Designation: D 1653 – 93 (Reapproved 1999)$^{\epsilon 1}$

Designation: D 1653 – 03

Standard Test Methods for Water Vapor Transmission of Organic Coating Films[1]

This standard is issued under the fixed designation D 1653; 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 Department of Defense.

~~ε[1] NOTE—Editorially changes made throughout in December 1999.~~

[1] These test methods are under the jurisdiction of ASTM Committee ~~D-1~~ D01 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.23 on Physical Properties of Applied Paint Films .

Current edition approved ~~Dec. 15, 1993.~~ July 10, 2003. Published ~~February 1994.~~ August 2003. Originally ~~published as D 1653 – 59 T.~~ approved in 1959. Last previous edition approved in 1999 as D 1653 – 99~~ε1~~ε1.

1. Scope

1.1 These test methods cover the determination of the rate at which water vapor passes through films of paint, varnish, lacquer, and other organic coatings. The films may be free films or they may be applied to porous substrates.

1.2 Two test methods are covered as follows:

1.2.1 *Test Method A*—Dry Cup Method, and

1.2.2 *Test Method B*—Wet Cup Method.

1.2.3 Agreement should not be expected between results obtained by different methods or test conditions. The method that most closely approaches the conditions of use should be selected.

1.3 The values stated in inch-pound units are to be designated as the standard. Factors for conversion are stated in 13.2.1.2 and 13.2.2.2.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[2]

D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers[2]

D 1193 Specification for Reagent Water[3]

D 4708 Practice for Preparation of Free Films of Organic Coatings[2]

E 104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *water vapor transmission rate, WVT*—the steady water vapor flow in unit time through unit area of a body, between two specific parallel surfaces, under specific conditions of temperature and humidity at each surface. Accepted inch-pound unit is grains per square foot per hour. Accepted SI unit is grams per square metre per 24 h.

3.1.2 *water vapor permeance, WVP*—the steady water vapor flow in unit time through unit area of a body (WVT) induced by unit vapor pressure difference (Δp) between the two surfaces of a coating. Therefore, WVP = WVT/Δ *p*. Accepted inch-pound unit is grains per square foot per hour per inch of mercury (called a perm). Accepted SI unit is grams per square metre per 24 h per millimetre of mercury (called a metric perm).

4. Summary of Test Methods

4.1 In Test Method A (Dry Cup Method), the test specimen is sealed to the open mouth of a cup or dish containing desiccant, and the assembly placed in a test chamber with a controlled atmosphere. Two sets of exposure conditions are acceptable for this test method.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 11.01.

[4] *Annual Book of ASTM Standards*, Vol 11.03.

4.1.1 *Condition A*, consisting of 50 % relative humidity at 73°F (23°C), and

4.1.2 *Condition B*, consisting of 90 % relative humidity at 100°F (38°C).

4.2 In Test Method B (Wet Cup Method), the test specimen is sealed to the open mouth of a cup or dish containing water, and the assembly placed in a test chamber with a controlled atmosphere. Two sets of exposure conditions are acceptable for this test method:

4.2.1 *Condition A*, consisting of 50 % relative humidity at 73°F (23°C), and

4.2.2 *Condition C*, consisting of very low (near zero) relative humidity at 73°F (23°C).

4.3 In both methods, periodic weighings of the cup or dish are made to determine the rate of water vapor movement through the specimen.

5. Significance and Use

5.1 One of the factors affecting the performance provided by an organic coating is its capability of resisting or aiding the passage of water vapor. In some services, for example, exterior wood and masonry, the coating has to allow moderate amounts of water vapor to pass through the film without damage to it. Hence, the water vapor transmission characteristics of coatings are important in assessing their performance in practical use.

5.2 The purpose of these test methods is to obtain values of water vapor transfer through coatings that range in permeability from high to low. These values are for use in design, manufacture, and marketing.

5.3 The water vapor transmission is not a linear function of film thickness, temperature or relative humidity.

5.4 Values of water vapor transmission rate (WVT) and water vapor permeance (WVP) can be used in the relative rating of coatings only if the coatings are tested under the same closely controlled conditions of temperature and relative humidity, and if their thicknesses are equal.

5.5 *Test Method A*—The Dry Cup Method is the preferred test method for obtaining values that relate to conventional dwellings where high relative humidities are not anticipated.

5.6 *Test Method B*—The Wet Cup Method is the preferred test method for obtaining values that relate to applications where high relative humidities are anticipated in the vicinity of the barrier material. In general, the more permeable a coating is to the passage of moisture as is typical of many water-reducible coatings, the greater its affinity for water and the greater the increase in transmission when tested in and exposed to high humidities. Absorption of water may make a coating less dense, thus allowing moisture to diffuse easily and cause a much higher moisture vapor transmission rate, (WVTR) than would occur in drier environments.

6. Apparatus

6.1 *Perm Cup or Dish*, consisting of a container made of a noncorroding material, impermeable to water or water vapor. If the cup or dish is made of aluminum, it must be anodized or given a protective clear coating to prevent corrosion.

6.1.1 One type of cup that is suitable has a flanged edge and is equipped with a separate corresponding flange, so that the test specimen can be held between them. The contacting faces of the flanges shall be ground to such flatness that when the film is in position, moisture transfer can occur only through the exposed film area. For hard films, or films having a very rough surface, a soft rubber gasket may be inserted between the film and the flange. The flanges shall then be held together with suitable clamps.

6.1.2 Another suitable cup is any open circular or rectangular dish to which the test film can be sealed with wax or sealant.

6.2 *Test Chamber*, with a controlled temperature and relative humidity as specified in Section 4. Air shall be circulated throughout the chamber to maintain uniform conditions at all test locations. For low or high humidity conditions, a standard desiccator or other suitable cabinet may be used. For maintaining constant relative humidity by means of aqueous solutions, refer to procedures outlined in Practice E 104.

6.3 *Analytical Balance*, having an adequate capacity for the weight of the test cups and a sensitivity of 1 mg.

7. Reagents and Materials

7.1 *Purity of Water*—Unless otherwise indicated, reference to water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

7.2 *Desiccant*, consisting of either anhydrous calcium chloride ($CaCL_2$) or anhydrous magnesium perchlorate ($Mg(CLO_4)_2$). The calcium chloride should be dried at 400°F (200°C) before use. If calcium chloride will react with the test specimen, an adsorbing desiccant such as a silica gel may be used but the moisture gain by this desiccant during the test must be limited to 4 %. Use caution in handling magnesium perchlorate because of possible chemical reaction that may be produced if it comes in contact with some organic materials and is subsequently heated to regenerate the anhydrous salt.

7.3 *Sealant*, such as wax for attaching the test specimen to the top of the perm cup or dish. It must be highly resistant to the passage of water vapor. 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 results by more than 2 %. It must not affect the vapor pressure in a water-filled dish.

NOTE 1—Among acceptable sealants are (*1*) a 60:40 mixture of microcrystalline wax and refined crystalline parafin wax, (*2*) tissue embedding wax, and (*3*) a 50:50 mixture of beeswax and rosin.

7.4 *Release Paper*, prepare free films, whenever possible to eliminate the potential interference of substrates, on release paper[5] or glass substrates following procedures outlined in Practice D 4708.

7.5 *Film Support*, for preparing films that are too brittle or otherwise unsatisfactory for handling as free films. Support materials such as paper charts,[6] filter paper, and glass cloth have been found satisfactory in some instances. Such support can have an effect on the test results.

8. Test Specimens

8.1 It is very important that the test specimens be smooth, and completely continuous films of uniform thickness throughout the test area. Apply air drying coatings to substrates using one of the methods described in Practices D 823 or D 4708.

NOTE 2—Special test conditions may require that the coating be applied by brushing, roller coating or other special methods. The thickness of the coating applied shall be within normal range for the type of material under test, and shall not vary by more than 5 % of the total thickness in any test series.

NOTE 3—When applying baking finishes, bake for specified time and temperature in accordance with manufacturers' instructions. Permeance may vary with the baking schedule or the time of air drying.

8.2 Air dry the coated material in a horizontal position for 7 days in a room preferably maintained at 73.5 ± 3.5°F (23 ± 2°C) and 50 ± 5 % relative humidity. If the material is to be tested as a free film, remove it from the substrate and allow the previously unexposed surface to dry for an additional 7 days. The drying schedule may be modified as recommended by manufacturer.

NOTE 4—Examine test films for the presence of pinholes or other defects before commencing the test. It may be advisable to apply the test material in two coats, applying the second coat perpendicular to the first coat and allowing for an adequate drying period between coats to achieve the desired film thickness.

8.3 Measure the thickness of the test specimen in several places with a micrometer using procedures in Test Methods D 1005 to ensure a uniform thickness.

8.4 When coatings are applied to support materials, the coated side of the test specimen should be placed away from the desiccant or towards the water in the cup, depending upon the service environment. Coatings should not be applied to both sides of a support. Glass cloth is preferred for coatings that are cured by baking.

TEST METHOD A—DRY CUP METHOD

9. Test Conditions

9.1 Unless other conditions are agreed upon between the purchaser and the seller, the tests shall be performed under one or more of the following conditions:

9.1.1 *Condition A*—Test chamber or cabinet maintained at 73° ± 1°F (23 ± 0.6°C) and 50 ± 2 % relative humidity.

9.1.2 *Condition B*—Test chamber or desiccator maintained at 100 ± 1°F (38 ± 0.6°C) and 90 ± 2 % relative humidity.

10. Procedure

10.1 Prepare at least three perm cups or dishes for each test material as follows:

10.1.1 Fill the cups with desiccant to within ¼ in. (6 mm) of the top edge.

10.1.2 If the cups are equipped with flanges, place the test specimen between the flanges and adjust the clamps to hold it firmly in position.

10.1.3 If the cups are not equipped with flanges, seal the test specimen to the top edge of the cups with wax as follows:

10.1.3.1 First carefully place the test specimen, cut to the size of the frame, on a thin cardboard ring soaked in molten wax.

10.1.3.2 Then place the specimen-covered frame over the mouth of the cup. Thoroughly seal the frame to the edge of the cup at the temperature to be used in the test. If the coating is on a substrate or support, place the coated side away from the desiccant in the cup.

NOTE 5—Imperfections in the film that are not readily visible may produce inconsistent results; consequently make sure that the test is always run at least in triplicate.

10.2 Weigh the loaded cups to 1 mg and if a test chamber is not being used, place them in the test cabinets or desiccators. Record time, temperature, and relative humidity.

10.3 Remove if necessary, the cups for periodic weighing to determine weight gain. Coatings expected to have high WVT ratings, over 10 perms, may require weighings more frequently than once a day.

---

[5] The sole source of supply of release Paper, Form RP-1K, known to the committee at this time is the Leneta Co., 15 Whitney Rd., Mahwah, NJ 07430 . If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[6] The sole source of supply of paper charts, Form NWK, known to the committee at this time is the Leneta Co., 15 Whitney Rd., Mahwah, NJ 07430 . If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

10.4 In general, weigh the cups every 24 h for a period of 3 weeks, or until the weight change versus time becomes constant. Record the time that weighings are taken to the precision of approximately 1 % of the time span between weighings. Thus, if weighings are made every day, a time to the nearest 15 minutes would be allowed.

10.5 Shake cups containing desiccant everyday to prevent surface saturation of the material. If moisture absorbed by the desiccant exceeds 20 % of the desiccant weight, discontinue the test.

10.6 Return the cups to the test chamber immediately after weighing.

TEST METHOD B—WET CUP METHOD

11. Test Conditions

11.1 Unless other conditions are agreed upon between the purchaser and the seller, perform the test(s) under one or more of the following conditions:

11.1.1 *Condition A*—Test chamber or cabinet maintained at 73 ± 1°F (23 ± 0.6°C) and 50 ± 2 % relative humidity.

11.1.2 *Condition C*—Test chamber or desiccator maintained at 73 ± 1°F and very low (near zero) relative humidity.

12. Procedure

12.1 Prepare at least three cups for each test material as follows:

12.1.1 Fill the cups with water to within ¼ in. (6 mm) of the top edge.

12.1.2 If the cups are equipped with flanges, place the test specimen over the opening of the cups between the flanges and adjust the clamps to hold them firmly in position. If the coating is on a substrate or support, place the coated side towards the water in the cups.

12.1.3 If the cups are not equipped with flanges, seal the test specimens to the top edge of the cups with wax in accordance with procedures in 10.1.3.1 and 10.1.3.2. If the coating is on a substrate or support, place the coated side towards the water in the cup.

12.2 Weigh the loaded cups to 1 mg and place them in the test chamber. Record time, temperature and relative humidity. Follow procedures outlined in 10.5 and 10.6.

12.3 Return the cups to the test chamber immediately after weighings.

13. Calculations

13.1 For each material tested, plot the weight change against elapsed time. When a straight line adequately fits the plot of at least four properly spaced points, a nominally steady state exists and the slope of the straight line is the rate of water vapor transmission.

13.2 Calculate one or more of the following, depending on the water vapor transmission characteristics to be determined:

13.2.1 Calculate the water vapor transmission rate, WVT:

13.2.1.1 In inch-pound units as follows:

TABLE 1 Saturation Vapor Pressure

Temperature		Pressure	
°F	°C	in. Hg	mm Hg
72.3	22.4	0.800	20.316
72.5	22.5	0.805	20.440
72.7	22.6	0.810	20.565
72.9	22.7	0.816	20.690
73.1	22.8	0.819	20.815
73.3	22.9	0.824	20.941
73.4	23.0	0.829	21.068
73.6	23.1	0.834	21.196
73.8	23.2	0.840	21.324
74.0	23.3	0.845	21.453
74.2	23.4	0.850	21.583
74.4	23.5	0.855	21.714
74.5	23.6	0.860	21.845
99.3	37.4	1.894	48.102
99.5	37.5	1.904	48.364
99.7	37.6	1.914	48.627
99.9	37.7	1.925	48.891
100.1	37.8	1.935	49.157
100.2	37.9	1.946	49.424
100.4	38.0	1.956	49.692
100.6	38.1	1.967	49.961
100.8	38.2	1.978	50.231
101.0	38.3	1.988	50.502
101.1	38.4	1.999	50.774
101.3	38.5	2.010	51.048
101.5	38.6	2.021	51.323

$$WVT = (G/t)/A = \text{grains per ft}^2 \text{ per 1 h} \quad (1)$$

where:
G = weight change, grains (from the straight line),
t = time during which G occurred, h, and
A = test area, ft^2,
1 g = 15.43 grains.

13.2.1.2 In metric units as follows:

$$WVT = (G/t)/A = \text{grams per m}^2 \text{ per 24 h} \quad (2)$$

where:
G = weight change, g (from the straight line),
t = time during which G occurred, h, and
A = test area, m^2.

13.2.2 Calculate the permeance, WVP:

13.2.2.1 In inch-pound units as follows:

$$WVP = WVT/\Delta p \quad (3)$$

$$= \text{grains per ft}^2 \text{ per 1 h per in. of mercury (perms)}$$

where:
Δp = $S\ (R_1 - R_2)$,
S = in. Hg (saturation vapor pressure at test temperature), (see Table 1),
R_1 = relative humidity (as a decimal) at vapor source, and
R_2 = relative humidity (as a decimal) at vapor sink.

13.2.2.2 In metric units as follows:

$$WVP = WVT/\Delta p \quad (4)$$

$$= \text{grams per m}^2 \text{ per 24 h per millimetreof mercury, (metric perms)}$$

where:
Δp = $S\ (R_1 - R_2)$,
S = mm Hg (saturation vapor pressure at test temperature), (see Table 1),
R_1 = relative humidity (as a decimal) at vapor source, and
R_2 = relative humidity (as a decimal) at vapor sink.

14. Report

14.1 Report the following information:
14.1.1 Method of coating application and curing procedure used.
14.1.2 Mean film thickness of the test specimens for each material.
14.1.3 Type of film support used, if any.
14.1.4 Method used (Test Method A (Dry Cup) or Test Method B (Wet Cup)).
14.1.5 Test temperature and relative humidity in the test chamber.
14.1.6 Computed rate of water vapor transmission (WVT), either in inch-pound or in metric units.
14.1.7 The computed permeance in terms of both perms and metric units.

15. Precision and Bias [7]

15.1 In an interlaboratory study of these test methods in which one operator in each of three laboratories determined in triplicate the permeance of three coatings covering the range of interest for vapor barrier coatings, the interlaboratory standard deviation for the dry-cup procedure was found to be 0.073 perms with 6 df and the interlaboratory wet-cup coefficient of variation 21.54 % relative with 6 df, with no results having been discarded. Based upon these values, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

15.1.1 *Repeatability*:

15.1.1.1 *Test Method A*—Two results, each the mean of triplicate runs, obtained by the same operator should be considered suspect if they differ by more than 0.25 perms at dry-cup permeance of less than 1.0 perms.

[7] Supporting data are available from ASTM International Headquarters. Request RR:D1 – 1064.

15.1.1.2 *Test Method B*—Two results, each the mean of triplicate runs, obtained by the same operator should be considered suspect if they differ by more than 74.2 % relative at wet-cup permeances of 5 to 30 perms.

15.1.2 *Reproducibility*—Intralaboratory precision is normally better than interlaboratory precision. However, one participant in this exchange has noted relatively large differences when the same coating was tested in quadruplicate with fairly long intervals between tests.

15.2 Bias is not applicable to these test methods.

16. Keywords

16.1 permeance; perms; water vapor permeance; water vapor transmission