DEVELOPMENT OF A SIMPLIFIED DWELLING AIRTIGHTNESS MEASURING DEVICE : IMPEC

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ABSTRACT

Studies on buildings' airtightness have shown that several issues can arise from uncontrolled airflow leakages in buildings (e.g., higher energy cost, thermal comfort and health of occupants, building components and equipment preservation). Indeed, the new French thermal regulation, RT2000, applicable since June 2001, has set airtightness performance levels for new buildings. Application of RT2000 should lead to an increase of airtightness on site controls, since nowadays the building airtightness performance knowledge is only possible by means of measurements. Yet, recent studies have shown that technical and economical limitations of on site airtightness measurement devices prevent controls from widening. The objectives of our work are to develop a simplified airtightness measuring device (IMPEC), in order to reduce both the duration and the number of technicians involved in the measurement controls. We present the characteristics of our automated instrument and the measurement protocol, based on dwellings' depressurization by means of a portable fan connected to the air distribution systems, through the kitchen ventilation exhausts. We compare the results of the IMPEC prototype with a commercially available device, taken as a reference, through a 20 dwelling field measurement campaign. Finally, we discuss the performances of IMPEC in terms of results accuracy, ergonomics and possible adaptation to RT2000 requirements.

KEYWORDS

Field measurements, Infiltration, Airtightness, Envelope, Dwellings, Thermal Regulation

BACKGROUND

Improvements in building envelope's thermal insulation increase the relative part of energy consumption caused by airtightness. Indeed, recent studies have shown that airtightness can significantly affect buildings' thermal performances and indoor air quality. These negative impacts have direct consequences on 1) occupants' health and comfort; 2) on building systems and fabrics' pathologies ; and 3) on energy consumption. Although these negative impacts and recommendations to improve the performances have been thoroughly detailed in the literature, general practices have not tended to improve significantly. Yet, the new French thermal regulation RT2000 and the international norm ISO 9972 offer the opportunity to improve this situation by 1) accounting explicitly for a mandatory airtightness building performance and 2) by proposing recommendations to control (by means of *in-situ* measurements) the effective performance of buildings. However, progress still need to be done to develop measurement tools that would be reliable and simplified, that are the 2 necessary conditions to widespread on site controls and consequently improve buildings' airtightness performances.

OBJECTIVES

This work aims at developing an on-site simplified measurement tool, called *IMPEC*, able to determine the airtightness performance of a dwelling according to RT2000 mandatory levels and following the ISO 9972 norm's recommendations. The objective of *IMPEC* is to allow a dwelling's airtightness measurement in less than 90 minutes by a unique technician.

METHODOLOGY

The development of the IMPEC aims at answering to a double concern. The objectives of IMPEC consist 1) in controlling and measuring the airtightness performance of the most important amount of dwellings and 2) in comparing the measured performance to the regulation levels with the best accuracy. According to these objectives, we defined the main characteristics of the IMPEC and we developed a prototype.

Airtightness indicators and air leakage assessment

The modelling of airflow patterns through cracks of the building envelope follows from the early works on hydronamics of pipes, that allowed to assess the airflow rates Q $_{[m^3/h]}$ through elementary holes, as a function of differential pressure between indoor and outdoor, $\Delta P_{[Pa]}$, see Eqn 1 :

$$\mathbf{Q = K \cdot \Delta P^n} \qquad \textbf{(1)}$$

where n $_{[-]}$ and K $_{[m^3/h/Pa^{-n}]}$ are the flow exponential and the airtightness constant.

For their specific requirements, some European countries, including France with RT2000, have decided to consider the leakage index $I_{\Delta P}$ [m³/h/m²], defined as the infiltration airflow rate at ΔP_0 weighted by envelope surface areas the most susceptible to promote the infiltration of air leakages. The RT2000 considers the specific *unheated surfaces of the whole building*, defined as the *« surfaces that separate the indoor heated volume from the outdoor air and indoor unheated air, excluding the floor »*. For RT2000, leakage airflow rates are to be assessed by extrapolating for the building of interest to 4 Pa the Eqn 1, determined by measurements in the pressure intervals [10-70 Pa] as recommended by the ISO 9972 norm.

State-of-the-art

Yet, the most accurate method to assess the airtightness of a construction consists in measuring it, since analytical tools for predicting buildings' airtightness are still limited. However, measurement instruments are still few and not widely spread. Indeed, instruments are generally developed for their own purpose by the organisms that perform the airtightness measurement tests. To our knowledge only one commercially available instrument, the BLOWERDOOR©, exists but is not very spread among practitioners. It consists in a fake door that replaces an actual large opening, through which an extracting fan depressurizes the dwelling. If this method is considered as the most accurate, it can not be considered as a simplified method and it does not account for the leakage airflow rates through the actual large opening, that can be sometimes significant. Possible alternative to BLOWERDOOR© device have been proposed in the literature. With the aim of simplifying the BLOWERDOOR© measurement protocol, an innovative system was proposed in France in the early 90s, by connecting a depressurizing fan to the dwelling's mechanical ventilation system through an extracting exhaust, generally located in the kitchen, Bienfait (1991). This work defined an experimental protocol and developed a first prototype. It concluded that this technique was promising but failed on significantly depressurizing the buildings, since the selected fan was not powerful enough to overcome the pressure losses of the ducts. Another alternative technique consisted in depressurizing the dwellings under different configurations with the own mechanical ventilation system fan and correlating the ventilation airflow rates with the differential pressures, Barles (2000). Although this method is the easiest and the cheapest one, its accuracy is still low, due to the limitations of reduced intervals of airflow rates.

IMPEC'S COMPONENTS AND PROTOCOL

In the light of the state-of-the-art review, we defined a measurement protocol based on the principle of a dwelling depressurization by means of a portable fan connected to the exhaust of the mechanical ventilation. The choice of the different components of the IMPEC was done according to the learning from the state-of-the-art review; for that, we did an analysis of the characteristics of French dwellings. The characteristics of the different components of the IMPEC have been defined and exhaustively described elsewhere, Litvak (2002).

Characteristics of French dwellings

Most of French dwellings are equipped with mechanical ventilation systems. As a matter of fact, the present applicable regulations prevent new residential French buildings from using natural ventilation, since permanent and variable ventilation airflow rates are required. Besides, a recent field studies has assessed the airtightness performance of 73 French dwellings, Guillot (2000). From this study, we determined the minimum airflow rate necessary to depressurize a representative sample of French dwellings : an airflow rate of 1 500 m3/h was predicted to allow the depressurization above 50 Pa of more than 75 % of the sample.

Measurement protocol

Preliminary checks and dwelling preparation

The presence of a 220 V plug and of a mechanical ventilation exhaust Ø 125 mm inside the dwelling are required to perform the test. The preparation of the dwelling for each test consists in sealing all air vents, except the kitchen's exhaust that is to be connected to the IMPEC. The external pressure sensor is set by drawing a Teflon duct through an air vent inlet. The IMPEC is connected to the kitchen's exhaust. An automated control and acquisition system software assists the technician in performing the test, via a laptop PC.

Initialization and measurement procedure

Baseline differential pressures of the dwelling are measured before the test. The maximum allowable dwelling pressure ΔP_{max} is reached by increasing the extracted airflow rate through the IMPEC. The corresponding airflow is maintained in order to inspect the dwelling and list the most frequent air leakage locations. The airtightness test is then performed, by measuring the airflow rates for 7 stages of ΔP equally distributed in the range [10 Pa - ΔP_{max}]. The airflow rate is assessed by measuring the differential pressure across the diaphragm. At the end of the test, the I_4 index is assessed by extrapolating Eqn 1 to 4 Pa.

Description of components

The main characteristics of the different components of the IMPEC are exhaustively described elsewhere, Litvak (2002). The 0.55 kW / 2800 rpm fan selected for the prototype operates in the range [0-2200 m^3/h] (1000 m^3/h at 950 Pa), and is controlled by a speed variator. The dimensions of the apparatus are 600×600×400 mm and the weight (excluding the connecting hoses) is less than 12 kg. The total cost of the different components is less than 2 650 €.

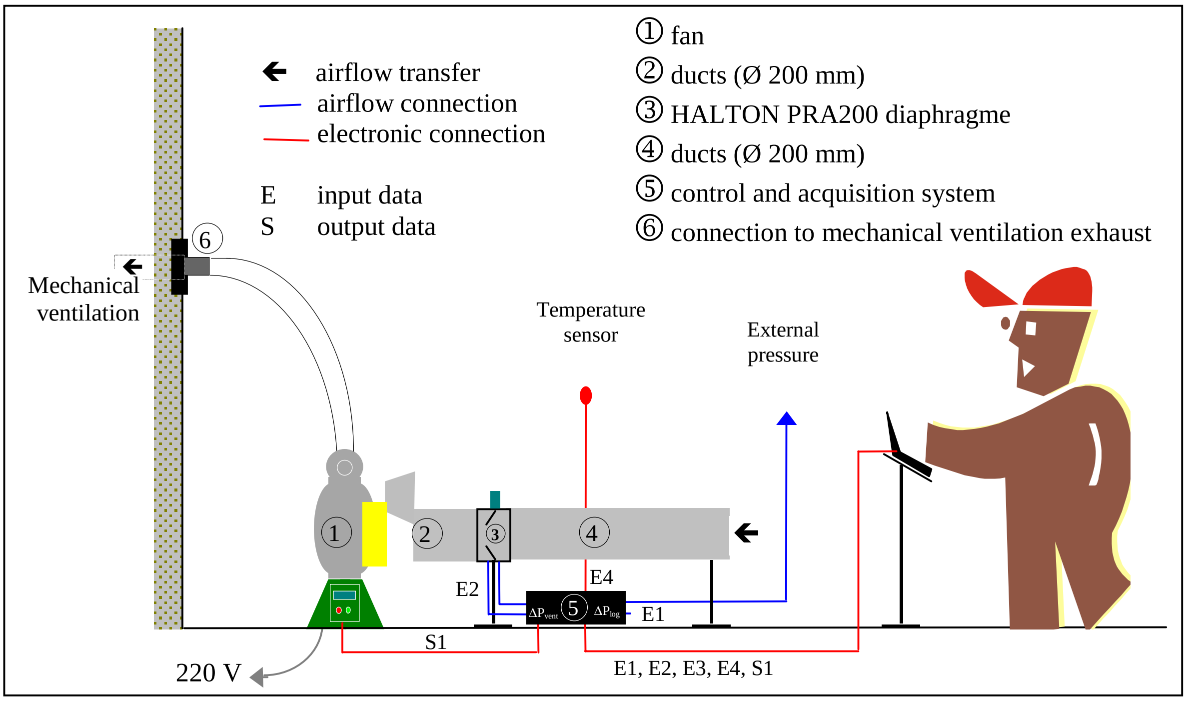

Figure 1 : Description of the components of the IMPEC

E1	ΔP_{log}	(Pa)	Differential pressure in the dwelling (<0)
E2	ΔP_{dia}	(Pa)	Differential pressure in the diaphragm (>0)
E3	κ	(-)	Diaphragm's position
E4	T	(°C)	Dwelling's temperature
S1	F	(Hz)	Fan motor frequency

Table 1 : Input and output data

IMPEC's PERFORMANCES

The performance of the apparatus was analyzed by comparing the measurement procedure in laboratory conditions and onsite tests conditions. For both configurations, the results of the IMPEC were compared to a reference apparatus. Accuracy and ergonomics of the IMPEC was assessed.

Laboratory measurements

The IMPEC equipment was compared to a reference laboratory instrument from CETIAT (France). For the tests, an environmental chamber was depressurized by the IMPEC and the IMPEC'S measurements (pressure and airflow rate) were compared to the measurements given by reference instruments from CETIAT. Three different airflow rate ranges were tested : [0 - 200 m^3/h], [120-400 m^3/h] and [280 - 850 m^3/h].

The airflow rates showed very good correlation between reference and IMPEC measurements. Although a technical failure on the IMPEC's pressure sensor was observed after the laboratory comparative test, we concluded that the relative difference between the airtightness measurements of IMPEC and of the reference instruments was at the most of 15%.

A comparative field measurement campaign

A field measurement campaign was lead on 20 dwellings in, order to analyze the ergonomics and the accuracy of the IMPEC apparatus as compared to a commercially available device, the BLOWERDOOR©, taken as a reference (see Figures 2 and 3). The 20 dwellings were selected among 5 new building projects (4 in multifamily buildings and 1 in semi-detached houses). All the dwellings were mechanically ventilated.

Figure 2 :
IMPEC
on site procedure

Figure 3 :
BLOWERDOOR©
on site procedure

The comparative tests were performed with the following procedure:
1) the BLOWERDOOR© was installed;
2) all the air vents of the dwelling were sealed;
3) a first test was performed with the BLOWERDOOR©;
4) a second test was performed with the IMPEC connected to an exhaust ventilation, the BLOWERDOOR© remaining installed.

The ergonomics of the IMPEC apparatus was found to be excellent since it answered to the requisite of a test requiring only one technician and less than 90 minute duration. Besides, the acquisition system being controlled by a software, no specific specialization was required for the unique technician leading the test.

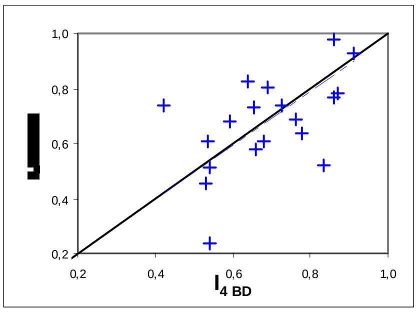

Figure 4 : Correlation between
BLOWERDOOR and IMPEC measurements
($y = 0.984\,x$, $r^2 = 0.2619$)

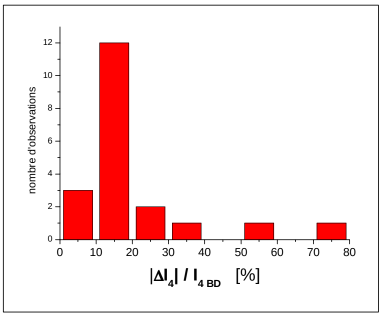

Figure 5 : Histogram of $|\Delta I_4| / I_{4BD}$
$\Delta I_4 = I_{4\ IMPEC} - I_{4\ BLOWERDOOR}$

The comparative test were performed on rather airtight dwellings, since the median value of the measured I_4 both by IMPEC and BLOWERDOOR© was 0.7 $m^3/h/m^2$ (RT2000 and recent studies, Guillot (2000), consider this value to characterize *airtight* dwellings). The measurements of both apparatus show similar results (see Figure 4). The ratios $|\Delta I_4| / I_{4BD}$ are mainly distributed in the range [10% - 20%] (cf. Figure 5). For 12 dwellings, the this ratio is below 15%, and only 3 dwellings show a ratio above 30 %.

DISCUSSION and CONCLUSION

The principle of the present IMPEC prototype appears to be acceptable according to the requirements of RT2000 for single family dwellings. For multi-family dwellings, as the RT2000 mandatory airtightness values refers to the whole building, it prevents the IMPEC from assessing the building's I_4 index. Nevertheless, a recent work proposed a sampling methodology for selecting specific zones of multifamily dwellings when performing airtightness measurements, Millet (2001). This method would make airtightness measurements with IMPEC compatible with RT2000.

Yet, a question still remains concerning the capacity of the IMPEC to overcome the pressure losses for higher airflow rates. Indeed, measurements in the 5 semi-detached houses, showed that the resistance in the ventilation duct system can prevented dwellings from being depressurized more than 20 Pa. Hence, a limitation of IMPEC can appear for non airtight dwellings with air resistant ventilation ducts. Yet, the technical specifications of the fan indicate that it is supposed to extract 1 200 m^3/h under 1 000 Pa.

As a conclusion, the difference between IMPEC and BLOWERDOOR© were found in the same order of magnitude for both the laboratory and the onsite conditions, i.e. in the order of 15 %. The analysis concerning the field measurement results refers to particularly airtight dwellings. Thus, the IMPEC accuracy could not be compared to BLOWERDOOR© measurements for non airtight buildings. However, the laboratory results show that the measurement relative difference is comparable in high and low airflow rates ranges and is below 15 %. The onsite results, measured for low air leakage flowrates show a good linear fit between both instruments. Future work is now needed to develop an industrial version of the present prototype, in order to widespread the onsite measurements.

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