Designation: D6132 – 13 (Reapproved 2017)

Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an Ultrasonic Coating Thickness Gage[1]

This standard is issued under the fixed designation D6132; 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 describes the use of ultrasonic film thickness gages to measure accurately and nondestructively the dry film thickness of organic coatings applied over a substrate of dissimilar material. Measurements may be made on field structures, on commercially manufactured products, or on laboratory test specimens. These types of gages can accurately measure the dry film thickness of organic coatings on a variety of substrates such as concrete, wood, wallboard, plastic, fiber composites and metal.

1.2 This test method is not applicable to coatings that will be readily deformable under load of the measuring instrument as the instrument probe is placed directly on the coating surface to take a reading.

1.3 The effective range of instruments using the principle of ultrasonics is limited by gage design. A thickness range of 8 µm to 7.60 mm (0.3 to 300 mils) has been demonstrated.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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.*

1.6 *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:*[2]

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

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

D4138 Practices for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive, Cross-Sectioning Means

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

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

2.2 *SSPC—The Society for Protective Coatings Standards:*[3]

PA 2 Procedure for Determining Conformance to Dry Coating Thickness Requirements

PA 9 Measurement of Dry Organic Coating Thickness on Cementitious Substrates Using Ultrasonic Gages

2.3 *ASME—The American Society of Mechanical Engineers:*[4]

B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *accuracy, n*—the measure of the magnitude of error between the result of a measurement and the true thickness of the item being measured.

3.1.1.1 *Discussion*—An accuracy statement predicts the ability of a coating thickness gage to measure the true thickness of a coating to be measured. Accuracy statements provide the performance capability across the full functional measurement

[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] Available from Society for Protective Coatings (SSPC), 800 Trumbull Dr., Pittsburgh, PA 15205, http://www.sspc.org.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

range of the gage. Accuracy statements frequently include a fixed portion that remains constant across the measurement range, plus a variable portion that is related to the measurement result for a particular thickness.

3.1.2 *adjustment, n*—the physical act of aligning a gage's thickness readings to match those of a known thickness sample (removal of bias), in order to improve the accuracy of the gage on a specific coating.

3.1.2.1 *Discussion*—An adjustment will affect the outcome of subsequent readings.

3.1.3 *calibration, n*—the high-level, controlled and documented process of obtaining measurements on traceable calibration standards over the full operating range of the gage, then making the necessary gage modification (as required) to correct any out-of-tolerance conditions.

3.1.3.1 *Discussion*—Calibration of coating thickness gages is typically performed by the equipment manufacturer, their authorized agent, or by an accredited calibration laboratory in a controlled environment using a documented process. The outcome of the calibration process is to restore/realign the gage to meet/exceed the manufacturer's stated accuracy.

3.1.4 *certification, n*—documentation of the state of condition of the gage, which can (but not required by definition) be accompanied by corrective action (such as adjustment or calibration, or both, or the replacement of components) necessary to correct any out-of-tolerance conditions.

3.1.5 *coating thickness standard, n*—coated metal plates, or uncoated shims of flat sheet, with assigned values traceable to a National Metrology Institution.

3.1.6 *couplant, n*—a substance such as water, oil, grease, or paste used to avoid the retarding of sound transmission by air between the transducer and the test piece during ultrasonic examination.

3.1.7 *dry film thickness, n*—the thickness of a coating (or coating layers) as measured from the surface of the substrate.

3.1.8 *gage (gauge), n*—an instrument for measuring quantity, or an instrument for testing.

3.1.8.1 *Discussion*—In this test method, the term "gage" refers to an instrument for quantifying coating thickness.

3.1.9 *manufacturer's specifications, n*—a statement or set of statements that describes the performance characteristics of the gage under a given set of conditions.

3.1.9.1 *Discussion*—Manufacturer's specifications typically include the range of measurement, accuracy statement, operating temperature range, power source, dimensions and weight, and conformance to industry standards.

3.1.10 *measurement (reading), n*—the value obtained when placing the probe of a thickness gage in contact with a surface.

3.1.11 *micrometer (micron), n*—one one-thousandth of a milimetre (0.001 mm); 25.4 microns =1 mil.

3.1.12 *mil, n*—a U.S. term referring to the imperial unit of measure of one one-thousandth of an inch (0.001 in.) referred to elsewhere in the world as "one thou;" 1 mil = 25.4 microns.

3.1.13 *reference sample, n*—a specimen, coated with a material that is as close as possible in composition to the intended application, used to adjust and/or verify the accuracy of an ultrasonic coating thickness measuring gage for a specific project.

3.1.13.1 *Discussion*—A coated reference sample may or may not have thickness values traceable to a National Metrology Institution. However, the reference sample should be marked with the stated value and the degree of accuracy. The coating thickness of the sample should be equal to or slightly greater than the user's coating thickness measurement requirement and the coating material must have the same acoustic velocity and attenuation as the coating to be measured.

3.1.14 *substrate, n*—the base material, the type of surface, or the component that is being coated.

3.1.15 *verification of accuracy, n*—obtaining measurements on coating thickness standards, comprising of at least one thickness value close to the expected coating thickness, prior to gage use for the purpose of determining the ability of the coating thickness gage to produce thickness results within the gage manufacturer's stated accuracy.

4. Summary of Test Method

4.1 Instruments complying with this test method measure thickness by emitting an ultrasonic pulse into the coating that is reflected back from the substrate to the probe. The travel time is converted into a thickness reading. The instrument's probe must be placed directly on the coating surface to take a reading.

4.2 After verifying accuracy on a known coated part of the object or material of the same kind, the instrument probe is coupled with the coated specimen, after proper cure and conditioning according to the coating manufacturer's instructions.

4.3 It should be recognized that the accuracy of the measurements can be influenced when:

4.3.1 The coated object to be measured is not planar with respect to the transducer face at the point of measurement,

4.3.2 Coating density is not uniform, and

4.3.3 The substrate peak-to-valley surface profile of the coated specimen exceeds the coating thickness.

NOTE 1—The height of surface profile can be determined in accordance with ASME B46.1.

5. Significance and Use

5.1 Many coating properties are markedly affected by the film thickness of the dry film such as adhesion, flexibility, wear, durability, chemical resistance, and hardness. To be able to compare results obtained by different operators, it is essential to measure film thickness carefully.

5.2 Most protective and high performance coatings are applied to meet a requirement or a specification for the dry-film thickness of each coat, or for the complete system, or both. Coatings must be applied within certain minimum and maximum thickness tolerances in order that they can fulfill their intended function. In addition to potential performance deficiencies, it is uneconomical to apply more material than necessary when coating large areas such as floors and walls.

5.3 Low readings may occur occasionally on coatings with rough surfaces. The instrument may allow a user adjustment to prevent this.

5.4 This test method may not be applicable to measure organic coating thickness on all substrates. The instrument's ability to detect a distinct interface between the coating and the substrate may be impeded if the coating and the substrate are of similar composition, density or attenuation or if the coating is non-homogeneous. Verify operation on a known thickness of the coating/substrate combination if these circumstances are thought to exist.

5.5 Multilayered coatings have many interfaces and the instrument will measure to the interface separating the two most acoustically different materials. Some instruments have the ability to detect and measure the individual layer thicknesses in a multi-layer system.

5.6 The use of this test method is not necessarily limited by the type of substrate material.

6. Apparatus

6.1 *Gage Body*—an electronic instrument that utilizes transducer probes.

6.2 *Transducer Probe*—a measurement probe (sensor) using an ultrasonic principle and numerical techniques, attached to the gage body. The appropriate transducer probe is selected based on the anticipated organic coating dry film thickness. The gage manufacturer may be contacted for a recommendation.

7. Test Specimen

7.1 When this test method is used in the field, the specimen is the coated structure or article on which the dry film thickness is to be evaluated.

7.2 For laboratory use, apply the materials to be tested to panels of the same composition, structure or article on which the dry film thickness is to be evaluated. Cure the organic coating in accordance with the coating manufacturer's instruction.

NOTE 2—Coatings should be applied in accordance with Practices D823, or as agreed upon between the purchaser and the seller.

8. Calibration, Verification and Adjustment of Apparatus

8.1 Calibration of coating thickness gages is performed by the equipment manufacturer, their authorized agent, or by an accredited calibration laboratory in a controlled environment using a documented process. A certificate of calibration showing traceability to a National Metrology Institute can be issued. There is no standard time interval for re-calibration, nor is one absolutely required, but a calibration interval can be established based on experience and the work environment. A one-year calibration interval is a typical frequency suggested by many gage manufacturers.

8.2 *Verification of Accuracy*—Before use, each instrument's calibration accuracy shall be verified by the user in accordance with the instructions of the manufacturer, employing suitable coating thickness standards and, if necessary, any deficiencies found shall be corrected. The probe should also be examined for cleanliness and excessive wear before verifying the accuracy and before obtaining coating thickness measurements.

8.2.1 If gage readings obtained during verification are outside the combined accuracy of the coating thickness standard and the manufacturer's stated gage accuracy, the gage should be returned to the manufacturer or their authorized agent for calibration.

8.3 *Adjustment*—Measurement accuracy directly corresponds to the sound velocity of the coating being measured. Because ultrasonic instruments measure the transit time of an ultrasonic pulse, they may require an adjustment by the user for each coating material. To determine if an adjustment is necessary, the user should measure a known thickness of the coating (reference standard) as determined by:

8.3.1 Using a destructive, cross-sectioning method such as described in Practice D4138, or

8.3.2 Nondestructively (that is, not destroying film integrity) removing and measuring the coating with a micrometer in accordance with Test Method D1005, or

8.3.3 Cross sectioning the product and measuring the coating thickness by imaging the coating cross-section under a microscope or by using computerized image analysis. In the case of variable coating thickness or coatings applied to rough substrate surfaces the average coating thickness should be calculated by computer image analysis.

8.4 Best adjustment results are achieved on coatings with a thickness equal to or greater than the coating thickness range to be measured and on coating material having the same acoustic velocity and attenuation as the coating to be measured. Follow the manufacturer's instructions.

NOTE 3—It has been reported that the physical properties of some coatings such as acrylic-melamine can vary over the time of the cure.

9. Procedure

9.1 Use the instrument only after calibration has been verified in accordance with Section 8.

9.2 Ensure that the coating is properly cured prior to use of the instrument.

9.3 A couplant is often required to transmit the ultrasonic pulse from the gage's probe into the coating. Water is ideal for coatings with a smooth surface. For coatings with a rough surface, a propylene glycol gel couplant is best, providing it is not a contaminant for the coating to be measured. Other couplants such as liquid, wall paper paste, oil, etc., may be used. Under certain conditions for example if the coating is soft, the probe may function without a couplant. For specific information regarding the use of couplants, refer to the gage manufacturer's instructions.

9.4 Place the instrument's probe flat on the surface and apply constant pressure. Hold the probe steady during the measurement.

9.5 Take a sufficient number of readings to measure the coating thickness with required statistical accuracy.

TABLE 1 Instrument A[A] — Coating Thickness (μm)

Panel	Average[B]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{X}$	S_r	S_R	r	R
1	77.05	2.31	2.69	6.47	7.52
2	52.86	2.52	4.16	7.05	11.66
3	59.48	1.25	2.65	3.51	7.43
4	51.73	2.09	2.64	5.85	7.39
5	66.01	1.64	1.70	4.59	4.76
6	81.50	1.89	4.08	5.30	11.43
7	139.5	2.03	7.47	5.70	20.91

[A] No adjustments as described in 8.3 were made to the instrument prior to this interlaboratory study.
[B] The average of the laboratories' calculated averages.

TABLE 2 Instrument B[A] — Coating Thickness (μm)

Panel	Average[B]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{X}$	S_r	S_R	r	R
1	71.92	2.54	3.21	7.11	8.98
2	41.55	1.81	6.93	5.08	19.41
3	55.63	1.94	3.90	5.44	10.92
4	47.53	0.89	1.35	2.50	3.79
5	64.73	1.00	1.80	2.80	5.04
6	75.20	0.87	3.21	2.44	9.00
7	114.9	1.50	5.44	4.19	15.24

[A] No adjustments as described in 8.3 were made to the instrument prior to this interlaboratory study.
[B] The average of the laboratories' calculated averages.

NOTE 4—SSPC-PA 2 specifies the location and number of readings needed to characterize a coated metal surface and SSPC-PA 9 specifies the location and number of readings needed to characterize a coated cementitious surface. Select the method most appropriate for the material being tested.

10. Report

10.1 Record the following information at the time of the measurements and include in the report:

10.1.1 Type of coating and substrate,

10.1.2 Instrument used including manufacturer, model number, serial number, and date of calibration,

10.1.3 Type of coating thickness standard or reference standard, or both, together with the method used for accuracy verification or any adjustment, or both.

10.1.4 Mean, and standard deviation of the thickness readings found,

10.1.5 Operator identification, and

10.1.6 Date of inspection.

10.2 Depending upon the application, it may be useful to record the individual measurements as well. For rough substrates or coatings, it is recommended to measure the coating in accordance with SSPC-PA 2 or SSPC-PA 9.

11. Precision and Bias[5]

11.1 *Precision*—The precision of this test method is based on an interlaboratory study of Test Method D6132 - 04, conducted in 2007. Each of eight laboratories tested seven different coated panels using two types of instrumentation. Every "test result" represents an individual determination. All laboratories reported two replicate test results for every panel with each instrument. Practice E691 was followed for the design and analysis of the data; the details are given in Research Report No. RR:D01-1144.

11.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

11.1.1.1 Repeatability limits are listed in Table 1 and Table 2.

11.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

11.1.2.1 Reproducibility limits are listed in Table 1 and Table 2.

11.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

11.1.4 Any judgment in accordance with statements 11.1.1 and 11.1.2 would have an approximate 95 % probability of being correct.

11.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

11.3 The precision statement was determined through statistical examination of 224 results, from eight laboratories, on seven coated panels. These seven coated panels were described as the following:

Panel 1: UV cured coating on hickory
Panel 2: water borne acrylic primer on plywood
Panel 3: factory primer on untextured molded hardboard
Panel 4: UV cured coating on unfilled maple
Panel 5: a roll and curtain coated acrylic filler/base/top coats on hardboard
Panel 6: sprayed lacquer on oak
Panel 7: powder coating on medium-density fiberboard

11.4 Each instrument's default calibration setting was used. For best accuracy, each instrument should be checked against a known thickness of the particular coating being measured and adjusted if necessary. To judge the equivalency of two test results, it is recommended to choose the coating/panel combination closest in characteristics to the test panel and coating.

12. Keywords

12.1 coatings; coating thickness; dry film thickness; nondestructive thickness; paint thickness; thickness testing; ultrasonic thickness gage

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1144. Contact ASTM Customer Service at service@astm.org.