DEMAND CONTROLLED VENTILATION: CONCILIATING INDOOR AIR QUALITY AND ENERGY SAVINGS

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ABSTRACT

Maintaining a good indoor air quality (for people and building conservation) is obviously the first aim of any ventilation system; nevertheless the main side effect – which is also the most visible one – is to spend energy, for heating first and for transport.

In these times of expensive energy, the temptation is high to lower the ventilation flows, with few consideration on indoor air quality. Demand controlled ventilation is still often accused of this behaviour and argued against as being “just a flow reduction”. The philosophy behind demand controlled ventilation is completely opposed to this and come from the indoor air quality level to the energy conservation one: by no mean the purpose is to decrease flows when the demand is high, but to take advantage of the fact that, in some periods, in some condition, the demand is lower and the flow can be adjusted without reverse effect on air quality. The swing between high flows and lower ones will lead to energy benefit compared to a single continuous flow value, on a yearly and statistic base. In dwellings, humidity appears to be the best compromise between representative need, accuracy and cost. Measurement results are given to show the adequacy between humidity and needs in dwellings.

The response of simple and cheap humidity controlled as the result of the swing between high and low levels is discussed and explained through theoretical examples, French regulation, and monitoring results from Asia to Europe. The increasing potential for demand controlled ventilation systems is presented through the evolution of the size of apartments and corresponding occupancy in France as an example. As a conclusion, humidity controlled ventilation – natural, assisted, or mechanical – has proved to be a reliable and relatively cheap system, economically valid in new or retrofit, in various climates.

1. INTRODUCTION

In these times of major increase of energy cost, all the attention is paid for solutions which decrease significantly the energy consumption. The weight of ventilation in the energy consumption of the building due to the air renewal –average 50% of the heat losses- and to the air transport has never been as important as today, since all other parts of the building –insulation, window, heaters, etc.- have been strongly optimised. Then, while the temptation to reduce airflows is high, it is necessary not to forget the first aim of ventilation which is to maintain a good indoor air quality for human comfort and health as for building conservation. Demand controlled ventilation systems aim at answering to this objective taking into account as best the energy aspect. Supported by theoretical examples and practical applications through numerous monitoring, this proceeding aims at better understanding the way to comprehend demand controlled ventilation systems.

2. CONSTRAINTS AND POTENTIAL

The energy aspect has become today as essential as the first objective of ventilation: providing a good IAQ. Even if new building regulations and standards generally take care of this dual aspect, retrofitting may now be a major threat to IAQ since lack of correct ventilation provision is very common when improving insulation and/or windows. It can be said that today's most active area for savings is retrofitting: Kyoto commitments cannot be achieved without taking strong measures in this field. It is thus essential to discuss solutions which are available both for new and retrofitting and that can be economically used to reach critical mass quantities.

DCV has a particular place among ventilation techniques which can answer to the double objective of IAQ and energy savings. *A double approach is necessary to understand how Indoor Air Quality can be maintained (or even improved – which means higher airflows) and how – in the same time – energy savings can be achieved (which means lower airflows).*

3. STANDARD REFERENCES FOR IAQ AND ENERGY SAVINGS

The notion of Indoor Air Quality improvement and energy saving has no sense if we do not talk about a standard reference system; Demand control ventilation does not save energy in the way of the heat recovery system does. DCV aims at spending less energy than the reference system, while achieving a comparable –or better- level of IAQ. This assumption shows the importance of the standard reference system choice. Depending on the regulation, it is not always obvious to agree on a common reference. The standard reference system is usually taken from the building regulation part dealing with ventilation flows: in general the airflow is constant, although it is not always obvious if this airflow is used for the ventilation system dimensioning or if it is a real constant one. The difference is huge: in the case of a non-constant airflow, the impact of the occupant may be of considerable importance on the real level if the system relies on his skill to drive the ventilation flows: the calculation of resultant energy cost and IAQ level may be very dependant on use.

This explains why it has been easier and faster to implement demand control ventilation in the countries where the airflows were assumed to be constant, with no influence (or known conventional influence) of the occupants. The constant airflows have been set for a reference use of dwellings, which means that some will be more occupied, and some will be less: these last dwellings constitute the real energy saving potentials. But even in a normally or over-occupied dwelling, there are periods of under-occupancy when it is possible to perform savings. *With demand control ventilation, IAQ must be approached at room or dwelling level while energy is to be considered on a yearly basis, at a statistic level.*

4. MOISTURE AND VENTILATION NEEDS IN WET ROOMS

Annex 18 of the IEA (1990) focussed on demand controlled ventilation and pointed out some questions regarding detection type, accuracy, long time behaviour; Almost 20 years later, it can be given some answers. As a conclusion of an Annex 18 workshop on DCV for dwellings, it was agreed that humidity problems are of main concern (moisture, mould growth, destruction of wall, etc.), far higher than the other aspects of IAQ: the general trend was that if ventilation is appropriate to control the humidity aspects, the other should be correctly dealt with too.

Measurements realised in 1989 during a monitoring in Europe[1] have shown that there is a clear link between the increase of CO_2 and the increase of absolute humidity. *Moreover, humidity control is more suitable than CO_2 control in the wet rooms,* which confirms the Annex 18's workshop conclusion.

[1] European project EE/166/87 (1987-1989). See § "References"

5. DCV BEHAVIOUR IN DRY ROOMS

The question remains for the other rooms: we know that the absorption-desorption phenomena is more active in habitable rooms as the materials used are in general more permeable to humidity and result in a damping coefficient. So the question can be asked: *Is humidity variation connected to CO_2 variation or mainly connected to damping behaviour of furniture?*

Resulting from measurements realised during an important monitoring holding in Paris[2], the graph Figure 1 can give a key for answering this question. Relative humidity and CO_2 measurements have been recorded in parallel along one week in a bedroom occupied by one person. The grey areas focus on the night period when the room is occupied.

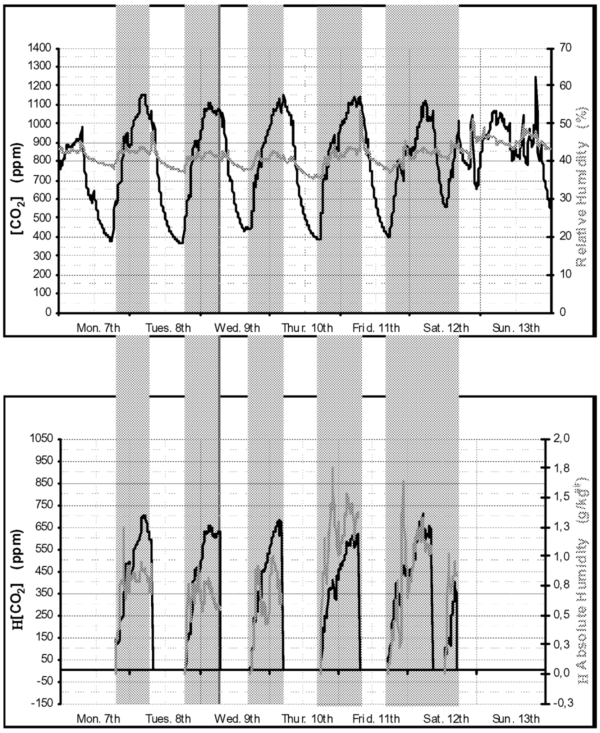

Figure 1. CO_2 and humidity levels in a bedroom, occupied by one person. Top graphic: complete record on one week; Bottom graphic: Measurements restricted to nights periods, when the bedroom is occupied (grey areas).

At the first glance on the top graphic, the variation of CO_2 in this bedroom seems to be much higher than the one of relative humidity. But if we concentrate on times when the person is inside the room during the night (grey areas) and calculate the evolution of the absolute humidity[3] from the beginning to the end of the night and the corresponding evolution of the CO_2, we obtain the bottom graphic of Figure 1. *We have thus a clear trend of a strong correlation between CO_2 increase and humidity increase.* The calculation made from the CO_2 levels gives a damping coefficient of around 50%: part of the water vapour is absorbed by the furniture and the material[4].

It is important to notice here that it is possible to detect a variation of humidity in habitable rooms, and that this variation is linked to the occupancy, but that *it cannot rely only on relative humidity alone.* This is why the air inlets, if humidity demand controlled, must include a temperature coefficient that adapts the response to outside conditions[5].

The reactivity of humidity controlled terminals has also been measured during a monitoring hold in Tokyo[6] in February 2008, to demonstrate that the time-reaction for opening did not excess 2 minutes.

6. STATISTICAL AND INSTANTANEOUS VARIATIONS OF RELATIVE HUMIDITY

For all rooms in a dwelling, the average relative humidity varies according to the seasons, following in a large way the outside absolute humidity. As the absolute outside humidity is always lower in winter, the basic flow is lowered accordingly: we can note that, to solve humidity problems like condensation, mould growth, etc., the air is more efficient in winter than in the other seasons. A side effect, especially for cold climates, is to limit the time when the indoor relative humidity is too

[2] "Performances" Project (2007-2008). See § "References"

[3] Absolute humidity was considered instead of relative humidity to erase the impact of temperature on the humidity level.

[4] Information on outside humidity level was not available in this monitoring

[5] "Thermal behaviour of humidity controlled air inlet", 23rd AIVC.

6 "Tokyo Gaz Monitoring". See § "References"

low for comfort, not using humidification process (which often costs a substantial part of the recovery in heat recovery constant airflow systems). If we consider an empty dwelling, the airflow will strictly follow this outside level. The human metabolism and specific activities will increase this level and must be detected to adjust the airflow when needed.

We have here the main point of demand controlled ventilation in general and of humidity controlled ventilation in dwellings in particular: *the average airflows will lower during cold season, but the individual airflows still follow the demand.* Long term monitoring show this dual response, as presented in the next figures.

Extracted from HR-VENT monitoring[7], the graph Figure 2 shows that in winter, when the humidity rises, the instantaneous response of the humidity controlled extract grille is a quick change in opening, giving higher airflow. The same instantaneous reaction occurs as well in summer, and can be observed on longer periods.

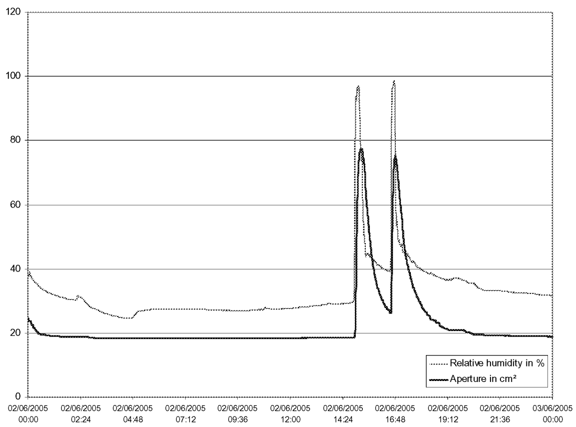

Figure 2. Instantaneous response of a humidity controlled extract grille (opening in cm², dark line) according to RH (in %, light line) in a bathroom on a 24 hours basis in winter

If we want to better understand now the dual behaviour of humidity controlled air extract grilles, we propose another view, more statistical, through an XY projection of the function [grille opening = f(relative humidity)] as shown on Figure 3 (Winter) and Figure 4 (Summer).

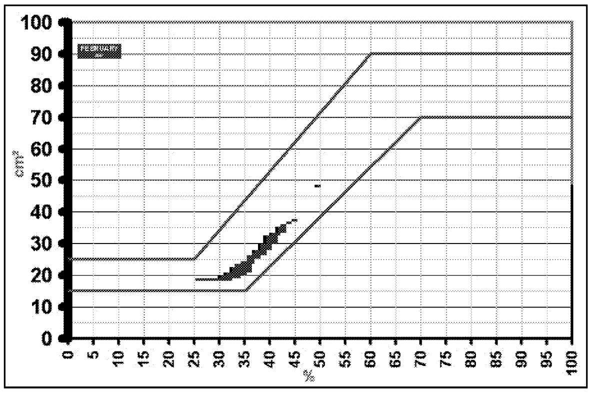

Figure 3. Statistical response of a humidity controlled extract grille (opening, in cm²) according to RH (in %) in a bathroom DURING ONE MONTH in WINTER[8] (February)

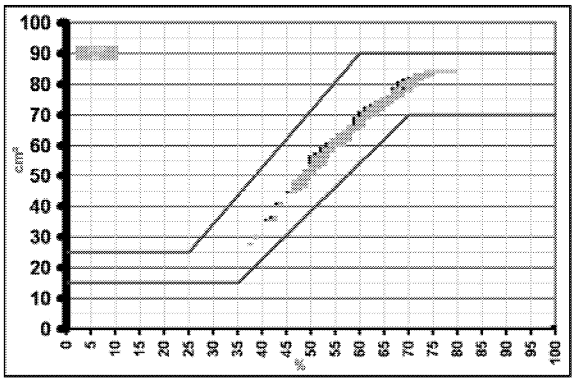

Figure 4. Statistical response of a humidity controlled extract grille (opening, in cm²) according to RH (in %) in a bathroom DURING ONE MONTH in SUMMER (June)

Due to the seasonal variations of outdoor humidity, the opening -thus the airflow- is statistically low in winter (Figure 3) and becomes higher in hot season (Figure 4). *The humidity controlled ventilation exploits the natural variations of outdoor humidity to save energy during the cold periods.*

In parallel to this statistical behaviour, the instantaneous reaction is always adapted to the needs as seen Figure 2. Whatever the season, the shortness of high humidity levels in the rooms make this impact on energy losses considerably limited in winter. *During*

7 "In-situ performances measurement of an innovative hybrid ventilation system in collective social housing retrofitting". See § "References"

8 The straight lines side the area of the tolerances of the product.

all the year, the fast answer of the humidity controlled ventilation ensures a good level of IAQ.

This behaviour has been observed in different places in the world like another monitoring hold in Japan (Hokkaido, northern and coldest part of Japan, where the winter temperature is often under –20°C) in 2001 has shown. The same seasonal average airflow variations had been recorded for a whole year of functioning.

7. DCV AND VOCs

Besides pollutants emitted by human activity and metabolism, VOCs must be taken into consideration as parameters which directly impact on the indoor air quality. But their heterogeneous and variable composition, their time-variation (higher concentrations at the beginning of the material's life), their variation according to temperature and humidity represent so numerous parameters which makes difficult to hand over the ventilation the role for the control of VOCs concentrations. The most efficient -and relevant- way to limit indoor VOCs rates still remains the control of the pollution at the source, which means at the level of the design and the material choice: low emitting material should always be preferred as the initial cost is lower than a higher level of ventilation.

Nevertheless, humidity controlled ventilation participate in decreasing the VOCs concentration, as most studies have found an increase of VOCs emission when humidity and/or temperature increase. Formaldehyde and other VOCs are not directly dealt with when using a humidity controlled ventilation but all factors concerning the indoor emissions and outdoor air dilution efficiency (regarding VOCs) are positive and consistent with the modulation of the airflows.

8. DCV: A RELEVANT SOLUTION AND A HUGE POTENTIAL

Benefiting from many advantages as seen before, demand controlled ventilation is more and more seen as a relevant alternative to heat recovery systems. The new building and the huge building stock that has to be thermo-refurbished need efficient ventilation solutions, but not only: the proposed solutions must be economically viable, their installation must not be critical, the maintenance should be the lowest and the most simple, and the performances must not suffer from the weight of the using years. Because DCV systems now conform to these requirements, sometimes better than the heat recovery systems do, the new and future regulations in Europe are now more open to it.

Unfortunately, DCV systems suffer from their constitutive principle: they vary. All the time, from one room to another and according to numerous parameters (occupancy, activities, meteorology, etc.). *For that reason, the regulators need to agree on different scenario of occupation and other parameters to be able to assess the DCV systems, and then to valorise the energy savings compared to the reference.*

In France, the system has been experimented from the early 80', with more than 1,5 million dwellings now equipped (2 millions worldwide), with no trend of particular drawback compared to a classic constant airflow ventilation system. The level of energy reduction is around 35% to 55% of the part needed to heat the air (depending on the reference and the system used); The energy needed for transport can also be lowered, by using a variable fan or hybrid system. Humidity controlled ventilation systems are now a standard in French Building and represent more than 50 % of new building. Humidity controlled ventilation systems exist in mechanical, hybrid or natural ventilation (exhaust type) which can easily be used in new building or retrofitting (often with re-use of existing ducts).

The potential for demand controlled ventilation is high and will become higher as the density of occupancy is lowering on a global trend for years in all countries. As shown in Figure 5 regarding French occupancy statistics, the occupancy rate has changed from 1/25 occupant per m² in 1973 to 1/37 in 2002.

	1973	1984	1992	2002
m² / occupant[9]	25	31	34	37
Over occupancy	4.7%	1.7%	1.3%	0.9%
Moderate over occupancy	17%	11.1%	9.6%	9.3%
Normal occupancy	29.4%	26%	22.8%	22.6%
Moderate under occupancy	25.6%	29.4%	26.7%	25.7%
Under occupancy	23.3%	31.8%	39.7%	41.6%

Figure 5. French statistical data (INSEE) concerning dwelling occupancy.

In 2008, the trend continues, and the number of under occupied dwellings (which is the main source of energy economies) will reach 70% in a few years. The idea of demand controlled ventilation was implemented in France in 1983 from the figures of 1978 (55% of under occupied dwellings) when it was found that energy savings were possible.

9. CONCLUSION

With a lower statistical airflow especially in winter to reduce heat losses and an instantaneous airflow always adapted to the needs, demand controlled –and particularly humidity controlled-ventilation systems have proved their major advantages in terms of IAQ as well as on energy savings. Numerous studies and monitoring from Europ to Asia have shown the interest of employing this ventilation system through various dwelling configurations, building type, occupancy and meteorological conditions. With a cost usually only 3 to 4 times the price of a classical exhaust only system -installation cost is the same-, the humidity controlled system gives a short payback period, depending on energy cost and winter temperature. Associated with a light and low critical maintenance compared to heat recovery, these systems are a relevant solution both for the new building and for the refurbishment of the building stock, which should enable to meet faster Kyoto protocol objectives. Most of countries involved in the energy consumption reduction in the building field are now working on the assessment of DCV systems in the regulation, following France and other countries that have already inserted these systems in their regulation.

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[9] Line "m²/occupant": the figures are related to the whole stock and not only urban areas where the size is smaller