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Report on the building airtightness measurement method in European countries

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1 Introduction

Building airtightness is a crucial aspect towards a better energy performance of buildings (EPB). In order to verify which airtightness has been achieved, a measurement is necessary. EN 13829:2000, based on ISO 9972:1996, describes a standardised procedure for an airtightness measurement with several variants (e.g. method A or B). In order to achieve univocal application in the context of an EPB-regulation, additional specifications should be defined (e.g. which of both methods should be used).

In the framework of the ASIEPI project, a sample survey of a number of European countries has been made concerning the existence of such additional specifications for the envelope airtightness measurement. The results are documented in this report, which reflects the state at the time of its last update, i.e.fall 2009. The information is supplied by different project partners and subcontractors, and is the state in their country as was know to them at the time of the enquiry. Care has been taken to collect correct information, but it cannot be guaranteed that it always represents the full picture as EPB-regulations are constantly evolving and/or the information may not always be widely disseminated and/or easily accessible.

National information has been contributed by the following partners:

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Much more information on many different aspects of airtightness has been made available by the ASIEPI project on its website: http://www.asiepi.eu/wp-5-airtightness.html

2 Situation in Belgium

The EPB-regulations in Belgium[1], are based on as-built proof after construction. In this context, the fan pressurisation method, described in the European standard EN 13829:2000 [1], is used to quantify building airtightness, in case one wants to prove a better performance than the (unfavourable) default value.

In the absence of an airtightness measurement (which is not obligatory), a default value of 12 $m^3/h.m^2$ envelope area at 50 Pa is taken into account for the calculation of the space heating needs in the EPB-method in Belgium. Thanks to a good result of the airtightness measurement, a reduction of the E-level (level of primary energy consumption) typically between 5 and 15 points can be achieved (compared to a reference value of the E-level of 100). It is thus important to ensure that the same measurement procedure is used by everyone.

At the request of the 3 Regions (who are, each for their territory, in charge of the EPB-implementation in Belgium), additional specifications to EN 13829:2000 were developed for use in the context of the EPB-regulation in Belgium [2]. They are composed of two different documents: (1) the additional specifications as such, and (2) justifications and explanation of these specifications. An unofficial English translation of these documents is available on the website www.epbd.be/go/airtightness-measurement [2] and is included as annex in this report.

3 Specific procedures in the EPB-context in several European countries

The information on additional specifications is summarised in table 1 and discussed in more detail in this paragraph.

To our knowledge, at present only Belgium, France, Germany and the United Kingdom have to a greater or lesser extent developed in an official way additional requirements for the measurement procedure in the context of their EPB-regulations. In France, such specifications are at time of writing in the process of formal approval.

Most of the European countries which have been consulted have no official additional specifications to the standard (Finland, Italy, Portugal, Spain, Czech Republic). In other countries some documents exist as a recommendation (Norway, Denmark) or for obtaining certain labels (in Poland and elsewhere, notably for Passive House certification) but these documents are generally speaking not available in English and only partial information is available from them. In Denmark, some requirements are mentioned in the building regulation and a voluntary certification of the professionals has been developed and will probably be mandatory in the future; there are some additional specifications in the context of this certification.

[1] Already applicable in Flanders since 1 January 2006, in Brussels since 2 July 2008 and due to take effect in Wallonia on 1 May 2010.

Table 1. Additional specifications to EN 13829:2000
(Note P+ is pressurization and P- is depressurization).

Country	Method	Openings	Measured Extent	Press* (Pa)	P+/P-	Ref
Belgium (3)	A	Closing: all openings with a closing device Sealing: mechanical ventilation ducts	Building or flats individually	50	P+ and P-	[2]
Denmark			Only flats: individually (voluntary scheme)		P+ and P-	[3]
France (3)	adapted	Method A with some deviations: - ventilation openings (natural or mechanical), taken into account in EPB-calculation: closed, or sealed if no closing device available - heating or cooling systems, taking air inside the building: left open, closed or sealed, depending on the way it is taken into account in the EPB-calculation	Sampling rules are defined		P+ and/or P-	[6]
Germany (1) and (3)	A/B	Method A proposed by FLiB (study group 13829) with one deviation: openings for the supply air of an exhaust system must be sealed (decision of the executive committee of FLiB) Method B proposed by DIBt with two deviations: the opening via a fan from a kitchen hood and "unplaned" openings (e.g. letter box flaps, cat flaps) must not be sealed	Sampling rules defined by FLiB		P+ and/or P-	[7] [10]
Netherlands (3)	-	Sealing: - ventilation ducts - supply or exhaust openings for gas appliances Closing (if closing device present): - ventilation openings (and "suskasten") - exhaust of open appliances	Building or parts individually	85	P+ and/or P-	[11] [12]
Norway (1)	B	Closing: all openings which can be closed in ordinary ways	Building or flats individually		P+ and P-	[13]
Poland (Passive house) (2)	B			100	P+ and P-	[14]
UK (3)	B	Closing: passive ventilation systems Sealing: - permanently open natural ventilation openings - mechanical ventilation openings - doors to building parts outside the measured extent	Building or flats individually	50	P+ and/or P-	[15]

(1) Guideline; (2) Specifications for a label; (3) Regulation or standard.

***** The column "Press" refers to the pressure difference that must at least be achieved during the measurement.

3.1 Choice of the method and treatment of the openings

The most important additional specification is the method to use and the related treatment of the openings in the building envelope. EN 13829 describes two different methods:

- Method A is applicable for measuring the airtightness of the building in use, with the building envelope representing the conditions during the season in which heating or cooling systems are used.
- Method B is applicable for measuring the airtightness of the building envelope. In this case, any intentional opening in the building envelope is closed or sealed.

In the context of the Belgian EPB-regulations, given that the aim is the assessment of energy losses due to in/exfiltrations, method A is more relevant and it is therefore imposed that method A be used. Only the energy losses due to hygienic ventilation are already taken into account elsewhere in the EPB-calculations. Thus, the openings involved in the hygienic ventilation must be closed for the measurement (closing of natural openings and sealing of mechanical openings). The other openings equipped with a closing device must also be closed (but not sealed). The air leakage rate due to all the other openings and leaks must then be taken into account in the measurement, such as permanently open grids, chimneys, leaks in the envelope, leaks of the ventilation openings in the closed position, etc.

In France, the additional specifications follow a strategy similar to the one proposed in Belgium. However, the additional specifications in France don't refer to either one of both methods described in the standard (i.e. A or B), but define the treatment of the openings in accordance to the EPB-calculation in France. The ventilation openings (for natural as well as mechanical ventilation), for which the flow rate is taken into account in the EPB-calculation, must be closed, or sealed if no closing device is available. For heating and cooling systems that bring outside air into the building:

- their openings must be sealed if the system and the flow rate brought into the building are already taken into account in the EPB-calculation, e.g. a ventilation extract system combined with a combustion device, most of the wood combustion devices (validated as innovative systems in French regulation) ;
- the openings must be left open (normal position) if the system is taken into account in the EPB-calculation but not the flow rate brought into the building, e.g. a combustion device other that wood (e.g. fuel oil, coal), ;
- and the openings must be closed if neither the system nor the flow rate are taken into account in the EPB-calculation. (Such kinds of systems can only be used occasionally, e.g. a chimney for an open fireplace)

All other openings in the building envelope can only be closed but not sealed.

The use of method B in Norway is perhaps related to the large scale use of balanced ventilation systems without any other ventilation openings, as suggested by the ASIEPI partner from Norway [16]; in this instance, methods A and B are identical in most cases.

In Germany, the official document from DIBt specifies the use of method B [7]. In contrast, the FLIB recommendations from 11/2001 [7], 6/2006 and 4/2008 (reprint of the 6/2006 version) [9] impose method A and give a detailed description of the treatment of the openings according to this method. The choice of the method is also extensively debated on a non-official website specialized in airtightness measurement (see http://www.luftdicht.de/auslegung-der-enev.htm for more details). In annex I a comparative table is given of the treatment of the intentional openings in the different specifications which have been established in Germany.

3.2 Measured extent

In Belgium, the measured extent must be defined in accordance with the subdivision of the building in the context of the EPB-regulation. It must cover at least that part of the building to which the EPB-requirements apply (i.e. the unit of a dwelling or the unit with a non-residential destination). Moreover, the measured extent cannot cover more than the "protected volume" (= volume within the insulated fabric) of the building. For apartment buildings this means that there is a free choice: the measurement can be carried out on each apartment individually or on the whole building at once.

In France, the additional specifications define rules of sampling for groups of similar houses and for multi-family buildings.

In most of the other surveyed countries, there don't seem to be additional requirements compared to those of the standard with respect to the measured extent. The measurement can apparently also be carried out either on each apartment individually or on the whole building at once, at least in Norway and the UK.

In Denmark, in the context of the voluntary certification of the professionals by the Danish organisation KLIMASKAERM (The Building Envelope Society), each flat must be measured separately.

3.3 Air leakage rate measurement

The EN 13829:2000 recommends carrying out two sets of measurements, both pressurisation and depressurisation, but this is only a recommendation. In the Belgian EPB-calculation method, the final aim is quantifying the infiltrations as well as the exfiltrations through the building envelope. Moreover, the deviation between both results can be large (see below). It is therefore required in the framework of the EPB-regulation to always carry out both sets of measurements.

In contrast, in most of the surveyed countries, it seems that only one measurement set is required. Two sets of measurements seem to be the usual practice in Norway, but it is not mandatory. In Poland, in the context of Passive House certification, two sets of measurements seem to be required. In Denmark, it is the average of the results under pressurisation and under depressurisation that is required in the building regulation.

In Belgium, the requirement for the highest pressure difference that must be achieved is also stricter in the Belgian EPB-specifications than the standard: a requirement of at least 50 Pa for all buildings and a recommendation of at least 100 Pa, while the standard only requires a minimum of 50 Pa for buildings smaller than 4000 m³ and only 25 Pa for larger buildings. However, it appears that a sufficiently large range of pressures below and above 50 Pa is necessary in order to ensure a sufficiently reliable result at 50 Pa.

At European level, the use of at least 50 Pa seems to be the common practice. A pressure difference of at least 100 Pa is required in the specific context of Passive House certification in Poland. According to certain experts, in particular in Norway, the highest pressure difference used for the measurement should be increased, for example up to 100 Pa, especially in bad wind conditions, in order to assure more reliable results.

3.4 Other requirements

Finally, in addition to the standard, also the following specifications are proposed in the Belgian EPB-context. For the time of measurement, it is recommended that the works possibly affecting the airtightness are finalised before the measurement, such as heating, ventilation, plumbing, electricity and wall finishing. With respect to the position of the pressurisation equipment, it must be placed in

the opening presenting *a priori* the highest airtightness, such as a door-window or a door with an airtightness gasket at the bottom.

4 Revision of ISO 9972

At its meeting of 4 May 2009, the ISO/TC 163/SC 1/WG10 working group has decided to start the revision work of the ISO 9972, and to seek collaboration with CEN/TC89 with respect to a simultaneous revision of EN 13829, with a view of achieving a unique, common EN ISO standard.

In this context, a draft position paper [19] has been developed with the collaboration of some ASIEPI partners. The paper discusses several points that seem appropriate to take into account during this revision. Future versions of this position paper will be available on the ASIEPI website: www.asiepi.eu.

5 References

[1] European Committee for Standardization. 2000. EN 13829:2000 Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method (ISO 9972:1996, modified).

[2] The Regions of Flanders, Wallonia and Brussels. Additional specifications on the building airtightness measurement in the scope of the EPB-regulation. The most recent version can be found on www.epbd.be/go/airtightness-measurement

[3] Kirsten Engelund Thomsen. 2008. e-mail communication in the ASIEPI project.

[4] R. Carrié, R. Jobert, M. Fournier, S. Berthault. 2006. Perméabilité à l'air de l'enveloppe des bâtiments, Généralités et sensibilisation. CETE de Lyon. France.

[5] Association Collectif EFFINERGIE. 2008. Règles techniques relatives au processus et à la mesure de l'étanchéité à l'air des bâtiments dans le cadre de la délivrance de la marque EFFINERGIE faisant l'objet d'un label bâtiment à basse consommation. France. Available on www.effinergie.org

[6] Normalisation française. Performance thermique des bâtiments. Guide d'application de la norme NF EN 13829 :2001. Draft version on 1/09/09.

[7] Justus Achelis. Auslegungsfragen zur Energieeinsparverordnung – Teil 9 – p.13. DIBt, 2008, Germany[2]. http://www.dibt.de/de/aktuelles_energieeinsparverordnung.html

[8] Fachverband Luftdichtheit im Bauwesen (FLiB). 1st edition 11/2002. Beiblatt zur DIN EN 13829. Wärmetechnisches Verhalten von Gebäuden - Bestimmung der Luftdurchlässigkeit von Gebäuden – Differenzdruckverfahren.

[9] Fachverband Luftdichtheit im Bauwesen 3rd edition 4/2008 (FLiB), (reprint of the 6/2006 version). Beiblatt zur DIN EN 13829. Wärmetechnisches Verhalten von Gebäuden - Bestimmung der Luftdurchlässigkeit von Gebäuden – Differenzdruckverfahren.

[10] Fachverband Luftdichtheit im Bauwesen (FLiB) 3/2005, Überprüfung der Luftdichtheit: Fachverband Luftdichtheit im Bauwesen e.V. stellt neue Checkliste vor. Sonderduck aus AIRTec, now available on http://www.flib.de/publikationen_sonder.html

[11] NEN 2686:1988. Luchtdoorlatendheid van gebouwen: Meetmethode. Nederlandse norm. The Netherlands, July 1988.

[12] NEN 2686/A2:2008 Luchtdoorlatendheid van gebouwen: Meetmethode. Nederlandse norm. The Netherlands, December 2008.

[13] SINTEF. 2007. Maling av bygningers lufttetthet Trykkmetoden (Document 720.035). Norway. Available on www.sintef.no

[14] Aleksander Panek. 2008. e-mail communication in the ASIEPI project.

[15] The airtightness testing and measurement association (ATTMA). 2007. Technical standard 1; Measuring air permeability of building envelopes. Available on www.attma.org

[16] Tormod Aurlien. 2008. e-mail communication in the ASIEPI project.

[2] This document (for EnEV 2007) supersedes the version related to the previous German EPB-regulation (EnEV 2002): Justus Achelis "Fachkommission Bautechnik der Bauministerkonferenz – Auslegungsfragen zur Energieeinsparverordnung – 5. Teil" p.5. DIBt, 2004, Germany.

[17] S. Caillou, P. Van den Bossche, C. Delmotte, D. Van Orshoven and L. Vandaele. 2008. Measurement of Building Airtightness in the EPB Context: Specific Procedure and Sources of Uncertainties. Building Physics Symposium, 29-31 october 2008, Leuven, Belgium.
[18] C. Delmotte, S. Caillou, P. Van den Bossche and P. Wouters. 2008. Determination of air permeability of buildings according to ISO 9972 or EN 13829 – Proposal for clarifications. The 29th AIVC Conference in 2008: Advanced building ventilation and environmental technology for addressing climate change issues, 14-16 october 2008, Kyoto, Japan.
[19] S. Caillou and D. Van Orshoven. 2009. ISO 9972: Position paper for propositions of revision. Brainstorming document. Future versions will be available on www.asiepi.eu

Annex I: Comparison of the different methods in use in Germany

This table has been contributed by Wilfried Walther from e.u.[z.], Germany. It gives an overview of the situation in the standard and the different additional specifications in Germany.

			Treatment of the intentional openings				
			Exact interpretation according to DIN EN 13829:2000-11		DIBt 2004-03 and 2008-03 [7]	FLiB "Beiblatt" 6/2006 and 4/2008 [9]	Executive committee FLiB [10]
	Openings	Para-graph in EN 13829[a)]	Method A	Method B	EnEV Method "B"	A	**EnEV (without indication of the method)**
1	Opening for the minimum air change (thermal -, wind -, or shaft ventilation)	§ 5.2.3	**1**	**3**	**3**	**1**	**1**
2	Non-closable opening with a grating, etc. (e.g. for air supply to a gas boiler, flue gas opening, opening for fire protection in elevator shafts)	§ 5.2.3	**1**	**3**	**3**	**1**	**1**
3	Opening via a fan, switched on for a short time only (e.g. WC-fan), except kitchen hood.	§ 5.2.3	**1**	**3**	**3**	**1**	**1**
4	Kitchen hoods	§ 5.2.3	**1**	**3**	**1**	**1**	**1**
5	Air path via fans "the whole time on"	§ 5.2.3	**3**	**3**	**3**	**3**	**3**
6	Openings for the supply air of an exhaust system - "all the time on"	§ 5.2.3	**2**	**3**	**3**	**2**	**3**
7	Openings with flaps and with a closing device	§ 5.2.3	**2**	**3**	**3**	**2**	**2**
8	Openings with flaps (e.g. letter box flaps, cat flaps, vacuum cleaners)	§ 5.2.2	**2**	**3**	**2**	**2**	**2**
9	Openings for electrical devices (e.g., dryer, dehumidifier)	§ 5.2.2	**2**	**2**	**2**	**2**	**2**
	Legend						
	1 do nothing						
	2 close						
	3 seal						

[a)] §5.2.2: Building components
§5.2.3: Heating, ventilation and air conditioning systems

Annex II: English translation of the two documents on the additional specifications for the airtightness measurements in Belgium

Document 1 (15 pages):
"Additional specifications on the measurement of the building airtightness within the context of EPB-regulations [in Belgium]"

Document 2 (8 pages):
"Annex B: Justifications on the Additional specifications on building airtightness measurement within the context of EPB-regulations [in Belgium]"

The latest versions of theses documents are available on the website www.epbd.be/go/airtightness-measurement.

This is an informal English translation of the specifications which have been established in Belgium. For official use, only refer to the original Dutch or French texts.

Additional specifications on the measurement of the building airtightness within the context of EPB-regulations [in Belgium][3]

Version 2

12 June 2009

In addition to the regulatory texts, the three regions (the Flemish region, the Walloon region and the Brussels-Capital region) together developed the following precisions for carrying out airtightness measurements within the context of the EPB-regulations. These rules have been approved by the three regions during their meeting of the EPB-platform on 12 June 2009 and apply in the same way in all three regions.

The latest version of this document can be downloaded from the following webpage: www.epbd.be/go/airtightness-measurement.

The modifications compared to the previous version of this document are listed briefly in chapter 9.

Contents

[3] The text between square brackets [ ] gives some additional explanation for non-Belgian readers. These additions are only included in the English version of this document.

1. Foreword

This document sets out the requirements to be respected for measuring the building airtightness within the context of the EPB-regulations. It is mainly addressed to *the measurement operator* (the person responsible for the measurement and the test report). *The test requester* (the person who orders the test or his representative, e.g. architect, EPB-rapporteur, etc) is only concerned with § 2 and annex A.
The EPB-regulations only make reference to the NBN EN 13829:2001 [EN 13829:2000, which is based on ISO 9972:1996] standard for the measurement of the air leakage rate at 50 Pa of the exterior envelope, $\dot{V}_{50}$. The other aspects of this standard, including the derived calculations, are thus not obligatory within the context of the EPB-regulations. This document establishes the requirements that are to be fulfilled: additional specifications to the NBN EN 13829:2001 standard. This standard is an essential prerequisite to this document.
By taking into account the results of the measurement of the airtightness of a building when calculating its energy performance, the test requester can achieve a more favourable level of primary energy consumption (E or E_w level) compared to that achieved using the default value for the airtightness. In the determination method of the level of primary energy consumption (§ 7.8.3 of the method for residential buildings (PER [in French] or EPW [in Dutch] [means "Energy performance for residential buildings", i.e. the unit of dwelling to which the EPB-regulations apply]) and § 5.5.3 of the method for offices and educational buildings (PEN [in French] or EPU [in Dutch] [means "Energy performance for non-residential buildings", i.e. the unit with a non residential destination to which the EPB-regulations apply])) the E or E_w level depends on the infiltration and exfiltration rates, calculated on the basis of the air leakage rate at 50 Pa, per unit of envelope area, $\dot{v}_{50,heat}$, indicated hereafter as $\dot{v}_{50}$ and expressed in (m³/h)/m². This specific air leakage rate, $\dot{v}_{50}$ (lower-case v), is determined based on the air leakage rate at 50 Pa of the exterior envelope, $\dot{V}_{50}$ (upper-case V) in m³/h, measured by the measurement operator in accordance with the NBN EN 13829:2001 standard and respecting the specifications provided in this document.

2. Measurement conditions

2.1 Extent of the measured zone

Requirements
The measured zone must be defined by the test requester, in conformity with the subdivision of the building carried out within the context of the EPB-regulations. The measured zone must cover at least the whole PER or PEN volume taken into consideration and cannot cover

spaces located outside of the protected volume (PV) [i.e. the volume within the insulated fabric] such as unheated adjacent spaces (UAS).
The measured zone must be described in a clear and precise way in the test report by the measurement operator. The building plans (plans[4] of the floors and sections) clearly indicating the limits of the measured extent can be annexed to the report.

Recommendations
In most cases, the airtightness test can be undertaken on the entire protected volume (PV). The measured extent can thus include several PER or PEN volumes.

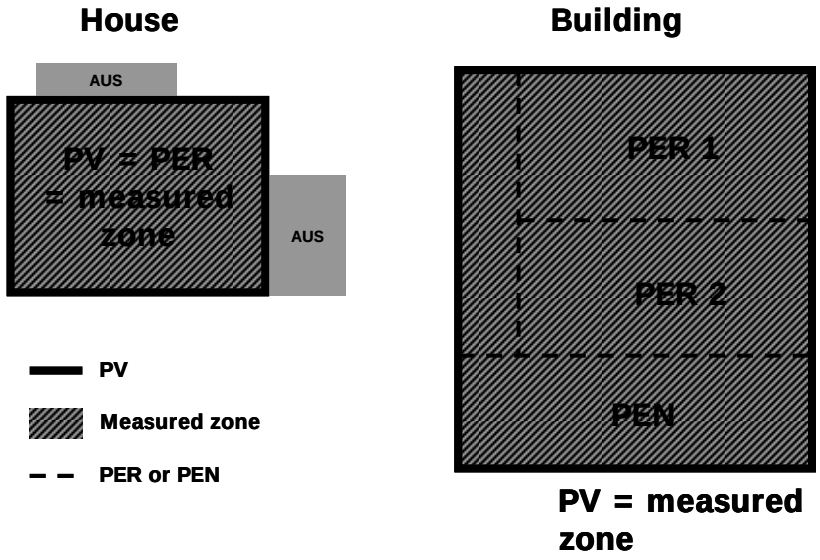

Figure 1 : Outline of the measured zone (hatched zone) corresponding to the protected volume (PV, solid line), for the cases of an individual dwelling and of a multi-unit building (AUS = adjacent unheated space).

In certain cases, however, the measurement can be carried out only on a part of the protected volume, but always at least on the PER or PEN volume considered (for example, an individual apartment; Figure 2).

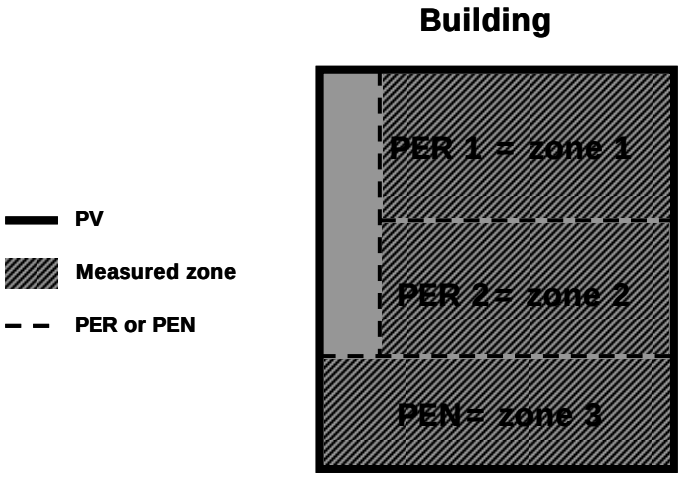

Figure 2 : Outline of the measured zone (hatched zone) corresponding to an individual PER or PEN volume

[4] This can refer to plans that have been simplified and/or reduced in scale to make them easier to annex to the test report.

Exception
In the unusual case where the PER or PEN volume is composed of several separate parts without openings (which can be opened without a tool) between each other, but each with openings towards outside, the measurement must be done for each of these parts individually. The total air leakage rate, $\dot{V}_{50}$, of this PER or PEN volume is thus the sum of the total air leakage rates measured for each part individually. Finally, A_{test} (see annex A), must be determined based on the limits of this PER or PEN volume.

2.2 Time of the measurement and the building status

Requirement (reminder of the standard)
The test cannot be undertaken before the envelope has been completely closed: installation of all windows and doors that delimit the measured zone.

Recommendations
As far as they can possibly affect the airtightness barrier, it is recommended that the following works be completed before the measurement is undertaken:

- heating,
- ventilation,
- sanitary facilities,
- electricity,
- finishing of walls (wall coating – plaster, etc. -, plates, panelling, etc),
- painting, carpeting.

3. Method and materials

3.1 Choice of the method

Requirement
Within the context of the EPB-regulations, the airtightness testing of the building must be carried out using the Method A defined in the NBN EN 13829:2001 standard.

3.2 Choice of the equipment

Requirement
The requirements regarding the pressurising equipment and the measurement instruments are detailed in the NBN EN 13829:2001 standard, § 4.

In addition to the standard, it is necessary that the manometers used allow the measurement of the pressure differences with an accuracy of 2 Pa in the range of the test measurement.

Recommendation

It is recommended that the measurement equipment be regularly calibrated, following the instructions provided by the manufacturer[5]. Calibration at least once every two years seems reasonable for most measurement instruments.

4. Building preparation

4.1 Heating, ventilation and other equipment

Requirement
With the exception of the systems that could be used in the airtightness measurement, all the systems that take in or expel air outside of the measured zone must be stopped before the measurement. At the minimum, this includes the following systems:

- Mechanical ventilation and air conditioning,
- Air heating,
- Appliance with open combustion (unsealed): boilers, water heaters, stoves or other,
- Kitchen hoods that expel air to the outside,
- Dryers that expel air to the outside.

4.2 Intentional openings

Requirements
Within this document:

- "To seal" means: to make hermetic by any appropriate means (adhesive, inflatable balloon, stopper, etc) ;
- "To close" means: to use the closing device present on the considered opening without additionally increasing the airtightness of the opening when in the closed position.

General rule for the openings in the envelope of the measured zone
Intentional openings in the envelope of the measured zones must be closed. These openings cannot be sealed. In the absence of a closing device, no action must be taken to increase the airtightness of the opening. The openings that could not have any closing device are for example: some air outlet (tumble-dryer, kitchen hood, etc), some chimneys (open fireplace, open combustion appliances, etc.), laundry chute, openings for vacuum cleaner, etc.
The openings must be closed in such a way as to remain closed during the whole measurement. In certain cases, intentional openings must be kept closed using an adequate additional device. The device used to keep an opening closed can be, for example, a small piece of adhesive tape, a mechanical device (a wedge, a weight, etc.) but cannot in any case be used in such a way as to increase the airtightness of the opening when in the closed position.

The openings that may need to be kept closed this way include, for example, cat-flaps, letter slots, etc.

[5] It is recommended to contact a calibration laboratory that satisfies the requirements of the NBN EN ISO/IEC 17025 standard. For information, a list of calibration laboratories accredited for Belgium can be found on the website www.belac.be.

The automatic functioning of certain adjustable supply or extract air terminal devices [for natural ventilation only; according to the terminology defined in EN 12792:2003; "supply air terminal device" is also sometimes called "trickle ventilator"], such as demand control by presence detectors, CO_2 sensors, etc, must also be deactivated so that these openings remain closed during the whole measurement.

Mechanical ventilation systems

The standard requires the sealing of all air terminal devices of mechanical ventilation systems or air conditioners. Alternatively, and as a departure from the standard, it is allowed to seal these systems at the level of their ducts as closely as possible to the place where these ducts cross the envelope of the measured zone (or the airtightness barrier). In practice, this means:

- - to seal all the individual air terminal devices (1 on Figure 3), or
- - to seal the main ducts, between the fan and the envelope of the measured zone (2 on Figure 3) whatever the position of the fan (inside or outside of the measured zone), or
- - to seal the openings to the outside, air intakes and evacuations (3 on Figure 3).

A practical way to seal the ducts or air terminal devices is to remove the air terminal devices and to seal the aeraulic duct using an inflatable balloon. The sealing must be reversible without damage to the duct.

The place where the ducts are sealed and the means used to do so must be mentioned in the test report.

If there is a fan in the extraction duct of a ventilation system of type A or B (see § 4.3.1.3, Remarque 3 of the Belgian standard NBN D 50-001:1991), this fan is always considered as a natural exhaust opening and not a mechanical one. According to the rules here above, such ducts can thus not be sealed, but their adjustable extract air terminal devices must be closed.

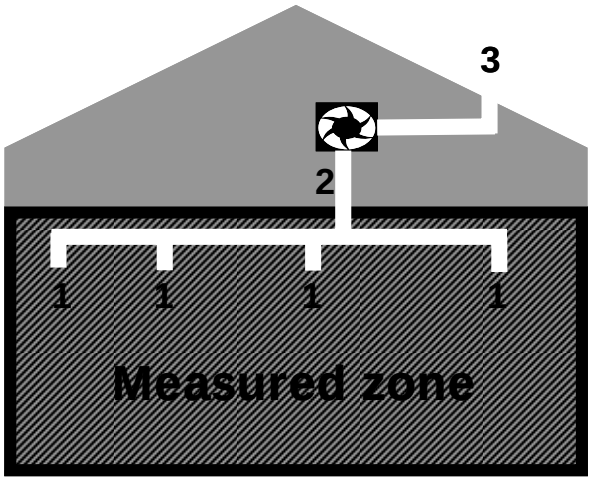

Figure 3 : Position of the sealing of the ventilation ducts (for a fan outside of the protected volume): at the level of individual air terminal devices (1) between the fan and the envelope of the measured zone (2), and at the level of the air intake and evacuation (3).

Waiting or unfinished openings

Intentional openings that are being worked on, or that are waiting for the installation of a device (combustion appliance, kitchen hood, tumble-dryer, solar heating systems, etc.) cannot be temporarily sealed for the measurement.

However, if these openings are not used in the normal in use conditions of the building, they may be sealed in an appropriate and durable manner[6]. The appropriate and durable sealing of these unused openings is not the responsibility of the measurement operator. He can however require the removal of any sealing device that he judges to be unjustified, inappropriate and/or not durable. Openings for devices that have not been installed, and for which sealing is not usually justified, include for example:

- An evacuation opening for a kitchen hood,
- An evacuation opening for a tumble-dryer,
- A chimney or air supply opening for a combustion device if the building is not yet equipped with heating ,
- An opening for a device that has already been delivered,
- etc.

Fireguards

The NBN EN 13829:2001 standard (§5.2.2) stipulates closing, among others, the fireguards in the envelope of the measured zone. In the context of the EPB-regulations, this requirement must be understood as follows:

- fireguards that are usually closed and that open automatically in case of fire, to evacuate smoke for example (type C), must indeed remain closed during the measurement ;
- however, fireguards that are normally open and that close automatically in case of fire (types A and B) cannot be closed during the measurement.

Openings in spaces adjacent to the measured zone

In the spaces (heated or unheated) outside of the measured zone (for example a greenhouse, a veranda, a garage, etc., that are not part of the measured zone), any doors, windows and adjustable ventilation grills that might be present in the exterior envelope may be closed but cannot be sealed.

Openings inside the measured zone

The NBN EN 13829:2001 standard (§5.2.2) stipulates, among others, the requirements concerning the connecting doors inside the measured zone. In the context of the EPB-regulation, the following additional specifications apply. Excluding cupboard and toilet doors, all doors, trapdoors and openings in the interior of the measured zone must remain open, if they can be opened without a tool, so that the whole of the measured zone reacts to the pressure in a homogeneous way. The term cupboard covers only cabinets or built-in cupboards. The openings that must therefore remain open are, for example:

- interior doors,
- trapdoors leading to technical locations inside the measured zone,
- trapdoors to service shafts that are part of the measured zone,

[6]For example, to be considered as appropriate and durable, the sealing device of an unused metallic chimney without a rain cap must still allow the evacuation of any rain or snow entering the chimney.

- boxroom doors,
- trapdoors to an attic or basement that is part of the measured zone.

For practical and safety reasons, it is allowed to keep some doors closed (for example, the access doors to elevators or to high-voltage cabins.

If a space that is part of the measured zone does not have any openings (that can be opened without tools) to the rest of the measured zone, it must be the object of a separate measurement (see § 2.1, Measured Zone).

If a space has openings (that can be opened without a tool) neither to the rest of the measured extent nor to the outside, no supplementary action needs to be taken.

Synthesis table

Table 1 provides an overall picture of the requirements for a certain number of current situations.

Table 1: Treatment of intentional openings.

Components	Status	Examples
Openings inside the measured zone		
o **Cupboard** and **toilet** doors	**Closed**	
o Other openings	**Opened**	o Door, trapdoor or opening within the measured zone which can be opened without a tool
Openings in the envelope of the measured zone		
o **Mechanical** ventilation opening	**Sealed**	o Inside air terminal devices or ducts or outside air terminal devices (1, 2 or 3, see Figure 3)
o Other openings **with** closing device	**Closed (1)**	o Exterior doors and windows o Door and trapdoor to a space outside of the measured zone: to a cellar, garage, an attic, a crawl space o Adjustable supply or extract air terminal device [for natural ventilation only] o Letter slot, cat-flap o Evacuation of used water (2) o Air outlet with closing device for tumble-dryer, kitchen hood (3) o Chimney with closing device (open fireplace, boiler, stove, etc.) (3) (4)
o Other openings **without** closing device	**Open**	o Unsealable air inlet for an open combustion appliance, etc. o Aeration of waste water discharges o Lock, openings for the belts of the shutters o Other air outlets and chimneys without closing device (3) (4) o Etc.

(1) By using the closing device(s) present on the opening, but no sealing. (2) Filling of the siphon = closing.
(3) If there is no closing device on the opening itself but an apparatus is connected to the opening, it is allowed to close the apparatus (example: valve of a kitchen hood, door of a dryer, door of a stove, etc.).
(4) All the combustion appliances concerned must imperatively be stopped before any intervention. Note that it is not necessary to take sealing measures for appliances with tight combustion circuits.

5. Measurement procedure

5.1 Installation of equipment

Requirements
In the case of pressurisation equipment that is fitted onto an exterior opening (door or window), an opening that is safely accessible and that presents a priori the highest airtightness will be chosen for the equipment placement. As a general rule, the measurement operator will choose, in order of preference:

1. a French window ("window-door") or a window with a sealing joint along its entire perimeter
2. a door equipped with a sealing device on its lower part (fitted or brush plinth, for example)
3. a door that is not equipped with a sealing device on its lower part.

The positioning of the equipment must be specified in the test report.

Recommendations
It is necessary to make sure of the sealing between the pressurisation equipment and the building. Adhesive tape can be used if necessary to guarantee the sealing along the edge of the equipment.

5.2 Measuring the air leakage rate

Requirements
It is required to conduct two series of measurements, one using pressurisation and the other using depressurisation.

For all types of buildings, the highest pressure difference reached must be at least 50 Pa (in absolute value).

Recommendation (reminder of the standard)
It is recommended to undertake measurements up to a pressure difference of 100 Pa (in absolute value), as specified in the standard.

6. Calculation of the air leakage rate $\dot{V}_{50}$

Requirements (reminder of the standard)
In conformity with the NBN EN 13829:2001 standard, the air leakage rate ($\dot{V}_{50}$) must be calculated separately for the pressurisation measurements (written here $\dot{V}_{50,pres}$) and for the depressurisation measurements (written $\dot{V}_{50,depres}$).
In conformity with § 6.3.1 of the standard, the final result for the air leakage rate is the average of the air leakage rates determined with pressurisation and depressurisation, calculated as follows :

$$\dot{V}_{50} = \frac{\dot{V}_{50,depres} + \dot{V}_{50,pres}}{2} \qquad (m^3/h)$$

Recommendation
The following simplifications can be used in the intermediate calculations[7] :

$$\left(\frac{\rho_i}{\rho_e}\right) = \left(\frac{T_e}{T_i}\right) \qquad \left(\frac{\rho_e}{\rho_i}\right) = \left(\frac{T_i}{T_e}\right)$$

$$\left(\frac{\rho_e}{\rho_0}\right) \approx \left(\frac{T_0}{T_e}\right) \qquad \left(\frac{\rho_i}{\rho_0}\right) \approx \left(\frac{T_0}{T_i}\right)$$

where T_e and T_i (in K) are the temperatures measured, respectively, in the exterior and in the interior; and where T_0 is the temperature under normal conditions (293.15 K).

7. Check-list for the test report

Requirements
In the context of the EPB-regulations, the test report on the airtightness of a building must contain the following information:

The following notification:
"The airtightness measurement complies with all the requirements in the context of EPB-regulation, as described in the Specification document, version x of dd mm yyyy".
The correct values of the version number (x) and the date (dd mm yyyy) must be mentioned.

Data on the measurement company:

- Company name, address and VAT number (if relevant),
- Date of the measurement,
- Name and signature of the manager of the test (measurements, calculations and report), and date of the signature ;

Data on the requester:

- Name, address

Data on the building and the measured zone:

- Complete address;
- Clear, precise and unequivocal description of the measured zone, possibly complemented with an outline on the plans ;
- Status (on or off) of the heating, ventilation and other apparatuses;
- Status (whether closed or unsealed) of the intentional openings in the envelope;
- Positioning of the sealing of the ventilation ducts.

Data on the test:

[7] As proposed in "International Organization for Standardization, ISO 9972:2006, Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method. Geneva, ISO, 2006."

- Brand, type and installation place of the pressurisation equipment and the measurement devices;
- Concerning the measurement devices: date of the last calibration and name of the institution that has carried out this calibration;
- Description of the type of opening in which the pressurisation equipment used for the measurement was placed (for example, 'French door', 'door with sealing on the sides and fitted plinth on the bottom' or 'door without sealing, without sealing devices on the bottom and with a letter slot equipped with a flap') ;
- Inside and outside temperatures;
- Details of the zero-flow pressure differences measured before and after the test, and average zero-flow pressure difference used in the calculations ;
- Data on the leakage rate/pressure pairs[8] for pressurisation and depressurisation ;
- Justifications if the highest pressure reached is below 100 Pa (in absolute value) ;
- Log/log graph presenting the data and the regression straight lines for pressurisation and depressurisation;
- Results of the intermediate calculations for both pressurisation and depressurisation : coefficient C_{env} and exponent n obtained by regression, corrected coefficient C_L et $\dot{V}_{50}$;
- Average air leakage rate, $\dot{V}_{50}$;
- At present, an error analysis is not necessary.

Optional information

Given that the determination method of the EPB-regulations only refers to the NBN EN 13829:2001 standard for measuring the air leakage of the exterior envelope at 50 Pa ($\dot{V}_{50}$), the other calculations are optional in a measurement report that is used as a justification for the calculation of the E or E_w level. The following points of the standard are concerned:

- Internal volume according to § 6.1.1 of the standard ;
- Net floor area according to § 6.1.3 ;
- Air change rate n_{50} at 50 Pa according to § 6.3.1.

However, if these parameters are mentioned in the test report, they must come with the calculation conventions used to determine them (internal or external dimensions, taking into account or not of the volume of the internal walls, etc.).

8. References

Institut belge de normalisation, NBN EN 13829, Performance thermique des bâtiments. Détermination de la perméabilité à l'air des bâtiments. Méthode de pressurisation par ventilateur. Bruxelles, IBN, 2001.

[European Committee for Standardization. 2000. EN 13829:2000 Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method (ISO 9972:1996, modified).]

[8] Air flow rates through the building envelope ($\dot{V}_{env}$) and induced pressure differences (Δp), see § 6.2 of NBN EN 13829:2001.

9. History of the document versions

- v1: October 20, 2008
- v2: 12 June 2009

9.1 Modifications from v2 to v1

- § 7: mention of a standardised declaration in the test report

10. Synthesis of the additional specifications (requirements and recommendations)

The table below includes only the additional specifications addressed in the present document; the basic requirements for measuring the air leakage rate, $\dot{V}_{50}$, can be found in the NBN EN 13829:2001 standard.

	Requirements	**Recommendations**
Measured zone (§2.1)	PER or PEN ≤ measured zone ≤ PV	Either measured zone = total PV or measured zone = individual PER or PEN
Time of measurement (§2.2)	Envelope finished	All works completed
Choice of method (§3.1)	Method A	
Equipment (§3.2)	Measurement of pressure with an accuracy of 2 Pa	Regular calibration
Heating, ventilation and other apparatuses (§ 4.1)	Stop all apparatuses that take in air from or evacuate air to outside	
Intentional openings	If closing device available: close and keep closed Mechanical ventilation openings : seal Adjacent spaces: close the openings	
Installation of equipment (§5.1)	In the best sealed opening (safely accessible)	Seal the joint between the equipment and the building envelope
Measurement of leakage rate (§5.2)	2 series : pressurisation and depressurisation Highest pressure difference of at least 50 Pa (in absolute value)	Highest pressure difference of 100 Pa (in absolute value)
Calculation of result (§6.1)	$\dot{V}_{50}$ is the average of the leakage rate for pressurisation and depressurisation	

Annexe A: Use of the result in the EPB-regulations

A.1 Envelope test area

The envelope test area, A_{test} (m²), does not necessarily have to be mentioned in the measurement report, but is necessary, in the context of the EPB-regulations, to calculate the air leakage rate by unit of the envelope area, $\dot{v}_{50}$ ((m³/h)/m²), on the basis of the air leakage rate at 50 Pa, $\dot{V}_{50}$ (m³/h), determined by measurement.

The value A_{test} must be determined according to the definition given in the EPB-regulations. To determine A_{test}, it is necessary to use the same conventions used to determine the loss surface area in the calculation of the level E or E_w:

- If the measured zone corresponds to a protected volume, the value of A_{test} must be equal to the value A_T of the K-level volume (calculation of K-level) ;
- If the measured zone corresponds to a PER or PEN volume considered in the EPB-regulations, A_{test} must be equal to $A_{T,E,PER\ or\ PEN}$;
- In the other cases, A_{test} must be calculated on the basis of the limits of the measured zone and according to the conventions used for the calculation of the E or E_w level.

Remark: this envelope test area is different from the envelope area (A_E) defined in § 6.1.2 of the NBN EN 13829:2001, on the basis of the internal dimensions of the whole envelope.

If the value of A_{test} is available, it can be mentioned in the test report by the measurement operator, specifying the source (architect, building owner, etc).

A.2 Calculation of the specific air leakage rate $\dot{v}_{50}$

The air leakage rate per unit of envelope area is calculated on the basis of the average air leakage rate and the envelope test area:

$$\dot{v}_{50} = \frac{\dot{V}_{50}}{A_{test}} \qquad ((m^3/h)/m^2)$$

If the value of $\dot{v}_{50}$ is available, it can be mentioned in the test report by the measurement operator. In this case, the value of A_{test} must also be mentioned.

Annex B: Justifications on the Additional specifications on building airtightness measurement within the context of EPB-regulations [in Belgium]

Version 1

20 October 2008

Contents

1. Foreword

The hereabove document sets out the requirements to be fulfilled for the building airtightness measurement within the context of the EPB-regulations (additional specifications to the NBN EN 13829:2001 standard).
The goal of the present document is to justify and explain these additional specifications, in parallel with the hereabove document.

2. Measurement conditions

2.1 Extent of the measured zone

The measured zone must cover at the minimum the whole PER or PEN volume taken into consideration, and at the maximum the protected volume.
When the PER or PEN volume under consideration covers the whole building, the measured zone is simply this PER or PEN volume.
In the other cases, the following justifications must be considered:

1) If the building contains one or more PER or PEN volumes and also one or more adjacent unheated spaces:

   The NBN EN 13829:2001 standard specifies: 'normally, the part of the building measured includes all deliberately conditioned rooms'. This refers to heated (and/or cooled) spaces included within the protected volume as defined in the EPB-regulations. Spaces outside of the protected volume cannot be part of the measured zone. From an energy point of view, these spaces adjacent to the protected volume will have a buffer effect on the losses by infiltration/exfiltration. This is the case in particular with greenhouses, verandas, garages, cellars or attics that are outside of the protected volume.
   It should be noted that the air leakage rate measured in these conditions is generally lower than those measured with the adjacent spaces included in the measured zone, because the equilibrium pressure in these spaces during measurement will be intermediate between that of the measured zone and that of the outside. The airtightness of the walls between these spaces and the exterior is not taken into consideration in the EPB-regulation.

2) If the building is made up of several PER and/or PEN volumes (for example, an apartment building) :

   The NBN EN 13829:2001 standard specifies: 'Individual parts of a building can be measured separately'. Within the context of the EPB-regulation, it refers at the minimum to an individual PER or PEN volume when several of these volumes are part of the same protected volume. In the EPB-regulation, it is considered (§ 5.2 of the PER annex and § 3.2 of the PEN annex) that no heat flow occurs through the common partition walls between adjacent heated spaces. The air leakage rate towards these adjacent spaces that are part of the protected volume should therefore not be taken into account in the calculation of the losses due to infiltration/exfiltration. However, it is allowed, for practical reasons, to carry out a measurement on an individual PER or PEN volume.
   It should be noted that the specific air leakage rate measured in these conditions will generally be higher than the one measured on the whole protected volume, because it also includes an air leakage rate towards the adjacent spaces.

There is an exception to these rules in the situation where the PER or PEN volume is made up of several separate parts and there are no openings between these parts. In this case, the PER or PEN volume cannot react to the pressurisation as a single and homogenous zone. Consequently, a measurement must be carried out in each individual part. To take into account the airtightness of each of these parts, the total air leakage rate of the PER or PEN volume must be calculated based on the sum of the rates obtained in each individual part.

Finally, the measured zone must be clearly described in the test report in such a way that makes it possible to calculate the areas and volumes.

2.2 Time of the measurement and building status

Even after the building envelope has been completed, some subsequent works can improve the airtightness, or, alternatively, damage the airtightness barrier and cause additional leakages.

The internal finishing of the walls constitutes an essential element of the airtightness barrier. Moreover, certain finishing works can damage the airtightness barrier (boring through a sealing film or wall coating –plaster, etc.-). The other works mentioned (heating, ventilation, sanitary facilities and electricity) generally require boring through internal or external walls and can thus damage the airtightness barrier, that is constituted by the wall finishing (plaster, etc.) or a plastic film, for example.
However, in practice it is difficult to require that all these works be completed before the measurement. This is consequently only a recommendation.

3. Method and materials

3.1 Choice of the method

The NBN EN 13829:2001 standard defines two measurement methods as a function of the purpose of the airtightness test.

Method A measures the airtightness of a building under real conditions. The NBN EN 13829:2001 standard mentions: 'The conditions of the building envelope should represent its condition during the season in which heating or cooling systems are used'. With this method, the intentional openings with a closing device must be closed (doors, windows, adjustable ventilation openings).
Method B measures the airtightness of the building envelope. The NBN EN 13829:2001 standard mentions: 'Any intentional openings in the building envelope shall be closed or sealed'.

The objective with Method A is to measure the air leakage rate that contributes to the infiltration/exfiltration flow under real conditions, and it is therefore used to measure the airtightness from an energy point of view.

The objective of Method B is to measure the air leakage rate that flows only through the building envelope and not through the intentional openings in the envelope; it is thus used specifically for evaluating the quality of the envelope finishing.

Within the context of the EPB-regulation, the airtightness measurements aim to quantify energy losses due to infiltrations/exfiltrations. Only the energy losses due to hygienic ventilation are already calculated elsewhere in the EPB-regulation. It is thus appropriate that only the intentional openings dedicated to the hygienic ventilation be closed to carry out the

measurement. The air leakage rate caused by all the other openings, whether intentional or not, must be taken into account when measuring the airtightness; and Method A is thus applicable. These other openings or leaks that contribute to the loss due to infiltration/exfiltration and that must be taken into account are, for example:

- Unclosable ventilation openings (within the meaning of the NBN D50-001 standard, in other words: that do not have a closing device) for an open combustion appliance ; a hood or a tumble-dryer, for example,
- chimneys,
- leaks through the envelope,
- leaks through the intentional openings when they are closed (these openings can therefore not be sealed),
- etc.

It should be noted that Method A is therefore more severe than Method B: an air leakage rate measured using Method A will always be higher or equal to an air leakage rate measured using Method B.

Example:

Building I: good airtightness of the envelope, only presence of mechanical ventilation ducts (system D). Result from Method A = Result from Method B = 3 $(m^3/h)/m^2$.

Building II: excellent airtightness of the envelope, but presence of many intentional openings in addition to the mechanical ventilation ducts (an open-fireplace chimney, a cat-flap, a letter slot in the door, an unclosable air intake opening for an open combustion appliance, etc). Result from Method A = 14 $(m^3/h)/m^2$ >> Result from Method B = 1 $(m^3/h)/m^2$.

It is clear that Building II presents greater losses from infiltration/exfiltration compared to Building I. From an energy point of view, Building I is more efficient than Building II, this is quantified by Method A, but not by Method B.

3.2 Choice of the equipment

It is clear that the calibration of the measurement instruments is essential for ensuring the accuracy of the measurement results. It is thus recommended to calibrate the measurement instruments regularly.

According to the practices of the consulted professionals, a two year period between calibrations seems reasonable.

4. Preparation of the building

4.1 Heating, ventilation and other equipment

There are no comments for this point.

4.2 Intentional openings

Taking into account the justifications given in § 3.1, the intentional openings must be treated in accordance with Method A.

In regard to mechanical ventilation openings, it is allowed, as a departure from the standard, to seal the main ducts between the fan and the envelope of the measured zone. The sealing of each air terminal device required by the standard presents several disadvantages:

- The possible air leakage rate through the duct walls will contribute to the measured air leakage rate (Dorer et al.);
- The time necessary to seal every air terminal device individually is perhaps longer than that for sealing the main duct at the level of the fan.

In practice, the possibility to disconnect the main ducts at the level of the fan for maintenance should normally be provided. It should thus be feasible to seal these main ducts between the fan and the envelope of the measured zone.

Concerning to the other intentional openings, they must be closed and kept closed, without being made airtight. Actually, the air leakage rate through the openings in the closed position contributes to the losses by infiltration/exfiltration.

Intentional openings that are being worked on or that are waiting to be connected to an apparatus cannot be sealed. It is not possible to know at the time of measurement:

- If the airtightness of the opening will be better after the finishing or the connection (for example of a kitchen hood or an unsealed combustion appliance) ;
- When the finishing or connection of this opening will take place.

However, some openings that are present during the construction are not used during the normal use of the building, and can be sealed in an adequate and durable manner (independently of the measurement). As examples:

- An air intake opening for a boiler that was initially foreseen and then became unnecessary because a sealed combustion appliance was installed ;
- A chimney that is not connected to an apparatus or an open fireplace, and that is not or no longer used.

The issue is thus to allow appropriate and durable sealing of these unused openings, while avoiding the abusive sealing of openings that will be used under normal conditions. This is why it is required that the sealing of an unused opening be appropriate and durable. Furthermore, it is the responsibility of the measurement operator to check that there has been no abusive sealing.

Regarding the fireguards within the envelope of the measured zone, which the standard stipulates must be closed, it is nevertheless necessary to leave open the type A and B fireguards, which are normally open and which close automatically in case of fire. Indeed, these fireguards are open during the normal use of the building and thus contribute to the ex/infiltrations.

5. Measurement procedure

5.1 Installation of equipment

The use of pressurisation equipment that is fitted on an exterior opening (door or window) does not allow the measurement of the air leakage rate caused by that particular opening. It is

thus recommended to place the pressurisation equipment in the most airtight opening possible, giving priority to a French door or a window that is equipped with a sealing joint all around its perimeter.
This type of French door or window may include hooks along its perimeter that require particular care to ensure the airtightness between the ventilation equipment and the building envelope.

5.2 Measuring the air leakage rate

The air leakage rates measured with pressurisation or with depressurisation can be different. The amplitude of this difference can vary from one building to another. Losses due to infiltration as well as exfiltration must be quantified when considering the measurement of the air leakage rate. To ensure that the results are representative for infiltration as well as for exfiltration, and to guarantee equity of the requirements for all the buildings, it is required to carryout two measurements, one with pressurisation and one with depressurisation.

In regard to the highest pressure that can be reached, the requirements of the present document are more stringent than those of the NBN EN 13829:2001 standard. Indeed, the precision of a regression straight line is maximal in the middle of the measurement range, and decreases significantly as one moves away from that point or when the line is extrapolated away from the measurement range. To be precise enough, the air leakage rate should thus be determined on a sufficiently large range of measurements, above and below 50 Pa; for example from 0 Pa up to 100 Pa (in absolute value).

Requiring a pressure of 50 Pa for all the buildings seems to be a good compromise, to avoid in all cases the extrapolations outside of the measurement ranges. A pressure of 100 Pa should be reachable in most of the cases. It cannot however be required, in particular for large buildings or buildings that have important leaks. For these buildings, there exist, however, very powerful fans that produce a high flow, that makes it possible to reach 100 Pa in most of the cases. For example, this pressure has been reached in a building larger than 700,000 m³ (Sharples et al.).
As a reminder, the standard requires a minimum 50 Pa and recommends 100 Pa for buildings smaller than 4000 m³. It recommends 50 Pa and requires 25 Pa for other buildings.

6. Calculation of the air leakage rate $\dot{V}_{50}$

The average of the flow measured with pressurisation and with depressurisation makes it possible to take into account the infiltrations as well as the exfiltrations.
It should be noted that only the calculation of $\dot{V}_{50}$ is required. The calculation of A_{test} and of $\dot{v}_{50}$ is not required by the NBN EN 13829:2001 standard, but is necessary within the context of the EPB-regulation if one wants to prove a better airtightness.
A_{test} depends on the limits of the measured zone, the conventions used in the EPB-regulation and the intended use of the spaces adjacent to the measured zone. Its determination is thus the responsibility of the test requester or of his representative, not of the measurement operator.

7. Check-list for the test report

It is required that the description of the measured zone be clear, precise and unequivocal, among other things so that it is possible to (re)calculate the A_{test} surface subsequently.

The other requirements for the measurement report make it possible to check that the procedure was followed while respecting the procedure and the calculation method of the NBN EN 13829:2001 standard and the additional EPB-specifications.

The value n_{50} is necessary in the NBN EN 13829:2001 standard. This value is often used to compare the measurements between buildings, especially at the international level. This value is not required, however, within the context of the EPB-regulations in order to avoid imposing the calculation of the internal volume, which can take quite a bit of time and results in an additional cost.

8. Check-list for the test order form

Different choices in the procedure to measure the building airtightness influence directly the test results: the choice of Method A or B, the treatment of intentional openings, the delimitation of the measured zone, etc.
Good communication between the test requester and the measurement operator is thus essential. Within the context of the EPB-regulation, the following information must usually be transmitted by the test requester to the measurement operator:

- Objective of the test: the measurement of the air leakage rate in the context of the EPB-regulations;
- Description of the measured zone, consistent with the EPB-declaration. This zone is at the minimum the PER or PEN volume taken into consideration and at the maximum the protected volume of the building.

9. References

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