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Standard Test Method for Tensile Properties of Organic Coatings[1]

This standard is issued under the fixed designation D2370; 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.

1. Scope

1.1 This test method covers the determination of the elongation, tensile strength, and stiffness (modulus of elasticity) of organic coatings when tested as free films.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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.* Specific hazard statements are given in Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels

D882 Test Method for Tensile Properties of Thin Plastic Sheeting

D1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

D3980 Practice for Interlaboratory Testing of Paint and Related Materials[3]

D4708 Practice for Preparation of Uniform Free Films of Organic Coatings

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *elongation*, *n*—the increase in specimen length from the point of initial load application to the point of film rupture in a tension test.

3.1.2 *gage length*, *n*—the initial length of the test specimen between the jaws of the tensile tester.

3.1.3 *stiffness (modulus of elasticity)*, *n*—the load per unit area required to elongate the film 1 % from the first point in the stress-strain curve where the slope becomes constant.

3.1.4 *stress-strain curve*, *n*—the curve resulting from a plot of tensile load against the distance of jaw separation (elongation of specimen).

3.1.5 *tensile strength (nominal)*, *n*—the load per original unit area at which a specimen fails or yields in a tension (pull) test.

4. Summary of Test Method

4.1 Free unsupported films of the materials to be tested are prepared. The tensile properties of the free films are determined by means of a tensile testing apparatus.

5. Significance and Use

5.1 Tensile properties determined by this method are of value in studying the behavior of coatings subjected to environmental stresses, such as those produced by aging and weathering. (See Refs. (**1-10**).)[4]

5.2 Tensile properties may vary with specimen thickness, method of preparation, gage length, rate of load application, tensile tester response, and type of grips used. Consequently, where precise comparative results are desired, these factors must be carefully controlled.

6. Apparatus

6.1 Equipment for applying films of uniform thickness as described in Practices D823.

6.2 *Micrometer Film Thickness Gage* as described in Test Method D1005.

6.3 *Tensile Tester* of the constant rate of jaw separation type, equipped with load cells having capacities of 0.2 to 4.4 lb

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[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.23 on Physical Properties of Applied Paint Films.

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[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.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

[4] Boldface numbers in parentheses refer to the list of references at the end of this standard.

(100 to 2000 g), and equipped with an indicating device such as an electronic constant speed chart recorder, a digital device that displays numerical values, or a printer that records the numerical values.

6.4 *Precision Specimen Cutter* having a double blade with a foot to hold the sample in place.[5]

6.5 *Alternative Substrates* on which test material can be deposited.

6.5.1 *Dental Tin Foil*, preferably 1 mil (25 µm) thick.[6]

6.5.2 *Sheet of FEP* (fluorinated ethylene-propylene),[7] preferably 2 mils (50 µm) thick, coated with a dry lubricant.[8]

NOTE 1—Other substrates that may be suitable are 10-mil (250-µm) thick polyethylene (7), photographic paper (8), polished steel (9), and fluoropolymer coated metal panels.

7. Hazards

7.1 *Mercury*—Mercury is a toxic metallic liquid. Its vapors are extremely hazardous. Small amounts of spilled mercury can vaporize sufficiently at room temperature to exceed the threshold limit values (TLV) of the vapor. Use with adequate ventilation (in a hood) and clean up spills immediately. Wear gloves when handling mercury. Keep containers closed. Droplets of mercury can be picked up by using a small glass pipet connected to a suction flask with a rubber hose.

8. Test Specimens

8.1 The test specimens shall be free films having a width that is between ½ and 1 in. (13 and 25 mm). No specimen shall vary by more than ±2 % in width along its entire length. The length shall be at least 2 in. (50 mm) longer than the gage length selected for the test.

8.2 Prepare free films by one of the procedures described in Test Method D4708.

9. Calibration

9.1 Balance, zero, and calibrate the load weighing and recording system of the tensile tester in accordance with methods specified by the manufacturer.

10. Conditioning

10.1 Unless otherwise agreed upon between the producer and the user, condition the test specimens for at least 24 h at 73.5 ± 3.5°F (23 ± 2°C) and 50 % relative humidity and test in the same environment.

11. Procedure

11.1 Select a mutually agreed upon gage length in the range of 1 to 5 in. (25 to 125 mm).

11.2 Prepare 10 test specimens for each material to be evaluated. These specimens should not exhibit any nicks or flaws. Measure the thickness of each specimen to ±0.1 mil (2.5 µm) with a micrometer in accordance with Test Methods D1005, taking five measurements within the gage length area.

11.3 Set the jaw separation of the tensile tester at the gage length selected. Place the test specimen in the grips of the testing machine, taking care to align the long axis of the specimen with an imaginary line joining the points of attachment of the grips to the machine. Tighten the grips evenly and firmly to the degree necessary to minimize slipping of the specimen during test.

NOTE 2—Mounting is facilitated by the use of air activated jaws. Line-type jaws will minimize slippage and breakage. The application of pressure-sensitive cloth to the ends of the film can improve jaw grip.

11.4 Select a mutually agreed upon rate of elongation (strain rate) that is in the range of 5 to 100 %/min. Set the crosshead speed of the tensile tester to provide this rate for the gage length chosen.

NOTE 3—A rate of elongation should be selected that is optimum for testing the types of materials to be evaluated. For relatively brittle films, elongation rates of 5 to 20 % are suggested. For relatively extensible films, elongation rates of 50 to 100 % are suggested. (Refer to Test Methods D882 for relation of elongation rate to elongation at break).

11.5 Elongate the test specimen until rupture of the film occurs and evaluate the stress-strain curve as follows:

11.5.1 Determine the specimen elongation by measuring the increase in jaw separation from the point of original load application to the point of rupture.

11.5.2 Measure the tensile pull in pounds (kg) required to rupture the film.

11.5.3 If stiffness is desired, determine the tensile pull in pounds (kg) to elongate the film 1 % from the first point in the stress-strain curve where the slope becomes constant.

11.6 Using the procedures in 11.1-11.5, run ten test specimens for each material under test.

12. Calculations

12.1 For each specimen compute the following:

12.1.1 The elongation E, in percent from the following equation:

$$E = 100\left(\frac{\Delta L}{L}\right) \quad (1)$$

where:

ΔL = increase in specimen length to break, and
L = initial specimen length (gage length).

12.1.2 The tensile strength, TS, in pounds per square inch, from the equation:

$$TS = (P_R)/(TW) \quad (2)$$

[5] The sole source of supply of the JDC precision cutter known to the committee at this time is the Thwing-Albert Instrument Co., 10960 Dutton Rd., Philadelphia, PA 19154. 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] Dental tin foil is suitable for this purpose.

[7] Teflon FEP 2-mil film thickness (Card No. 03111, Item #29499) from E. I. du Pont de Nemours & Co., Inc., Wilmington, DE 19898, was found suitable for this purpose. However, it is no longer available. See Note 1 for alternatives.

[8] The sole source of supply of a dry lubricant (MS-122 Fluorocarbon Release Agent), known to the committee at this time is the Miller-Stephenson Chemical Co., Inc., 55 Backus Ave., Danbury, CT 06810. 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.

where:
P_R = tensile pull to rupture, lb (kg),
T = thickness of test specimen, in. (mm), and
W = width of test specimen, in. (mm).

12.1.3 The stiffness (modulus of elasticity), S, from the following equation:

$$S = (P_E)/(TW) \quad (3)$$

where:
P_E = pull in pounds (kg) to elongate the film 1 % from the first point in the stress-strain curve where the slope remains constant,
T = thickness of test specimen, in. (mm), and
W = width of test specimen, in. (mm).

12.2 Examine the uniformity of the tensile strength and elongation results obtained for the ten specimens measured for a material. Choose one of the following procedures for discarding spurious values and calculate the mean of the remaining results:

12.2.1 Use the results from those five specimens showing the highest tensile strength in evaluating all three properties, discarding those from the remaining five. This is done on the basis that the expected errors (nicks or flaws in the specimen, breaks within the jaw, slippage in the jaw, etc.) would all tend to produce results on the low side.

12.2.2 Discard the values for those specimens where both the tensile strength and elongation values are significantly lower than those for most of the specimens. Use the test for outliers given in Practice D3980 – 88.

13. Report

13.1 Report the mean values obtained with the test specimens for:

13.1.1 Tensile strength,

13.1.2 Elongation, and

13.1.3 Stiffness (modulus of elasticity), if desired.

13.2 Report the conditions of the test.

13.2.1 Procedure for preparation of free films,

13.2.2 Rate of elongation in percent per minute,

13.2.3 Specimen size (length, width, and thickness),

13.2.4 Temperature and relative humidity during test and treatment, and

13.2.5 Aging and treatment given the specimens.

14. Precision and Bias

14.1 *Precision*—An interlaboratory test of this test method was conducted in which three coatings (representing a brittle film, a film with limited elasticity, and a very elastic film) were tested by five laboratories. The test was conducted with Instron tensile testers operated at two elongation rates (10 and 100 %) with a specimen gage length of 2 in. (50 mm) and specimen thicknesses of 2.5 to 3.5 mils (65 to 90 µm). The between laboratory coefficients of variation were found to be 30 % for percent elongation and 18 % for tensile strength. Based on these coefficients, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

14.1.1 *Reproducibility*—Two results for percent elongation obtained by operators in different laboratories should be considered suspect if they differ by more than 118 % of their mean. Two results for tensile strength obtained by operators in different laboratories should be suspect if they differ by more than 70 % of their mean.

14.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method for measuring tensile properties using tensile testers, bias has not been determined.

15. Keywords

15.1 elongation; organic coatings; stiffness; tensile properties; tensile strength

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