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Air Infiltration and Ventilation Centre

Airtightness of ventilation ducts

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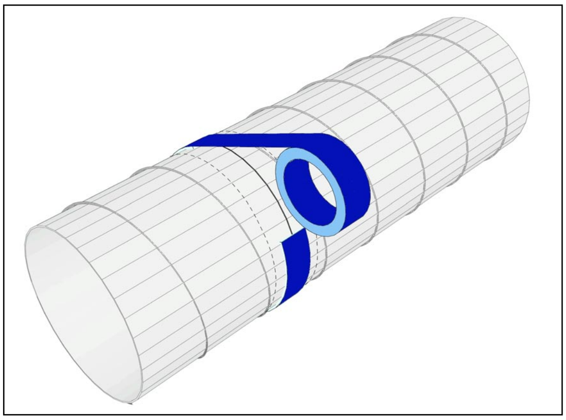


1 Introduction

The necessity to make waterproof sanitary water ducts or central heating tubing and to make airtight natural gas distribution tubing is of primary importance to both construction professionals and the public. However, the airtightness of ventilation ducts and heating or cooling ducts is subject to less attention.
An assessment campaign, aimed to measure the latter, was conducted within the framework of a European project[1], and demonstrated that the leakage in air ducts in France and Belgium reached figures up to 20% of the average nominal flow rate [Ref 1].
What importance can that have, how does one measure leakages, what airtightness criteria can one adopt and finally, what are the possibilities of improvement… All these are questions to which this document aims to bring an answer or solution.

2 Importance of Airtightness

The aim of a ventilation system is to guarantee an acceptable air quality in buildings, at all times. If, for a reason of bad airtightness of the ducts, an important quantity of air does not reach its target, one would notice a local deterioration of the quality of the indoor air, due to a lack of ventilation. The areas in which leakages would occur would certainly undergo uncomfortable drafts caused by the over-ventilation. Leaky ducts would also represent a source of pollution. For example, an exhaust air duct could loose a certain quantity of polluted air into the rooms it goes through.

To compensate these leakages, the flow rate in the ventilation systems is sometimes increased, which entails an increase of the installation cost as well as the energy use since one needs to bring more air into movement and either warm or cool. This gives way to a waste of energy, since some of the air leakages occur in spaces where both air and energy that it contains are not put to profit. With a first approximation, one can estimate that 1% of leaks entail a 3% increase of the electric consumption and 1% of the heating consumption [Ref 4].

Ventilation control can also prove very difficult at times, if the ducts are not air tight. Indeed, the ducts are proportioned according to the pressure losses caused by the air flows they are designed to convey. All modification to the air flows thereby entails a modification in the distribution of pressure losses, thereby causing an imbalance of the ventilation installation. This is further aggravated with the importance of leakages.

We can therefore conclude that, although they may appear insignificant, the consequences of

[1] Save-Duct

a lack of airtightness in air ducts are far from being negligible.

3 How is the air tightness quality defined?

When the airtightness quality of an air duct needs to be characterized, one generally speaks of airtightness classes. The definition[2] of these classes is based on the notion of leakage coefficient (K):

$$K = \frac{q_{vl}}{A \cdot \Delta p_{ref}^{\ 0.65}}$$

Whereby:

K is the leakage coefficient per m² of duct ($m^3/s.m^2.Pa^{0.65}$);

q_{vl} is the leakage flow rate (m^3/s);

A is the surface of the duct (m^2);

Δp_{ref} is the pressure of reference (Pa) *(difference of pressure applied to the duct during the test)*.

This coefficient has the advantage of being virtually independent from the reference pressure. This allows for a comparison between the airtightness of different installations, and to express some performance criteria based on this coefficient.

Table 1 indicates the superior values of the leakage coefficient for the four different classes defined by the draft standard prEN 13779 [Ref 4]. Every time, the successive classes represent a factor 3 improvement to airtightness. Class D does not appear in prEN 13779 but is required for some applications in Scandinavia.

The specific leakage flow rate (that is to say the leakage flow rate per duct surface unit, also known as leakage factor) associated to these airtightness classes is described in Figure 1 and Table 2 for different pressure references.

As an example, let us calculate the leakage flow rate of a rectangular duct of the following size: 0.4 m x 0.2 m, with a length of 10 m and with an overpressure of 20 Pa.

For airtightness class K, the maximum leakage flow rate will be of 12 m² x 2.044 m³/h.m² = 24.5 m³/h.

While for airtightness class C, the maximum leakage flow rate will be of 12 m² x 0.076 m³/h.m² = 0.9 m³/h.

Thereby, a leakage flow rate 27 times less important for class C than for class K!

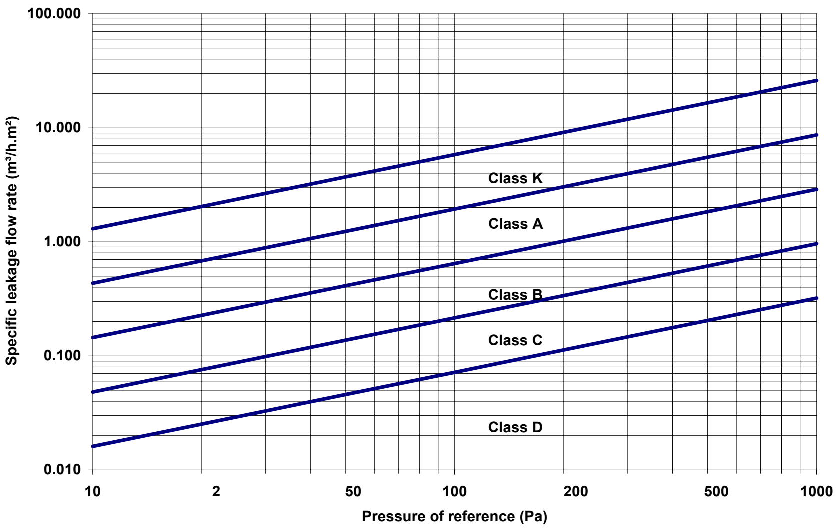


Figure 1: Specific leakage flow rate for the different classes of Airtightness

[2] This definition is used in Europe, but there is a slightly different definition of the leakage class in ASHRAE. In SI units, it is equivalent to 1000 x K.

Table 1: Airtightness classification as defined by prEN 13779 and additional class D ($.10^{-3}$ $m^3/s.m^2.Pa^{0.65}$)

Class K	K_K=	0.081
Class A	K_A=	0.027
Class B	K_B=	0.009
Class C	K_C=	0.003
Class D	K_D=	0.001

Table 2: Specific leakage flow rate for the different classes of airtightness ($m^3/h.m^2$)

Δp (Pa)	Airtightness classes				
	K	A	B	C	D
10	1.303	0.434	0.145	0.048	0.016
20	2.044	0.681	0.227	0.076	0.025
50	3.708	1.236	0.412	0.137	0.046
100	5.818	1.939	0.646	0.215	0.072
200	9.130	3.043	1.014	0.338	0.113
500	16.562	5.521	1.840	0.613	0.204
1000	25.989	8.663	2.888	0.963	0.321

4 Measuring method

The measuring method for leaks is described in EN 12599 [Ref 5]. The measuring process takes place by means of a fan, which is connected to the ductwork through the intermediary of a flow measuring equipment. This fan is used to create a testing pressure difference that is either superior or lower to the air pressure. The ventilation system itself is stopped and the air terminal devices are closed up during the measuring process in order to highlight the leakage flow rate. The measuring process is repeated with several pressure differences.

In order to calculate the leakage coefficient, one must also measure the surface area of the duct. The procedure for the measurement is described in prEN 14239 [Ref 6]. This can be quite challenging when part of the ductwork is hidden or when as-built plans are not available.

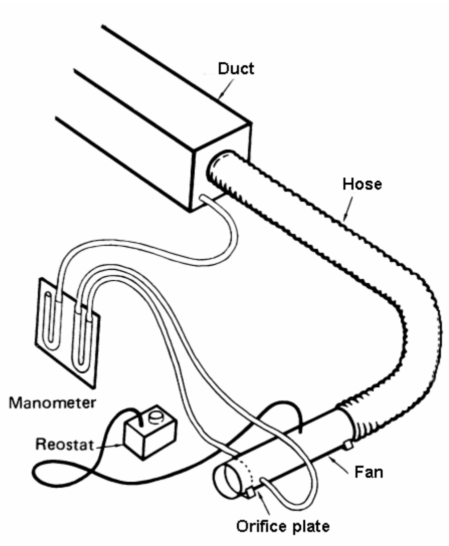


Figure 2: Example of ductwork airtightness measuring equipment

5 Airtightness in practice

5.1 Measuring campaign

Between 1997 and 1998, the SAVE-DUCT Project focused on the on-site airtightness of ventilation ducts [Ref 1]. The measures taken within the framework of this survey demonstrated that only 2 of the 42 duct systems tested in Belgium and in France reached class B and that 5 others reached class A (Figure 3). One could also note that the leakage flow rate rose to 20% of the nominal flow rate on average (but much greater leakage flow ratios were found).

In Sweden, nearly all installations are leak-tested at commissioning and, as a consequence, much data were available. A randomly selected sample of 69 Swedish control measurements was therefore collected.
In that sample, nearly all the installations reach class B, sometimes even class C or class D (Figure 4). These good results are a direct consequence of the Swedish legislative context, which imposes performance criteria and systematic controls, amongst which some controls related to airtightness (OVK - Obligatorisk Ventilations-Kontroll) [Ref 7].

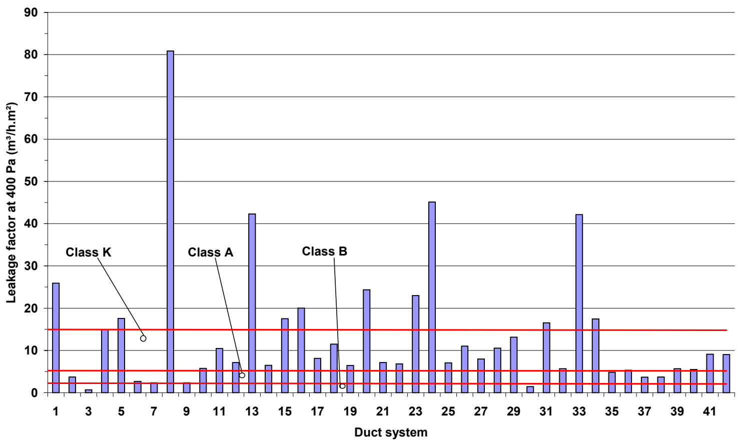


Figure 3: Airtightness of ventilation ducts in Belgium and France

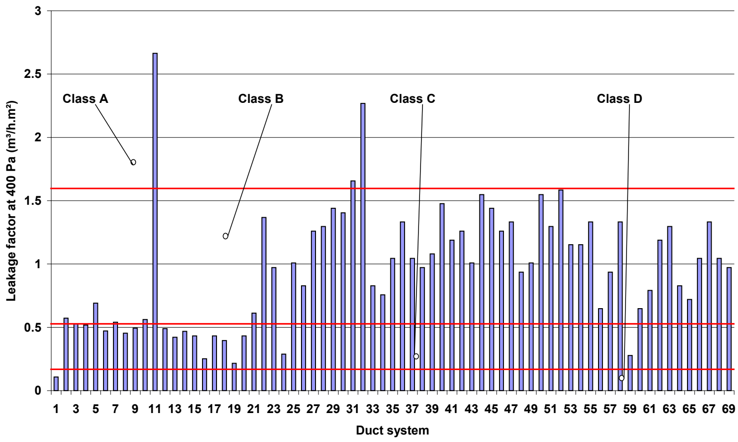


Figure 4: Airtightness of air ducts in Sweden

5.2 Available technology

The greatest part of air leakages in ventilation ducts is located at the connection between the different components of the ducts. Depending on the shape of the ducts, circular or rectangular, different techniques can be applied to make them airtight.

The connections of rectangular ducts are generally tightened by mean of gaskets (Figure 5), tape or sealing compound.

Although it is possible to achieve a good airtightness with rectangular ducts, it could be in some cases quite difficult. Different reasons can be invoked:

- The accessibility of some junctions is sometimes very limited (duct that is (too) near the ceiling, for instance);
- The conditions of site cleanliness may harm the adhesion of the products (dust or grease under the tape or mastic for instance)
- The disassemblies and successive reassemblies are prejudicial to airtightness;
- The properties of some products deteriorate with the passing of the time.

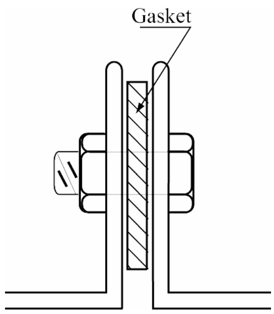


Figure 5: Sealing gasket at flange joint. Drive slips, fasteners, rivets or bolts are used to hold the pieces together.

As far as circular ducts are concerned, one should make the distinction between ducts with or without factory-fitted sealing devices.

The circular ducts without factory-fitted sealing devices are generally tightened by mean of tape (Figure 6) or sealing compound. The same comments than for rectangular ducts apply.

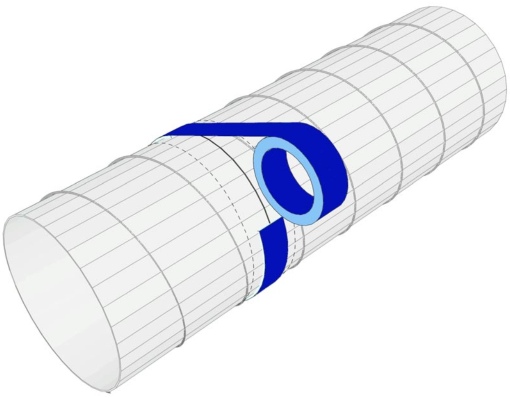
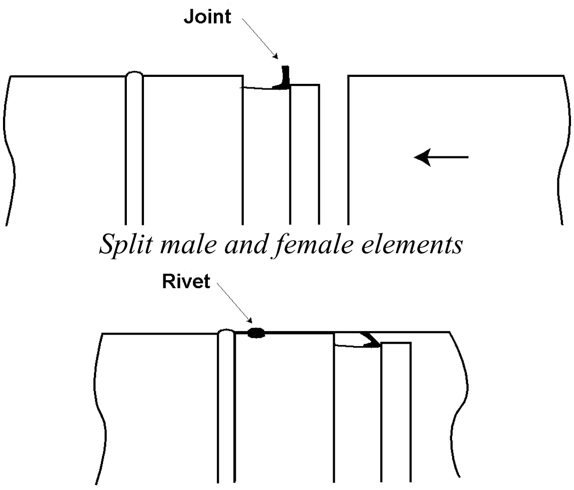


Figure 6 : Sealing tape



Split male and female elements

Joined male and female elements

Figure 7: Accessory for circular ducts equipped with factory-fitted gaskets (photo: Lindab)

Circular ducts and related accessories with factory-fitted sealing devices are now widely available on the market (Figure 7). They allow for an efficient tightening of the ductworks even in case of disassembly and reassembly. Apart from the improvement of the airtightness, they also allow to reduce the time required for the installation of the ductwork. This kind of duct is commonly used in Scandinavia where airtightness classes C and D are often required.

Another source of leakage in the ventilation ducts comes from the perforations done at the time of commissioning of the installation. These holes, aimed at introducing a thermometer or an anemometer, for example, must obviously be carefully closed up after the measures have been taken.

6 Different ways to stimulate airtightness

As mentioned before, achieving airtight ductwork results in several advantages.

If there is an explicit worry in terms of airtightness (e.g. because of IAQ concerns), the most appropriate approach is to impose a minimum airtightness level. Of course, this will then require a systematic testing of the airtightness. (see Figure 8, ❶)

If energy efficiency of the building stock is the primary consideration, it might be more appropriate to handle ductwork airtightness as part of an energy performance regulation (EPR) approach (see Figure 8, ❷):

- By imposing an overall energy efficiency target at building level in combination with a calculation method which pays attention to ductwork airtightness, it might be possible to achieve a better cost-benefit relation since the building owners will opt for the most cost-efficient measures. This can be improving the ductwork airtightness, but it might also be other measures (e.g. more insulation, heat recovery,…).
- Given the fact that the European Energy Performance Directive has been adopted at the end of 2002, all EU countries must implement such energy performance

regulation before 2006 and this makes the treatment of ductwork airtightness in an EPR approach attractive.

- As far as market implementation is concerned, the advantage of the EPR approach is that the market has more time to become used with the issue of airtightness and this might result in less resistance and lower costs. Moreover, this approach doesn't require a systematic testing of the ductwork airtightness since a default value can be used.

Such energy performance approach is adopted in the French RT 2000 regulation.

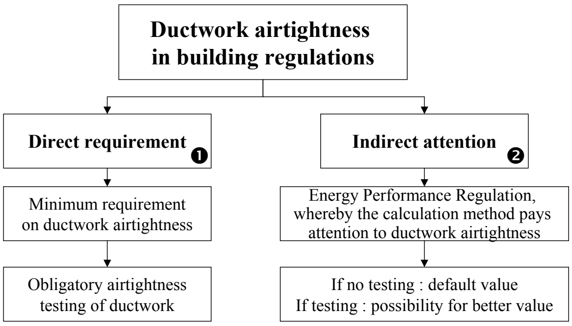


Figure 8: Different ways to stimulate airtightness

7 Conclusion

The airtightness of ducts reaches a significant importance in terms of ventilation efficiency and energy consumption. While it is possible to achieve state-of-the-art airtightness with conventional sealing techniques (i.e., mastic or tape), the Scandinavian experience shows that airtightness class C or D can easily be reached when using circular ducts and accessories with factory-fitted sealing devices This duct sealing technology is available in many countries.

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The Air Infiltration and Ventilation Centre was inaugurated through the International Energy Agency and is funded by the following six countries: Belgium, France, Greece, the Netherlands, Norway and United States of America.

The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.