



Designation: D5229/D5229M – 20

Standard Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials¹

This standard is issued under the fixed designation D5229/D5229M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

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

INTRODUCTION

Consistent evaluation and comparison of the response of polymer matrix composites to moisture absorption can only be performed when the material has been brought to a uniform through-the-thickness moisture profile. The procedures described in Test Method **D570** and Practice **D618** do not guarantee moisture equilibrium of the material. A similar, but more rigorous, procedure for conditioning to equilibrium is described by this test method, which can also be used with fluid moisture other than water, and which, additionally, can provide the moisture absorption properties necessary for the analysis of single-phase Fickian moisture diffusion within such materials.

1. Scope

1.1 This test method covers a procedure for the determination of moisture absorption or desorption properties in the through-the-thickness direction for single-phase Fickian solid materials in flat or curved panel form. Also covered are procedures for conditioning test coupons prior to use in other test methods; either to an essentially moisture-free state, to equilibrium in a standard laboratory atmosphere environment, or to equilibrium in a non-laboratory environment. Also included are procedures for determining the moisture loss during elevated temperature testing, as well as moisture loss resulting from thermal exposure after removal from the conditioning environment, such as during strain gauge bonding. While intended primarily for laminated polymer matrix composite materials, these procedures are also applicable to other materials that satisfy the assumptions of **1.2**.

1.2 The calculation of the through-the-thickness moisture diffusivity constant in Procedure A assumes a single-phase Fickian material with constant moisture absorption properties through the thickness of the specimen. The validity of the equations used in Procedure A for evaluating the moisture diffusivity constant in a material of previously unknown moisture absorption behavior is uncertain prior to the test, as the test results themselves determine if the material follows the

single-phase Fickian diffusion model. A reinforced polymer matrix composite material tested below its glass-transition temperature typically meets this requirement, although two-phase matrices such as toughened epoxies may require a multi-phase moisture absorption model. While the test procedures themselves may be used for multi-phase materials, the calculations used to determine the moisture diffusivity constant in Procedure A are applicable only to single-phase materials. Other examples of materials and test conditions that may not meet the requirements are discussed in Section **6**.

1.3 The evaluation by Procedure A of the moisture equilibrium content material property does not assume, and is therefore not limited to, single-phase Fickian diffusion behavior.

1.4 The procedures used by this test method may be performed, and the resulting data reduced, by suitable automatic equipment.

1.5 This test method is consistent with the recommendations of CMH-17 Rev G **(1)**,² which describes the desirable attributes of a conditioning and moisture property determination procedure.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

¹ This test method is under the jurisdiction of ASTM Committee **D30** on Composite Materials and is the direct responsibility of Subcommittee **D30.04** on Lamina and Laminate Test Methods.

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² The boldface numbers in parentheses refer to the list of references at the end of this standard.

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

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

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

2. Referenced Documents

2.1 ASTM Standards:³

D570 Test Method for Water Absorption of Plastics

D618 Practice for Conditioning Plastics for Testing

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D883 Terminology Relating to Plastics

D2344/D2344M Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates

D2584 Test Method for Ignition Loss of Cured Reinforced Resins

D2734 Test Methods for Void Content of Reinforced Plastics

D3171 Test Methods for Constituent Content of Composite Materials

D3878 Terminology for Composite Materials

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

2.2 Military Standard:⁴

MIL-B-131 Barrier Materials, Water Vapor-Proof, Grease-Proof, Flexible, Heat-Sealable

3. Terminology

3.1 Definitions:

3.1.1 Terminology **D3878** defines terms relating to high-modulus fibers and their composites. Terminology **D883** defines terms relating to plastics. In the event of a conflict between terms, Terminology **D3878** shall have precedence over the other terminology standards.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 If the term represents a physical quantity, its analytical dimensions are stated immediately following the term (or letter symbol) in fundamental dimension form, using the following ASTM standard symbology for fundamental dimensions, shown within square brackets: $[M]$ for mass, $[L]$ for length, $[T]$ for time, $[Θ]$ for thermodynamic temperature, and $[nd]$ for non-dimensional quantities. Use of these symbols is restricted

to analytical dimensions when used within square brackets, as the symbols may have other definitions when used without the brackets.

3.2.2 *accuracy criterion, n* —the maximum amount of change in average moisture content for a test coupon, over the span of the reference time period, which is allowable for the establishment of effective moisture equilibrium. (See also *average moisture content*, *moisture equilibrium*, and *reference time period*.)

3.2.3 *average moisture content, M (%)*, n —the average amount of absorbed moisture in a material, taken as the ratio of the mass of the moisture in the material to the mass of the oven-dry material and expressed as a percentage, as follows:

$$M, \% = \frac{W_i - W_o}{W_o} \times 100 \quad (1)$$

where:

W_i = current specimen mass, g, and

W_o = oven-dry specimen mass, g.

(See also *oven-dry*.)

3.2.4 *Fickian diffusion, n* —a model of material moisture absorption and desorption that follows Fick's second law, as follows in one-dimension:

$$\frac{\partial c}{\partial t} = D_z \frac{\partial^2 c}{\partial z^2}$$

3.2.5 *glass transition temperature, T_g [°C]*, n —the approximate midpoint of the temperature range over which a reversible change takes place between a viscous or rubbery condition and a hard, relatively brittle condition, in an amorphous polymer, or in amorphous regions of a partially crystalline polymer.

3.2.5.1 *Discussion*—The glass transition temperature of many polymer matrix composites is lowered by the presence of absorbed moisture.

3.2.6 *moisture, n* —liquid (water, jet fuel, salt water, or any other liquid) that is either diffused in relatively small quantity and dispersed through a gas as a vapor, condensed on a surface as visible dew, or present in quantity sufficient for immersion of an object.

3.2.6.1 *Discussion*—The dictionary definition of moisture for this test method is extended to include not only the vapor of a liquid and its condensate, but the liquid itself in large quantities, as for immersion.

3.2.7 *moisture concentration, c [ML^{-3}]*, n —the absolute amount of absorbed moisture in a material expressed as the mass of moisture per unit volume.

3.2.8 *moisture diffusivity constant, D_z [L^2T^{-1}]*, n —the property of a material that describes the rate at which the material absorbs or desorbs moisture.

3.2.8.1 *Discussion*—In Fickian materials, this property is relatively independent of the moisture exposure level (and thus the moisture equilibrium content material property). However, the moisture diffusivity constant is strongly influenced by temperature. Moisture diffusivity can be anisotropic; the subscript z indicates the value in the through-the-thickness direction for anisotropic diffusion behavior.

³ 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.

⁴ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.