Designation: E 2178 – 01

Standard Test Method for Air Permeance of Building Materials[1]

This standard is issued under the fixed designation E 2178; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method is to determine the air permeance of building materials at various pressure differentials with the intent of determining an assigned air permeance rate of the material at the reference pressure difference (ΔP) of 75 Pa.

1.2 The method is intended to assess flexible sheet or rigid panel-type materials using a 1 m × 1 m specimen size.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurements are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 283 Test Method for Rate of Air Leakage through Exterior Windows, Curtain Walls and Doors[2]

E 1677 Specification for an Air Retarder Material or System for Low-Rise Framed Building Walls[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *air permeance*—the rate of air flow (L/s), per unit area (m^2) and per unit static pressure differential (Pa).

4. Significance and Use

4.1 The purpose of this test is to measure the air permeance of flexible or rigid sheet materials. The results of this test may be useful in determining suitability of that material as a component of an air retarder system.

4.2 This method does not address the installed air leakage performance of building materials. The installed performance of air retarder materials and air retarder systems in low-rise framed wall construction is addressed in Specification E 1677.

5. Sampling

5.1 The number of specimens to be tested must be suitable to establish an air leakage rate which is representative of the product. In no case shall less than five specimens be tested.

NOTE 1—Because of the variability in the manufacture of a product, the number of specimens to be tested may vary from product to product. Certain materials may have standard methods for sampling that shall be used to sample these materials.

6. Test Apparatus

6.1 A schematic of the air leakage test apparatus is presented in Fig. 1.

6.1.1 *Airtight Test Chamber*—The airtight test chamber shall be at least 0.32 m deep and capable of receiving a 1 m by 1 m test specimen, anchored to the test chamber by means of a compression frame and clamping devices. The test chamber and compression frame shall be stiff enough to limit deflection within the operating flexibility of the gaskets used to seal the test specimen to the chamber. Two parallel ribbons of self-adhesive gasket material shall be applied at all sealing points of the apparatus/test specimen assembly. The gasket ribbons shall be made of medium-density gasket material that can be fused or glued at joints. The test apparatus shall contain an overpressure control device and windows to verify the specimen installation.

6.1.2 *Flow Measuring Devices*—The flow measuring devices used to gage the air flow through the test specimen shall be capable of measuring air flow rate from 1×10^{-6} m^3/s (.001 L/s) up to 1.88×10^{-2} m^3/s (18.8 L/s), with an accuracy of ± 3 % of the reading.

6.1.3 *Pressure Measuring Devices*—The static pressure differential across the test specimen shall be measured by pressure measuring devices with an accuracy of ± 0.5 % of the pressure reading. The laboratory barometric pressure shall be measured with a device capable of measuring barometric pressure within ± 3 % of the reading.

6.1.4 *Piping*—The piping connecting the flow measuring devices and the vacuum blower shall be airtight and contain flow control devices to regulate the static pressure across the test specimen within ± 0.5 % of the pressure reading. The pipe connection to the test chamber shall contain an air filter to prevent dust or particulate matter from affecting the flow

[1] This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.41 on Air Leakage and Ventilation Performance.

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[2] *Annual Book of ASTM Standards*, Vol 04.11.

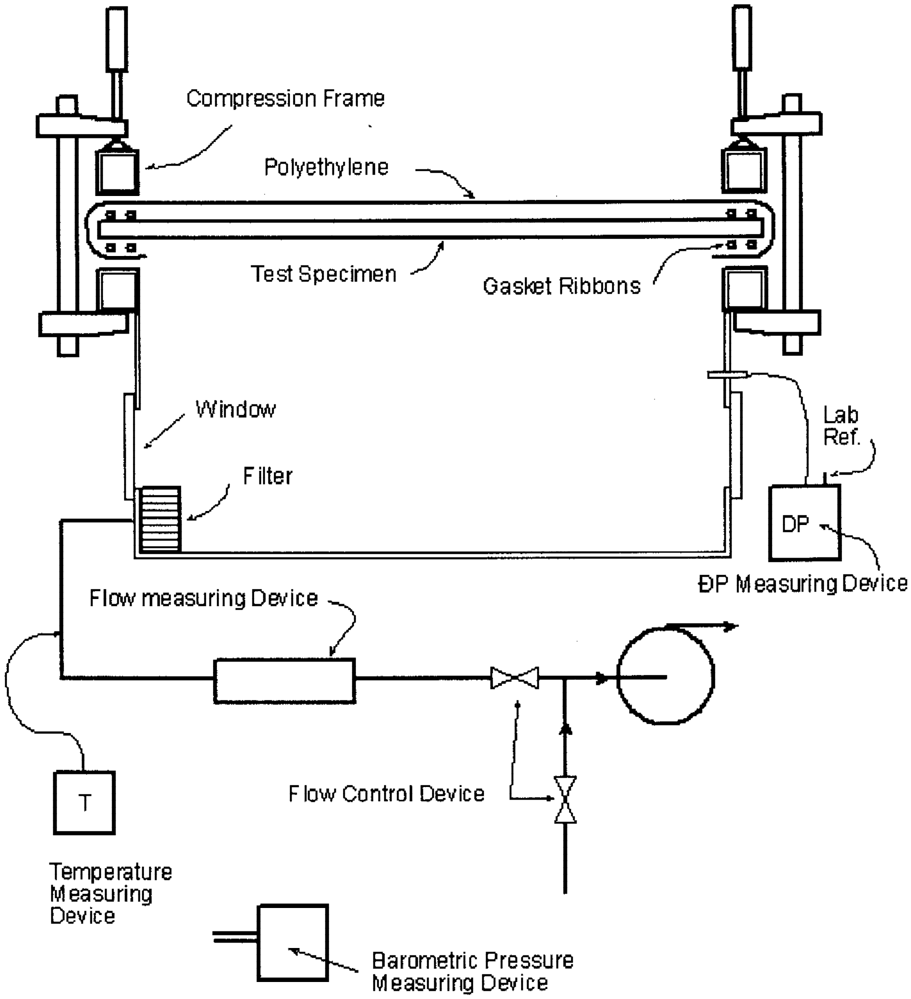

FIG. 1 General Configuration of Test Apparatus

measuring device reading. The piping downstream and upstream of the flow measuring device shall be designed so the flow regime does not affect the device's accuracy. The piping shall contain a temperature measuring device capable of measuring air temperature within ± 0.5°C to convert all flow rate measurement to STP.

6.1.5 *Vacuum Blower*—The blower used to create a vacuum in the test chamber shall be able to produce static pressure differential across the test specimen within ± 0.5 % of the pressure reading.

7. Specimen Preparation

7.1 *Conditioning for Tests*—Unless otherwise stated, all specimens to be tested shall be conditioned for a minimum period of seven days at 21 ± 1°C and 40 ± 5 % RH.

7.2 *Flexible Sheet Materials*—Due to lack of rigidity, flexible materials must be tested over a rigid support having an air permeance much greater than the test specimen. An open grill or wire mesh/screen, fabricated with welded wire having a minimum of 25 mm × 25-mm-square grid (or an alternative means that provides an equivalent degree of support and air permeance) shall be used for this purpose. The wire mesh portion of the support should be welded to a solid metal frame which shall be gasketed and compressed within the test frame. A detailed description of the support grill, including the gage wire used, shall be included in the test report. Fig. 2 shows the preparation for a typical flexible sheet material. The following procedure must be used to seal the perimeter of the specimen:

7.2.1 Apply a self-adhesive gasket ribbon over the frame of the wire mesh/screen around the entire perimeter of the test area under investigation (1 m × 1 m);

7.2.2 Apply a second self-adhesive gasket ribbon along the perimeter of the first ribbon in 7.2.1;

7.2.3 All joints in the gasket ribbons must be fused or glued;

7.2.4 Cut the flexible sheet material specimen to 1100 mm × 1100 mm;

7.2.5 Upon removal of the protective paper over the self-adhesive gasket, install the specimen over the wire mesh/screen;

7.2.6 Apply the self-adhesive gasket over the specimen so it lines up with the first ribbon in 7.2.1, and then apply a second self-adhesive gasket along its perimeter;

7.2.7 All joints in the gasket ribbons must be fused or glued;

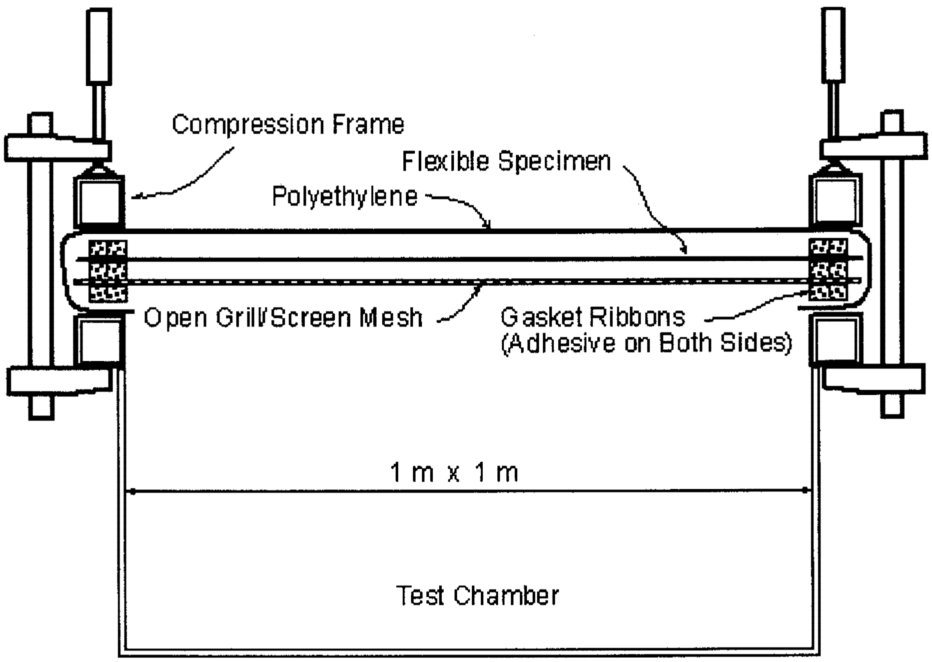

FIG. 2 Flexible Sheet Test Specimen

7.2.8 Cut polyethylene film (0.15 mm (6 mils)) to 1400 mm × 1400 mm;

7.2.9 Upon removal of the protective paper over the ribbon, cover the specimen with the polyethylene film;

7.2.10 Cut the polyethylene film at each corner as per Fig. 3;

7.2.11 Apply two self-adhesive gaskets to the underside of the wire mesh/screen support (the gaskets should line up below the first ribbon installed in 7.2.1);

7.2.12 Upon removal of the protective paper over the gasket, fold and tape each corner of the film with construction tape to ensure complete airtightness as per Fig. 4;

7.2.13 From the interior line of the adhesive gasket, cut and remove all the excess polyethylene film.

7.3 *Rigid Materials*—Fig. 5 shows the preparation for a typical rigid panel-type material. The following procedure must be used to seal the perimeter of the specimen:

7.3.1 Apply a self-adhesive gasket ribbon over the rigid test specimen around the entire perimeter of the area under investigation (1 m × 1 m);

7.3.2 All joints in the gasket ribbons must be fused or glued;

7.3.3 Cut polyethylene film (0.15 mm (6 mils)) to 1400 mm × 1400 mm;

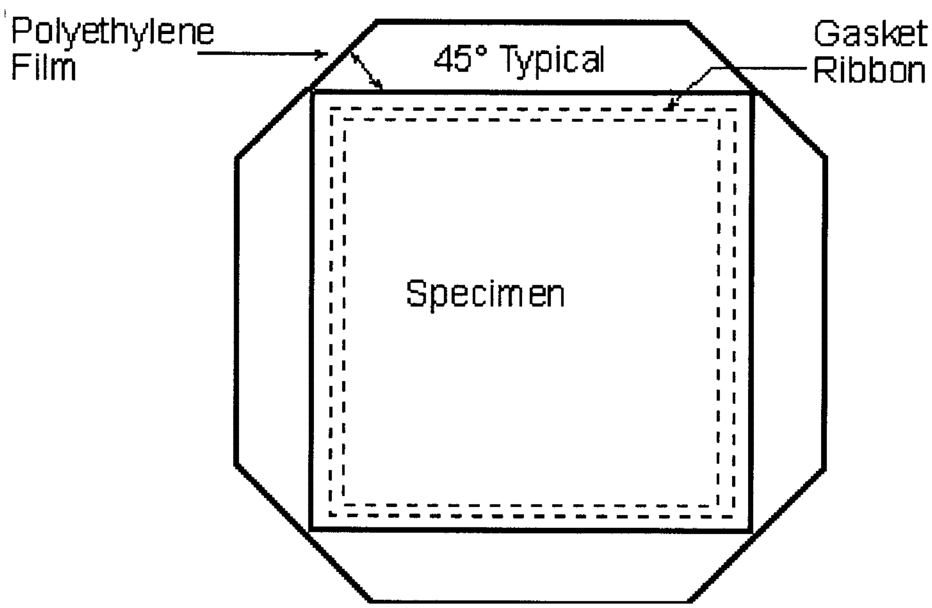

FIG. 3 Top View of Polyethylene Placement Over Specimen with Double Perimeter Gaskets

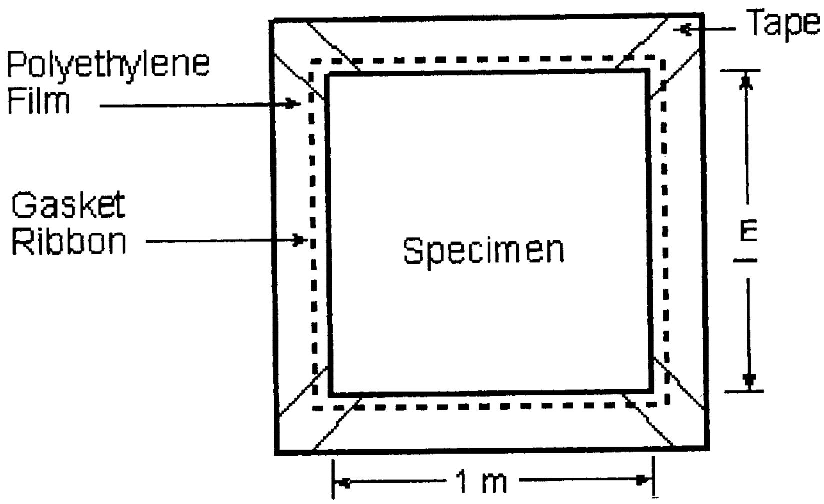

FIG. 4 Bottom View of Polyethylene Seal at Double-Perimeter Gaskets on Underside of Rigid Specimen or Open Mesh/Screen for Flexible Sheet Specimen Set-up

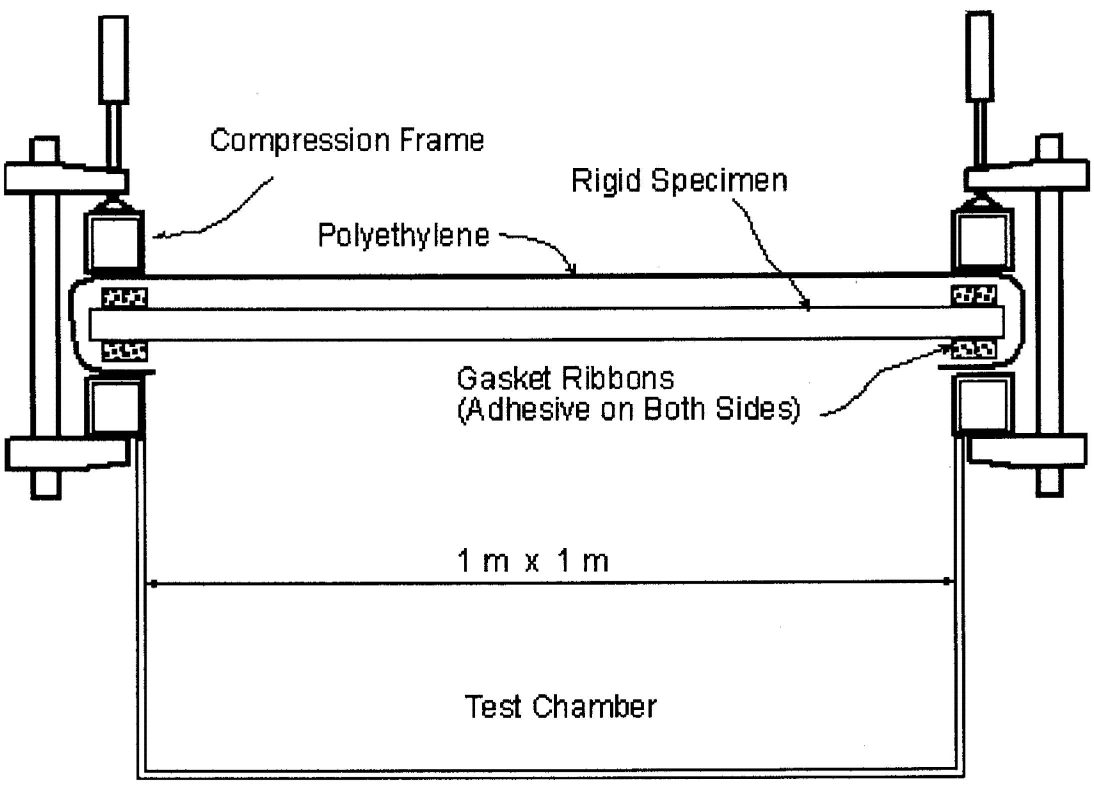

FIG. 5 Rigid Specimen Test Set-up

7.3.4 Upon removal of the protective paper over the self-adhesive gasket ribbon, cover the specimen with the polyethylene film;

7.3.5 Cut the polyethylene film at each corner as per Fig. 3;

7.3.6 Apply a second self-adhesive gasket ribbon to the underside of the specimen (the ribbon should be applied directly below the first ribbon installed in 7.3.1), and seal corner junctions by fusing or gluing;

7.3.7 Upon removal of the protective paper over the self-adhesive gasket ribbon, fold and tape each corner of the film with construction tape to ensure complete airtightness as per Fig. 4;

7.3.8 From the interior line of the self-adhesive gasket ribbon, cut and remove all the excess polyethylene film.

8. Test Procedure

8.1 *Control Tests*—The laboratory shall confirm the integrity and accuracy of the apparatus by verifying the following:

8.1.1 The impact of the open mesh/screen on the air leakage rate measurements shall be assessed. If not negligible, it must be taken into account when calculating the air permeance.

8.1.2 The air leakage rate across one specimen of a 12.5-mm-thick regular gypsum board shall be determined in accordance with procedures outlined in 7.3, for a rigid panel-type material. The air leakage rate of the regular gypsum board shall not exceed 0.02 L/(s · m^2) at a pressure differential of 75 Pa.

8.2 *Specimen Testing*—The testing on each specimen shall be conducted as follows:

8.2.1 Install the sealed test specimen on the test chamber;

8.2.2 Install the compression frame over the specimen;

8.2.3 Check through the window if the specimen is properly placed;

8.2.4 Anchor the specimen to the test chamber and compress the gaskets, as required;

8.2.5 Measure the extraneous air leakage (Q_{ei}) of the test apparatus/specimen at various static pressure differentials (ΔP) as follows: 25, 50, 75, 100, 150 and 300 Pa.

8.2.6 Cut the top section of the polyethylene film;

8.2.7 Measure the total air leakage (Q_{ti}) at various static pressure differentials (ΔP), and correct the air flow rate values to STP. The air permeance of each specimen shall be determined with a minimum of six measurements when conducted in accordance with Test Method E 283. The six measurements shall be taken as follows: 25, 50, 75, 100, 150 and 300 Pa.

8.2.8 After measuring the air leakage at the maximum static pressure differential (ΔP), 300 Pa, remeasure the air leakage at 100, 75, and 50 Pa to determine if the measurement process has effected the air leakage of the material. If the difference between the two air leakage measurements is greater than 10 %, the cause of the air leakage rate change shall be identified.

9. Calculation of Air Permeance

9.1 The flow rate across the specimen shall be Q_{ti} minus the extraneous flow rate of Q_{ei}.

9.2 The flow rate equation of the form $Q = C\,A\,(\Delta P)^n$ shall be established by fitting the data, and errors estimated. A recommended procedure is provided in Annex A1.

9.3 Calculate the material permeance at the pressure differences measured. The air permeance (P) of a specimen at a given pressure differential (ΔP) is calculated by the following equation.

$$P = \frac{Q}{(A)(\Delta P)} \tag{1}$$

where:

Q = flow rate from the flow rate equation (see 9.2),
A = specimen cross-sectional area (1 m^2), and
ΔP = pressure difference.

9.4 An error analysis shall be performed that includes an examination of the sources of error, an evaluation of systematic errors and propagation of error, and the resulting value of error on air flow values through the material tested.

10. Report

10.1 The report shall include the following:

10.1.1 Identification of the material tested, including thickness and basis weight.

10.1.2 The material sampling procedure used.

10.1.3 The measured air flow versus pressure difference data in graphic form (log/log graph) for the specimens. The air leakage rate at the reference pressure difference, ΔP, of 75 Pa must be identified on the graph.

10.1.4 The calculated air permeance versus the pressure difference in tabular form.

10.1.5 The error analysis as described in 9.4.

11. Precision and Bias

11.1 The precision and bias of the test method have not been determined.

12. Keywords

12.1 air permeance; air retarder; building materials; buildings

ANNEX

(Mandatory Information)

A1. RECOMMENDED PROCEDURE FOR ESTIMATING ERRORS IN DERIVED QUANTITIES

A1.1 This test method contains several derived quantities which are often used to summarize the air tightness of the building or component tested. It is important to report an estimate of the error in such quantities. The following method is recommended: all derived quantities depend on the estimation of the air leakage coefficient C and air pressure exponent n of Eq A1.1. To determine C and n, make a log transformation of the variables Q and dP for each reading.

$$x_i = ln(dP_i) \tag{A1.1}$$

$$y_i = ln(Q_i)$$

$$\text{for } i = 1..N$$

where:
N = total number of test readings.

Eq A1.1 then transforms into:

$$y = ln(C) + n \cdot x \tag{A1.2}$$

Compute the following quantities:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{A1.3}$$

$$\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \tag{A1.4}$$

$$S_x^2 = \frac{1}{N-1}\sum_{i=1}^{N} (x_i - \bar{x})^2 \tag{A1.5}$$

$$S_y^2 = \frac{1}{N-1}\sum_{i=1}^{N} (y_i - \bar{y})^2 \tag{A1.6}$$

$$S_{xy} = \frac{1}{N-1}\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y}) \tag{A1.7}$$

Then the best estimate of n and ln(C) is given by:

$$n = \frac{S_{xy}}{S_x^2} \tag{A1.8}$$

$$ln(C) = \bar{y} - n \cdot \bar{x} \tag{A1.9}$$

$$C = exp^{(\bar{y} - n \cdot \bar{x})} \tag{A1.10}$$

The 95 % confidence limits for C and n can be determined as follows. The variance of n is given by the estimate:

$$S_n = \frac{1}{S_x}\left(\frac{S_y^2 - n \cdot S_{xy}}{N-2}\right)^{\frac{1}{2}} \tag{A1.11}$$

and the estimate of the variance of ln(C) is given by

$$S_{ln(C)} = S_n\left(\frac{\sum_{i=1}^{N} x_i^2}{N}\right)^{\frac{1}{2}} \tag{A1.12}$$

The confidence limits for ln(C) and n are respectively:

$$I_{ln(C)} = S_{ln(C)}\, T\,(95\,\%, N-2) \tag{A1.13}$$

$$I_n = S_n\, T(95\,\%, N-2) \tag{A1.14}$$

Where the values of the two-sided Student distribution (T(95 %, N–2)) are given in Table A1.1. This means that the probability is 95 % that the pressure exponent n lies in the interval ($n - I_n, n + I_n$) and the air leakage coefficient C lies in the interval ($c \cdot exp^{-I_{ln(C)}}$, $c \cdot exp^{I_{ln(C)}}$).

The estimate of the variance around the regression line (Eq A1.1) at the value x is

$$S_y(x) = S_n\left(\frac{N-1}{N} S_x^2 + (x - \bar{x})^2\right)^{\frac{1}{2}} \tag{A1.15}$$

and the confidence interval in the estimate of y using Eq A1.1 at any x is

$$I_y(x) = S_y(x) T(95\,\%, N-2) \tag{A1.16}$$

Therefore the airflow rate Q predicted by Eq A1.1 at any pressure difference dP lies in the interval ($Q \cdot exp^{-I_{y(ln((dP))}}$, $Q \cdot exp^{I_{y(ln((dP))}}$) with a probability of 95 %. It is this interval that should be used to estimate the error in the leakage area or the airflow rate across the building material at a reference pressure (for example 75 Pa). In practice, the above error analysis can be carried out using standard statistical computer programs.

TABLE A1.1 Two-Sided Confidence Limits *T* (95 %, N–2) for a Student Distribution

N–2	3	4	5	6	7	8	9	10
T(95 %, N–2)	3.182	2.776	2.571	2.447	2.365	2.306	2.262	2.228