



Standard Test Method for Water Migration in Honeycomb Core Materials¹

This standard is issued under the fixed designation F1645/F1645M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of water migration in honeycomb core materials.

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. Combining values from the two systems may result in non-conformance with the standard.

1.2.1 Within the text the inch-pound units are shown in brackets.

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

2. Referenced Documents

2.1 ASTM Standards:²

C271/C271M Test Method for Density of Sandwich Core Materials

C274 Terminology of Structural Sandwich Constructions

D883 Terminology Relating to Plastics

D3878 Terminology for Composite Materials

D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

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

E456 Terminology Relating to Quality and Statistics

E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases

E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases

3. Terminology

3.1 **Definitions**—Terminology **D3878** defines terms relating to high-modulus fibers and their composites. Terminology **C274** defines terms relating to structural sandwich constructions. Terminology **D883** defines terms relating to plastics. Terminology **E456** and Practice **E177** define terms relating to statistics. In the event of a conflict between terms, Terminology **D3878** shall have precedence over the other terminologies.

3.2 Symbols:

CV = coefficient of variation statistic of a sample population for a given property (in percent)

S_{n-1} = standard deviation statistic of a sample population for a given property

x_1 = test result for an individual specimen from the sample population for a given property

$\bar{x}$ = mean or average (estimate of mean) of a sample population for a given property

V_c = volume of water necessary to fill one core cell

V_f = volume of water transfused

W_c = mass of specimen after filling the primary cell with water

W_f = mass of specimen after water transfusion

W_i = mass of specimen after conditioning, prior to water introduction

4. Summary of Test Method

4.1 This test method consists of bonding a honeycomb core material to transparent facings using a water-resistant adhesive, drilling an access hole through one facing to an individual core cell, filling the cell with water, subjecting the filled cell to a constant hydrostatic pressure by maintaining a specified water column height, then measuring the amount of water transferred

¹ This test method is under the jurisdiction of ASTM Committee **D30** on Composite Materials and is the direct responsibility of Subcommittee **D30.09** on Sandwich Construction.

Current edition approved April 1, 2012. Published May 2012. Originally approved in 1995. Last previous edition approved in 2007 as F1645 – 07. DOI: 10.1520/F1645_F1645M-12.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

into the honeycomb core specimen (primarily due to diffusion through the cell walls) within a 24-h period. The amount of water transferred is presented as an approximate number of honeycomb core cells filled with water.

5. Significance and Use

5.1 Water permeability is a fundamental physical property that can be used in conjunction with other properties to characterize honeycomb sandwich core materials. Migration testing can be used to characterize and compare the relative permeability of honeycomb core materials to water.

5.2 This test method provides a standard method of characterizing the rate of water migration within honeycomb sandwich core materials for design properties, material specifications, research and development applications, and quality assurance.

5.3 Factors that influence water migration rate characteristics of honeycomb sandwich core materials and shall therefore be reported include the following: core material, methods of material fabrication, core geometry (cell size), core thickness, core thickness uniformity, cell wall thickness, specimen geometry, specimen preparation, specimen conditioning, facing material, facing permeability, adhesive permeability, adhesive thickness, and methods of mass, volume, and water column height measurement.

6. Interferences

6.1 *Material and Specimen Preparation*—Poor material fabrication practices and damage induced by improper specimen machining are known causes of high data scatter in composites and honeycomb sandwich structures in general. Important aspects of honeycomb sandwich core specimen preparation that contribute to data scatter include the existence of joints, voids or other core discontinuities, out-of-plane curvature, and surface roughness.

6.2 *Core Geometry*—Core-specific geometric factors that affect honeycomb core material water migration rate include core cell size, uniformity of core cell geometry, core cell thickness, core cell thickness uniformity, core thickness, and core thickness uniformity.

6.3 *Facings*—Results are affected by the permeability of the facing material and the flatness of the facing bonding surfaces.

6.4 *Adhesive*—Results are affected by the permeability of the adhesive, the adhesive thickness, and the thickness uniformity of the adhesive. Results are also affected by the presence of voids, cracks, and other defects which compromise the complete bonding of the cell walls to the facings.

6.5 *Environment*—Results are affected by the environmental conditions under which specimens are conditioned, as well as the conditions under which the tests are conducted. Specimens tested in various environments can exhibit differences in water migration rate.

7. Apparatus

7.1 *Micrometers and Calipers*—A micrometer having a flat anvil interface, or a caliper of suitable size, shall be used. The accuracy of the instrument(s) shall be suitable for reading to within 1.0 % of the sample length, width and thickness. For

typical specimen geometries, an instrument with an accuracy of $\pm 25 \mu\text{m}$ [$\pm 0.001 \text{ in.}$] is desirable for thickness measurement, whereas an instrument with an accuracy of $\pm 250 \mu\text{m}$ [$\pm 0.010 \text{ in.}$] is acceptable for length and width measurement.

7.2 *Balance or Weighing Scale*—If the amount of water transferred into the honeycomb core material specimen is to be measured by mass, an analytical balance or weighing scale is required that is capable of measuring the initial mass of the honeycomb core material specimen accurately to $\pm 0.5 \%$.

7.3 *Syringe*—If the amount of water transferred into the honeycomb core material specimen is to be measured volumetrically, a graduated syringe is required that is capable of measuring accurately to $\pm 10 \text{ mm}^3$ [$\pm 0.0005 \text{ in.}^3$].

7.4 *Water Migration Setup*—The water migration test setup, shown in Fig. 1, shall consist of a buret, a scale to measure height such as a meter stick [yardstick], a support stand, clamps to secure the buret to the support stand, and a flexible hose or tube. The scale to measure water column height shall be capable of measuring accurately to $\pm 1 \text{ mm}$ [$\pm 0.063 \text{ in.}$].

8. Sampling and Test Specimens

8.1 *Sampling*—Test at least five specimens per test condition unless valid results can be gained through the use of fewer specimens, as in the case of a designed experiment. For

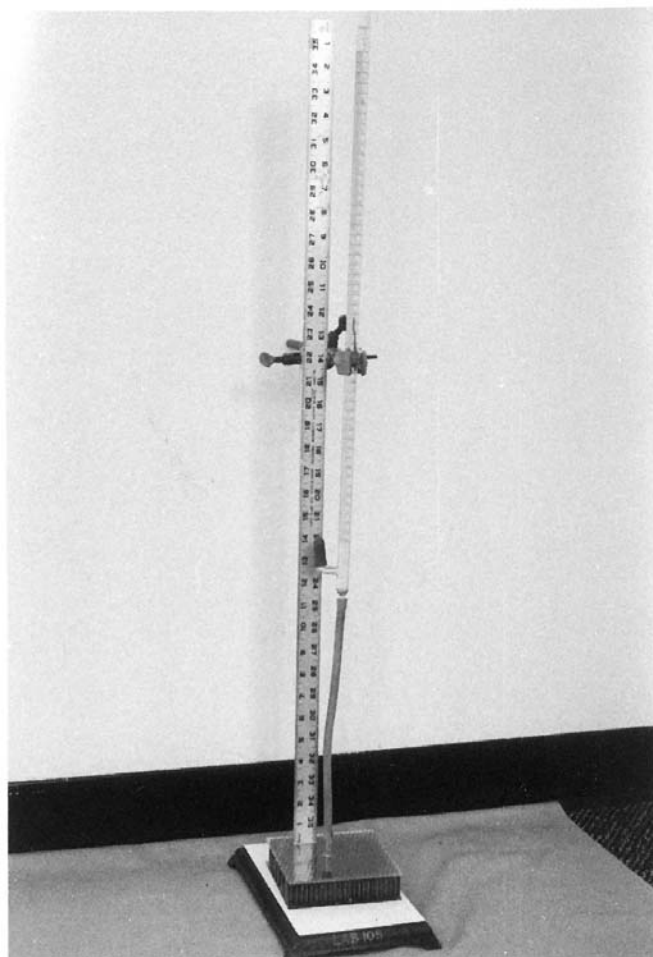


FIG. 1 Water Migration Test Setup

statistically significant data, consult the procedures outlined in Practice **E122**. Report the method of sampling.

8.2 Test Specimens:

8.2.1 Core Geometry—Honeycomb core material test specimens shall have a square or rectangular cross-section. The recommended minimum specimen size is 75 mm [3.0 in.] in length by 75 mm [3.0 in.] in width by 13 mm [0.5 in.] thick.

NOTE 1—The honeycomb core specimen's cross-section is defined to be in the facing plane, in regard to the orientation that the core would be placed in a structural sandwich construction. For a honeycomb core the cross-section is in the plane of the cells, which is perpendicular to the orientation of the cell walls.

8.2.2 Core Preparation and Machining—Prepare the honeycomb core material samples so that the facing plane surfaces are parallel to each other and perpendicular to the sides of the core. Take precautions when cutting specimens from large sheets of core material to avoid notches, undercuts, rough or uneven surfaces due to inappropriate machining methods. Obtain final dimensions by lubricated precision sawing, milling, or grinding. The use of diamond tooling has been found to be extremely effective for many material systems. Record and report the honeycomb core material specimen cutting preparation method.

8.2.3 Facings—The honeycomb core material shall be bonded to impermeable, transparent facings which permit visual observation into the honeycomb core cells by illumination. Clear plastic facings are recommended, for ease of locating a hole over a single cell as well as observation of water migration (see **Fig. 2**).

8.2.4 Adhesive—The honeycomb core material shall be bonded to the facings using a water-resistant adhesive. Use of a clear adhesive is recommended. The adhesive shall be applied so that fairly heavy fillets form between the honeycomb core material cell walls and the facings, thus assuring a watertight joint between the facings and core. After bonding the facings to the core, the honeycomb core material specimen shall be inspected for flawed or damaged cells, porous or cracked adhesive, and other defects which can become pathways for water seepage or flow from cell to cell, thus invalidating results.

8.2.5 Specimen Preparation for Water Introduction—A hole shall be drilled through the upper facing over one centrally

located honeycomb core material cell. The hole shall permit access of water into only one cell. A suitable connection, such as a tube bonded over or into the hole, shall be provided for the application of hydrostatic pressure (see **Fig. 2**). If the amount of water transferred is monitored by mass, an appropriate seal shall be used to cover the hole, to prevent water loss during weighings.

8.3 Labeling—Label the test specimens so that they will be distinct from each other and traceable back to the sheet of origin, and will neither influence the test nor be affected by it.

9. Calibration

9.1 The accuracy of all measuring equipment shall have certified calibrations that are current at the time of use of the equipment.

10. Conditioning

10.1 The recommended pre-test condition is effective moisture equilibrium at a specific relative humidity as established by Test Method **D5229/D5229M**; however, if the test requestor does not explicitly specify a pre-test conditioning environment, no conditioning is required and the test specimens may be tested as prepared.

10.2 The pre-test specimen conditioning process, to include specified environmental exposure levels and resulting moisture content, shall be reported with the test data.

NOTE 2—The term moisture, as used in Test Method **D5229/D5229M**, includes not only the vapor of a liquid and its condensate, but the liquid itself in large quantities, as for immersion.

10.3 If no explicit conditioning process is performed the specimen conditioning process shall be reported as “unconditioned” and the moisture content as “unknown”.

11. Procedure

11.1 Parameters to Be Specified Before Test:

11.1.1 The specimen sampling method, specimen geometry, and conditioning travelers (if required).

11.1.2 The properties and data reporting format desired.

NOTE 3—Determine specific material property, accuracy, and data reporting requirements prior to test for proper selection of apparatus.

11.1.3 The environmental conditioning test parameters.

11.1.4 The buret measurement accuracy.

11.2 General Instructions:

11.2.1 Report any deviations from this test method, whether intentional or inadvertent.

11.2.2 If honeycomb core material density is to be reported, then obtain these samples from the same sheet of honeycomb core material being tested. Density may be evaluated in accordance with Test Method **C271/C271M**.

11.2.3 Following final honeycomb core material specimen machining, but before conditioning and testing, measure the specimen length and width (including the facings) at three places. The thickness of the specimen (including the facings) shall be measured at four locations surrounding the primary honeycomb core cell, and recorded as the average of the four measurements. The accuracy of these measurements shall be within 1.0 % of the dimension. Measure the specimen length

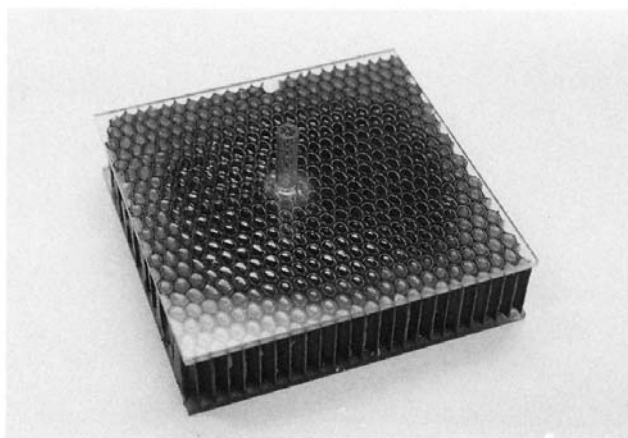


FIG. 2 Water Migration Specimen

and width with an accuracy of $\pm 250 \mu\text{m}$ [$\pm 0.010 \text{ in.}$]. Measure the specimen thickness with an accuracy of $\pm 25 \mu\text{m}$ [$\pm 0.001 \text{ in.}$]. Record the dimensions to three significant figures in units of millimeters [inches].

11.2.4 If the amount of water transferred into the honeycomb core material specimen is to be measured by mass, determine the mass of the specimen (including the facings and seal) with an accuracy of $\pm 0.5 \%$.

11.3 Condition the specimens as required. Store the specimens in the conditioned environment until test time, if the test environment is different than the conditioning environment.

11.4 Following final specimen conditioning, but before testing, re-measure the specimen length, width and thickness as in 11.2.3. If the amount of water transferred is to be measured by mass, re-measure the specimen mass (including the facings and seal) as in 11.2.4.

11.5 Using a syringe, fill the primary honeycomb core material cell with distilled or deionized water. If the amount of water transferred is to be measured by volume, record the volume of water required to fill the cell. It is recommended to add a colored dye to the water to make it easier to see where the water has migrated. If the amount of water transferred is to be measured by mass, seal the hole in the facing and re-measure the specimen mass as in 11.4, with the primary cell filled with water.

11.6 Place the test specimen in the water migration test setup. Using the flexible hose or tube, connect the buret to the test specimen such that water can be introduced into the test specimen. Place the meter stick [yardstick] so that the height of the column of water is measured from the surface of the upper facing, as shown in Fig. 1.

11.7 Fill the buret with room temperature distilled or deionized water such that the primary honeycomb core material cell is maintained under a constant head of $900 \pm 5 \text{ mm}$ [$36.0 \pm 0.2 \text{ in.}$] as shown in Fig. 1. If the amount of water transferred is to be measured by volume, record the volume of water added to the buret (using a syringe) to maintain the head of water.

11.8 Measure the amount of water transfused into the honeycomb core material specimen after 24-h, either by determining the mass of the specimen 24 +1/-0 h after beginning water transfusion, or by determining the volume of water transfused in 24 +1/-0 h. If the amount of water transferred is to be measured by mass, remove the buret, seal the hole in the facing and re-measure the specimen mass (including the facings) as in 11.5.

11.9 After the 24-h period is complete, using a honeycomb diagram (see Fig. 3) mark the honeycomb core material cells into which water has migrated. Differentially mark those cells

which are only partially filled with water from those cells which appear to be full of water.

12. Validation

12.1 Property values shall not be calculated for any specimen that contains some obvious flaw described in 6.1, unless such flaw constitutes a variable being studied. Retests shall be performed for any specimen on which values are not calculated.

13. Calculations

13.1 *Mass-Based Water Migration*—If the amount of water transferred into the honeycomb core material specimen is measured by mass, determine water migration by dividing the total mass of transfused water by the mass necessary to fill one cell.

$$\text{Number of Cells Filled} = \frac{(W_f - W_c)}{(W_c - W_i)} \quad (1)$$

where:

W_f = mass of specimen after water transfusion, g [lbm];
 W_c = mass of specimen after filling the primary cell with water, g [lbm]; and
 W_i = mass of specimen after conditioning, prior to filling the primary cell with water, g [lbm].

13.2 *Volume-Based Water Migration*—If the amount of water transferred into the honeycomb core material specimen is measured by volume, determine water migration by dividing the total volume of transfused water by the volume necessary to fill one cell.

$$\text{Number of Cells Filled} = \frac{V_f}{V_c} \quad (2)$$

where:

V_f = volume of water transfused (added into the buret using the syringe, after filling the primary cell with water), mm^3 [in.^3];
 V_c = volume of water used to fill the primary core cell, mm^3 [in.^3].

13.3 *Statistics*—For each series of tests calculate the average value, standard deviation, and coefficient of variation (in percent) for the number of cells filled:

$$\bar{x} = \left(\sum_{i=1}^n X_i \right) / n \quad (3)$$

$$S_{n-1} = \sqrt{\left(\sum_{i=1}^n x_i^2 - n\bar{x}^2 \right) / (n-1)} \quad (4)$$

$$CV = 100 \times S_{n-1} / \bar{x} \quad (5)$$

where:

$\bar{x}$ = sample mean (average);
 S_{n-1} = sample standard deviation;
 CV = sample coefficient of variation, %;
 n = number of specimens; and
 x_1 = measured or derived property.

14. Report

14.1 Report the following information, or references pointing to other documentation containing this information, to the

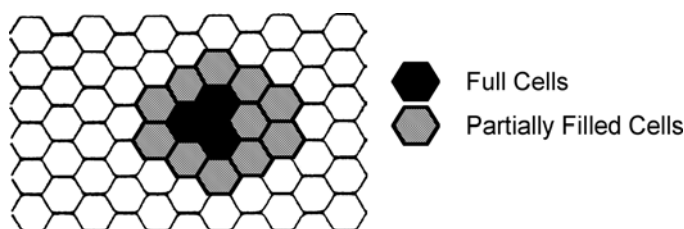


FIG. 3 Honeycomb Cell Diagram

maximum extent applicable (reporting of items beyond the control of a given testing laboratory, such as might occur with material details or panel fabrication parameters, shall be the responsibility of the requestor):

NOTE 4—Guides E1309 and E1434 contain data reporting recommendations for composite materials and composite materials testing.

14.1.1 The revision level or date of issue of this test method.

14.1.2 The name(s) of the test operator(s).

14.1.3 Any variations to this test method, anomalies noticed during testing, or equipment problems occurring during testing.

14.1.4 Identification of all the materials constituent to the sandwich core specimen tested (including the facings and adhesive), including for each: material specification, material type, manufacturer's material designation, manufacturer's batch or lot number, source (if not from manufacturer), date of certification, and expiration of certification.

14.1.5 Description of the fabrication steps used to prepare the sandwich core specimen including: fabrication start date, fabrication end date, process specification(s), and a description of the equipment used.

14.1.6 Method of preparing the test specimen, including specimen labeling scheme and method, specimen geometry, sampling method, specimen cutting method(s) and specimen drilling method.

14.1.7 Results of any nondestructive evaluation tests.

14.1.8 Calibration dates and methods for all measurements and test equipment.

14.1.9 Type of balance or weighing scale and measurement accuracy.

14.1.10 Description of water migration setup.

14.1.11 Individual and average measurement values of length, width and thickness for each specimen (prior to and after conditioning, if appropriate).

14.1.12 Mass of specimen prior to water migration (prior to and after conditioning, if appropriate).

14.1.13 Measured core density.

14.1.14 Conditioning parameters and results.

14.1.15 Relative humidity and temperature of the testing laboratory.

14.1.16 Number of specimens tested.

14.1.17 Method(s) of monitoring water migration (by mass, by volume, or both).

14.1.18 Mass of specimen after filling the primary cell with water.

14.1.19 Volume of water required to fill one cell (the primary cell).

14.1.20 Mass of specimen after water migration.

14.1.21 Volume of water migrated.

14.1.22 Individual values for the number of cells filled during 24-h period, as well as average value, standard deviation, and coefficient of variation (in percent) for the population.

14.1.23 Diagram showing the cells the water has migrated into for each specimen, differentiating between those cells which are only partially filled with water from those cells which appear to be full of water.

15. Precision and Bias

15.1 *Precision*—The data required for the development of a precision statement are not available for this test method.

15.2 *Bias*—Bias cannot be determined for this test method as no acceptable reference standards exist.

16. Keywords

16.1 core; honeycomb; sandwich; water migration

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