# 译序

杯式法，是水蒸气透过测试的基准方法，源于该方法具备以下特征：1、可溯源； 2、误差可准确估计，且随测试时间衰减至0；3、过程数据能表征关键测量单元（天平）的工况；

目前国际上杯式法水透测量的标准方法中，美国ASTM E96标准最为详尽，其版本更新速度最快，2000年、2005年、2013年、2015年均有更新，其中2013年、2015年为军用版。本公司对ASTM E96M-15版进行全文翻译。M-15版本存在一些争议内容，译文有注解。

为阻隔性标准的一致，译文中使用下列术语：“水蒸气透过率”对应WVTR和WVT；“水蒸气透过性”对应ASTM的Permeance；“水蒸气透过系数”对应ASTM的Permeability。

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2018年7月13日

# Standard Test Methods for Water Vapor Transmission of Materials[1]

# 材料水蒸气透过性能的标准测试方法

## 1. Scope

1.1 These test methods cover the determination of water vapor transmission (WVT) of materials through which the passage of water vapor may be of importance, such as paper, plastic films, other sheet materials, fiberboards, gypsum and plaster products, wood products, and plastics. The test methods are limited to specimens not over 1 1/4 in. [32 mm] in thickness except as provided in Section 9. Two basic methods, the Desiccant Method and the Water Method, are provided for the measurement of permeance, and two variations include service conditions with one side wetted and service conditions with low humidity on one side and high humidity on the other. Agreement should not be expected between results obtained by different methods. The method should be selected that more nearly approaches the conditions of use.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other.

## 1范围

1.1这些方法涵盖各种材料的水蒸气透过测试，例如：纸张、塑料薄膜、片材、纤维板、石膏和石膏制品、木制品和塑料。水蒸气透过性能对这些材料也许很重要。这些测试方法仅限于厚度不超过1.25英寸(32mm)的样品 (第9部分的例外)。测量透过性能的两种基本方法有：干燥剂法和水法；另外有两种变体：一种是一面受水浸湿的（译注：倒杯法）、另一种是一面低湿而另一面高湿。不同方法的测试结果未必一致。选择测试的方法应尽量接近材料使用的环境。

1.2文中英制单位或国际单位，是标准的两个独立单位体系。两种单位的数据不会精确相等；两个单位体系应独立使用。

Combining values from the two systems may result in non-conformance with the standard. However, derived results can be converted from one system to the other using appropriate conversion factors (see Table 1).

两个单位体系的混合使用会导致与标准的不一致。但使用适当的换算系数，可以将一个单位体系的数值换算成另一种单位体系的数值.（见表1）

1.3 This standard does not purport to address all of the safety problems, 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.

1.3本标准无意列举全部的安全问题；如果有，也仅限于使用相关。标准使用者，有责任在使用本标准前建立适当的安全和健康规程，并确定使用前的应用限制规范。

## 2. Referenced Documents

2.1 ASTM Standards:

C168 Terminology Relating to Thermal Insulation

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

D449/D449M Specification for Asphalt Used in Dampproofing and Waterproofing

D2301 Specification for Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

## 2引用标准

2.1ASTM标准

C168 绝热材料的相关术语

E177 ASTM测试标准中精度与偏差的术语使用规范

D449 用于防湿防水的沥青规格

D2301 敏压绝缘聚氯乙烯电胶带的规格

E691 实验之间确定测试方法精度的研究规范

## 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.

## 3术语

3.1本标准中所用术语的定义，可以在C768中找到相关引用：

**"水蒸气透过系数"**（译注：材质的本征性能）--在特定温湿度条件下，单位厚度的平面材料的两个表面之间的单位水蒸气压差引起的在单位时间、单位面积内透过的水蒸气量。

**讨论**--透过系数是材质的一种性质，但表现象材质的物体也可用透过系数来表征。透过系数是透过性与厚度的乘积。

**水蒸气透过性**（译注：产品通用性能）--在特定温湿度条件下，平面材料或者结构的两个表面之间的单位水蒸气压差引起的在单位时间、单位面积内透过的水蒸气量。

讨论--透过性是一种性能评价而非材质性质。

3.2 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 determine the rate of water vapor movement through the specimen into the desiccant.

**TABLE 1 Metric Units and Conversion Factors**[A,B]

| Multiply | by | To Obtain (same condition) |
|---|---|---|
| | *WVT* | |
| g/h·m$^2$ | 1.43 | grains/h·ft$^2$ |
| grains/h·ft$^2$ | 0.697 | g/h·m2 |
| | *Permeance* | |
| g/Pa·s·m$^2$ | $1.75 \times 10^7$ | 1Perm (inch-pound) |
| 1Perm (inch-pound) | $5.72 \times 10^{-8}$ | g/Pa·s·m$^2$ |
| | *Permeability* | |
| g/Pa·s·m | $6.88 \times 10^8$ | 1 Perm inch |
| 1 Perm inch | $1.45 \times 10^{-9}$ | g/Pa·s·m |

[A]These units are used in the construction trade. Other units may be used in other standards.

[B]All conversions of mm Hg to Pa are made at a temperature of 0°C.

4.2 In the Water Method, the dish contains distilled water, and the weighings determine the rate of vapor movement through the specimen from the water to the controlled atmosphere. The vapor pressure difference is nominally the same in both methods except in the variation, with extremes of humidity on opposite sides.

3.2水蒸气透过率（译注：产品的特定环境性能）--物体的两个平行表面处于特定温湿度条件下，单位时间内垂直通过物体两个表面单位面积的水蒸气量。

## 4测试方法概要

4.1在干燥剂法中，试样密封在测试杯的开口上，测试杯内盛有干燥剂，测试组合体放置在一个受控的大气环境中。周期称重组合体，计算出水蒸气穿透样品进入干燥剂的速度。

表1 度位单位转换因子[A,B]

| 原单位 | 变换系数 | 结果单位 (相同测试条件) |
|---|---|---|
| | *WVT* | |
| g/h·m$^2$ | 1.43 | grains/h·ft$^2$ |
| grains/h·ft$^2$ | 0.697 | g/h·m2 |
| | *Permeance* | |
| g/Pa·s·m$^2$ | $1.75 \times 10^7$ | 1Perm (inch-pound) |
| 1Perm (inch-pound) | $5.72 \times 10^{-8}$ | g/Pa·s·m$^2$ |
| | *Permeability* | |
| g/Pa·s·m | $6.88 \times 10^8$ | 1 Perm inch |

[A]这些单位用于建筑业. 其它单位可用于其它行业标准。

[B]所有的mmHg到Pa转换数据均是在0℃情况下进行。

4.2在水法中，测试杯中盛放蒸馏水，称重组合体，计算出水蒸气穿透样品进入受控大气环境的速度。两种测试方法中，水蒸气压差名义上是相同的，不同之处在于对立面的湿度。

## 5. Significance and Use

5.1 The purpose of these tests is to obtain, by means of simple apparatus, reliable values of water vapor transfer through permeable and semipermeable materials, expressed in suitable units. These values are for use in design, manufacture, and marketing. A permeance value obtained under one set of test conditions may not indicate the value under a different set of conditions. For this reason, the test conditions should be selected that most closely approach the conditions of use. While any set of conditions may be used and those conditions reported, standard conditions that have been useful are shown in Appendix X1.

## 6. Apparatus

6.1 Test Dish—The test dish shall be of any noncorroding material, impermeable to water or water vapor. It may be of any shape. Light weight is desirable. A large, 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 $mm^2$]. The desiccant or water area shall be not less than the mouth area except if a grid is used, as provided in 12.1, its effective area shall not exceed 10 % of the mouth area. An external flange or ledge around the mouth, to which the specimen may be attached, is useful when shrinking or warping occurs.

When the specimen area is larger than the mouth area, this overlay upon the ledge is a source of error, particularly for thick specimens. This overlay material should be masked as described in 10.1 so that the mouth area defines the test area. The overlay material results in a positive error, indicating excessive water vapor transmission. The magnitude of the error is a complex function of the thickness, ledge width, mouth area, and possibly the permeability. This error is discussed by Joy and Wilson **(1)** (see 13.4.3).

This type of error should be limited to about 10 to 12 %. For a thick specimen the ledge should not exceed $^3/_4$ in. [19 mm] for a 10-in. [254-mm] or larger mouth (square or circular) or $^1/_8$ in. [3 mm] for a 5-in. [127-mm] mouth (square or circular). For a 3-in. [76-mm] mouth (square or circular) the ledge should not exceed 0.11 in. [2.8 mm] wide.

## 5意义与用途

5.1这些测试方法的目标是：用简单的仪器获得可信的渗透和半渗透材料的水蒸气透过性能数值，并以合适的单位表达。这些数值用于设计、制造和营销。一种测试条件下获得的渗透性数值不能说明其它条件下的数据。因此，应该选择最接近使用环境的测试条件。各种测试环条件均可使用，并记录在报告中。附录X1列举了诸多标准测试条件。

## 6仪器

6.1测试杯--测试杯材料须耐腐蚀、不透水和水蒸气。测试杯可为任何形状，质量尽量小。优选大而浅的测试杯，但尺寸与质量应控制在能让分析天平检测出其微小的重量变化。测试杯开口大小据实际情况选择，但至少3000 $mm^2$(4.65 $in.^2$)。干燥剂或水的面积不应小于测试杯的口径，使用格栅时，如12.1中所示，其有效面积不应超过杯口面积的10%。沿着口径外沿固定试样，有利于防止试样收缩和卷曲。

当试样面积超过杯口时，杯口边缘的重叠部分是一个误差来源，尤其是厚的试样。试样的杯口边缘重叠区应按10.1中所示进行遮挡，以便口径的大小决定测试面积。材料的重叠区导致产生了更多的水透量，从而导致正误差。误差的大小是厚度、边宽、口径、透湿性的复杂函数。Joy和Wilson对此进行过讨论（详见13.4.3）。

此类误差应控制在10到12%内。对于厚型样品，测试杯边缘宽度应当遵循下述限制：

| 测试杯口径（方形或圆形杯） | 测试杯外缘宽度 |
|---|---|
| ≥254 mm(10 in.) | < 19 mm(0.75 in.) |
| 127 mm(5 in.) | 3 mm(1/8in.) |
| 76 mm(3 in.) | 2.8mm(0.11in.) |

An allowable ledge may be interpolated for intermediate sizes or calculated according to Joy and Wilson.**(1)** A rim around the ledge (Fig. X2.1) may be useful. If a rim is provided, it shall be not more than 1/4 in. [6 mm] higher than the specimen as attached. Different depths may be used for the Desiccant Method and Water Method, but a 3/4-in. [19-mm] depth (below the mouth) is satisfactory for either method.

6.2 *Test Chamber*—The room or cabinet where the assembled test dishes are to be placed shall have a controlled temperature (see Note 1) and relative humidity. Some standard test conditions that have been useful are given in Appendix X1. The temperature chosen shall be determined according to the desired application of the material to be tested (see Appendix X1). The relative humidity shall be maintained at 50±2%, except where extremes of humidities are desired, when the conditions shall be 100±1.8°F [38± 1°C] and 90±2% relative humidity. Both temperature and relative humidity shall be measured frequently or preferably recorded continuously. Air shall be continuously circulated throughout the chamber, with a velocity sufficient to maintain uniform conditions at all test locations. The air velocity over the specimen shall be between 0.066 and 1 ft/s [0.02 and 0.3 $m \cdot s^{-1}$]. Suitable racks shall be provided on which to place the test dishes within the test chamber.

NOTE 1—Simple temperature control by heating alone is usually made possible at 90°F [32°C]. However, it is very desirable to enter the controlled space, and a comfortable temperature is more satisfactory for that arrangement. Temperatures of 73.4°F [23°C] and 80°F [26.7°C] are in use and are satisfactory for this purpose. With cyclic control, the average test temperature may be obtained from a sensitive thermometer in a mass of dry sand. The temperature of the chamber walls facing a specimen over water should not be cooler than the water to avoid condensation on the test specimen.

6.3 *Balance and Weights*—The balance shall be sensitive to a change smaller than 1 % of the weight change during the period when a steady state is considered to exist. The weights used shall be accurate to 1 % of the weight change during the steady-state period (Note 2). A light wire sling may be substituted for the usual pan to accommodate a larger and heavier load.

对于其它口径的测试杯，用中间插值法或根据Joy和Wilson(1)的方法计算出允许的边缘宽度。沿着边缘装一个环是有用的 (Fig. X2.1)。若使用环，则环高不应超出安装样品厚度的1/4 in (6mm)。干燥剂法和水法的测试杯深度可以不同，但3/4in. (19mm)的深度（低于杯口）对二者均合适.

6.2测试室--放置测试杯组合体的实验室或者箱体，应当控制温度（见注1）和相对湿度。附录X1中给出一些标准测试条件。温度的选择应根据被测材料需要的应用来决定(见附录X1)。相对湿度应保持在50±2%，除非要求使用极端的湿度，此时测试条件将是38±1℃(100±1.8°F)的温度和90±2%的相对湿度。

温度和相对湿度都应经常测量，并尽量连续记录。测试箱内空气应持续循环流动，其速度应能保证箱体内所测试位置均保持相同的环境。流过试样上方的风速应为：0.02~0.3m/s (0.066~1ft/s)。测试箱内应提供合适的杯架，用于放置透湿杯。

注 1--单单加热这样的这样温控就能将温度控制在 32℃(90°F)。但是，将测试杯安置在一个受控空间，一个舒适的温度会更能令人满意。23℃(73.4°F)或 26.7℃(80°F)的温度正是为此目标而使用。循环控制时，平均测试温度可用埋在干沙中的温度计测量。面对水面上试样的测试箱壁（测试箱顶板）的温度不应低于水温，以避免试样上的冷凝。

6.3天平和称量--在透过稳定状态持续到试验结束的过程中，天平感量应小于重量变化的1%。在透过稳定的时间里，称重应精确到重量变化的1%（注2）。在天平中用轻质金属吊环取代称重托盘以适应更大或更重的称重需求。

6.4 *Thickness-Measuring Gage*—The nominal thickness of the specimen shall be determined using a thickness-measuring gage with an accuracy of ±1 % of the reading or 0.0001 in. [0.0025 mm], whichever is greater.

NOTE 2—For example: 1-perm [57 ng·Pa$^{-1}$·s$^{-1}$·m$^{-2}$] specimen 10 in. [254 mm] square at 80°F [26.7°C] passes 8.6 grains or 0.56 g/day. In 18 days of steady state, the transfer is 10 g. For this usage, the balance must have a sensitivity of 1 % of 10 g or 0.1 g and the weights must be accurate to 0.1 g. If, however, the balance has a sensitivity of 0.2 g or the weights are no better than 0.2 g. the requirements of this paragraph can be met by continuing the steady state for 36 days. An analytical balance that is much more sensitive will permit more rapid results on specimens below 1 perm [57 ng·Pa$^{-1}$·s$^{-1}$·m$^{-2}$] when the assembled dish is not excessively heavy.

## 7. Materials

7.1 Desiccant and Water:

7.1.1 For the Desiccant Method, anhydrous calcium chloride in the form of small lumps 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 (Note 3). It shall be dried at 400°F [200°C] before use.

NOTE 3—If CaCl2 will react chemically on the specimen, an adsorbing desiccant such as silica gel, activated at 400°F [200°C], may be used; but the moisture gain by this desiccant during the test must be limited to 4 %.

7.1.2 For the Water Method, distilled water shall be used in the test dish.

7.2 Sealant—The sealant used for attaching the specimen to the dish, in order to be suitable for this purpose, must be highly resistant to the passage of water vapor (and water). It must not lose weight to, or gain weight from, the atmosphere in an amount, over the required period of time, that would affect the test result by more than 2 %. It must not affect the vapor pressure in a water-filled dish. Molten asphalt or wax is required for permeance tests below 4 perms [230 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$]. Sealing methods are discussed in Appendix X2.

6.4 测厚仪----使用精确度为示值的±1%或者最小读数为 0.0025mm (0.0001in.)（取更精确的）的厚度测量仪。

注2--例如：透过系数为1-perm (57ng.Pa$^{-1}$s$^{-1}$m$^{-2}$)且边长为254mm (10in.)正方形的试样，在26.7℃(80ºF)的温度下，水透量为0.56g或8.6grains /天。在18天稳定状态中，水蒸气透过质量为10g。因此，天平灵敏度应达到10g的1%或0.1g。称重必须精准到0.1g。但是，若天平灵敏度为0.2g而称重精确度不高于0.2g时，要达到本节要求，则可将稳定状态时间延长到36天。在测试杯组件不太重的时候，更灵敏的分析天平对于透过系数低于1 perm (57ng.Pa$^{-1}$s$^{-1}$m$^{-2}$)的试样，能更快地得到结果。

7.材料

7.1干燥剂和水

7.1.1干燥剂法，使用可通过NO.8 [2.36mm (0.1in.)]的颗粒状和通过NO.30[600µm]筛网的粉末状无水$CaCl_2$(注3)。使用前应在200℃(400º F)的烘箱内烘干。

注3-若CaCl2会与试样上发生化学反应，则可选用在200℃(400º F)干燥过的硅胶；但这种干燥剂在测试中的水气吸收量必须控制在4%以下。

7.1.2水法，测试杯应使用蒸馏水。

7.2密封胶--密封胶用于将试样封装在测试杯上。为达到密封的功效，密封胶须具有优异的阻止水蒸气(和水）穿透的性能。密封胶在大气中因吸收而增加或因释放而减少的质量，在需要的测试时间内影响测试结果的比例，不得超过2%。密封胶还不得影响装水的测试杯内的水蒸气压力。在透过量低于4 perms[230 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$]时，需要使用熔融的沥青或蜡。密封方法将在附录X2中讨论。

## 8. Sampling

8.1 The material shall be sampled in accordance with standard methods of sampling applicable to the material under test. The sample shall be of uniform thickness. If the material is of nonsymmetrical construction, the two faces shall be designated by distinguishing marks (for example, on a oneside-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 sides of a product are indistinguishable, three specimens shall be tested by the same method. When the sides of a product are different and either side may face the vapor source, four specimens shall be tested by the same method, two being tested with the vapor flow in each direction and so reported.

9.2 A slab, produced and used as a laminate (such as a foamed plastic with natural “skins”) may be tested in the thickness of use. Alternatively, it may be sliced into two or more sheets, each being separately tested and so reported as provided in 9.4, provided also, that the “overlay upon the cup ledge” (6.1) of any laminate shall not exceed 1⁄8 in. [3 mm].

9.3 When the material as used has a pitted or textured surface, the tested thickness shall be that of use. When it is homogeneous, however, a thinner slice of the slab may be tested as provided in 9.4.

9.4 In either case (9.2 or 9.3), 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, and its tested permeance shall be not greater than 5 perms [≈ 300 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$].

9.5 For homogeneous (not laminated) materials with thickness greater than 1⁄2 in., the overall nominal thickness of each specimen shall be measured with an accuracy of ±1%ofthe reading at the center of each quadrant and the results averaged.

8取样

8.1 材料的取样应根据材料的标准取样方法进行。样品的厚度应一致。如果材料结构不对称，应用两个明显的标志区分材料的两个面（例如，涂覆样品表面，“I”表示涂层面，“II”表示无涂层面）。

9试样

9.1试样应具备测试材料的代表性。当一个产品设计成单向时，应使用同一方法测试3个试样在指定方向上的水蒸气透过。如果产品各面不加区分，用同一方法测试3个试样。如果产品各面不同并且每面均会与水蒸气接触，应使用同一方法测试4个试样，在每个水蒸气渗透方向测试2个试样，并记录。

9.2复合成型片材（如有着天然“皮肤”的泡沫塑料）可以按使用厚度进行测试。或者，也可将片材剥离成两层或更多层，按节9.4所述，每层单独测试并报告。此外，要求复合膜在测试杯边缘重叠区（节6.1）不应超过不可超过3mm(1/8in.)。

9.3当使用的材料表面不平整或者有纹路，按实际使用的厚度测试。但若材质是均匀的，则可将片材切薄片，再按9.4测试。

9.4在9.2和9.3两种情况下，测试的总厚度，如果小于实际使用的厚度，那么至少5倍于两面最大凹坑深度之和，并且其透过量应小于5 perms [≈ 300 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$]。

9.5 对于厚度超过12.7mm(0.5in.)的均质材料(非复合)，需测量每个试样的四个象限中心的厚度，精确到示值的±1%，并取平均值。

9.6 When testing any material with a permeance less than 0.05 perms [3 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$] or when testing a low permeance material that may be expected to lose or gain weight throughout the test (because of evaporation or oxidation), it is strongly recommended that an additional specimen, or "dummy," be tested exactly like the others, except that no desiccant or water is put in the dish. Failure to use this dummy specimen to establish modified dish weights may significantly increase the time required to complete the test. Because time to reach equilibrium of water permeance increases as the square of thickness, thick, particularly hygroscopic, materials may take as long as 60 days to reach equilibrium conditions.

## 10. Attachment of Specimen to Test Dish

10.1 Attach the specimen to the dish by sealing (and clamping if desired) 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, exposed to conditioned air so that its exposure duplicates the mouth shape and size and is directly above it. A template is recommended for locating the mask. Thoroughly seal the edges of the specimen to prevent the passage of vapor into, or out of, or around the specimen edges or any portion thereof. The same assurance must apply to any part of the specimen faces outside their defined areas. Suggested methods of attachment are described in Appendix X2.

NOTE 4—In order to minimize the risk of condensation on the interior surface of the sample when it is placed in the chamber, the temperature of the water prior to preparation of the test specimen should be within ±2°F [±1°C] of the test condition.

## 11. Procedure for Desiccant Method

11.1 Fill the test dish with desiccant within 1/4 in. [6 mm] of the specimen. Leave enough space so that shaking of the dish, which must be done at each weighing, will mix the desiccant.

11.2 Attach the specimen to the dish (see 10.1) and place it in the controlled chamber, specimen up, weighing it at once. (This weight may be helpful to an understanding of the initial moisture in the specimen.)

9.6 在测试透过量小于0.05 perms [3 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$]的材料时，或者需要考虑测试过程中材料重量的降少或者增加（因蒸发或氧化）的低透过材料时，强烈推荐使用一个额外的试样，即“空白样”，该试样和其它样品一样，应进行精确测试，不同之处是，空白样的测试杯内既没有干燥剂也没有水。若不使用空白样进行测试杯的重量修正，将会显著增加完成测试所需时间。由于水蒸气透过达到平衡的时间随厚度的平方增长，对于厚型材料，特别是吸湿的材料，达到透过平衡的时间将长达60天。

## 10试样安装到测试杯

10.1将试样安装到测试上并密封（需要时应夹紧），实现由测试杯的开口决定试样暴露到杯内水蒸气的面积。如有必要，用一个试样罩来罩住试样上表面，并置于测试杯口上方，然后放置在受控环境中，这样罩子暴露的部分就复制了测试杯口的形状与尺寸。建议使用一个模板以定位样品罩。彻底密封试样的边缘，防止水蒸气沿边缘部位或其它部位进入或渗出。须用同样的方法确保密封住试样的任何规定渗透范围以外的部位。建议的安装方法见附录X2。

注4:测试杯组件放置在测试腔内，为了最小化样品内表面冷凝的风险，在安装样品之前，测试杯内的水温应达到达到测试温度的±1℃(2°F)。

## 11干燥剂法的测试流程

11.1测试杯内装入干燥剂至试样面6mm(0.25in.)以内。留下足够的空间，以便摇晃测试杯混匀干燥剂。每次称重时必须摇晃。

11.2将试样安装在测试杯上(见10.1)。把测试杯放入受控的实验箱内，试样向上，并立刻称重。（这次称重有助于了解试样的初始湿度）。

11.3 Weigh the dish assembly periodically, often enough to provide eight or ten data points during the test. A data point is the weight at a particular time. The time that the weight is made should 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 would be allowed. At first the weight may change rapidly; later a steady state will be reached where the rate of change is substantially constant. Weighings should be accomplished without removal of the test dishes from the controlled atmosphere, but if removal is prescribed necessary, the time the specimens are kept at different conditions, temperature or relative humidity, or both, should be kept to a minimum. When results of water vapor transmission are expected to be less than 0.05 perm [3 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$], a dummy specimen is strongly recommended. Such a dummy specimen should be attached to an empty cup in the normal manner. The environmental effects of temperature variation and buoyancy variability due to barometric pressure fluctuation can be arithmetically tared out of the weighing values. This precaution permits earlier and more reliable achievement of equilibrium conditions. Analyze the results as prescribed in 13.1.

11.4 Terminate the test or change the desiccant before the water added to the desiccant exceeds 10 % of its starting weight. This limit cannot be exactly determined and judgement is required. The desiccant gain may be more or less than the dish weight-gain when the moisture content of the specimen has changed.

NOTE 5—The WVT of some materials (especially wood) may depend on the ambient relative humidity immediately before the test. An apparent hysteresis results in higher WVT if the prior relative humidity was above the test condition and vice versa. It is therefore recommended that specimens of wood and paper products be conditioned to constant weight in a 50 % relative humidity atmosphere before they are tested. Some specimens may be advantageously preconditioned to minimize the moisture that the specimen will give up to the desiccant. This applies when the specimen is likely to have high moisture content or when it is coated on the top (vapor source) side.

11.3周期性称量测试杯组件。一次测试通常8到10个数据就足够了。一个数据点是指测试杯组件在一个特定时间的重量。称重时间要记录，并精确到连续两次称重的时间间隔的1%左右。因此，如果每小时称重一次，时间记录到最近的30s；如果每天称重一次，时间记录要到最近的15分钟。开始重量变化变化较快；过段时间后重量变化率基本恒定，系统进入一个稳定状态。称重应在测试杯不离开受控环境的条件下完成。如果测试杯必须离开受控环境，那么试样放置不在同温度、相对湿度环境的时间应尽量最短。当水蒸气透过系数小于0.05 perm [3 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$]时，强烈推荐使用空白样。这个空白样应以通常的方式安装在一个空杯上。环境温度的变化、大气压力导致的浮力的变化，可以根据空白样的质量变化在数字上扣除。这个预防措施允许更早、更可靠地达到平衡状态。分析结果见13.1。

11.4 在干燥剂的吸湿量超过初始质量的10%时，结束试验，或者更换干燥剂。这个限制不能精确确定，需要判断。当试样的含水量发生变化时，干燥剂的增重可能大于也可能少于测试杯的增重。

注5---某些材料的WVT（特别是木材）取决于测试前材料所处环境的相对湿度。如果测试前材料处于环境的相对湿度比测试时大，明显的迟滞会导致较高WVT，反之亦然。因此建议，木质和纸质试样造纸在测试前应放置在50%相对湿度的大气环境中调节至恒重。某些试样应预置以最小化试样释放到干燥剂的水分。这种预置运用在含水量可能很高的试样或者顶面（水蒸气进入面）有涂层的试样。

## 12. Procedure for Water Method

12.1 Fill the test dish with distilled water to a level 3/4 ± 1/4 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 1/8 in. [3 mm] to ensure coverage of the dish bottom throughout the test. However, if the dish is of glass, its bottom must be visibly covered at all times but no specific depth is required. Water surges may be reduced by placing a grid of light noncorroding material in the dish to break the water surface. This grid shall be at least 1/4 in. [6 mm] below the specimen, and it shall not reduce the water surface by more than 10 %.

NOTE 6—For the Water Method, baking the empty dish and promptly coating its mouth with sealant before assembly is recommended. The water may be added most conveniently after the specimen is attached, through a small sealable hole in the dish above the water line.

12.2 Attach the specimen to the dish (see 10.1). Some specimens are likely to warp and break the seal during the test. The risk is reduced by preconditioning the specimen, and by clamping it to the dish ledge (if one is provided).

12.3 Weigh the dish assembly and place it in the controlled chamber on a true horizontal surface. Follow the procedure given in 11.3. If the test specimen cannot tolerate condensation on the surface, the dish assembly shall not be exposed to a temperature that differs by more than 5°F [3°C] from the control atmosphere to minimize the risk of condensation on the specimen. When results of water vapor transmission are expected to be less than 0.05 perm [3 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$], a dummy specimen is strongly recommended. Such a dummy specimen should be attached to an empty cup in the normal manner. The environment effects of temperature variation and buoyancy variability due to barometric pressure fluctuation can be arithmetically tared out of the weighing values. This precaution permits earlier and more reliable achievement of equilibrium conditions. Analyze the results as prescribed in 13.1.

## 12水法的测试流程

12. 1测试杯内加注蒸馏水，液面距离试样19±6 mm [3/4 ± 1/4 in.]。有必要保留的一个空气空间，尽管这部分空气对水蒸气有一定阻力，但可以减少处理测试杯时水接触到试样的风险。对纸张、木头和其它亲水的材料，水的接触将使得测试无效。水深应不低于3 mm [1/8 in.]，确保整个测试过程中覆盖测试杯底。但若测试杯是玻璃的，则在任何时间可以看到杯底即可，不需要规定水深。在测试杯内，用一个轻质面耐腐蚀材质的栅格划分水面，可以减少水的波动。这个栅格低于试样至少6 mm [1/4 in.]，且水面面积的减少不得超过10%。

注 6—对于水法，建议装配透湿杯组件前，先烘干空测试杯，并用密封脂快还涂抹在测试杯开口。安装试样后，通过杯上高于水面且可密封的小孔，可以非常方便地向杯内加水。

12.2将试样安装在测试杯上（见10.1）。某些材料在测试时可能卷曲，破坏密封。这种风险可以通过预置试样和将试样夹紧到测试杯边缘（如果有）来防范。

12.3 称量测试杯组件，并将水平放置在受控的测试箱内。按 13.1 的流程进行。如果试样不能耐受冷凝，那么为了最小化试样上冷凝的风险，测试杯组件不能暴露在受控测试环境温差大于 3°C [5°F]的环境。当预计水蒸气透过系数小于 0.05 perm [3 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$]时，强烈推荐使用空白样。空白样以正常方式安装在空测试杯上。环境温度的变化、大气压力导致的浮力的变化，可以根据空白样的质量变化在数字上扣除。这个预防措施允许更早、更可靠地达到平衡状态。分析结果见13.1。

12.4 Where water is expected to be in contact with the barrier in service, proceed as in 11.3 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. With highly permeable specimens it is especially important to locate the test dish so that air circulates over the exposed surface at the specified velocity. The test dishes may be placed on the balance in the upright position for weighing, but the period during which the wetted surface of the specimen is not covered with water must be kept to a minimum.

12.4 当使用中要求水与防水层直接接触时，将测试杯倒置，其它按 11.3 操作。测试杯须足够水平，以水覆盖试样的内表面，即便试样因水重力而产生各种形变。特别重要的是，放置好测试杯，以便空气环流以规定的速度流经暴露在外的试样表面。测试杯可以正立放置（杯底向下）在天平上称量，但试样的湿润面不覆盖水的时间须保持最短。（译注：倒杯法）

## 13. Calculation and Analysis of Results

13.1 The results of the rate of water vapor transmission may be determined either graphically or numerically.

13.1.1 *Dummy Specimen*—If a dummy specimen has been used to compensate for variability in test conditions, due to temperature or barometric pressure, or both, the daily recorded weights can be adjusted by calculating the weight change from initial to time of weighing. This adjustment is reversing the direction of the dummy's weight change, relative to its initial weight, and modifying all the appropriate specimen weight(s) recorded at this time. This permits earlier achievement of equilibrium conditions. An alternate procedure, particular for tests of long duration and more than six weighings, is to subtract the arithmetic mean slope of the rate of weight change of the dummy specimen from the arithmetic mean slope of each similar specimen to get an effective rate of weight change. These procedures are also desirable if the specimen is changing weight due to a curing process while under test.

13.1.2 *Graphic Analysis*—Plot the weight, modified by the dummy specimen when used, against elapsed time, and inscribe a curve that tends to become straight. Judgment here is required and numerous points are helpful. When 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), a nominally steady state is assumed, and the slope of the straight line is the rate of water vapor transmission.

## 13.结果计算与分析

13.1水蒸气透过率的结果可用图表或者数字来确定。

13.1.1空白样--如果使用空白样来补偿由于温度和大气压力而导致的测试环境变化，每天记录的重量可以通过计算当前重量与初始重量的变化来调整。将空白样重量相对于初始重量的变化量取负，然后用此数值修正同一时间的全部对应试样的重量。这样处理可以更早在达到平衡条件。一个可选的方法，特别是对长测试时间和超过6次称重的试验，可以从每个相似试样的算术平均斜率中减去空白样的算术平均斜率，从而得到有效的重量变化。如果试样在测试时因熟化而产生重量变化，这些处理过程也很有必要。

13.1.2图表分析--画一条重量与时间曲线，逐渐趋于一条直线。重量经过空白样修正（如果有空白样），时间是测试时长。此时需要判断，数据点多更有帮助。画出一条直线至少需要6个合适间隔数据点（定期称量的重量变化，20%达到或者灵敏度100倍），此时达到基本稳定的状态，直线的斜率即是水蒸气透过率。

13.1.3 *Numerical Analysis*—A mathematical least squares regression analysis of the weight, modified by the dummy specimen when used, as a function of time will give the rate of water vapor transmission. An uncertainty, or standard deviation of this rate, can also be calculated to define the confidence band. For very low permeability materials, this method can be 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.

13.2 Calculate the water vapor transmission, WVT, and permeance as follows:

13.2.1 Water Vapor Transmission:

$$WVT=G/tA=(G/t)/A \quad (1)$$

where:

In inch-pound units:

G = 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

WVT = rate of water vapor transmission, grains/h·$ft^2$.

In metric units:

G = 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

WVT = rate of water vapor transmission, g/h·$m^2$.

13.2.2 Permeance:

$$Permeance= WVT/\Delta p=WVT/S/(R_1-R_2) \quad (2)$$

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

13.1.3 数值分析---用最小二乘回归的数学方法分析重量-时间函数，可以给出水蒸气透过率，其中重量经过空白样调整（如果有空白样）。水蒸气透过率不确定度，或者标准偏差，也能计算出来，并定义置信区间。对于极低透过性材料，会经过30-60 天测试并用灵敏度约为 1mg 的分析天平称量。这种方法能确定此情况的水蒸气透过量，即使重量的变化不满足 6.3 要求的 100 倍灵敏度。这些试样应在报告中详细指明。

13.2 计算水蒸气透过率 WVT、透过量和透过性：

13.2.1 水蒸气透过率

$$WVT=G/tA=(G/t)/A \quad (1)$$

其中：

英制单位：

G =质量变化，grains (源自直线)，

t = G产生时对应的时间， h，

G/t = 直线的斜率，grains/h，

A = 测试面积（测试杯口的面积），$ft^2$，

WVT=水蒸气透过率，grains/h·$ft^2$，

公制单位：

G =质量变化（源自直线），g，

t =时间，h，

G/t = 直线的斜率，g/h，

A = 测试面积（测试杯口的面积），$ft^2$，

WVT=水蒸气透过率，g/h·$m^2$。

13.2.2 透过量

$$透过量= WVT/\Delta p=WVT/S/(R_1-R_2) \quad (2)$$

其中，

英制单位：

Δp= 水蒸气分压差，in. Hg；

S = 测试温度下的饱和水蒸气分压，in. Hg，

$R_1$=试样的水蒸气源侧相对湿度，以百分数表达（干燥剂法为测试室的相对湿度，水法为杯内的相对湿度）；

$R_2$ = relative humidity at the vapor sink expressed as a fraction.

In metric units:

Δp = vapor pressure difference, mm Hg (1.333 × $10^2$ Pa),

S = saturation vapor pressure at test temperature, mm Hg (1.333 × $10^2$ 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.

13.2.3 In the controlled chamber the relative humidity and temperature are the average values actually measured during the test and (unless continuously recorded) these measurements shall be made as frequently as the weight measurements. 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).

13.3 The calculation of permeability is optional and can be done only when the test specimen is homogeneous (not laminated) and not less than $^{1}/_{2}$ in. [12.5 mm] thick, calculate its average permeability as follows:

*Average permeability=Permeance ×Thickness* (3)

13.4 *Corrections*—It is important that all applicable corrections be made to all measurements that result in permeance value more than 2-perm [114 ng·$Pa^{-1}$·$s^{-1}$·$m^{-2}$]. Corrections for materials with permeance value below 2-perm [114 ng·$Pa^{-1}$·$s^{-1}$·$m^{-2}$] are insignificant and need not be done **(2)**. The procedures for making various corrections, as summarized below, are found in the literature. **(2, 3, 4, 5, 6)**

$R_2$=试样的水蒸气吸收侧相对湿度，以百分数表达（干燥剂法为测试杯内的相对湿度，水法中为测试室内的相对湿度）；

公制单位：

Δp= 水蒸气分压差，in. Hg(1.333×$10^2$Pa)；

S = 测试温度下的饱和水蒸气分压，in. Hg(1.333×$10^2$Pa)，

$R_1$=试样的高湿侧（干燥剂法为测试室，水法为测试杯内）的相对湿度，百分数表达；

$R_2$=试样的低湿侧（干燥剂法为测试杯内，水法中为测试室内）的相对湿度，百分数表达；

13.2.3在受控测试室内，温度和相对湿度是测试过程中的实际测量值的平均值（除非未连续记录）。这些测量应和称重一样频繁。测试杯内的相对湿度在干燥剂时为0%，在水法时为100%。在试样透过量低于4 perms [230 ng·$Pa^{-1}$·s-$^{1}$·$m^{-2}$]且要求的环境（$CaCl_2$吸湿不超过10%；杯内水面距离试样不超过25 mm [1 in.]）能保持时，这些值通常与实际的相对湿度相差3%以内。

13.3 透过系数的计算可选，且仅当试样是均质（非复合）及厚度不低于 12.5 mm [$^{1}/_{2}$ in.]才可进行。计算平均透过系数如下：

*Average permeability=Permeance ×Thickness* (3)

13.4 修正--对于结果透过量超过 2-perm [114 ng· $Pa^{-1}$ ·$s^{-1}$ ·$m^{-2}$]的所有测试，应用全部的修正很重要的。对于透过量低于 2-perm [114 ng· $Pa^{-1}$ ·$s^{-1}$ ·$m^{-2}$] 的材料来说，修正不显著，因而不必修正(2)。下面总结的各种修正方法的过程，可以文献(2,3,4,5,6)中找到。

13.4.1 *Buoyancy Correction*—The duration for one set of measurements can be many days or weeks. The atmospheric pressure may significantly change during such periods. If the test specimen is highly vapor resistant, the changes in mass due to vapor transport may be overshadowed by the apparent gravimetric changes observed. In such cases, all gravimetric data should be corrected to vacuum or any base line pressure. The following equation **(3)** can be used for buoyancy correction.

$$\frac{m_2}{m_1} = 1 + \frac{\rho_a(\rho_1 - \rho_2)}{\rho_1(\rho_2 - \rho_a)} \quad (4)$$

where:

$m_1$ = mass recorded by balance, kg,

$m_2$ = mass after buoyancy correction, kg,

$\rho_a$ = density of air, kg $m^{-3}$,

$\rho_1$ = density of material of balance weights, kg $m^{-3}$, and

$\rho_2$ = bulk density of test assembly, kg $m^{-3}$.

13.4.1.1 The density of air can be calculated using the ideal gas law for the measured atmospheric pressure and ambient temperature.

13.4.1.2 The buoyancy correction is important **(7)** when measured mass changes are in the range of 0 to 100 mg.

13.4.2 *Corrections for Resistance due to Still Air and Specimen Surface*—In general, if the material is highly permeable, these corrections are more significant. With known thickness of the still air layer in the cup, the corresponding vapor resistance can be calculated using the following equation **(4)** for permeability.

$$\delta_a = \frac{2.306\times10^{-5} P_0}{R_v T P}\left(\frac{T}{273.15}\right)^{1.81} \quad (5)$$

where:

$\delta_a$ = permeability of still air, kg·$m^{-1}$·$s^{-1}$·$Pa^{-1}$,

$T$ = temperature, K,

$P$ = ambient pressure, Pa,

$P_o$ = standard atmospheric pressure, that is, 101325 Pa, and

13.4.1 浮力修正--一套测试的时长可以持续几天到几周。在测试期间大气压力可能显著变化。如果试样是高阻水性的，因水蒸气透过而产生的质量变化可能被观察到的显著重力变化所遮掩。此时，所有的重力数据应修正到真空或者某一基准压力。下式（3）用于浮力修正：

$$\frac{m_2}{m_1} = 1 + \frac{\rho_a(\rho_1 - \rho_2)}{\rho_1(\rho_2 - \rho_a)} \quad (4)$$

其中：

$m_1$= 天平记录的质量，kg，

$m_2$= 浮力修正后的质量，kg，

$\rho_a$= 空气密度，kg $m^{-3}$，

$\rho_1$= 天平砝码的材料密度，kg $m^{-3}$，

$\rho_2$= 测试杯组件的体积密度，kg $m^{-3}$。

13.4.1.1空气密度可用测到的大气压力和环境温度根据理想气体公式计算。

13.4.1.2当测量到的质量变化在0-100mg以内时浮力修正很重要。

13.4.2静止空气与试样表面的阻隔修正--通常如果材料是高透过性的，这些修正就很重要。已知测试杯内静止空气层的厚度，对应的水蒸气阻抗可按式（4)计算。

$$\delta_a = \frac{2.306\times10^{-5} P_0}{R_v T P}\left(\frac{T}{273.15}\right)^{1.81} \quad (5)$$

其中：

$\delta_a$= 静止空气的透过系数， kg·$m^{-1}$·$s^{-1}$·$Pa^{-1}$，

$T$= 温度， K，

$P$= 环境压力，Pa，

$P_o$= 标准大气压力，即101325 Pa，

$R_v$ = ideal gas constant for water, that is, 461.5 $J \cdot K^{-1} \cdot kg^{-1}$.

13.4.2.1 In the absence of any measured data, the surface resistances (that is, inside and outside surfaces of the specimen) may be approximated using Lewis' relation.**(5)** For cup methods that follow this standard, the total surface resistance (Hansen and Lund **(6)**) should be ≈ $4\times10^{7}$ $Pa \cdot s \cdot m^{2} \cdot kg^{-1}$.

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

$$\text{Perc excessWVT} = \frac{400 \cdot t}{\pi S_1} \log_e \left( \frac{2}{1 + e^{-(2\pi b/t)}} \right)$$

(6)

where:

$t$ = specimen thickness, m,

$b$ = width of masked edge, m, and

$S_1$ = four times the test area divided by the perimeter, m.

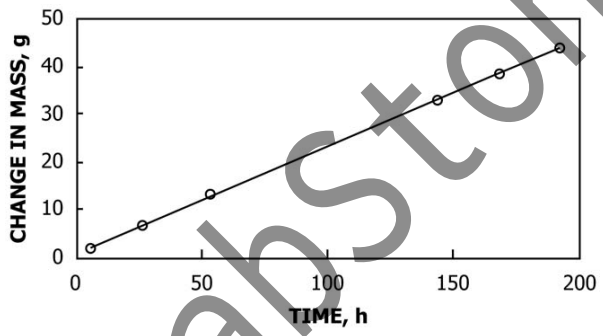


**FIG. 1**

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

13.5 Metric units and conversion factor are given in Table 1.

13.6 *Example (in SI unit)*—In a desiccant test on a sample of medium density glass fiber insulation the following results were recorded.

Thickness of the specimen = 25.81 mm

Test area = 0.01642 $m^2$

Mass of the test specimen = 20.44 g

$R_V$ =水的理想汽化能常数,为 461.5 $J \cdot K^{-1} \cdot kg^{-1}$。

13.4.2.1由于缺少测量数据，表面阻隔量（试样的内、外表面）可用Lewis'公式（5）估算。对遵循本标准的杯式法，总的表面阻隔量（Hansen and Lund **(6)**）约为$4\times10^{7}$ $Pa \cdot s \cdot m^{2} \cdot kg^{-1}$。

13.4.3**边缘罩修正**--下式（Joy and Wilson**(1)**）用于修正边缘罩产生的额外水蒸气透过量：

$$\text{Perc excessWVT} = \frac{400 \cdot t}{\pi S_1} \log_e \left( \frac{2}{1 + e^{-(2\pi b/t)}} \right)$$

（6）

其中：

$t$ =试样厚度， m,

$b$ = 边缘罩宽度， m

$S_1$ = 4×测试面积/周长， m。

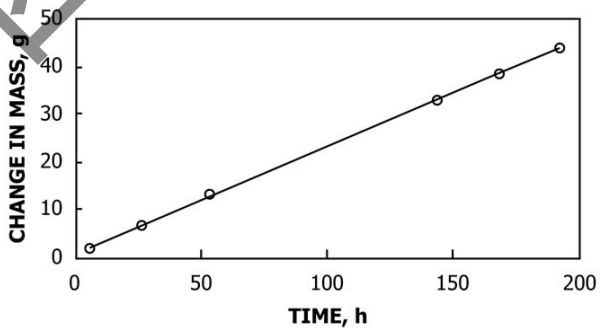


**图 1**

13.4.3.1 如果测试杯组件包括了边缘罩，那么应该进行修正。

13.5 公制单位和换算系数在表 1 中给出.

13.6 例子(英制单位)--一个中等密度玻璃纤维隔热材料样品用干燥剂法测试结果记录如下。

样品的厚度 =25.81mm

测试面积 =0.01642$m^2$

试样质量 =20.44g

Mass of the desiccant = 554.8 g

Initial mass of the test assembly = 1.257810 kg

Thickness of air layer in the cup = 15 mm

| Elapsed Time (h) | Mass of the Test Assembly (g) | Change in Mass (g) | Chamber Temperatur (°C) | Chamber RH (% ) | Barometric Pressure mm Hg (kPa) |
|---|---|---|---|---|---|
| 0.000 | 1257.810 | 0.000 | 22.83 | 52.60 | 744.7 (99.27) |
| 6.067 | 1259.469 | 1.659 | 22.84 | 52.6 | 741.11 (98.79) |
| 26.633 | 1264.609 | 6.799 | 22.78 | 52.2 | 744.41 (99.23) |
| 53.150 | 1271.062 | 13.252 | 22.82 | 52.1 | 743.21 (99.07) |
| 143.767 | 1290.773 | 32.963 | 22.74 | 52.2 | 757.69 (101.00) |
| 168.283 | 1296.389 | 38.579 | 22.78 | 52.1 | 749.81 (99.95) |
| 192.883 | 1301.953 | 44.143 | 22.78 | 52.1 | 758.44 (101.10) |

13.6.1 *Buoyancy Correction*—As mentioned in 13.4.1, the buoyancy effect will be insignificant for this set of readings as recorded changes of mass are all above 100 mg. However, for example, the corrected mass of the test assembly weight 1257.810 g (1st reading) can be calculated using Eq 4.

$m_1$ =mass recorded by balance, kg=1257.81×$10^{-3}$ kg

P = Barometric pressure, Pa = 99.27 × $10^{3}$ Pa

R = Gas constant for dry air = 287.055 J / (kg·K)

T = Chamber temperature = 22.83 + 273.15 = 295.98 K

$\rho_a$ = density of air, kg $m^{-3}$ = P / (RT) = 1.1684 kg $m^{-3}$

$\rho_1$ = density of material of balance weights, kg $m^{-3}$ = 8000 kg $m^{-3}$

h1 = height of the test assembly, m = 44.7 × $10^{-3}$ m

d1 = diameter of the test assembly, m=168.0×$10^{-3}$ m

$\rho_2$ = bulk density of test assembly, kg $m^{-3}$

$$= \frac{4 \times m_1}{\pi \times d_1^2 \times h_1} = 1269.4 \text{ kg m}^{-3}$$

$m_2$=mass after buoyancy correction=1258.8×$10^{-3}$ kg

13.6.2 A graphic analysis of the data, according to 13.1.2 is shown in Fig. 1.

干燥剂质量 =554.8g;

测试杯组初始质量 =1.257810kg

杯内空气层厚度 =15mm

| 测试时长 (h) | 杯组件质量 (g) | 质量变化 (g) | 测试箱温度 (°C) | 测试箱湿度 (% ) | 大气压力 mm Hg (kPa) |
|---|---|---|---|---|---|
| 0.000 | 1257.810 | 0.000 | 22.83 | 52.60 | 744.7 (99.27) |
| 6.067 | 1259.469 | 1.659 | 22.84 | 52.6 | 741.11 (98.79) |
| 26.633 | 1264.609 | 6.799 | 22.78 | 52.2 | 744.41 (99.23) |
| 53.150 | 1271.062 | 13.252 | 22.82 | 52.1 | 743.21 (99.07) |
| 143.767 | 1290.773 | 32.963 | 22.74 | 52.2 | 757.69 (101.00) |
| 168.283 | 1296.389 | 38.579 | 22.78 | 52.1 | 749.81 (99.95) |
| 192.883 | 1301.953 | 44.143 | 22.78 | 52.1 | 758.44 (101.10) |

13.6.1浮力修正--如13.4.1所述，当全部的记录读数的质量变化均超过100mg时，浮力修正是不显著的。下例为一个测试杯组合件质量为1257.810 g（第一次称量）的修正用公式（4）的计算。

$m_1$=天平称量记录的质量， kg=1257.81×$10^{-3}$ kg

P= 大气压力，Pa = 99.27 × $10^{3}$ Pa

R= 干燥空气的热能常数 = 287.055 J / (kg·K)

T= 测试箱温度= 22.83 + 273.15 = 295.98 K

$\rho_a$= 空气密度，kg $m^{-3}$ = P / (RT) = 1.1684 kg $m^{-3}$

$\rho_1$= 天平平衡物（砝码）的密度， kg $m^{-3}$ = 8000 kg $m^{-3}$

h1= 测试杯组件的高度， m = 44.7 × $10^{-3}$ m

d1= 测试杯组件的直径， m=168.0×$10^{-3}$ m

$\rho_2$= 测试杯组件的密度， kg $m^{-3}$

$$= \frac{4 \times m_1}{\pi \times d_1^2 \times h_1} = 1269.4 \text{ kg m}^{-3}$$

$m_2$=浮力修正后的质量=1258.8×$10^{-3}$ kg

13.6.2 根据13.1.2，用图表分析数据，如图1所示。

13.6.3 A linear least-squares analysis of the data according to 13.1.3 gives the slope of the straight line as 0.225±0.002 $g \cdot h^{-1}$, with a linear regression coefficient > 0.998.

WVT = 0.225 $g \cdot h^{-1} / 0.01642\ m^2$

= 19.595 $grains \cdot h^{-1} \cdot ft^{-2}$

≈3.81 × $10^6$ $ng \cdot m^{-2} \cdot s^{-1}$

S = 2775.6 Pa

$R_1$ = 0.523

$R_2$ = 0

Permeance = 3.81 × $10^6$ $ng \cdot m^{-2} \cdot s^{-1}$ /(2775.6 Pa ×0.523)

= 2630 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

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

Permeability of still air layer (Eq 5)

$$= \delta_a = \frac{2.306\times10^{-5}\times101325}{461.5\times(22.5+273.15)\times99860}\left(\frac{22.5+273.15}{273.15}\right)^{1.81}$$

= 198 $ng \cdot m^{-1} \cdot s^{-1} \cdot Pa^{-1}$

Permeance of 15 mm still air layer

= (198) / (0.015) $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

= 13200 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

Hence, the 15 mm air layer offers a vapor resistance

= 1 / (13200) $m^2 \cdot s \cdot Pa \cdot ng^{-1}$

≈7.6 × $10^7$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

Surface resistances (see 13.4.2)

≈4.0 × $10^7$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

Total corrections for resistance due to still air and specimen surface

= (7.6 × $10^7$ + 4.0 × $10^7$) $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

13.6.5 *Edge Mask Correction*—The test assembly used does not include any edge masking. However, for example, if it includes an edge mask of width 5 mm correction is to be made (see 13.4.3).

t = specimen thickness, m =25.81 × $10^{-3}$ m

b= width of masked edge, m = 5 × $10^{-3}$ m

Test area = 0.01642 $m^2$

Perimeter = 0.4541 m

$S_1$ = four times the test area divided by the perimeter

$$= \frac{4\times0.01642}{0.4541} = 0.1446m$$

13.6.3根据13.1.3，用线性最小二乘法分析数据，给出直线的斜率范围为0.225±0.002$g.h^{-1}$，线性回归系数大于0.998。

水蒸气透过率（WVTR）= 0.225 $g \cdot h^{-1} / 0.01642\ m^2$

= 19.595 $grains \cdot h^{-1} \cdot ft^{-2}$

≈3.81 × $10^6$ $ng \cdot m^{-2} \cdot s^{-1}$

S = 2775.6 Pa

$R_1$ = 0.523

$R_2$ = 0

水蒸气透过量 = 3.81 × $10^6$ $ng \cdot m^{-2} \cdot s^{-1}$ /(2775.6 Pa ×0.523)

= 2630 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

13.6.4 静止空气与试样表面的阻隔量修正

静止空气的透过系数(Eq 5)

$$= \delta_a = \frac{2.306\times10^{-5}\times101325}{461.5\times(22.5+273.15)\times99860}\left(\frac{22.5+273.15}{273.15}\right)^{1.81}$$

= 198 $ng \cdot m^{-1} \cdot s^{-1} \cdot Pa^{-1}$

15 mm静止空气层的水蒸气透过量

= (198) / (0.015) $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

= 13200 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

于是，15 mm静止空气层的阻隔量

= 1 / (13200) $m^2 \cdot s \cdot Pa \cdot ng^{-1}$

≈7.6 × $10^7$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

试样表面的阻隔量（(见13.4.2）

≈4.0 × $10^7$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

静止空气与试样表面阻隔量的总修正值

= (7.6 × $10^7$ + 4.0 × $10^7$) $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

13.6.5边缘罩的修正--常用的测试杯组件不包含边缘罩。但在下例，若测试杯组件包含了一个宽度为5mm的边缘罩，则修正将按以下进行。

t = 试样厚度， m =25.81 × $10^{-3}$ m

b=边缘罩宽度， m = 5 × $10^{-3}$ m

测试面积= 0.01642 $m^2$

周长 = 0.4541 m

$S_1$ = 4×测试面积/周长

$$= \frac{4\times0.01642}{0.4541} = 0.1446m$$

Percent excess WVT

$$= \frac{400 \times 25.81 \times 10^{-3}}{\pi \times 0.1446} \log_e \left( \frac{2}{1 + e^{-(2\pi \times 5 \times 10^{-3})/(25.81 \times 10^{-3})}} \right)$$

=9.86%

13.6.6 The applicable corrections required for the analysis of the test results in this case are due to resistance of still air and specimen surface.

Water vapor resistance of the test specimen + corrections

= 1 / Permeance = (1 / 2630) $m^2 \cdot s \cdot Pa \cdot ng^{-1}$

= $3.80 \times 10^8$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

The water vapor resistance of the test specimen

= $(3.80 \times 10^8 - (7.6 \times 10^7 + 4.0 \times 10^7))$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

= $2.64 \times 10^8$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

Permeance of the test specimen

= $1 / (2.64 \times 10^8\ m^2 \cdot s \cdot Pa \cdot kg^{-1})$

= $3.79 \times 10^{-9}$ $kg \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

= 3790 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

Permeability

= 3790 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1} \times 0.02581$ m

= 97.8 $ng \cdot m^{-1} \cdot s^{-1} \cdot Pa^{-1}$

## 14. Report

14.1 The report shall include the following:

14.1.1 Identification of the material tested, including product thickness for homogeneous materials (not laminated) greater than 1/2 in.,

14.1.2 Test method used (desiccant or water),

14.1.3 Test temperature,

14.1.4 Relative humidity in the test chamber,

14.1.5 Permeance of each specimen in perms (to two significant figures),

14.1.6 The side of each specimen on which the higher vapor pressure was applied. (The sides shall be distinguished as “side A” and “side B” when there is no obvious difference between them. When there is an obvious difference, this difference shall also be stated, such as “side A waxed” and “side B unwaxed.”),

14.1.7 The average permeance of all specimens tested in each position,

额外增加的水蒸气透过量百分比

$$= \frac{400 \times 25.81 \times 10^{-3}}{\pi \times 0.1446} \log_e \left( \frac{2}{1 + e^{-(2\pi \times 5 \times 10^{-3})/(25.81 \times 10^{-3})}} \right)$$

=9.86%

13.6.6 本例中静止空气和试样表面的阻隔量导致的测试结果分析所需适当修正。

试样的阻隔量 + 修正量

= 1 / Permeance = (1 / 2630) $m^2 \cdot s \cdot Pa \cdot ng^{-1}$

= $3.80 \times 10^8$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

试样的水蒸气阻隔量

= $(3.80 \times 10^8 - (7.6 \times 10^7 + 4.0 \times 10^7))$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

= $2.64 \times 10^8$ $m^2 \cdot s \cdot Pa \cdot kg^{-1}$

试样的水蒸气透过量

= $1 / (2.64 \times 10^8\ m^2 \cdot s \cdot Pa \cdot kg^{-1})$

= $3.79 \times 10^{-9}$ $kg \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

= 3790 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

试样的透过系数

= 3790 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1} \times 0.02581$ m

= 97.8 $ng \cdot m^{-1} \cdot s^{-1} \cdot Pa^{-1}$

## 14报表

14.1报表应包括以下内容：

14.1.1被测材料的识别，包括厚度大于1/2 in.的均质材料（非复合）的产品厚度；

14.1.2测试方法（干燥剂法或者水法）；

14.1.3测试温度；

14.1.4测试箱的相对湿度；

14.1.5每个试样的水蒸气透过量，以Perms为单位（保持两位有效数字）；

14.1.6每个试样的承受高水蒸气压的一面。（当试样两面没有明显差异时，试样面可以区分为“A面”和“B面”。当试样两面有明显差异时，应当标明差异，比如“A面-蜡”和“B面-无蜡”。）

14.1.7每个部位上全部试样的平均透过量；

14.1.8 The permeability of each specimen (as limited by 13.3), and the average permeability of all specimens tested,

14.1.9 Include a portion of the plot indicating the section of the curve used to calculate permeability, and

14.1.10 State design of cup and type or composition of sealant.

## 15. Precision and Bias

15.1 *Precision*—Table 2 is based on interlaboratory tests conducted in 1988 and 1991.[5] In 1988 four materials (A, B, C, D) were tested using the dessicant 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 dessicant method and the water method. Tables 3 and 4 are based on another interlaboratory test conducted in 1995–96.**(8)** 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.

15.1.1 Test results were analyzed using Practice E691.

15.2 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 permeance 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 analysis of the data; the details are given in ASTM Research Report No. C16-1040.[6]

15.2.1 *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 different operators using different equipment in different laboratories.

14.1.8每个试样的透过系数（按13.3要求），所有被测试样的平均透过系数；

14.1.9包括用于计算透过系数的曲线部分的图表；

14.1.10标明测试杯的设计、密封脂的类型或成份。

## 15精度与偏差

15.1精度--表2基于多个实验室在1988年和1991年进行的测试数据。1988年用干燥剂法测和水法测试测试了四种材料（A，B，C，D），每种材料3个试样。15个实验室贡献了数据，4个实验室给出了可靠的所有数据。1991年10个实验贡献了材料E的数据，使用了3个试样，运用干燥剂法和水法两种方法。表3和表4基于另一次多个实验室在1995-1996进行的测试（8）。10个参与实验室，对一种名义厚度为25 mm (1 in.)的材料进行测试。仅有9个有实验室的数据用于分析，因为第十个实验室是以严格的局外观察者（规范E691）的身份出现的。

15.1.1 用规范 E691 分析测试结果。

15.2 测试方法的附加精度数据与分析，建立在2010 年进行的多个实验室的研究基础之上。6 个实验室参与此次研究，分析了 4 个不同的特别低透过的材料。流程 A，采用了 73°F/50% RH 的干燥剂法。每个报告的“测试结果”代表了一个独立的测量，所有的参与者均报告了每种材料的 3 个重复测试结果。实验设计与数据分析，遵循了规范 E691；详细情况在 ASTM 研究报告 No. C16-1040 中给出。

15.2.1 重复性极限（r）--从一个实验获得的两个测试结果，若其差异大于 r，应判定不一致。“r”表示同一种材料在不同实验室里、不同操作员、用不同设备获得的两个测试结果的最大差异。

15.2.1.1 Repeatability limits are listed in Table 5 below.

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

15.2.4 Any judgment in accordance with statements 9.1.1 and 9.1.2 would have an approximate 95% probability of being correct.

15.3 The precision statement was determined through statistical examination of 72 test results, submitted by six laboratories, for four materials. The four materials were described as:

Material A: 6 mil high barrier PVDC-based film

Material B: 10 mil high barrier PVDC-based film

Material C: 15 mil high barrier HDPE-based film

Material D: PET film/1 mil aluminum foil/PET film lamination

15.4 To judge the equivalency of two test results, it is recommended to choose the material that is closest in characteristics to the test material.

15.5 Using information from this ILS, Appendix section X3 discusses the testing of extremely low permeance materials.

**16. Keywords**

16.1 permeability; plastics (general); plastic sheet and film; sheet material; thermal-insulating materials; thermal insulation permeability films; water vapor transmission (WVT)

15.2.1重复性极限列于表5。

15.2.3上文术语（重复性极限和重现性极限）按规范E177使用。

15.2.4依据陈述9.1.1和9.1.2进行的判定，正确的概率约为95%。

15.3精度描述取决于来自6个试验室4种材料的72个测试数据的统计检验。这些材料分别是：

材料A：6 mil高阻隔的PVDC膜

材料B：10mil高阻隔的PVDC膜

材料C：15mil高阻隔的HDPE膜

材料D：PET/1mil铝箔/PET复合膜

15.4为了判定两个测试结果的一致性，推荐选择与测试材料的特征最接近的材料。

15.5附录X3讨论了特别低透过材料的测试。

16关键词

16.1透过系数；塑料（通用）；塑料片与膜；片材；隔热材料；隔热渗透膜；水蒸气透过率

**TABLE 2 Results on Precision from Interlaboratory Testing**

| For Desiccant Method at 23°C | | | Repeatability | | | Reproducibility | | |
|---|---|---|---|---|---|---|---|---|
| Material | Thickness (mm)[A] | Mean Permeance ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] | s ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] | CV (%) | LSD ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] | s ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] | CV (%) | LSD ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] |
| **A** | 0.0254 | 34.7 | 0.95 | 2.7 | 2.70 | 5.60 | 16.2 | 15.90 |
| **B** | 0.1397 | 0.74 | 0.16 | 21.7 | 0.46 | 0.31 | 42.6 | 0.92 |
| **C** | 12.7000 | 3.51 | 0.25 | 7.2 | 0.69 | 1.06 | 30.2 | 2.80 |
| **D** | 25.4000 | 44.8 | 1.50 | 3.3 | 4.20 | 3.50 | 7.8 | 10.00 |
| **E** | 0.3556 | 2.64 | 0.13 | 5.0 | 0.40 | 0.31 | 11.7 | 0.86 |
| For Water Method at 23°C | | | Repeatability | | | Reproducibility | | |
| Material | Thickness (mm)[A] | Mean Permeance ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] | s ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] | CV (%) | LSD ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] | s ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] | CV (%) | LSD ($ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$)[B] |
| **A** | 0.0254 | 40.91 | 0.77 | 1.9 | 2.20 | 8.90 | 21.8 | 25.20 |
| **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 | 1.10 | 20.1 | 3.10 |
| **D** | 25.4 | 59.50 | 1.10 | 1.8 | 3.10 | 12.40 | 20.9 | 35.50 |
| **E** | 0.3556 | 3.40 | 0.19 | 5.7 | 0.57 | 0.47 | 13.8 | 1.30 |

[A] 1 in. = 25.4 mm

[B] 1 perm (inch-pound) =1 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$

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=2s

NOTE 1—Material B was Teflon[5] 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 ($ng \cdot m^{-1} \cdot s^{-1} \cdot Pa^{-1}$)*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-01 | -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 |
| | | | | $\bar{\bar{x}}$ | $s_r$ | $s_x$ | $s_R$ | |
| | | | | 3.10 | 1.63E-01 | 4.69E-01 | 4.87E-01 | |

**TABLE 2 多实验室测试结果的精度分析**

| 干燥剂法（23°C） | | | 重复性 | | | 重现性 | | |
|---|---|---|---|---|---|---|---|---|
| 材料 | 厚度 (mm)[A] | 平均透过量 $(ng·m^{-2}·s^{-1}·Pa^{-1})^B$ | 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 | 2.70 | 5.60 | 16.2 | 15.90 |
| **B** | 0.1397 | 0.74 | 0.16 | 21.7 | 0.46 | 0.31 | 42.6 | 0.92 |
| **C** | 12.7000 | 3.51 | 0.25 | 7.2 | 0.69 | 1.06 | 30.2 | 2.80 |
| **D** | 25.4000 | 44.8 | 1.50 | 3.3 | 4.20 | 3.50 | 7.8 | 10.00 |
| **E** | 0.3556 | 2.64 | 0.13 | 5.0 | 0.40 | 0.31 | 11.7 | 0.86 |
| 水法（23°C） | | | Repeatability | | | Reproducibility | | |
| 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 | 2.20 | 8.90 | 21.8 | 25.20 |
| **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 | 1.10 | 20.1 | 3.10 |
| **D** | 25.4 | 59.50 | 1.10 | 1.8 | 3.10 | 12.40 | 20.9 | 35.50 |
| **E** | 0.3556 | 3.40 | 0.19 | 5.7 | 0.57 | 0.47 | 13.8 | 1.30 |

[A] 1 in. = 25.4 mm

[B] 1 perm (英寸-磅) =1 $ng·m^{-2}·s^{-1}·Pa^{-1}$

缩写：

S = 标准差；

CV = 百分差异系数 (s × 100/ Mean)；

LSD =基于95%置信水平的两个单独测试的最小显著差；

注1--材料B是Teflon PTFE（聚四氟乙烯）。这种材料特别难找到合适密封脂，这导致较差的重复性。

**TABLE 3 实验室间测试数据精度分析—发泡聚苯乙烯的干燥杯测量**

| 实验室 | 透过系数$(ng·m^{-1}·s^{-1}·Pa^{-1})^A$ | | | $\bar{x}$ | s | d | h | k |
|---|---|---|---|---|---|---|---|---|
| | 规格#1 | 规格 #2 | 规格#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-01 | -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 |
| | | | | $\bar{\bar{x}}$ | $s_r$ | $s_x$ | $s_R$ | |
| | | | | 3.10 | 1.63E-01 | 4.69E-01 | 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$^{-1}$.

**TABLE 4 Results on Precision from Interlaboratory Testing—Wet 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 | 2.90 | 3.14 | 2.94 | 2.99 | 1.29E-01 | -3.58E-01 | -0.94 | 0.77 |
| 2 | 3.50 | 3.46 | 3.52 | 3.49 | 3.06E-02 | 1.43E-01 | 0.37 | 0.18 |
| 3 | 4.23 | 3.76 | 3.65 | 3.88 | 3.08E-01 | 5.29E-01 | 1.39 | 1.84 |
| 5 | 3.32 | 3.29 | 2.97 | 3.19 | 1.94E-01 | -1.58E-01 | -0.41 | 1.16 |
| 6 | 2.61 | 2.82 | 2.80 | 2.74 | 1.16E-01 | -6.08E-01 | -1.59 | 0.69 |
| 7 | 3.53 | 3.18 | 3.41 | 3.37 | 1.77E-01 | 1.92E-02 | 0.05 | 1.06 |
| 8 | 3.30 | 3.42 | 3.29 | 3.34 | 7.23E-02 | -1.42E-02 | -0.04 | 0.43 |
| 9 | 3.75 | 3.97 | 3.67 | 3.80 | 1.55E-01 | 4.46E-01 | 1.17 | 0.93 |
| | | | | | | | | |
| | | | | $\bar{\bar{x}}$ | $s_r$ | $s_x$ | $s_R$ | |
| | | | | 3.35 | 1.67E-01 | 3.82E-01 | 4.06E-01 | |

[A] 1 perm in. = 1.45 ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$

Legend:

$\bar{x}$ = Cell average or the average from one laboratory

s = Cell standard deviation, or the standard deviation for one laboratory

$\bar{\bar{x}}$ = Average of the Cell averages

d = Cell deviation or the difference ( $\bar{x} - \bar{\bar{x}}$ )

$s_r$ = Repeatability standard deviation (within a laboratory)

$s_R$ = Reproducibility standard deviation (between the laboratories)

h = the between-laboratory consistency statistic

k = the within-laboratory consistency statistic

NOTE 1—The average of the cell averages gives the permeability for the round robin material, according to the wet cup measurements, as 3.35 ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$.

NOTE 2—The repeatability standard deviation is 1.7 × 10$^{-01}$ ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$.

NOTE 3—The reproducibility standard deviation is 4.1 × 10$^{-01}$ ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$.

**TABLE 5 Water Vapor Transmission (perms) ILS #512**

| Material | Average[A] | Repeatability Standard Deviation | Reproducibility Standard Deviation | Repeatability Limit | Reproducibility Limit |
|---|---|---|---|---|---|
| | $\bar{x}$ | sr | $s_R$ | r | R |
| A | 0.00877 | 0.00166 | 0.00336 | 0.00465 | 0.00940 |
| B | 0.00843 | 0.01067 | 0.01067 | 0.02988 | 0.02988 |
| C | 0.02028 | 0.01698 | 0.01698 | 0.04756 | 0.04756 |
| D | 0.00567 | 0.00938 | 0.00967 | 0.02626 | 0.02706 |

[A] The average of the laboratories' calculated averages.

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

注1—按干燥杯法测试，各腔平均值的平均值给出透过系数为：3.10 ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$。

注2—重复性标准差为： $1.6 \times 10^{-1}$ ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$。

注3—重现性标准差为： $4.9 \times 10^{-1}$ ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$。

**TABLE 4实验室间测试数据精度分析—发泡聚苯乙烯的湿杯测量**

| 实验室 | 透过系数 (ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$)[A] | | | $\bar{x}$ | s | d | h | k |
|---|---|---|---|---|---|---|---|---|
| | 规格 #1 | 规格#2 | 规格#3 | | | | | |
| 1 | 2.90 | 3.14 | 2.94 | 2.99 | 1.29E-01 | -3.58E-01 | -0.94 | 0.77 |
| 2 | 3.50 | 3.46 | 3.52 | 3.49 | 3.06E-02 | 1.43E-01 | 0.37 | 0.18 |
| 3 | 4.23 | 3.76 | 3.65 | 3.88 | 3.08E-01 | 5.29E-01 | 1.39 | 1.84 |
| 5 | 3.32 | 3.29 | 2.97 | 3.19 | 1.94E-01 | -1.58E-01 | -0.41 | 1.16 |
| 6 | 2.61 | 2.82 | 2.80 | 2.74 | 1.16E-01 | -6.08E-01 | -1.59 | 0.69 |
| 7 | 3.53 | 3.18 | 3.41 | 3.37 | 1.77E-01 | 1.92E-02 | 0.05 | 1.06 |
| 8 | 3.30 | 3.42 | 3.29 | 3.34 | 7.23E-02 | -1.42E-02 | -0.04 | 0.43 |
| 9 | 3.75 | 3.97 | 3.67 | 3.80 | 1.55E-01 | 4.46E-01 | 1.17 | 0.93 |
| | | | | $\bar{\bar{x}}$ | $s_r$ | $s_x$ | $s_R$ | |
| | | | | 3.35 | 1.67E-01 | 3.82E-01 | 4.06E-01 | |

[A] 1 perm in. = 1.45 ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$

缩写：

$\bar{x}$ = 腔平均值，或者一个实验室的平均值；

s = 腔标准差，或者一个实验室的标准差；

$\bar{\bar{x}}$ = 各腔均值的平均值；

d = 腔偏差或者差值 ($\bar{x} - \bar{\bar{x}}$)；

$s_r$ = 重复性标准差 (实验室内部)

$s_R$ = 重现性标准差 (实验室之间)

h = 实验室之间一致性系数；

k = 实验室内部一致性系数。

注1—按湿杯法测量，各腔平均值的平均值给出透过系数为：3.35 ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$。

注2—重复性标准差为：$1.7 \times 10^{-01}$ ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$。

注3—重现性标准差为：$4.1 \times 10^{-01}$ ng·m$^{-1}$·s$^{-1}$·Pa$^{-1}$。

**TABLE 5 水蒸气透过量 (perms) ILS #512**

| 材料 | 平均值[A] | 重复性标准差 | 重现性标准差 | 重复性极差 | 重现性极差 |
|---|---|---|---|---|---|
| | $\bar{x}$ | $s_r$ | $s_R$ | r | R |
| A | 0.00877 | 0.00166 | 0.00336 | 0.00465 | 0.00940 |
| B | 0.00843 | 0.01067 | 0.01067 | 0.02988 | 0.02988 |
| C | 0.02028 | 0.01698 | 0.01698 | 0.04756 | 0.04756 |
| D | 0.00567 | 0.00938 | 0.00967 | 0.02626 | 0.02706 |

[A] 各实验室的平均值再平均。

## APPENDIXES (Nonmandatory Information)

### X1. STANDARD TEST CONDITIONS

X1.1 Standard test conditions that have been useful are:

X1.1.1 *Procedure A*—Desiccant Method at 73.4°F [23°C].

X1.1.2 *Procedure B*—Water Method at 73.4°F [23°C].

X1.1.3 *Procedure BW*—Inverted Water Method at 73.4°F [23°C].

X1.1.4 *Procedure C*—Desiccant Method at 90°F [32.2°C].

X1.1.5 *Procedure D*—Water Method at 90°F [32.2°C].

X1.1.6 *Procedure E*—Desiccant Method at 100°F [37.8°C].

X1.2 Unless otherwise prescribed by regulation, specification, ASTM standard, or other governing document, select test conditions similar to those to which the material will be exposed to actual use.

### X2. CUP DESIGN AND SEALING METHODS

X2.1 An ideal sealing material has the following properties:

X2.1.1 Impermeability to water in either vapor or liquid form.

X2.1.2 No gain or loss of weight from or to the test chamber (evaporation, oxidation, hygroscopicity, and water solubility being undesirable).

X2.1.3 Good adhesion to any specimen and to the dish (even when wet).

X2.1.4 Complete conformity to a rough surface.

X2.1.5 Compatibility with the specimen and no excessive penetration into it.

X2.1.6 Strength or pliability (or both).

X2.1.7 Easy handleability (including desirable viscosity and thermal of molten sealant).

X2.1.8 Satisfactory sealants possess these properties in varying degrees and the choice is a compromise, with more tolerance in items at the beginning of this list for the sake of those at the latter part of the list when the requirements of 7.2 are met. Molten asphalt or wax is required for permeance tests below 4 perms [240 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$]. Tests to determine sealant behavior should include:

X2.1.8.1 An impervious specimen (metal) normally sealed to the dish and so tested, and

X2.1.8.2 The seal normally assembled to an with no specimen and so tested.

X2.2 The following materials are recommended for general use when the test specimen will not be affected by the

temperature of the sealant:

X2.2.1 Asphalt, 180 to 200°F [82 to 93°C] softening point, meeting the requirements of Specification D449/D449M, Type C. Apply by pouring.

X2.2.2 Beeswax and rosin (equal weights).A temperature of 275°F [135°C] is desirable for brush application. Pour at lower temperature.

X2.2.3 Microcrystalline wax (60 %), mixed with refined crystalline paraffin wax (40 %).

## 附录 (非强制性信息)

### X1. 标准测试条件

X1.1 已用的标准测试条件如下：

X1.1.1 流程A—干燥剂法，温度23°C [73.4°F]。

X1.1.2 流程B—水法，温度23°C [73.4°F]。

X1.1.3 流程BW—倒杯法，温度23°C [73.4°F]。

X1.1.4 流程C—干燥剂法，温度32.2°C [90°F]。

X1.1.5 流程D—水法，温度32.2°C [90°F]。

X1.1.6 流程E—干燥剂法，温度37.8°C [100°F]。

X1.2 如无另行规定和特别说明，ASTM标准或者其它政府文件，应选择与材料实际使用环境相似的测试条件。

### X2. 测试杯设计与密封方法

X2.1 理想的密封材料应具以下特性：

X2.1.1不渗透液态水或者气态水蒸气；

X2.1.2不从测试箱增加或减少重量（不能有：蒸发、氧化、吸湿、水溶）。

X2.1.3对试样和测试的良好附着力（即使是湿的）。

X2.1.4 对粗糙表面的完全贴合能力。

X2.1.5与试样相容且无额外的穿透性。

X2.1.6强度或者柔韧性（或者两者兼备）。

X2.1.7易处理 (包括适合的黏稠和密封剂的热熔性）。

X2.1.8满意的密封剂在一定程度上拥有这些特性，并且选择是一个折衷的过程，需要更多考虑本清单前述条款，以方便本清单后半部内容，同时满足7.2。须用熔化的沥青或蜡来测试低于4 perms [240 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$] 的透过性。测定密封剂性状应包括：

X2.1.8.1 一个不透过的试样（金属）密封到测试杯并测试，

X2.1.8.2 密封剂集成到一个无样品的空测试杯并测试。

X2.2 当试样不受密封剂的温度影响时，推荐使用下列材料作为普通检测用：

X2.2.1沥青，82 to 93°C [180 to 200°F] 软化点，满足规范 D449/D449M, Type C的要求。倾倒使用。

X2.2.2蜂蜡和柏油（对半分）。在刷涂使用时需要达到温度135°C [275°F]。低温倾倒。

X2.2.3微晶蜡（60%），混合精练的微晶石蜡 (40 %)。

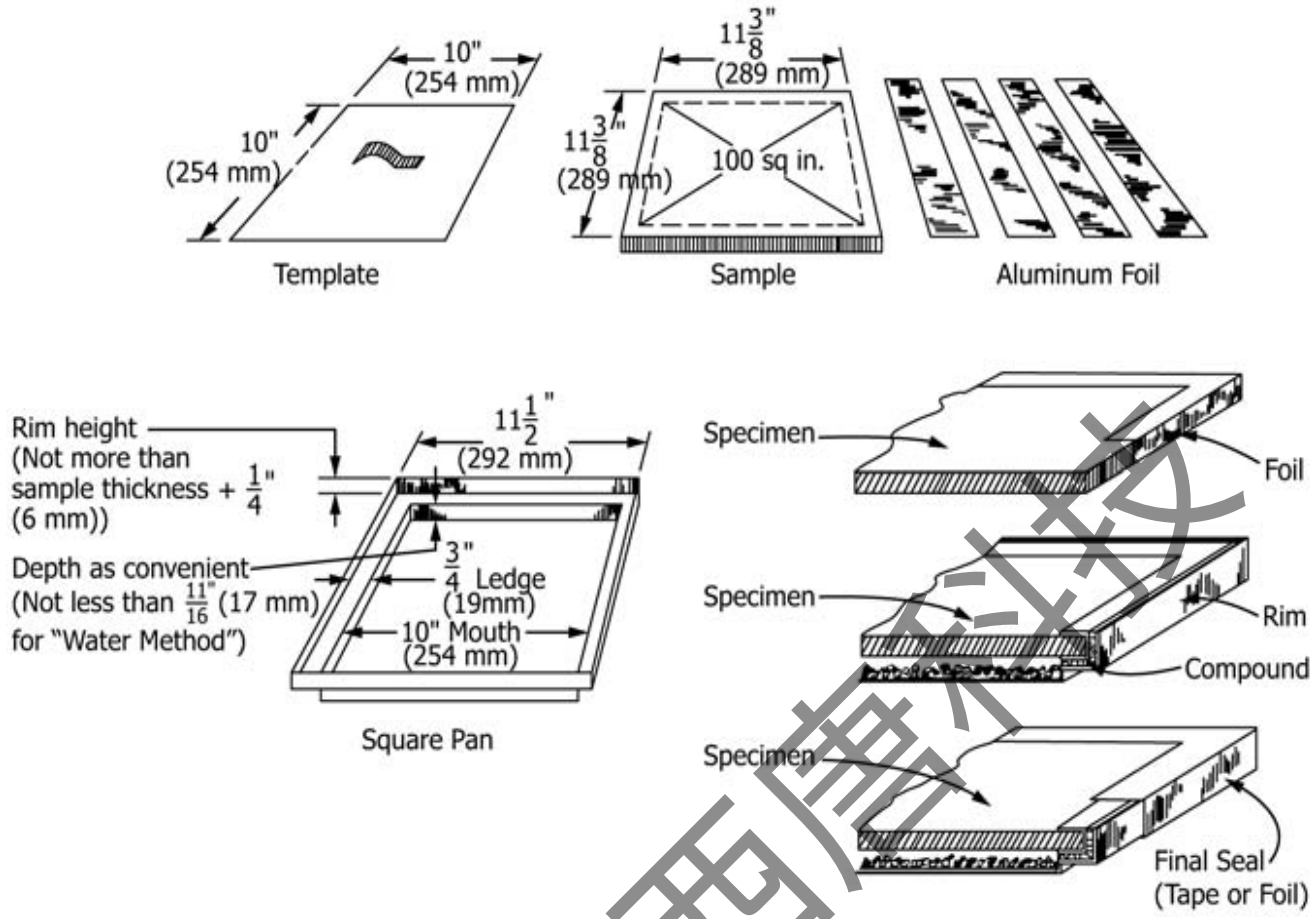


**FIG. X2.1 Apparatus for Water Vapor Transmission Tests of Large Thick Specimens**

X2.3 The materials listed in X2.3.1 are recommended for particular uses such as those shown in Fig. X2.1. The suggested procedure described in X2.3.2 applies to an 11 3/8-in. [289-mm] square specimen if its permeance exceeds 4 perms [240 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$] (limited by evaporation of sealants).

X2.3.1 *Materials:*

X2.3.1.1 Aluminum foil, 0.005 in. [0.125 mm] minimum thickness.

X2.3.1.2 Tape, meeting the requirements of Specification D2301, vinyl chloride plastic pressure-sensitive, electrical insulating tape.

X2.3.1.3 Cement, contact bond, preferably rubber base.

X2.3.2 *Procedure:*

X2.3.2.1 *Step 1*—Seal aluminum foil around edges of specimen, leaving a 100-in.$^2$ [0.0654-m$^2$] exposed test area on each side. Use contact bond cement as directed by the manufacturer.

X2.3.2.2 *Step 2*—Spread sealant on inside of rim and ledge. Place desiccant (dry), or water and surge control material (wet) in pan. Press specimen in place. Avoid squeezing compound into the test area.

X2.3.2.3 *Step 3*—Coat outside of rim and bottom of ledge with contact bond cement, and place foil strips from edge of template, around rim, and bottom of ledge.

X2.4 A method of using hot asphalt, as applied to a 10-in. [254-mm] square-mouth dish with ledge and rim, is as follows:

X2.4.1 *Apparatus:*

X2.4.1.1 *Template*—A square frame of brass or steel, 3/16 in. [5 mm] thick and 3/4 in. [19 mm] deep. The 3/16-in. [5-mm] thickness is tapered to zero at the bottom of the frame where it will touch the test specimen and maintain a 10-in. [254-mm] square test area.

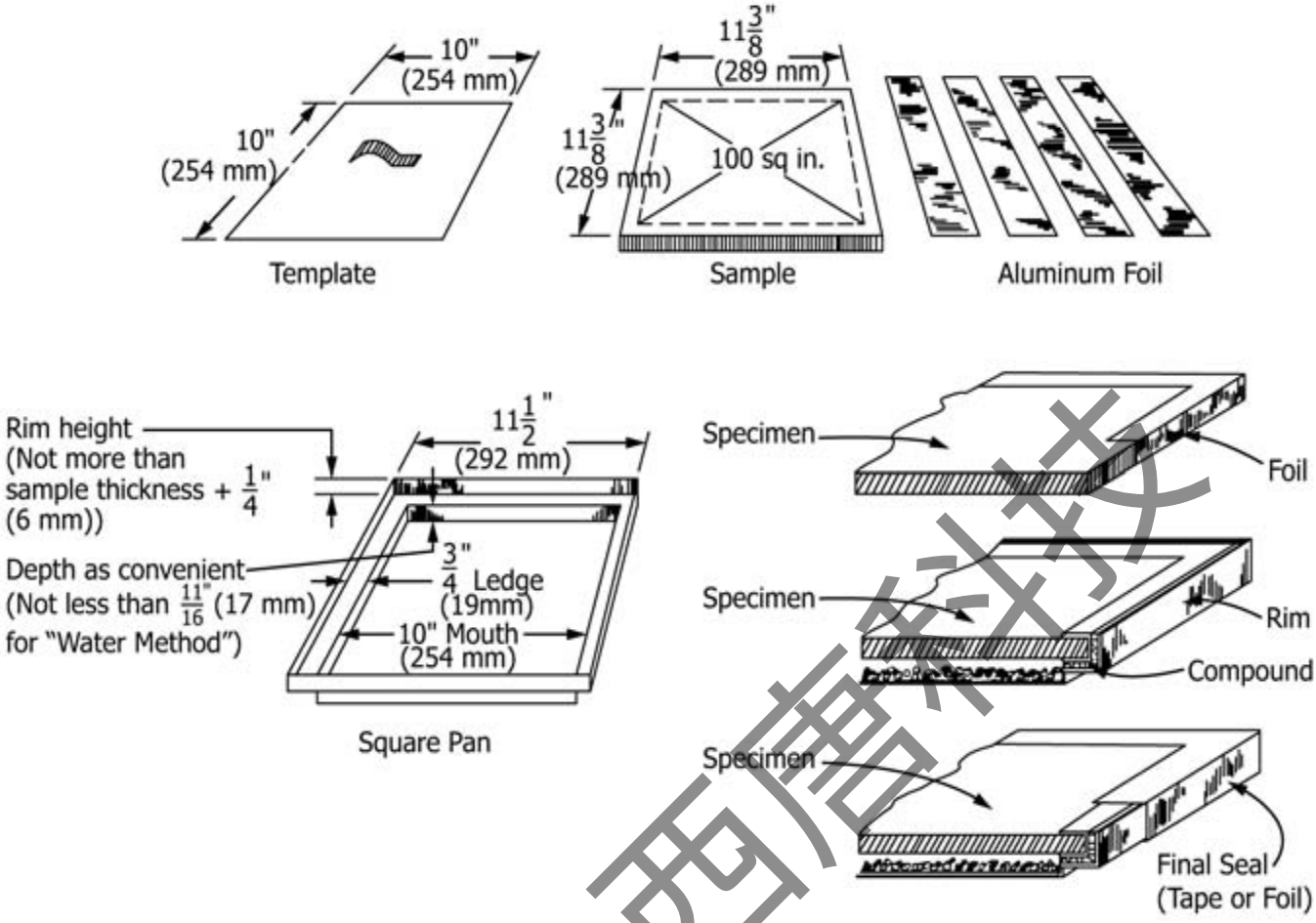


**FIG. X2.1 大尺寸厚型试样的水蒸气透过测试装置**

X2.3 推荐使用列于X2.3.1的材料特别用于图X2.1。建议的流程在X2.3.2中写明，应用于透过量超过4 perms [240 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$]（密封剂蒸发性的限制）的11 3/8-in. [289-mm] 方形试样测试。

X2.3.1 材料：

X2.3.1.1 铝箔，厚度至少0.125 mm [0.005 in.] 。

X2.3.1.2 胶带，满足规范D2301要求，氯乙烯塑料压敏胶，电绝缘胶带。

X2.3.1.3 水泥、粘合剂，最好是橡胶材料。

X2.3.2 流程：

X2.3.2.1*步骤 1*—将铝箔沿试样边缘密封，每面留下0.0654-m$^2$ [100-in.$^2$] 的暴露面积用于测试。按厂家要求用胶粘剂粘牢。

X2.3.2.2*步骤 2*—在边框和边台的内沿涂抹密封脂。在盘中放置干燥剂（干燥过的），或者水，或湿度控制材料（湿的）。将试样放置到位。避免各种材料接触到测试区域。

X2.3.2.3*步骤 3*—在边框的外沿和边台的底部涂上一层胶粘剂， 然后用铝箔将包裹模板的边缘，应环绕边框与边台。

X2.4 使用热沥青浇注带边台和边框的254-mm[10-in.]见方的测试杯的方法如下：

X2.4.1 *装置:*

X2.4.1.1 *模块*—铜或者钢的方框，5 mm [3/16 in.] 厚，19 mm [3/4 in.] 深。 在接触试样的方框底部，方框的5 mm [3/16 in.] 厚度收缩到0并保持边长254-mm [10-in.]的方形测试面积。

X2.4.1.2 *Sealant*—Asphalt (see X2.3.1 used at the proper pouring consistency of 375 to 450°F [179 to 232°C].

X2.4.1.3 *Melting Pot,* for the asphalt, electrically heated, with one dimension greater than 11 3/8 in. [289 mm].

X2.4.1.4 *Small Ladle,* for pouring.

X2.4.2 *Procedure*—Mark the 11 3/8-in. [289-mm] specimen with a line at an equal distance from each edge, so that the area enclosed by the lines is as nearly as possible a 10-in. [254-mm] square. The template may be used for marking. Dip each edge of the specimen in molten asphalt up to the line, so that the test area is defined and all edges are coated with a heavy layer of asphalt. Place the specimen over the pan containing water or desiccant. Lightly oil the template or coat with petroleum jelly on its outer side, and place on the specimen. Pour molten asphalt into the space between the template and the rim of the pan. After the asphalt has cooled for a few minutes, the template should be easily removable.

X2.5 Hot wax may be applied like asphalt. It may also be applied (freely) with a small brush. Its lower working temperature may be advantageous when a specimen contains moisture.

X2.6 Several designs for dishes with supporting rings and flanges are shown in Fig. X2.2. Various modifications of these designs may be made provided that the principle of prevention of edge leakage by means of a complete seal is retained. The dishes may be constructed of any rigid, impermeable, corrosion-resistant material, provided that they can be accommodated on the available analytical balance. A lightweight metal, such as aluminum or one of its alloys, is generally used for larger-size dishes. In some cases when an aluminum dish is employed and moisture is allowed to condense on its surface, there may be appreciable oxidation of the aluminum with a resulting gain in weight. Any gain in weight will ordinarily depend on the previous history of the dish and the cleanness of the surface. An empty dish carried through the test procedure as a control will help to determine whether any error may be expected from this cause. When aluminum dishes are used for the water methods, a pressure may develop inside the assembly during a test due to corrosion. This can cause seal failure or otherwise affect the result. Where this is a problem, it can be overcome by providing inside the dish a protective coating of baked-on epoxy resin or similar material. Dishes with flanges or rings that project from the inner walls of the dish are to be avoided, as such projections influence the diffusion of the water vapor. The depth of the dish for the water procedures is such that there is a 0.80 6 0.20-in. [20 6 5-mm] distance between the water surface and the under surface of the specimen, with a water depth of about 0.20 in. [5 mm].

X2.6.1 For the desiccant-in-dish procedures, the dishes need not be as deep as those required for the water-in-dish procedures. The desiccant is within 1/4 in. [6 mm] of the under surface, and a minimum depth of only 1/2 in. [12 mm] of desiccant is required.

X2.6.2 The dishes shown in Fig. X2.2 require a molten seal.

X2.6.3 A template such as is shown in Fig. X2.3 is usually used for defining the test area and effecting the wax seal. It consists of a circular metal dish 1/8 in. [3.18 mm] or more in thickness with the edge beveled to an angle of about 45°. The diameter of the bottom (smaller) face of the template is automatically on the test specimen. A small hole through the template to admit air, and petrolatum applied to the beveled edge of the template facilitate its removal after sealing the test specimen to the dish. In use, the template is placed over the test specimen and when it is carefully centered with the dish opening, molten wax is flowed into the annular space surrounding the beveled edge of the template. As soon as the wax has solidified, the template is removed from the sheet with a twisting motion. The outside flange of the dish should be high enough to extend over the top of the specimen, thus allowing the wax to completely envelop the edge.

X2.6.4 Gasketed types of seals are also in use on appropriately designed dishes. These simplify the mounting of the specimen, but must be used with caution, since the possibility of edge leakage is greater with gasketed seals than with wax seals. Gasketed seals are not permitted for the measurement of permeance less than 4 perms [240 $ng \cdot m^{-2} \cdot s^{-1} \cdot Pa^{-1}$]. As a further precaution when gasketed seals are used instead of preferred sealants, a blank test run is suggested using glass or metal as a dummy specimen.

X2.6.5 A suitable weighing cover consists of a circular disk of aluminum 1/32 to 3/32 in. [0.8 to 2.4 mm] in thickness provided with a suitable knob in the center for lifting. The cover fits over the test specimen when assembled and makes contact with the inside beveled surface of the wax seal at, or just above, the plane of the

X2.4.1.2 *密封剂*—沥青（见 X2.3.1，在179 to 232°C [375 to 450°F]使用，保持合理的浇注粘稠度）

X2.4.1.3 *坩锅*，熔化沥青用，电加热，至少一个尺寸大于289 mm [11 3/8 in.]。

X2.4.1.4 *长柄勺*，浇注用。

X2.4.2 *流程*—在边长289-mm [11 3/8-in.] 的试样的边缘标记等距的直线，将直线包围的区域面积尽可能接近254-mm[10-in.]见方。模板可用于标记直线。将试样的每个边缘浸泡到熔化的沥青，淹没到直线上，这样除测试区域外，试样边缘部分覆盖上厚厚的一层沥青。将试样放置在盛有水或者干燥剂的盘上。在模板的外边抹上油或者涂上凡士林，放置在试样上方。将熔化的沥青浇注到模板与盘的边框之间的空间里。等沥青冷却几分钟后，模板应很容易取出。

X2.5 热的蜡可象沥青一样使用。蜡可以用小刷子涂抹。对于含水的试样，蜡的低熔点是一个优点。

X2.6 其它几种装有环形边框和边台的设计见图Fig. X2.2.。这样设计可以进行修改，但应对试样边缘进行彻底密封以杜绝边缘泄漏。测试杯，可用各种规则的、不渗透的、不腐蚀的材料制造，并且适应于可用的分析天平。轻质材料，如铝或者铝合金，常用于大尺寸的测试杯。某些情况下，使用铝制测试杯而且其表面允许有冷凝，此时铝会一定的氧化，致使重量增加。重量的任何增加，通常依赖于测试杯的陈迹和表面的清洁。全程使用空测试杯，有助于确定是否有误差因氧化而产生。在水法中使用铝制测试杯时，由于腐蚀的原因，测试杯的压力会在测试过程中增加。这可能导致密封失效，或者影响测试结果。当存在这个问题时，有一个办法来克服，那就是：测试杯内部涂盖一层环氧树脂或其它类似的保护材料并烘干。测试杯要避免从边台或者环边沿杯的内壁突出来，因为这样会影响水蒸气白的扩散。水法的测试杯深度要保证水面到样面底面的距离为20±5-mm [0.80±0.20-in.] 且水深约为5 mm [0.20 in.]。

X2.6.1 干燥剂法的测试杯深不必与水法一样深。干燥剂应在试样表面以下6 mm[1/4 in.]以内距离，并须保持干燥剂的深度至少12 mm [1/2 in.]。

X2.6.2 图X2.2所示的测试杯需要熔化的密封脂。

X2.6.3 图X2.3所示的模板通常用于规定测试区域并影响蜡封。它由一个3.18 mm [1/8 in.]厚或者更厚的金属圆盘，并有一个约45°倾斜的边沿。测试杯底面（更小）的直径自动放置在试样的上面。模板上的通透小孔允许空气、凡士林加注到模板的斜边，并且在将试样密封到测试杯之后方便取出模板。使用时，模板放置在试样上方，在模板小心放置在测试杯开口的中心位置之后，熔化的蜡流进模板斜边下的环形空间。一旦蜡固化，模板可以拧下来。测试杯的边台应该足够高以便容纳试样的顶面，这样就能用蜡彻底封住试样的边缘。

X2.6.4 密封圈也可运用在适当设计的测试杯中。这简化了试样的安装，但使用时必须小心，因为密封圈的边缘泄漏大于蜡封。密封圈不允许用在透过量小于4 perms [240 ng·m$^{-2}$·s$^{-1}$·Pa$^{-1}$]的测试（译者注：此语仅针对厚型材料。对于薄膜，密封圈是可用的）。 当用密封圈替代优选的密封脂时，必须更谨慎，建议使用玻璃或者金属的空白样进行空白测试。

X2.6.5 一个可行的称量盖由一个厚度为0.8 to 2.4 mm [1/32 to 3/32 in.] 的铝质圆形盘组成，其上中心有一把手用于揭盖。这个称量盖适于覆盖住安装的试样，并接触到测试杯内部斜面，该斜面处的密封蜡密封了试样面。

specimen. The cover is free of sharp edges that might remove the wax and is numbered or otherwise identified to facilitate its exclusive use with the same dish.

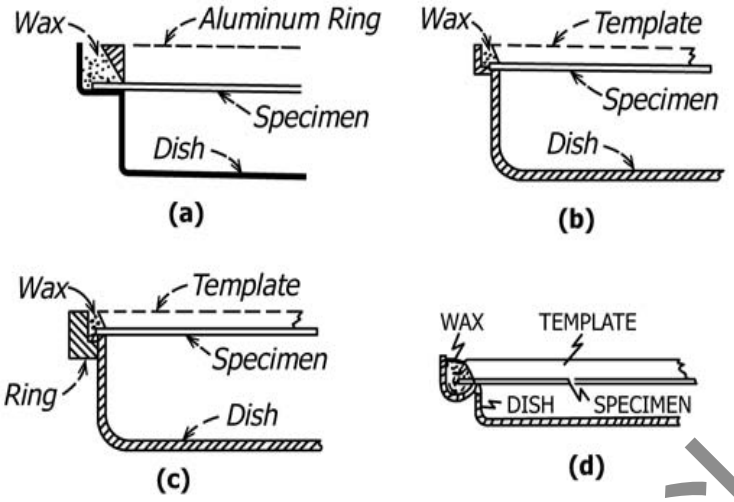


**FIG. X2.2 Several Types of Dishes for Water Vapor TransmissionTests of Materials in Sheet Form**

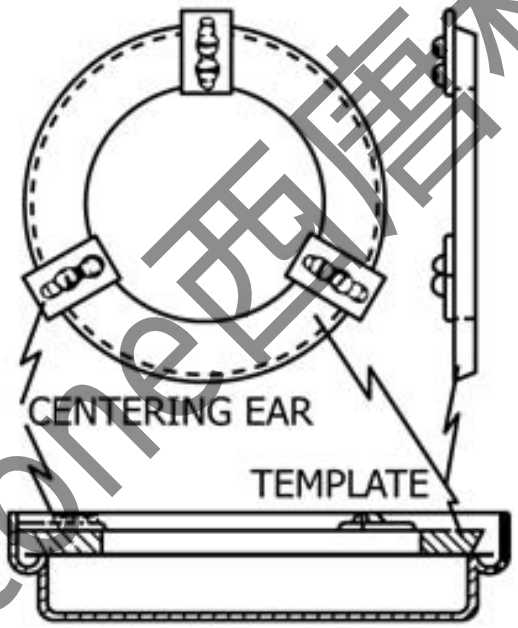


**FIG. X2.3 Template Suitable for Use in Making the Wax Seals on Test Dishes**

## X3. PROCEDURE TO CALCULATE DEPENDENCY OF WATER VAPOR TRANSMISSION RATE ON RELATIVE HUMIDITY

X3.1 The dependency of the water vapor transmission (WVT) rate of materials on relative humidity (RH) can be determined using a combination of desiccant and water method **(9)**.

### X3.2 Procedure

X3.2.1 Dry cup tests with desiccant method test set up but also with additional chamber RH levels other than 50% are carried out. Three chamber RH levels: 50%, 70%, and 90% shall be selected.

X3.2.2 Wet cup measurements with water method test set up but at two chamber RH levels are to be carried out. Two chamber RH levels, 70% and 90% shall be selected.

称量盖的边缘无毛刺，避免损伤密封蜡。盖子还应该编号，或者标明其适用的测试杯。

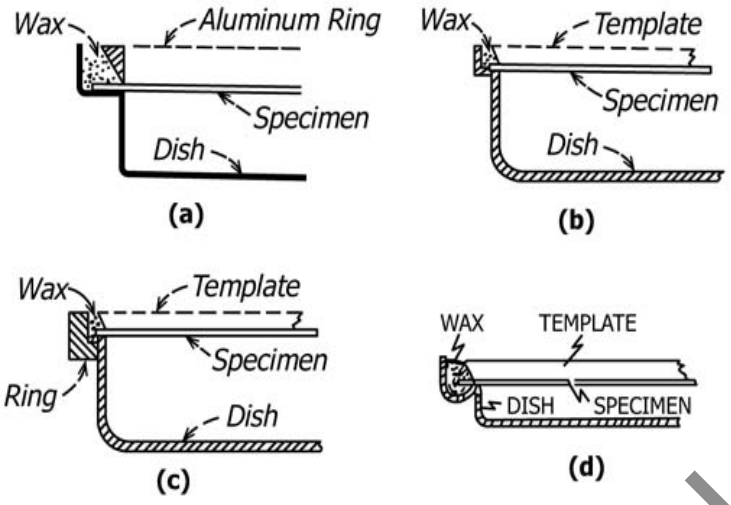


**FIG. X2.2 片材的水蒸气透过测试杯的几种类型**

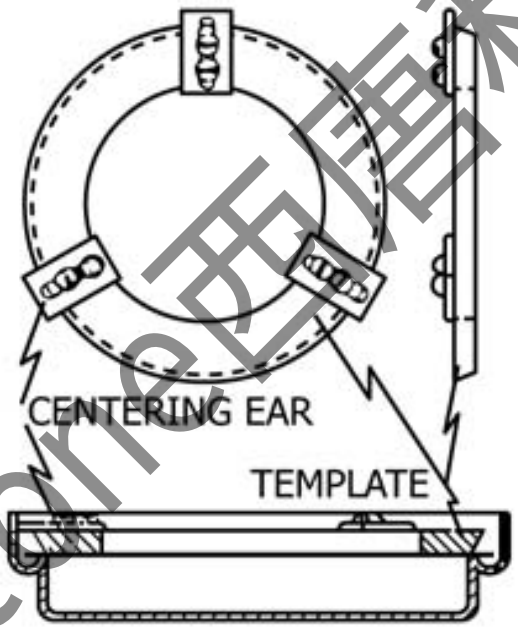


**FIG. X2.3 适于在测试杯上进行蜡密封的模板T**



## X3. 计算水蒸气透过率与相对湿度关联性的流程

X3.1 材料水蒸气透过率与相对湿度的关联性可以通过干燥剂法和水法的组合使用来确定**(9)**。

### X3.2 流程

X3.2.1 用除50%以外的其它多种测试箱相对湿度进行干燥剂法的干杯测试。可选的测试箱相对湿度有三个：50%，70%和90%。

X3.2.2 用两种测试箱相对湿度进行水法的湿杯测试。可选的2种相对湿度是：70%和90% 。

**X3.3 Data Analysis**

X3.3.1 From the slope of the time versus mass change data plot, for each chamber RH levels, the rate of WVT for the corresponding test specimen at a specific chamber RH level is determined according to 13.2.1.

X3.3.2 The WVT rate is plotted against the chamber RH. This results in two separate but intersecting plots.

X3.3.2.1 If the plots are linear and intersect at 50% chamber RH, it is concluded that the material under consideration is nonhygroscopic and the rate of WVT does not depend on the local chamber RH.

X3.3.2.2 For the hygroscopic material the intersection of the plots will be at a chamber RH greater than 50% and water method may yield a nonlinear dependency.

X3.3.3 For hygroscopic materials the sum of the rate of WVT from dry and wet cup measurements at the 90% chamber RH represents theoretically the dry cup measurements for WVT rate done at 100% chamber RH.

X3.3.4 Similarly for hygroscopic materials the sum of the rate of WVT from dry and wet cup measurements at the 70% chamber RH represents theoretically the dry cup measurements for WVT rate done at 100% chamber RH. If this calculated value of WVT rate at 100% chamber RH differs from the same calculated in centilitres X3.3.3 by more than 10% then the whole test procedure should be repeated.

X3.3.5 The calculated dry cup WVT rate at 100% chamber RH, as shown above, is combined with the directly measured dry cup measurements data at 50%, 70% and 90% chamber RH to generate a set of WVT rate values spanned over the entire range of chamber RH (that is, 0 to 100%). These values of WVT rate when plotted against the corresponding chamber RH would define the dependency of WVT rate on RH.

X3.3.6 The algebraic expression of the best-fitted curve that passes through the origin from the WVT rate versus chamber RH is to be used to determine the derivative of the plot at any given local RH.

X3.3.7 The water vapor permeance of the material at a specific chamber RH is derived from the following expression.

$$\textit{Water Vapor Permeance}\ (WVP) = \left\{\frac{(\text{Magnitude of derivative}) \times 100}{\text{Saturation water vapor pressure at } 73.4\text{F}(23\text{C})}\right\} \quad \text{(X3.1)}$$

X3.3.8 All normal required corrections (13.4) are applicable to X3.3.7.

## X4. TESTING OF EXTREMELY LOW PERMEANCE MATERIALS

X4.1 In 2010-2011 an inter-laboratory study using Procedure A was conducted using thin, extremely low permeance materials as the test specimens. The statistics from this study related to precision of the method are covered in Section 15 of these test methods.

X4.2 In addition to developing a precision statement, a number of other objectives was targeted in undertaking this round robin. Those objectives and a discussion of the findings are discussed herein:

X4.3 Provide experience testing extremely low and “zero perm” materials.

X4.3.1 Many labs that conduct the E96/E96M tests do not have occasion to test such materials. The materials tested in the study ranged from anticipated values of about 0.015 perm down to zero perm. All materials were 0.015 in. (0.38 mm) thick or less. Circumstances were such, however, that the final group of participating labs in fact did have experience testing in this range. As such, input from inexperienced labs was not available.

X4.4 Determine what difficulties are encountered in testing at these levels.

X4.4.1 With one exception, no notable difficulties were reported by the labs. One lab was consistently obtaining loss of weight during the tests. An assignable cause was not determined, and it was decided not to use their results. Otherwise, there was no feedback on problems with the test.

**X3.3 数据分析**

X3.3.1 按照13.2.1，对测试箱的每个RH值，绘制时间--质量变化曲线图，从其斜率可以确定相应测试试样的对应此相对湿度的水蒸气透过率。

X3.3.2 绘制水蒸气透过率与测试箱相对湿度的网线。这将产生两个独立但交叉的曲线。

X3.3.2.1 如果曲线是线性并且交叉在测试箱的50%相对湿度处，那么可以得出结论：考察的材料是不吸湿的，并且水蒸气透过率不依赖于测试箱相对湿度。

X3.3.2.2 对于吸湿材料，曲线的交叉点将出现在高于50%RH的测试箱湿度，并且水法会获得一个非线性的关联性。

X3.3.3 对吸湿材料，干杯法和湿杯法在测试箱湿度为90%RH时的水蒸气透过率之和，理论上代表了干杯法在测试箱湿度为100%RH时的水蒸气透过率。

X3.3.4 类似地，对吸湿材料，干杯法和湿杯法在测试箱湿度为70%RH时的水蒸气透过率之和，理论上代表干杯法在测试箱湿度为100%RH时的水蒸气透过率。 如果在100%RH的测试箱湿度处计算的水蒸气透过率与X3.3.3中相差超过10%，那么整个测试过程应该重来。

X3.3.5 如前述，干杯法在100%RH处计算的水蒸气透过率值，可直接与50%，70%和90%测试箱湿度时测试值组合，计算出一系列的覆盖全湿度量程（即0到100%RH）的水蒸气透过率值。绘制水蒸气透过率与相应测试箱湿度的曲线，水蒸气透过率与相对湿度的关联性就建立了。

X3.3.6 表示水蒸气透过率与测试箱相对湿度关系的最佳拟合代数公式，可用于确定在任意给定相对湿度处的推导水蒸气透过量。

X3.3.7 在特定测试箱相对湿度处的材料水蒸气透过量可以下式推导：

$$\textit{水蒸气透过量}(WVP) = \left\{ \frac{(\text{水蒸气透过率}) \times 100}{23C(73.4F)\text{的饱和水蒸气压力}} \right\} \qquad \text{(X3.1)}$$

X3.3.8 所有通常的修正（13.4）按X3.3.7执行。

**X4. 极低渗透性材料的测试**

X4.1 2010-2011年，用一个薄且极低渗透性的材料作为试样，多实验室间运用流程A展开了研究工作。此项研究的方法精度统计数据在本标准的第15节有描述。

X4.2 除了建立一个精度结论，在执行此轮任务时还有一些其它目标。这些目标和发现的讨论将在下面讨论：

X4.3 提供经验丰富的的特低和零透过的材料测试案例。

X4.3.1 许多参与E96/E96M的实验室没有机会参与测试这些材料。研究中测试材料的预计透过量的范围为0.015 perm到0。所有材料的厚度均为0.38 mm (0.015 in.)或更薄。不过，最后一组参与的实验室均有此范围材料的实际测试经验。因此，没有取得无经验的实验室数据。

X4.4确定测试这些透过水平的材料时会遭遇的困难。

X4.4.1 很异外，各实验室没有报告明显的困难。一个实验室在测试过程连续获得质量损失。一个不可忽视的原因没能得到确定，因此决定不使用他们的结果。除此以外，没有收到测试问题反馈。

X4.4.2 The occurrence of outliers indicates problems that were undetected or uncorrected by the operators, or both. The outliers are always high results. Absent the presence of obvious defects in the test specimens, which would be visible under normal lighting or over a light box, the cause for outliers is invariably inadequate sealing to the dish. It would appear that operators were not recognizing outliers appearing early in the test, or were not taking action to correct otherwise determine a cause.

X4.4.3 The types of materials tested can be expected to be very consistent. One exception could be laminations, which can contain pinholes of a size or number that can produce apparently outlying results. These will be detectable over a light box. The foil lamination samples in this study were pre-screened for presence of pinholes, and only pinhole-free specimens were used.

X4.4.4 The primary problem encountered in testing extremely low permeance materials then would appear to be inadequate or failing seals. It is critical that operators monitor data early on for apparent outliers. When one is suspected, whether or not a breach in the seal is visible in the test dish, the seal should be "re-flowed", the specimen taken out of the test, or a replacement replicate started.

X4.4.5 It is strongly recommended that a program be set up to provide either water vapor transmission rate or permeance, and correlation coefficient computation, real time at each weighing. This way outliers can be spotted immediately and checked for cause.

X4.5 *Application of correlation coefficient:*

X4.5.1 The correlation coefficient indicates if a strong linear relationship in the coordinate data points exists.

X4.5.2 Very high correlation indicates a very straight line slope for the weight gain per unit time, which in turn can be used as an indication of steady state.

X4.5.3 High correlation is not necessarily expected when testing materials of extremely low permeance, since the slope of the weight gain per unit time is approaching zero, and any variation in the test conditions has a greater impact on individual weighings. Zero or near-zero permeance tests may never show good correlation.

X4.6 *Time required to reach steady state:*

X4.6.1 It is generally thought that extremely low permeance materials require many weeks or months to reach a true steady state and to provide a reliable result.

X4.6.2 A graph of perm vs. time at steady state should show a flat line.

X4.6.3 Using the data from one lab that obtained the most consistent expected results, the approximately first one third of the test duration (18 days) showed perm results that indicated a condition that was not steady-state.

X4.6.4 The second third (19-36 days) graph showed a much straighter line, but one not totally flat.

X4.6.5 The last third (37-54 days) showed the straightest you line of perm results; given the range of the data, steady state is well indicated.

X4.6.6 While the above findings would indicate that two months or more may be needed to reach steady state, the change in results after the first two or three weeks was very small, less than would impact a result rounded to two significant figures. The purpose of the test might dictate the duration required; that is, screening or QC tests might be run for shorter durations than R&D tests where a high degree of accuracy is desired, which might be run for more than two months .

X4.6.7 It is known that thicker materials and moisture-retaining materials need upwards of two months or longer to reach steady-state. Evidence shows that very thin materials such as those tested in this ILS, even if of extremely low permeance, may not need such a long test duration to reach steady state.

X4.4.2 离群点的出现指明了操作员未发现问题，或者未修正的问题，或者二者同时存在。离群数据点总是更高的结果。试样极少出现明显的缺陷，这可以正常灯光或者灯箱里看到。导致离群点的原因是不同程度的测试杯密封不充分。操作员要么在离群点的早期测试中没有发现问题，要么没有采取行动去确定原因和解决问题。

X4.4.3 此类材料的测试可以预期是相当一致的。异常情况发生在复合材料，这种材料可能有一定数量或尺寸的针孔，这将导致明显的离群结果。但这些异常可用灯箱检测到。本研究中的箔复合样品被投影到屏蔽上以发现针孔，并且只有使用无针孔的试样。

X4.4.4 在检测极低透过材料时，重大的问题就是密封不充分或失效。操作员的早期数据监测对发现明显的离群数据很关键。当发现疑点时，无论是否发现密封破裂，都需要取出试样，或者替换试样，重新加注密封脂再次开始测试。

X4.4.5 强烈推荐建立一个流程，在称量的实时过程中计算水蒸气透过率、水蒸气透过量和相关系数。这样异常可以即时挑出并检查原因。

X4.5 相关系数的运用：

X4.5.1 相差系数指示坐标数据是否存在强的线性相关性。

X4.5.2 极高的相关性指明重量增益--时间曲线有一个非常直的斜率，这些相关系数可以依序使用，指明数据的稳定状态。

X4.5.3 高相关性不必预期在检测极低透过时获得，因为重量增益--时间曲线的斜率趋近0，并且测试条件的任何变化都会对每次称量施加更大的影响。零或接近零的透过量测试永远不会显示良好的相关性。

X4.6 达到稳定状态的时间：

X4.6.1通常认为极低透过材料的测试需要几周或者几月的时间才达到一个真空的稳定状态并获得一个可信的结果。

X4.6.2 透过量--时间曲线应呈现一条平直曲线。

X4.6.3 依据预期结果最具一致性的实验室数据，测试周期的大约前三分之一（1-18天）显示的透过量结果指明测试并未达到稳定透过状态。

X4.6.4 第二个三分之一时间(19-36 days)的图形显示一个更直的直线，但总体并未平衡。

X4.6.5 最后三分之一时间(37-54 days) 显示最直的透过量结果直线；在给定数据的范围内，清晰地指示了稳定状态。

X4.6.6 上述发现指明达到稳定状态需要两个月甚至更多时间，在最初两三个星期后结果的变化非常小，小到不影响将结果取整到两位有效数字。此测试的目标指明需要的测试时长：亦即，筛查或者QC检测的测试时间可以更短，而研发部门因为需要更高的精度，需要长达超过2个月的测试时间。

X4.6.7众所周知，更厚的材料和吸湿材料需要长达2个甚至更长的时间才能达到稳定透过状态。有证据显示，更薄的材料，如此次ILS（Inter Laboratory Study)测试的材料，即使透过量极低，达到稳定透过状态的可以不需要这么长的测试时间。

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