Designation: E96/E96M – 22a[ε1]

Standard Test Methods for
Gravimetric Determination of Water Vapor Transmission Rate of Materials[1]

This standard is issued under the fixed designation E96/E96M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

ε1 NOTE—Corrected 5.3 editorially in March 2023.

1. Scope

1.1 These test methods cover the determination of water vapor transmission rate (WVTR) of materials, such as, but not limited to, paper, plastic films, other sheet materials, coatings, foams, fiberboards, gypsum and plaster products, wood products, and plastics. Two basic methods, the Desiccant Method and the Water Method, are provided for the measurement of WVTR. In these tests, the desired temperature and side-to-side humidity conditions, with resultant vapor drive through the specimen, are used. The test conditions employed are at the discretion of the user, but in all cases, are reported with the results.

1.2 The values stated in either Inch-Pound or SI units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, each system shall be used independently of the other. Derived results are converted from one system to the other using appropriate conversion factors (see Table 1).

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
C168 Terminology Relating to Thermal Insulation
C1809 Practice for Preparation of Specimens and Reporting of Results for Permeance Testing of Pressure Sensitive Adhesive Sealed Joints in Insulation Vapor Retarders
D449/D449M Specification for Asphalt Used in Dampproofing and Waterproofing
D2301 Specification for Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 Definitions of terms used in this standard will be found in Terminology C168, from which the following is quoted:
"*water vapor permeability*—the time rate of water vapor transmission through unit area of flat material of unit thickness induced by unit vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions.

Discussion—Permeability is a property of a material, but the permeability of a body that performs like a material may be used. Permeability is the arithmetic product of permeance and thickness.

water vapor permeance—the time rate of water vapor transmission through unit area of flat material or construction induced by unit vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions.

Discussion—Permeance is a performance evaluation and not a property of a material.

TABLE 1 Units and Conversion Factors[A,B]

Multiply	by	To Obtain (for the same test condition)
WVTR		
g/h·m²	1.43	grains/h·ft²
grains/h·ft²	0.697	g/h·m²
Water Vapor Permeance (WVP)		
ng/Pa·s·m²	1.75×10^{-2}	perm
g/Pa·s·m²	1.75×10^{7}	perm
perm	57.2	ng/Pa·s·m²
perm	5.72×10^{-8}	g/Pa·s·m²
Permeability		
ng/Pa·s·m	0.688	perm-inch
g/Pa·s·m	6.88×10^{8}	perm-inch
perm-inch	1.45	ng/Pa·s·m
perm-inch	1.45×10^{-9}	g/Pa·s·m

[A] These units are commonly used in the construction and building materials industries. Additional units are used in other industries, such as packaging.
[B] All conversions of mm Hg to Pa are made at a temperature of 0°C.

water vapor transmission rate—the steady water vapor flow in unit time through unit area of a body, normal to specific parallel surfaces, under specific conditions of temperature and humidity at each surface."

4. Summary of Test Methods

4.1 In the Desiccant Method the test specimen is sealed to the open mouth of a test dish containing a desiccant, and the assembly placed in a controlled atmosphere. Periodic weighings are used to determine the rate of water vapor movement through the specimen into the desiccant.

4.2 In the Water Method, the dish contains distilled water, and the weighings are used to determine the rate of vapor movement through the specimen from the water to the controlled atmosphere.

4.3 Given a common controlled atmosphere, the vapor pressure difference is nominally the same in both methods, but the water method exposes the specimen to higher humidity, which potentially affects the water vapor transmission through the material. The controlled atmosphere temperature and humidity levels are selected by the user.

5. Significance and Use

5.1 The purpose of these tests is to obtain, by means of simple apparatus, reliable values for water vapor transfer rate through materials, expressed in suitable units.

5.2 A WVTR value obtained in one method under one set of test conditions is not necessarily indicative of the value that would be obtained using the other method or under a different set of conditions. See Appendix X3 for discussion of determining dependency of WVTR on different relative humidity (at a given temperature).

5.3 Commonly used test conditions are listed in Appendix X1, but given the caution in 5.2, the selection of test conditions other than those listed, and which closely approach exposure conditions of material in actual use, is allowed. Where tests are conducted for classification or compliance purposes, environmental conditions are typically defined in product standard specifications.

6. Apparatus

6.1 *Test Dish*—The test dish shall be of any noncorroding material, impermeable to water or water vapor. There is no specified shape or maximum size for the test dish. Light weight is desirable. A shallow dish is preferred, but its size and weight are limited when an analytical balance is chosen to detect small weight changes. The mouth of the dish shall be as large as practical and at least 4.65 in.² [3000 mm²] in area. The desiccant or water area shall not be less than the mouth area except when a grid is used, as provided in 13.1, with its effective area not exceeding 10 % of the mouth area. A flange or ledge around the mouth, on which the specimen rests is commonly used to ensure sealing, but other configurations are allowed.

6.1.1 When the specimen area is larger than the mouth area, this overlay upon the ledge is a source of error. The magnitude of this error increases with the width of the overlay upon the ledge. The overlay material results in a positive error, indicating excessive water vapor transmission. To minimize this error, this overlay material is to be masked as described in 11.1 so that the mouth area defines the test area. The magnitude of the edge mask error is a complex function of the specimen thickness, ledge width, mouth area, and in some cases the specimen permeability. This error is discussed by Joy and Wilson (1)[3] (see 14.4.3). This type of error is to be limited to no more than 12 %. For a thick specimen the ledge width shall not exceed ¾ in. [19 mm] for a 10-in. [254-mm] or larger span mouth (square or circular) or ⅛ in. [3 mm] for a 5-in. [127-mm] span mouth (square or circular). For a 3-in. [76-mm] span mouth (square or circular) the ledge shall not exceed 0.11 in. [2.8 mm] wide. An allowable ledge that limits error to 12% shall be determined by interpolation for intermediate sizes. Per Joy and Wilson (1), using Equation 7, it is possible to solve for the ledge width that results in a specific or lower error rate. To achieve a lower error rate or to calculate specific intermediate ledge widths, the ledge width is solved for using Equation 7. When a rim is incorporated, it shall not be more than ¼ in. [6 mm] higher than the specimen as attached. See sections 12.1 and 13.1 for requirements for the clearance for the test dishes for the Desiccant Method and Water Method, respectively.

6.2 *Test Chamber*—The room or cabinet where the assembled test dishes are to be placed shall have a controlled temperature and relative humidity. Common test conditions are listed in Appendix X1. If not listed among these, temperature and relative humidity corresponding to the intended application of, or specification for, the material to be tested (see Appendix X1) are used. Refer to product standard specification for test conditions for classification or compliance purposes. Temperature shall be maintained at ± 5 °F [2.8 °C] at a given measurement point, with the average at the end of the test period being within ± 2 °F [1.1°C] of the specified test condition. Relative humidity shall be maintained at ± 5 % at a given measurement point, with the average at the end of the test period being within ± 2% of the specified test condition. Provisions shall be made to prevent water from dripping onto

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[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

the surface of a specimen when tested at high humidity, when condensation on the chamber walls is possible. Both temperature and relative humidity shall be measured and recorded at a frequency of at least once every 15 min for the duration of the test. Air shall be continuously circulated throughout the chamber, with a velocity sufficient to maintain uniform conditions within the chamber. Test dishes shall be placed in the chamber in such a way that air flow is not restricted over the top of the specimen. Barometric pressure shall be measured and recorded at every weighing for use in the still air correction. See 15.6.1.1.

6.3 *Balance*—Weighing shall be performed using an electronic analytical balance of suitable capability (See Note 1).

NOTE 1—Various aspects of balance specifications and performance other than capacity and resolution should be considered in choosing equipment suitable for the weighing demands of these tests. In use, best laboratory practices for verification of balance performance, along with proper care and maintenance should be followed.

6.3.1 The balance shall have sufficient capacity to accommodate the assembled dish mass and, in the case of desiccant method tests, added mass of any moisture gained.

6.3.2 Resolution (or readability) of the balance shall be no more than 1 % of the assembled dish assembly weight change during the span of six or more consecutive steady state weighings utilized per 14.3.

6.3.2.1 If the resolution does not meet the requirement of 6.3.2, weighing shall be extended until such a point that the weight change is at least 100 times the resolution of the balance (See Note 2).

NOTE 2—Example: The following table lists the days at steady state required at various balance resolutions less than that of the balance used for the hypothetical specimen shown.

Balance Resolution = 0.1 mg (0.0001 g)
Weighed once every 24 h
Steady state observed, six points chosen (five days)
Weight gain over steady state span = 0.7815 g

Balance Resolution	Number of Days
0.1 mg	5
0.001 g	5
0.01 g	7
0.1 g	64
1.0 g	640

6.3.2.2 In cases where WVTR is near zero and weight gain or loss is so small that the requirements of this section cannot be fulfilled regardless of test duration, the report shall make note of such.

6.4 *Thickness-Measuring Gage*—The gage shall have an accuracy of ±1 % of the reading or 0.0001 in. [0.0025 mm], whichever is greater.

7. Materials

7.1 *Desiccant*—For the Desiccant Method, anhydrous calcium chloride in the form of small pellets that will pass a No. 8 [2.36-mm] sieve, and free of fines that will pass a No. 30 [600-µm] sieve, shall be used.

7.1.1 Desiccant to be re-used shall be dried at 400°F [200°C] for 4 hours per inch, or any fraction thereof, of desiccant depth in vessel. Re-dried desiccant shall be stored in a sealed container and be at room temperature before use.

7.1.2 Virgin material that has been in a sealed container does not have to be dried before use.

7.2 *Water*—For the Water Method, distilled water shall be used in the test dish (Note 5).

7.3 *Sealant*—The sealant used for attaching the specimen to the dish must be impervious to the passage of water vapor (and water). Seals of molten asphalt or wax are required for tests producing results below 4 perms [230 ng·m^{-2}·s^{-1}·Pa^{-1}]. Sealing methods are discussed in Appendix X2.

8. Sampling

8.1 The material shall be sampled in accordance with standard methods of sampling applicable to the material or product under test. For homogenous materials, the sample shall be of uniform thickness. When the opposing faces of a product are dissimilar, the two faces shall be designated by distinguishing identification (for example, on a one-side-coated sample, "I" for the coated side and "II" for the uncoated side).

9. Test Specimens

9.1 Test specimens shall be representative of the material tested. When a product is designed for use in only one position, three specimens shall be tested by the same method with the vapor flow in the designated direction. When the faces of a product are indistinguishable, three specimens shall be tested by the same method. When the faces of a product are different, and the location of the vapor source is independent of the installation, six specimens shall be tested by the same method, three being tested with the vapor flow in each direction and so reported. A blank specimen for both orientations is required (see 9.6).

9.2 Materials of homogeneous composition and physical structure shall be tested at any thickness to determine water vapor permeance (WVP). When determining permeability, the specimen must be a minimum of ½ in. [12.5 mm] thick.

9.3 A slab of a singular material that varies in physical structure by layer (such as a foamed plastic or rubber with natural "skins") shall be tested at the thickness of use.

9.4 When a material has a pitted or textured surface, the tested overall thickness, if less than that of use, shall be at least five times the sum of the maximum pit depths in both its faces.

9.5 When testing pressure sensitive adhesive sealed joints used in insulation vapor retarder systems, prepare the specimens according to Practice C1809.

9.6 *Use of a Blank Specimen:*

9.6.1 All tests require an additional blank specimen to be tested exactly like the others, except that no desiccant or water is put in the dish. Failure to use this blank specimen to establish modified dish weights may significantly increase the time required to complete the test. The time to reach equilibrium of water vapor transmission increases as the square of thickness. Some thick, particularly hygroscopic, materials take as long as 60 days to reach equilibrium conditions.

9.6.2 The blank specimen is used to cancel out the effects of barometric pressure changes eliminating the need for buoyancy corrections, moisture changes of hygroscopic materials, and

mass changes of uncured specimens. This enables simpler, more accurate calculations and reduces the time to establish steady state mass change.

9.6.3 The blank specimen becomes the fourth specimen of a standard three dish test set.

10. Specimen Thickness Measurement

10.1 When testing permeability of homogeneous materials, the overall thickness of each specimen shall be measured. Divide the specimen into quadrants and measure each quadrant with a gage meeting the requirements of 6.4, and average the results.

11. Attachment of Specimen to Test Dish

11.1 Attach the specimen to the dish by sealing in such a manner that the dish mouth defines the area of the specimen exposed to the vapor pressure in the dish. If necessary, mask the specimen top surface that is exposed to conditioned air so that its exposure duplicates the mouth shape and size and is directly above it. A template is useful for locating the mask. Thoroughly seal the edges of the specimen to prevent the passage of vapor into, out of, or around the specimen edges or any portion thereof. Suggested methods of attachment are described in Appendix X2.

11.2 It is possible that some specimens will warp and break the seal during the test. The risk is reduced by preconditioning the specimen to the controlled environmental conditions of the test for 24 hours, while mechanically restraining it to the dish.

12. Procedure for Desiccant Method

12.1 Fill the test dish with desiccant within ¼ in. [6 mm] of the specimen. Weigh the amount of desiccant placed in each dish. Leave enough space so that shaking of the dish, to be done at each weighing, will mix the desiccant.

12.2 Attach the specimen to the dish (see 11.1) and place it in the controlled environment room or chamber.

12.3 Weigh the dish assembly periodically, often enough to obtain at least six data points at steady state. A data point is the weight at a particular time. The time of weighing shall be recorded to a precision of approximately 1 % of the time span between successive weighing. Thus, if weighings are made every hour, record the time to the nearest 30 s; if recordings are made every day, a time to the nearest 15 min is acceptable. Ideally, weighing is done without removal of the test dishes from the controlled environment, but if removal is necessary, the time outside of the test environment shall be kept to a minimum.

12.4 Terminate the test or change the desiccant before the water absorbed by the desiccant exceeds 10 % of its starting weight. The desiccant gain is isolated using the blank specimen to adjust for moisture content change of the specimen.

12.5 Analyze the results as prescribed in 14.1.

NOTE 3—The WVTR of some materials (especially of wood and paper) is influenced by the ambient relative humidity immediately before the test. A hysteresis results in higher WVTR when the relative humidity to which the specimen is exposed prior to testing is above the test condition or vice versa. Conditioning specimens of wood, paper, or other materials having significant moisture content to constant weight in a 50 % relative humidity atmosphere prior to testing can reduce the time needed to reach a steady state weight gain.

13. Procedure for Water Method

13.1 Fill the test dish with distilled water to a level ¾ ± ¼ in. [19 ± 6 mm] from the specimen. The air space thus allowed has a small vapor resistance, but it is necessary in order to reduce the risk of water touching the specimen when the dish is handled. Such contact invalidates a test on some materials such as paper, wood, or other hygroscopic materials. The water depth shall be not less than ⅛ in. [3 mm] to ensure coverage of the dish bottom throughout the test. When using a glass dish, its bottom must be visibly covered at all times but no specific depth is required. Reduce water surges by placing a grid of light non-corroding material in the dish to break the water surface. This grid shall be at least ¼ in. [6 mm] below the specimen, and it shall not reduce the water surface by more than 10 %.

NOTE 4—When it is desirable to reuse an assembled specimen for a subsequent test series It is acceptable to add water through a small sealable hole in the dish above the water line.

13.2 Attach the specimen to the dish (see 11.1) and place it in the controlled environment on a horizontal surface. Follow the procedure given in 12.3 through 12.5.

NOTE 5—When *preparing* specimens, to avoid possible formation of condensation on the interior surface of the specimen, it is advisable to bring the temperature of the prepared specimen dish to within ±2°F [1°C] of the test temperature prior to placing into controlled test environment.

NOTE 6—When *weighing* water method test specimens, if the specimen is exposed to an environment that is below the temperature of the controlled environment and the inside surface of the specimen could reach dew point for the air inside the dish, condensation might form on that surface. Instruction in 12.3 addresses avoidance of this.

13.3 Where water is expected to be in contact with the barrier in service, proceed as in 13.2 except place the dish in an inverted position. The dish must be sufficiently level so that water covers the inner surface of the specimen despite any distortion of the specimen due to the weight of the water. Locate the test dish so that air circulates over the exposed surface. Place the test dishes on the balance in the upright position for weighing, but keep the period during which the wetted surface of the specimen is not covered with water to a minimum.

14. Determination and Utilization of Steady State

14.1 The rate of weight change of a specimen is at steady state when that rate is essentially constant over a period that is a minimum of six consecutive weighings. However, additional weighings increase the confidence in the measurement.

14.2 The data from the beginning or the end, or both, of the weighing sequence is not always part of the steady state portion of the test due to internal moisture content changes or loss of desiccant efficiency or excess water loss. Analysis of the data per 14.3 is needed to ensure only steady state portions of the test are used for calculating WVTR.

14.3 The steady state portion of the test is most easily identified graphically.
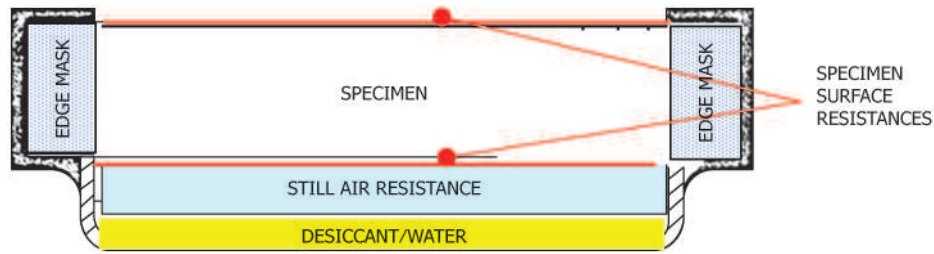
FIG. 1 Referenced Corrections in 15.6

14.3.1 Plot the weight, modified by the blank specimen, against elapsed time.

14.3.2 Where a straight line adequately fits the plot of at least six properly spaced points (periodic weight changes matching, or exceeding 20 % of the multiple of 100 times the scale sensitivity), steady state is assumed.

14.3.3 The slope of that fitted line is the water vapor transmission rate. See Appendix X4 for additional discussion regarding measurements of materials of zero or near-zero water vapor permeance (WVP).

15. Calculation and Analysis of Results

15.1 *Blank Specimen*—The blank specimen is used to compensate for variability in test conditions due to temperature and/or barometric pressure fluctuations. The test specimen recorded weights are adjusted by calculating the weight change of the blank specimen from the beginning of the test to time of weighing. This adjustment is made by subtracting the weight change of the blank specimen from the weight change of the test dish at the time of weighing of both. This permits earlier recognition of steady state conditions.

15.2 A mathematical least squares regression analysis of the weight, modified by the blank specimen, as a function of time will give the water vapor transmission rate.

15.2.1 For materials with very low water vapor permeance, this method is used to determine the results after 30 to 60 days when using an analytical balance, with a sensitivity of ≈1 mg, even if the weight change does not meet the 100 times the sensitivity requirement of 6.3. These specimens must be clearly identified in the report. Reference Appendix X4 for discussion regarding measurements of near zero or zero water vapor permeance (WVP) materials.

15.3 Calculate the water vapor transmission rate, WVTR, and WVP as follows:

15.3.1 *Water Vapor Transmission:*

$$WVTR = \frac{G}{t \cdot A} = \frac{(G/t)}{A} \tag{1}$$

where:

In inch-pound units:

G	=	steady state weight change, grains (from the straight line),
t	=	time during which G occurred, h,
G/t	=	slope of the straight line, grains/h,
A	=	test area (cup mouth area), ft^2, and
WVTR	=	water vapor transmission rate, grains/h·ft^2.

In SI units:

G	=	steady state weight change (from the straight line), g,
t	=	time, h,
G/t	=	slope of the straight line, g/h,
A	=	test area (cup mouth area), m^2, and
WVTR	=	water vapor transmission rate, g/h·m^2.

15.3.2 *Water Vapor Permeance:*

$$WVP = \frac{WVTR}{\Delta p} = \frac{WVTR}{S \cdot (R_1 - R_2)} \tag{2}$$

where:

In inch-pound units:

Δp	=	vapor pressure difference, in. Hg,
S	=	saturation vapor pressure at test temperature, in. Hg,
R_1	=	relative humidity at the source expressed as a fraction (the test chamber for desiccant method; in the dish for water method), and
R_2	=	relative humidity at the vapor sink expressed as a fraction.

In SI units:

Δp	=	vapor pressure difference, Pa,
S	=	saturation vapor pressure at test temperature, Pa,
R_1	=	relative humidity at the source expressed as a fraction (the test chamber for desiccant method; in the dish for water method), and
R_2	=	relative humidity at the vapor sink expressed as a fraction.

15.4 In the controlled room or chamber the relative humidity and temperature are the average of values actually measured during the test. In the dish the relative humidity is nominally 0 % for the desiccant and 100 % for the water. These values are usually within 3 % relative humidity of the actual relative humidity for specimens below 4 perms [230 ng·Pa⁻¹·s⁻¹·m⁻²] when the required conditions are maintained (no more than 10 % moisture in $CaCl_2$ and no more than 1 in. [25 mm] air space above water).

15.5 Perform the calculation of permeability only when the test specimen is homogeneous and not less than ½ in. [12.5 mm] thick, as follows:

$$Permeability = WVP \cdot thickness \tag{3}$$

15.6 *Corrections*—It is important that all applicable corrections be made to all measurements that result in WVP value more than 2 perms [114 ng·Pa⁻¹·s⁻¹·m⁻²]. Corrections for materials with WVP value 2 perms [114 ng·Pa⁻¹·s⁻¹·m⁻²] or less

are insignificant and need not be applied (**2**). The procedures for making various corrections, as summarized below, are found in the literature (**2, 3, 4, 5, 6**). Fig. 1 contains a diagram of the corrections referenced in this section.

15.6.1 *Corrections for Resistance due to Still Air and Specimen Surface:*

15.6.1.1 When the material is highly permeable, these corrections become more significant. With known thickness of the still air layer in the cup, the corresponding vapor resistance is calculated using the following equations (Eq 4 and Eq 5) for permeability.

$$\delta_a = \frac{5.3081 \times 10^6}{R_v T} \cdot \left(\frac{P_o}{P} \right) \cdot \left(\frac{T}{491.67} \right)^{1.81} \quad (4)$$

where:

δ_a = permeability of still air, Perm in.,
T = temperature, °R,
P = ambient barometric pressure, in Hg,
P_o = standard barometric pressure, that is, 29.92 in. Hg, and
R_v = ideal gas constant for water, that is, 85.780 ft·lbf·lb^{-1}·°R^{-1}.

$$\delta_a = \frac{2.306 \times 10^{-5} \cdot P_o}{R_v \cdot T \cdot P} \left(\frac{T}{273.15} \right)^{1.81} \quad (5)$$

where:

δ_a = permeability of still air, kg·m^{-1}·s^{-1}·Pa^{-1},
T = temperature, K,
P = ambient barometric pressure, Pa,
P_o = standard barometric pressure, that is, 101325 Pa, and
R_v = ideal gas constant for water, that is, 461.5 J·K^{-1}·kg^{-1}.

15.6.1.2 In the absence of any measured data, the surface resistances (that is, inside and outside surfaces of the specimen) is approximated by using Lewis' relation (**5**). For cup methods that follow this standard, the total surface resistance (Hansen and Lund (**6**)) is ≈ 2.29 × 10^{-3} h·ft^2·in.Hg·grains^{-1} (4 × 10^{-5} Pa·s·m^2·ng^{-1}).

15.6.2 *Edge Mask Correction*—The following equation (Joy and Wilson (**1**)) is to be used to correct the excess effect due to edge masking during specimen preparation:

$$Percent\ excess\ WVT = \frac{400 \cdot t}{\pi \cdot S_1} \log_e \left(\frac{2}{1 + e^{-\left(\frac{2 \cdot \pi \cdot b}{t} \right)}} \right) \quad (6)$$

where:
In inch-pound units:

t = specimen thickness, ft,
b = width of masked edge, ft, and
S_1 = four times the test area divided by the perimeter, ft.

where:
In SI units:

t = specimen thickness, m,
b = width of masked edge, m, and
S_1 = four times the test area divided by the perimeter, m.

15.6.2.1 If the cup assembly includes any edge masking this correction shall be made.

15.7 Example calculations are presented in Appendix X5.

16. Report

16.1 The report shall include the following:

16.1.1 Identification of the material tested, including product thickness for homogeneous materials tested for permeability.

16.1.2 The side of each specimen on which the higher humidity was applied. The surfaces shall be clearly identified when there is a difference between the two sides. The orientation of the specimen shall be described.

16.1.3 Method used (desiccant or water).

16.1.4 Average test temperature.

16.1.5 Average relative humidity in the test chamber.

16.1.6 WVTR, WVP, and permeability when calculated, of each specimen in appropriate units.

16.1.7 The average WVTR, WVP, and permeability of all specimens tested.

16.1.7.1 When reporting in Inch-Pound units, for results 1.0 perm and greater, report the results to two significant figures. For results less than 1.0 perm report the result to two decimals.

16.1.7.2 When reporting in SI units, for results 57.2 ng·m^{-2}·s^{-1}·Pa^{-1} and greater, round to the nearest whole unit. For perm results less than 57.2 ng·m^{-2}·s^{-1}·Pa^{-1} round to one decimal place.

16.1.8 Portion of the plot indicating the section of the curve used to calculate WVP

16.1.9 Description of cup and type or composition of sealant.

16.1.10 Corrections applied, if any.

17. Precision and Bias

17.1 *Precision*—Table 2 is based on interlaboratory tests conducted in 1988 and 1991.[4] In 1988 four materials (A, B, C, D) were tested using the desiccant method and the water method in triplicate. Fifteen laboratories contributed data, with full results secured from four laboratories. In 1991 ten laboratories contributed data for material E, using triplicate specimens, again using both the desiccant method and the water method. Tables 3 and 4 are based on another interlaboratory test conducted in 1995–96. (**7**) One material at a nominal thickness of 1 in. (25 mm) was tested by ten participating laboratories. Results from only nine laboratories were used in the analyses because of the presence of severe outliers (see Practice E691) in the observation of tenth laboratory.

17.1.1 Test results were analyzed using Practice E691.

17.2 Additional precision data and analysis for this test method is based on an interlaboratory study (#512) conducted in 2010. Six laboratories participated in this study, analyzing four different extremely low WVP materials. Procedure A, desiccant method at 73°F/50 % RH, was used. Each "test result" reported represents an individual determination, and all participants reported three replicate test results for every material. Practice E691 was followed for the design and

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[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C16-1014. Contact ASTM Customer Service at service@astm.org.

TABLE 2 Results on Precision from Interlaboratory Testing

			Repeatability			Reproducibility		
For Desiccant Method at 23°C								
Material	Thickness (mm)^A	Mean Permeance (ng·m^{-2}·s^{-1}·Pa^{-1})^B	s (ng·m^{-2}·s^{-1}·Pa^{-1})^B	CV (%)	LSD (ng·m^{-2}·s^{-1}·Pa^{-1})^B	s (ng·m^{-2}·s^{-1}·Pa^{-1})^B	CV (%)	LSD (ng·m^{-2}·s^{-1}·Pa^{-1})^B
A	0.0254	34.7	0.95	2.7	2.7	5.6	16.2	15.9
B	0.1397	0.74	0.16	21.7	0.46	0.31	42.6	0.92
C	12.7	3.51	0.25	7.2	0.69	1.06	30.2	2.8
D	25.4	44.8	1.5	3.3	4.2	3.5	7.8	10.0
E	0.3556	2.64	0.13	5.0	0.40	0.31	11.7	0.86
For Water Method at 23°C								
Material	Thickness (mm)^A	Mean Permeance (ng·m^{-2}·s^{-1}·Pa^{-1})^B	s (ng·m^{-2}·s^{-1}·Pa^{-1})^B	CV (%)	LSD (ng·m^{-2}·s^{-1}·Pa^{-1})^B	s (ng·m^{-2}·s^{-1}·Pa^{-1})^B	CV (%)	LSD (ng·m^{-2}·s^{-1}·Pa^{-1})^B
A	0.0254	40.91	0.77	1.9	2.2	8.9	21.8	25.2
B	0.1397	0.90	0.13	14.0	0.35	0.12	13.4	0.34
C	12.7	5.55	0.31	5.7	0.92	1.1	20.1	3.1
D	25.4	59.5	1.1	1.8	3.1	12.4	20.9	35.5
E	0.3556	3.40	0.19	5.7	0.57	0.47	13.8	1.3

^{A} 1 in. = 25.4 mm
^{B} 1 perm (inch-pound) = 57.2 ng·m^{-2}·s^{-1}·Pa^{-1}

Legend:
s = standard deviation
CV = percent coefficient of variation (s × 100/ Mean)
LSD = least significant difference between two individual test results based on a 95 % confidence level = 2$\sqrt{2}$s

NOTE 1—Material B was Teflon[4] PTFE fluorocarbon resin brand of tetrafluoroethylene. It was extremely difficult to provide a seal to this sample, which accounts for the poor repeatability.

TABLE 3 Results on Precision from Interlaboratory Testing—Dry Cup Measurements on Expanded Polystyrene

Lab	Permeability (ng·m^{-1}·s^{-1}·Pa^{-1})^A			$\bar{x}$	s	d	h	k
	Spec #1	Spec #2	Spec #3					
1	2.54	2.46	2.21	2.40	1.72E-01	-7.01E-01	-1.50	1.06
2	2.65	2.87	2.68	2.73	1.19E-01	-3.71E-01	-0.79	0.73
3	3.79	3.49	3.65	3.64	1.50E-01	5.39E-01	1.15	0.92
4	2.77	2.73	2.69	2.73	4.00E-02	-3.74E-02	-0.80	0.25
5	2.67	2.66	2.79	2.71	7.23E-02	-3.98E-01	-0.85	0.44
6	3.26	3.38	3.29	3.31	6.24E-02	2.06E-01	0.44	0.38
7	3.05	3.72	3.33	3.37	3.37E-01	2.62E-01	0.56	2.07
8	3.76	3.53	3.87	3.72	1.73E-01	6.16E-01	1.31	1.07
9	3.24	3.48	3.26	3.33	1.33E-01	2.22E-01	0.47	0.82
			$\bar{\bar{x}}$ 3.10		s_r 1.63E-01	$s_{\bar{x}}$ 4.69E-01	s_R 4.87E-01	

^{A} 1 perm in. = 1.45 (ng·m^{-1}·s^{-1}·Pa^{-1})

NOTE 1—The average of the cell averages gives the permeability for the round robin material, according to the dry cup measurements, as 3.10 ng·m^{-1}·s^{-1}·Pa^{-1}.

NOTE 2—The repeatability standard deviation is 1.6 × 10^{-1} ng·m^{-1}·s^{-1}·Pa^{-1}.

NOTE 3—The reproducibility standard deviation is 4.9 × 10^{-1} ng·m^{-1}·s^{-1}·Pa^{-1}.

analysis of the data; the details are given in ASTM Research Report No. C16-1040.[5]

17.2.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

17.2.1.1 Repeatability limits are listed in Table 5.

17.2.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

17.2.2.1 Reproducibility limits are listed in Table 5.

17.2.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

17.2.4 Any judgment in accordance with statements 16.2.1 and 16.2.2 would have an approximate 95% probability of being correct.

17.3 The precision statement was determined through statistical examination of 72 test results, submitted by six