Designation: D4213 – 08 (Reapproved 2012)

Standard Test Method for Scrub Resistance of Paints by Abrasion Weight Loss[1]

This standard is issued under the fixed designation D4213; 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 an accelerated procedure for determining the resistance of paints to erosion caused by scrubbing. (Note: The term *wet abrasion* is sometimes used for *scrubbing*, and *wet abrasion resistance* or *scrubbability* for *scrub resistance*.) Although scrub resistance tests are intended primarily for interior coatings, they are sometimes used with exterior coatings as an additional measure of film performance.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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]

D562 Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer

D1193 Specification for Reagent Water

D1475 Test Method For Density of Liquid Coatings, Inks, and Related Products

D2486 Test Methods for Scrub Resistance of Wall Paints

D3450 Test Method for Washability Properties of Interior Architectural Coatings

D3980 Practice for Interlaboratory Testing of Paint and Related Materials (Withdrawn 1998)[3]

D4828 Test Methods for Practical Washability of Organic Coatings

E70 Test Method for pH of Aqueous Solutions With the Glass Electrode

E180 Practice for Determining the Precision of ASTM Methods for Analysis and Testing of Industrial and Specialty Chemicals (Withdrawn 2009)[3]

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

3. Summary of Test Method

3.1 The material under test is applied to a black plastic scrub test panel, and after drying one week, a section of the test panel is placed in a straight-line abrasion tester, adjacent to a similar section of a standard calibration panel. The two sections are scrubbed simultaneously to produce essentially identical abrasion experiences and the amount of erosion loss in each section determined from the panel weights before and after scrubbing.

3.2 The scrub resistance on a dry-film basis is calculated as the percent ratio of the weight loss of the calibration panel to that of the test panel. From that value, scrub resistance is calculated on the basis of both dry- and wet-film volume.

4. Significance and Use

4.1 Interior paint films often become soiled, especially near doorways, windows, and play areas, and frequently need to be cleaned by scrubbing. This test method covers the determination of the relative resistance of paints to erosion when scrubbed.

4.2 The precision of scrub resistance measurements in absolute physical values, such as Test Methods D2486 cycles-to-failure or this test method, microlitres per 100 cycles, is poor due to the relatively large effect of subtle and difficult-to-control variables in test conditions. The test method described herein minimizes this problem by using a standard calibration panel as an integral part of each scrubbing operation and relating its weight loss to that of the paint film under test to establish the latter's scrub resistance.

NOTE 1—The numerical scrub resistance values obtained by this test method are of significance only in relation to the specific calibration panel types with which the value is obtained. Thus, for example, a scrub resistance value of 83 with a Type X calibration panel would be reported as 83X.

4.3 Results obtained by this test method do not necessarily represent the scrub resistance that might be determined if the

[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 D01.42 on Architectural Coatings.

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

test film is allowed to dry before testing appreciably longer than the seven-day period specified herein.

4.4 Results obtained by this test method do not necessarily relate to ease of soil or stain removal (also referred to as "cleanability" or "cleansability"). To test for those characteristics use Test Methods D3450 and D4828.

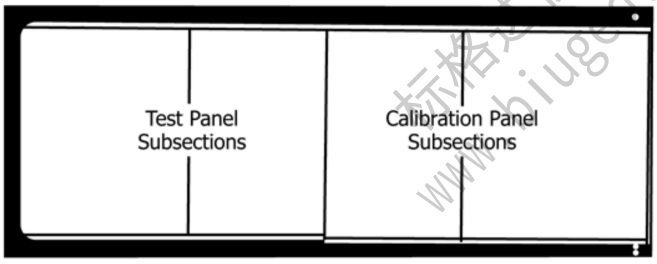

FIG. 1 Alignment of Panels for Scrubbing

5. Apparatus and Materials

5.1 *Straight-line Scrub Tester,* set for 37 ± 1 cycles per minute, having a minimum intrinsic stroke length of 255 mm (10 in.), counter for recording the number of scrub cycles, base pan, glass support plate, "Lilly" frame, and C-clamps to hold down the entire test assembly.

5.2 *Sponge Holder,* stainless steel construction, weight: 450 ± 10 g, approximate inside dimensions: 22 by 75 by 95 mm (⅞ by 3 by 3¾ in.).

5.3 *Polyurethane Sponges,*[4] skin free, open-cell formation, density 0.032 to 0.040 g/cm^3 (2 to 2.5 lb/ft^3), compression (25 % deflection) 4.8 kPa (0.7 psi), width and length 0.08 in. (2 mm) larger than the sponge holder with which it is to be used, thickness such that when inserted into the sponge holder it protrudes about 5 to 6 mm (0.25 in.) beyond the skirt (see Fig. 1).

5.4 *Abrasive Pad,*[5] 6-mm (¼-in.) thick, cut to same size as the sponge with which it is to be used.

5.5 *Film Caster,* with horseshoe frame, clearance 175 µm (7 mils), film width approximately 135 mm (5¼ in.).

5.6 *Black Plastic Panels,*[6] dimensions: 0.25 ± 10 % by 165 by 430 mm (0.01 ± 10 % by 6.5 by 17 in.). Level and uniform dull black surface, impervious to and unaffected by water or aliphatic solvents, plasticizer-free, density 1.33 ± 0.05 g/cm^3.

NOTE 2—With dark colored paints use white panels. These should be the same as the black except for color, and density: 1.41 ± 0.05 g/cm^3.

5.7 *Drawdown Plate,* 6-mm (¼-in.) thick, clear float glass, size adequate to be used as a base for drawdowns on the specified scrub test panels.

5.8 *Non-Abrasive Scrub Medium,*[7] standard wetting liquid. Formula and preparation instructions are as follows:[8-10]

Formula—Parts by Weight	
Water, reagent, Specification D1193, Type IV	89.6[A]
Hydroxyethyl cellulose[8]	2.0
Detergent [9]	4.0
Trisodium phosphate, anhydrous	4.0
Acetic acid glacial	0.3[B]
Preservative [10]	0.1
	100.0

[A] Vary to achieve a final consistency of 165 to 220 g (75 to 85 Krebs Units) with a Stormer viscometer in accordance with Test Method D562.
[B] Vary to achieve a final pH from 9.5 to 10.0 in accordance with Test Method E70.

5.8.1 Slowly add the hydroxyethyl cellulose to the water while stirring mechanically. Stir until uniform and then slowly add 2 to 3 drops of 28 % ammonium hydroxide solution while mixing, and continue mixing until the solution turns clear. In the order shown, add the other ingredients separately, stirring continuously. Be sure each item is uniformly dispersed before adding the next one. Finally, add the preservative and adjust the pH with glacial acetic acid.

NOTE 3—When a referee test is made the medium should be freshly prepared, or from a previously unopened container that is no more than 1-year old.

5.9 *Analytical Balance With Windshield Enclosure,* reading to 0.1 mg and accurate to 1 mg.

5.10 *Static Shield,* a thin gage metal plate, size 110 by 165 mm (4¼ by 6½ in.), to be placed on the balance pan when weighing. A satisfactory shield can be made from 0.175 to 0.300 mm (7 to 12 mil) thick aluminum or tinplate.

5.11 *Oven,* adjusted to 50 to 55°C (120 to 130°F).

5.12 *Calibration Panels,*[11] prepared in advance using paints of suitable scrub resistance.

NOTE 4—The procedure for preparing calibration panels is the same as described in 6.1 and 6.2 for regular test panels, except that the panels shall be aged sufficiently before use to ensure that the effect of additional ageing on their scrub resistance is negligible. A period of 6 months has been found adequate. Earlier use requires that in a given test series all calibration panels be the same age.

5.13 *Pycnometer,* for example, "weight-per-gallon" cup.

[4] Sponges, available from suppliers of scrub testers, cut to precise size for their respective holders.
[5] Abrasive pad—Scotch-Brite #7448 manufactured by 3M Company, 3M Center Bldg., St. Paul, MN 55144-1000 has been found satisfactory. Pads cut to the correct size are available from suppliers of scrub testers.
[6] Scrub Test Panels—Black: Form P121-10N and White: Form P122-10N, available from The Leneta Co., 15 Whitney Rd., Mahwah, NJ 07430, were used in the round-robin for this method. Other charts that are in compliance with requirements stated in 5.6 may be used also.

[7] Non-Abrasive Scrub Medium—Catalog Item SC-1 available from The Leneta Company is made in accordance with these requirements.
[8] Hydroxyethyl cellulose having a molar substitution (MS) value from 1.8 to 2.5 and a 2 % solution viscosity in the range of 4400 to 6500 cps.
[9] Iso-octylphenoxy polyethoxyethanol detergent, such as Triton X-100 has been found satisfactory for this purpose.
[10] 1,3,5-triethyl hexahydro-sym-triazine (Vancide TH), obtainable from R. T. Vanderbilt Co., 30 Winfield St., Norwalk, CT 06855, has been found satisfactory.
[11] Calibration panels may be prepared by individual laboratories for internal use and for relating their results to those of associated laboratories. Suitably aged and standardized calibration panels, having "poor," "good," and "very good" scrub resistance are available commercially from the Leneta Company. These are identified as Type A, C, and D respectively. The scrub resistance of Type A has been found to be approximately 35 % of Type C, and Type C approximately 50 % of Type D.

6. Procedure

6.1 Stir the test paint well by hand. (Do not shake). Strain if necessary to remove skins and large particles. Clean the surface of the glass drawdown plate carefully, then dust the scrub test panel making sure both sides are free of specks. Immediately after cleaning and dusting, place the panel on the drawdown plate (see 5.7) and tape or otherwise fasten it to the far end. Rub the panel against the plate with a lint-free cloth to develop static attraction.

6.2 Position the applicator at the fastened end of the panel, with its 7-mil (175-µm) clearance edge down, and evenly distribute approximately 12 mL of test paint across the front of the blade. Draw the paint down at a uniform rate of speed. The rate of application should be fairly slow (3 to 4 s from beginning to end) to prevent formation of pinholes or holidays in the film. Air dry for one week in a horizontal position, in a well ventilated area kept at 23 ± 2°C (73 ± 3.5°F) and 50 ± 10 % relative humidity.

6.3 At the end of the specified drying time cut the panel accurately in half with a paper cutter across the short dimension, and set aside one of the half-sections for a second test. Take the other half-section and make two subsections by cutting again, parallel to and 75 mm (3 in.) from the previous cut.

6.4 Weigh the narrower subsection in grams to four decimal places. It is essential while weighing, for the static shield to rest on the weighing pan and the panel to rest fully and flatly on the static shield.

NOTE 5—Weighing to four places is needed to ensure accuracy in the third (viz., to the nearest mg).

6.5 Place the two subsections in the machine, on the glass support plate, with the first-cut edge across the exact center line of the scrub path, and the wider subsection positioned so that the two second-cut edges are adjacent.

6.6 Repeat procedures 6.3, 6.4 and 6.5 using the selected calibration panel (see Note 6), placing the first-cut edge of the calibration panel adjacent to that of the test panel. See Fig. 1 for the configuration of the panel subsections on the support plate at this point.

NOTE 6—Use a calibration panel type similar in scrub resistance to that of the test paint, unless a single standard is required for a widely varying group of paints. In the latter case use calibration panels that can be characterized as having "good" or intermediate scrub resistance.

6.7 Place the Lilly frame (see 5.1) on the panel assembly and clamp it down firmly to prevent any shift in the test assembly while scrubbing.

6.8 Soak the sponge in tapwater and squeeze to a weight of about 20 g, then place it in the sponge holder making sure the sponge protrudes approximately 5 to 6 mm (¼ in.) (see Fig. 2).

6.9 Dampen the abrasive pad with tap water. Fill the 30-mL syringe with scrub medium and distribute 15 mL evenly over its unprinted face.

6.10 Place the unprinted face downward on the panel assembly and attach the sponge holder with sponge to the scrubbing machine, with the sponge resting squarely on the pad.

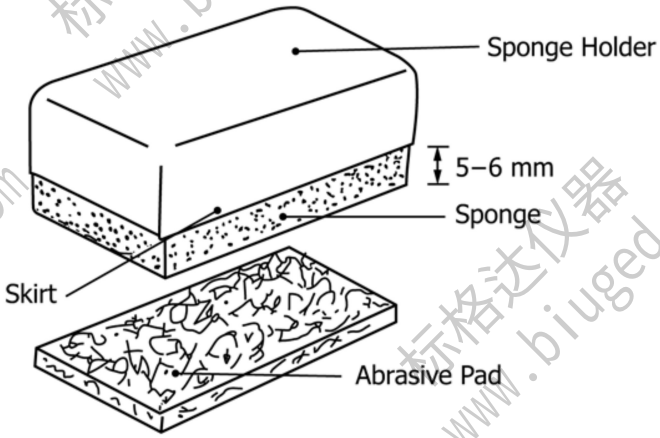

FIG. 2 Abrasion Boat Components

6.11 Distribute an additional 15 mL of scrub medium along the scrub path then start the machine. (No additional scrub medium is required during the test).

6.12 Scrub until either one of the two center sections has been worn down sufficiently for the black substrate to become faintly visible without actual break-through. In any case, do not exceed 800 cycles. During the first 200 cycles (if both films last that long) reverse the direction of the pad every 50 cycles, and above 200 cycles, reverse after every 100, so that the pad is run about the same number of cycles in each direction. Record the number of scrub cycles at the stopping point.

NOTE 7—If the scrub medium obscures the abrasion path, making it difficult to observe the show-thru status of the film, stop the machine at convenient intervals and sweep the surface briefly with a 50-mm (2-in.) paint brush dampened with water.

6.13 Remove and wash off the two center (narrow) subsections with tap water. Press them between paper towels to absorb free moisture, then oven-dry for 15 min at 50 to 55°C (120 to 130°F). After drying reweigh the two subsections to determine their weight losses, recording them as M_{test} and M_n in grams to four decimal places ("n" indicates identifying letter of the calibration panel type being used in the particular test, for example M_A, M_C, M_D, etc.).

6.14 Starting with 6.3, repeat the subsequent steps with the other halves of the test and calibration panels, to obtain two sets of weight loss values. For this second test use a fresh pad and reverse the positions of the test and calibration panel sections in the machine.

6.15 Determine the density (D) of the paint in g/mL, in accordance with Test Method D1475.

6.16 Determine the nonvolatile fraction by weight (N) of the paint as follows:

6.16.1 Sandwich 0.4 mL of paint (dispensed from a 1-mL disposable syringe) between a previously weighed pair of glass or plastic slides, squeezing them together so that the paint spreads evenly to a diameter of about 50 mm (2 in.). Reweigh to obtain the weight of specimen. Separate the slides and allow the films to air dry for a week along with the scrub test panels. Weigh a third time to determine the dry film weight, then calculate the nonvolatile fraction $N$to three decimal places. Run

in duplicate, repeating a third time if the duplicate results differ by more than 1 in the second decimal place. Calculate and record the mean value of *N*, excluding any result that is obviously in error (see Practice D3980).

7. Calculation of Relative Scrub Resistance (*R*)

7.1 *Dry Film Weight Basis (R_M)*—Calculate and record the values obtained from the two tests in accordance with the following equation:

$$R_M = \frac{M_n}{M_{test}} \times 100 \quad (1)$$

where:

M_n = grams of calibration film erosion (see 6.13),
M_{test} = grams of test film erosion (see 6.13), and
R_M = milligrams of calibration film erosion per 100 mg of test film erosion.

Then calculate and record their mean value.

7.2 *Dry Film Volume Basis (R_{DV}):*

$$R_{DV} = d \cdot R_M \quad (2)$$

where:

d = the displacement density of the paint film in g/mL or mg/µL, and
R_M = the mean value of R_M from 7.1.
R_{DV} = milligrams of calibration film erosion per 100 µL (displacement volume, that is, volume exclusive of air) of test film erosion.

NOTE 8—With water-borne paints: $d = ND \div (1 - D + ND)$. With solvent-borne paints (aliphatic mineral spirits): $d = 0.78\ ND \div (0.78 - D + ND)$.

where:

N = the nonvolatile fraction by weight of the test paint, and
D = the density of the test paint in g/mL.

7.3 *Equivalent Wet Volume Basis (R_{WV}):*

$$R_{WV} = N_V R_{DV} = NDR_M \quad (3)$$

where:

N_V = the nonvolatile fraction by volume of the test paint, and
R_{WV} = the number of mg of calibration film erosion per 100 µL of equivalent wet paint erosion.

NOTE 9—For any paint: $N_V = ND \div d$.

NOTE 10—R_{WV} relates to the whole paint and is therefore analogous to the cycles-to-failure values of Test Methods D2486.

7.4 In stating scrub resistance values, append the letter identification of the associated calibration panel type, as discussed in 4.2, Note 1.

8. Report

8.1 Report the following information:

8.1.1 *Scrub Resistance*—Dry film weight basis (R_M), as calculated in 7.1.

8.1.2 *Scrub Resistance*—Dry film displacement volume basis (R_{DV}), as calculated in 7.2.

8.1.3 *Scrub Resistance*—Equivalent wet volume basis (R_{WV}), as calculated in 7.3.

8.1.4 Number of scrub cycles in each test.

8.1.5 Manufacturer and model number of the scrubbing machine, and

8.1.6 Any deviation from procedure or equipment specifications.

9. Precision and Bias[12]

9.1 *Precision*—In an interlaboratory study of this test method, one operator in each of five laboratories used one of two makes of straight-line scrub tester and in one laboratory both makes (see Note 11) to evaluate, in duplicate, four paints that varied widely in scrub resistance. The tests were made in conjunction with calibration panels characterized as having "good" or intermediate scrub resistance, all prepared identically from the same paint in accordance with 5.14. After discarding divergent results (see Note 12) the intralaboratory pooled replicate coefficients of variation were found to be 4.16 %, 4.14 %, and 4.93 % with 26 df for R_M, R_{DV} and R_{WV} respectively. The corresponding interlaboratory coefficients are 6.52 %, 7.91 %, and 6.47 % with 23 df. Based on these coefficients the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

NOTE 11—The results obtained by the laboratory using both makes of tester were treated as coming from different laboratories (No. 1 and No. 2) because the differences for each paint were not significantly smaller than those among the other five laboratories.

NOTE 12—Results from one laboratory for one paint were rejected (Lab No. 7, Paint No. 4) because the density value differed significantly from that obtained by the other laboratories, thus making the range for that paint significantly higher than those of the other three paints. A single result from another laboratory (Lab No. 3, Paint No. 3, R_{DV}) was discarded because the range exceeded the rejection quotient calculated in accordance with Table 1 of Practice D3980. See also Practice E691.

9.1.1 *Replicate Repeatability*[13]—Duplicate results obtained by the same operator should be considered suspect if their difference, calculated as a percentage of their mean, is greater than shown in the following table.

9.1.2 *Reproducibility*—Two results, each the mean of duplicates, obtained by operators in different laboratories, should be considered suspect if their difference, calculated as a percentage of their mean, is greater than shown in the following table.

9.1.3 *Precision Summary:*

Comparison Basis	Replicate Repeatability, %	Reproducibility, %
Dry-film weight (R_M)	12.1	19.1
Dry-film volume (R_{DV})	12.1	23.2
Wet-film volume (R_{WV})	14.4	19.0

9.2 *Bias*—Bias cannot be determined because there is no standard reference paint or panel against which bias may be measured.

10. Keywords

10.1 abrasion resistance; resistance/abrasion/wet abrasion/scrub; scrub resistance; washability; wet abrasion resistance

[12] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1098. Contact ASTM Customer Service at service@astm.org.

[13] Also referred to in Practice E180 as "checking limits." True repeatability is determined by running the appropriate number of replicates at two different times. See 3.3 and 3.4 of Practice D3980 for the distinction between replication and repetition.

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