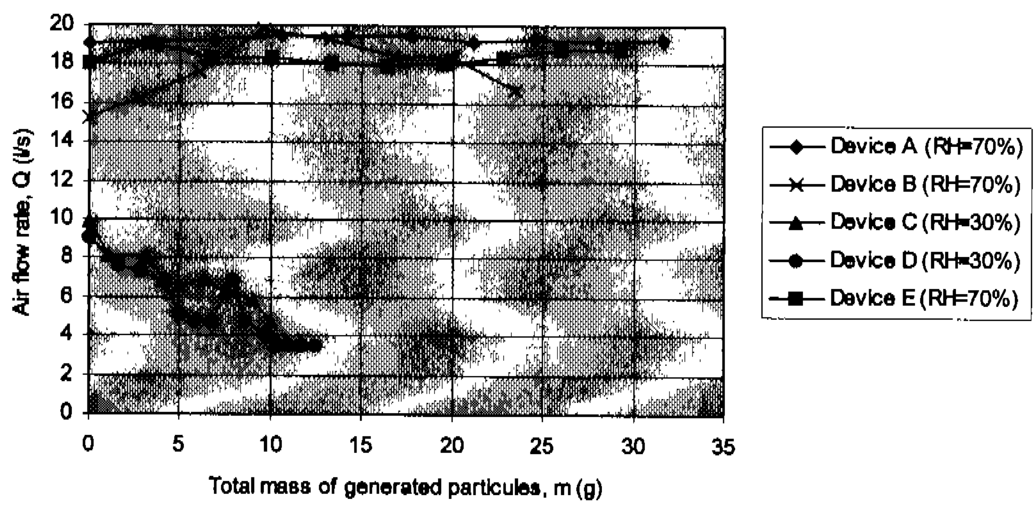

Figure 3 : Characteristic curves of the device A (ΔP=100 Pa) before and after the accelerated fouling

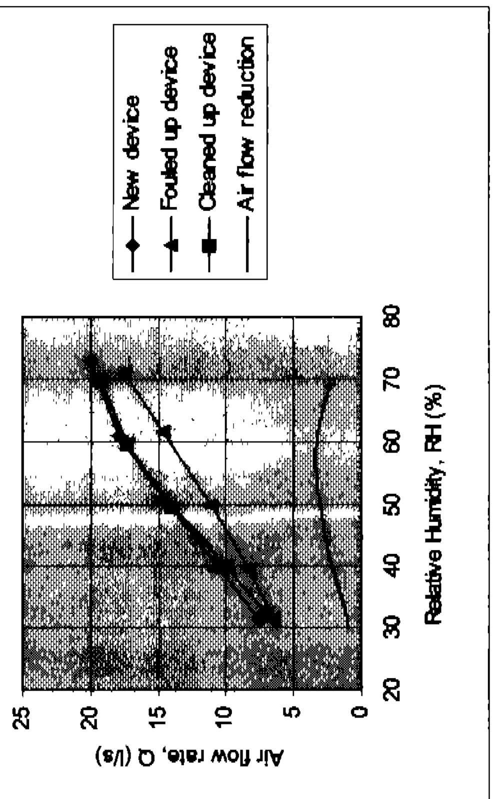

Figure 4 : Characteristic curves of the device B (ΔP=100 Pa) before and after the accelerated fouling

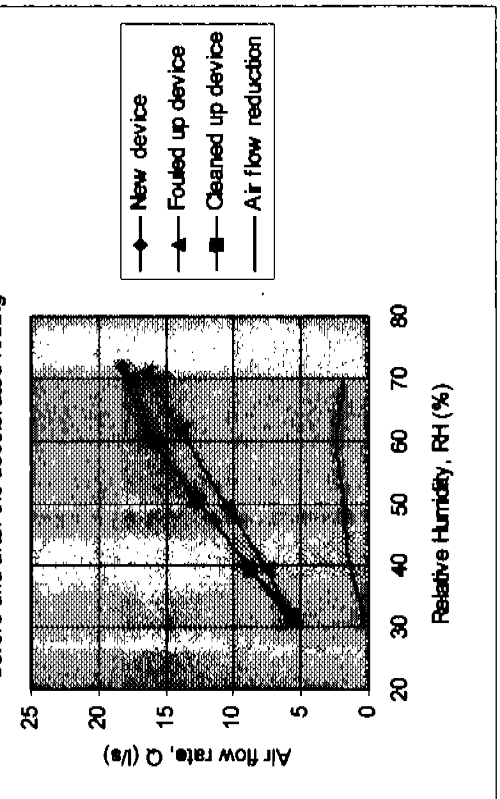

Figure 5 : Characteristic curves of the device C (ΔP=100 Pa) before and after the accelerated fouling

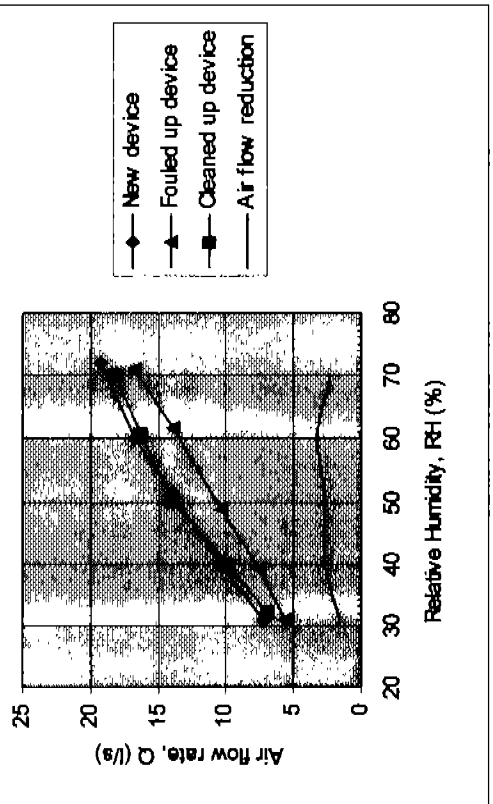

Figure 6 : Characteristic curves of the device D (ΔP=100 Pa) before and after the accelerated fouling

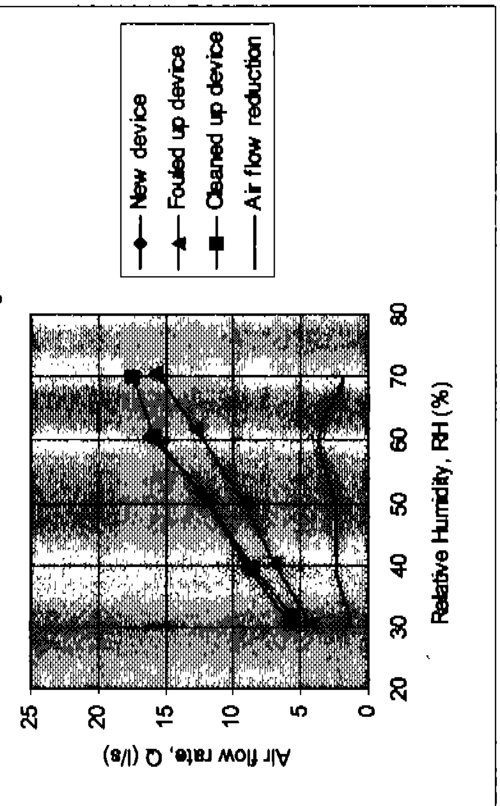

Figure 7 : Characteristic curves of the device F (ΔP=100 Pa) fouled up in a real dwelling and after the cleaning

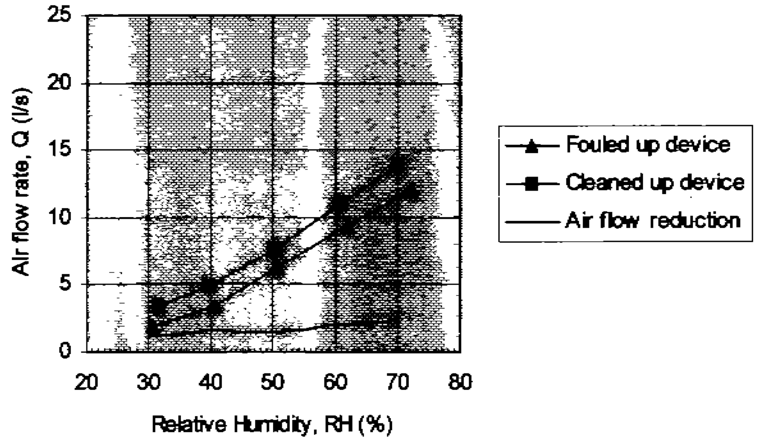

Figure 8 : Characteristic curves of the device G (ΔP=100 Pa) fouled up in a real dwelling and after the cleaning

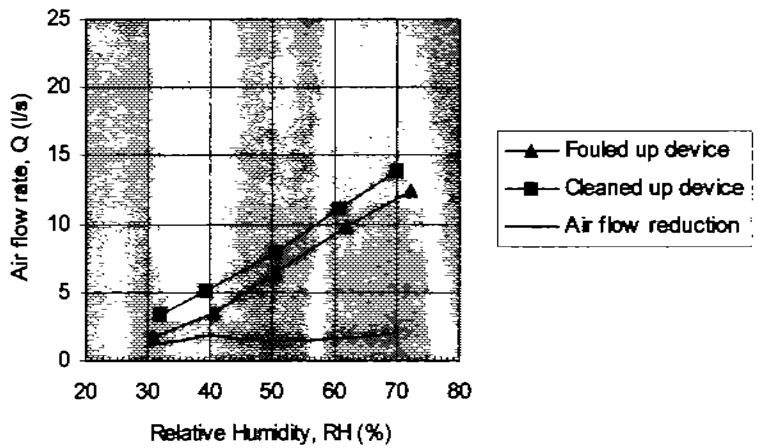

Figure 9 : Characteristic curves of the device H (ΔP=100 Pa) fouled up in a real dwelling and after the cleaning