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Operating Agent and Management
Lozenberg 7
B-1932 Sint-Stevens-Woluwe
Belgium
inive@bbri.be - www.inive.org

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An overview of national trends in envelope and ductwork airtightness

François Rémi Carrié, CETE, France
Bernd Rosenthal, e.u.[z.], Germany

1 Introduction

This paper summarises presentations and discussions that took place during the workshop entitled " Trends in national building ventilation markets and drivers for change" held in Ghent, Belgium, in march 2008 with a specific focus on envelope and ductwork airtightness. Before this workshop, experts were asked to provide information regarding the trends in ventilation in their country and the difficulties they felt to improve the situation in terms of market penetration of innovative systems, indoor air quality and energy use requirements, and compliance check schemes. This has resulted in a set of Ventilation Information Papers published in the same series. Based mostly on these papers and on the workshop discussions, this paper starts summarising energy savings estimates and energy regulation measures ; it continues with a number of issues that have been stressed by the experts such as indoor air quality impacts, airflows through insulation layers, airtightness databases and metrics, and finally, ways to explore to achieve good airtightness.

2 Estimates of energy impacts

One key reason behind the interest for envelope and ductwork leakage lies in their potential impact on the energy performance of a building. Three countries provided quantified information with this regard for the workshop. In Belgium and in Germany, it is estimated that envelope airtightness accounts for about 10% of the energy performance level. In addition, these countries estimated that the potential benefit of better envelope airtightness is similar to the installation of solar collectors. These orders of magnitude apply also to France, where the energy wastage due to envelope leakage lies between 2 to 5 kWh/m^2/year per unit of n_{50} for the heating needs. For ductwork airtightness, the range is 0 to 5 kWh/m^2/year for the heating needs; in addition, fans also use more electricity in leaky ductwork systems. In the US, there exists a significant body of literature on duct leakage with rough estimates of 10 kWh/m^2/year for commercial buildings on the fan energy use. A typical California house with ducts located in the attic or crawlspace wastes approximately 20% of heating and cooling energy through leaks and draws approximately 0.5 kW more electricity during peak cooling periods.

Figure 1 gives some examples of the impact of envelope leakage on the energy consumption in France. These estimates are based on the EP-calculation method, which includes an hourly simulation of the thermal behaviour of the building as well as a pressure-network code based on EN 13465 to calculate the airflow rates.

3 A growing concern in many countries

Envelope and, to a lesser extent, ductwork airtightness are taken into account in the energy performance calculation methods in many countries. These concerns have probably grown due to the uptake of low-energy buildings and their actual impact on the energy performance, as shown above. In sum, only 4 countries out of the 16 represented during the workshop have not included envelope airtightness in their EP-calculation procedure, two of them stating that it was probably not a critical issue due to local standard building practice.

Among the other 12 countries, there remains significant differences in the way envelope airtightness is taken into account. Most of the time, it is possible to reward good envelope

airtightness as it results in a lower “regulatory” energy consumption. However, in some cases (PL, PT, JP), specific requirements apply to components such as windows. Some countries also have minimum requirement (e.g. DE, NO), but only the UK has compulsory testing of new buildings.

As regards ductwork airtightness, four countries represented (BE, FR, UK, USA) take into account the impact of leaky ductwork in their energy calculation procedure, although it is sometimes limited to some building types. Note that ductwork leakage has been identified as a major source of energy wastage in Nordic countries (DK, NO, FI) for several decades. It has been resolved with the widespread use of duct components with pre-fitted joints and therefore, does not seem to be a critical issue in these countries.

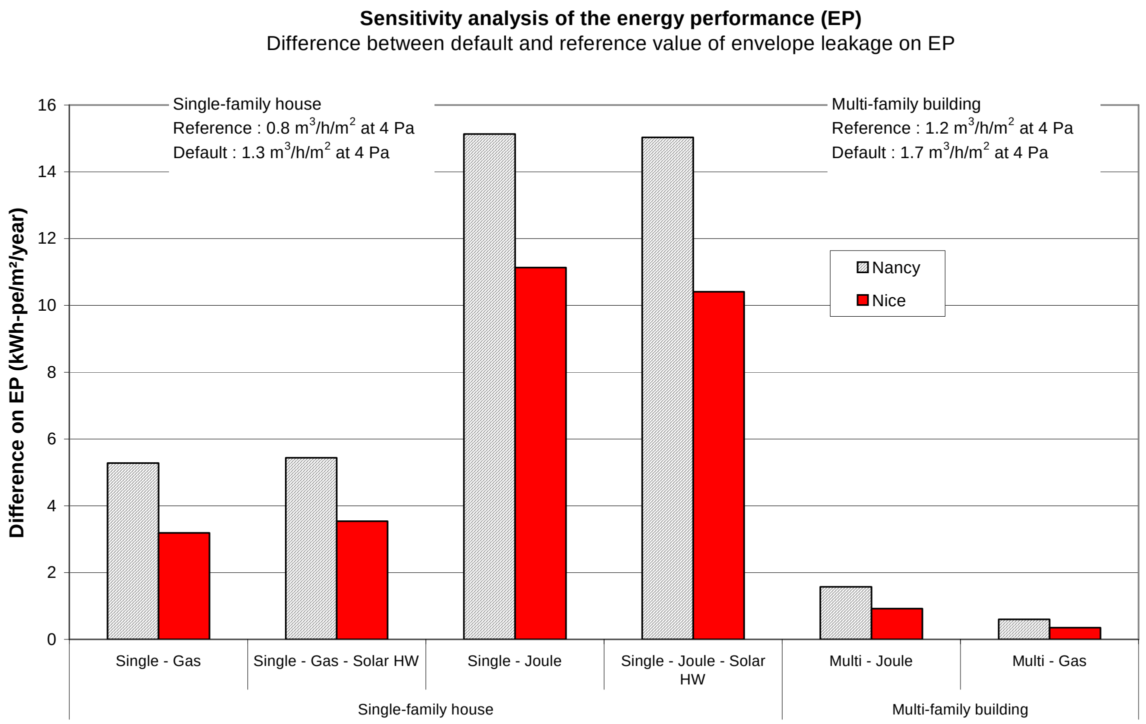

Figure 1: Examples of the energy impact (in kWh of primary energy) of envelope leakage in a single-family house and a multi-family building for the climates of Nancy and Nice (France), for extract-only relative humidity controlled ventilation systems.

4 Compliance

The compliance scheme to the regulation obviously depends on the nature of the requirements. Most of the time, a pressurisation test has to be performed to be able to claim for a reward for good envelope or ductwork airtightness. In theory, the compliance to a minimum requirement should be systematically tested. However, this is done only in the UK, where envelope pressurisation tests are compulsory since 2006 in all new buildings. This requirement extends the previous one in force since 2002 for large buildings (over 1000 m^2). Note that although compulsory testing does not apply in Denmark and Germany, these countries test respectively 5% and 15-20% of their new buildings. Also, ductwork testing is very widespread in Denmark.

There exists alternative routes to pressurisation tests. Quality management approaches are rewarded in Finland and in France. In other words, if a builder can prove that he has implemented a quality management approach to obtain good envelope airtightness, he can use a value different from the default value in his energy performance calculation. In Finland, this route is targeted primarily at pre-fabricated houses. In France, the alternative route is applicable by all builders of individual houses. The approach has to be approved by the ministry based on a dossier filled by the builder that includes airtightness measurements on a sample of buildings. A few dossiers are being processed in 2008.

An alternative route had been explored in the UK as well some years ago, based on the adoption by builders of "robust" construction details for residences, defined in a reference document. However, we heard that the evaluation of the scheme, based on leakage measurements of buildings that went through this process, did not give satisfactory results: apparently, about half of the buildings tested failed.

The UK experience calls into question the relevance of the more recent French and Finnish approaches, although it is clear that the success of such schemes depends heavily of fine details. These approaches appear similar in principle, but they include important differences in their implementations. Therefore, especially if found successful, these approaches should be carefully evaluated, in particular to identify the keys to success and barriers, so that other countries could benefit from their experience.

5 Envelope airtightness and indoor air quality (IAQ)

Several countries have stressed in their presentation the link between envelope airtightness and indoor air quality. Indeed, good airtightness can help better ventilate a building, provided that an adequate ventilation system be installed, which is not always the case. Therefore, there appears to be frequent problems in renovation of existing buildings originally ventilated by building leaks in the Czech Republic or in Poland. The replacement of windows with more energy-efficient and tighter ones can drastically reduce the infiltration rate and therefore the ventilation rate in the building. These problems have also been identified in France in the 1980s. For this, the new regulation for existing buildings requires that provisions be taken to assure that ventilation is not impaired by the replacement of windows. This translates most of the time into self-regulating air inlets integrated in the window frame, unless a balanced mechanical ventilation system is installed.

IAQ problems associated with under-ventilated residences were mentioned in the USA as well : in new tighter buildings, the ventilation requirements remain very low although the ventilation air provided through building leaks is significantly lower than the infiltration rate in older and leakier buildings. Besides, the traditional assumption that people open their window and use natural ventilation to supplement does not hold any longer.

6 Airflows through insulation layers

In Japan, the reduction of the thermal resistance of insulation materials has been identified as the first reason to address airtightness. In fact, laboratory experiments performed in Germany on a 1 x 1 x 0.14 m insulation panel have demonstrated that air flowing through the panel because of a 1 m x 1 mm slot could reduce the thermal resistance by a factor of 4.8. Therefore the thermal performance of insulation exposed to outdoor air, for instance, in ventilated attics or crawlspaces, installed on the exterior part of a façade, or even installed internally, can be significantly affected. This remark is not relevant when a dynamic insulation strategy is used because the degradation of the thermal resistance is expected to be compensated by the heat recovered as the air flows through the insulation material.

Good airtightness is also desirable to prevent condensation damages due to exfiltrations. Indoor warm air gets colder as it flows out through an insulation layer. In this process, condensation within the insulation may occur. This aspect has been stressed in the Japanese presentation only, but it has been identified in the past in many other countries as well.

7 Airtightness status and monitoring

7.1 Databases

Although many tests may be performed in some countries, the data is rarely collected. This work has been performed in the USA where over 100 000 tests have been integrated in a database. It is envisioned in Germany : a database should be operational in 2009.

There are many ways such databases can be used: one is to provide a status on envelope and ductwork airtightness ; another one may be to monitor the progress over time, for example due to regulations or other incentives ; a third one may be to back out statistical models to estimate the envelope or ductwork leakage to help refine regulations.

Apart from the USA and Germany, the data collection schemes seem limited to some research data. The likely uptake of pressurisation tests in some countries could be an excellent opportunity to set up national schemes to collect airtightness data.

7.2 Comparing envelope airtightness between countries : a difficult exercise

It would be very useful to compare airtightness levels observed, recommended, or required between countries. However, although there exists an international and European standard covering envelope airtightness, there exists an array of metrics adopted locally. These metrics usually comply with the standards that define three different possibilities to normalize the leakage flow rate usually estimated at 50 Pa:

- the infiltration airflow rate divided by the internal volume gives the n_{50} in air changes per hour at 50 Pa;
- when divided by the cold wall surface area, one obtains the q_{50} in $m^3/h/m^2$;
- w_{50}, expressed in $m^3/h/m^2$, is derived by normalizing to the heated floor area.

The key advantage of the n_{50} is that it can be easily used as an input in an airflow simulation tool in which the volume is usually necessary to evaluate the dynamic behaviour of contaminants. However, this is not the case in thermal simulation tools that do not require the building volume as an input to calculate the energy use. In such tools, the surface area of cold walls is usually known, which explains why some countries use the q_{50} in their regulation. On the other hand, the rationale behind the w_{50} metric lies in the ease to have access or calculate the floor area.

One common problem of these indicators is that, although they are specified in the standard, there remains some variation between countries or even regions or technicians in their precise definition. For example, standard EN 13829 states that the floor area used to calculate w_{50} is calculated according to national regulations. In some countries, the cold wall surface area used to derive q_{50} includes the lower floor whereas this area is excluded in others. Finally, because building shapes are often complex, the volume calculation may differ between operators.

Still, it was concluded that the n_{50} was probably the most appropriate indicator for international comparisons, although some other indicator may be used in the EP regulation. Therefore, it would be relevant to give some guidance on the volume calculation beyond those stated in EN 13829 to enhance the reliability of the n_{50}s reported.

7.3 Method A or B ?

EN 13829 describes two methods to perform a pressurisation test named methods A and B (the newest version of ISO 9972 mentions 3 methods). The key difference between the methods lies in the openings that are sealed for testing. Method A assumes that the heating or cooling systems are left operational, whereas all intentional openings must be closed or sealed for method B. Of course, the choice of method A or B may lead to major differences in the measured airtightness, for instance, if a fireplace damper is sealed, closed, or left open. (This is why publications should systematically indicate the method used.)

There may be good reasons for using either methods. For example, if the EP calculation includes the effect of a given opening, it is relevant to seal it for the test to use the measured airtightness as an input. However, in most countries, there does not seem to be information available on this subject for technicians who perform tests. The only publicly available information we found is a paper recently published in Belgium (Delmotte, 2007).

Therefore, work is needed to guide technicians in their measurements beyond EN 13829. This aspect is also important both to estimate correctly envelope leakage impacts for a specific building with an energy calculation tool, and to compare airtightness results between constructions.

8 Ways to stimulate good envelope and ductwork airtightness

With regard to envelope leakage, most regulations put emphasis on the result, i.e., a good airtightness can be rewarded (sometimes significantly as shown in

In most countries not familiar with this process, a learning phase seems necessary a) to raise awareness among prescribers, designers, and craftsmen; and b), to provide tools to designers to help them design adequate junctions. This phase can be accelerated locally, in particular with technical conferences with these specific target groups and adequate training of designers who are well placed to forward this message to craftsmen. The success of the local events recently held in France with a specific focus on this issue, some being supported locally by low-energy buildings programmes, is very interesting with this respect. Over 700 persons have participated to 5 events held in various regions. These have contributed to a growing demand by the designers themselves for practical tools to design and achieve good airtightness. The actual result will heavily depend on the capacity of designers to effectively integrate this issue.

As regards ductwork airtightness, the situation is more confusing: excellent ductwork airtightness seems common in Scandinavian countries with the widespread use of duct components with pre-fitted seals, although this aspect may not be pushed by regulations; some countries (BE, FR, USA) reward good ductwork airtightness in their energy performance regulations but have poor results; other countries do not consider ductwork airtightness in their regulations and are likely to have poor results. Maybe the design plays an important role: the use of duct components with pre-fitted seals is clearly a relevant answer to the problem, but it requires a more careful design as these components cannot be used with as much flexibility as raw components. For example, the benefit of a pre-fitted tee-junction vanishes if the component has to be customized on site because a water pipe is in the way. Probably, designers' training can contribute to improve the situation.

9 Conclusions

The stimulation of good envelope or ductwork airtightness should not rely uniquely on regulatory measures that reward good results. Experiences in different countries show that awareness raising and training among prescribers, designers and craftsmen is essential to trigger a market transformation, beyond regulatory measures. It seems that the envelope airtightness market is changing in some countries that go in this direction, or at least that there is a growing interest on this subject. With few exceptions, this does not seem to be the case with ductwork airtightness, although some regulatory measures may have been taken. However, most of these experiences are very recent and the overall schemes set up to improve airtightness have not been evaluated yet. A careful evaluation of these schemes, including the analysis of measurement datasets and impact of training programmes, would be very beneficial to the countries themselves as well to other countries that could be inspired by success stories.

10 References

1. Delmotte, C. 2007. Mesurer l'étanchéité à l'air des bâtiments selon la norme NBN EN 13829 : quelques précisions. Les Dossiers du CSTC – N° 1/2007 – Cahier n° 6.
2. EN 13829:2000 Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method (ISO 9972: 1996, modified)
3. EN 13465:2004 Ventilation for buildings – Calculation methods for the determination of air flow rates in dwellings
4. Knights, C., and Potter, N. 2006. Airtightness testing for new dwellings. The essential guide to Part L1 of the 2006 Buildings Regulations. BSRIA Guide BGII/2004.2. BSRIA. March 2006
5. Pickavance, D., and Jones, T. 2006. Airtightness testing. The essential guide to Part L2 of the 2006 Building Regulations. BSRIA Guide 4/2006. March 2006

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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.