BRITISH STANDARD

BS EN 13829:2001

Thermal performance of buildings — Determination of air permeability of buildings — Fan pressurization method

The European Standard EN 13829:2000 has the status of a British Standard

ICS 91.120.10

National foreword

This British Standard is the official English language version of EN 13829:2000. The European Standard EN 13829:2000 is based on ISO 9972:1976.

The UK participation in its preparation was entrusted by Technical Committee RHE/9, Thermal insulating materials, to Subcommittee RHE/9/2, Thermal properties of insulating materials, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 21 and a back cover.

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This British Standard, having been prepared under the direction of the Engineering Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 January 2001

ISBN 0 580 36935 8

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 13829

November 2000

ICS 91.120.10

English version

Thermal performance of buildings — Determination of air permeability of buildings — Fan pressurization method (ISO 9972:1996, modified)

Performance thermique des bâtiments — Détermination de la perméabilité à l'air des bâtiments — Méthode de pressurisation par ventilateur (ISO 9972:1996, modifiée)

Wärmetechnisches Verhalten von Gebäuden — Bestimmung der Luftdurchlässigkeit von Gebäuden — Differenzdruckverfahren (ISO 9972:1996, modifiziert)

This European Standard was approved by CEN on 18 October 2000.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. EN 13829:2000 E

Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 89, Thermal performance of buildings and building components, the Secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2001, and conflicting national standards shall be withdrawn at the latest by May 2001.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

This document modifies prEN ISO 9972:1996, Thermal insulation — Determination of building airtightness — Fan pressurization method, which failed the Unique Acceptance Procedure (UAP).

This standard is one of a series of standards for the assessment of the thermal performance of buildings and building components.

Annexes A, B, C and D of this European Standard are for information only.

This standard includes a bibliography.

Introduction

The fan pressurization method is intended to characterize the air permeability of the building envelope or parts thereof. It can be used:

a) to measure the air permeability of a building or part thereof for compliance with a design airtightness specification;
b) to compare the relative air permeability of several similar buildings or parts of buildings;
c) to identify the leakage sources; and
d) to determine the air leakage reduction resulting from individual retrofit measures applied incrementally to an existing building or part of building.

This method does not measure the air infiltration rate of a building. The results of the fan pressurization test can be used to estimate the air infiltration by means of calculation. Other methods are applicable when it is desired to obtain a direct measurement of the air infiltration rate. It is better to use the fan pressurization method for diagnostic purposes and measure the actual infiltration rate with tracer gas methods. A single tracer gas measurement will give limited information on the performance of ventilation and infiltration of buildings.

This method applies to measurements of air flow through the construction from outside to inside or vice versa. It does not apply to air flow measurements from outside, through the construction, and back to outside.

The proper use of this standard requires a knowledge of the principles of air flow and pressure measurements. Ideal conditions for the test described in this standard are small temperature differences and low wind speeds. For tests conducted in the field, it needs to be recognized that field conditions may be less than ideal. Nevertheless, strong winds and large indoor-outdoor temperature differences should be avoided.

1 Scope

This standard is intended for the measurement of the air permeability of buildings or parts of buildings in the field. It specifies the use of mechanical pressurization or depressurization of a building or part of a building. It describes the measurement of the resulting air flow rates over a range of indoor-outdoor static pressure differences.

This standard is intended for the measurement of the air leakage of building envelopes of single-zone buildings. For the purpose of this standard, many multi-zone buildings can be treated as single-zone buildings by opening interior doors or by inducing equal pressures in adjacent zones.

It does not address evaluation of air permeability through individual components.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN ISO 7345, *Thermal Insulation — Physical quantities and definitions (ISO 7345:1987)*

3 Terms and definitions

For the purposes of this standard, the terms and definitions in accordance with EN ISO 7345 and as indicated in the following apply.

3.1
air leakage rate
air flow rate across the building envelope

> NOTE: This movement includes flow through joints, cracks and porous surfaces, or a combination thereof, induced by the air-moving equipment used in this standard (see clause 4).

3.2
internal volume
deliberately heated, cooled or mechanically ventilated space within a building or part of a building subject to the measurement, generally not including the attic space, basement space and attached structures

3.3
building envelope
boundary or barrier separating the internal volume subject to the test from the outside environment or another part of the building

3.4
air change rate at reference pressure
air leakage rate per internal volume at the test reference pressure differential across the building envelope

> NOTE: Usually 50 Pa.

3.5
air permeability
air leakage rate per envelope area at the test reference pressure differential across the building envelope

> NOTE: Usually 50 Pa.

3.6
specific leakage rate
air leakage rate per net floor area at the test reference pressure differential across the building envelope

> NOTE: A pressure difference of 50 Pa is the most common.

3.7 Symbols and units

Symbol	Quantity	Unit
$\dot{V}_{\mathrm{r}}$	readings of air flow rate	m^3/h
$\dot{V}_{\mathrm{m}}$	measured air flow rate	m^3/h
$\dot{V}_{\mathrm{env}}$	air flow rate through the building envelope	m^3/h
$\dot{V}_{\mathrm{L}}$	air leakage rate	m^3/h
$\dot{V}_{\mathrm{pr}}$	air leakage rate at a specified reference pressure difference	m^3/h
$\dot{V}_{50}$	air leakage rate at 50 Pa	m^3/h
Q	tracer gas injection rate	m^3/h
C_{env}	air flow coefficient	m^3/(h·Pa^n)
C_{L}	air leakage coefficient	m^3/(h·Pa^n)
P	air density	kg/m^3
φ	relative humidity	-
θ	temperature	°C
n	air flow exponent	-
p	pressure	Pa
p_{bar}	uncorrected barometric pressure	Pa
p_{v}	partial vapour pressure of water	Pa
p_{vs}	saturation vapour pressure of water	Pa
Δp	induced pressure difference	Pa
Δp_{m}	measured pressure difference	Pa
Δp_0	zero flow pressure difference (average)	Pa
$\Delta p_{0,1}$; $\Delta p_{0,2}$	zero-flow pressure difference before and after the test (air moving equipment closed)	Pa
Δp_{r}	reference pressure	Pa
A_{E}	envelope area	m^2
A_{F}	floor area	m^2
V	internal volume	m^3
n_{50}	air change rate at 50 Pa	h^{-1}
Q_{50}	air permeability at 50 Pa	m^3/(h·m^2)
w_{50}	specific leakage rate at 50 Pa	m^3/(h·m^2)

4 Apparatus

4.1 General

The following description of apparatus is general in nature. Any arrangement of equipment using the same principles and capable of performing the test procedure within the allowable tolerances is permitted. Examples of equipment configurations commonly used are indicated in annex A.

Periodic calibration of the measurement system used in this test method according to manufacturer specifications or to standardized quality insurance systems is required.

4.2 Equipment

4.2.1 Air-moving equipment

Device that is capable of inducing a specific range of positive and negative pressure differences across the building envelope or part thereof. The system shall provide constant air flow at each pressure difference for the period required to obtain readings of air flow rate.

In large buildings, the heating, ventilating and air conditioning systems can be used.

4.2.2 Pressure-measuring device

Instrument capable of measuring pressure differences with an accuracy of ±2 Pa in the range of 0 Pa to 60 Pa.

4.2.3 Air flow rate measuring system

Device to measure air flow rate within ±7 % of the reading.

Care shall be taken if the principle underlying the measurement of volumetric flow rate is an orifice. The reading of the air flow rate shall be corrected according to air density (see manufacturers specifications).

4.2.4 Temperature-measuring device

Instrument to measure temperature to an accuracy of ±1 K.

5 Measurement procedure

5.1 Measurement conditions

5.1.1 General

The accuracy of this measurement procedure is largely dependent on the instrumentation and apparatus used and on the ambient conditions under which the data are taken.

5.1.2 Measured extent

The extent of the building or part of the building measured is defined as follows.

1) Normally the part of the building measured includes all deliberately conditioned rooms.

2) In special cases the extent of the part of the building actually to be tested can be defined in agreement with the client.

3) If the aim of the measurement is compliance with the airtightness specification of a building code or standard and the measured extent is not defined in this code or by a standard, the measured extent is defined as in 1).

Individual parts of a building can be measured separately; e.g. in apartment buildings each apartment can be measured individually. However, interpretation of results shall consider that air leakage measured in this way may include flow through leaks to adjacent parts of the building.

> NOTE 1: It is possible that an apartment building meets airtightness requirements but one or more individual apartments do not.
>
> NOTE 2: Good practice would require measuring pressures induced in adjoining spaces such as the attic and basement or adjacent apartments, since air flow into or out of these spaces may be induced by the test method.

5.1.3 Time of measurement

The measurement can only take place after the envelope of the building or part of the building to be tested has been completed.

> NOTE: A preliminary air permeability measurement of the air barrier may allow leakages to be repaired more easily than when the building is completed.

5.1.4 Meteorological conditions

If the product of the indoor/outdoor air temperature difference, in K, multiplied by the height of the building envelope, in m, gives a result greater than 500 m·K, it is unlikely that a satisfactory zero flow pressure difference will be obtained (see 5.3.3).

If the meteorological wind speed exceeds 6 m/s or reaches 3 on the Beaufort scale it is unlikely that a satisfactory zero flow pressure difference will be obtained (see 5.3.3).

5.2 Preparation

5.2.1 General

This standard describes two types of test method depending on the purpose. Both types need different preparation of the building:

Method A (test of a building in use):

The condition of the building envelope should represent its condition during the season in which heating or cooling systems are used.

Method B (test of the building envelope):

Any intentional opening in the building envelope shall be closed or sealed as specified in 5.2.2 and 5.2.3.

5.2.2 Building components

Close all intentional exterior openings of the building or part of the building to be tested (windows, doors, fireguard).

For the purpose of method A (building in use) do not take any further measures to improve the airtightness.

For the purpose of method B (building envelope) all adjustable openings shall be closed and remaining intentional openings shall be sealed.

The entire building or part of the building to be tested shall be configured to respond to pressurization as a single zone:

All interconnecting doors (except for cupboards and closets, which should be closed) in part of the building to be tested shall be opened so that a uniform pressure is maintained within a range of less than 10 % of the measured inside/outside pressure difference.

> NOTE: When testing large or complex buildings this condition becomes increasingly important and can be verified by selected differential pressure measurements between different rooms at the highest pressure contemplated.

Make general observations of the condition of the building. Take notes on the windows, doors, opaque walls, roof and floor, position of adjustable openings and any sealings applied to intentional openings.

5.2.3 Heating, ventilation and air conditioning systems

Heating systems with indoor air intake shall be turned off. Open fire places shall be cleared of ashes. Mechanical ventilation and air conditioning systems shall be turned off.

Air terminal devices of mechanical ventilation or air conditioning systems shall be sealed. Other ventilation openings (for example openings for natural ventilation) shall be closed for purposes of method A and sealed for method B.

Take measures to avoid exhaust hazards from heating systems. Take into account heating sources in adjacent apartments.

If there is an intention to estimate the infiltration/exfiltration air change rate according to EN 832 (see bibliography), natural system openings are kept open for the purpose of the pressurization test or their contribution is calculated.

5.2.4 Air-moving equipment

Connect the air-moving equipment to the building envelope using a window, door, or vent opening. Ensure that the joints between the equipment and the building are sealed to eliminate any leakage.

If the building heating, ventilation and air conditioning system is used as the air moving equipment, arrange the fans and dampers to allow the system to pressurize or to depressurize the building in a manner such that the total inward or outward air flow rate can be measured (see A.4).

> NOTE: In an airtight building, it is possible for the door, window or vent used to pass air during the test to produce the most leakage. One should be careful in such a case with regard to the selection of the position of the air-moving equipment and/or the interpretation of the test results.

5.2.5 Pressure measuring devices

The indoor/outdoor pressure difference is usually measured at the lowest floor level of the building envelope under consideration.

> NOTE: In tall buildings it is good practice to measure the pressure difference at the top floor level of the building envelope under consideration as well.

Ensure that interior and exterior pressure drops are not influenced by the air moving equipment. The exterior pressure tap should be protected from the effects of dynamic pressure, e.g. by fitting a T-pipe or connecting it to a perforated box. Especially in windy conditions, it is good practice to place the exterior pressure tap some distance away from the building but not close to other obstacles.

The pressure tubes should not be aligned vertically. It shall be avoided that the tubing is exposed to large temperature differences (e.g. due to the sun).

5.3 Steps of the procedure

5.3.1 Preliminary check

Always check the complete building envelope at approximately the highest pressure difference used in the test for large leaks and failings of temporarily sealed openings. If such leaks are detected take detailed notes.

Any temporary sealings found missing or deficient, e.g. of heating, ventilation and air conditioning components, shall be fixed at this time.

Check that water traps in plumbing systems are correctly filled or sealed.

5.3.2 Temperature and wind conditions

To correct the air flow rate measurement for air density (see annex B), read the temperature inside and outside the building before, during or after the test.

Record the wind speed or force. Determining wind force by visual assessment of trees, water etc., as for the Beaufort scale (see Table D.1), is sufficient.

5.3.3 Zero-flow pressure difference

Short-circuit the pressure measuring device and check or adjust the zero reading.

Connect the pressure measuring device to measure inside-outside pressure difference and temporarily cover the opening of the air moving equipment. Observe and record the average of the positive values of zero-flow pressure difference Δp_{01+} over a period of at least 30 s. Observe and record the average of the negative values of zero-flow pressure difference Δp_{01-} over a period of at least 30 s. If either of these average values of zero-flow pressure difference is greater than 5 Pa do not perform the test.

Observe and record the average of all values of zero-flow pressure difference Δp_{01} over a period of at least 30 s.

Repeat this process at the end of the test (to obtain Δp_{02+} , Δp_{02-} and Δp_{02}). If either the positive or negative zero-flow pressure difference reading after the test is greater than 5 Pa the test shall be declared not valid. If a test report is produced for such a test, this failure to meet required test conditions shall be stated in the test report.

5.3.4 Pressure difference sequence

Uncover and turn on the air-moving equipment.

The test is carried out by taking measurements of air flow rate and indoor-outdoor pressure difference over a range of applied pressure differences in increments of no more than 10 Pa. The minimum pressure difference shall be 10 Pa, or five times the zero-flow pressure difference (greater of positive and negative average), whichever is greater. The highest pressure difference being tested may depend upon the size of the building according to a) and b).

a) Single dwellings and other small buildings

The highest pressure difference shall be at least 50 Pa but it is recommended that readings are taken at pressure differences up to ±100 Pa for best accuracy of calculated results.

b) Large buildings (greater than a volume of approximately 4 000 m^3)

Wherever possible the highest pressure difference shall be the same as for single dwellings [see a)]. However, because of the large size of many non-domestic buildings and practical limitations on the capacity of portable air moving equipment used to test them it is often found that a pressure difference of 50 Pa is not achievable. In these cases, either additional air moving equipment should be employed (to increase total capacity) and/or the test may be carried out up to the highest pressure difference which can be achieved with the available air moving equipment. In such cases the test shall not be valid unless a pressure difference of 25 Pa can be achieved. Where the pressure difference is between 25 Pa and 50 Pa, this shall be clearly recorded in the test report with a statement that the requirements of this standard have not been fully met and an account of the reasons why.

It is recommended that two sets of measurements are made, for pressurization and depressurization. However, it is permitted to make only one set of measurements for either pressurization or depressurization and still comply with the requirements of this standard. For each test at least five approximately equally spaced data points between the highest and the lowest pressure differences shall be defined.

NOTE 1: It is more precise to take data at higher pressure differences than at lower differences. Therefore, special care should be exercised when measurements are taken at low pressure differences.

NOTE 2: It is advisable to check that the condition of the building envelope has not changed during each test, for example that sealed openings have not become unsealed or that doors, windows or dampers have not been forced open by the induced pressure.

6 Expression of results

6.1 Reference values

6.1.1 Internal volume

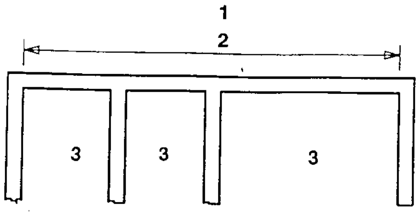
The internal volume, V, is the volume of air inside the measured building or part of building. The internal volume is calculated by multiplying the net floor area (see 6.1.3) with the mean net ceiling height. The volume of furniture is not subtracted.

6.1.2 Envelope area

The envelope area A_E of the building or measured part of the building is the total area of all floors, walls and ceilings bordering the internal volume subject to the test. This includes walls and floors below external ground level.

Overall internal dimensions shall be used to calculate this area. No subtractions shall be made for the area at junction of internal walls, floors and ceilings with exterior walls, floors and ceilings (see Figure 1).

NOTE: In the context of this standard the envelope area of a row house includes the division wall(s). The envelope area of an apartment in a multiple story building includes the floors, walls and ceilings to adjacent apartments.



Key
1 Outside
2 Overall size
3 Inside

Figure 1 — Envelope area

6.1.3 Net floor area

The net floor area A_F is the total floor area of all floors belonging to the internal volume subject to the test. It is calculated according to national regulations.

6.2 Calculation of the air leakage rate

Subtract the average zero-flow pressure difference (offset) from each of the measured pressure differences, Δp_m, to obtain the induced pressure differences, Δp, using equation (1). Attention shall be drawn to plus or minus signs.

$$\Delta p = \Delta p_{\mathrm{m}} - \frac{\Delta p_{0,1} + \Delta p_{0,2}}{2} \tag{1}$$

First convert the readings of the air flow rate measuring system, $\dot{V}_{\mathrm{r}}$, to the measured air flow rate, $\dot{V}_{\mathrm{m}}$, at the temperature and pressure at the flow measuring device in accordance with manufacturers specifications:

$$\dot{V}_{\mathrm{m}} = f\ (\dot{V}_{\mathrm{r}}) \tag{2}$$

Then convert the air flow rate, $\dot{V}_{\mathrm{m}}$, to air flow rate through the building envelope, $\dot{V}_{\mathrm{env}}$, for depressurization using equation (3).

$$\dot{V}_{\mathrm{env}} = \dot{V}_{\mathrm{m}} \left(\frac{\rho_{\mathrm{i}}}{\rho_{\mathrm{e}}} \right) \tag{3}$$

where:

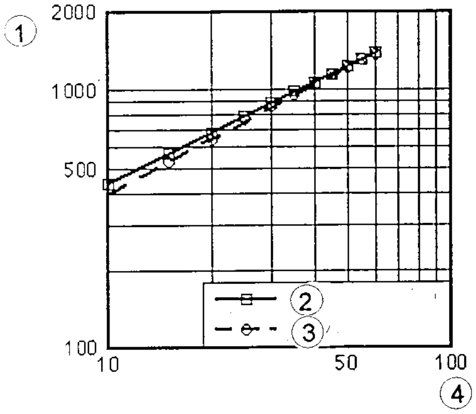
ρ_i is the internal air density, in kg/m^3;

ρ_e is the external air density, in kg/m^3.

Convert the measured air flow rate, $\dot{V}_{\mathrm{m}}$, to air flow rate through the building envelope, $\dot{V}_{\mathrm{env}}$, for pressurization using equation (4).

$$\dot{V}_{\mathrm{env}} = \dot{V}_{\mathrm{m}} \left(\frac{\rho_{\mathrm{e}}}{\rho_{\mathrm{i}}} \right) \tag{4}$$

Plot the air flow rate through the building envelope against the corresponding pressure differences on a log-log plot to complete the air leakage graph for both pressurization and depressurization (see Figure 2).



Key

1 Air flow rate, in m^3/h
2 Depressurization
3 Pressurization
4 Pressure difference, in Pa

Figure 2 — Example of an air leakage graph

The converted data shall be used to determine the air flow coefficient, C_{env} , and air flow exponent, n, in accordance with equation (5) using a least squares technique.

$$\dot{V}_{\text{env}} = C_{\text{env}} (\Delta p)^n \tag{5}$$

where:

$\dot{V}_{\text{env}}$ is the air flow rate through building envelope, in m^3/h;
Δp is the induced pressure difference, in Pa.

In determining the fit of equation (5), the confidence intervals of the derived air flow coefficient, C_{env} , and air flow exponent, n, should be calculated. C_{env} and n shall be calculated separately for pressurization and depressurization.

To get the air leakage coefficient, C_{L}, correct the air flow coefficient, C_{env} , to standard conditions [(20 ± 1) °C and 1,013 × 10^5 Pa] using equation (6) for depressurization.

$$\text{C}_{\text{L}} = C_{\text{env}} \left(\frac{\rho_{\text{e}}}{\rho_0} \right)^{1-n} \tag{6}$$

where:

ρ_{e} is the outdoor air density, in kg/m^3;
ρ_0 is the air density at standard conditions, in kg/m^3.

For pressurization use equation (7).

$$C_L = C_{env}\left(\frac{\rho_i}{\rho_0}\right)^{1-n} \tag{7}$$

where:

ρ_i is the indoor air density, in kg/m^3;
ρ_0 is the air density at standard conditions, in kg/m^3.

Annex B contains the appropriate tables and equations for the temperature, barometric pressure and relative humidity dependence of ρ. In general the effect of barometric pressure is negligible. If it is to be considered, use the uncorrected barometric pressure measured on site or the barometric pressure according to height above sea level. Relative humidity can be set to 0 (dry air).

The air leakage rate, $\dot{V}_L$, can be calculated using equation (8).

$$\dot{V}_L = C_L (\Delta p)^n \tag{8}$$

where:

C_L is the air leakage coefficient, in m^3/(h·Pa^n);
Δp is the induced pressure difference, in Pa;
n is the air flow exponent from equation (5).

6.3 Derived quantities

6.3.1 Air change rate at reference pressure difference

The air leakage rate at the reference pressure difference Δp_r, usually 50 Pa, $\dot{V}_{\Delta pr}$, is determined using equation (9).

$$\dot{V}_{\Delta p_r} = C_L (\Delta p_r)^n \tag{9}$$

e.g. $\dot{V}_{50} = C_L$ (50 Pa)^n

where:

C_L is the air leakage coefficient, in m^3/(h·Pa^n).

Derived values are calculated for the mean air leakage rate at 50 Pa for pressurization and depressurization test. The air change rate $n_{\Delta pr}$ at the pressure difference, e.g. 50 Pa, is calculated by dividing the mean air leakage rate at 50 Pa by the internal volume according to 6.1.1 using equation (10).

$$n_{\Delta p_r} = \frac{\dot{V}_{\Delta p_r}}{V} \tag{10}$$

e.g.

$$n_{50} = \frac{\dot{V}_{50}}{V}$$

6.3.2 Air permeability

The air permeability at 50 Pa, q_{50} , is calculated by division of the mean air leakage rate at 50 Pa by the envelope area according to 6.1.2 using equation (11).

$$q_{50} = \frac{\dot{V}_{50}}{A_E} \tag{11}$$

6.3.3 Specific leakage rate

The specific leakage rate, w_{50} , is calculated through division of the mean air leakage rate at 50 Pa by the net floor area according to 6.1.3 using equation (12).

$$w_{50} = \frac{\dot{V}_{50}}{A_F} \tag{12}$$

6.3.4 Air leakage rate at reference pressure difference

The air leakage rate at specified reference pressure difference, $\dot{V}_{\Delta pr}$, expressed in m³/h, is calculated using equation (9).

7 Test report

The report shall contain at least the following information:

a) all details necessary to identify the object tested: purpose of test (method A or B); post address and estimated date of construction of the building;

b) a reference to this standard and any deviation from it;

c) test object:
  - description of which parts of the building were subject to the test; apartment number;
  - net floor area and internal volume of space subject to the test and other required dimensions of the building;
  - documentation of calculations so that the stated results can be verified;
  - the status of all openings on the building envelope, latched, sealed, open, etc.;
  - detailed description of temporarily sealed openings, if any;
  - the type of heating, ventilating and air conditioning system;

d) apparatus and procedure:
  - equipment and technique employed;

e) test data:
  - zero-flow pressure differences $\Delta p_{0,1+}$, $\Delta p_{0,1-}$, $\Delta p_{0,2+}$, $\Delta p_{0,2-}$, $\Delta p_{0,1}$ and $\Delta p_{0,2}$ for pressurization and depressurization test;
  - inside and outside temperatures;
  - wind speed, barometric pressure if it is part of the calculation;
  - table of induced pressure differences and corresponding air flow rates;
  - air leakage graph (example: see Figure 2);
  - the air flow coefficient, C_{env} , the air flow exponent, n, and the air leakage coefficient, C_L , for both pressurization and depressurization tests determined by the method indicated in clauses 4, 5 and 6 along with their confidence limits;
  - air change rate, n_{50} , at 50 Pa, for pressurization and/or depressurization and mean value;
  - derived quantity according to national regulation;

f) date of test.

8 Accuracy

8.1 General

The overall accuracy of a pressurization test depends on many factors. For any derived quantity, an estimate of the confidence interval shall be included in the data analysis.

NOTE: Annex C describes a simplified procedure for estimating the uncertainty of the derived quantities of C and n. This uncertainty is not the uncertainty of the measurement.

8.2 Reference value

The accuracy of reference values can be estimated using error propagation calculation. Typically, the uncertainty will be between 5 % and 10 %.

8.3 Overall uncertainty

The overall uncertainty in the derived quantities described in 6.3.1, 6.3.2, 6.3.3 and 6.3.4 of a pressurization test done according to this standard, can be estimated using error propagation calculation. This calculation should include uncertainties of all quantities used for the final result.

NOTE: In calm conditions the overall uncertainty will be less than ±15 % in most cases. In windy conditions the overall uncertainty can reach ±40 %.

Annex A (informative)

Description of equipment used to pressurize buildings

A.1 General

There are several ways to pressurize the building envelope. The most common are indicated in A.2 to A.4.

A.2 Fan and duct system

An assembly including a fan, a duct and an air flow meter is connected to the building (see Figure A.1). The size of the air duct and the capacity of the fan are matched so that the linear flow velocity within the air duct falls within the range of measurement of the air flow meter.

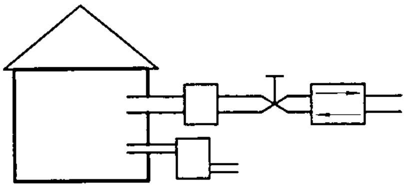


Figure A.1 — Schematic layout of equipment for whole building test

A.3 Blower door

A blower door assembly is an accepted device in many countries for performing envelope permeability measurements. The assembly includes a door mount for a fan or blower that is adjustable to fit common door openings. The fan or blower should possess a variable-speed motor to accommodate the range of required air flow rates.

A.4 Building heating, ventilation and air conditioning system fans

To determine the air permeability of large buildings, it may be possible to use the building ventilation system fans for pressurization and depressurization of the building. An initial site inspection is advisable to establish the number of main supply (or exhaust) fans, likely air flow performance, the possibility of operating the fans with either 100 % outside air or 100 % exhaust air, and the available means of controlling the supply (or exhaust) air flow rates (e.g. adjusting damper openings or adjusting fan speeds). The duct system can also be examined and suitable locations for air flow rate measurements selected.

Since it is often difficult to satisfy accepted criteria for air flow rate measurements in ducts in an actual building heating, ventilation and air conditioning system, the air flow rate, $\dot{V}$, can be determined by using a constant injection of tracer into the air stream entering or leaving the building. The air flow rate $\dot{V}$, expressed in m³/s, is determined using equation (A.1).

$$\dot{V} = \frac{q}{w_B} \tag{A.1}$$

where:

q is the tracer gas injection rate, in m³/s;

w_B is the tracer gas concentration, in m³/m³.

NOTE: Particular care is required where dampers and/or fan speeds are normally controlled automatically (e.g. by a building energy management system) to ensure that they can be operated independently as required for the test. Some heating, ventilation and air conditioning system interior grilles or openings may also have to be sealed in order to perform the test.

Annex B (informative)

Dependence of air density on temperature, dew point and barometric pressure

The air density, ρ, in kg/m^3, at a temperature, θ, in °C, barometric pressure, p_{bar} , in Pa, and the relative humidity, φ, in %, can be obtained by equation (B.1).

$$\rho = \frac{p_{\text{bar}} - 0{,}378\,02\ p_{\text{v}}}{287{,}055\ (\theta + 273{,}15)} \tag{B.1}$$

where:

p_{v} is the partial water vapour pressure in air calculated using equation (B.2).

$$p_{\text{v}} = \varphi\ p_{\text{vs}} \tag{B.2}$$

where:

p_{vs} is the saturation water vapour pressure in air at a temperature , θ , obtained using equation (B.3).

$$p_{\text{vs}} = \exp\ \{59{,}484\,085 - \left(\frac{6\,790{,}498\,5}{\theta + 273{,}15}\right)\ 5{,}028\,02\ \ln(\theta + 273{,}15)\} \tag{B.3}$$

Annex C (informative)

Recommended procedure for estimating errors in derived quantities

This standard contains several derived quantities which are often used to summarize the air permeability of the building or part of the building tested. The following method is recommended: all derived quantities depend on the estimation of the air leakage coefficient C and air flow exponent n of equations (5) to (7). Make logarithmic transformation of the variables and Δp for each reading to determine C and n.

$$x_i = \ln(\Delta p_\text{i})$$
$$y_i = \ln(V_\text{i}) \qquad \text{for } i = 1 \ldots N$$

where N is the total number of test readings. Equation (5) then transforms to equation (C.1).

$$y = \ln(C) + n\,x \tag{C.1}$$

Compute the following quantities:

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{C.2}$$

$$\overline{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \tag{C.3}$$

$$s_x^2 = \frac{1}{N-1}\sum_{i=1}^{N} (x_i - \overline{x})^2 \tag{C.4}$$

$$s_y^2 = \frac{1}{N-1}\sum_{i=1}^{N} (y_i - \overline{y})^2 \tag{C.5}$$

$$s_{xy} = \frac{1}{N-1}\sum_{i=1}^{\mathrm{N}} (x_i - \overline{x})(y_i - \overline{y}) \tag{C.6}$$

Then the best estimate of n, $\ln(C)$ and C are given by equations (C.7) to (C.9).

$$n = \frac{s_{xy}}{s_x^2} \tag{C.7}$$

$$\ln(C) = \overline{y} - n\,\overline{x} \tag{C.8}$$

$$C = \exp^{(\overline{y} - n\,\overline{x})} \tag{C.9}$$

An estimate of the confidence intervals of C and n can be determined as follows.

The standard deviation, s, of n is given by equation (C.10).

$$s_n = \frac{1}{s_x}\left(\frac{s_y^2 - n\, s_{xy}}{N - 2}\right)^{\frac{1}{2}} \tag{C.10}$$

and the estimate of the standard deviation of ln(C) is given by equation (C.11).

$$s_{\ln(C)} = s_n\left(\frac{\sum_{i=1}^{N} x_i^2}{N}\right)^{\frac{1}{2}} \tag{C.11}$$

If $T(P,N)$ is the confidence limit of the two-sided Student distribution for a probability P on N events, then half the length of the confidence intervals at that probability for ln(C) and n respectively is:

$$I_{\ln(C)} = s_{\ln(C)}\, T(P, N - 2) \tag{C.12}$$

$$I_n = s_n\, T(P, N - 2) \tag{C.13}$$

The values of the two-sided confidence limits $T(P, N)$ for a Student distribution are indicated in Table C.1.

This means that with a probability P the air flow exponent n lies in the confidence interval ($n - I_n$, $n + I_n$) and the air leakage coefficient C lies in the confidence interval

$$\left(C \exp\left[-I_{\ln(C)}\right], C \exp\left[I_{\ln(C)}\right]\right) \tag{C.14}$$

The estimate of the standard deviation around the regression line [equation (C.1)] at the value x is

$$s_y(x) = s_n\left\{\frac{N - 1}{N} s_x^2 + (x - \bar{x})^2\right\}^{\frac{1}{2}} \tag{C.15}$$

and half of the length of the confidence interval in the estimate of y using equation (C.1) at any x is

$$I_y(x) = s_y(x) T(P, N - 2) = I_y(\ln\Delta p) \tag{C.16}$$

Therefore, the air flow rate, $\dot{V}$, predicted by equation (5) at any pressure difference, Δp, lies in the confidence interval with a probability, P.

$$\left(\dot{V}\exp\left[-I_y \ln(\Delta p)\right], \dot{V}\exp\left[I_y \ln(\Delta p)\right]\right) \tag{C.17}$$

Table C.1 — Two-sided confidence limits *T*(*P*,*N*) for a Student distribution

N	***P***					
	0,8	**0,9**	**0,95**	**0,99**	**0,995**	**0,999**
1	3,078 0	6,313 8	12,706 0	63,657 0	127,320 0	636,619 0
2	1,886 0	2,920 0	4,302 7	9,924 8	14,089 0	31,598 0
3	1,638 0	2,353 4	3,182 5	5,840 9	7,453 3	12,924 0
4	1,533 0	2,131 8	2,776 4	4,604 1	5,597 6	8,610 0
5	1,476 0	2,015 0	2,570 6	4,032 1	4,773 3	6,869 0
6	1,440 0	1,943 0	2,446 9	3,707 4	4,317 0	5,959 0
7	1,415 0	1,894 6	2,364 6	3,499 5	4,029 3	5,408 0
8	1,397 0	1,859 5	2,306 0	3,355 4	3,832 5	5,041 0
9	1,383 0	1,833 1	2,262 2	3,249 8	3,689 7	4,781 0
10	1,372 0	1,812 5	2,228 1	3,169 3	3,581 4	4,578 7
∞	-	1,645 0	1,960 0	2,576 0	2,807 0	3,291 0

In practice, the above error analysis can be carried out using standard statistical computer programs.

Annex D (informative)

Beaufort scale for wind force indication

Table D.1 — Beaufort scale for wind force (extract)

Beaufort Number	**Name**	**Wind speed** m/s	**Description**
0	calm	less than 0,45	calm; smoke rises vertically
1	light air	0,45 to 1,34	direction of wind shown by smoke but not by wind vanes
2	light breeze	1,8 to 3,1	wind felt on face; leaves rustle; ordinary vane moved by wind
3	gentle breeze	3,6 to 5,4	leaves and small twigs in constant motion; wind extends light flag
4	moderate breeze	5,8 to 8	raises dust and loose paper; small branches are moved
5	fresh breeze	8,5 to 10,7	small trees in leaf begin to sway; crested wavelets form on inland waters
6	strong breeze	11,2 to 13,9	large branches in motion; telegraph wires whistle; umbrellas used with difficulty
7	moderate gale	14,3 to 17	whole trees in motion; inconvenience in walking against wind
8	fresh gale	17,4 to 20,6	breaks twigs off trees; generally impedes progress

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