Designation: D 4518 – 91

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Methods for Measuring Static Friction of Coating Surfaces[1]

This standard is issued under the fixed designation D 4518; 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 These test methods cover the determination of the resistance to sliding on coating surfaces by measuring the static friction.

1.2 Two test methods are described as follows:

	Sections
Method A—Inclined Plane Test	8-13
Method B—Horizontal Pull Test	14-19

1.3 *This standard does not purport to address all of the safety problems, 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:*

D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[2]

3. Terminology

3.1 *Definition:*

3.1.1 *static friction*—the force required to start the test sled moving, divided by the mass of the sled.

4. Summary of Test Methods

4.1 With the inclined plane test (Test Method A), a weighted sled is placed on a test specimen and the specimen is gradually inclined from the horizontal until the sled begins to slide. The tangent of this angle of inclination is reported as the static friction.

4.2 With the horizontal pull test (Test Method B), a weighted sled is placed on a horizontal test specimen and is pulled across the specimen. The static friction is reported as the force required to start the sled moving, divided by the mass of the sled.

5. Significance and Use

5.1 The friction characteristics of coating surfaces can be important to the use of the coatings. For example, low friction of exterior can coatings is beneficial to the flow of the cans on production lines. Also low friction of interior pipeline coatings is beneficial to the flow of materials through pipes. On the other hand, low friction of floor coatings can be hazardous to foot traffic.

5.2 Under some conditions, measurement of the static friction can be used to evaluate the slip resistance of coatings under use conditions. However, results can be extremely dependent on the type of coating surface and the type of sliding unit used.

5.3 The tendency for footwear to slip may be influenced by foreign materials or lubricants on the shoe materials or on the walking surfaces. Also, these test methods do not incorporate all the directional forces involved in the walking process. Consequently, levels of slip resistance as determined by these test methods may not predict a person's resistance to slipping when walking on various surfaces.

5.4 The best precision and sensitivity are obtained when stainless steel is used as the facing of the sliding unit. In some tests where a leather facing is used, poor precision is obtained because of the inability to control the uniformity of its surface during the test. The use of a hard synthetic rubber facing provides somewhat better precision.

5.5 These test methods provide for static friction measurements when the sled facing and the coating surfaces are wet with water. Results from such tests must be treated with caution because frequently the static friction values obtained for wet, smooth coatings are higher than those obtained for the same surfaces dry. This is because, when stationary at the beginning of the test, the sled contact can produce a“ suction cup” effect on a wet surface. Measurements performed on wet coatings with rough surfaces have been more satisfactory.

5.6 A test procedure is offered that eliminates the "suction cup" effect of wet surfaces. The wet sled is dropped onto the wet coating surface at the start of the test.

5.7 Results obtained by these test methods may be extremely sensitive to the age of the test coating because the blooming action of additives or plasticizers is often time-dependent. It may be meaningless to compare slip and frictional properties of test coatings applied at different times unless this effect is being studied.

5.8 The measurement of static friction may be influenced by the length of time that the sled rests on the test specimen before motion is initiated.

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[1] These test methods are under the jurisdiction of ASTM Committee D-1 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 Sept. 15, 1991. Published November 1991. Originally published as D4518 – 85. Last previous edition D4518 – 90.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

5.9 Static friction measurements have been useful in evaluating (*1*) the suitability of coatings for the exterior of cans, (*2*) the slipperiness of floor polishes, and (*3*) the slip resistance characteristics of footwear on floor tiles and floor coatings. Also, static friction measurements have been useful in determining the effect of coating additives (for example waxes, silicones) on the slipperiness of coating surfaces.

6. Test Specimens

6.1 Apply test coatings in accordance with Test Methods D 823 to substrates of at least 4 in. (100 mm) in width and length. The substrates may be of glass, steel, aluminum, or other appropriate material that remains smooth and plane after the test coating has been applied and cured at 73.5 ± 3.5°F (23 ± 2°C) and 50 ± 5% relative humidity for 7 days, unless otherwise specified. Prepare at least two test panels for each coating.

6.2 Take care during application of the test coating to minimize entrainment of dust and particulate matter in the surface of the coating. Extreme care is required when handling the panels, even after sufficient cure. The surface should be kept free of all dust, lint, fingerprints, or any foreign matter that may change the characteristics of the surface.

7. Conditions for Testing

7.1 Test the coated test specimens under one or more of the following conditions as agreed upon by the purchaser and the seller:

7.1.1 Both sled facing and coating surfaces dry at 73.5± 3.5°F (23± 2°C).

7.1.2 Both the sled face and the coating surface wet with water containing a slight amount of wetting agent at 73.5 ± 3.5°F (23 ± 2°C). Sea water containing a slight amount of wetting agent may be used when it is appropriate. A wetting solution consisting of 1 mL of surfactant[3] added to 200 mL of water has been found to be satisfactory.

7.1.3 One or both of the above at 35.5 ± 3.5°F (2 ± 2°C).

TEST METHOD A—INCLINED PLANE TEST

8. Apparatus

8.1 *Inclined Plane*, having a smooth, incompressible surface, at least 1 in. (25 mm) wider than the sliding unit and of sufficient length to allow the test sled to move by gravity at least 0.5 in. (12 mm), provided with clamps for the test specimen, and an inclinometer to indicate the angular displacement of the plane to within 0.5°.

NOTE 1—A suitable apparatus is shown in Fig. 1. It may be assembled from items obtained from laboratory instrument supply houses.

8.2 *Test Sleds*—Alternative sleds that may be used are:

8.2.1 *Stainless Rounded Edge Steel Block*, with a highly polished plane lower surface 3 by 3 in. (75 by 75 mm) in area and a mass of 1.8 lb (0.82 kg) to provide a pressure of 0.2 psi (1.4 kPa) when horizontal.

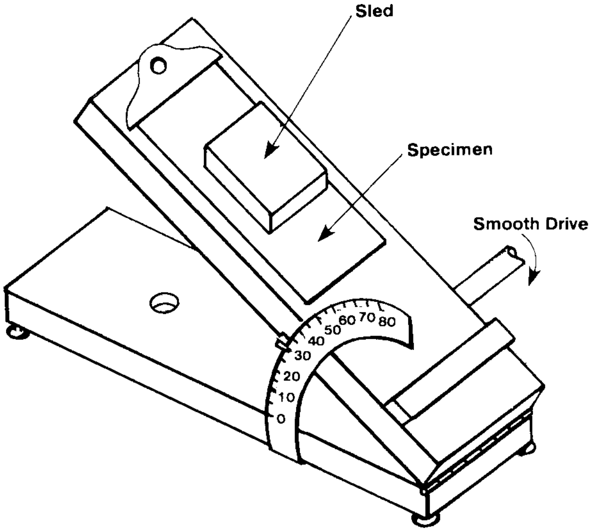

FIG. 1 Schematic of Inclined Plane Apparatus

8.2.2 *Stainless Steel Block*, with a plane lower surface of 3 by 3 in. (75 by 75 mm) and a mass of 1.8 lb (0.82 kg). Adhered to the lower surface is a ¼-in. (6-mm) thick vulcanized neoprene rubber having a Shore "A" hardness of 65 ± 5. A screw eye or other means to attach the sled to the force-measuring device is provided.

8.3 *Inclinator*—Means to smoothly increase the inclination of the plane from the horizontal through an arc of at least 45° at a rate of 1.5 ± 0.5°/s.

NOTE 2—Procedures found suitable for smoothly increasing the inclination of the plane are (*1*) pulling the top of the plane upward with a motor driven dip coater and (*2*) pushing the top of the plane upward with a laboratory jack equipped with a hand crank.

9. Preparation of Apparatus

9.1 *Preparation of Sled Facing*:

9.1.1 If a synthetic rubber facing is used on the test sled, it must be preconditioned by light sanding before each determination.

9.1.2 Place a sheet of 400A wet or dry silicon carbide abrasive paper on a flat surface. Sand the synthetic rubber facing by rubbing it gently back and forth over the paper four times. Repeat at 90° to the first direction. Wipe the surface of the synthetic rubber facing with a clean, dry cloth to remove dust or loose material from the surface.

10. Procedure

10.1 Level the plane so it is horizontal when the inclinometer reads zero.

10.2 Clamp the test specimen to the plane. Recheck the levelness of the panel in two directions (along the length of the panel and across the panel at 90° to the first measurement).

10.3 *Dry Surfaces*:

10.3.1 Center the sled on the test coating. Immediately commence inclining at a rate of 1.5 ± 0.5°/s. When the sled starts to move, stop the inclinometer immediately and read the angle of displacement at the moment the sled starts to move.

10.3.2 Return the plane to a level position and make two additional tests on the test specimen as described in 8.3.

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[3] A surfactant such as Aerosol OT manufactured by American Cyanamid Co., Chemical Group, One Cyanamid Plaza, Wayne, NJ 07470, has been found suitable for this purpose.

10.4 For *Wet Surfaces:*

10.4.1 Check levelness of plane and test panel according to procedures given in 10.1 and 10.2.

10.4.2 Wet the test coating surface and the sled facing with the prescribed solution. Apply the solution with a soft brush. Make certain that all surfaces are completely wet.

10.4.3 Set the plane of the angle of displacement determined for the dry coating surface in 10.3.1.

10.4.4 From a height of ½ in. (12 mm), drop the sled onto the coating surface. Determine if the sled begins to slide.

10.4.5 Change the angle of the slide, and after rewetting coating and sled surfaces, repeat dropping the sled. Continue in this manner until the plane angle at which the sled starts to slide is determined.

10.4.6 Return the plane to the initial position of 10.4.3 and repeat 10.4.4 and 10.4.5.

11. Calculation

11.1 Calculate the mean of the three measurements on the test specimen. Determine the trigonometric tangent of the mean angle, which is the static friction value.

12. Report

12.1 Report the following information for the coated panels tested:

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

12.1.2 Type of facing used on the test sled,

12.1.3 Whether facing and coating surface were wet or dry,

12.1.4 Inclination angle determined for each measurement,

12.1.5 Static friction value for each measurement, and

12.1.6 Mean static friction value for the replicate panels.

13. Precision

13.1 An interlaboratory study of Test Method A (Inclined Plane Test) in which one operator in each of four laboratories, using sled surfaces of neoprene, polished steel and mildly abraded steel, tested the dry surfaces of eight coated panels with a wide range of slip resistance. The intralaboratory and interlaboratory standard deviations were found to be as shown in Table 1. Based on these standard deviations, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

13.1.1 *Repeatability*—Two results obtained by the same operator should be suspect if they differ by more than the maximum allowable difference given in Table 1.

13.1.2 *Reproducibility*—Two results obtained by operators in different laboratories should be considered suspect if they differ by more than the maximum allowable difference given in Table 1.

13.2 Comparison of inclined plane results are shown in Table 2.

13.3 Bias cannot be determined since there is no standard for slipperiness or slip resistance.

TABLE 1 Precision Values Obtained in 1987 Round-Robin Test of Test Method D 4518

Inclined Plane Test					Dry Surfaces	
			Intralaboratory			
Type of Sled Surface	Standard Deviation		Coefficient of Variation	Degree of Freedom	Maximum Allowable Difference	
	Angle of Inclination	Static Friction			Angle of Inclindation	Static Friction
Polished Steel	3.6	0.08	23 %	14	10.9	0.24
Abraded Steel	3.7	0.08	10 %	13	11.3	0.24

			Interlaboratory			
Type of Sled Surface	Standard Deviation		Coefficient of Variation	Degree of Freedom	Maximum Allowable Difference	
	Angle of Inclination	Static Friction			Angle of Inclination	Static Friction
Polished Steel	4.2	0.09	28 %	32	12.1	0.26
Abraded Steel	4.0	0.09	20 %	32	11.5	0.26
Neoprene	4.2	0.21	17 %	19	12.4	0.62

TEST METHOD B—HORIZONTAL PULL TEST

14. Apparatus [4]

14.1 *Test Base*, a horizontal plane surface of a smooth, incompressible material (metal, wood, plate glass, or plastic) having a width at least 1 in. (25 mm) wider than the test sled (14.2) with means of leveling it in two directions. This base serves as a support for the rest of the mechanism and the test specimen. When placed on a solid support, it must be free of vibration.

14.2 *Test Sleds*—Alternative sleds that may be used are:

14.2.1 *Stainless Steel Block*, with a highly polished lower plane surface of 3 by 3 in. (75 by 75 mm) and a mass of 1.8 lb (0.82 kg) to provide a pressure of 0.2 psi (1.4 MPa) on the horizontal surface. A screw eye or other means to attach the sled to the force-measuring device is provided.

14.2.2 *Steel Block*, with a smooth lower surface of 3 by 3 in. (75 by 75 mm) in area and a mass of 1.8 lb (0.82 kg). Adhered to the lower surface is a ¼-in. (6-mm) thick vulcanized neoprene rubber having a Shore "A" hardness of 65 ± 5. A screw eye or other means to attach the sled to the force-measuring device is provided.

14.2.3 *Steel Block*, having a smooth lower surface 4 by 5 in. (100 by 125 mm) in area and a thickness of 1 to 1.5 in. (25 to 40 mm). Adhered to the lower surface is vulcanized neoprene rubber having a Shore "A" hardness of 65 ± 5 and a thickness of ⅛ in. (3 mm). The total mass of the sled with the rubber facing shall be 6.0 ± 0.5 lb (2.7 ± 0.2 kg).

14.3 *Mechanical Power Unit*—Means for moving the test sled horizontally over the test specimen or the test specimen under a fixed test sled under the following conditions:

14.3.1 For the sleds described in 14.2.1 and 14.2.2, a speed of 6.0 ± 1.0 in./min (150 ± 25 mm/min) shall be provided and a sled (or panel) travel of 4 in. (100 mm).

14.3.2 For the sled described in 14.2.3, a speed of 12 ± 1 in. (300± 25 mm)/min shall be provided and the sled (or panel) allowed to travel 4 in. (100 mm).

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[4] A facing of heel material such as Neolite, with a Shore "A" hardness of 95 ± 5 may be used if appropriate.

TABLE 2 Comparison of Inclined Plane Results Obtained with Stationary and Dropped Sleds on Panel Surfaces

Panel	Sled	Surface	Angle of Slide, °		Static Friction	
			Sled Stationary	Sled Dropped	Sled Stationary	Sled Dropped
A	Steel	Dry	12	12	0.21	0.21
	Neoprene		27	31	0.50	0.61
	Steel	Wet	...	14	...	0.25
	Neoprene		...	32	...	0.61
B	Steel	Dry	20	25	0.35	0.46
	Neoprene		47	34	1.07	0.68
	Steel	Wet	...	19	...	0.34
	Neoprene		...	26	...	0.49
C	Steel	Dry	17	26	0.31	0.49
	Neoprene		36	41	0.73	0.86
	Steel	Wet	...	19	...	0.23
	Neoprene		...	26	...	0.56
D	Steel	Dry	20	25	0.35	0.46
	Neoprene		47	34	1.07	0.68
	Steel	Wet	...	15	...	0.27
	Neoprene		...	29	...	0.56
G	Steel	Dry	20	20	0.35	0.35
	Neoprene		38	32	0.80	0.61
	Steel	Wet	...	19	...	0.34
	Neoprene		...	26	...	0.49
H	Steel	Dry	25	22	0.46	0.39
	Neoprene		14	36	0.96	0.74
	Steel	Wet	...	13	...	0.23
	Neoprene		...	18	...	0.32

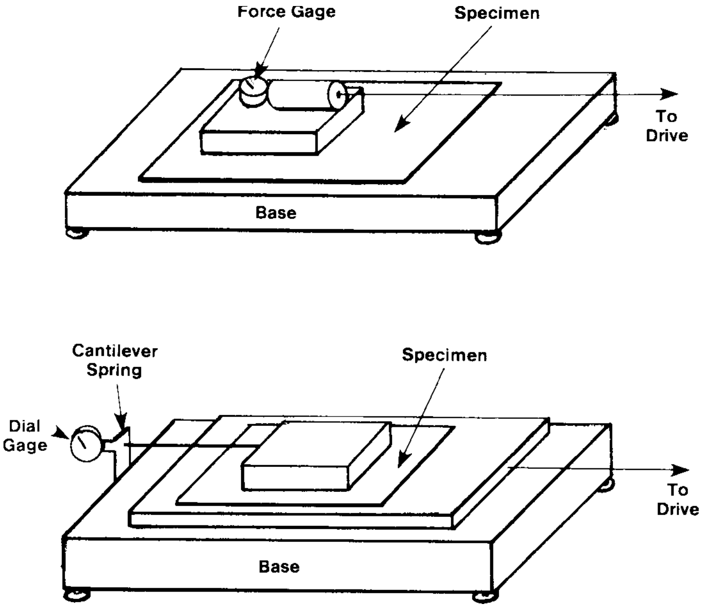

FIG. 2 Schematics for Two Horizontal Plane Instruments

14.3.3 *Force Measuring Device*—Means for measuring the force to 0.01 lb (0.04 N) required to move or restrain the test sled.

NOTE 3—A force gage[5] that can be preset to display the highest force encountered is desirable.

NOTE 4—Fig. 2 illustrates a suitable apparatus. There are various commercial instruments available but some require modification to meet the requirements of these test methods.

15. Preparation of Apparatus

15.1 *Preparation of Sled Facing*:

15.1.1 If a synthetic rubber facing is used on the test sled, it must be preconditioned by light sanding before each determination.

15.1.2 Place a sheet of 400A wet or dry silicon carbide abrasive paper on a plane surface. Sand the synthetic rubber facing by rubbing it gently back and forth over the paper four times. Repeat at 90° to the first direction. Wipe the surface of the synthetic rubber facing with a clean, dry cloth to remove dust or loose material from the surface.

16. Procedure

16.1 Select the test sled and traverse the speed appropriate for the type of test desired:

16.1.1 The test sled described in 14.2.2 with a traverse speed of 6 in. (150 mm)/min is recommended if the best precision of measurement on a smooth coating is desired.

16.1.2 The test sled described in 14.2.2 with a traverse speed of 6 in. (150 mm)/min is recommended if it is desired to measure the resistance of a smooth coating to the slipping of a rubber shoe heel or sole.

16.1.3 The test sled described in 14.2.3 with a traverse speed of 12 in. (300 mm)/min is recommended if it is desired to measure the resistance of a rough coating to the slipping of a rubber shoe heel or sole.

16.2 Clamp the test specimen to the base. Position the test sled and connect it to the power unit or force gage. Fasten the inelastic linkage (cable or chain) to the test sled and connect to the power unit or the force gage.

16.3 As soon as possible after positioning the sled, start the power unit, taking care to maintain tautness in the linkage as the power unit takes up the load.

16.4 Record the force required to just begin motion of the test slide; that is, the maximum force value recorded.

16.5 For the evaluation of smooth coatings, make two

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[5] Chatillon dynamometer gages, available from Chatillon, Inc., 83-30 Kew Garden Rd., Kew Garden, NY 11415, have been found suitable for this purpose.

additional determinations on the test specimen as described in 16.1-16.4. For the evaluation of rough coatings, make four additional determinations on the test specimen.

17. Calculation

17.1 Calculate the mean of the force value obtained for the replicate determinations.

17.2 Divide the mean force by the mass of the test sled. This is the static friction value.

18. Report

18.1 Report the following information for the coated panels tested:

18.1.1 Temperature and humidity during curing and testing,
18.1.2 Whether facing and coating surfaces were dry or wet,
18.1.3 Mass of test sled used,
18.1.4 Type of facing used on the test sled,
18.1.5 Traverse speed of sled used,
18.1.6 Static friction value for each coated panel, and
18.1.7 Mean static friction value for the replicate panels.

19. Precision and Bias

19.1 An interlaboratory test will be conducted to determine the precision and bias of this test method. Tests conducted by several laboratories have shown that this measuring technique has sufficient sensitivity and precision to differentiate coatings exhibiting significantly different sliding friction characteristics.

20. Keywords

20.1 coating surface slipperiness; horizontal pull slipmeter test; inclined plane; static friction