# Durability of humidity-based ventilation components after 15 years of operation in French residential buildings – Lab tests

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## SUMMARY

Humidity-based DCV systems have been widely used in France for 35 years and are considered as a reference system, including for low-energy residential buildings. The on-going Performance 2 project delivers the new results of a thirteen-year monitoring in twenty-two social housing apartments. The involved consortium is composed of Cerema, Univ. Savoie Mont Blanc and two industrials partners: Aereco and Anjos.
The initial project was a large-scale monitoring on thirty new occupied apartments equipped with this DCV system, which extended from 2007 to 2009. The equipment included IAQ sensors in different rooms of each dwelling (temperature, humidity, and CO2), as well as pressure and volume flow sensors for monitoring the ventilation system. Recordings were performed every minute over two years. This former study showed: The good IAQ in terms of CO2 and humidity, a good correlation between CO2 and airflows, savings on heat losses of 30 % in average compared to regulatory constant airflows.
Thirteen years later the building is re-visited, and the monitoring system is turned back on with the intention to assess the ventilation system performance after a prolonged in-situ functioning period.
Then, the components have been collected and tested in laboratory facilities, before and after cleaning, and then after light rehabilitation. In this article, we give the results of these data about the durability of ventilation components.
In the context of the increasing awareness about smart ventilation, these feedbacks highlight as a crucial issue, the durability of the ventilation systems and its components (including the sensors) and their robustness to a lack of maintenance or even a bad use by occupants.

## KEYWORDS

Smart ventilation, residential ventilation, IAQ, energy efficiency, durability, humidity

## 1 INTRODUCTION AND OBJECTIVES

### 1.1 General context towards demand controlled ventilation

In Europe, two recently published directives – n°1253/2014 regarding the eco-design requirements for ventilation units and n°1254/2014 regarding the energy labelling of residential ventilation units (European Parliament and the Council, 2014) – are moving towards a generalization of low-pressure systems, demand-controlled ventilation (DCV) systems and balanced heat recovery systems by 2018. Performance-based approaches generally guaranty the indoor air quality (IAQ) and the energy performance of DCV systems, through agreement procedures or certification (Guyot et al., 2018). As ventilation systems become more sophisticated (or 'smart') standards and regulations are changing to accommodate their use. A key smart ventilation concept is to use controls to ventilate more at times it provides either an energy or IAQ advantage (or both) and less when it provides a disadvantage. This paper discusses the favorable contexts that exist in many countries, with regulations and standards proposing 'performance-based approaches' that both enable and reward smart ventilation. The paper gives an overview of such approaches from five countries. The common thread in all these methods is the use of metrics for the exposure to an indoor generated parameter (usually CO2), and condensation risk. As the result, demand-control ventilation strategies (DCV) are widely and easily available on the market, with more than 20–30 systems available in some countries (Guyot et al., 2017). In Europe, several countries already enable and/or promote the use of DCV systems in ventilation codes, including Belgium, France, Spain, Poland, Switzerland, Denmark, Sweden, the Netherlands, Germany (Borsboom, 2015; Guyot et al., 2018; Kunkel et al., 2015; Savin and Laverge, 2011)

Humidity-controlled mechanical extract ventilation (RH-MEV) systems have been widely used in France for 39 years. Most of the new residential buildings complying with RT 2012 energy performance regulation, are equipped with such systems (Mélois et al., 2019). They are also considered today as a reference system.

## 1.2 Technological context: presentation of the reference humidity based DCV system

Humidity-based mechanical exhaust ventilation (RHMEV), further described in (Jardinier et al., 2018), is based on the sweeping principle: an exhaust fan ensures an under-pressure in the dwelling, allowing the outdoor air to come in through air inlets situated in the “dry” rooms (bedrooms and living room) and go out through exhaust units located in the service or “wet” rooms (kitchen, bathroom, toilets). In the humidity-controlled MEV (RH-MEV) system described here, both the exhaust units and air inlets are humidity sensitive. The unit aperture is controlled by a mechanical humidity sensor and actuator. If the air is dry enough, the unit’s opening area is minimum, so that the airflow is at its minimum. When a pollution episode – such as cooking or showering – occurs, or for prolonged occupation, the humidity rises in the room and is detected by the unit sensor. As a result, the opening area gets wider, according to the humidity level, and the volume of air passing through the room is increased, removing and diluting the pollutants. When no activity or occupancy is detected, minimum airflows are maintained, as required by the French regulation for correct dilution of pollutants not linked to occupancy.

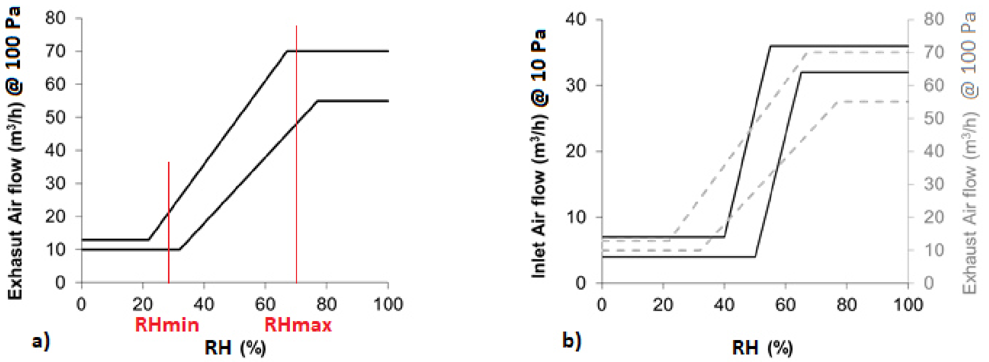


Figure 1 : a) Exhaust unit hygroscopic curve envelope. b) Inlet hygroscopic curve envelope (black curve).

A RH-MEV unit is defined by its hygroscopic curve (Figure 1.a): for RH < RHmin, the airflow is minimum. For $RH_{min}$ < RH < $RH_{max}$, the airflow varies more or less linearly, for RH > $RH_{max}$, the airflow is maximum.

Air inlets (see a typical envelope on figure 1.b), exhibit higher sensitivity to small changes of relative humidity on lower ranges, such as the one brought by human breathing. As a result, in an occupied room, the inlet aperture widens-up in response to rising humidity, increasing the proportion of the total airflow passing through it. In the meantime, in an unoccupied room, the opening area remains minimum, reducing the airflow passing through the air-inlet.

In addition, the humidity-charged air travels through the dwelling towards the humidity-controlled exhaust units, which become more opened, increasing the total airflow.

In 2019, the “Performance 2” project was launched in three phases in order to (1) get a first full winter analysis of the system after 13 years of in-situ operation, with the installed sensors (non-recalibrated) and no major intervention, (2) collect the ventilation units and sensors for laboratory testing before and after cleaning and maintenance, (3) reinstall the cleaned and maintained ventilation units (hygroscopic components unchanged) with new calibrated sensors. The phase (1) has been described in (Guyot et al., 2022). In this article, we present the phase (2) of the Performance 2 project.

## 2 METHODS

### 2.1 Case studies and previous ventilation diagnosis

The two social housing buildings studied are :

- a building of Paris Habitat where 19 dwellings had been instrumented by Aereco in 2007 (from the 4th to the 8th floor),
- a building of Lyon Métropole Habitat where 12 dwellings had been instrumented by Anjos in 2007.

The Performance 2 campaigns include continuous measurements at the ventilation terminals (CO2, Temperature and Relative Humidity (RH) sensors already in place since Performance 1 project 13 years ago, and Volatile Organic Compounds and Particulates added for Performance 2 for the building in Paris). In order to characterise the reliability of these sensors and also to characterise the current performance of the ventilation terminals, we intervened in the voluntary dwellings of the buildings in order to sample these terminals and sensors. These interventions allowed to carry out an inventory of the ventilation installations, partly applying the French Promevent protocol (Bailly Melois and Mouradian, 2018). Figure 2 illustrates, for example, the result of the inspections of the air intake conditions in the voluntary dwellings of the Villeurbanne building.

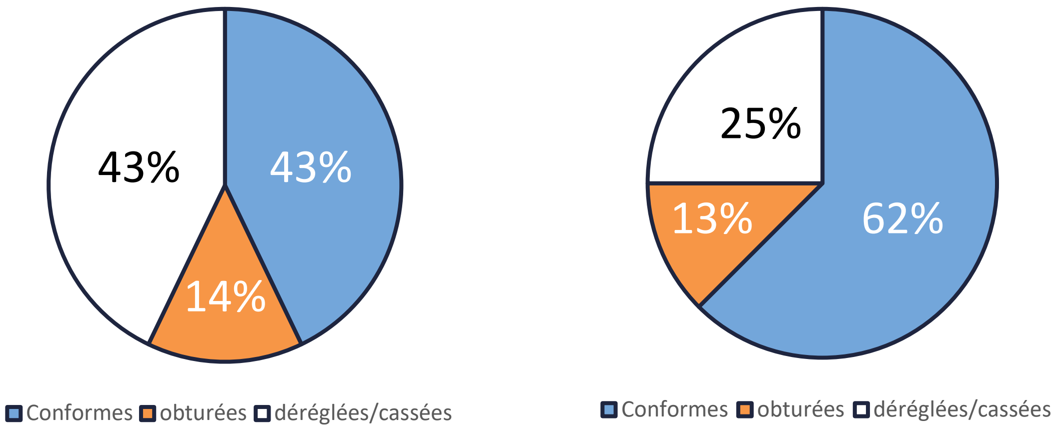


Figure 2 : Representation of the state of the air inlets present in the living room (Left, Total: 7). B) and in the bedrooms (Right, Total: 16) in the volunteer dwellings in the Villeurbanne building

### 2.2 Methodology for laboratory measurements on components

Since the Performance 1 project, the ventilation terminals (extract units and air inlets) of the dwellings in the study buildings as well as the various sensors installed during Performance 1 have remained in the dwellings. A laboratory study of these terminals and sensors was carried out to:

- Characterise the current hygro-regulated performance of the ventilation terminals;
- Verify the operation and reliability of the on-board sensors: the sensors installed during Performance 1 (CO2, Relative Humidity (RH) and temperature), as well as the new sensors integrated in the acquisition cards in Paris (VOC and Particles)

#### 2.2.2 Characterisation of terminals and sensors - Paris site

For 15 volunteer flats in the Paris building, Aereco sampled all ventilation terminals (extract units and air inlets) as well as all sensors dating from Performance 1 (replacement terminals were temporarily installed). Two characterisations were carried out in the laboratory.

##### 2.2.2.1 Ventilation components

First of all, the performance of the 52 extract units was characterised, after 13 years of operation: 15 in the kitchen, 22 in the bathroom (SdB) and 15 in the WC. Their condition was evaluated and the extract units were classified in 4 categories: good condition / average condition / bad condition / degraded. The hygroscopic performance of each vent was then assessed using tests carried out in laboratory rooms, with controlled temperature and relative humidity. The hygroscopic performance curves were plotted for the three test phases:

- Vent in condition (directly from the sampling in the dwellings) ;
- Cleaned vent;
- Refurbished vent: a change of the dampers was carried out because the first tests showed a creep of the test material, modifying the shape and thus the operation of the dampers. In order to characterise the performance of the humidity sensitive device only, it was decided to carry out this maintenance operation for all the registers of the study.

For each grille, the 3 curves obtained were compared to the curves of 2007, allowing to evaluate the evolution of the humidity sensitive device performance.
In preparation of the in-situ campaign, the Hall effect sensors (which allow to measure the opening of the damper) embedded in the diffusers (dating from Performance 1) have been "calibrated", in order to link the airflow through the diffuser to the signal sent by the Hall effect sensor and to the signal of the pressure sensor. Thus, charts have been produced that will allow the evaluation of the real in-situ flow rates from the signals sent by the Hall effect sensors and the pressure sensors once the diffusers are reinstalled in the dwellings.

A similar protocol was used to characterise the performance of the 54 air inlets. The tests were carried out on the air inlets :
- in the state after sampling in the dwellings
- cleaned ;
- refurbished: shutters and acoustic foam changed.

For each air inlet, 3 hygroscopic operating curves could be drawn and compared to the initial curves of 2007.
As for the air inlets, the Hall effect sensors embedded in the air inlets were calibrated.

#### 2.2.2.2 IAQ sensors

In parallel with the characterisation of the performance of the ventilation terminals, the functioning of the IAQ sensors that will be used during the in-situ campaigns was evaluated. These are :

- temperature, relative humidity and CO2 sensors installed during Performance 1 ;
- the temperature, relative humidity, CO2, VOC and particulate matter sensors fitted on the new electronic boards for Performance 2.

Tests in a controlled environment were carried out by comparing the values obtained by the sensors with the values given by a reference for each parameter measured. The difference obtained is then compared to the technical specifications announced by the manufacturer, which take into account the 13 years of aging of the sensor.

The accuracy of the sensors on the new cards was also evaluated for each parameter measured, including the implementation of an intercomparison of all cards:

- for the VOC measurement, with the use of VOC-emitting wipes ;
- for the particle counter, with a smoke emission generated by cigarettes (without measurement reference).

### 2.2.3 Ventilation components and sensor characterisation - Villeurbanne site

For the 7 voluntary flats in the Villeurbanne building, Anjos sampled all the ventilation terminals (extract units and air inlets) as well as all the sensors dating from Performance 1 (replacement terminals were temporarily installed). Two characterisations were carried out in the laboratory.

#### 2.2.3.1 Ventilation components

First of all, the performances of the 10 humidity sensitive extract units were characterised: 4 in the kitchen, 6 in the bathrooms (in some dwellings, units were replaced by non similar units). The hygroscopic operation of each extract unit was evaluated from tests carried out in laboratory rooms, with controlled temperature and relative humidity. The hygroscopic operating curves were plotted for the three test phases:

- vent in state (directly from the sampling in the dwellings) ;
- cleaned vent;

- rehabilitated vent: the dampers and ducts were changed.

For each vent, the 3 curves obtained were compared to the initial product specifications.

In preparation for the in-situ campaign, the Hall effect sensors (which measure the opening of the damper) embedded in the diffusers (dating from Performance 1) were "calibrated", in order to link the airflow through the diffuser to the signal sent by the Hall effect sensor. Thus, charts were produced that will allow the evaluation of the real in-situ flow rates from the signals sent by the Hall sensors once the diffusers are reinstalled in the dwellings.

A similar protocol was implemented to characterise the performance of the 14 air inlets (in some dwellings, air inlets were absent). The tests were performed on the air inlets :

- in condition after sampling in the dwellings (for 6 air inlets) ;
- cleaned and refurbished: shutters and acoustic foam changed.

For each air inlet, one or two hygroscopic operating curves could be traced and compared to the initial specifications.
As for the diffusers, the Hall effect sensors embedded in the air inlets were calibrated.

## 3 ACKNOWLEDGEMENTS

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