Designation: ~~D968 – 17~~ D968 – 22

Standard Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive[1]

This standard is issued under the fixed designation D968; 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 resistance of organic coatings to abrasion produced by abrasive falling onto coatings applied to a plane rigid surface, such as a metal or glass panel.

1.2 Two test methods based on different abrasives are covered as follows:

	Sections
Method A—Falling Sand Abrasion Test	6 – 13
Method B—Falling Silicon Carbide Abrasion Test	14 – 21

1.3 These methods should be restricted to testing in only one laboratory when numerical values are used because of the poor reproducibility of the methods (see 13.1.2 and 21.1.2). Interlaboratory agreement is improved significantly when ranking is used in place of numerical values.

1.4 The values stated in SI units are to be regarded as the ~~standard with the exception of mils when determining coating thickness.~~ standard. The values given in parentheses after SI units are for information ~~only.~~only and are not considered 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]

D16 Terminology for Paint, Related Coatings, Materials, and Applications

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

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

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[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.

Current edition approved ~~June 1, 2017~~June 1, 2022. Published ~~June 2017~~July 2022. Originally approved in 1948. Last previous edition approved in ~~2015~~2017 as ~~D968 – 15.~~D968 – 17. DOI: ~~10.1520/D0968-17.~~10.1520/D0968-22.

[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.

***A Summary of Changes section appears at the end of this standard**

D7091 Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *Other Standards:*

ANSI B74.12 ~~Specifications~~Specification for the Size of Abrasive Grain — Grinding Wheels, Polishing and General Industrial Uses[3]

FEPA Standard ~~42-2:2006~~42-2 Grains of Fused Aluminum Oxide, Silicon Carbide and other Abrasive Materials for Bonded Abrasives and for General Applications — Microgrits F230 to F2000[4]

3. Terminology

~~3.1 *Definitions of Terms Specific to This Standard:*~~

~~3.1.1 *abrasion resistance, n*—the amount of abrasive required to wear through a unit film thickness of the coating.~~

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 Abrasion resistance is expressed as the amount of abrasive required to wear through a unit film thickness of the coating.

3.2 For definitions of other terms used in this standard, refer to Terminology D16.

4. Summary of Test Method

4.1 Abrasive ~~is allowed to~~ particles fall from a specified height through a guide tube onto the surface of a coated panel until the ~~substrate becomes visible.~~ film is worn away, exposing a small area of the substrate or previous coating layer if two or more coatings are present. The amount of abrasive per unit film thickness is reported as the abrasion resistance of the coating on the panel. Silica sand or silicon carbide may be used, as specified.

5. Significance and Use

5.1 Silica sand produces a slower rate of abrasion for organic coatings than that provided by silicon carbide. For some types of coatings, it may also provide greater differentiation.

5.2 The abrasion resistance scales produced by the two methods differ, but the methods provide approximately the same rankings of coatings for abrasion resistance.

5.3 Each of the methods has been found useful for rating the abrasion resistance of specific types of coatings. For example Method A (falling sand) has been used for rating floor coatings while Method B (falling silicon carbide) has been used for rating coatings for ship decks.

METHOD A—FALLING SAND ABRASION TEST [5]

6. Apparatus and Materials

6.1 *Abrasion Tester,* as illustrated in Fig. 1 and Fig. 2. ~~A gate for starting the flow of abrasive is located near the top of the guide tube. It consists of a metal disk inserted into a slit in the side of the guide tube with a collar covering the slit. The guide tube shall be firmly supported in a vertical position over a suitable receptacle, which shall contain a support for holding the coated panel at an angle of 45° to the vertical. The opening of the tube is directly above the area to be abraded and the distance from the tube to the coated surface face at the nearest point is 25 mm (1 in.) when measured in the vertical direction. The base of the apparatus shall be fitted with adjusting screws for properly aligning the equipment.~~, and consisting of the following elements.

6.1.1 A funnel with an opening of 20 cm (8 in.). The lower part of the funnel shall consist of a wall that converges continuously at a 60° angle until the minimum inside diameter coincides with the outside diameter of the guide tube. The funnel may be

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[4] Available from Federation of European Producers of Abrasives (FEPA), 20 av., Reille, Paris, F-75014, www.fepa-abrasives.com.
[5] Hipkins, C. C., and Phain, R. J., "The Falling Sand Abrasion Tester," *ASTM Bulletin*, No. 143, December 1946, pp. 18–22.

FIG. 1 ~~Apparatus for Falling Sand~~ Abrasion Test Apparatus

continued from this point on as a cylindrical collar that fits snugly over the outside diameter of the guide tube as shown in Fig. 2. The upper part of the funnel may be a 20 cm (8 in.) cylinder.

6.1.2 A straight, smooth-bore metal guide tube with an inner diameter of 19.1 mm (¾ in.) and outer diameter of 22.2 mm (⅞ in.) and length of 91.4 cm (36 in.), with both ends of the guide tube cut square and all burrs removed. The upper end of the guide tube shall coincide with the minimum diameter of the funnel at the area of the juncture. A gate for starting the flow of abrasive may be located near the top of the guide tube, consisting of a metal disk inserted into a slit in the side of the guide tube with a collar that covers the slit when the metal disk is removed. The guide tube shall be firmly supported in a vertical position.

NOTE 1—A guide tube with an inner diameter greater than 19.1 mm (¾ in.) may result in a larger overall abraded area due to the lower concentration of abrasive particles per unit area. Therefore, an increased amount of abrasive particles may be required to wear through to the base material, resulting in lower abrasion values being reported.

NOTE 2—A guide tube with an outer diameter greater than 22.2 mm (⅞ in.) will change the established 25 mm (1 in.) distance between the guide tube and specimen if the measurement is taken from the outer edge of the guide tube (see 8.2 and Fig. 2).

6.1.3 A suitable receptacle, which shall contain a support for holding the coated panel at an angle of 45° ± 1° to the vertical. The opening of the guide tube shall be directly above the area to be abraded and the position of the support from the bottom of the guide tube shall be adjustable.

6.1.4 A base which shall be fitted with adjusting screws for properly aligning the equipment.

6.2 *Container,* to collect the used abrasive particles after they have fallen through the receptacle.

6.3 *Dry Film Thickness Gage,* to measure coating thickness, according to Test Method D1005 or Practice D7091.

6.4 *Standard Abrasive*—Natural silica sand from the St. Peters or Jordan sandstone deposits (located in the central United States)

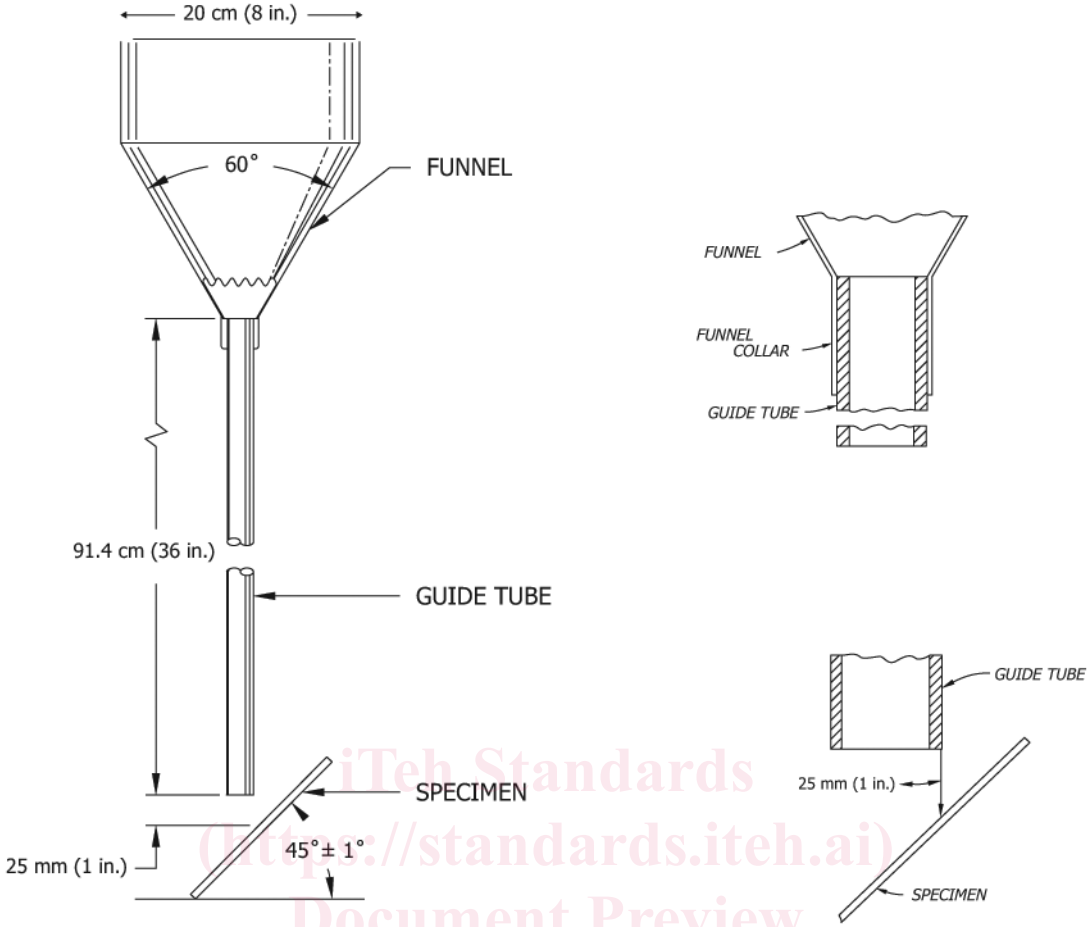

FIG. 2 ~~Design~~ Details of Abrasion Test Apparatus

shall be considered standard when graded as follows after 5 min of continuous sieving. Use the sieves described in Specification E11.

0 % retained on a No. 16 (1.18 mm) sieve
Maximum 15 % retained on a No. 20 (850 µm) sieve
Minimum 80 % retained on a No. 30 (600 µm) sieve
Maximum 5 % passing a No. 30 (600 µm) sieve

The sand is characterized by its grain shape and has a silicon dioxide content greater than 99 %.

NOTE 3—The abrading qualities of sand obtained from different sources may differ slightly even though the sand meets the sieve requirements. Therefore, for maximum precision of test results, ~~purchaser and seller~~the interested parties should use sand from the same source.

7. Test Specimens

7.1 Apply uniform coatings of the material to be tested to a plane, rigid surface such as a metal or glass panel. The preferred size of a test specimen is 100 mm × 100 mm (4 in. × 4 in.). Prepare a minimum of two coated panels for the material. The coatings should be applied in accordance with Practices D823, or as agreed upon between the interested parties.

7.2 Cure the coated panels under the conditions of humidity and temperature agreed upon between the ~~purchaser and seller.~~interested parties.

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

~~NOTE 3—The thickness of the dry coatings should be measured in accordance with Test Methods D1005 or D7091.~~

NOTE 4—While the minimum of two coated panels is acceptable, evaluating three or more panels per material will provide greater confidence in your test results.

8. Standardization

8.1 Pour a quantity of standard sand into the funnel and examine the sand stream falling from the lower end of the guide tube. Align the apparatus by means of the adjusting screws in the base until the inner concentrated core of the sand stream falls in the center of the flow when viewed at two positions at 90° to each other. Introduce a measured volume of sand ~~(2000 ± 10 mL is a convenient amount)~~ (2 L ± 0.01 L) and determine the time of efflux. The rate of flow shall be 2 L of sand in ~~21~~21 s to ~~23.5 s.~~23.5 s.

8.2 Secure a trial panel in the testing position, ~~as described~~ and adjust the distance from the guide tube to the coated surface face at the nearest point to 25 mm (1 in.) when measured in ~~6.1, and introduce the~~the vertical direction (see Fig. 2). Introduce the sand in increments until a spot 4 mm (5⁄32 in.) in diameter is worn through to the base material. The overall abraded area shall be elliptical in ~~shape, about 25 mm (1 in.) in width and 30 mm (1~~shape with the ~~¼ in.) in length. The~~ center of the area of maximum abrasion ~~shall be~~ on the centerline through the longer axis of the abraded ~~pattern and within 14 to 17 mm (~~pattern. ~~9⁄16 to 11⁄16 in.) of the top edge.~~ Slight final adjustment of the instrument may be required to center the abrasion spot in the pattern.

NOTE 5—The abrasive particle distribution has an effect on the end point obtained and is dependent on the proper alignment of the guide tube. The desired distribution consists of a concentration of particles in the center of the falling stream and a decrease in density as the tube wall is approached (see Fig. 3). When adjusting the instrument, the entire apparatus should be leveled as to locate the abrasive particle stream in the center, rather than by placing a level on the guide tube itself.

NOTE 6—Typical measurements of the abraded area are 25 mm (1 in.) in width and 30 mm (1¼ in.) in length, with the center of the area of maximum abrasion within 14 mm to 17 mm (9⁄16 in. to 11⁄16 in.) of the top edge.

~~8.3 A final check on alignment is made by determining the amount of sand that passes through a 4-mm (5⁄32-in.) hole in a metal panel placed directly under the tube. Place a container under the hole in the panel and allow a weighed amount of sand to pass through the tube onto the panel. Weigh the amount of sand that passed through the hole into the container. The apparatus can be considered to be in calibration if the amount of sand that passed through the hole is 90 to 93 % of the amount of sand that impinged on the panel.~~

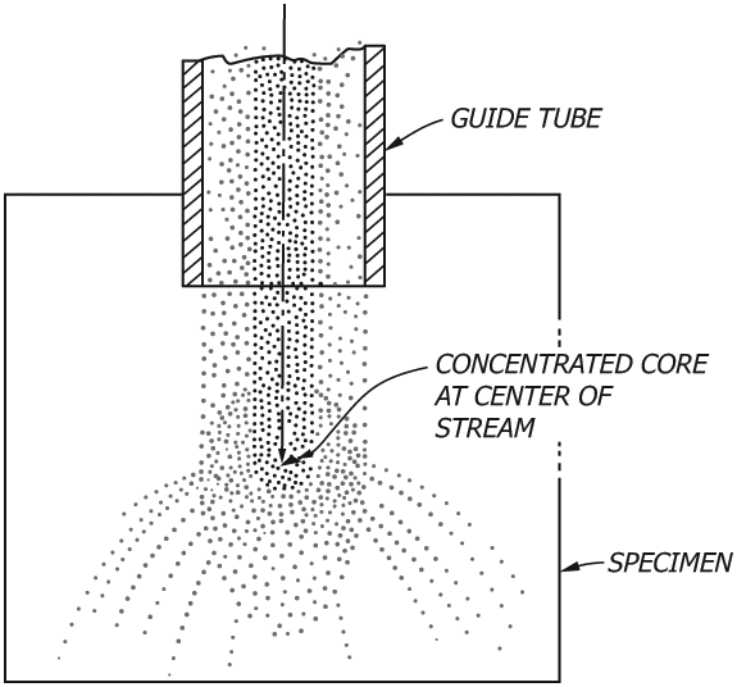

FIG. 3 Example of Abrasive Particle Stream

9. Conditioning

9.1 Unless otherwise agreed upon between ~~purchaser and seller,~~the interested parties, condition the coated test panels for at least 24 h at ~~23~~23 °C ± ~~2°C~~2 °C and ~~50~~50 % ± 5 % relative humidity. Conduct the test in the same environment or immediately on removal therefrom.

10. Procedure

10.1 On each coated panel mark three circular areas, each approximately 25 mm (1 in.) in diameter, and so arranged that each can be properly positioned in the panel support of the abrasion tester according to 10.3.

10.2 ~~On each coated panel mark three circular areas, each approximately 25 mm (1 in.) in diameter, and so arranged that each can be properly positioned in the panel support of the abrasion tester.~~ Measure the thickness of the coating by Test ~~Methods~~Method D1005 or Practice D7091 in at least three locations ~~in~~within each area. Record the mean of each set of measurements as the thickness of the coating over the respective area.

10.3 After conditioning, secure the coated panel in the tester as described in ~~6.1~~8.2. Adjust the panel so that one of the marked areas will be centered under the guide tube.

NOTE 7—Positioning the coated panel so the marked-off areas are oriented horizontally will minimize the abrasive particles from contacting the areas not being tested.

10.4 Pour standard sand, measured volumetrically, into the funnel. Withdraw the gate and allow the sand to flow through the guide tube and impinge on the coated panel. Collect the sand in a container located at the bottom of the tester. Repeat this operation until a 4-mm (5⁄32-in.) diameter area of the coating has worn through to the substrate. A convenient increment of sand to employ during the test is ~~2000 ± 10 mL.~~2 L ± 0.01 L. As the end-point is approached, increments of ~~200~~0.2 L ± ~~2 mL~~ 0.002 L may be introduced into the funnel.

~~NOTE 5—When the gate is withdrawn from the guide tube, make certain that a collar covers the slit opening in the tube.~~

10.5 Abrade each of the remaining marked-off areas of the coated panel as outlined in ~~10.2~~10.3 to 10.4.

NOTE 8—Check the alignment of the guide tube at frequent intervals to ensure that the concentrated inner core of the sand stream is falling in the center of the ~~flow.~~flow (see 8.1).

NOTE 9—After 25 passes through the apparatus, resieve the sand with a No. 30 sieve to remove fines. Replace the sand after 50 passes.

NOTE 10—~~Sand should be stored in a humidity controlled environment.~~ Excessive moisture level of the sand may influence the ~~results and can be corrected by drying~~ results. To minimize this, store sand in a humidity-controlled environment. Drying the sand for 1 h in an oven at approximately ~~82°C (180°F).~~82 °C (180 °F) can correct this condition.

10.6 Repeat 10.1 – ~~10.4~~10.5 on at least one additional panel coated with the material under test.

11. Calculation

11.1 For each area of the coated panel tested, calculate the abrasion resistance, A, in litres per ~~mil~~µm from the following equation:

$$A_{volume} = V/T \quad (1)$$

where:

V = volume of abrasive used, L (to one decimal place) and
~~T~~ = ~~thickness of coating, mils (to one decimal place).~~
T = thickness of coating, µm (to two decimal places).

11.2 Calculate the mean of the abrasion resistance values obtained for ~~different areas~~ each area tested of the coated panel and the mean value of the replicate panels.

NOTE 11—Previous versions of this method reported thickness of coating in mils.

12. Report

12.1 Report the following information for each coated panel tested:

12.1.1 Temperature and humidity during curing and at the time of testing,

12.1.2 Type and source of abrasive,

12.1.3 Litres of abrasive used for each area tested,

12.1.4 Wear pattern measurements, if different than 8.2 and Note 6,

12.1.5 Coating thickness in ~~mils~~um for each area tested,

12.1.6 Abrasion resistance values for each area tested,

12.1.7 Mean abrasion resistance for each coated panel tested, and

12.1.8 Mean abrasion resistance and range of the replicate coated panels.

13. Precision[6]

13.1 On the basis of an interlaboratory test of this test method in which three laboratories tested four types of coatings differing in their abrasion resistance, the within-laboratory coefficient of variation was found to be 9 % with 22 df and the between-laboratories coefficient of variation 35 % with 7 df. Based on these coefficients, the following criteria should be used for judging the acceptability of results at the 95 % confidence level.

13.1.1 *Repeatability*—Two results, each the mean of three runs, obtained by the same operator should be considered suspect if they differ by more than 25 % of their mean value.

13.1.2 *Reproducibility*—Two results, each the mean of three runs, obtained by operators in different laboratories should be considered suspect if they differ by more than 118 % of their mean value.

NOTE 12—The reproducibility of this test is improved substantially when rankings of the coatings by magnitude of abrasion resistance are used. In the interlaboratory test for evaluating precision, all laboratories ranked the coatings in the same order.

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

METHOD B—FALLING SILICON CARBIDE TEST

14. Apparatus and Materials

14.1 *Abrasion Tester,* as described in 6.1, with two exceptions:

14.1.1 A metal washer with an opening of ~~8.5~~8.5 mm ± ~~0.1 mm~~ 0.1 mm is centered in the bottom opening of the funnel to restrict the flow of the abrasive.

14.1.2 The disk gate installed in a slit at the top of the guide tube may be replaced by a gate in the bottom of the funnel. This gate consists of a solid metal disk attached to a long vertical screw and mounted above the washer.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1037. Contact ASTM Customer Service at service@astm.org.