Designation: G132 – 96 (Reapproved 2013)

Standard Test Method for Pin Abrasion Testing[1]

This standard is issued under the fixed designation G132; 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 a laboratory procedure for determining the wear resistance of a material when relative motion is caused between an abrasive cloth, paper, or plastic film and a contacting pin of the test material. The principal factors and conditions requiring attention when using this type of apparatus to measure wear are discussed.

1.2 The values stated in SI units are to be regarded as 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]

A128/A128M Specification for Steel Castings, Austenitic Manganese

A514/A514M Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

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

F732 Test Method for Wear Testing of Polymeric Materials Used in Total Joint Prostheses

G40 Terminology Relating to Wear and Erosion

G99 Test Method for Wear Testing with a Pin-on-Disk Apparatus

3. Terminology

3.1 Refer to Terminology G40 for definitions of terms related to this test method.

4. Summary of Test Method

4.1 For the pin abrasion test method, two pin specimens are required. One is of the test material. The other is of a reference material. Each pin, in turn, is positioned perpendicular to the abrasive surface, which usually is mounted on, or supported by, a flat circular disk, another flat surface, or the cylindrical surface of a drum. The test machine permits relative motion between the abrasive surface and the pin surface. The wear track of a pin describes a continuous, non-overlapping path such as a spiral, helix, or saw-tooth curve, preferably with a displacement between successive passes sufficient to allow the other pin to trace a parallel track in the intervening space. Fig. 1 shows some possible arrangements. The pin specimen is pressed against the abrasive surface with a specified loading by means of dead weights or another suitable loading system. Rotation of the pin about its axis during testing is optional. Note, however, that results with and without pin rotation or with different loading systems may differ.

4.2 The amount of wear is determined by weighing both specimens before and after testing. Mass loss values should be converted to volume losses using the best available values of specimen densities. The use of length changes to indicate the amount of wear is not recommended for the purposes of this test method, and no procedure for processing such data is included in this test method.

4.3 Wear results are reported as a volume loss and as the wear volume normalized with respect to the applied normal load, to the wear path length, and to the mean wear of the reference specimen on the same type of abrasive. The reference specimen wear is included in the calculation in order to correct for abrasivity variations (see 4.5 and 10.2).

4.4 Various sizes and types of abrasive have been used. These include silicon carbide, alumina, emery, garnet, flint, or other silicas, and synthetic compounds, but wear results normally will differ with different types of abrasive (see Table X3.1). The abrasive is bonded to a cloth, paper, or plastic film

[1] This test method is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.30 on Abrasive Wear.

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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.

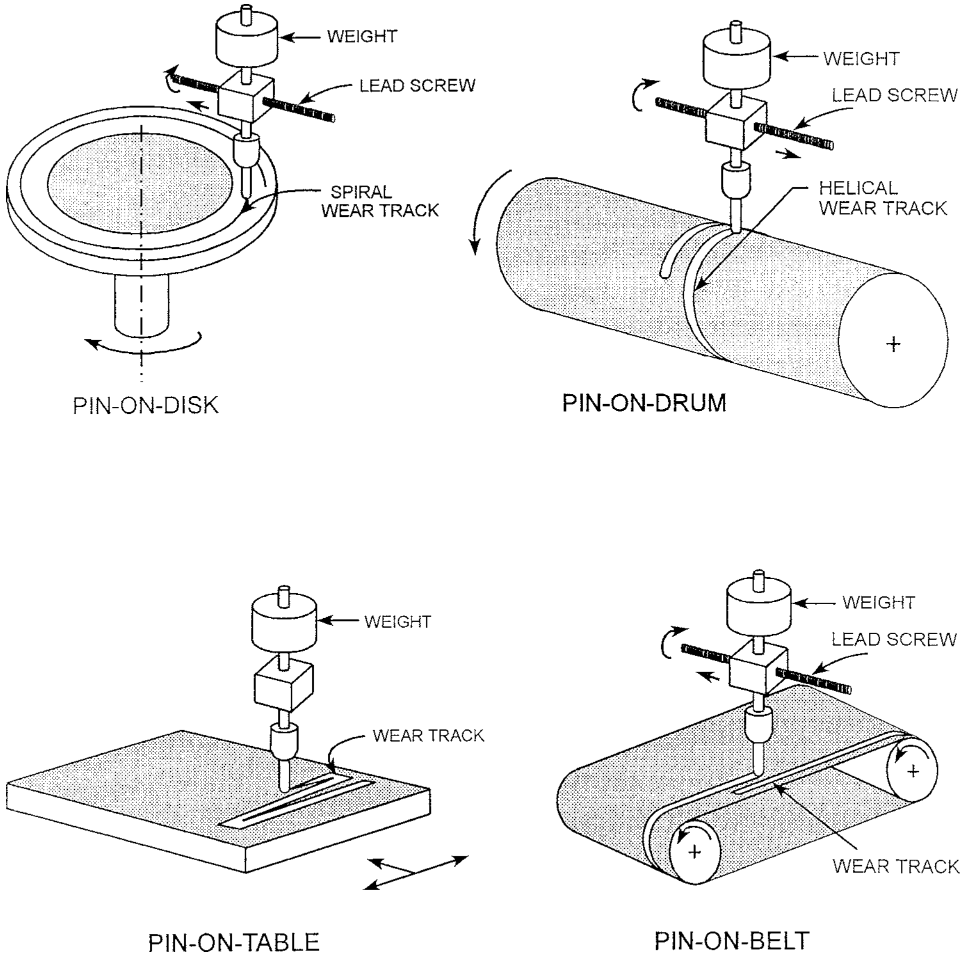

FIG. 1 Four Configurations of Pin Abrasion Testing Machines

(usually polyester) backing that is mounted on or supported by a smooth, firm surface (for example, disk, other flat, or cylinder). For purposes of this test method, a garnet is the preferred abrasive and has given good correlations with many types of abrasive services (**1**).[3] The field experience has included a wide variety of abrasive minerals, ranging from coarse rock to fine ore, rounded or crushed, with high or light loading.

4.5 In this test method, the primary role of the reference material is to correct for variations in the abrasivity of the abrasive cloth or paper. Because of abrasivity variability, the reference material wear in a particular test may deviate from the overall mean for tests using the same abrasive. The reference material's function here differs from that in other tests where a direct comparison between the test material and reference material is used as a basis for ranking the abrasion resistances of materials or where the wear of a reference material is used as the basis for ranking the abrasivities of abrasive materials.

5. Significance and Use

5.1 The amount of wear in any system will, in general, depend upon a number of system factors such as the applied load, machine characteristics, sliding speed, sliding distance, the environment, and material properties. The primary value of this wear test method lies in predicting the relative ranking of materials. This test method imposes conditions that cause measurable mass losses and it is intended to rank materials for applications in which moderate to severe abrasion occurs. Test materials should be reasonably resistant to such abrasion. Since this abrasion test does not attempt to duplicate all of the conditions that may be experienced in service (for example, abrasive particle size, shape, hardness, speed, load, and presence of a corrosive environment), there is no assurance that this test method will predict the wear rate of a given material under conditions differing from those in this test method.

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.

6. Apparatus

6.1 *General Description*—Refer to Fig. 1 where schematic drawings of typical pin-on-disk, pin-on-table, pin-on-belt, and pin-on-drum wear testing systems are shown.[4] In each of the systems, the end of a pin, which may or may not be rotating about its axis, is pressed against an abrasive surface with application of a prescribed normal force while relative motion occurs between the pin and the abrasive surface. By moving either the abrasive surface or the pin, or both, the pin progressively moves over unused abrasive for a prescribed wear track length.

NOTE 1—Other descriptions of contemporary pin-on-disk, pin-on-table, and pin-on-drum systems may be found in Practice F732, Test Method G99, and Ref (**2**).

6.1.1 The wear path is normally a spiral on disks, a combination of linear segments on other flats, an oval helix on belts, and a cylindrical helix on drums. Successive wear track passes of the test pin should be spaced far enough apart so that the reference pin can be tested on unused abrasive in a path adjacent and parallel to that of the test pin. If, as in some machines, insufficient unused abrasive space is left between the tracks, the wear track of the reference pin should be generated in two equal parts located immediately before and after the test pin track (see 9.10).

6.2 *Machine Rigidity*—The testing machine must be sufficiently rigid and stable to keep vibrations from affecting wear test results. The load capacities of bearings should be large relative to the loads carried. The surface that supports the abrasive should be rigid. Additional guidance concerning rigidity requirements for wear testing may be found in Ref (**3**).

6.3 *Drive System*—A drive system capable of maintaining a constant steady-state speed of the abrasive relative to the pin is needed. For the pin-on-disk machine, the rotational speed must vary inversely with the radial distance of the pin from the disk's center in order for the linear speed to be constant. For the pin-on-table machine, there inevitably must be a point of rest and transient deceleration and acceleration periods at each end of each stroke, and the translational speed can be constant only between the acceleration and deceleration periods. The transient periods should be kept as short as possible. If the pin is rotated, its rotational speed should be constant.

6.4 *Cycle Counter*—The test machine shall be equipped with a device that will count and record the number of revolutions in the case of a disk, drum, or belt, or the number of strokes or cycles in the case of a nonrotating flat. This device should also have the capability to shut off the machine after a preselected number of revolutions, strokes, or cycles.

6.5 *Pin Specimen Holder*—A chuck, collet, or other device is required to securely hold the pin. The holder must move freely, with negligible friction, in the direction of its longitudinal axis (that is, perpendicular to the abrasive surface), even if rotated. The pin must be restrained from lateral deflection due to pin drag. A means of applying a load to the pin, preferably by dead weights, shall be provided.

6.6 *Wear Measuring System*—The balance used to measure the mass loss of specimens shall have a sensitivity of 0.0001 g or better.

7. Test Specimens, Abrasive, and Sample Preparation

7.1 *Materials*—The test method may be applied to a variety of wear-resistant materials. The only requirement is that specimens having suitable dimensions can be prepared and that they will withstand the stresses imposed during the test without failure or excessive flexure. This test method is not intended for a material that would be unsuitable for a wear-resistant application.

7.1.1 Experience during the development of this test method has shown that the use of Specification A514/A514M, Type B steel of Hardness 269 HB, as the reference material has very adequately corrected for abrasivity variations. It is therefore specifically recommended for that purpose. If another reference material is used, it must be fully described and characterized in the report of results.

7.2 *Test Specimens*—Pin specimens used with a pin-on-drum machine during the development of this test method were circular cylinders, 6.35 mm in diameter and approximately 3 cm long. More generally, typical pin diameters range from 2 to 10 mm. Specimens of square cross section also have been used. Pin ends are conformed to the abrasive surface by wearing in as part of the test procedure (see 9.3), so the starting shape is not critical. However, flat ends are most common and, in most cases, require shorter times and path lengths for wearing in.

7.2.1 Test specimens shall be free from scale which could flake off and interfere with the specimen-abrasive contact. Porosity, unless it is an inherent characteristic of the material being tested, may adversely affect test results and should be avoided. The shank of a specimen that must be gripped should be smooth and regularly shaped. A ground surface roughness of 1 µm (40 µin.) R_a or less is usually adequate.

7.3 *Abrasive*—The abrasive recommended is a 105-µm (150-grit) garnet, bonded to cloth, paper, or plastic (for example, polyester film) with animal glue or synthetic resin, or both. The abrasive coverage is 50 to 70 % of the surface area, uniformly distributed. Normally, the abrasive cloth, paper, or film is obtained from a commercial producer.[5] If other particle sizes of the same or another mineral are used, they should be in the range from 65 to 175 µm (220 to 80 grit).

7.4 *Abrasivity*—The abrasivity of a particular abrasive cloth, paper, or film normally is not uniform over its surface nor is the mean abrasivity of different pieces of the same type

[4] Many lathes should be adaptable for pin-on-drum testing. The sole source of supply of the pin-on-disk machine known to the committee at this time is Falex Corp., 1020 Airpark Dr., Sugar Grove, IL 60554. 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,[1] which you may attend.

[5] Acceptable cloths, papers, and films coated with garnet or other minerals may be obtained from authorized distributors of the 3M Co. Inquiries may be directed to the General Offices, 3M Center, St. Paul, MN 55102. The sole source of supply of the materials known to the committee at this time is 3M Company. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

of material necessarily the same. Variations in abrasivity range up to ±20 % from the overall mean. Corrections for abrasivity variations are made by normalizing the results of individual tests to the mean wear of the reference material over many tests (see 10.2).

8. Test Parameters

8.1 *Load*—The magnitude of the normal force, in newtons, at the wearing contact. Based on the nominal contact area of the specimen, the nominal contact pressure should be within the range from 1 to 2.5 MPa. It has been shown (**1**) that, within this range, the wear is essentially proportional to the loading. A nominal contact pressure of about 2 MPa allows minimal use of abrasive by limiting the requisite path length without a high risk of tearing the backing material.

8.2 *Translational Speed*—The mean relative sliding speed (track length/sliding time) between the contacting surfaces. It should be within the range from 1 to 10 cm/s.

8.3 *Rotational Speed*—The rate at which pins are rotated. Unless it was zero it has been typically in the range from 1.57 to 5.24 rad/s (15 to 50 r/min).

8.4 *Track Length*—The distance slid, in metres.

8.5 *Environment*—Room air at a nominal temperature of 20 to 25°C. The relative humidity and any uncommon environmental exposure should be reported.

8.6 Table 1 gives some typical values of test parameters.

9. Procedure

9.1 Immediately prior to testing, and prior to weighing, thoroughly clean and dry the specimens. Care must be taken to remove all dirt and foreign matter from the specimens. Use non-chlorinated, non-film-forming, noncorrosive cleaning agents and solvents. Extra effort may be needed with open-grained materials to ensure removal of all traces of fluids which may be entrapped in the material. Demagnetize ferromagnetic materials having residual magnetism. Report the methods used for cleaning.

9.2 Mount a sheet, disk, sleeve, or belt of the selected abrasive cloth, paper, or film to or over the appropriate supporting surface in the test machine. If a sheet is wrapped on a drum and edges must be joined, be sure that the edges are cut cleanly and be careful to avoid any gaps, ridges, or other unevenness at the join.

9.3 The ends of the pins should be worn in by performing 9.6 – 9.9 to remove enough material to conform the contacting surfaces. The length of pin removed by abrasion also should equal or exceed the dimension of the largest microstructural feature of the pin material. A 4 to 10-m track length is adequate for most steels unless the pin end is unusually irregular. However, most of the wearing in can be done on previously used abrasive, finishing up on fresh abrasive.

TABLE 1 Typical Test Parameters Used By Three Laboratories With Various Abrasives

Pin Diameter, mm	Force, N	Speed, m/s	Pin Rotation, r/min	Path Length, m
6.35	66.7	0.04	17 to 20	4 to 16

9.4 If necessary, mount fresh abrasive material in the test machine.

9.5 Weigh the pins to the nearest 0.0001 g (0.1 mg).

9.6 Insert a pin specimen securely in the holder. Do not allow the pin to protrude more than 4 mm. If the pin was not rotated as it was worn in, it must be carefully repositioned in the same orientation on any curved surface.

9.7 Apply the prescribed force on the pin perpendicular to the abrasive surface.

9.8 Set the cycle counter to the appropriate number of revolutions or strokes to achieve the desired track length.

9.9 Begin the test with the specimen in contact under load. Stop the test when the desired track length has been achieved.

9.10 Repeat the test with the other pin. The sequence of testing the test pin and reference pin depends upon the wear track configuration. If the wear track on the abrasive surface leaves an unworn space, as the preferred configuration would, either the test pin or the reference pin may be tested first and the other pin will then be tested for the same distance on the intervening unworn abrasive. If insufficient unworn space is left, the reference pin should be tested last for the same total distance on a divided track, half ahead of and half following the test pin track.

9.11 Using precautions such as those in 9.1, clean the specimens to remove any extraneous material and reweigh them to obtain their masses to the same tolerance level as the initial values. Report the cleaning procedure.

9.12 Repeat the test as required to obtain results with an acceptable degree of statistical significance. (See Practice E691.)

10. Calculation and Reporting

10.1 The report must contain all information necessary to permit independent repetition of the test method. This shall include the shape and dimensions of specimens, the material type, composition, processing or preparation history, microstructure and indentation hardness, if appropriate, and any other characterizing details that may apply in special cases. The abrasive shall be adequately described. The type, grit or particle size, the backing material and bonding materials used, the manufacturer, source, and lot number should be given. Test conditions to be reported include the type of testing machine used, the load applied, the linear speed of specimens across the abrasive surface, and the track length. The ambient temperature and relative humidity should also be reported.

10.2 The volume losses (that is, mass losses divided by density) of individual specimens shall be reported in cubic millimetres. In addition, to account for abrasivity variations, report wear measurements as a normalized volume loss per unit track length per unit load, in cubic millimetres per newton/metre.

10.2.1 Use the following equation for calculating the normalized wear:

$$\text{wear} = \frac{C\,W_x}{\rho\,S_x}\ \text{mm}^3/\text{Nm} \quad (1)$$

where:

W_x = mass loss of the test specimen, any units,
S_x = mass loss of the reference specimen, same units,
ρ = density of the test specimen, known or measured to three significant figures, g/cm^3 (mg/mm^3),
C = reference constant equal to the mean mass loss (mg) of the reference pin per unit track length (m) per unit load (N), for the abrasive type and test parameters used. (The ratio C:S_x functions as a normalizing factor.)

10.2.2 The value of the constant *C* for a given reference material and abrasive is determined from a large number of tests, preferably in several test machines at various locations. Several preliminary values of *C*, determined in a single laboratory, are given in Table 2. These were determined for a Specification A514/A514M steel in a pin-on-drum machine, using parameters consistent with Table 1. A preliminary comparison of *C* values determined in two different laboratories with two different types of machine is given in Table 3.

10.2.3 Mass loss results may be used internally by a laboratory to rank materials of equivalent densities without requiring the density factor in Eq 1. However, this test method requires wear to be reported as volume loss in order to compare the wear of materials of different densities. Care should be taken to use and report the best available density values for the materials tested when calculating volume loss from measured mass loss. The density of the reference material need not be used in the calculation. However, if results of separate tests are to be compared meaningfully, the density and other properties of the reference material must be the same in each case.

11. Precision and Bias

11.1 *Precision:*

11.1.1 *Repeatability*—The precision, as indicated by repeatability, of measurements obtained with this test method will depend upon the material tested, the test conditions and parameters, the test configuration, the abrasive used, and the reference material. In a miniature interlaboratory test program, two wear volumes per material were measured in each of two laboratories. The results are summarized in Table X2.1 and Table X2.2. In both tables, standard deviations listed for an individual laboratory, A or B, in the reproducibility columns, are within-laboratory cell standard deviations, in accordance with Practice E691. The combined A and B values in those same columns are repeatability standard deviations, again as defined in Practice E691. Based on the standard deviations listed, the approximate 95 % confidence limits for wear volume measurements for different materials (Table X2.1) ranged from ±0.028 to ±1.68 mm^3 in Laboratory A, and from ±0.084 to ±0.448 mm^3 in Laboratory B. The corresponding 95 % confidence limit ranges for normalized wear (Table X2.2) were $\pm 2.8 \times 10^{-5}$ mm^3/Nm to $\pm 210 \times 10^{-5}$ mm^3/Nm in Laboratory A and $\pm 11.2 \times 10^{-5}$ mm^3/Nm to $\pm 50.4 \times 10^{-5}$ mm^3/Nm in Laboratory B. The 95 % confidence limits derived from repeatability standard deviations are given in the next to last column of each table.

11.1.2 *Reproducibility*—Data sufficient to fully determine the reproducibility of this test method are not yet available. Valid test comparisons among laboratories can be made only for the same type and grade of abrasive and the same reference pin material used to establish a mutually agreeable value of the constant *C*. An interlaboratory program should also be consistent with established statistical guidelines as may be found in Practices E122 and E691. Even so, the reproducibility will depend on the material tested, the test conditions and parameters selected, the test configurations involved, and the particular machine-operator combinations involved. The interlaboratory data now available (refer to Table X2.1 and Table X2.2) are very limited, but provide some insight into reproducibility. Between-laboratory reproducibility standard deviations and the 95 % confidence limits associated with them are listed in each table. A 95 % confidence limit may be approximated by multiplying the corresponding standard deviation or coefficient of variation by ±2.8. The reproducibility (that is, between-laboratory) coefficients of variation listed in the tables are especially revealing. The range for wear volume measurements (Table X2.1) was 4 to 13 %. But when normalized wear calculations are made (Table X2.2), the range was reduced to 0.5 to 5.4 %. This means that much of the between-laboratory differences was due to abrasive differences which were offset by the normalization procedure, as intended.

11.2 *Bias*—In accordance with Practice E177, a measure of a particular laboratory's bias could be the deviation of the average value of the constant *C* as measured in that laboratory for a particular combination of reference material, abrasive, and test conditions from the corresponding average value of *C* obtained for the same materials and conditions in several laboratories. A statistically significant interlaboratory *C* average for one or more combinations of materials and conditions would have to come from more extensive interlaboratory

TABLE 2 Preliminary Values of *C* Determined in a Single Laboratory [Rotating Pin of Specification A514/A514M Steel, Type B, 269 HB Hardness]

Type	Abrasive Size Grit	Abrasive Size µm	C^A, mg/Nm
garnet	220	65	0.131
garnet	150	105	0.151
garnet	120	125	0.153
garnet	60	250	0.214
SiC	150	105	0.159
SiC	120	125	0.169
Al_2O_3	150	125	0.180

^{A} Any one value of *C*, corresponding to a particular set of conditions can be used to test a wide variety of materials.

TABLE 3 Preliminary Values of *C* Determined in Two Laboratories With Different Testers [6.35-mm Diameter Pin of Specification A514/A514M Steel, Type B, 269 HB Hardness, Abraded on 105-µm (150-Grit) Garnet Cloth with a 66.7-N Load]

Laboratory	Machine	Abrasive Number of Lots	Abrasive Number of Rolls	Abrasive Area, m^2	C, mg/Nm
A	pin-on-drum	5	5	144	0.1514
B	pin-on-table	3	7	78	0.1723

testing than has been done. However, an early and possibly pessimistic indication of the individual laboratory biases that might be expected can be obtained by referring again to Table 3 where the deviation of each laboratory is 0.01045 mg/Nm or about 6.5 % from their 0.16185-mg/Nm mean. The bias of the test method itself would depend on deviation of the interlaboratory average from a generally accepted value of *C* for the particular materials and conditions. But because general acceptance of a *C* value would have to be based on use of the method itself, the concept is meaningless in this case. A test cannot be biased against itself.

12. Keywords

12.1 abrasion; abrasives; tribology; wear; wear resistance

APPENDIXES

(Nonmandatory Information)

X1. BACKGROUND INFORMATION ADAPTED FROM REF (2)

X1.1 Considerable pin-abrasive wear testing has been done with pin-on-disk equipment, beginning with Robin's machine in 1910 (**4**). This machine wore a pin sample along a single path on the surface of an abrasive cloth fixed to the flat surface of a disk. Krushchov made a major improvement by making the pin follow a spiral path, like a phonograph, to always encounter fresh abrasive. The work on this type of machine, reviewed by Moore (**5**), helped to establish the effect of many parameters, such as abrasive material and size, specimen load, and speed, on two-body abrasion. Muscara and Sinnott (**6**) developed a pin-on-table machine, using a converted milling machine with abrasive material attached to a moving table. The test specimen was rotated to abrade the pin surface from all directions. Using operating parameters from this machine, Mutton (**7 and 8**) developed a pin-on-drum abrasion machine in which a slowly rotating drum was substituted for the moving table. Blickensderfer and Laird (**1**) used a further refinement of this design to evaluate test parameters and reproducibility.

X2. SUPPLEMENTARY INTERLABORATORY COMPARISONS FOR A WHITE CAST IRON AND VARIOUS STEELS

X2.1 Although an interlaboratory testing program has not yet been implemented fully, there has been a preliminary comparison of results from two laboratories, for a group of nine different iron alloys. Table X2.1 presents the comparison when volume losses were measured, and Table X2.2 shows a comparison based on normalized wear (also see 11.1.2). The data were obtained in the same two laboratories responsible for the data in Table 3. A pin-on-drum machine was used in Laboratory A, and a pin-on-table machine was used in Laboratory B. Each laboratory used 105-µm (150-grit) garnet abrasive from the same supplier, but from different production lots. The same set of pins was exchanged between the laboratories for testing and each laboratory tested each pin twice. In every case, a 66.7-N load was applied and the track lengths were 12.8 m in Laboratory A and 12.55 m in Laboratory B. In accordance with Practice E177 and in accordance with 11.1.2, 95 % confidence limits may be estimated for a particular material when tested in either or both laboratories, as ±2.8 times the applicable standard deviation, or, if preferred, as ±2.8 times the applicable coefficient of variation. This preliminary information is presented here to provide interim guidance to users of this test method until a more complete interlaboratory testing program can be organized.

TABLE X2.1 Comparisons, Between Two Laboratories and Two Machines, of Wear Volume Measurements for a Range of Iron-Based Alloys[A]

Specimen	Material/Hardness, HB	Laboratory	Mean Wear, mm^3	Standard Deviation, mm^3 (COV, %)			95 % Confidence Limits, mm^3	
				Repeatability	Cell Average	Reproducibility[B]	Repeatability	Reproducibility
299	Hi-Cr white cast iron/730	A	4.47	0.17 (3.8)				
		B	5.26	0.10 (1.9)				
		A and B	4.87	0.14 (2.9)	0.56 (11.0)	0.57 (12.0)	0.39	1.57
313	D-2 tool steel/700	A	7.16	0.01 (0.1)				
		B	7.97	0.10 (1.3)				
		A and B	7.57	0.07 (0.9)	0.57 (7.6)	0.57 (7.6)	0.20	1.60
314	AISI 52100 steel/670	A	7.85	0.14 (1.8)				
		B	8.91	0.08 (0.9)				
		A and B	8.38	0.12 (1.4)	0.75 (8.9)	0.76 (9.0)	0.34	2.13
093	UNS G10600 steel/680	A	8.79	0.01 (0.1)				
		B	9.88	0.04 (0.4)				
		A and B	9.34	0.03 (0.3)	0.77 (8.3)	0.77 (8.2)	0.08	2.16
315	A128/A128M Hadfield steel/230	A	9.94	0.02 (0.2)				
		B	11.90	0.12 (1.0)				
		A and B	10.92	0.08 (0.7)	1.39 (12.7)	1.39 (12.7)	0.22	3.89
198	Low-alloy AR steel/520	A	11.37	0.60 (5.3)				
		B	11.87	0.03 (0.3)				
		A and B	11.62	0.42 (3.6)	0.35 (3.0)	0.46 (4.0)	1.18	1.29
311	UNS G43400 steel/520	A	11.97	0.07 (0.6)				
		B	13.19	0.11 (0.8)				
		A and B	12.58	0.09 (0.7)	0.86 (6.9)	0.86 (6.9)	0.25	2.41
316	UNS S30400 steel/230	A	11.47	0.01 (0.1)				
		B	13.79	0.04 (0.3)				
		A and B	12.63	0.03 (0.2)	1.64 (13.0)	1.64 (13.0)	0.08	4.59
184	A514/A514M steel, Type B/277	A	16.53	0.19 (1.1)				
		B	18.19	0.16 (0.9)				
		A and B	17.36	0.18 (1.0)	1.17 (6.8)	1.18 (6.8)	0.50	3.30

[A] Based on two replications per laboratory. Conditions included (105-µm) 150-grit garnet abrasive and 66.7-N loads.
[B] Provisional value.

TABLE X2.2 Comparisons, Between Two Laboratories and Two Machines, of Normalized Wear, Calculated for a Range of Iron-Based Alloys[A]

Specimen	Material/Hardness, HB	Laboratory	Mean Wear, mm^3/Nm × 10^{-5}	Standard Deviation, mm^3/Nm × 10^{-5} (COV, %)			95 % Confidence Limits, mm^3/Nm × 10^{-5}	
				Repeatability	Cell Average	Reproducibility[B]	Repeatability	Reproducibility
299	Hi-Cr white cast iron/730	A	560	21 (3.8)				
		B	591	11 (1.8)				
		A and B	576	17 (2.9)	22 (3.8)	25 (4.4)	62	70
313	D-2 tool steel/700	A	896	2 (0.2)				
		B	895	11 (1.2)				
		A and B	896	8 (0.9)	1 (0.1)	6 (0.6)	3	17
314	AISI S2100 steel/670	A	983	18 (1.8)				
		B	995	9 (0.9)				
		A and B	989	14 (1.4)	8 (0.9)	13 (1.3)	22	36
093	UNS G10600 steel/680	A	1102	2 (0.2)				
		B	1109	5 (0.5)				
		A and B	1106	4 (0.3)	5 (0.5)	6 (0.5)	14	17
315	A128/A128M Hadfield steel/230	A	1240	2 (0.2)				
		B	1330	13 (1.0)				
		A and B	1285	9 (0.7)	64 (5.0)	64 (5.0)	179	179
198	Low-alloy AR steel/520	A	1430	75 (5.2)				
		B	1340	4 (0.3)				
		A and B	1385	53 (3.8)	64 (4.6)	74 (5.4)	179	207
311	UNS G43400 steel/520	A	1500	8 (0.6)				
		B	1480	12 (0.8)				
		A and B	1490	10 (0.7)	14 (0.9)	16 (1.1)	39	45
316	UNS S30400 steel/230	A	1440	1 (0.1)				
		B	1550	5 (0.3)				
		A and B	1495	4 (0.2)	78 (5.2)	78 (5.2)	218	218
184	A514/A514M steel, Type B/277	A	2070	24 (1.2)				
		B	2040	18 (0.9)				
		A and B	2055	21 (1.0)	21 (1.0)	26 (1.3)	59	73

[A] Based on two replications per laboratory and calculated with Eq 1 of 10.2.1, using C = 0.16185 mg/Nm (the average of values listed in Table 3). Other conditions included (105-µm) 150-grit garnet abrasive and 66.7-N loads.
[B] Provisional value.

X3. ON THE EFFECT OF DIFFERENT ABRASIVES

X3.1 For this test method, 7.3 includes a recommendation that 105-µm (150-grit) garnet be used as the abrasive material. In addition, 4.4 cautions that results are likely to differ if another abrasive is used. Nevertheless, it is inevitable that circumstances will arise when the use of another abrasive seems appropriate. For this reason, other particle sizes of garnet and other abrasive materials were included in Table 2, where some values of the normalizing constant, *C*, are listed. Table X3.1 further illustrates the influence of the abrasive choice. As stated in 5.1, the principal result of this test method is a ranking of materials with respect to their abrasion resistances, so it is this ranking that was chosen as the basis of comparison in the tabulation. The materials ranked and the data on which the rankings are based are the same as those given in Appendix X2.

TABLE X3.1 Dependence of Abrasion Resistance Rankings[A] on the Type and Coarseness of Abrasive for a Range of Iron-Based Alloys

Specimen	Material/Hardness	Table X2.2 Ranking	Laboratory A Rankings for Various Abrasives as Indicated								
			Garnet			Alumina			Silicon Carbide		
			220	150	120	60	150	80	150	120	80 Grit
299	Hi-Cr white cast iron/730 HB	1	1	1	1	1	1	2	5	5	6
313	D-2 tool steel/700 HB	2	2	2	3	4	3	4	4	3	4
314	AISI 52100 steel/670 HB	3	3	3	2	2	2	1	1	1	1
093	UNS G10600 steel/680 HB	4	4	4	4	3	4	3	2	2	2
315	A128/A128M Hadfield steel/230 HB	5	5	5	5	5	5	5	3	4	3
198	Low-alloy AR steel/475 HB	6	6	6	6	6	6	6	6	6	5
311	UNS G43400 steel/520 HB	7	7	8	7	7	8	7	8	7	7
316	UNS S30400 steel/230 HB	8	8	7	8	8	7	8	7	8	8
184	A514/A514M steel, Type B/277 HB	9	9	9	9	9	9	9	9	9	9

[A] In order of decreasing wear resistance according to normalized wear calculations.

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