Measurement of Building Airtightness in the EPB Context:

Specific Procedure and Sources of Uncertainties

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1. INTRODUCTION

Building airtightness is a crucial aspect towards a higher energy performance of buildings (EPB). In the scope of the EPB regulation in Belgium, which is based on as-built proof after construction (already applicable in Flanders since the beginning of 2006, and taking effect in Wallonia and Brussels in the course of 2009), 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 (less favourable) default value.

In the absence of airtightness measurements (not obligatory), a default value of 12 $m^3/h.m^2$ at 50 Pa is taken into account in the EPB calculation method. Thanks to a good result of airtightness, a reduction of the E-level (level of primary energy consumption) between 5 and 15 points (present requirement: the total E-level should not exceed 100) can be achieved. It is thus necessary to assure that the same procedure is used by everyone and that the uncertainties on the result are limited.

2. SPECIFIC PROCEDURE IN THE EPB CONTEXT

The EN 13829:2000, based on ISO 9972:1996, describes a standardised procedure for airtightness measurement with several variants (e.g. method, A or B), which should be specified in the EPB context. At the request of the 3 Regions (in charge of EPB implementation in Belgium), additional specifications to the standard were developed in the scope of the EPB regulation [2].

To our knowledge, at present only the United Kingdom has developed in an official way additional requirements for the measurement procedure in the context of their EPB regulations. Most of the European countries have no official additional requirements to the standard (Finland, Italy, Portugal, Spain). In other countries some documents exist as a recommendation or for obtaining a label (Germany, France, Poland, Norway, Denmark) but these documents are not available in English and only partial information is available from them.

The additional specifications developed in the scope of the EPB regulation in Belgium and the information available in these European countries are summarised in table 1 and discussed in more detail in the paragraphs below.

2.1 Method choice and treatment of openings

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

- Method A applies for the airtightness measurement 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 applies for measurement of the airtightness of the building envelope. In this case, any intentional opening in the building envelope is closed or sealed.

In the Belgian EPB scope, given that the aim is the assessment of energy losses due to in/exfiltrations, the method A is more relevant and must be used. Only the energy losses due to hygienic ventilation are already calculated elsewhere in the EPB. The openings involved in this hygienic ventilation must then 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 opened grilles, chimneys, leaks in the envelope, leaks of the ventilation openings in the closed position, etc.

In other European countries, it seems that little attention is paid to the method used and the B method is in use in some countries. In France, the Effinergie label follows a strategy similar to the one proposed in Belgium, sealing only the openings already taken into account in ventilation flow rate. The use of the B method in Norway is perhaps related to the large scale use of the balanced ventilation systems without any other ventilation openings; in this case the method A and B should give the same result in most of the cases.

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

Country	Meth	Openings	Meas. Volume	Press (Pa)	P+/P-	Ref
Belgium	A	Closing: all openings with a closing device Sealing: mechanical ventilation ducts	Building or flats	50	P+ and P-	[2]
France (1)		Sealing: all openings	Building or flats	70	P-	[3]
France (2)	A	Not closing : open combustion devices Closing : other openings with a closing device Sealing : - combustion devices type VMC (4) - mechanical ventilation openings			P+ and/or P-	[4]
Germany (1)	A?	(list available in German in ref [5])				[5]
Norway (1)	B	Closing: all openings which can be closed in ordinary ways	Building or flats	100	P+ and P-	[6]
Poland (2)	B			100	P+ and P-	[7]
UK (3)	B	Closing : passive ventilation systems Sealing : - permanently open natural ventilation openings - mechanical ventilation openings - doors to building parts outside the measured volume	Building or flats	50	P+ and/or P-	[8]

(1) Guideline; (2) Criteria for a label; (3) Regulation; (4) If the additional flow is taken into account in the EPB calculation, as part of ventilation flow rate.

2.2 Measured volume

In Belgium, the measured volume must be defined in accordance with the subdivision of the building in the scope 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 dwelling or the unit with a non residential destination). Moreover, the measured volume cannot cover more than the "protected volume" (= volume within the insulated fabric) of the building. For apartment buildings this means that the measurement can be carried out on each apartment individually or on the whole building at once, as is also the case in most of the studied European countries.

2.3 Air leakage rate measurement

The EN 13829:2000 recommends carrying out two sets of measurements, for 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 then required in the framework of the

EPB regulation to always carry out both sets of measurements. This seems not to be the case in the studied European countries where only one measurement set is required.

The requirement for the highest pressure difference to achieve is also stricter in the proposed EPB document in Belgium compared to the standard: a requirement of 50 Pa for all buildings and recommendation of 100 Pa, while the standard requires 50 Pa for buildings smaller than 4000 m³ and only 25 Pa for larger buildings. A sufficiently large range of pressures below and above 50 Pa is however necessary to assure a significant result at 50 Pa. At European level, the use of at least 50 Pa seems to be the practice, and it seems that a pressure of 100 Pa is required in Norway and Poland.

2.4 Other requirements

Finally, other specifications are proposed in the Belgian EPB context, in addition to the standard as follows. 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. For 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 airtightness gasket at the bottom.

3. SOURCES AND ESTIMATION OF THE UNCERTAINTIES

The main sources of uncertainties for airtightness are summarised in Figure 1 for the whole process of the test from pressure and flow measurement to calculation of derived quantities such as n_{50} or v_{50} (the specific leakage flow rate per envelope surface area, as used in the EPB in Belgium). These main sources or error and their propagation are discussed in the paragraphs below.

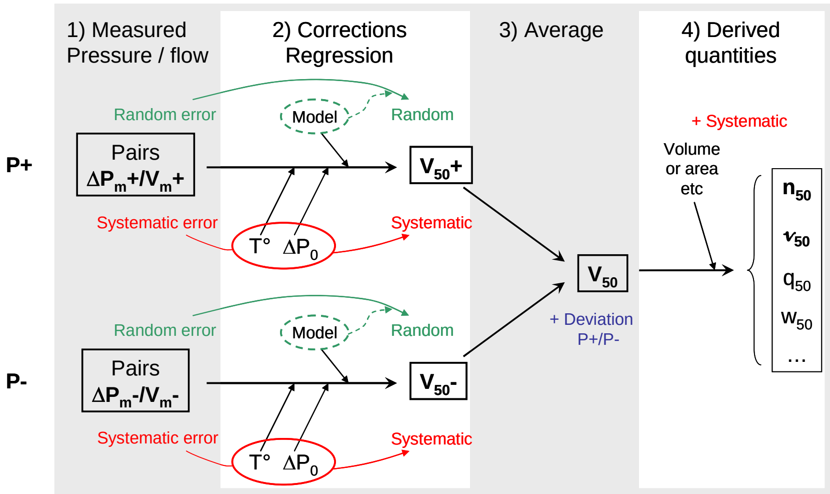

Fig. 1. Main sources and propagation of errors in the airtightness test.

3.1 Systematic error of V_{50}+ and V_{50}-

The systematic error of a measurement (accuracy) is due to a systematic bias between the measured value and the "true" value. It is highly important to note that the systematic error is not directly accessible because the "true" value is a priori not known.

Systematic errors are due possibly to bad calibration of the measurement instruments and possibly to the experimental conditions, especially the wind and the temperature difference between inside and outside, which are at least partially corrected (see § 6.2 of the standard). The first correction concerns the density of the air depending on temperature (T° in Figure 1). The second correction concerns the pressure difference across the envelope for zero flow rate (ΔP_0 in Figure 1). Additional systematic error for the measured pressure can be due to the variation of the pressure along the building envelope (wind or temperature) and the inhomogeneous leak repartition over this building envelope. In contrast, wind and temperature do not involve significant systematic error for the measured flow rate [9].

The propagated systematic error on V50+ and V50- can be limited by:

- assuring proper calibration of the measurement instruments;
- avoiding to carry out the test when the wind speed or the temperature difference are too high;
- taking care of the measurement of the pressure difference at zero flow rate;
- taking care of the calculations (especially the sign of the pressure in P+ and P-).

3.2 Random error of V_{50}+ and V_{50}-

The random error (precision) of a measurement is due to the random variability of the experimental conditions, of the instrument and the amount of data. In contrast to the systematic error, the random error can be easily estimated using statistical tools if several experimental data are available.

Several pairs of measured pressure and flow are used in the linear regression (log/log) to estimate V_{50}+ and V_{50}-. If it is assumed that the error introduced by the model is negligible [10] (fulfillment of the equation $V = C(\Delta P)^n$ and roughly the same exponent, n, for all leaks), the random error estimated from the regression is directly related to the random error of the experimental measurements. The procedure recommended in annex C of the standard was used to estimate the random error on V+ and V_{50}- on a sample of about 20 different buildings. Shortly, a confidence interval (95%) is calculated for the air leakage rate, based on statistical analysis of the regression data. This random error is presented in Figure 2, expressed in relative value (%). The average random error for all the samples is around 2%.

First, the random error seems to slightly increase with the total flow rate through the building envelope (Figure 2A). At higher flow rate, the equilibrium is probably less stable due to the large amount of air transferred through the whole building. Moreover, in certain conditions, the fan is not able to achieve a sufficiently high pressure, as it is the case for the worst result of the graph (triangle) for which the highest pressure achieved was less than 40 Pa. Second, the wind and temperature conditions seemed to have limited effect on the random error in the tested conditions (Figure 2B and C). Nevertheless, high variation of the wind in speed or direction should affect the random error.

To limit the random error, it is recommended to:

- increase the number of measurement points, especially in variable wind conditions;
- assure that the measured volume is as homogeneous as possible, especially with a high flow rate.

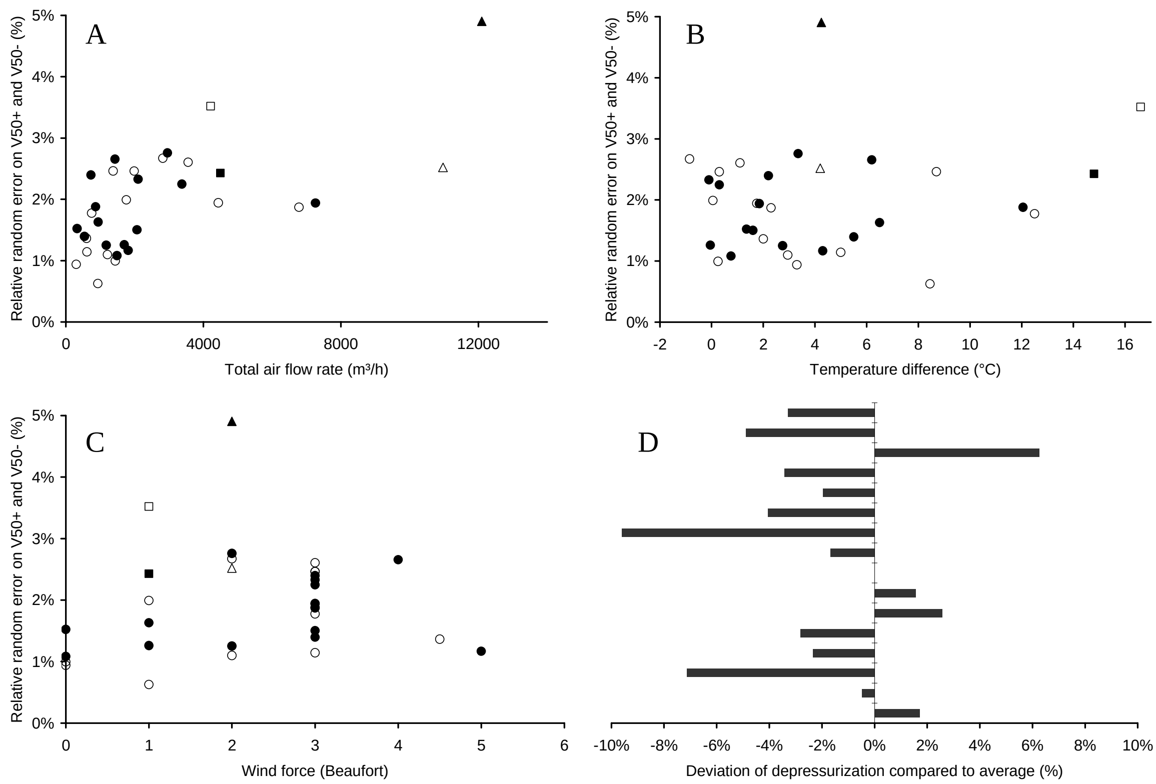

Fig. 2. Evolution of the random error of air leakage rate with the total flow rate (A), the temperature difference (indoor – outdoor) (B) and the wind force (C). Deviation between pressurization and depressurization (D).

3.3 Deviation between pressurization and depressurization

When two sets of measurements in pressurisation (P+) and depressuriszation (P-) are carried out, as required in the Belgian EPB context, the average between both results is used to calculate the derived quantities such as n_{50} and v_{50}. However, the deviation between these both results is often not negligible and can vary largely from one building or one test to another.

The deviation (%) between the air leakage rate in P- and the average between P- and P+ is shown in Figure 2D for the same sample of tests used in § 3.2. Compared to the 2 % for the average random error in this sample, the deviation between P+ and P- is higher than 2% for most of the tested buildings, and reached even much higher than 10% (not shown in the figure) in certain buildings.

This deviation can be partly due to the physical difference between the two sets of measurements. Some leaks are probably asymmetric, such as leaks in the form of valves, such as the exhaust vents of certain kitchen hoods. It is thus recommended to always mention both results in the test reports.

3.4 Errors from volume or area calculations

The last step of the process of the airtightness test is the calculation of the derived quantities, such as n_{50} and v_{50}, based on the average air leakage rate and on the volume or envelope area of the building. The error on the volume or area can be highly significant in some cases and depends at least on:

- conventions used for calculations: internal or external dimensions, volume of partitions and floors included or not, volume of window openings taken into account or not, etc;
- reliability of the data: from the drawings, measured on drawing or measured on site;

The influence of such error was estimated for a very simple case, as following: rectangular building of 12 m in length, 8 m in width and 5 m in height. A systematic error of 10 cm on each of these values implies an error of 4% on the volume and 3% on the area. Moreover, the use of external or internal dimensions can lead to an error as high as 25% on the volume and 16% on the envelope area (for a wall thickness of 0.3 m). It is thus highly recommended to pay attention to the volume and/or area calculation and to mention the conventions used for the calculation in the test report.

4. CONCLUSION

The procedure for the building airtightness measurement is closely related to the objective of the test. In the scope of the energy performance of building, additional specifications to the EN 13829:2000 have been proposed in the framework of the Belgian EPB regulation.

Besides a standardised procedure, the limitation of uncertainties is highly relevant for the quantification of building airtightness.

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