COMPARISON OF BUILDING PREPARATION RULES FOR AIRTIGHTNESS TESTING IN 11 EUROPEAN COUNTRIES

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ABSTRACT

Mandatory building airtightness testing came gradually into force in the UK, France, Ireland and Denmark. It is considered in many other European countries because of the increasing weight of the building leakage energy impact on the overall energy performance of low-energy buildings. Therefore, because of related legal and financial issues, the building airtightness testing protocol and reporting have become crucial issues to have confidence in the test results as well as the consistency between the measurement results and values used in the energy performance calculation method.
The reference testing protocol in Europe is described in EN 13829, but many countries have developed specific guidelines to detail or adapt EN 13829 requirements.
This study compares building preparation rules for airtightness testing in 11 European countries.
Information has been collected through a questionnaire sent to TAAC (TightVent Airtightness Associations Committee) members. We found that building preparation differs significantly from one country to another and that the two methods described in the standard are either too detailed or insufficiently described to fit with the specificities of each country regarding building preparation. It concludes on possible improvement for EN 13829 including:

- In one hand describing more precisely the basic principles of the preparation to avoid ambiguities and,
- In another hand, allowing some flexibility to the countries to specify rules consistent with their energy performance calculation method.

KEYWORDS

Airtightness testing, building preparation

1 INTRODUCTION

Building airtightness is a key issue to reach low- and very low-energy targets. Therefore an increasing number of tests are performed in European countries for various reasons: compliance to the energy performance regulation; compliance to a specific energy programme; or will of the building owner. For instance, to our knowledge, measuring the airtightness of all new buildings or at least part of them is required by the energy performance regulation in UK, France, Ireland and Denmark. Besides, specific energy programs (such as Passivhaus or Minergie) that require or encourage building airtightness testing are increasingly popular in many other countries. Likely, within a few years, over a million tests will be performed every year in Europe.

Airtightness measurements are useful to check that the building envelope complies with a given requirement. The measurement protocol is described in the European standard EN 13829 adapted from ISO 9972 which is now under revision.
Measurement uncertainty has been discussed in various publications (Bailly, 2012) (Delmotte C. , 2013) (Delmotte C. L., 2011) (Rolfsmeier, 2010) (Sherman, 1995) and it is widely accepted that the building preparation (i.e., the way openings and vents are sealed, closed, or left as during the airtightness test) represents one of the main sources of uncertainty.
Rolfsmeier et al (Rolfsmeier, 2010) have had tests performed by 17 testers on the same building, firstly with a preparation made by the tester himself, and secondly with homogenous preparation rules. 70% of testers obtained a V_{50} within 7% of the right result, but for the 30% the error could reach 63% because of an inappropriate preparation and a misinterpretation of the volume to be tested. When the preparation was done correctly, results stayed within 6% of the right results for all testers. The consequences of such discrepancies can be crucial for building professionals or owners seeking e.g., if the subsidies are given on condition to meet a given airtightness level, or if the remedial actions are costly and impractical to implement.
Moreover, if the result is used in energy performance calculation method, the building preparation has to be consistent with the calculation method. Logically, one should seal or close the openings through which the airflow rate is taken into account elsewhere in the calculation method and leave as what is not. In principle, this is clear for instance for the air terminal devices of a mechanical ventilation system, but it may be ambiguous for devices such as unvented combustion appliances.
Therefore, to address the question raised by the increasing number of airtightness tests, we have collected and analysed information on building preparation.

2 OBJECTIVES

This study aims at answering the following questions:

- How is EN 13829 used and interpreted in European countries?
- Does EN 13829 fit with countries' needs in terms of protocol description?
- How can the standard be improved to better march those needs?

3 APPROACH

This work has been done in the context of the TightVent Airtightness Associations Committee (TAAC). TAAC is a European working group, set up and hosted within TightVent. The scope of this working group includes various aspects such as:

- Airtightness requirements in the countries involved
- Competent tester schemes in the countries involved
- Applicable standards and guidelines for testing
- Collection of relevant guidance and training documents.

At present, the participants are from Belgium, Czech Republic, Denmark, Estonia, France, Germany, Latvia, Ireland, Poland, Sweden, UK and contacts have been established with other European countries.
A questionnaire has been developed within the group to compare building preparation with the objective of being useful for someone who:

- plans to perform a test in a foreign country
- would compare the test results from different countries
- prepares guidelines for airtightness measurements in its country

A representative from each country has kindly accepted to answer the questionnaire.
This document summarizes their answer.
Note that the scope of the answers differs between countries:

- For the UK, Denmark, Germany and Ireland, the answers concern only the energy performance regulations
- For France and Belgium, the answers concern both energy performance regulation and specific energy savings programs.
- For Czech Republic, Poland and Sweden, they concern specific energy saving programs only.

3.1 Analysis of questionnaire results

Airtightness requirements and guidelines

Out of the 11 countries who have answered the questionnaire only four of them have requirements in the building regulation to measure airtightness (Denmark, France, Ireland and UK)[1]. Those four countries have all developed specific guidelines to detail airtightness testing conditions.
Three other countries (Belgium, Czech Republic and Germany) have also developed specific guidelines for airtightness testing in the context of specific energy saving program or for voluntary testing in the context of energy performance regulation.
This means that 7 out of the 11 countries have developed specific guidelines beyond the European standard EN 13829.

Time of measurement

This question concerns the requested completion of the building. EN 13829 specifies that even if preliminary measurement may be done during the constructions, the effective measurement can take place only when the envelope of the building is completed.
We noticed large differences between countries:

- In Sweden, for example, as building regulation and even energy performance programs give very few guidelines to perform airtightness tests, most of the time it is the client himself who chooses time and condition of measurements. As a consequence, most of the time, he prefers to make the test when it is still possible to reach the airtight layer in case leakages have to be repaired. Thus the building envelope may not even be completed (some doors or traps could be missing and sealed instead). Most often, a final test is not performed.
- In Belgium, test has to be performed when the envelope is completed. It is recommended to have it done when all works are finished.
- In Denmark and UK the building envelope has to be in its final complete state.
- Germany requires that the building envelope – all airtightness concerning parts – shall be completed.
- In France and Czech Republic, the tests have to be done after all work that may affect airtightness is completed.
- In Ireland, the building must be in “practical completion”, i.e., almost ready for occupation (possibly just need to have painting done and furniture placed)

General rules for the building preparation

Testing according to EN 13829 requires that all intentional exterior openings of the building or part of the building to be tested (windows, doors, fireguard) be closed. Besides all interconnecting doors in the part of the building to be tested shall be opened to have a homogeneous pressure in the building (except for cupboards and closets, which should be closed).

[1] The regulation does not impose to measure every buildings but at least part of them have to be

Beyond these basic rules, "method A" of the standard does not allow further improvement of the air tightness of building components. On the other hand, with "method B", all adjustable openings shall be closed and remaining intentional openings shall be sealed.
The underlying ideas behind the methods are the following:

- Method A: the building as prepared represents its condition during the season in which heating or cooling systems are used.
- Method B: the leakage measured represents the leakage through the envelope excluding those due to the HVAC equipment and its penetrations.

Method A is used in the energy performance regulation only in two countries (Ireland and Belgium). Three countries (Czech Republic, France and Germany) have developed a specific method. However, in the Czech Republic and Germany, this method is used only for specific energy saving program and method B is required by energy performance regulation. Therefore, in 8 out of the 11 countries, method B is used to estimate the building airtightness in the energy performance regulation context.
To further describe the building preparation, we have defined six categories to classify how each opening shall be processed:

- "Sealed": make hermetic by any appropriate means (adhesive, inflatable balloon, stopper, etc.)
- "Depends on EP-calculation": sealed if the associated flow rate is already taken into account in the energy performance calculation method, left as if not
- "Closed": Closed if there is a closing device, left as if not
- "Held with tape": the device is closed with a tape to prevent it from moving during the test, but the tape should not sealed the opening
- "Left as": left in normal position of us (this can be closed if the normal position is close like some fire-door or open of if normal position during heating or cooling period is "open")
- "Open"

Those categories were re-constructed after the survey to fit with respondents' answers but there is still some specificity. In UK the rule can be "closed if closing device exists, sealed if not": in those cases both categories are selected in the analysis. In Sweden, the rule can be "closed if the closing device leads to a perfect airtightness of the opening, sealed if not", thus in those cases, for Sweden, the category "sealed" has been selected.
The category "depends on EP-calculation" is only used in Czech Republic and France.

Openings for ventilation
EN 13829 requires to seal air terminal devices of mechanical ventilation or air conditioning system and to close other ventilation openings for purposes of method A and seal them for method B.
The general requirements of EN 13829 (§5.2.3) does not detail what is included in air terminal devices of mechanical ventilation (local, general, permanent, intermittent…) and do not detail what shall be done with openings for natural ventilation that do not have closing devices.
To overcome this problem, we have agreed on the following additional definitions:

- Openings for whole building mechanical ventilation or air conditioning: openings that have one side plugged on a duct linked to a fan that provides general and permanent ventilation for the building. "Permanent" means that it cannot be turned off manually; this includes

permanently regulated system which may sometimes be automatically turned off (for example when offices are unoccupied).

- opening for local mechanical ventilation of air conditioning with intermittent use: openings that have one side linked to a local fan that can be turned off manually (not including kitchen hood)
- ventilation openings for natural ventilation: straight openings from outside to inside (or vice-versa) including opening that contribute to the general ventilation system in association with openings for mechanical ventilation

All respondents agreed that openings for whole building mechanical ventilation or air conditioning have to be sealed.
Regarding openings for local mechanical ventilation of air conditioning with intermittent use, the answer is "sealed" for 7 out of the 9 respondents (or closed in UK) and "Depends on the EP-calculation" for 2 out of the 9.
Last, regarding ventilation openings for natural ventilation, the answer is sealed for 7 countries out of 9 (or closed in UK), "depends on EP-Calculation" for one and closed for Belgium (which is consistent with Method A).

Opening for the heating system and smoke exhaust
EN 13829 only requests to avoid exhaust hazards from heating systems.
Inlet and outlet openings for the main heating system (this may include air intake of a combustion appliance, chimney flue, air handling unit…) shall be sealed in Estonia, Denmark, France, Germany and UK and closed in Ireland and Belgium.
Inlet and outlet openings for additional heating system shall be sealed in Estonia, Denmark, Germany and UK, prepared consistently with energy performance calculation method in France and closed in Belgium and Ireland.
If we take a closer look at the preparation of various specific components we can see that the interpretation on general rules differs (Figure 1 and Figure 2).
For example, chimney flue either have to be sealed (5 out of 9) or it "depends on EP-calculation" (1 out of 9), or it shall be closed (1 out of 9) or it shall be left as (2 out of 9). And it is about the same with chimney rear ventilation opening.

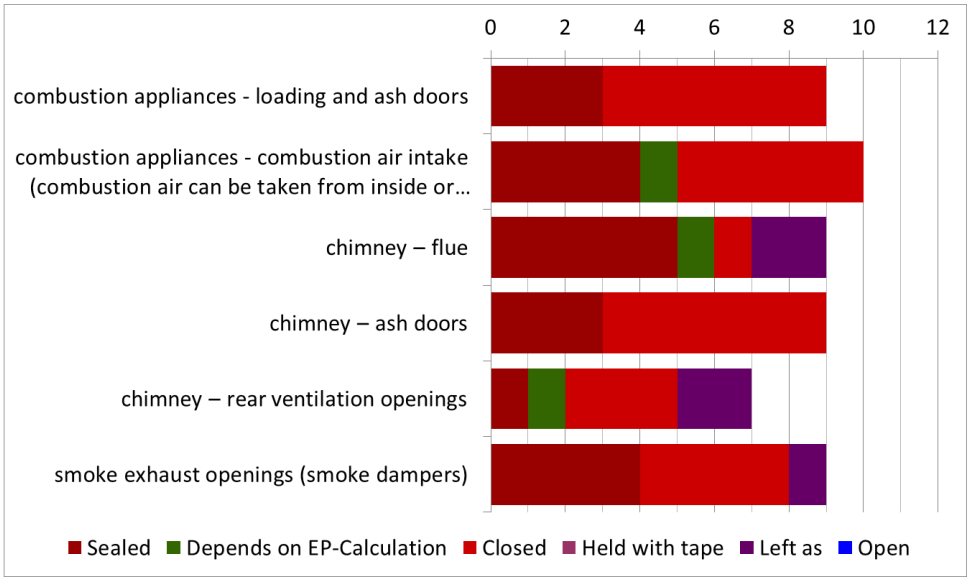

Figure 1: Preparation of openings for heating system and smoke exhaust

Specific openings

We have listed 6 “other envelope openings” but this list is not exhaustive.

Belgium remains consistent with method A: those openings are “left open” or only “held with a tape”. France mostly recommends to leave them in normal position of use or to be consistent with energy performance calculation. Estonia is consistent with method B and seals all of them. Other countries (Czech Republic, Denmark, Germany, Ireland, Sweden and UK) have a preparation depending on the kind of opening Figure 2 .

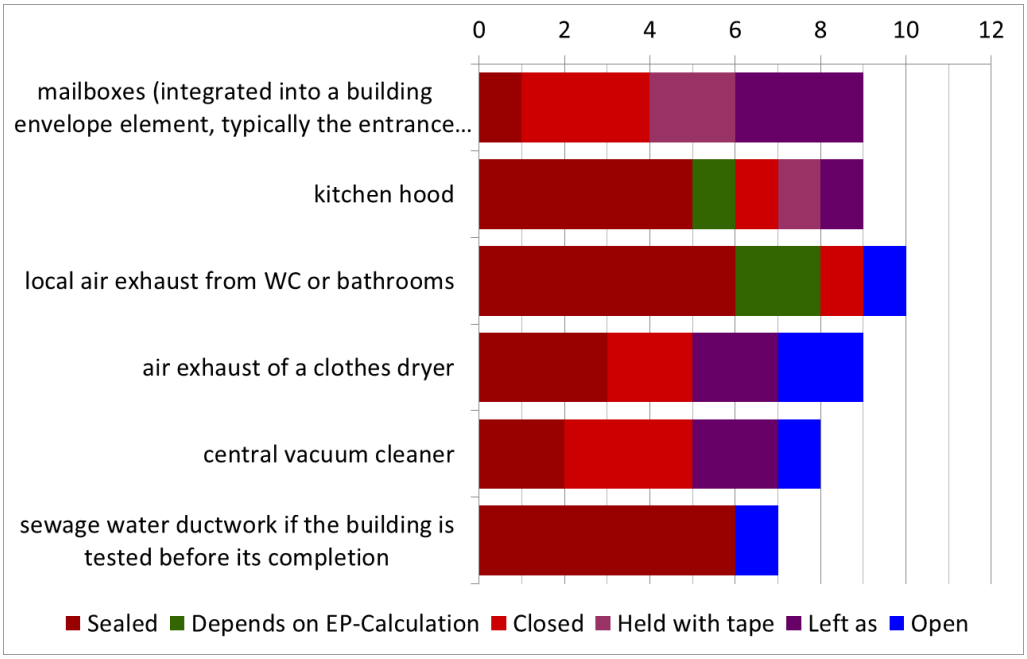

Figure 2: Preparation for "other openings"

4 DISCUSSION

The analysis of the questionnaires brings to light the importance of the purpose of the measurement.

Regarding the time of measurement, if the purpose of the test is to estimate the energy losses of the building by leakage it seems obvious that the test shall be done after all work that may affect airtightness is completed.

Nevertheless, requiring test after the completion of the building can lead to organization problem in some cases --e.g., in multi-family buildings some dwelling may be occupied while others are not completed yet. Furthermore when the work is completed it is hard to improve efficiently the airtightness. This probably explains why some countries (BE, SE) have chosen not to require the completion of the building before the test is performed.

Of course, some designs allow testing before completion without compromising the validity of the test for regulatory compliance purposes. This could apply for instance when interior membranes are used as air barriers and the design is such that there are little penetrations of this barrier after it is installed. On the other hand, other systems may be severely affected by works until completion—e.g., interior gypsum boards used as air barriers. It seems difficult to go into that level of detail in a regulatory framework.

Regarding the building preparation, the survey shows that most countries agree on basic principles such as closing windows, doors and trapdoors and leaving internal doors open. On the other hand, the interpretation of the purpose and details of methods A and B varies significantly.

To check the compliance to the energy regulation, the general rule should be to seal all openings for which the air flow is taken into account in the calculation, and leave in normal position of use all other openings. The underlying idea is closer to method A but it can

deviate significantly depending on aspects and components taken into account in the calculation method.
Method B is appropriate if the purpose is to impose a minimum requirement for the envelope only, excluding all penetrations (due to HVAC equipment's, mailbox, etc.). However, it is unclear to us how useful this requirement would be. It would be similar to a minimum requirement for the level of insulation of some of the walls but not all of them. Therefore, motivations behind the choice of method B versus method A are rather unclear to us. It seems that the issue of consistency with the energy performance calculation method is not well understood. Method B seems mostly chosen by default because method A is too restrictive.
Those variations in interpretations mean that it is impossible to compare measurements and building airtightness performance from one country to another, unless prior check of the consistency of the building preparation on the samples analyzed. Moreover, it appears challenging for a tester to perform tests in a foreign country unless he well acquainted with the specificities of building preparation in that context.
Nevertheless, there are two obstacles to harmonize pressurization test methods between countries:

- In each country the test method shall be consistent with the energy performance calculation method. But, there are significant differences in calculation methods between countries in the way airflow rates are taken into account.
- There are specific devices and construction traditions in each country that may require tailored rules.

As an illustration of the last obstacle, closing devices are forbidden on air inlets in France. However, the test can only be done with those inlets sealed as most of them self-adjust their position according to the pressure difference. This is nevertheless consistent with the calculation method which takes into account the contribution of these devices to the airflow rates.
Maybe, the standard could leave the possibility to define a measurement protocol at national level consistent with the purpose of airtightness testing.
Nevertheless, to help decision makers setting it, a protocol schemes could be defined in the standard. This scheme may give a detailed list of openings and how to determine the way they should be prepared to be consistent with the test purpose.

5 CONCLUSION

This study shows that building preparation in the 11 countries investigated differs significantly from one country to another even when the same method is used and without clear and technically-sound motivations behind the choices. Therefore, it is clear that building airtightness should not be compared between countries unless precaution is taken in the sample analyzed and in the interpretation of the results.
To address this issue, the revision of the standard shall, in one hand, describes more precisely the basic principles and avoid ambiguities and, in another hand, allows some flexibility to the countries to specify rules consistent with the energy performance calculation method. At the same time, it should allow the identification of tests performed under comparable conditions to allow meaningful comparative analysis between countries.

6 ANNEX

The following table gives references of specific guidelines for each country

Country	**France**	**UK**	**Czech republic**

Name of the document where the guidelines are specified	GA –P 50-784 (application guide of NF EN 13829)	ATTMA Technical Standard L1 – Measuring Air Permeability of Building Envelopes (Dwellings)	Metodický pokyn - Pravidla pro měření průvzdušnosti obálky budovy (Methodical instruction – Rules for measurement of air permeability of building envelopes, in Czech)
Author or editor of the document	Afnor	The Air Tightness Testing and Measurement Association (ATTMA) Technical Committee	Association Blower Door CZ, www.asociaceblowerdoor.cz
Institution which issued the document	Working group set by the ministry of ecology	The Air Tightness Testing and Measurement Association (ATTMA)	Státní fond životního prostředí České republiky (State environmental fund of the Czech Republic)
Date of issue	February 2010	October 2010	not yet issued, prepared for publication (state from September 2013)
The document is available (for downloading or purchase) at:	http://www.boutique.afnor.org	www.attma.org	http://www.nzu2013.cz/zadatele-o-dotaci/rodinne-domy/dokumenty/metodicke-pokyny/
Comments:	This document is under revision		Document issued as a part of instructions for subsidy applicants from the New green savings programme

Country	**Belgium**	**Denmark**	**Germany**	**Ireland**
Name of the document where the guidelines are specified	Spécifications supplémentaires	"Metoder for certificerede virksomheders trykprøvning efter EN 13829 og gældende bygningsreglement" version 1,	EnEG_Staffel 11 – Auslegungsfragen zur Energieeinsparverordnung – Teil 11	ATTMA publication "Measuring air permeability of Building Envelopes" & EN 13829
Author or editor of the document	Governments of the three regions	Klimaskærm	Dr. Justus Achelis, DIBt	ATTMA/CEN
Institution which issued the document	Governments of the three regions	Klimaskærm	Fachkommission Bautechnik der Bauministerkonferenz	ATTMA/CEN

Date of issue		5. September 2013	9.3.2004; 9.12.2009	October 2010 Issue - 18 October 2000
The document is available (for downloading or purchase) at:	www.epbd.be	www.klimaskaerm.dk	https://www.dibt.de/de/Service/Dokumente-Listen-EnEV.html	http://www.attma.org/wp-content/uploads/2013/10/ATTMA-TSL1-Issue-1.pdf

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