Feedback on installation, maintenance, and aging of mechanical humidity-controlled ventilation exhaust units

BERTHIN Stéphane*[1], PARSY François[1]

[1] *AERECO SA*
62 rue de Lamirault – Collégien
77615 Marne la Vallée, France

** Corresponding author:*
stephane.berthin@aereco.com

ABSTRACT

With 35 years of existence and more than 10 million equipped dwellings, mechanical humidity-based demand-controlled ventilation (RH-DCV) can provide a comprehensive feedback on installation, aging, and maintenance of its components. Their working principle is based on the extensions and retractions of a hygroscopic fabric, which pulls on a shutter to modify the device's cross-section – hence the airflow – upon humidity changes in their environment.
In 2006, before generalizing the usage of RH-DCV in French residential buildings, the Ministry for Housing ordered an evaluation of these systems after prolonged on-site operation. For this purpose, the COSTIC laboratory selected 21 social housings in the Parisian suburb, and collected 57 exhaust units after 6 years of in-situ functioning.
During the collecting phase, the first on-site observations were the following:

- 12 % of the exhaust units were installed in incorrect rooms (kitchen/bathroom swap, for instance).
- 14 % of the units had suffered damage, either due to voluntary modifications by the occupants (e.g. blocking of the shutter), or to bad re-assembly after maintenance. In 1 out of 3 dwellings, at least one device presented such defects.
- 75 % of the units showed an absence of sufficient maintenance (dusting), when 58 % visually exhibited clogging of the canal.

The devices were first characterized on a laboratory test bench as-collected (i.e. still soiled). Characterization of RH-DCV units consists in plotting the volume-flow crossing the unit as a function of relative humidity.

- 100 % of the non-damaged exhaust units exhibited a conform hygroscopic behavior or showed a slight shift of their characteristic when still soiled.
- 46 % of the kitchen units complied with factory specifications despite the absence of maintenance.
- 100 % of the bathroom exhaust units showed an airflow reduced by 5 m^3/h.

Devices were then cleaned and properly re-assembled. The shutter and shutter-case (passive elements) were replaced when irreversible damaged was observed.

- 75 % of the units complied with factory specifications after cleaning.
- Among the other 25 %, the kitchen elements showed an increase of volume flow lower than 3 m^3/h, while bathroom units exhibited a decrease lower than 2 m^3/h.

For the same study, self-adjusting exhaust units were also collected and tested. These devices were installed in utility-rooms. Their working principle is based on the deformation of a membrane solely due to pressure forces to maintain a constant airflow despite pressure variations in the ventilation ductwork.

- 100 % of the soiled units were out of their specification, with volume flows 4 to 10 m^3/h (25 to 65 %) lower than their initial setting.
- Once cleaned, 100 % of the units complied with factory specifications.

The results of this samples collection highlight the necessity of ventilation units' maintenance; it also shows the robustness of RH-DCV settings after prolonged in-situ operation.

KEYWORDS

Demand-controlled ventilation, humidity, installation, maintenance, feedback

1 INTRODUCTION

With 35 years of existence and more than 10 million equipped dwellings, mechanical humidity-based demand-controlled ventilation (RH-DCV) has become a reference system for new buildings in certain European countries like France. Three main factors contributed to the success of this ventilation system: the simplicity, the heat loss reduction obtained by adapting the extracted airflows to the needs, and the guaranteed indoor air quality (IAQ). Both later aspects are ensured by national standards, in conformity with European directives.

In 2006, before allowing the generalization of this technology in new residential buildings, the French Ministry for Housing ordered an evaluation of RH-DCV after prolonged on-site operation. For this purpose, the COSTIC laboratory was mandated to select 21 social housings in the Parisian suburb in order to collect and test 57 exhaust units after 6 years of in-situ functioning.

The devices were characterized twice on a laboratory test bench: first as-collected (i.e. still soiled), then after cleaning and fixing when necessary so that the drift of the humidity sensor could be assessed.

The aim of the present paper is to examine the results of this study. In section 2, we explain the working principle of RH-DCV ventilation systems. Section 3 constitutes a feedback on installation and maintenance. Section 4 is dedicated to the performances of exhaust units after prolonged in-situ functioning; results are presented for hygroscopic and self-adjusting exhaust units. Finally, conclusions are given with a link between performance and maintenance.

2 HUMIDITY-BASED DEMAND CONTROLLED VENTILATION

As described on Figure 1, RH-DCV is a Mechanical Exhaust Ventilation (MEV) system implementing the "sweeping" principle: a constant-pressure exhaust fan (3) extracts air from the dwelling via exhaust units in the wet rooms (2), thus generating an under-pressure which sucks the air in from the outside via air inlets located in the dry rooms (1) (Savin, 2009).

Label 1: Air inlet

Label 2: Exhaust unit

Label 3: Exhaust fan

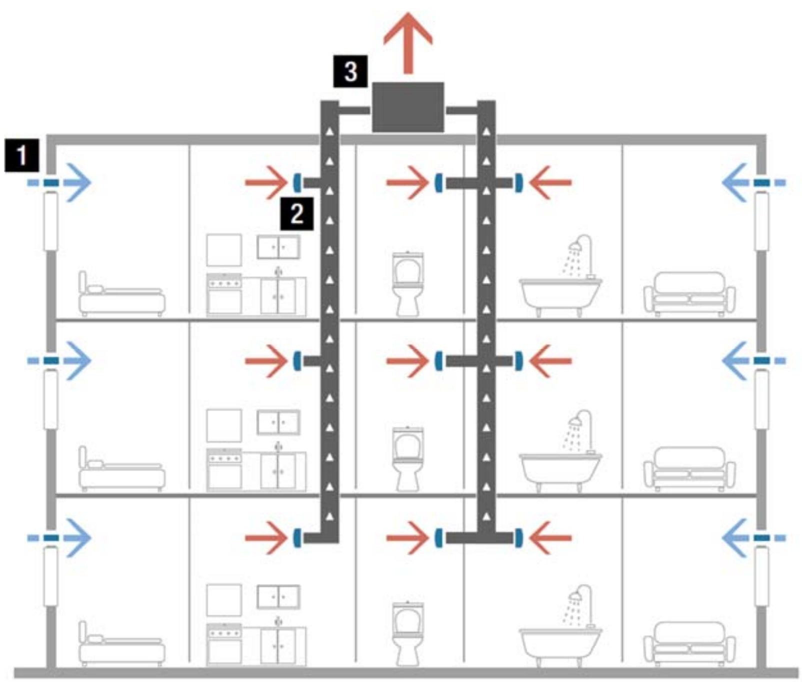


Figure 1: Principle of RH-DCV

Examples of air inlets and exhaust units are shown in Figure 1, labels 1 and 2 respectively. These devices are humidity-sensitive by design.
Activities in wet rooms generating water vapor (cooking, showering, washing, and drying of clothes), exhaust units regulate the total airflow crossing the dwelling by adapting their cross-sections to the current need.
Air inlets, on the other hand, control the repartition of fresh air entering the dry rooms based on the relative occupation of the rooms. Occupation is evaluated by the humidity generated by the human metabolism (breathing, perspiration) (ADEME, 2009).
The focus of this study is only on exhaust units. Fixed air inlets were installed in the dwellings.

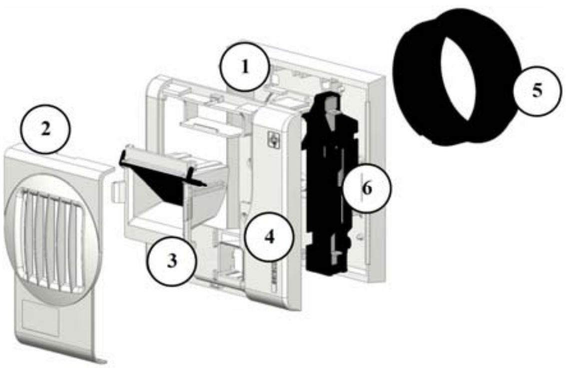


Figure 2: Exploded-view drawing of a humidity-controlled exhaust unit


Figure 3: Close-view on the humidity sensing strip

The working principle of the hygroscopic devices is based on a calibrated nylon strip which acts as local humidity sensor and actuator. The strip is connected to a shutter which controls the cross-section of the device, hence the airflow crossing it.
Figure 2 shows an exploded-view of a humidity-controlled exhaust unit. Labels 1, 4 and 5 indicate plastic housing and adaptor pieces; label 2 shows the protection grid inside the wet-room; label 3 shows the shutter inside its shutter-case (passive part) and label 6 is the humidity sensing strip (active part), of which a close-view is presented in Figure 3.

The airflow/humidity characteristics of each device is adapted depending on the dwelling size and the room type. An optimal trade-off between heat loss and indoor air quality is established based on standardized simulations.
An example a nominal characteristic is presented in red on Figure 4. The measured curve must fit into a template based on the tolerances linked to the aforementioned standardized simulations (in blue).

Figure 4: Example of airflow/humidity characteristic for a kitchen humidity-controlled exhaust unit

3 FEEDBACK ON USAGE

In this section, we present feedback statistics on the installation, degradation, and maintenance. Comments in this section are based on visual inspection of the collected exhaust units

3.1 On-site installation

Hygroscopic and self-adjusting exhaust units are considered in this work. Numerous cases of incorrect installations were observed, independently of the kind of ventilation system.

- 12% (4 out of 33 devices) of the exhaust units were installed in incorrect rooms (kitchen/bathroom swap, for instance).
- Another 6% (2 out of 33 devices) of the exhaust units were installed in incorrect apartments.

Both cases result in incorrect airflows in the dwelling. Higher airflows induce higher thermal losses, while lower airflows reduce the indoor air quality. In general, 55% (6 out of 11 dwellings) of the dwellings presented a non-conformity linked to installation.

3.2 Degradations by the occupant

- 14% (5 out of 33 units) of the collected exhaust units were found with damage, either due to voluntary modifications by the occupants (e.g. blocking of the shutter), or to wrong re-assembly after maintenance.
- These degradations concern 36% (4 out of 11 dwellings) of the apartments.

Figure 5: Shutter blocked open with a match

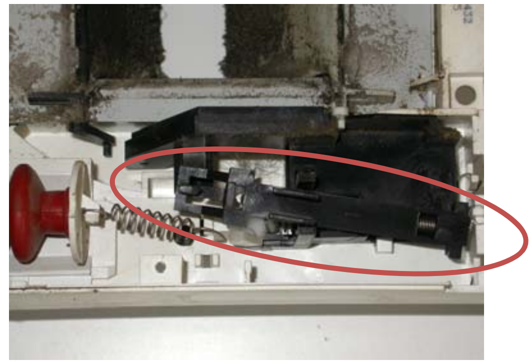


Figure 6: Humidity-sensitive strip detached from its base

3.3 Maintenance

A total of 75% (28 out of 37 devices, including cellar units) of the exhaust units showed insufficient or absent maintenance. All rooms considered, 91% (10 out of 11 dwellings) of the apartments contained an insufficiently maintained exhaust unit.

Excluding the previous 5 devices which had been degraded by the occupants, we divide the maintenance of the exhaust units in three categories: sufficient, insufficient, and absent.

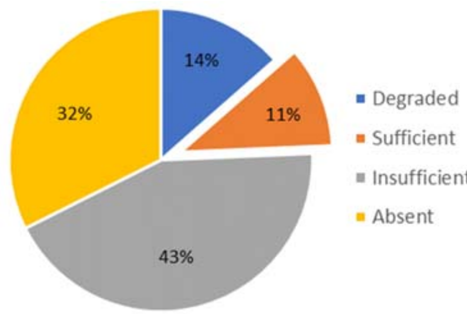


Figure 7: Statistics on maintenance over 37 collected devices

The nature of the accumulated dirt is also categorized: on one hand, dirt found on the exhaust units in the kitchens is thick and oily, because cooking activities generate volatile grease. On the other hand, the dirt found on toilet and bathroom units is generally dry and fibrous.

1. 11% (4 out of 37 units) of the exhaust units were considered to have received sufficient maintenance. Devices in this category presented aspects such as given in Figure 8 to Figure 13 or cleaner.

Figure 8: Kitchen humidity-controlled exhaust unit, with protection grid

Figure 9: Kitchen humidity-controlled exhaust unit, protection grid removed

Figure 10: Bathroom humidity-controlled exhaust unit, with protection grid

Figure 11: Bathroom humidity-controlled exhaust unit, protection grid removed

Figure 12: Fixed (not humidity-controlled) exhaust unit

Figure 13: Self-adjusting exhaust unit

2. 43% (16 out of 37 units) of the exhaust units were considered to have received insufficient maintenance. Devices in this category presented aspects similar to devices shown in Figure 14 to Figure 19.

Figure 14: Kitchen humidity-controlled exhaust unit, with protection grid

Figure 15: Kitchen humidity-controlled exhaust unit, protection grid removed

Figure 16: Bathroom humidity-controlled exhaust unit, with protection grid

Figure 17: Bathroom humidity-controlled exhaust unit, protection grid removed

Figure 18: Fixed (not humidity-controlled) exhaust unit

Figure 19: Self-adjusting exhaust unit

3. The remaining 32% (12 out of 37 units) of the exhaust units were excessively dirty (absence of maintenance). Devices in this category presented aspects such as shown in Figure 20 to Figure 25.

Figure 20: Kitchen humidity-controlled exhaust unit, with protection grid

Figure 21: Kitchen humidity-controlled exhaust unit, protection grid removed

Figure 22: Hygroscopic bathroom exhaust unit, with protection grid

Figure 23: Hygroscopic bathroom exhaust unit, protection grid removed

Figure 24: Fixed (not humidity-controlled) exhaust unit

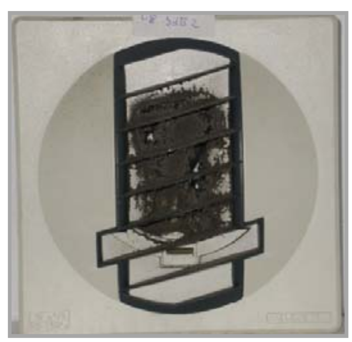


Figure 25: Self-adjusting exhaust unit

4 PERFORMANCE OF EXHAUST UNITS IN ABSENCE OF MAINTENANCE

In this section, we study the performance of non-degraded exhaust units which have received little to no maintenance as presented on Figure 20 to Figure 25.

4.1 Humidity-controlled devices

Before any cleaning or fixing, we characterize the humidity-controlled devices by plotting the airflow versus relative humidity. The measurement is performed on a dedicated test bench under a pressure difference of 100 Pa.

As a first example, the curve obtained for the kitchen exhaust device from Figure 20 and Figure 21 has been plotted in dark brown on Figure 26. The dirt on this unit was thick and greasy, which is typical of dirt accumulated in kitchens. The curve's hysteresis is seen on every hygroscopic device; it is due to mechanical clearances. The initial tolerance envelope is shown in dark brown on the graph.

Without cleaning or dusting, the device exhibits a conform hygroscopic behavior by modulating the airflow as a function of humidity on the expected relative humidity range.

Despite the partial clogging of the canal, the unit can reach a maximal airflow reduced by 25% compared to its original value.

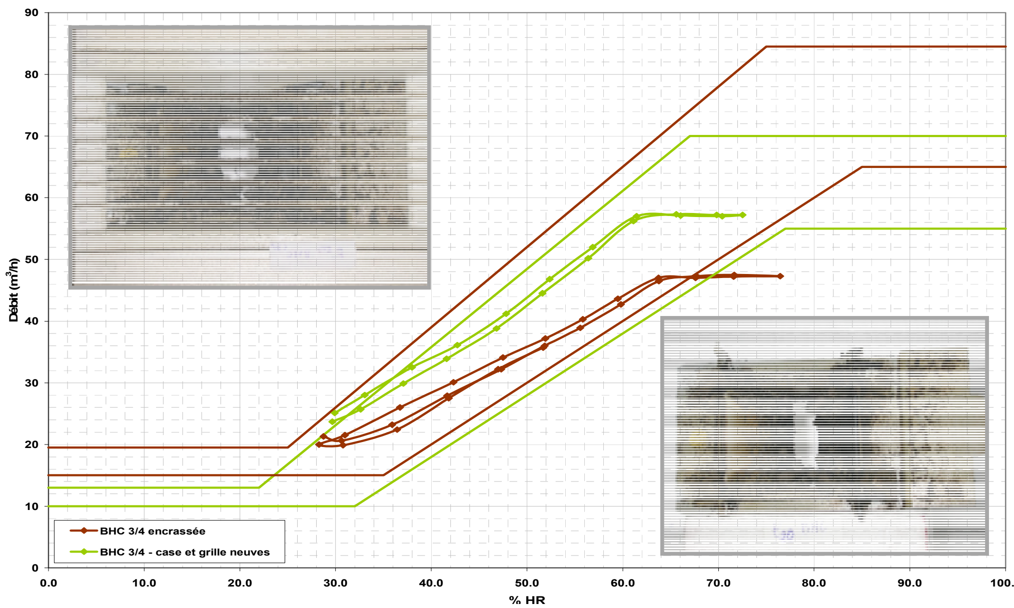


Figure 26: Laboratory characteristic of an excessively dirty kitchen exhaust unit

In order to characterize the aging of the humidity sensing strip alone, the shutter-case and the protection grid (see Figure 2) have been replaced by new parts with slightly different nominal airflows and tolerance envelope. The devices were then characterized on the same test bench under the same conditions. This test is representative of the device, had it been well maintained. The curve and envelope are plotted in light green on Figure 26.

The curve exhibits a maximal airflow within the tolerances corresponding to the new shutter. With a slight drift of +2 %RH visible at low humidity values, the curve fits well within its tolerance template after six years of in-situ functioning.

A second example is given on Figure 27 for a device installed in toilets (the unit was installed in the kitchen first, then moved to the toilets by the occupant). The accumulated dirt in this case was dry and dusty, which is typical of toilets and bathrooms.

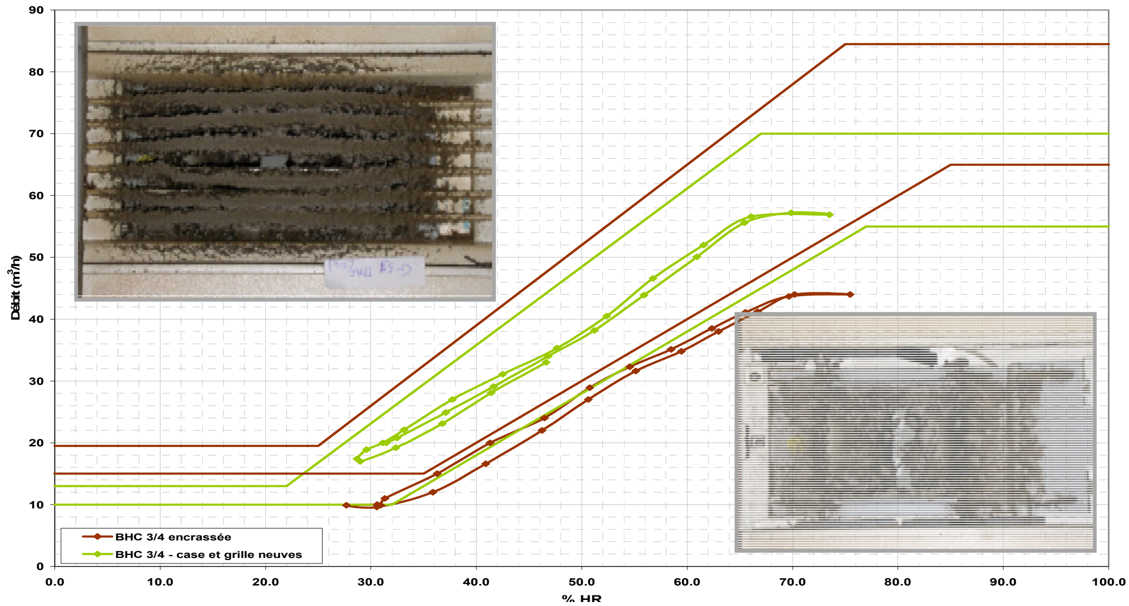


Figure 27: Laboratory characteristic of an excessively dirty exhaust unit installed in the toilets

The device exhibits a conform hygroscopic characteristic: the crossing airflow is humidity-dependent between 30 and 70 %RH. The dirt and dust accumulation on the shutter reduces both maximal and minimal airflows of 34 % compared to nominal values.
After replacing the shutter-case and the protection grid, the measured curve (light green) fit into the tolerance template.

In general, for as-collected humidity-controlled devices:

- 100 % of the non-damaged exhaust units exhibited a conform hygroscopic behavior, or showed a shift of their characteristic lower than 2 %RH when still soiled.
- 46 % of the kitchen units which received no maintenance complied with factory specifications. The other 54 % showed reduction of the measured airflows due to clogging of the canal.
- 100 % of the bathroom exhaust units which received no maintenance showed an airflow reduced by 5 m^3/h over the entire humidity range.

Despite the reduction of airflow, the conform hygroscopic behavior still ensures a control of steady-state humidity levels: on the above example, the shutter will stay open as long as relative humidity is higher than 70 %RH. The airflow being reduced, the shutter will stay open for a longer period.

After proper cleaning and reassembly (the shutter and shutter-case were replaced when irreversible damaged was observed):

- 75 % of the units complied with factory specifications after cleaning.
- among the other 25 %, the kitchen elements showed an increase of volume flow lower than 3 m^3/h, while bathroom units exhibited a decrease lower than 2 m^3/h.

A proper maintenance of the humidity-controlled exhaust units ensures a behavior of the device close to factory specifications. A thorough measurement of the actual in-situ drift of the devices is planned as a joint study lead by the CEREMA, as presented by Jardinier et al. in these proceedings (Jardinier, 2018).

4.2 Self-adjusting devices

Self-adjusting exhaust units have been characterized following the same process. The test curves of a moderately dirty (Figure 28) and an excessively dirty (Figure 29) self-adjusting exhaust units are shown below.

The goal of these products is to provide a constant airflow, independent of the pressure within the ventilation ducts. Therefore, we analyze the airflow for different values of pressure difference within their working pressure range.

The bold red curve represents the theoretical behavior, while fine red curves show the measured behavior on the new devices. Orange curves represent the measurements on the device as-collected (i.e. still soiled), when the blue curves show the same measurement after the unit had been cleaned.

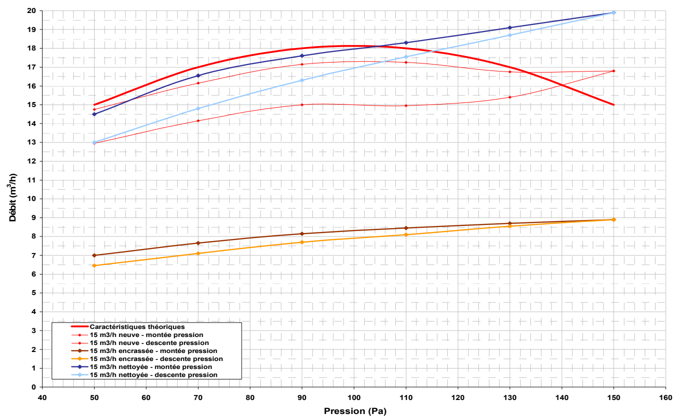
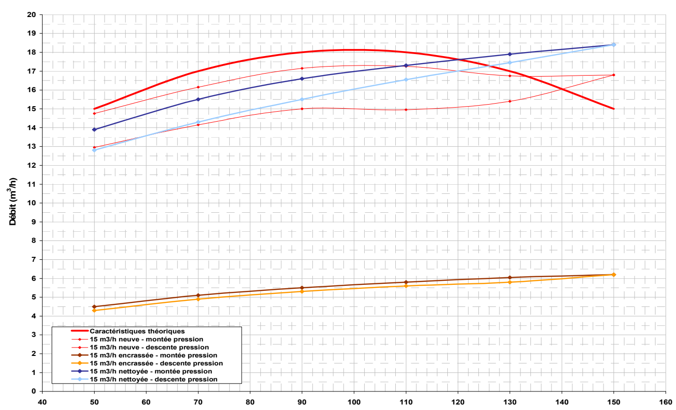


Figure 28: Test curves for a moderately dirty self-adjusting unit



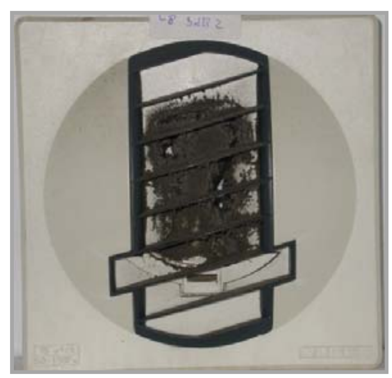


Figure 29: Test curves for an excessively dirty self-adjusting unit

In the examples above, self-adjusting exhaust units show a high sensitivity to maintenance: the average airflows are reduced by 55 % of the nominal value in the case of moderate maintenance, and 65 % of the nominal value in the case of insufficient maintenance. Once properly maintained, the measured airflows are close to the original values.

In general, for collected self-adjusting units:

- 100 % of the soiled units were out of their specification, with volume flows 4 to 10 m^3/h (25 to 65 %) lower than their initial setting.
- Once properly maintained, 100 % of the units complied with factory specifications.

5 CONCLUSIONS

With 75% of insufficiently maintained exhaust units, the results of this samples collection highlight a crying lack of maintenance of ventilation systems.

This lack is especially detrimental for the sampled self-adjusting exhaust units, which airflows are significantly reduced (25 to 65%) by accumulated dirt, without any compensation.
The collected humidity-controlled devices also exhibit reductions of the airflows, but all still react to relative humidity variations. This reaction generates a feedback-loop on humidity which minimizes the impact of airflow reduction due to dirty exhaust units.

For both self-adjusting and humidity-controlled devices, a proper maintenance ensures behaviors close to or within the original settings.
Aware of this result, public authorities and the ventilation industry are acting together to enhance the performance of ventilation systems over time: recommendations and informative standards are published concerning schedules and good practice of maintenance. Modifications of certain products to prevent dust accumulation are implemented, such as the removal of protection grids.

6 REFERENCES

- Savin, J.L., Jardinier, M., (2009) *Humidity Controlled Exhaust Ventilation in Moderate Climate*, Ventilation Information Paper, issue 31.

- ADEME, (2009), Performance Project, *Performance de la ventilation et du bâti – Phase 3, Performance énergétique et QAI des systèmes hygroréglables*.

- Jardinier, E., Parsy, F., Guyot, G., Berthin, S., (2018) *Long-term durability of humidity-based demand-controlled ventilation: results of a 10 years monitoring in residential buildings*, 39th AIVC Proceedings.