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DUCTWORK AIRTIGHTNESS: RELIABILITY OF MEASUREMENTS AND IMPACT ON VENTILATION FLOWRATE AND FAN ENERGY CONSUMPTION

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ABSTRACT

Reduction of energy consumption and green house gas emissions of buildings is a great challenge in Europe. In this context French energy performance regulation, RT2012, requires an improvement of the buildings' airtightness. In airtight buildings, ventilation must be perfectly controlled to ensure good indoor air quality. However, many failures are observed when ventilation systems are inspected (Jobert, 2012). They are mainly due to bad conception, poor implementation and lack of maintenance. Most of the time, dysfunction leads to a reduction of the ventilation flowrates and to poor indoor air quality.

To improve the ventilation systems' reliability, French energy label “Effinergie +” imposes the ductwork airtightness to be at least Class A. This leads to various issues regarding ductwork airtightness:

- What is the impact of each component of a ductwork on the leakage rate? Is good airtightness reachable with existing products?
- What is the impact of airtightness on ventilation flowrate and fan energy consumption?
- Are ductwork pressurization tests reliable? Do the position of the measurement devices, leakage distribution and ductwork pressure drop have an impact on the result of the test?

To answer those questions a full-scale exhaust ductwork of multi-family building was set in our laboratory. The impact of each components of the ductwork (rigid, circular GALVA) was tested. Holes were then drilled in the ductwork to vary airtightness.

Our study showed that:

- Even with good implementation it is difficult to reach class C for ductwork airtightness because of some leaky components in the ductwork;

- A decrease of the airtightness (from class C to 1,6*class A) may either reduce flowrates by 10% at the air terminal devices or increase the energy consumption of the fan by 10 to 40% ;
- Neither the position of the fan, nor the leakage distribution, nor the pressure drop has an impact on the result of the airtightness test (at class C and 1,6*class A).

KEYWORDS

Ventilation – Airtighness – Ductwork – Implementation – Measurement

1 INTRODUCTION

The improvement of thermal regulation in France leads to more and more efficient and airtight buildings. Therefore, an issue which was forgotten till recently is becoming crucial: how to ventilate buildings well enough to ensure healthy indoor air (Kirchner et al., 2011) and durable building structure while keeping good energy performance?

To achieve such opposite targets, new mechanical ventilation systems were designed with growing complexity. These systems make it possible to meet both sanitary and energy targets provided that they are very well implemented and maintained.

However, literature shows that design, implementation and maintenance are often neglected (Jobert, 2012; Lucas et al., 2009; Save-Duct, 1999; Observatoire CSTB-ORTEC, 2009). Ventilation systems' quality therefore becomes a growing concern because of observed dysfunctions, which highlight a need for information and technical support to professionals together with control of the proper operation of these systems. The ductwork airtightness is one of the various implementation issues.

In such a context, this study aims to better understand:

1. The airtightness of ductworks and its impact on flowrates and fan consumption
2. The reliability of ductwork airtightness tests

by implementing a simple flux ventilation ductwork in our laboratory. This ductwork represents a small collective housing's system which is described in the following section.

2 DESIGN OF THE DUCTWORK STUDIED

The ductwork is made of two main columns which are supposed to connect to four dwellings of different sizes (figure 1 and 2). Each dwelling included a kitchen and a bathroom both connected to ventilation.

The ductwork was made of:

- Circular GALVA ducts
- Specific elements with joint such as curves, branch connections, dampers, T-connections, inspection hatches, conical reduction, ... (figure 3)
- A "C.VEC micro-watt +" extraction fan and automatic constant-flow regulated terminal devices

The extraction fan is a constant pressure one. This means that it automatically adapts its speed to maintain a constant pressure when the flowrate varies (when kitchen terminal devices open and close).

Figure 1: The ductwork studied

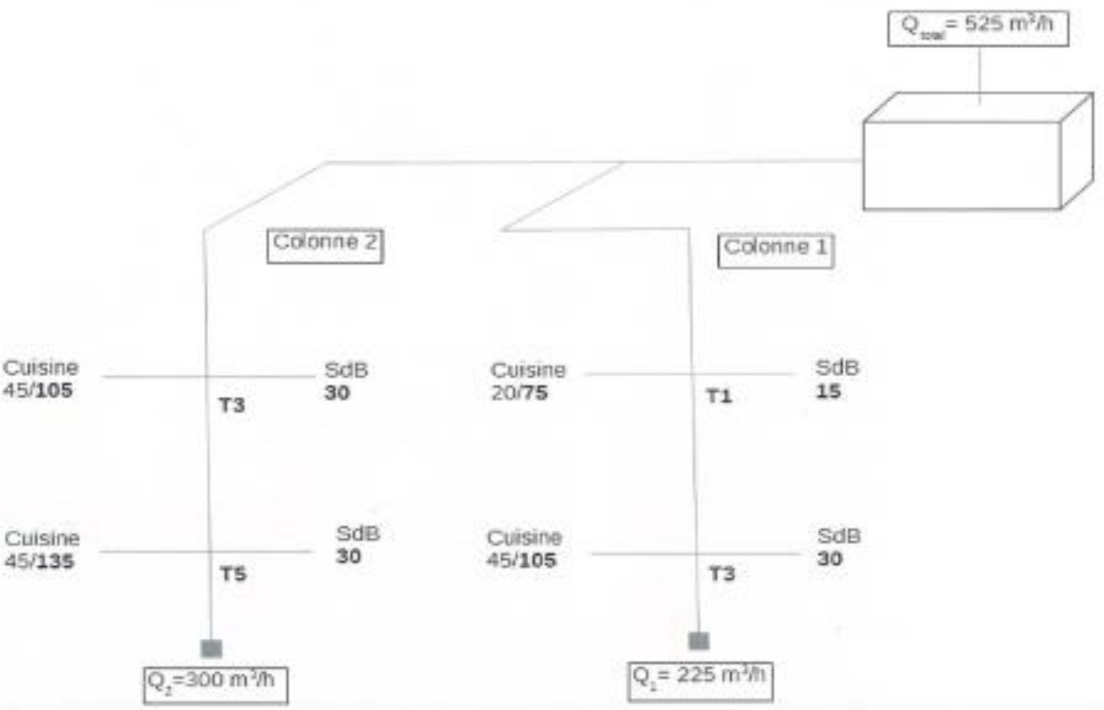

Figure 2: Outline of the ductwork

3 METHODOLOGY

3.1 Impact of airtightness

3.1.1 Impact of each specific element of the ductwork on airtightness

The aim was to quantify the leakages of each specific element of the ductwork (figure 3). The methodology was as follows:

1. Connect each specific element one by one
2. Measure airtightness after each element is connected without being screwed (20 measurements were carried out)
3. Measure airtightness after each element is connected and screwed (20 measurements were carried out)

				
GALVA ducts	Damper	Roof T-connections	T-connections	Inspection hatch
				
Simple connection	Plug	Curve	Conical reduction	Branch connection

Figure 3: Specific elements tested in this study

3.1.2 Impact of the airtightness level on ventilation flowrates and fan energy consumption

The aim was here to quantify the fan's energy overconsumption due to a decrease of the ductwork's airtightness, and the associated impact on ventilation flowrates observed at air terminal devices.

The methodology consisted in measuring flowrates and the fan's energy consumption in the following conditions:

1. Ductwork airtightness: class C, B, A and 1.5 * class A (from class C, the ductwork was drilled to reach other classes)
2. Pressure setpoint of the fan: 90 Pa and 120 Pa

3.2 Reliability of ductwork airtightness test

3.2.1 Impact of pressure drop in the ductwork

The aim was to quantify the impact of pressure drop in the ductwork on the result of the airtightness test. To induce pressure drop, two dampers were placed in the ductwork (see figure 4). Measurements were carried out in the following configurations:

1. Ductwork airtightness: class C and 1.5 * class A
2. Dampers' position: 7 different positions from closed to open position

The pressure drop due to the damper was estimated by measuring the pressure variation at an air terminal device. Leakages were equally distributed along the ductwork.

3.2.2 Impact of leakage distribution and location of the measurement device

The aim was to quantify the impact of leakage distribution and location of the measurement device on the result of the airtightness test.

Four different leakage distributions inducing approximately the same airtightness level were tested:

1. Concentrated leaks close to the fan
2. Concentrated leaks at the bottom of columns 1 and 2
3. Concentrated leaks at the bottom of column 2
4. Equally distributed leaks all along the ductwork

Leakages were created by drilling.

Tests were carried out by placing the measuring device at three different locations:

1. By the fan
2. On column 1
3. On column 2

4 RESULTS

4.1 Impact of airtightness

4.1.1 Impact of each specific element of the ductwork on airtightness

Main leaks were observed at (figure 4):

- Roof T-connections
- Dampers

Even with careful implementation, the ductwork was only class B if the plug of the roof T-connection was not tightened with tape. With tape on the plug, the ductwork reached class C.

It was also observed that elements were slightly leakier when screwed than when just connected together.

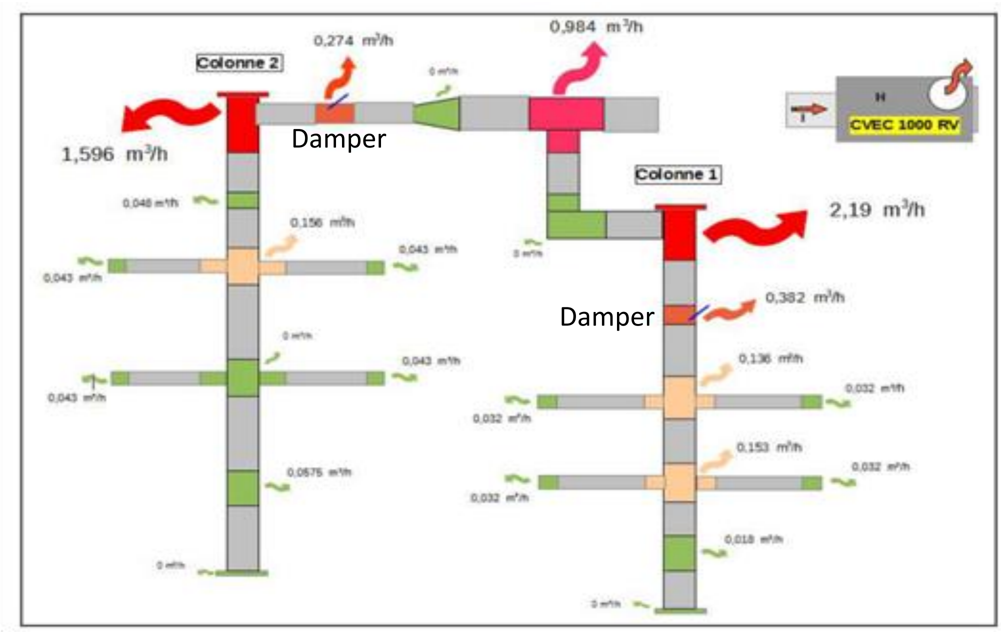

Figure 4: Leakage rates of specific elements

4.1.2 Impact of the airtightness level on ventilation flowrates and fan energy consumption

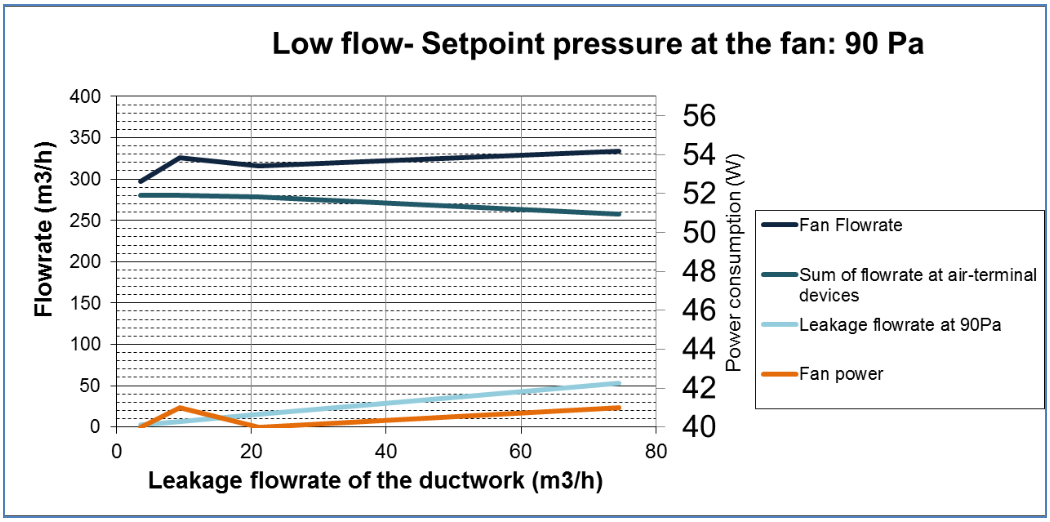

Figure 5: Operating conditions of the ductwork with airtightness varying from class C to 1.5 * class A (pressure setpoint at the fan: 90 Pa)

The first result, shown on Figure 7, is that flowrate targets are no longer met for 4 of the terminal devices for a 90 Pa pressure setpoint at the fan if the ductwork is class 1,5 * A, while it is met when it is class C. For this configuration, the leaky ductwork would lead to a lack of ventilation and maybe poor indoor air quality.

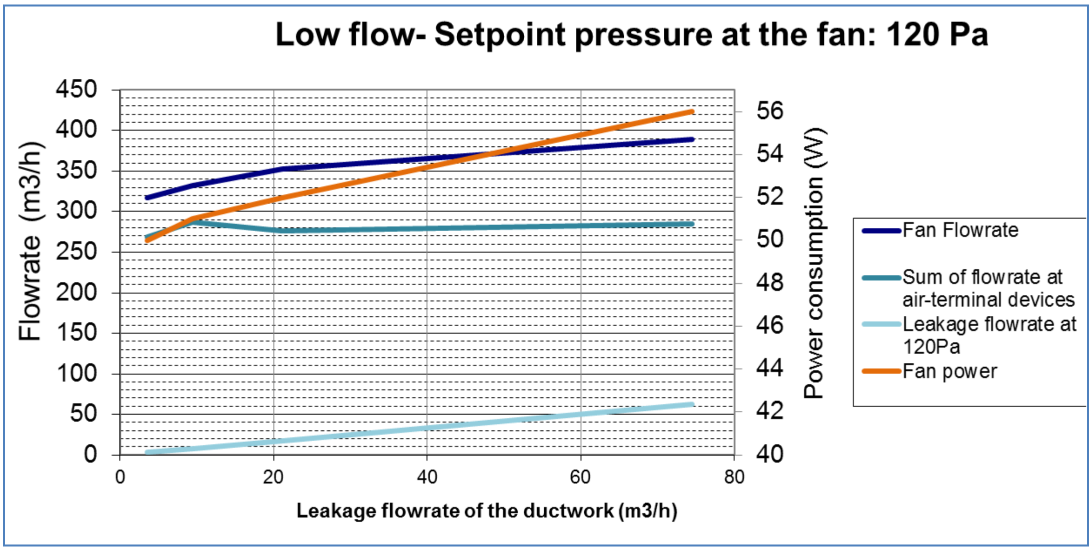

Figure 6: Operating conditions of the ductwork with airtightness varying from class C to 1.5 * class A (pressure setpoint at the fan: 120 Pa)

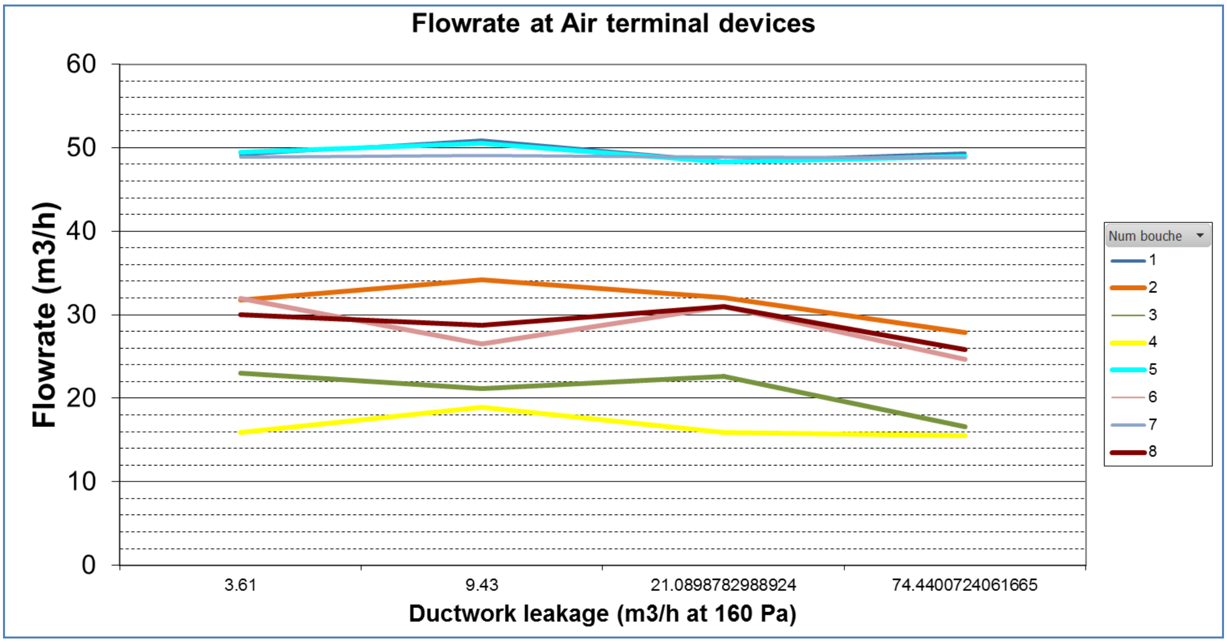

Figure 7: Flowrates at terminal devices with airtightness varying from class C to 1.5 * class A

Flowrate targets:

- Terminal devices 1, 5 and 7: 45 m^3/h
- Terminal devices 2, 6 and 8: 30 m^3/h
- Terminal device 3: 20 m^3/h
- Terminal device 4: 15 m^3/h

Thus, to maintain the flowrate target at air terminal devices, when the airtightness of the ductwork decreases, it is necessary to change the setpoint of the fan from 90 Pa to 120 Pa. We can see from figures 5 and 6 that it leads to an increase of the fan's power from 40 W to 50 W (comparing with class C consumption).

Moreover, when airtightness varies from class C to 1.5 * class A and the fan is set at 120 Pa, the fan's energy consumption increases by 12%.

Therefore, for this configuration, poor airtightness can either lead to an overconsumption of fan of 40% (16W) or to flowrates not complying with the regulation.

4.2 Reliability of ductwork airtightness test

4.2.1 Impact of pressure drop in the ductwork

Even if the damper's position induces a high pressure drop in the ductwork, as can be seen in figure 8, it does not significantly affect the result of the ductwork airtightness test, as shown in figures 9 and 10, at airtightness levels of class C and 1.5 * class A.

For this ductwork, at class C, the damper's position has no impact at all (see figure 10). At 1.5 * class A, the results of the test is 15% smaller when the two dampers are closed compared to when they are open.

An interpretation could be that it depends to the tightness of the damper with respect to the tightness of the ductwork. A mathematical model could be set to explain this phenomenon.

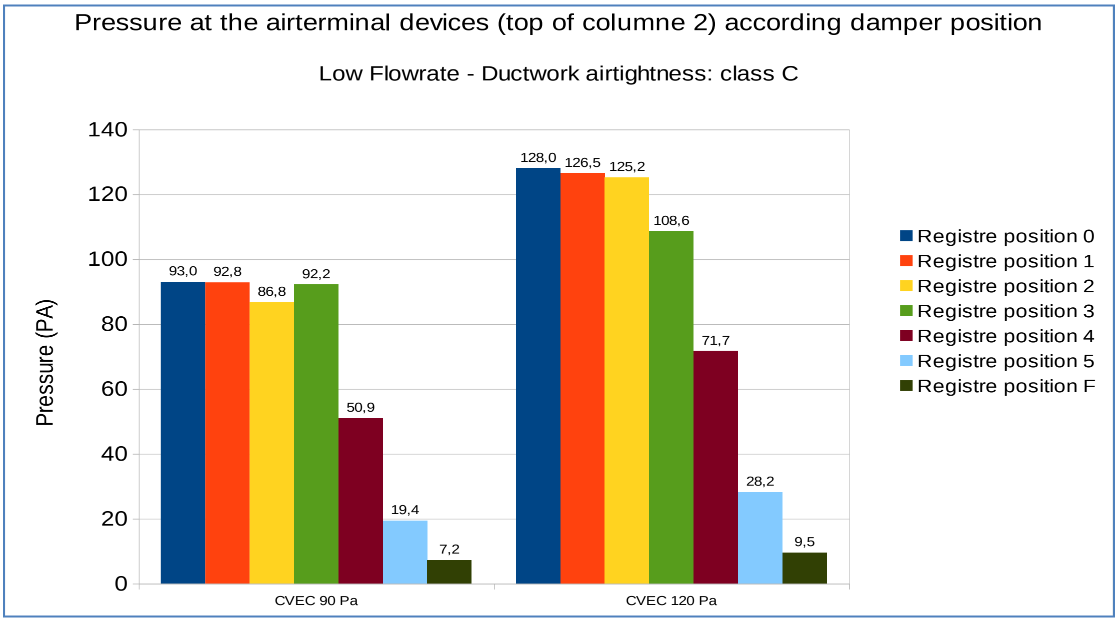

Figure 8: Pressure at the kitchen's terminal device (top of column 2) as a function of the damper's position

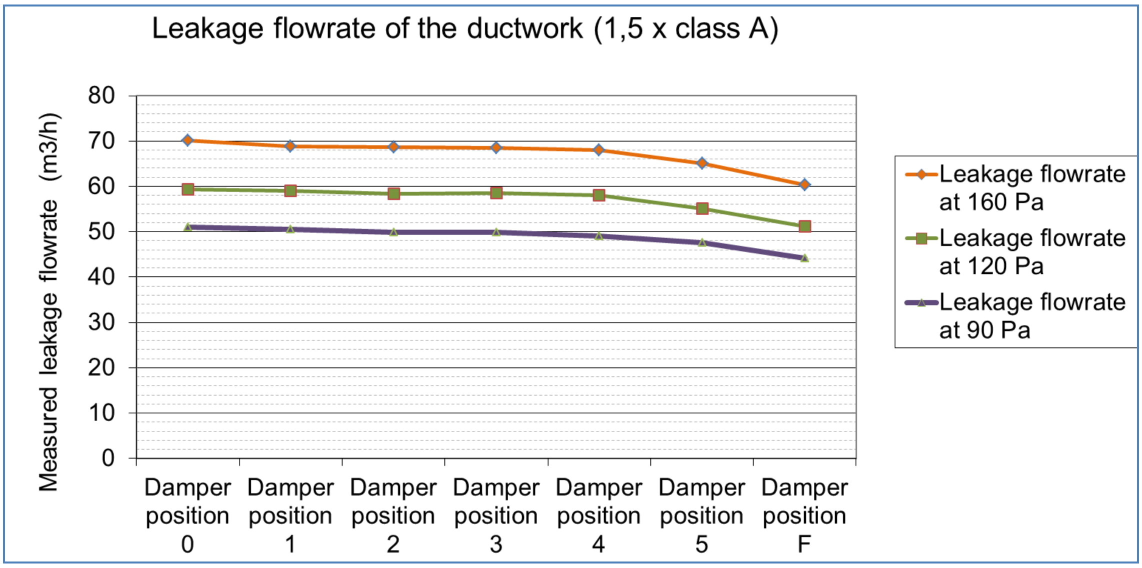

Figure 9: Leakage flowrate of the ductwork as a function of the damper's position at 1.5 * class A (position 0: open; position F: closed)

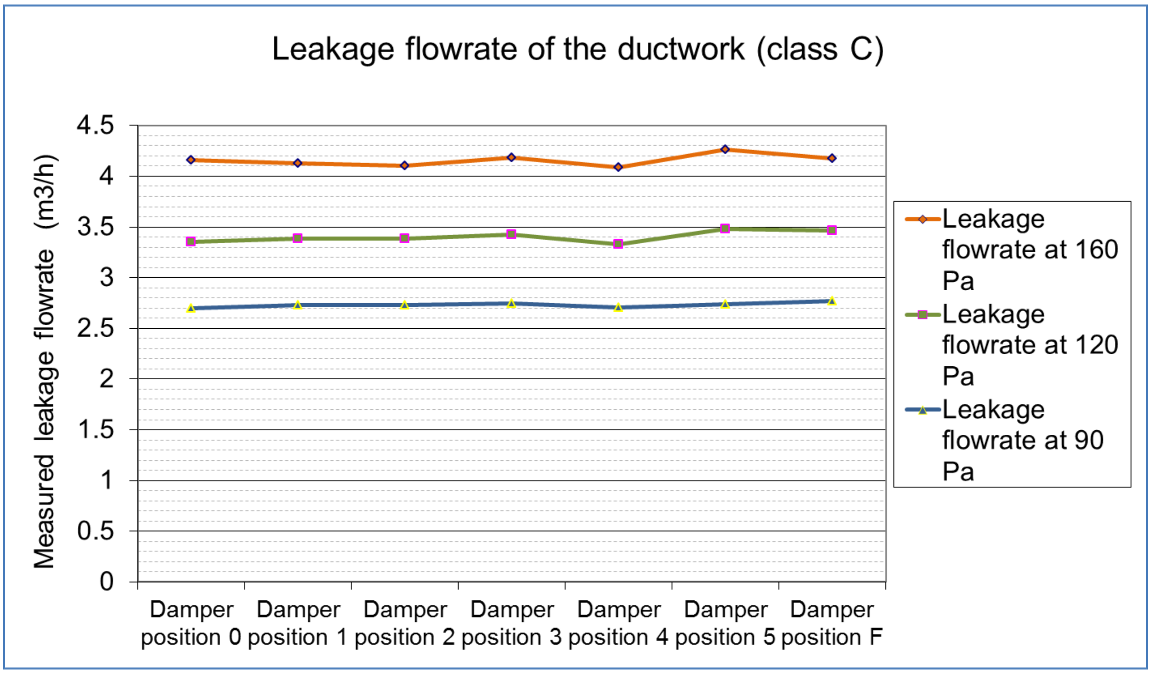

Figure 10: Leakage flowrate of the ductwork as a function of the damper's position at class C (position 0: open; position F: closed)

4.2.2 Impact of leakage distribution and location of the measurement device

Figure 11 shows that the location of the measurement device does not modify the result of the ductwork airtightness test whatever the leakage distribution is.

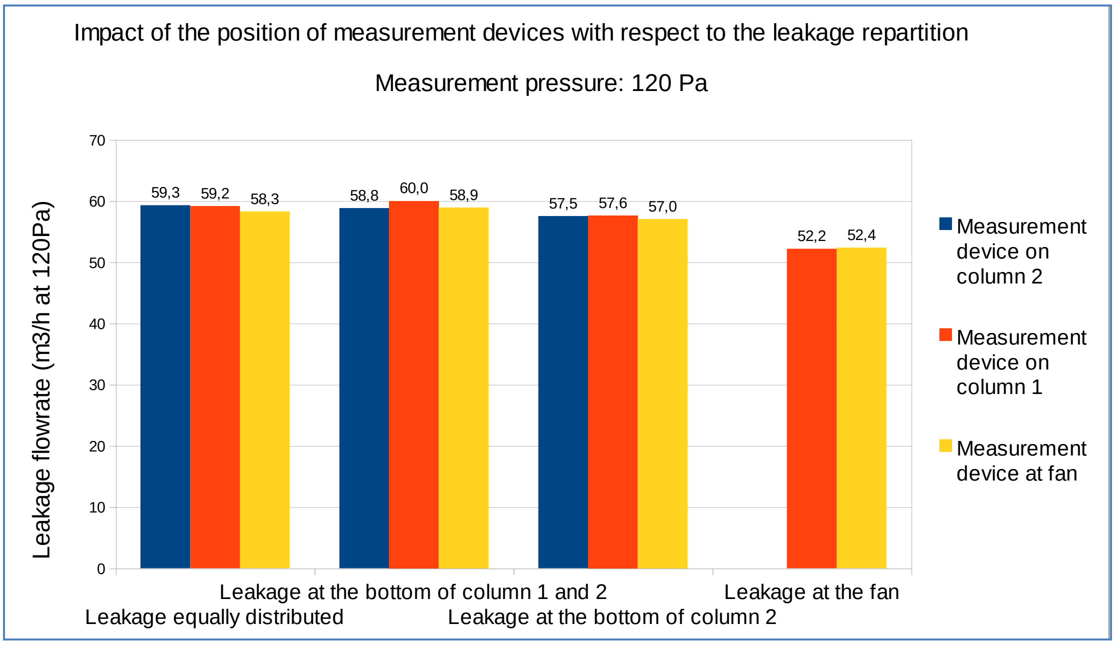

Figure 11: Leakage flowrate as a function of leakage distribution and location of the measurement device at 1.5 * class A

5 CONCLUSIONS

In its first part, this study showed that a careful implementation of the ductwork only makes it possible to reach class B. To achieve class C it is necessary to treat roof T-connections with tape.

Moreover, the airtightness level of the ductwork has proved to have a major impact on the fan consumption (till 40% in this case). Furthermore, if the ductwork is too leaky the flowrate target at air terminal devices may not be reached which may have a major impact on indoor air quality. In its second part, regarding the ductwork airtightness test, this study concluded that for this ductwork, the result of the test is neither influenced by the pressure drop in the ductwork nor by the location of the measurement device whatever the leakage distribution is. This study could now be completed by a mathematical model to explain those results.

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