Thermal performance of buildings — Air permeability of building components and building elements — Laboratory test method

The European Standard EN 12114:2000 has the status of a British Standard

ICS 91.120.10

National foreword

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The UK participation in its preparation was entrusted by Technical Committee B/540, Energy performance of materials, components and buildings, to SubcommitteeB/540/1, European Standards for thermal insulation, which has the responsibility to:

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Summary of pages

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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.

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Introduction

Air permeability is an important performance characteristic for many types of building envelopes. The general test method given in this standard sets out the main features (definitions, apparatus, test procedure, expression of results) for the laboratory testing of air permeability of building components and parts of building envelopes. Annex A (normative) gives test conditions (which may depend on the type and use of the tested products), to be followed unless product specifications specify otherwise.

Except where specific products have properties which make application of this standard difficult, this standard should be used as the reference by all harmonized product specifications.

1 Scope

This standard defines a general laboratory test method for determining the air permeability of building components or building elements, when subjected to positive or negative air pressure differences. It specifies the definitions, the test equipment and procedure, and provides directions for the interpretation of results.

Annexes give indications on test conditions and a method for expressing results using a regression technique.

This standard is not applicable to whole buildings or on site measurements.

2 Normative references

No other European or International Standards are referred to.

3 Definitions, symbols and units

3.1 Definitions

For the purposes of this standard, the following definitions apply:

3.1.1 pressure difference: Difference in static pressure across a specimen.

NOTE: The pressure difference is positive if the pressure on the external face is higher than the pressure on the internal face. It is negative if the pressure on the external face is lower than the pressure on the internal face.

3.1.2 air flow rate: Volume of air transferred to or from a system divided by time.

3.1.3 air permeability: Air flow rate, at reference conditions, as a function of the pressure difference.

3.1.4 leakage coefficients: Flow coefficient, *C*, and flow exponent, *n*, in the empirical leakage equation:

$$\dot{V} = C\,\Delta p^{n} \tag{1}$$

where Δp is the pressure difference.

3.1.5 flow coefficient: Air flow rate through the test specimen at a pressure difference of 1 Pa.

3.1.6 equivalent leakage area: Area of an ideal orifice having a discharge coefficient equal to 1 and the same leakage flow rate as the measured element at a conventional pressure difference.

3.1.7 overall area: Area calculated from the overall dimensions of the test specimen.

3.1.8 discharge coefficient: Ratio of air flow rate through an orifice to a theoretical air flow rate through the same orifice obtained with laminar flow of an incompressible fluid without viscosity.

3.1.9 reference conditions: Conventional air temperature, relative humidity and atmospheric pressure for calculation of air permeability.

3.2 Symbols and units

Symbol	Name of quantity	Unit
A	overall area	m^2
A_L	equivalent leakage area	m^2
C	flow coefficient	$m^3/(s\cdot Pa^n)$
T	thermodynamic temperature of air flow	K
T_0	reference temperature	K
$\dot{V}$	air flow rate	m^3/s, m^3/h
n	flow exponent	-
p	pressure	Pa
p_a	barometric pressure	Pa
p_0	reference barometric pressure	Pa
p_w	water vapour pressure	Pa
Δp	pressure difference	Pa
ϕ	relative humidity of air	-
ρ	density of air	kg/m^3
Subscripts		
L	leakage	
a	air, atmosphere	
w	water	
0	reference conditions (101325 Pa, 20 °C, 50 % RH)	

4 Principle

A set of pressure difference steps (positive and/or negative) is applied across the specimen and the air flow rate through the specimen is measured at each step. The measurement results are corrected to reference conditions. A graph of air flow rate versus pressure difference is drawn. When appropriate, the leakage coefficients characterizing the building component are derived from the measured results.

5 Apparatus

The test apparatus shall include the following (see figure 1):

a) a rig into which the test specimen can be fitted;

b) means of applying a controlled air pressure difference over the test specimen;

c) means of producing rapid changes of air pressure differences, controlled within defined limits;

d) an apparatus for measuring the air flow rate to an accuracy of ± 5 %, calibrated at reference conditions (20 °C, 101 325 Pa and 50 % RH);

e) a means for measuring the applied air pressure difference with an accuracy of ± 5 %.

f) means of sealing all joints of the test specimen (either with an adhesive tape or with an airtight sheet covering the whole of the test specimen).

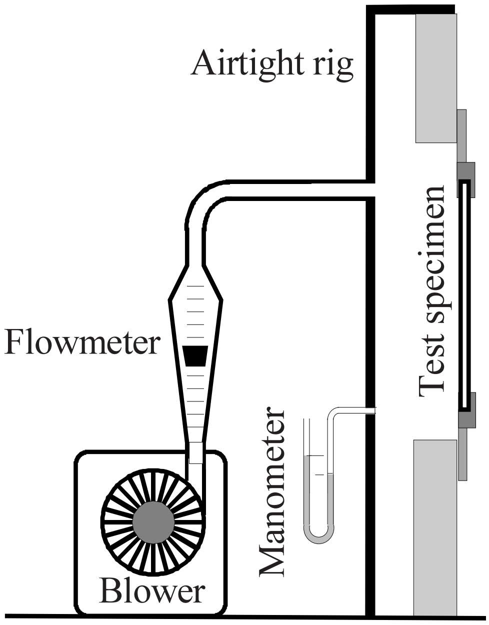

Figure 1: Example of apparatus

The air permeability of the test rig shall be determined at least once a year or whenever a test rig is disassembled, by replacing the test specimen by an airtight panel and by following the procedure described in clause 7 up to the maximum possible pressure difference and both for positive and negative pressure differences. The residual air flow rates shall be recorded for each pressure difference.

6 Preparation of test specimen

The test specimen shall be representative of the tested component. If the test specimen includes joints or other potential air leakage paths, ensure that their length or area are representative of conditions in use.

A surround for the test specimen shall be provided. It shall be able to withstand the pressures applied during the test without deflecting to an extent likely to influence the test results.

The test specimen shall be fixed plumb, level, square and without visible twists or bends induced by the fixings. Any transport blocks, bracings, packing or protective wrapping shall be removed. The test specimen shall be cleaned and surfaces dry. Any ventilation opening or device shall be either sealed, closed or left open, according to the purpose of the test.

7 Test procedure

7.1 Preliminaries

Measure the air temperature in the apparatus to an accuracy of ± 2 K, the barometric pressure to an accuracy of ± 1 kPa and relative humidity to an accuracy of ± 10 %. Ensure that these quantities remains constant within the ranges mentioned during the whole test.

The ambient temperature and humidity in the apparatus shall be within the range 15 °C to 30 °C and 25 % to 75 % RH. The specimen shall be conditioned at these ambient conditions before the test, for a time period sufficient to obtain thermal and moisture equilibrium within the specimen

Select the maximum pressure difference, Δp_{max}, according to the related product specification. When not available, use annex A.

7.2 Procedure

The test is performed with positive pressure differences and, if required, also with negative pressure differences.

The procedure is dependent on the air-tightness of the test rig itself. A test rig is considered airtight if its residual air flow rate is less than 5 % of the smallest flow rate to be measured.

> NOTE: For non-airtight test rigs, it is advisable to measure the residual air flow rates for negative pressure differences immediately after measuring the residual air flow rates for positive pressure differences.

7.2.1 Measurement of air permeability of specimen fitted in an airtight test rig

Three pressure pulses shall be applied. The duration of increase in pressure shall not be less than one second. Each pulse shall be maintained for at least three seconds. Each pulse shall produce a pressure difference 10 % to 12 % greater than the maximum pressure difference Δp_{max} for the test. Figure A.1 shows the variation of pressure differences with time.

Air pressure differences shall then be applied in several steps according to the related product specification. When not available, use annex A. The smallest pressure differential shall be such that it can be measured with a relative accuracy of 5 %.

The air flow rate and static pressure difference are measured and recorded at each step. The duration of each step shall be such that the air pressure in the test rig is stabilized before the air flow rate is measured.

7.2.2 Measurement of air permeability of specimen fitted in a non-airtight test rig

7.2.2.1 Residual air flow rate measurements

All joints of the test specimen shall be sealed, either with an adhesive tape or with an airtight sheet covering the whole of the test specimen.

The three pressure pulses as defined in 7.2.1 shall be applied on the sealed test specimen.

Measure and record the residual air flow rates according to 7.2.1.

7.2.2.2 Global air permeability measurement

The test specimen shall be unsealed.

Then the three pressure pulses as defined in 7.2.1 shall be applied.

Measure and record the global air flow rates according to 7.2.1.

NOTE 1: It is recommended to check again the residual air flow rate according to 7.2.2.1 after global air permeability measurements.

NOTE 2: The procedure described in 7.2.2 can also be used to measure, by difference, the air permeability of a part of a specimen. The other parts are sealed for that purpose.

8 Calculation and expression of results

8.1 Air flow rate readings

Obtain the air flow rate through the specimen as the difference between the global air flow rate and the residual air flows rate, if any. This applies at each pressure difference step.

For airtight rigs, an estimate of error on air flow rate is the sum of the error on air flow rate measurement and 5 % of the smallest air flow rate.

For non-airtight rigs, this estimate is the sum of the estimates of errors on global air flow rate and residual air flow rate.

8.2 Corrections for reference conditions

When atmospheric conditions in the apparatus and around the sample are not within the range:

18 to 22 °C air temperature,
100 000 to 102 000 Pa atmospheric pressure, or
25 to 50 % relative humidity,

the measured air flow rates shall be corrected as follows:

$$\dot{V}_0 = \dot{V}\sqrt{\left(\frac{\rho}{\rho_0}\right)} \qquad (2)$$

where:

$\dot{V}_0$ is the corrected air flow rate at reference conditions
$\dot{V}$ is the measured air flow rate at laboratory conditions
ρ_0 is the density of the air at reference conditions: $\rho_0 = 1{,}1988$ kg/m³
ρ is the density of the air at laboratory conditions, calculated by:

$$\rho = \frac{p_a - 0{,}378802\, p_w}{287{,}055\, T} \qquad (3)$$

where:
p_a is the atmospheric pressure, in pascal;
T is the absolute temperature, in kelvin;
p_w is the water vapour pressure, in pascal, calculated by:

$$p_W = 610{,}5\ \phi \exp\left(\frac{21{,}875 \cdot (T - 273{,}15)}{T - 7{,}65}\right) \qquad (4)$$

where ϕ is the relative humidity.

Uncertainties on these corrections are neglected in the error analysis.

8.3 Plotting of data

Plot the corrected air flow rate through the specimen against the corresponding pressure difference for both positive and, if appropriate, negative pressure differences.

NOTE: The relationship between air flow rate and pressure difference is normally not linear. The use of a log-log plot is recommended for general cases, where equation (1) is applicable.

8.4 Determination of leakage coefficients

When required by a product specification or by any other convention, determine the flow coefficient C and the exponent n, using an appropriate regression technique. C and n shall be calculated separately for positive and negative pressure differences.

NOTE: Annex B provides an appropriate regression technique.

8.5 Equivalent leakage area

When required by a product specification or by any other convention, the equivalent leakage area of each element is calculated from the leakage coefficients as follows, for a given, conventional pressure difference:

$$A_L = C\sqrt{\frac{\rho}{2}}\Delta p^{(n-0.5)} \quad (5)$$

This is the area of a sharp edge orifice having a discharge coefficient equal to 1 and the same leakage at pressure difference, Δp, as the measured element.

Unless otherwise specified in the test report, the conventional pressure difference is 10 Pa.

NOTE: For this pressure difference, A_L in m^2 is close to C expressed in $m^3/(s \cdot Pa)$.

The standard deviation of the equivalent leakage area is computed from the standard deviations of flow coefficient, s_C, and of exponent, s_n, by

$$s(A_L) = A_L\sqrt{\left(\frac{s_C}{C}\right)^2 + \left(s_n \ln|\Delta p|\right)^2} \quad (6)$$

9 Accuracy

Calculate the 95% confidence intervals for C and n and, if relevant, for A_L

NOTE 1: Annex B gives guidance for the calculation

NOTE 2: The expected measurement uncertainty of the flow coefficient is less than 8 %. This is based on the assumption of non-correlated uncertainties in $\dot{V}$ and Δp, both 5 % so that the uncertainty is $\sqrt{0{,}05^2 + (-0{,}05\,n)^2}$.

The maximum error, when $n = 1$, is $\sqrt{0{,}005} < 0{,}08$.

10 Test report

The test report shall include:

a) reference to this standard and, when appropriate, to the applied product specification;

b) a concise description of the test specimen, including at least the following information, checked before the tests:
   - manufacturer's name and specific product identification;
   - type of materials and, if applicable, their surface treatment;
   - width, height, overall area, and thickness when appropriate;
   - plans with details of the test specimen or the reference to documents which give this information; this plan shall show the position of the fixing devices and sealed parts, if any;
   - other information as appropriate;

c) description of the test conditions, including at least the following:
   - air temperature and relative humidity in the apparatus, and barometric air pressure;
   - conditioning of test specimen;
   - details of mounting the test specimen in its surround;
   - maximum and minimum pressure difference;
   - testing organization and date of test;

d) table of measured and corrected values with confidence intervals, and graph showing the air flow rate as a function of pressure difference both for positive and, if applicable, negative pressure differences;

e) if relevant, the leakage coefficients C and n for positive and, if applicable, negative pressure differences along with their confidence limits;

f) when required, the equivalent leakage area together with its confidence interval;

g) mention of the existence of any leaks found during the test and of their position.

Annex A (normative)
Test pressure differences

When available, the test pressure differences shall be taken from the appropriate product specification. If no specification is available, the following procedure shall be used.

The maximum pressure difference, Δp_{max}, shall be one of the following:

50 Pa 100 Pa 200 Pa 500 Pa 1000 Pa.

The maximum pressure difference is selected, according to the characteristics and future use of the specimen tested and to the purpose of the test. It should be such that the element does not show, after test, irreversible changes in permeability characteristics.

The minimum pressure difference, Δp_{min}, shall be at least equal to the smallest pressure difference measurable with the required accuracy of 5 %. However, Δp_{min} shall not exceed a fifth of Δp_{max}.

If no other requirements are specified, the pressure steps are distributed in a geometric series between and including Δp_{min} and Δp_{max} in such a way that there are at least seven measured points (see figure A.1). The full range is divided into N ($N \geq 6$) pressure steps, Δp_i, with equal intervals on a logarithmic scale, that is:

$$\Delta p_i = 10^{i \frac{\log \Delta p_{max} - \log \Delta p_{min}}{N} + \log \Delta p_{min}}$$

or (A.1)

$$\Delta p_i = \exp\left(i \frac{\ln(\Delta p_{max}) - \ln(\Delta p_{min})}{N} + \ln(\Delta p_{min}) \right)$$

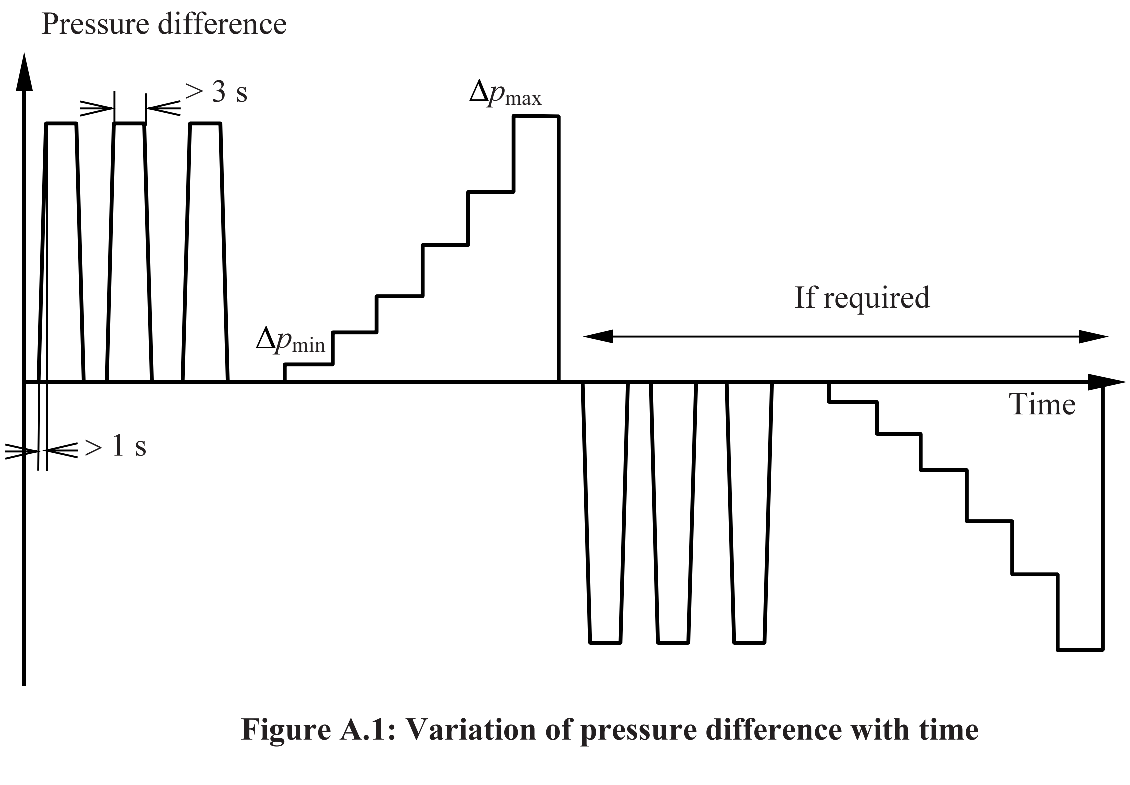

Figure A.1: Variation of pressure difference with time

Annex B (informative)
Regression technique

B.1 Determination of leakage coefficients

The leakage coefficients, C and n, are obtained by fitting the measured results, $\dot{V}$ (Δp), to the equation:

$$\dot{V} = C\,\Delta p^n \qquad \text{(B.1)}$$

Equation is first linearized by taking the logarithm of both sides:

$$\ln(\dot{V}) = \ln(C) + n\ln(\Delta p) \qquad \text{(B.2)}$$

which can be written as a linear relationship

$$y = a + n\,x \qquad \text{(B.3)}$$

with:

$$y = \ln(\dot{V}), \qquad a = \ln(\mathrm{C}) \qquad \text{and} \qquad x = \ln(\Delta p) \qquad \text{(B.4)}$$

The coefficients a and n are determined using the linear regression technique described below. The flow coefficient C can then be calculated by

$$C = \exp(a) \qquad \text{(B.5)}$$

The coefficients are calculated using the following relationships. First compute:

- the estimates of the averages

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad \text{and} \qquad \overline{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \qquad \text{(B.6)}$$

- and the estimates of the variances

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

$$s_y^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_i - \overline{y})^2 \qquad \text{(B.7)}$$

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

Then the best estimates of the coefficients a and n, are:

$$n = \frac{s_{xy}}{s_x^2} \qquad \text{and} \qquad a = \overline{y} - n\overline{x} \qquad \text{(B.8)}$$

NOTE: Strictly speaking, the slope given by equation (B.8) is correct only when the abscissa, x_i are exactly known and when the distribution of the ordinates around the regression line is normal, with a constant standard deviation.

The identification method given in this annex can be replaced by any other method proven to be more accurate.

B.2 Accuracy of leakage coefficients

The variances on the linear coefficients of the regression are estimated using the following relations.

$$s_n = \frac{1}{s_x}\left(\frac{s_y^2 - n\, s_{xy}}{N-2}\right)^{\frac{1}{2}} \quad \text{and} \quad s_a = s_n \sqrt{\frac{\sum_{i=1}^{N} x_i^2}{N}} \qquad \text{(B.9)}$$

If $T(P, \nu)$ is the significance limit of the two-sided Student distribution for a probability P for degree of freedom ν, then the confidence levels on the coefficients are

$$I_a = s_a\, T(P, N\text{-}2) \qquad \text{(B.10)}$$

$$I_n = s_n\, T(P, N\text{-}2) \qquad \text{(B.11)}$$

This means that with a probability P the coefficient a lies in the interval $[a - I_a , a + I_a]$ and the same for n.

The values of the two-sided Student distribution are given in table B1.

Table B.1: Two-sided confidence limits *T*(*P*, *N*-2) for a Student distribution

	$T(P, N\text{-}2)$ for probability P =					
N-2	0,8	0,9	0,95	0,99	0,995	0,999
1	3,078	6,3138	12,706	63,657	127,32	636,619
2	1,886	2,9200	4,3027	9,9248	14,089	31,598
3	1,638	2,3534	3,1825	5,8409	7,4533	12,924
4	1,533	2,1318	2,7764	4,6041	5,5976	8,610
5	1,476	2,0150	2,5706	4,0321	4,7733	6,869
6	1,440	1,9432	2,4469	3,7074	4,3168	5,959
7	1,415	1,8946	2,3646	3,4995	4,0293	5,408
8	1,397	1,8595	2,3060	3,3554	3,8325	5,041
9	1,383	1,8331	2,2622	3,2498	3,6897	4,781
10	1,372	1,8125	2,2281	3,1693	3,5814	4,5787
NOTE: From Kiem & Lentner (ed.): Documenta Geigy, Scientific Tables. Geigy, Basle, 1970.						

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