Designation: D1640/D1640M – 14

Standard Test Methods for Drying, Curing, or Film Formation of Organic Coatings[1]

This standard is issued under the fixed designation D1640/D1640M; 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.

1. Scope

1.1 These test methods cover the determination of the various stages and rates of film formation in the drying or curing of organic coatings under laboratory controlled conditions of air temperature, (low, ambient and/or elevated) and/or humidity. Procedures for assessing drying under prevailing conditions of temperature and humidity in the shop and field are also described.

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.

1.3 *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]

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

D4414 Practice for Measurement of Wet Film Thickness by Notch Gages

2.2 *ISO Standards:*

ISO 9117–4 Paints and varnishes — Determination of drying — Part 4: Method using a mechanical recorder

3. Significance and Use

3.1 These test methods can be used to determine the various stages and rates of drying, curing, and film formation of organic coatings for comparing types of coatings, assessing the impact of compositional changes on drying time, or for assessing drying/curing time in the shop or field. Low temperature can significantly slow the drying rate of coatings so low temperature curing agents, catalysts and/or accelerators are often available to aid drying and film formation under cooler temperatures. Method B is designed to evaluate these components and/or to determine the effect of cooler temperatures on drying rates. Conversely, the drying/curing rate of certain coatings can be accelerated under elevated temperature/humidity conditions, while others may be adversely impacted by elevated humidity. Method C is designed to evaluate the effects of elevated temperature and relative humidity conditions on drying, curing, and film formation of paints and coatings. The terms dry or drying, cure or curing, and film formation are used interchangeably throughout this standard.

3.2 Test Methods A, B and C are limited to a comparison of paints/coatings applied to smooth, non-absorbent substrates and do not reflect the effect of absorption of the paint vehicle into the substrate material.

4. Substrate, Coating Application Method and Film Thicknesses

4.1 Obtain agreement between the contracting parties as to the substrate, wet film thickness (WFT), and application method for testing the specific coating involved. The product is tested as manufactured (without reducer, unless otherwise agreed upon by contracting parties). Unless otherwise agreed, the thickness of the cast film shall conform to the coating manufacturer's product data sheet. If the wet film thickness is not stated on the manufacturer's product data sheet, it can be calculated using the formula in 4.1.1 based on the manufacturer's recommended dry film thickness (DFT) and percent non-volatile by volume (% solids by volume). If this information is not provided, contact the coating manufacturer to obtain the recommended wet film thickness for testing.

4.1.1 $\text{WFT} = (\text{DFT} \div \%\ \text{Solids by Volume})$

[1] These test methods are under the jurisdiction of ASTM Committee 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.

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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.

5. Test Conditions

5.1 *Method A (Laboratory Procedure — Normal Drying Conditions):*

5.1.1 Conduct all drying tests in a well-ventilated room or chamber, free from direct drafts, dust, products of combustion, laboratory fumes and under diffused light (see 5.1.4). Make all measurements at an air temperature of 23 ± 2°C and 50 ± 5 % relative humidity with the coated panels in a horizontal position while drying.

5.1.2 Apply the wet film according to the coating manufacturer's instructions. In the absence of any specific material specification or product data sheets, instructions for casting the film should be agreed upon between contracting parties.

5.1.3 Films to be tested should have practical thicknesses commensurate with the coating manufacturer's recommendations. All testing should be performed within an area at least 15 mm [½ in.] from any film edge.

5.1.4 Illumination of the films during the entire drying test period must be from low, non-radiant energy light sources, such as normal laboratory or sky sources, never from direct sunlight.

5.2 *Method B (Laboratory Procedure — Low Air Temperature Drying Conditions):*

5.2.1 Conduct all drying tests in a ventilated temperature and humidity-controlled chamber. Allow the temperature and relative humidity to stabilize within the chamber prior to use.

5.2.2 Condition the substrate material, the coating to be tested, and the application device for a minimum of 1 h in the temperature/humidity-controlled chamber prior to casting the wet film.

5.2.3 Make all measurements at a temperature and relative humidity as agreed upon between contracting parties. Record the actual temperature and relative humidity employed for testing. All dry time measurements are made with the coated panels in a horizontal position while drying.

5.2.4 Apply the wet film according to the coating manufacturer's instructions. In the absence of any specific material specification or product data sheets, instructions for casting the film should be agreed upon between contracting parties.

5.2.5 Films to be tested should have practical thicknesses commensurate with the coating manufacturer's recommendations. All testing should be performed within an area at least 15 mm [½ in.] from any film edge.

5.2.6 Minimize opening and closing of the temperature and humidity-controlled chamber to prevent fluctuations in conditions.

5.3 *Method C (Laboratory Procedure — Elevated Air Temperature and Humidity Drying Conditions):*

5.3.1 Conduct all drying tests in a ventilated temperature and humidity-controlled chamber. Allow the temperature and relative humidity to stabilize within the chamber prior to use. If elevated temperature without consideration for humidity is desired, a convection oven can be used.[4,5]

5.3.2 Condition the substrate material, the coating to be tested, and the application device for a minimum of 1 h in the temperature/humidity-controlled chamber prior to casting the wet film.

5.3.3 Make all measurements at a temperature and relative humidity as agreed upon between contracting parties. Record the actual temperature and relative humidity employed for testing. All dry time measurements are made with the coated panels in a horizontal position while drying.

5.3.4 Apply the wet film according to the coating manufacturer's instructions. In the absence of any specific material specification or product data sheets, instructions for casting the film should be agreed upon between contracting parties.

5.3.5 Films to be tested should have practical thicknesses commensurate with the coating manufacturer's recommendations. All testing should be performed within an area at least 15 mm [½ in.] from any film edge.

5.3.6 Minimize opening and closing of the temperature and humidity-controlled chamber to prevent fluctuation of conditions.

5.4 *Method D (Shop/Field Procedure):*

5.4.1 Measure and record air and surface temperature, and relative humidity immediately prior to coating application.

5.4.2 Apply the wet film according to the coating manufacturer's instructions. In the absence of any specific material specification or product data sheets, instructions for applying the film should be agreed upon between contracting parties.

5.4.3 Apply the wet film to the same substrate and surface texture using the same application equipment and parameters as are intended to be used in the shop/filed during production.

5.4.4 Films to be tested should have practical thicknesses commensurate with the coating manufacturer's recommendations.

6. Preparation of Test Specimens

6.1 Carry out all tests as described in 6.1.1 – 6.1.5, unless otherwise noted.

6.1.1 All test specimens (test surfaces for Method D) shall be prepared and tested by one operator proficient in the methods to be used. Apply the coating material to the agreed upon substrate in duplicate at a time arranged so that evaluation intervals will fall within the normal working hours of the operator.

6.1.2 If the coating to be tested requires an induction time, cast/apply the wet film after the induction period.

6.1.3 For Methods A, B and C, apply the materials to be tested on clean glass panels, smooth cold-rolled steel panels or other specific substrate of suitable dimensions agreed upon between contracting parties. Ground-glass plates are more suitable for certain types of coatings that tend to crawl, such as low-viscosity drying oils. Suitable plates can be prepared by roughening the surface of polished glass by grinding a paste of silicon carbide (grit 1–F) and water between two glass plates.

6.1.4 For Methods A, B and C cast the coating materials to the substrate with a wet film applicator having a clearance sufficient to yield the recommended wet and resulting dry film

[4] Consider potential safety hazards associated with the flash point of any organic solvents included in the paint/coating vehicle.

[5] A hot plate may be used to generate different air and surface temperature, if required.

thickness. Other methods to produce a film of uniform thickness such as those described in Practices D823 may be used as agreed upon between contracting parties.

6.1.5 Measure the wet film thickness in accordance with Practice D4414.

7. Procedure

7.1 When test methods or end points other than those listed in 7.2 – 7.8 are used, there shall be a prior agreement between the contracting parties.

7.2 *Set-To-Touch Time*—Lightly touch the test film with the tip of a finger (clean and free of grease) and immediately place the fingertip against a piece of clean, clear glass. Observe if any of the coating is transferred to the glass. For the purpose of this test, the pressure of the fingertip against the coating shall not be greater than that required to transfer a spot of the coating from 3 to 5 mm [⅛ to 3⁄16 in.] in cross section. The film is set-to-touch when it still shows a tacky condition, but none of it adheres to the finger. Remove any coating from the fingertip immediately. The use of a glove, finger cots or the presence of freshly-applied cosmetic products/hand creams may interfere with the test results.

7.3 *Dust-Free Times (Applicable to Methods A, B, and C only):*

7.3.1 *Cotton Fiber Test Method*—Separate a number of individual fibers from a mass of absorbent cotton with the aid of tweezers. At regular drying intervals, drop several of the cotton fibers from a height of 25 mm [1 in.] onto a marked section of the film. The film is considered to have dried dust free when the cotton fibers can be removed by blowing lightly over the surface of the film.

7.4 *Tack-Free Times (Applicable to Method A only):*

7.4.1 *Mechanical Test Method (Tack Tester*[6])—The tack tester is comprised of a base or surface-contacting portion 25-mm [1-in.] square and a counter-balancing portion 25 by 50 mm [1 by 2 in.] in area. Both portions are made up from a continuous metal strip 0.41 to 0.46 mm [0.016 to 0.018 in.] in thickness. To prepare the apparatus for use (see 7.4.1.1), fit the base with several thicknesses of masking tape and paper strips to provide a means of attaching the aluminum foil and so adjust the angle of the 1 by 2-in. counter-balancing strip so that a weight of 5 g placed in the geometric center of the base portion is just sufficient to overcome the unbalanced force.

7.4.1.1 The tester is prepared by following steps in sequence:

(1) Wrap the metal base with three thicknesses of masking tape, sticky side out,

(2) Cover the outer layer with a good grade of paper, except for two exposed strips, equally spaced, about 6.4 by 25 mm [¼ by 1 in.] in area on the top of the tester, and

(3) Cover the paper on the contact side of the base with one thickness of pressure-sensitive cellulose tape previously fixed to the metal base of the tester. The cellulose tape serves two purposes: (*1*) to pull the layers of masking tape firmly against the front of the metal base, and (*2*) to provide a smooth surface for the foil.

(4) Attach the aluminum foil to the base of the tester by pressing gently but firmly a 25 by 50-mm [1 by 2-in.] piece of foil, 13 µm [0.0005 in.] in thickness against one of the 6.4 by 25-mm [¼ by 1-in.] exposed strips of masking tape on the top surface of the base. Wrap the foil tightly and smoothly around the base, exposing the shiny side, and finally press the outer end gently against the remaining exposed strip of masking tape. When it finally becomes necessary to replace wrinkled or soiled aluminum foil, the ends are easily removed from the masking tape by exerting a slow, even, upward pull sufficient to overcome the tack of the tape without tearing the foil.

7.4.1.2 A film is considered to have dried tack-free when the tack tester tips over immediately on removing a 300-g weight allowed to act for 5 s on the counter-weighted metal square base fitted with masking tape and aluminum foil.

7.5 *Dry-To-Touch Time:*

7.5.1 Continue testing after the set-to-touch time (7.2) has been observed. The film is considered dry-to-touch when it no longer adheres to the finger and does not rub up appreciably when the finger is lightly rubbed across the surface. Remove any coating from the fingertip immediately. The use of a glove, finger cots or the presence of freshly-applied cosmetic products/hand creams may interfere with the test results.

7.6 *Dry-Hard Time:*

7.6.1 With the end of the thumb resting on the test film and the forefinger supporting the test panel, exert a maximum downward pressure (without twisting) of the thumb on the film. Lightly polish the contacted area with a soft cloth. The film is considered dry-hard when any mark left by the thumb is completely removed by the polishing operation. Remove any coating from the thumb immediately. The use of a glove, finger cots or the presence of freshly-applied cosmetic products/hand creams may interfere with the test results.

7.7 *Dry-Through (or Dry-To-Handle) Time:*

7.7.1 For Methods A, B, and C, place the test panel in a horizontal position at a height such that when the thumb is placed on the film, the arm of the operator is in a vertical line from the wrist to the shoulder. For Method D, perform the testing on a coated horizontal surface when feasible. Bear down on the film with the thumb, exerting the maximum pressure of the arm, at the same time turning the thumb through an angle of 90° in the plane of the film. The film is considered dry-through or dry-to-handle when there is no loosening, detachment, wrinkling, or other evidence of distortion of the film. Remove any coating from the thumb immediately. The use of a glove, finger cots or the presence of freshly-applied cosmetic products/hand creams may interfere with the test results.

7.8 *Dry-To-Recoat:*

7.8.1 A film is considered dry for recoating when a second coat or specified topcoat can be applied without the development of any film irregularities such as lifting or loss of

[6] A straight line or circular mechanical drying-time recording device described in ISO 9117–4 can be used as an alternative to the tack tester. Follow the manufacturer's instructions. Data generated using the tack tester should not be compared to data generated using the mechanical drying-time recording devices.

adhesion of the first coat, and the dry time of the second coat does not exceed the maximum specified (if any) for the first coat.

8. Frequency of Testing

8.1 *Known Dry Time (Verification only):*

8.1.1 Suggested test intervals are approximately 10 % of the total test time. The actual intervals used shall be reported when the frequency varies considerably from the suggested interval or such time interval is impractical. Use shorter evaluation intervals when approaching the end-point.

8.2 *Unknown Dry Time:*

8.2.1 When the dry time is unknown start evaluations at 0.5-hour intervals for coatings projected to have a characteristically long dry time and a 0.25-hour intervals for coatings projected to have a characteristically short dry time. Use shorter evaluation intervals when approaching the end-point. The actual intervals used shall be reported.

9. Report

9.1 Report the following:

9.1.1 Coating manufacturer,

9.1.2 Product name and No.,

9.1.3 Batch No.'s for each component,

9.1.4 Generic coating type,

9.1.5 Test Method used (A, B, C, D),

9.1.6 Method of application,

9.1.7 Applied wet film thickness,

9.1.8 Temperature during testing,

9.1.9 Relative humidity during testing,

9.1.10 Test procedure(s) (from Section 7), and

9.1.11 Actual time intervals.

10. Precision and Bias

10.1 Because of the subjective nature of the drying time tests, the agreement to be expected between laboratories depends upon their understanding of the terms used, and is difficult to establish with certainty. Within any laboratory, the agreement depends upon the material being tested, some coatings being much sharper in their end point than others, but duplicate determinations should agree within 10 % of the time of drying.

10.2 *Bias*—These test methods have no bias because the value for dry times are defined only in terms of these test methods.

11. Keywords

11.1 cure; curing; dry; drying; drying time; film formation