



Designation: D4060 – 19

# Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser<sup>1</sup>

This standard is issued under the fixed designation D4060; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope\*

1.1 This test method covers the determination of the resistance of organic coatings to abrasion produced by the Taber Abraser on coatings applied to a plane, rigid surface, such as a metal panel.

1.2 The values stated in SI units are to be regarded as the standard, with the exception of mils when determining coating thickness.

1.3 This standard is similar in content (but not technically equivalent) to ISO 7784–2.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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:<sup>2</sup>

**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**

**D968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive**

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

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

**D3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials (Withdrawn 2016)<sup>3</sup>**

**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**

**G195 Guide for Conducting Wear Tests Using a Rotary Platform Abraser**

### 2.2 Other Standards:

**ISO 7784–2 Paints and varnishes—Determination of resistance to abrasion—Part 2: Rotating abrasive rubber wheel method<sup>4</sup>**

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 Abrasion resistance can be expressed as one or more of the following terms:

3.1.2 *wear index, n*—the average loss in weight in milligrams per thousand cycles of abrasion.

3.1.3 *weight loss, n*—the loss in weight in milligrams, determined at a specified number of cycles.

3.1.4 *wear cycles per mil, n*—the number of cycles of abrasion required to wear a film through to the substrate per mil (0.001 in.) of film thickness.

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

## 4. Summary of Test Method

4.1 The organic coating is applied at uniform thickness to a plane, rigid panel and, after curing, the surface is abraded using

<sup>1</sup> 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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<sup>2</sup> 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.

<sup>3</sup> The last approved version of this historical standard is referenced on www.astm.org.

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

rotary rubbing action under controlled conditions of pressure and abrasive action. The test specimen, mounted on a turntable platform, turns on a vertical axis, against the sliding rotation of two abrading wheels. The wheels shall be mounted in such a way that when they are in contact with the rotating test specimen, they rotate in opposing directions. One abrading wheel rubs the specimen outward toward the periphery and the other, inward toward the center. The resulting abrasion marks form a pattern of crossed arcs over an area of approximately 30 cm<sup>2</sup>.

4.2 Abrasion resistance is calculated as loss in weight at a specified number of abrasion cycles, as average loss in weight per thousand cycles of abrasion, or as number of cycles required to remove a unit amount of coating thickness.

### 5. Significance and Use

5.1 Coating on substrates can be damaged by abrasion during its service life. This test method has been useful in evaluating the abrasion resistance of coatings. Ratings produced by this test method have correlated well with ratings produced by the falling abrasive values in Test Method D968.

5.2 For some materials, abrasion tests utilizing the Taber Abraser may be subject to variation due to changes in the abrasive characteristics of the wheel during testing. Depending on abradant type and test specimen, the wheel surface may change (that is, become clogged) due to the adhesion of debris generated during the test and must be resurfaced at more frequent intervals as agreed upon by the interested parties. To determine if more frequent resurfacing is required, plot the total weight loss every 50 cycles. If a significant negative change in slope is observed prior to 500 cycles, the point at which the slope changes determines the resurfacing frequency.

5.3 When evaluating resistance to abrasion of two or more coatings, other factors may need to be considered for an accurate comparison. Flexible coatings that include air entrain-

ment bubbles could alter the mass loss during comparison tests. Coatings that include dense fillers may result in greater mass loss but have less change in coating thickness. Coatings that include silica, metal oxides or other extremely dense particulates, may wear the abrasive wheel. Wear debris that includes extremely dense particulates may cause three-body abrasion that contributes to the break-down of the coating if not removed by the vacuum suction system. Coatings that have a hardness value or coefficient of friction greater than the abrasive wheel may cause the abrasive wheel to break down faster. Coatings that have different coefficient of friction ratings, must be taken into consideration during comparison tests. Examples of coatings that may be impacted include, but are not limited to; epoxies, polymethyl-methacrylate (PMMA), polyurethane-methacrylate (PUMA), methyl-methacrylate (MMA), and carbon resin.

NOTE 1—*Example*—A urethane coating of 20 mil thickness, embedded with 1.2 μm titanium particles resulted in a 2.1 mil loss in coating thickness and 110 mg mass loss. A similar urethane coating without titanium particles, resulted in a 2.9 mil to 3.1 mil loss in coating thickness and 44 mg mass loss.

### 6. Apparatus

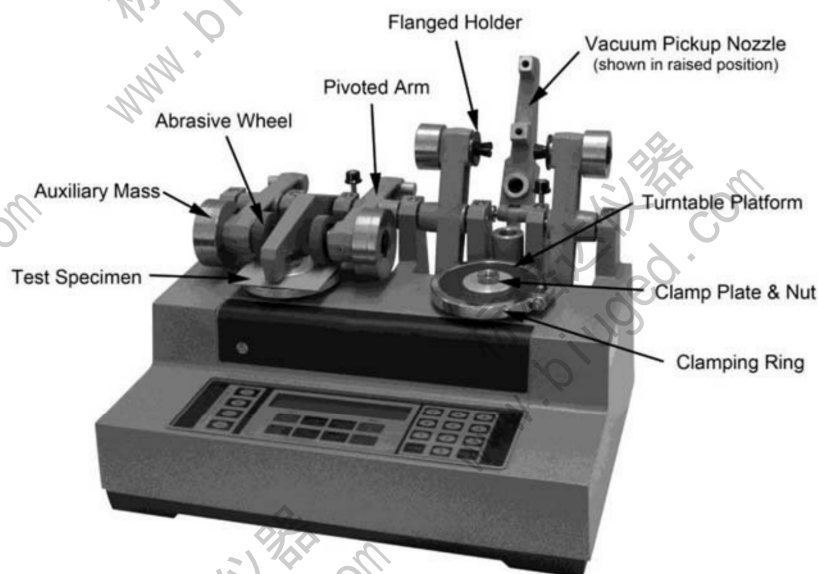
6.1 *Taber Abraser*<sup>5</sup> (Fig. 1), as described in Guide G195 and consisting of the following elements:

6.1.1 A horizontal turntable platform; comprised of a rubber pad, clamp plate, and nut to secure the specimen to the turntable. A clamping ring is provided to secure the resurfacing medium.

6.1.2 A motor capable of rotating the turntable platform at a speed of either 72 r/min ± 2 r/min for 110v/60Hz or 60 r/min ± 2 r/min for 230v/50Hz.

6.1.3 A pair of pivoted arms, to which the abrasive wheels and auxiliary masses may be attached; loads of 250 g, 500 g,

<sup>5</sup> Available from Taber Industries, 455 Bryant St., North Tonawanda, NY 14120.



Note: Vacuum Suction System not shown.

FIG. 1 Taber Abraser

or 1000 g on each wheel may be obtained by use of these changeable masses. Counterweight attachments of 125 g or 175 g are available to reduce the load against the specimen, and can be used with or without the auxiliary masses.

NOTE 2—Without auxiliary masses or counterweights, each arm will apply a load against the specimen of 250 g per wheel (exclusive of the mass of the wheel itself).

6.1.4 A vacuum suction system and vacuum pick-up nozzle to remove debris and abrasive particles from the specimen surface during testing. The height of the vacuum pickup nozzle shall be adjustable, and the nozzle openings shall be 8 mm in diameter. The vacuum system shall operate when testing commences.

6.1.5 A counter to record the number of cycles (revolutions) made by the turntable platform.

6.2 *Abrasive Wheels*<sup>6</sup>—Resilient Calibrase wheels CS-10 or CS-17, as required, shall be used unless otherwise agreed upon by the interested parties. Because of the slow hardening of the bonding material, resilient wheels shall not be used after the date marked on them.

NOTE 3—The CS-17 wheels produce a harsher abrasion than the CS-10 wheels.

6.2.1 The wheels shall be cylindrically shaped, have a diameter between 52.4 mm and 44.4 mm, a width of 12.7 mm  $\pm$  0.3 mm, and an axial hole 16.0 mm  $\pm$  0.1 mm in diameter to allow the wheel to be mounted to the flanged holder on the pivoted arms.

6.3 *Resurfacing Medium*, an S-11 abrasive disk, used for resurfacing the abrasion wheels. The resurfacing disk shall be silicon carbide coated abrasive with an average particle size of 92  $\mu$ m (150 grit CAMI-grade), approximately 102 mm diameter with a 7 mm center hole.

## 7. Test Specimens

7.1 Apply a uniform coating of the material to be tested to a rigid panel having both surfaces substantially plane and parallel. Specimens shall be a disk or a square plate with a 6.5 mm hole centrally located on each panel. Typical dimensions for a test panel are 100 mm in diameter or 100 mm by 100 mm. Thickness of the specimen should be no greater than 6.5 mm unless an S-21 extension nut<sup>5</sup> or arm height extension kit<sup>5</sup> is utilized.

NOTE 4—The coatings should be applied in accordance with Practices D823, or as agreed upon between the interested parties.

NOTE 5—The thickness of the dry coatings should be measured in accordance with Test Method D1005 or Practice D7091.

NOTE 6—For those materials greater than 6.3 mm but less than 12.7 mm thick, the S-21 extension nut may be used to affix the specimen to the turntable. This requires a 9.5 mm center hole in the specimen. Alternatively, an arm height extension kit will permit testing of specimens up to 40 mm thick and requires the center hole to be 14.5 mm.

<sup>6</sup> The sole source of supply of the apparatus known to the committee at this time is Taber Industries, 455 Bryant Street, North Tonawanda, NY, 14120. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend.

## 8. Calibration

8.1 Verify calibration of the Taber Abraser as directed by the equipment manufacturer (see Appendix X1).

## 9. Standardization

9.1 To ensure that the abrading function of the wheels is maintained at a constant level, prepare the abrading wheels prior to each test and after every 500 cycles unless otherwise agreed to by the interested parties.

NOTE 7—Inorganic coatings do not require the abrasive wheels to be resurfaced after every 500 test cycles.

9.1.1 Mount the selected abrasive wheels on their respective flange holders, taking care not to handle them by their abrasive surfaces.

9.1.2 A load of 1000 g (per wheel) shall be used, unless otherwise agreed upon by the interested parties.

9.1.3 Mount the resurfacing medium (S-11 abrasive disk) on the turntable and secure in place with the clamp plate, nut and clamping ring. Lower the pivoted arms carefully until the wheels rest squarely on the abrasive disk. Place the vacuum pick-up nozzle in position and adjust it to a distance of 3 mm  $\pm$  1 mm, or as agreed upon between the interested parties, above the abrasive disk.

9.1.4 Set the vacuum suction force to 100. The vacuum suction force may be decreased if agreed upon by the interested parties.

9.1.5 Resurface the wheels by running them 25 or 50 cycles against the resurfacing medium. Each S-11 resurfacing disk is good for one resurfacing operation, after which it shall be discarded. **Warning**—Do not brush or touch the surface of the wheels after they are resurfaced.

NOTE 8—If resurfacing did not refresh the wheels sufficiently, it may be necessary to resurface the wheels a second time using a new S-11 resurfacing disk.

## 10. Conditioning

10.1 Cure the coated panel under conditions of humidity and temperature as agreed upon between the interested parties. For additional information, reference Specification D3924.

10.2 Unless otherwise agreed upon between the interested parties, condition the coated panel for at least 24 h at 23 °C  $\pm$  2 °C and 50 %  $\pm$  5 % relative humidity. Conduct the test in the same environment or immediately on removal therefrom.

## 11. Procedure

11.1 Weigh the test specimen to the nearest 0.1 mg and record this weight if either the wear index or the weight loss is to be reported.

NOTE 9—When comparing the wear resistance of coatings that have different specific gravities, a correction for the specific gravity of each coating shall be applied to the weight loss to give a true measure of the comparative wear resistance. Calculate the wear index as shown in 12.1 or weight loss as shown in 12.2, then divide the result by the coating's specific gravity as determined by D1475. The use of this correction factor provides a wear index or weight loss relative to the loss in volume of the material to which it is applied. When comparing coatings of different specific gravities, the test parameters shall be the same.

11.2 When wear cycles per mil is required, measure the coating thickness of the test specimen on a minimum of four points along the path to be abraded and take the average of the readings.

11.3 Mount the test specimen on the abraser turntable platform with the side to be abraded facing up. Secure using the clamp plate and nut. Lower the abrasive wheels onto the test specimen and the vacuum pick-up nozzle in position as outlined in 9.1.3. Affix the auxiliary masses as outlined in 9.1.2. Set the vacuum suction as outlined in 9.1.4.

NOTE 10—To generate a uniform wear pattern, specimen surfaces must be plane and parallel. If a specimen is slightly warped, the model E140-14 Rimmed Specimen Holder with Ring Clamp<sup>5</sup> or similar may be used. This holder clamps the specimen against a flat rigid plate about the perimeter of the specimen.

NOTE 11—If using a dual table abraser and the second table is not in use, mount a specimen to the turntable platform and set the vacuum nozzle height as stated in 9.1.3.

11.4 Subject the test specimen to abrasion for the specified number of cycles or until wear through of the coating is observed. When determining the point of wear through, stop the instrument periodically for examination of the test specimen.

11.4.1 When required, stop the instrument at defined intervals (such as every 100 cycles) to measure weight loss or coating thickness.

NOTE 12—For specimens that have a rough surface, it may be advisable to run a preliminary break-in period before measuring weight loss or coating thickness. It may be advisable to disregard the final reading after the substrate is exposed, if the results are affected by abrasion of the exposed substrate.

11.5 Remove any loose abradings remaining on the test specimen by light brushing. Reweigh the test specimen.

11.6 Repeat 11.1 to 11.5 on at least one additional test specimen of the material under test.

NOTE 13—Evaluating three or more panels per material will provide greater confidence in the test results.

**12. Calculation**

12.1 *Wear Index*—Compute the wear index, *I*, (average mass loss per thousand cycles of abrasion, in mg) of a test specimen as follows:

$$I = \frac{(A - B) 1000}{C} \tag{1}$$

where:

- A* = weight of test specimen before abrasion, mg,
- B* = weight of test specimen after abrasion, mg, and
- C* = number of cycles of abrasion recorded.

12.2 *Weight Loss*—Compute weight loss, *L*, (change in mass caused by abrasion, in mg) of the test specimen as follows:

$$L = A - B \tag{2}$$

where:

- A* = weight of test specimen before abrasion, mg, and
- B* = weight of test specimen after abrasion, mg.

12.3 *Wear Cycles Per Mil*—Compute the wear cycles per mil, *W*, of the test specimen as follows:

$$W = D/T \tag{3}$$

where:

- D* = number of cycles of abrasion required to wear coating through to substrate and
- T* = thickness of coating, mils.

**13. Report**

13.1 Report the following information for each test material:

- 13.1.1 Temperature and humidity during conditioning and at the time of testing,
- 13.1.2 Thickness of coating when wear cycles per mil are specified,
- 13.1.3 Type of abrasive wheels used and frequency of resurfacing if different than 9.1,
- 13.1.4 Load applied to the abrasive wheels (per arm),
- 13.1.5 Vacuum nozzle height,
- 13.1.6 Vacuum suction setting,
- 13.1.7 Number of wear cycles recorded for each test specimen,
- 13.1.8 Wear index, weight loss, or wear cycles per mil for each test specimen, and
- 13.1.9 Mean and range of the abrasion resistance values of the replicate coated panels.

**14. Precision and Bias<sup>7</sup>**

14.1 The precision of this test method is based on an interlaboratory study of Test Method D4060 - 01, conducted in 2006. Seven laboratories tested five materials. Each “test result” represented an individual determination. Every laboratory obtained five replicate specimens for each material.<sup>7</sup>

14.1.1 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the “*r*” value for that material given in Table 1; “*r*” is the

<sup>7</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1135. Contact ASTM Customer Service at service@astm.org.

**TABLE 1 Precision of Taber Abrasion Values<sup>A</sup>**

Coating	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{X}$	sr	sR	r	R
Polyamide/Epoxy Coating A	129.6	3.1	15.3	8.7	43.0
Polyamide/Epoxy Coating B	109.1	14.6	19.1	40.9	53.6
Polyurethane Coating	49.5	3.0	6.1	8.3	17.2
Polyester/Epoxy Powder Coating	61.3	2.6	6.8	7.1	19.1
Nylon Powder Coating	7.7	1.6	3.2	4.4	8.9

<sup>A</sup> Weight loss (milligrams) – no consideration was given to specific gravity.

interval representing the critical difference between two test results for the same material, obtained by the same operator, using the same equipment, in the same laboratory, on the same day.

14.1.2 *Reproducibility*—Two test results shall be judged not equivalent if they differ by more than the “R” value for that material given in Table 1; “R” is the interval representing the difference between two test results for the same material, obtained by different operators, using different equipment, in different laboratories.

14.1.3 Any judgment in accordance with these two statements has approximately a 95 % probability of being correct.

14.1.4 The precision statement was determined through statistical analysis of 173 results, from seven laboratories, on five materials.

NOTE 14—Versions of this test method issued before 2001 specified a vacuum nozzle height of 1 mm above the specimen surface. This was not the intent of the equipment manufacturer, as it could cause variation in the vacuum pick-up efficiency across the radius of the abrasion track. The data summarized in Table 1 utilized a vacuum nozzle height of 6.5 mm above the specimen surface and a vacuum setting of 100. The vacuum nozzle gap of  $3 \text{ mm} \pm 1 \text{ mm}$  was changed in 2014.

14.2 *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.

15. Keywords

15.1 abrasion resistance; wear index; Taber Abraser tester

APPENDIX

(Nonmandatory Information)

X1. CALIBRATION VERIFICATION

X1.1 To facilitate the verification of calibration of the Taber Abraser, a kit is available<sup>5</sup> that provides a fast reliable system check. This kit is not meant as a substitute for regular instrument calibration. Procedures in the kit allow the user to verify:

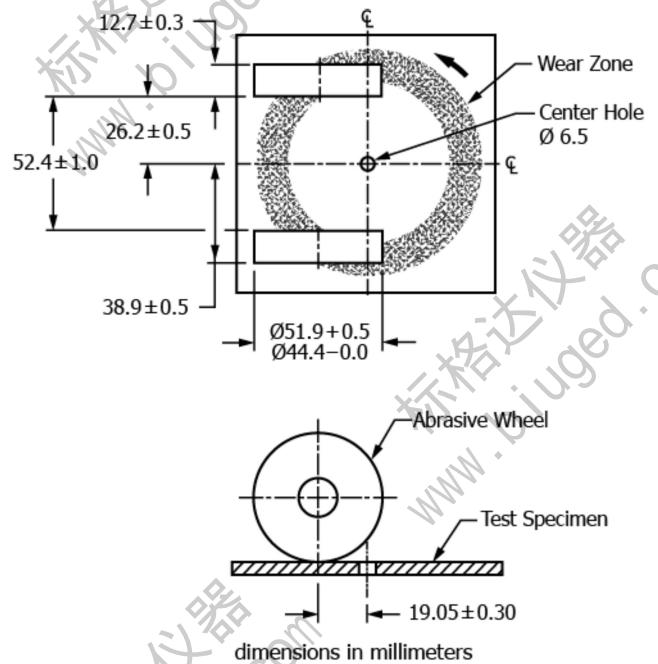
X1.1.1 *Wheel Alignment and Tracking*—The wheels should be spaced equally on both sides from the wheel-mounting flange to the center of the specimen holder. When resting on the specimen, the wheels will have a peripheral engagement with the surface of the specimen, the direction of travel of the periphery of the wheels and of the specimen at the contacting portions being at acute angles, and the angles of travel of one wheel periphery being opposite to that of the other. Wheel internal faces shall be  $52.4 \text{ mm} \pm 1.0 \text{ mm}$  apart and the hypothetical line through the two spindles shall be  $19.05 \text{ mm} \pm 0.3 \text{ mm}$  away from the central axis of the turntable (Fig. X1.1).

X1.1.2 *Wheel Bearings Condition*—The Taber Abraser wheel bearings should be able to rotate freely about their horizontal spindles and not stick when the wheels are caused to spin rapidly by a quick driving motion of the forefinger.

X1.1.3 *Vacuum Suction Force*—The vacuum suction force shall be 13.7 kPa or greater as measured by a vacuum gauge at the vacuum pick-up nozzle port.

NOTE X1.1—Vacuum suction force may be influenced by the condition of the collection bag, which must be emptied or replaced on a regular basis. Any connection or seal leaks will also influence suction force.

X1.1.4 *Turntable Platform Position*—The vertical distance from the center of the pivot point of the Taber Abraser arms to the top of the turntable platform should be approximately 25 mm. The turntable platform shall rotate substantially in a



This schematic shows the proper wheel position in relation to the turntable platform.

FIG. X1.1 Arrangement of Taber Abraser Test Set-up

plane with a deviation at a distance of 1.6 mm from its periphery of not greater than 0.20 mm.

X1.1.5 *Turntable Speed*—The turntable should rotate at the speed stated in 6.1.2.

X1.1.6 *Load*—The auxiliary mass marked 500 g shall weigh  $250 \text{ g} \pm 1 \text{ g}$  and the auxiliary mass marked 1000 g shall weigh  $750 \text{ g} \pm 1 \text{ g}$ .

**SUMMARY OF CHANGES**

Committee D01 has identified the location of selected changes to this standard since the last issue (D4060–14) that may impact the use of this standard. (Approved October 1, 2019.)

- (1) Updated the definition of wear index in section 3.1.2.
- (2) Updated summary of test in section 4.1.
- (3) Added section 5.3 explaining other factors that may need to be considered for comparison of coatings of different formulations.
- (4) Added sole source footnote for abrasive wheels and updated description of in section 6.2.1.
- (5) Removed Note 2 describing wheel hardness measurements. The procedure used by the manufacturer is similar but not equivalent to D2240.
- (6) Updated description of resurfacing disk in section 6.3.
- (7) Changed the minimum number of coated panels to be prepared in section 7.1 to as agreed upon by the interested parties.
- (8) Moved Note 4 to after section 11.6.
- (9) Moved resurfacing frequency (500 cycles) from Note 8 to procedure in section 9.1.
- (10) Added **Note 7** stating that resurfacing frequency of 500 cycles is not required for inorganic coatings.
- (11) Added **Note 8** stating that an additional resurfacing may be required if the wheels were not sufficiently refreshed.
- (12) Added **Note 9** discussing the use of specific gravity to obtain a true measure of the comparative wear resistance.
- (13) Added option to take more frequent data point measurements in section 11.4.1, Combined Notes 11 and 12, and moved to after 11.4.1.
- (14) Increased maximum deviation for the turntable platform when rotating in a plane from 0.10 mm to 0.20 mm to match manufacturer's dimension, in section X1.1.4.
- (15) Updated all values and dimensions to comply with Form & Style requirements.

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