INTERNATIONAL

Designation: ~~D5235 – 14~~ D5235 – 18

Standard Test Method for Microscopic Measurement of Dry Film Thickness of Coatings on Wood Products[1]

This standard is issued under the fixed designation D5235; 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 measurement of dry film thickness of coatings applied to a smooth, textured or curved rigid substrate of wood or a wood-based ~~product~~product.

1.2 This test method covers the preparation of wood or wood-based specimens for the purpose of microscopic measurement of dry film thickness.

1.3 This test method suggests an analysis of dry film thickness of coatings on wood or wood-based products using a microscopic measurement.

1.4 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.

1.5 *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~~ safety, health, and ~~health~~environmental 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]

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *dry film thickness or DFT, n*—the thickness of dried, cured coating film on the substrate surface which may include attached fibers but excludes free fibers that are encapsulated in the layer itself.

3.1.2 *edge face, n*—that part of the specimen that is a plane perpendicular to the surface showing a cross section of the coating and substrate.

3.1.3 *soak in, n*—refers to a coating on a porous (wood) where the coating does not lie essentially on the surface of the wood or wood-based product, but has penetrated into the fiber structure of the wood or wood-based material.

3.1.3.1 *Discussion—*

Wood or wood-based products are generally of a porous nature; sometimes exhibiting uniform absorption of coatings. Frequently

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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.

absorption of coatings is of a non-uniform nature and influenced by localized surface density differences or wood pore size. These conditions of coating absorption are commonly referred to as soak in.

4. Summary of Test Method

4.1 A specimen of coated wood or wood-based product is cut to convenient size and edge face with the coating film cross-section is prepared by polishing or cutting with a sharp blade.

4.2 The prepared edge of the specimen is imaged by a calibrated imaging system with known magnification in order to measure the dry film thickness using an image analysis computer program.

4.3 Suggestions regarding interpretation of dry film thickness on porous wood or wood-based material are offered.

5. Significance and Use

5.1 As a base for calibration adjustment or accuracy verification of dry film coating thickness measuring instruments.

5.2 The dry film thickness of coatings on wood or wood-based products is specified in written product warranties for proper decorative and protective performance of coatings on wood or wood-based products.

5.3 The minimum and maximum dry film thickness of coatings is recommended by coating companies for satisfactory decorative and protective performance on wood or wood-based products.

5.4 The average dry film thickness of coatings on wood or wood-based material may be used by manufacturing companies to estimate the theoretical cost of applied coatings.

5.5 The ratio of minimum to maximum dry film thickness on textured products is used as an indication of coating uniformity.

5.6 Specific coated product requirements may dictate certain film thickness determinations to be made. Agreement between buyer and seller may be advisable to accommodate product needs relative to dry film thickness.

6. Apparatus

6.1 *Microscope with Attached Digital Camera (see Note 1),* providing sufficient magnification and image quality in the field of view; generally 100× to 200× magnification is sufficient.

NOTE 1—Certain digital cameras can provided sufficient magnification and image quality of the coating cross-section without a microscope.

6.2 *Source of Oblique Illumination,* for the microscope.

6.3 *Image Analysis Program,* with capabilities for lines to be drawn along the coating/substrate interface and the coating surface and for calculation of the average distance between these lines on the specimen image.

6.4 *Microscope Image Calibration Tool.*

6.5 *Cutoff Saw.*

6.6 *Belt or Disc Sander.*

6.7 *C-Type Clamp.*

6.8 *Sharp Utility Knife or Razor Blade.*

7. Materials

7.1 *200 and 600-Grit Sand Paper.*

7.2 *Mould,* such as a paper cup, aluminum weighing dish, or a 50.8 mm [2 in.] or larger diameter plastic pipe that is at least 25.4 mm [1 in.] high.

7.3 *Source of Sanding Adhesive,* which is used as encapsulating medium such as:
7.3.1 *Hot Melt Glue,*
7.3.2 *Fast-Cure Acrylic Mounting Kit,* or
7.3.3 *Epoxy.*

7.4 *Solvent-borne Tint Dispersion,* which is compatible with the sanding adhesive.

7.5 *Mineral Oil.*

7.6 *Automotive Red Transmission Oil.*

7.7 *Zinc Stearate Powder.*

8. Procedure

8.1 *Specimen Preparation*—Select the area to be measured for coating thickness and remove it from the coated wood or wood-based material by a suitable method. Methods of sawing, core drilling, chiseling etc., can be used. Avoid collection of samples near the edges of sheeting material or the ends of boards, particularly those coated in vacuum coaters, unless defective coating application is being investigated. For textured surfaces, areas representative of varying degrees of texture (average, extreme, minimal or non-existent) should be selected. Take care that areas of interest are not damaged. Cutting across wood grains is preferable in exposure of area of the interest and must be conducted when a coated rough wood surface is being tested. Inspection of the surface of interest for excessive damage, as well as preliminary assessment of coating conditions and uniformity of application should be conducted under a microscope. Appropriate areas for coating dry film thickness measurements should be selected based on testing purpose.

8.1.1 Frequently the purpose of testing is the measurement of the average coating dry film thickness for coating spread assessment or identification of areas with excessively thick or thin coating dry film thickness.

8.2 *Specimen Surface Preparation*—Two methods are described for specimen surface preparation due to the variability in the properties of wood coatings. Method A is recommended to be used for hard coatings, for example, melamine furniture coating or polyester coating, which are brittle at room temperature and could shatter in contact with a sharp blade. Method B is recommended for flexible, exterior finishes, which would smear in contact with sandpaper. Such smearing may mask the appearance of voids or fracture lines in the coating and substrate and may eliminate coating/wood substrate interface details, thereby increasing measurement error.

8.3 *Method A:*

8.3.1 Select the desired coated area of a wood or wood-based material that is to be measured for dry film thickness. With the cutoff saw, cut off a sample at least 38.1 mm [1½ in.] wide from this area for mounting and encapsulation in casting resin (Note 2).

NOTE 2—Some specimens could be satisfactorily prepared and tested without mounting. Mounting may be omitted, if careful microscopic inspection of the sanded specimen does not show any damage to the area of interest or coating edge distortion.

8.3.2 Cut this specimen to a length that is at least 12.7 mm [½ in.] less than the inside diameter of the mold to be used.

8.3.3 Place the specimen, with the sample edge to be measured, face down and approximately centered in the mold.

8.3.4 Prepare the sanding adhesive according to the manufacturer's directions for use. A dispersed pigment may be added to the adhesive for better microscopic contrast between the dry film and the adhesive.

8.3.5 Pour the sanding adhesive around the sample in the mold and allow to harden according to the manufacturer's directions.

8.3.6 Remove the mold from the hardened and encapsulated specimen edge.

8.3.7 Using a disc sander, belt sander or 200-grit sandpaper mounted on a glass plate, sand the edge face of the encapsulated specimen until the edge face is relatively smooth. Maintain the edge face of the specimen as flat as possible during sanding. Avoid heat buildup of the sanding adhesive by intermittent sanding if necessary.

8.3.8 Polish the edge face of the rough sanded specimen as follows:

8.3.8.1 Mount a piece of 600-grit sandpaper on a flat glass plate. Rub the edge face of the rough sanded specimen over the 600-grit sandpaper in one direction, then reverse direction by 180° for several more rubs. Zinc stearate powder can be sprinkled on the 600-grit sandpaper or the 600-grit sandpaper can be wetted with mineral oil to produce a highly polished edge face free of scratches.

8.3.8.2 Some laboratories find that a mold for the specimen encapsulation with sanding adhesive is not necessary. In this case two specimens are prepared with the cutoff saw. The sanding adhesive after proper mixing is generously applied to the coated face of each specimen, the specimens are placed together and a C-clamp is used to squeeze out some of the sanding adhesive. The C-clamp is not removed until sanding adhesive has hardened.

8.4 *Method B:*

8.4.1 Select the desired area of coated wood or wood-based material that is to be measured for dry film thickness and obtain a suitable sample using the cutoff saw or other appropriate tool cut off a suitable sample. There is a handling advantage if the sample to be tested has a rectangular shape.

8.4.2 To aid in the preparation of the cross-section for testing, the sample must be additionally cut at an acute angle 70 to 85° with respect to the coated surface (Fig. 1). Then, using a sharp blade in a slow continuous movement, make a shallow cut parallel to the edge face with the coating cross-section, cutting from the coating surface into the substrate to remove any loose wood fibers and/or damaged coating from the area of interest. Inspect the obtained cross-section under microscope for surface quality. A clean view of the cellular wood structure and clear focus along the coating cross-section with well-visible interface details is a good indication of proper surface preparation. The cutting direction depends on the wood grains and coating properties.

8.5 *Dry Film Thickness Measurement From the Image of the Edge Face of the Specimen:*

8.5.1 Place the polished or clean cut edge face under the microscope lens.

8.5.2 Adjust the illuminating light at a convenient oblique angle. Proper light angle adjustment is helpful in obtaining good contrast along the coating surface edge, inter-coat boundaries, and coating/wood interface. This is particularly important when measuring transparent coating DFT.

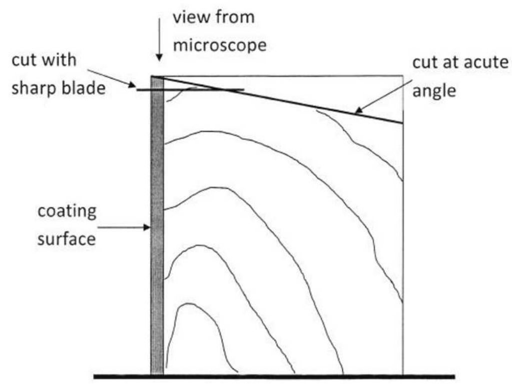

FIG. 1 Diagram of Sample Cutting

8.5.3 Adjust magnification. Generally 100× magnification is sufficient for coating DFT above 50 µm and 200× magnification is sufficient for coating DFT above 25 µm. Lower magnification allows for a larger field of view which is beneficial when measuring a coating applied to rough wood containing peaks and valleys.

8.5.4 Adjust contrast and lighting for best imaging of the coating surface edge and coating/wood interface.

8.5.5 To improve contrast between wood and coating interface light coat of mineral oil or automotive red transmission fluid may be applied.

8.5.6 Capture image of the edge face of the specimen preferably with the coating film cross-section in the centre of the field of view.

8.5.7 Capture calibration image (Note 3) at the same magnification.

NOTE 3—A certified silicon test specimen, with a 10 micron grid and 1.9 micron dividing lines, for imaging system calibration could be used. Such a specimen can be supplied by Agar Scientific.[3] Other objects with known dimensions measured with certified tools could also be used for imaging and calibration.

8.5.8 Enter the calibration data into the image analysis program according to the software manufacturer's[4] instruction.

8.5.9 Determine the average coating DFT using the image analysis program following software manufacturer's instruction (Note 4).

NOTE 4—This analysis usually involves drawing two lines: one along the entire coating surface edge and another along the entire coating/wood interface or interface of interest. Porous substrates tend to have the coating soaked into their open cellular structure and fibers of the wood or wood-based product. A clear demarcation line between substrate and coating may not be discernible. In this case, such a demarcation line should be drawn as shown in Figs. X1.1-X1.9.

8.5.10 The average coating thickness for a tested group of samples is reported based on the average DFT calculated for all tested samples. The minimum DFT of the coating is reported as the lowest average DFT found within the tested samples while the maximum DFT of the coating is reported as the largest average DFT found within the tested samples. A minimum of three samples taken at different locations must be tested.

8.5.11 Repeat measurements a sufficient number of times to obtain statistically valid average dry film thickness of the coating on the substrate of the interest and required data about maximum and minimum DFT.

TABLE 1 Average Film Thickness (*µm*)

	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit[A]	Reproducibility Limit
	$\bar{X}$	s_r	S_R	r	R
Engineered flooring	49.24	0.58	9.29	1.62	26.01
MDF molding	85.04	0.25	3.50	0.71	9.80
Siding board 1st coat (base coat)	65.26	0.66	20.95	1.83	58.66
Siding board 2nd coat (top coat)	56.12	0.22	2.50	0.61	7.01
Siding board 1st coat and 2nd coat (*Combined*)	121.37	0.53	23.04	1.48	64.52

[A] Only a single laboratory reported replicate data.

[3] Available from Agar Scientific, 66a Cambridge Rd, Stansted, Essex CM2A 8DA, England.

[4] ImagePro Premier, ImagePro Premier On Line and ImagePro Inside, available from Media Cybernetics, 8788 Georgia Ave., Silver Spring, MD 20910, were found suitable for this application.

9. Report

9.1 Description of the material tested, including form of wood or wood-based product, wood or composite grade, smooth or rough sawn and type of the composite surface finish, volume of coated material, number of specimens collected, and technique used for selection of the sampling area.

9.2 Report number of samples tested. Average and average standard deviation, minimum, and maximum dry film thickness for the tested group of samples in microns (with mils given in parentheses).

9.3 Observations related to coating cross-section such as non-uniformity, air voids, cracks, and contaminants, etc.

9.4 Attach, if requested, photomicrographs of the specimen edge face with coating cross-section used for measurement.

9.5 For textured substrates, report the following information, if requested:
9.5.1 The dry film thickness measurement for extreme textured areas,
9.5.2 The dry film thickness for average textured areas, and
9.5.3 The dry film thickness for flat areas.

9.6 Optionally, some laboratories report the ratio of the peak to valley dry film thickness.

10. Precision and Bias[5]

10.1 The precision of this test method is based on an interlaboratory study of D5235~~and bias statement will be developed~~, Test Method for Microscopic Measurement of Dry Film Thickness of Coatings on Wood Products, conducted in 2016. Six laboratories participated in this study. Five of the six labs reported a single test result for four different materials, and one laboratory reported five replicate test results for each of the study materials. Every "test result" reported represents an individual determination. Except for the use of only six laboratories and the lack of a complete replicate data set, Practice E691~~in round-robin testing.~~ was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:D01-1183.

10.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

10.1.1.1 Repeatability can be interpreted as the maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

10.1.1.2 Repeatability estimates are listed in Table 1.

10.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

10.1.2.1 Reproducibility can be interpreted as the maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

10.1.2.2 Reproducibility estimates are listed in Table 1.

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

10.1.4 Any judgment in accordance with statements 10.1.1 and 10.1.2 would normally have an approximate 95 % probability of being correct, however the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of materials tested and laboratories reporting results guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95 % probability limit would imply. The repeatability limit and the reproducibility limit should be considered as general guides, and the associated probability of 95 % as only a rough indicator of what can be expected.

10.2 *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.

10.3 The precision statement was determined through statistical examination of 50 test results, from five laboratories, on four materials.

10.3.1 To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material.

11. Keywords

11.1 coated wood or wood-based product; dry film thickness; microscopic measurement

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1183. Contact ASTM Customer Service at service@astm.org.

APPENDIX

X1. EXAMPLES OF IMAGES OF COATING/WOOD SUBSTRATE CROSS-SECTIONS, WITH SUGGESTED INTERPRETATIONS OF THE COATING AND INTERFACE FEATURES FOR DRY FILM THICKNESS MEASUREMENTS

X1.1 The following recommendations and photographs are provided to familiarize individuals conducting coating dry film thickness measurements with features that frequently appear in coating film cross-sections and at the coating/wood or wood-based product interface. The images are intended to provide some guidance in the interpretation and selection of the boarders of interest for coating/wood or intercoat interfaces. It should be noted that the features shown are only examples and individuals conducting the measurements must use their own judgement for specific image interpretations. Generally, the following rules are recommended:

(1) Wood vessels and cellular structure fully filled with coating material, such as encapsulated wood fibers or entrapped air voids in the coating, are to be included in the thickness of the dry coating film being measured.

(2) Wood vessels and cellular structure partially filled with coating material, such as wood fibers protruding into the coating film but connected with the wood substrate or air voids at the wood substrate surface preventing direct contact of the coating with the wood, are to be excluded from the thickness of the dry coating being measured.

X1.2 List of Figures:

Figure X1.1 — Medium density fiber (MDF) board with smooth hardwood veneer finished with sealer and solvent based topcoat

Figure X1.2 — Hardwood moulding surface finished with primer and two coats of latex paint

Figure X1.3 — Embossed hardboard composite substrate finished with two coats of latex acrylic coating

Figure X1.4 — Rough sawn Western Red Cedar with flat surface area finished with one coat of paint

Figure X1.5 — Rough sawn Western Red Cedar with flat surface area finished with alkyd primer and latex topcoat

Figure X1.6 — Flat surface of rough sawn softwood coated with latex paint

Figure X1.7 — Flat surface of rough sawn softwood coated with latex paint

Figure X1.8 — Peak and valleys of the rough sawn softwood coated by two coats of latex paint with distinct colours

Figure X1.9 — Peak of the rough sawn softwood finished with a single coat of latex paint

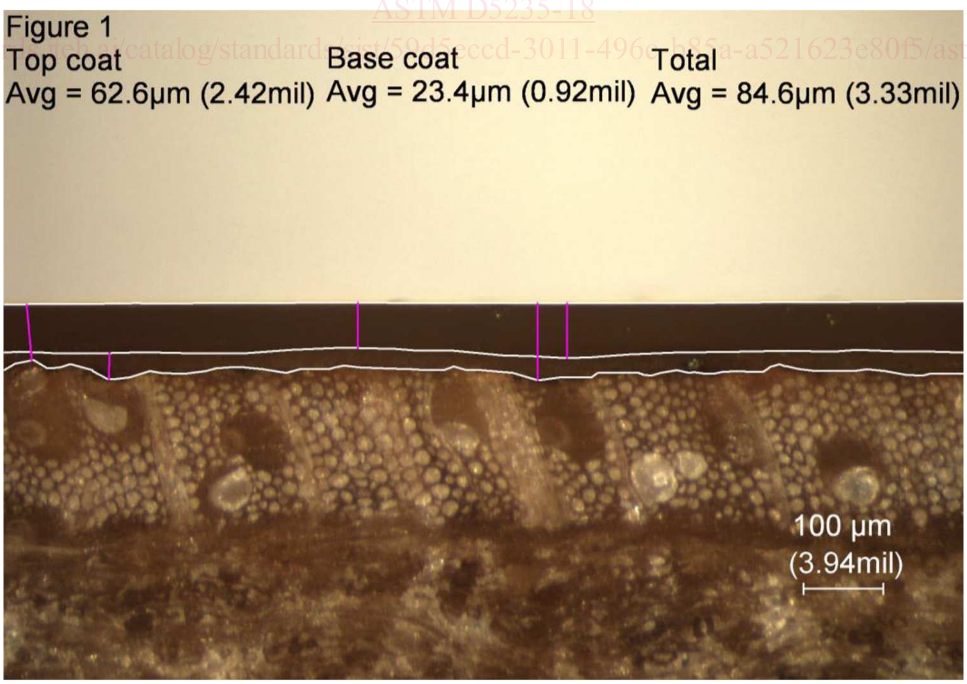

FIG. X1.1 Medium Density Fiber (MDF) Board with Smooth Hardwood Veneer Finished with Sealer and Solvent Based Topcoat.
The sealer was sanded before topcoat application. The variable thickness of the sealer filling some of the veneer roughness and a relatively uniform top coat film can be seen and were included in the dry film thickness measurement**.**