HYGROTHERMAL BEHAVIOR OF A HUMIDITY CONTROLLED AIR INLET

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ABSTRACT

This paper deals with the real behavior of a humidity controlled air inlet, regarding to relative humidity and temperature. It has been often heard, that relative humidity is not the best indicator for detecting a need of ventilation in main rooms (living room and bedrooms) because it is season dependant (the absolute humidity outside varies in a wide range from winter to summer, which should lead the air inlet to be closed in winter and open in summer). Designing a humidity controlled air inlet is much more complex than designing a humidity controlled extract grille because this effect of the wide variation of the outside absolute humidity must be fought to ensure a proper functioning throughout the year. The sensor is sensitive to relative humidity, in its own environment. The local relative humidity depends on the absolute humidity and the temperature of the sensor's environment, which is linked to inside and outside temperature. The 'know-how' of designers allows to have a controlled drift of the response curve (aperture Vs internal relative humidity) that makes it possible to keep a good answer to occupancy, without any manual adjustment during the year.

KEYWORDS

air, inlet, humidity, control, energy efficiency, temperature

TECHNOLOGY OF HUMIDITY CONTROLLED AIR INLETS

General aspect

The constitution of humidity controlled air inlets concerns an elaborate technology which concentrates the benefit of more than twenty years experiments and advanced research. It already made it possible to equip more than 1.5 million houses and apartments by means of an efficient ventilation system: i.e. aiming at ventilating what is necessary, when it is necessary and where it is necessary.

Even without air inlet, it is admitted according to the laws of physics that the fresh air flows are equal to the outgoing flows ; but the random character of air leakage positions makes it impossible to speak about distribution of fresh air flows.

First, in order to ensure that fresh air flows in from the main rooms to the service rooms and that they are all ventilated, it has been chosen to integrate air inlets with fixed apertures in these rooms.

In this configuration, the total fresh air flow was divided and not really distributed. Even if we consider that these air inlets can be equipped with a fixed shutter, the regulation of the flows remains a On/Off modulating and controlled according to the goodwill of the occupants.

Thus, the idea to develop air inlets integrating a mechanical modulating/proportional aperture control with the relative humidity, usually considered as a good indicator of the ventilation's need of a room.

Principle

The technology of humidity controlled product relies on the exploitation of the physical property of a material to lengthen or retract according to the ambient relative humidity. Thus, the nylon stripes selected for the manufacture of humidity controlled air inlets or extract units have the property to lengthen from 2 to 5 mm/m for a 10% relative humidity increase.

As it is established on the psychrometric chart, the relative humidity is related to 2 parameters : the absolute humidity and the temperature. The influence of this second parameter is very important considering for example that around 20°C, a ±1°C temperature variation generates a relative humidity variation of almost ± 3 points.

Because the temperatures in the sensor's environment of extract units and in the middle of service rooms are close the one to the other, the determination of a response curve for such a product does not set particular problems. However, a special attention must be paid to the stratification's phenomena, in particular in the dwellings where heating is ensured by a warm air system.

This point relative to air inlets is much more complex taking into account that the amplitude of relative humidity in main rooms is rather low. For example, it is generally admitted that the increase of relative humidity between a non occupied room and an occupied room with 2 persons is about 10 to 15 points. Now then you have to consider that for a non occupied room the variations of relative humidity due to the temperatures variations throughout the year can be higher than 30 points. So, whether we position for a fixed outdoor climate and then it is rather easy to determine a response curve which is able to cover accurately the whole selected range of inside relative humidity variations, or we integrate a possibility to take into account these outdoor climatic parameters. This point illustrates the problematic and all the difficulties of the mechanical constitution of humidity controlled air inlets which have only to be influenced by the inside humidity.

The imagined solution to fight the effects of this wide variation of the outside absolute humidity throughout the year, was to develop a technology based on an amplification of the inside relative humidity amplitude between an occupied and non occupied room. The only one way to make it possible was to reduce locally the temperature in the sensor's environment of air inlets using the thermal influence of the outside temperature.

Here was now the concept to design such an air inlet able to create an equivalent temperature near the sensor, intermediate between indoor and outdoor temperature and as constant as possible whatever the airflow getting through is. Twenty years of research and development prevailed to design an elaborate mechanical system aiming at creating the conditions of this equivalent temperature.

Mechanical constitution

A humidity controlled air inlet is composed of a front face and a base made of plastic, one or two shutters to make the opening section varying and a humidity sensor made of 8 nylon stripes which lengthens proportionally to the locally read relative humidity (about 2 to 5 mm/m for a 10 points relative humidity increase).

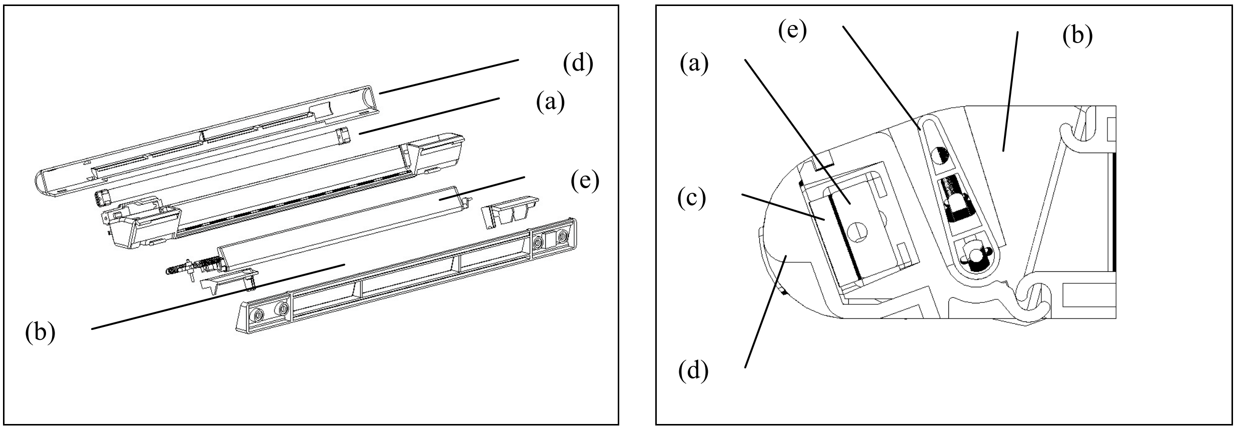


Figure 1 : Components and cross section of a humidity controlled air inlet

In detail, the bundle of stripes (a) is tended by an extension spiral spring. Its free side, animated with small translatory motion when humidity varies, involves the rotation of an arm which pushes a shutter (e) in the direction of closing or opening in response to the relative humidity variations. The air inlet consists of a main duct (b) for the introduction of outdoor air and a second duct (c), located between the main duct and the protection cap (d) of control units. The second duct (c) is crossed by the indoor air. Thus the nylon stripes are well influenced by indoor humidity.

Hygrothermal behavior

Characteristics

Humidity controlled air inlets are characterized by a nominal response curve (aperture Vs internal relative humidity) at 10 Pa pressure difference and equal indoor and outdoor temperatures.

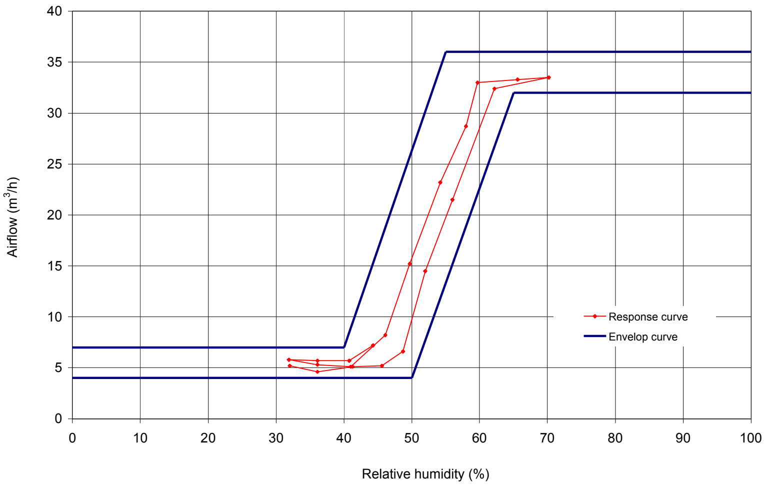


Figure 2 : Airflow Vs. Relative humidity for 10 Pa pressure difference and equal indoor and outdoor temperatures

The chart above shows the response curve presenting a hysteresis specific to the aperture / closing cycle of a common air inlet (From 4 to 32 m^3/h between 45 to 60% relative humidity under 10 Pa).

The temperature of this sensor is not the same as the temperature in the middle of the room. The airflow passing through the opening section and the insulation of the air inlet generates near the sensor an intermediate temperature between the indoor and outdoor temperature. For the same indoor absolute humidity, the relative humidity in the sensor's environment is different. The sensor equivalent temperature is given by the following equation (Eqn. 1) :

$$T_{sensor} = T_{room} - \alpha.(T_{room} - T_{outdoor}) \qquad \text{(Eqn 1)}$$

Where α is a temperature correction coefficient, α ˜ 0.25

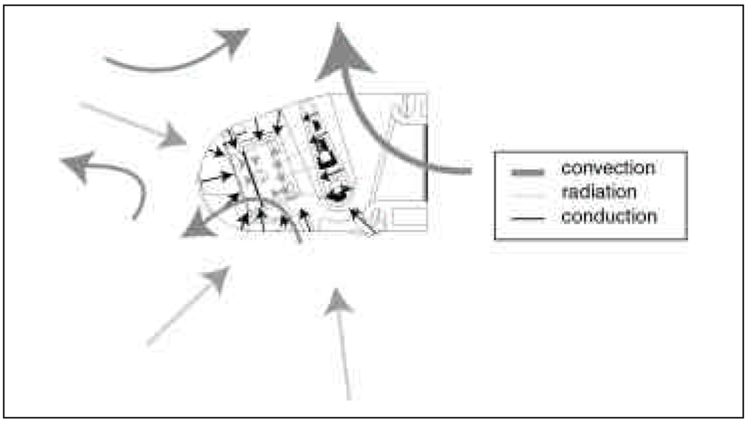


Figure 3 : Heat transmissions flows on a humidity controlled air inlet

Evaluation method of the α temperature correction coefficient

The α temperature correction coefficient is estimated regarding average response curves aperture Vs internal relative humidity for various outdoor temperatures. The curve given for an outdoor temperature equal to the indoor temperature is considered as the reference curve.

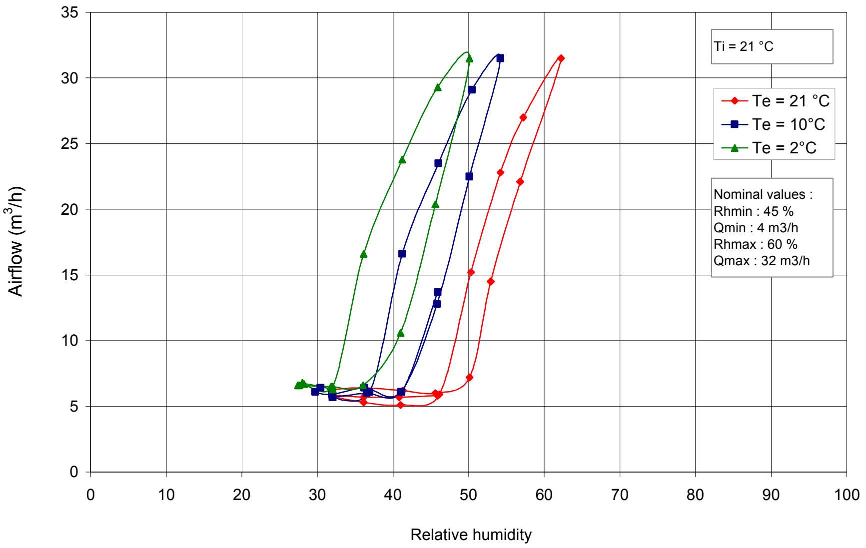


Figure 4 : Response curve (airflow Vs internal relative humidity) for various outside temperatures and 10 Pa pressure difference

For an outside temperature lower than the inside temperature, to each airflow corresponds an equivalent relative humidity equal to the read relative humidity on the nominal curve for the same airflow. From this equivalent relative humidity and from the inside water vapor concentration, we deduce an equivalent temperature in the humidity sensor's environment.
Finally, at a constant inside temperature, we can determinate a correlation between the outside temperature and this equivalent temperature in the humidity sensor's environment integrating the α temperature correction coefficient.
The previous chart (Figure 4) gives the following relative humidity ranges of opening/closing cycle for various outside temperatures.

- From 31 to 50 % for an outside temperature close to 2°C
- From 37 to 53 % for an outside temperature close to 10°C
- From 46 to 62 % for an outside temperature close to the inside temperature

Influence of the temperature correction coefficient on the hygrothermal behavior of air inlets

In cold period, the more is the difference between indoor and outdoor temperature, the more is the relative humidity's fall generated by the ventilation . That means that the bundle of stripes must be cooled by the fresh air in order to get a relative humidity near the humidity sensor included in a range authorizing the opening of the shutter(s). An α coefficient equal to 0.25 determining the equivalent temperature in the sensor's environment (Eqn. 1) is judged optimal to get a local relative humidity included in the opening range of the shutter whatever the outside temperature is. The case study selected below illustrates this principle.

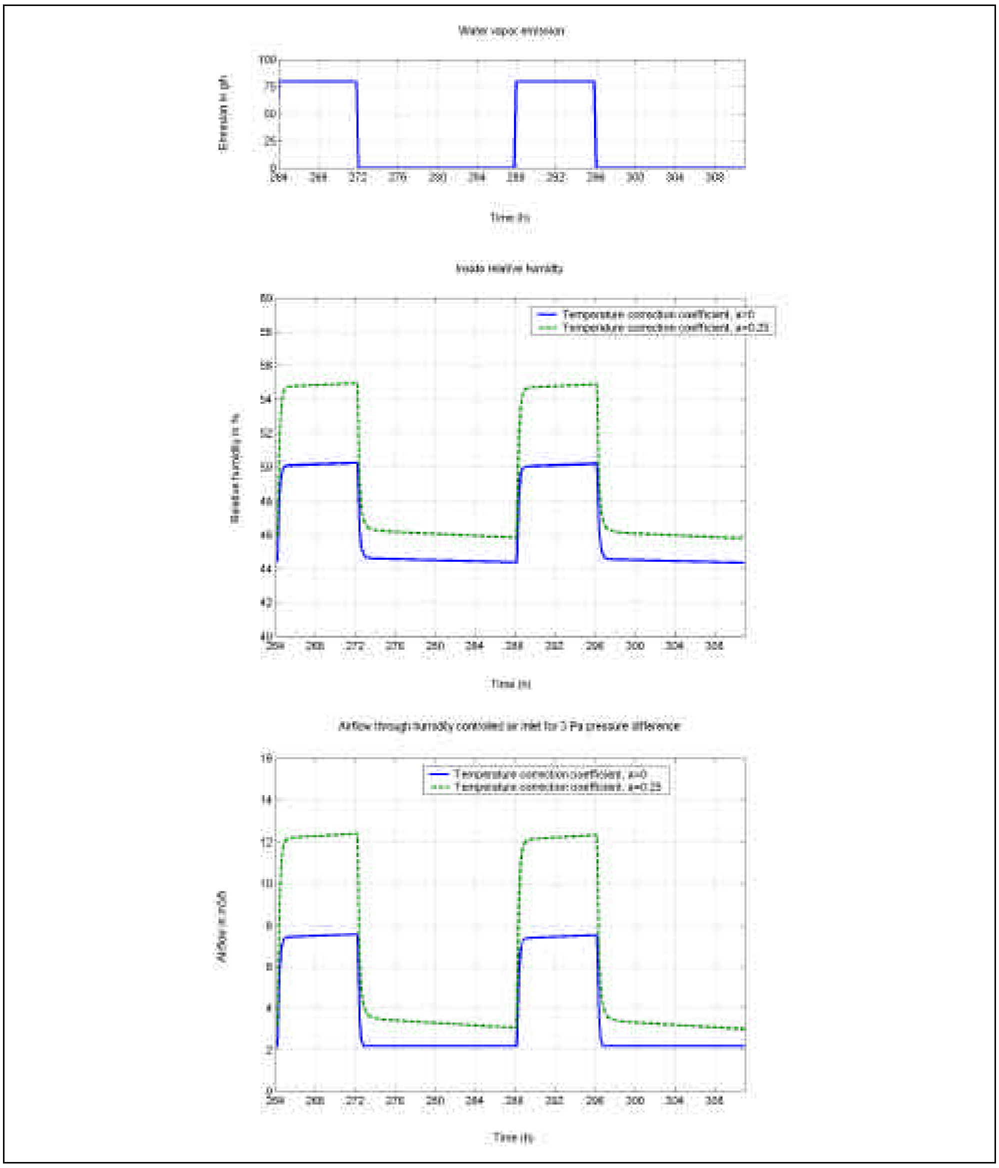
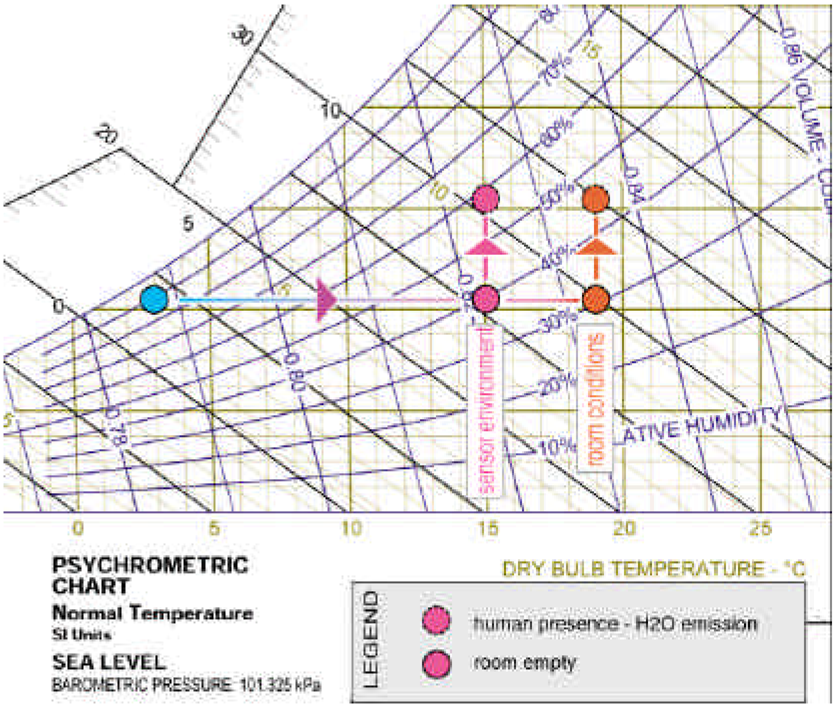


Figure 5 : Influence of the temperature correction coefficient on the extracted airflow for a -5°C outside temperature

Considering that the regime is pseudo-established, the figure above shows that for an outside temperature close to -5°C, the relative humidity in the sensor's environment integrating a 0.25 temperature correction coefficient is still in the aperture's range of the air inlet (between 45.8% and 55%). On the contrary, in the sensor's environment integrating a null temperature correction coefficient, the equivalent relative humidity range is located between 44.5% and 50.2%. This means, that the relative humidity differential has been amplified by the effect of the α temperature correction coefficient. Consequently, such a correction temperature coefficient makes humidity controlled air inlets possible to work under almost all climates whatever the outdoor temperature is. Even in presence of a low relative humidity in the middle of the room, the relative humidity in the sensor's environment will always remain in the aperture's range of controlled air inlets, to allow well-adapted to the needs air flows.

The next two schemes show physically how a controlled air inlet is maintained working whatever the outdoor temperature can be.



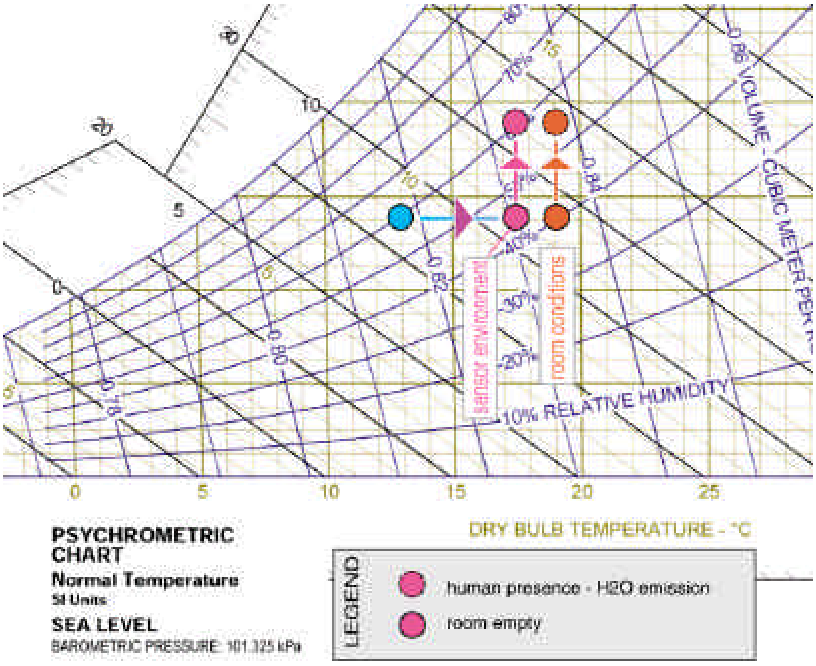
Outdoor climate :
Te = 3°C
RHe = 90%

Occupied room :
Indoor conditions :
Ti = 19°C
RHi = 45%
Sensor's environment :
Ts = 15°C
RHs = 59%

Non occupied room :
Indoor conditions :
Ti = 19°C
RHi = 30%
Sensor's environment
Ts = 15°C
RHs = 40%

Figure 6 : Ranges of relative humidity in the sensor's environment and in the middle of the room in cold period

For a 3°C outdoor temperature, the relative humidity in the sensor's environment is replaced between 40% and 59% although the relative humidity in the middle of the room is only included between 30% and 45%.



Outdoor climate :
Te = 13°C
RHe = 60%

Occupied room :
Indoor conditions :
Ti = 19°C
RHi = 56%
Sensor's environment :
Ts = 17.5°C
RHs = 61%

Non occupied room :
Indoor conditions :
Ti = 19°C
RHi = 41%
Sensor's environment :
Ts = 17.5°C
RHs = 45%

Figure 7 : Ranges of relative humidity in the sensor's environment and in the middle of the room in mid-season

In mid-season, the same effect is observed, keeping the relative humidity near the sensor between 45% and 61% when the inside relative humidity remains between 41% and 56%. Thus, we can note that this equivalent humidity always remains in the air inlet opening range whatever the outside conditions are.

COMPARISON BETWEEN HUMIDITY CONTROLLED AND FIXED AIR INLETS

To illustrate the efficiency of humidity controlled air inlets, we chose to compare their behaviors with the ones of fixed air inlets in a basic example. Figure 8 shows the different rooms composing the considered dwelling.

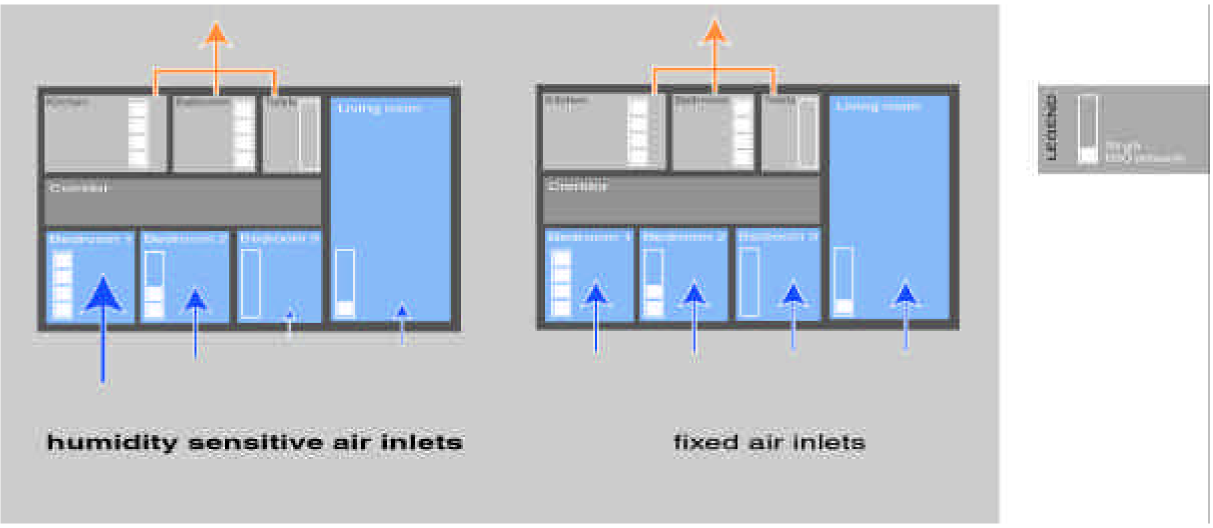


Figure 8 : Comparison between dwellings equipped with humidity controlled air inlets and with fixed air inlets

TABLE 1 below gives the characteristics of air inlets and the environment in a permanent established regime.

TABLE 1
Comparison between dwellings equipped with humidity controlled air inlets and with fixed air

	Humidity controlled air inlets	Fixed air inlets
	Emission (g/h)	
Bedroom1	80	
Bedroom2	40	
Bedroom3	0	
Living-room	20	
	Water vapor concentration (g/kg)	
Bedroom1	6.41	8.48
Bedroom2	5.96	6.19
Bedroom3	3.90	3.90
Living-room	5.67	5.04
	Airflow (m^3/h)	
Bedroom1	31.8	17.4
Bedroom2	19.3	17.4
Bedroom3	7.4	17.4
Living-room	11.3	17.4

Note : The parameters below are supposed constant and identical in both dwellings.
Inside conditions : temperature : 19°C, n_{50} = 0 h^{-1}, Airtightness: n_{50} = 0 h^{-1}
Outside conditions : temperature : 0°C, relative humidity : 80%

Adaptation to the needs

The previous simulation shows that the air flows getting through fixed air inlets are absolutely not adapted to the real needs. The amount of air passing through each of these inlets is equal to the total airflow divided between the amount of inlets. On the contrary, the air flows getting through humidity controlled air inlets are not divided but distributed according to the ventilation's needs of each room.

Airtightness of the dwellings

If we now consider a cross-ventilation through air leakage, it may be interesting to see what is its impact on the hygrothermal air inlets behavior. For that, we carried out basic simulations for 3 different levels of airtightness (n_{50}=0.5 h^{-1}, n_{50}=2.0 h^{-1}, n_{50}=3.0 h^{-1}).
In the next table, the air flows are quantified for those different leakage areas. Obviously, this air leakage comes to bypass the standard ventilation system. The pressure differential created between both sides of each air inlets decreases ; thus, the phenomena of air flows distribution according to relative humidity level is slightly reduced. But it is also very important to note that even with a pretty bad airtightness n_{50}=3.0 h^{-1}, the distribution of air flows is always ensured.

TABLE 2
Airflow through humidity controlled air inlets and with fixed air inlets for different airtightness

	Spatial distribution of air leakage	Water vapor emission (g/h)	Air leakage					
			n_{50}=0.5 h^{-1}		n_{50}=2 h^{-1}		n_{50}=3 h^{-1}	
			Airflow (m^3/h)					
			Humidity controlled air inlets	fixed air inlets	Humidity controlled air inlets	fixed air inlets	Humidity controlled air inlets	fixed air inlets
Homogeneous distribution of air leakage								
Bedroom1 (15m^2)	20%	80	27.2	16.9	23.0	16.0	21.1	15.7
Bedroom2 (15m^2)	20%	40	17.8	16.9	16.2	16.0	16.0	15.7
Bedroom3 (15m^2)	20%	0	9.5	16.9	10.8	16.0	11.4	15.7
Other room	40%							
Non homogeneous distribution of air leakage								
Bedroom1 (15m^2)	10%	80	26.5	15.7	19.1	13.0	16.6	12.2
Bedroom2 (15m^2)	70%	40	25.8	22.8	34.7	30.6	37.3	33.3
Bedroom3 (15m^2)	10%	0	6.9	15.7	6.5	13.0	6.6	12.2
Other room	10%							

The phenomena is even worse for fixed air inlets if we consider a non homogeneous distribution for the leakage. The imbalance of the air flows distribution is all the more accentuated as the air leakage is badly distributed.

Eventually, this shows that a good airtightness accentuates the efficiency of the humidity controlled ventilation on both energy savings and air quality.

CONCLUSION

This article shows that humidity controlled air inlets are the fruit of an elaborate technology. Such a control is designed to automatically ensure that fresh air is delivered only when it is needed and only to the area where it is needed. Because rooms obviously have varying ventilation requirements, and because humidity is well known to be a good pollution level indicator, the efficiency of humidity controlled air inlets relative to air quality and energy savings is no more to demonstrate. Moreover, one of the most powerful aspects of humidity controlled air inlets is their ability to work in almost all climates getting local equivalent temperature in the sensor's environment: to the common affirmation which has been very often urged against us according to humidity controlled air inlets depend more on the wide outdoor climatic conditions variations and less on narrow inside relative humidity variations, this paper gives definitively the answer and the proofs that this point has been solved taking into account both outdoor and indoor temperatures. Thus, this technology has allowed to equip buildings in a wide heterogeneity of climatic areas from Italy to Scandinavia. And when it is technically possible to develop more powerful elements taking directly into account outside climatic conditions, the additional cost seems not to be justified in comparison with the good performance level of the present technology.