Designation: G65 − 16

Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus[1]

This standard is issued under the fixed designation G65; 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 laboratory procedures for determining the resistance of metallic materials to scratching abrasion by means of the dry sand/rubber wheel test. It is the intent of this test method to produce data that will reproducibly rank materials in their resistance to scratching abrasion under a specified set of conditions.

1.2 Abrasion test results are reported as volume loss in cubic millimetres for the particular test procedure specified. Materials of higher abrasion resistance will have a lower volume loss.

NOTE 1—In order to attain uniformity among laboratories, it is the intent of this test method to require that volume loss due to abrasion be reported only in the metric system as cubic millimetres. $1\ mm^3 = 6.102 \times 10^{-5}\ in^3$.

1.3 This test method covers five recommended procedures which are appropriate for specific degrees of wear resistance or thicknesses of the test material.

1.3.1 *Procedure A*—This is a relatively severe test which will rank metallic materials on a wide volume loss scale from low to extreme abrasion resistance. It is particularly useful in ranking materials of medium to extreme abrasion resistance.

1.3.2 *Procedure B*—A short-term variation of Procedure A. It may be used for highly abrasive resistant materials but is particularly useful in the ranking of medium- and low-abrasive-resistant materials. Procedure B should be used when the volume–loss values developed by Procedure A exceeds 100 mm^3.

1.3.3 *Procedure C*—A short-term variation of Procedure A for use on thin coatings.

1.3.4 *Procedure D*—This is a lighter load variation of Procedure A which is particularly useful in ranking materials of low-abrasion resistance. It is also used in ranking materials of a specific generic type or materials which would be very close in the volume loss rates as developed by Procedure A.

1.3.5 *Procedure E*—A short-term variation of Procedure B that is useful in the ranking of materials with medium- or low-abrasion resistance.

1.4 *This standard does not purport to address 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]

D2000 Classification System for Rubber Products in Automotive Applications

D2240 Test Method for Rubber Property—Durometer Hardness

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

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

G40 Terminology Relating to Wear and Erosion

G105 Test Method for Conducting Wet Sand/Rubber Wheel Abrasion Tests (Withdrawn 2016)[3]

2.2 *American Foundrymen's Society Standards:*

AFS Foundry Sand Handbook, 7th Edition[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *abrasive wear*—wear due to hard particles or hard protuberances forced against and moving along a solid surface (Terminology G40).

[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.

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

[4] Available from American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, IL 60016.

NOTE 2—This definition covers several different wear modes or mechanisms that fall under the abrasive wear category. These modes may degrade a surface by scratching, cutting, deformation, or gouging (**1** and **2**).[5]

4. Summary of Test Method

4.1 The dry sand/rubber wheel abrasion test (Fig. 1) involves the abrading of a standard test specimen with a grit of controlled size and composition. The abrasive is introduced between the test specimen and a rotating wheel with a chlorobutyl or neoprene rubber rim of a specified hardness. This test specimen is pressed against the rotating wheel at a specified force by means of a lever arm while a controlled flow of grit abrades the test surface. The rotation of the wheel is such that its contact face moves in the direction of the sand flow. Note that the pivot axis of the lever arm lies within a plane that is approximately tangent to the rubber wheel surface, and normal to the horizontal diameter along which the load is applied. The test duration and force applied by the lever arm is varied as noted in Procedure A through E. Specimens are weighed before and after the test and the loss in mass recorded. It is necessary to convert the mass loss to volume loss in cubic millimetres, due to the wide differences in the density of materials. Abrasion is reported as volume loss per specified procedure.

5. Significance and Use (1-7)

5.1 The severity of abrasive wear in any system will depend upon the abrasive particle size, shape, and hardness, the magnitude of the stress imposed by the particle, and the frequency of contact of the abrasive particle. In this practice these conditions are standardized to develop a uniform condition of wear which has been referred to as scratching abrasion (**1** and **3**). The value of the practice lies in predicting the relative ranking of various materials of construction in an abrasive environment. Since the practice does not attempt to duplicate all of the process conditions (abrasive size, shape, pressure, impact, or corrosive elements), it should not be used to predict the exact resistance of a given material in a specific environment. Its value lies in predicting the ranking of materials in a similar relative order of merit as would occur in an abrasive environment. Volume loss data obtained from test materials whose lives are unknown in a specific abrasive environment may, however, be compared with test data obtained from a material whose life is known in the same environment. The comparison will provide a general indication of the worth of the unknown materials if abrasion is the predominant factor causing deterioration of the materials.

6. Apparatus and Material[6]

6.1 Fig. 2 shows a typical design and Fig. 3 and Fig. 4 are photographs of the test apparatus which may be constructed from readily available materials. Also, see Ref (**3**). Several elements are of critical importance to ensure uniformity in test results among laboratories. These are the type of rubber used on the wheel, the type of abrasive and the shape, positioning and the size opening of the sand nozzle, and a suitable lever arm system to apply the required force.

6.2 *Rubber Wheel*—The wheel shown in Fig. 5 shall consist of a steel disk with an outer layer of chlorobutyl or neoprene rubber molded to its periphery. Uncured rubber shall be bonded to the rim and fully cured in a steel mold. The optimum hardness of the cured rubber is Durometer A-60. A range from A58 to 62 is acceptable. At least four hardness readings shall be taken on the rubber approximately 90° apart around the periphery of the wheel using a Shore A Durometer tester in accordance with Test Method D2240. The gage readings shall be taken after a dwell time of 5 s. The recommended composition of the rubber and a qualified molding source is noted in Table 1 and Table 2. (See 9.9 for preparation and care of the rubber wheel before and after use and see Fig. 2 and Fig. 5.)

6.3 *Abrasive*—The type of abrasive shall be a rounded quartz grain sand as typified by AFS 50/70 Test Sand (Fig. 6).[7] The moisture content shall not exceed 0.5 weight %. Sand that has been subjected to dampness or to continued high relative humidity may take on moisture, which will affect test results. Moisture content may be determined by measuring the weight loss after heating a sample to approximately 120°C (250°F) for 1 h minimum. If test sand contains moisture in excess of 0.5 % it shall be dried by heating to 100°C (212°F) for 1 h minimum and the moisture test repeated. In high-humidity areas sand may be effectively stored in constant temperature and humidity rooms or in an enclosed steel storage bin equipped with a 100-W electric bulb. Welding electrode drying ovens, available

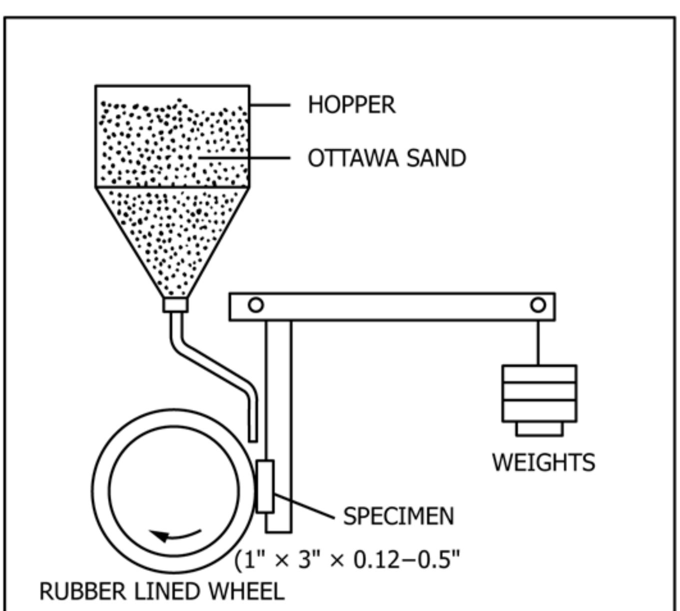

FIG. 1 Schematic Diagram of Test Apparatus

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

[6] Original users of this test method fabricated their own apparatus. Machines are available commercially from several manufacturers of abrasion testing equipment.

[7] Available from U.S. Silica Co., P.O. Box 577, Ottawa, IL 61350. Sand from other sources was not used in the development of this test method and may give different results.

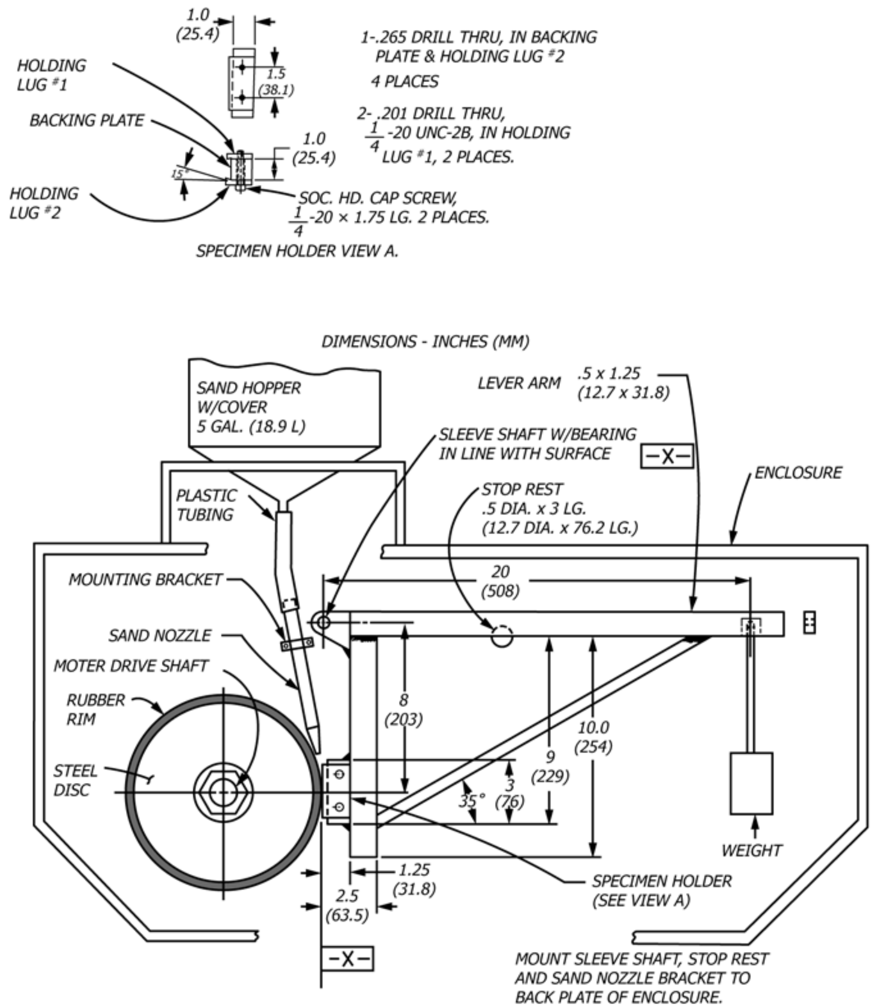

FIG. 2 Dry Sand/Rubber Wheel Abrasion Test Apparatus

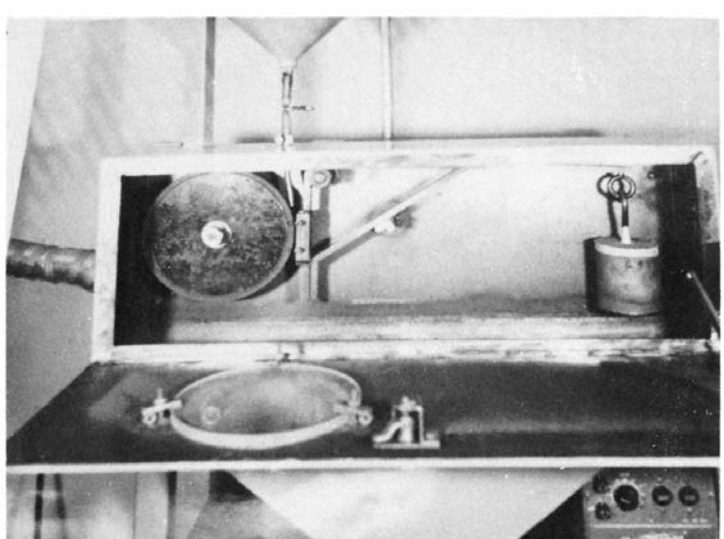

FIG. 3 Wheel and Lever Arm

from welding equipment suppliers are also suitable. Multiple use of the sand may affect test results and is not recommended. AFS 50/70 Test Sand is controlled to the following size range using U.S. sieves (Specification E11).

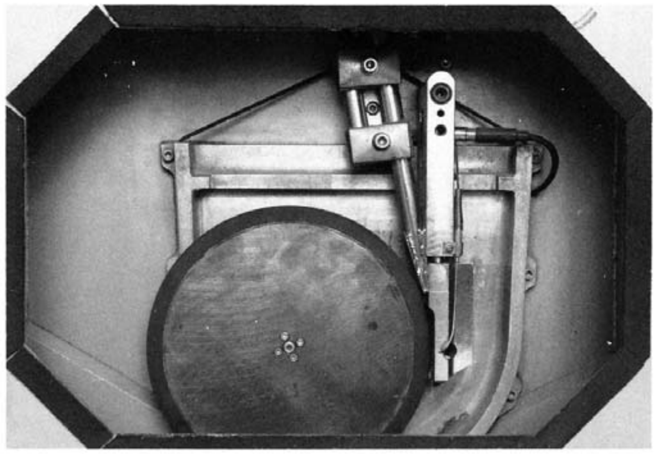

FIG. 4 Enclosure Frame

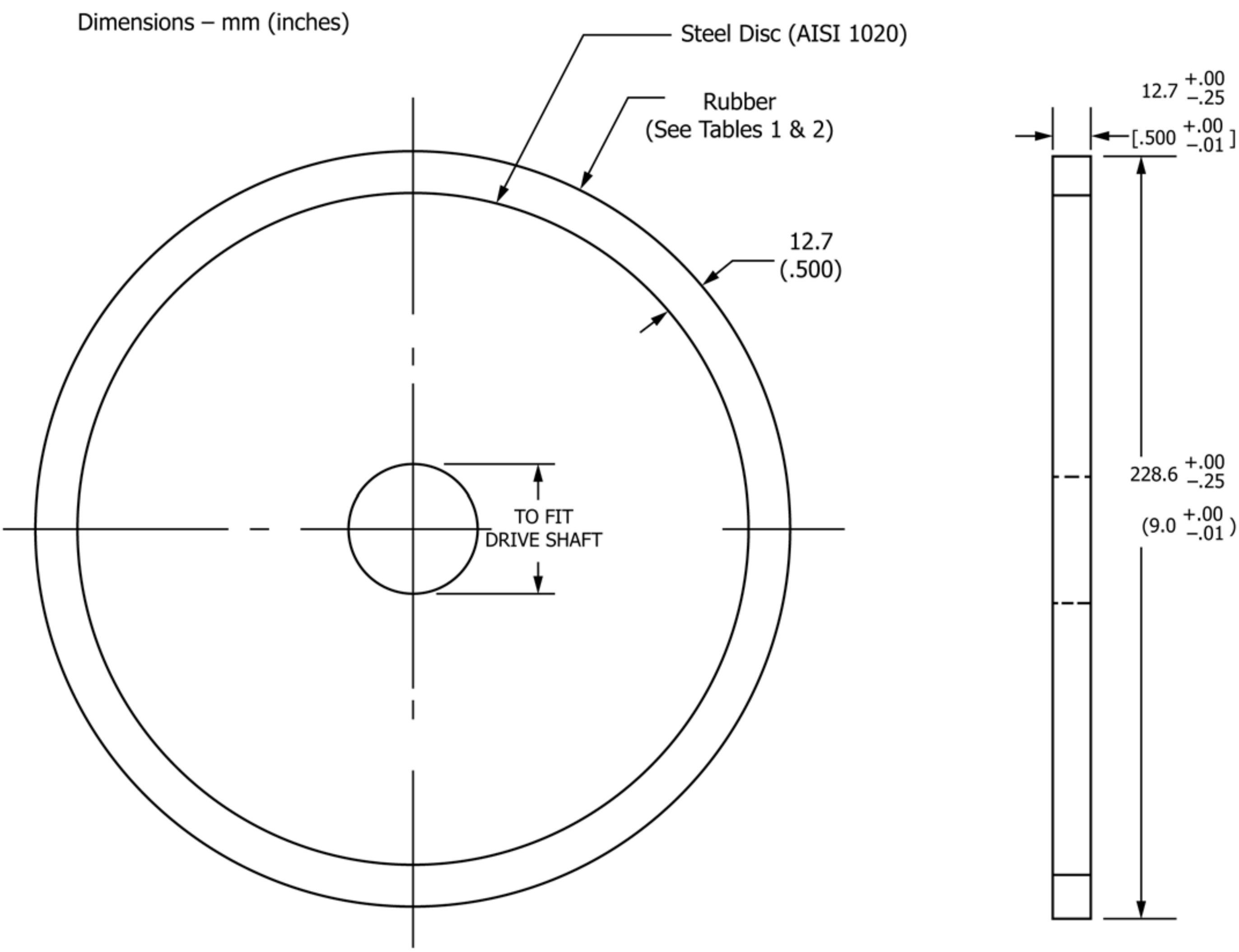

FIG. 5 Rubber Wheel

U.S. Sieve Size	Sieve Opening	% Retained on Sieve
40	425 µm (0.0165 in.)	none
50	300 µm (0.0117 in.)	5 max
70	212 µm (0.0083 in.)	95 min
100	150 µm (0.0059 in.)	none passing

6.4 *Sand Nozzle*—Fig. 7 shows the fabricated nozzle design which was developed to produce an accurate sand flow rate and proper shape of sand curtain for test procedures. The nozzle may be of any convenient length that will allow for connection

TABLE 1 A Formula for Chlorobutyl Rubber[A]

NOTE 1—Specific gravity of mix: 1.15. Pressure cure: 20 min at 160°C (320°F).

Materials	Proportions by Weight
Chlorobutyl No. HT 10-66 (Enjay Chemical)	100
Agerite Staylite-S	1
HAF black	60
Circolight oil	5
Stearic acid	1
Zinc oxide	5
Ledate	2

[A] The sole source of supply known to the committee at this time is Falex Corporation, 1020 Airpark Dr., Sugar Grove, IL 60554. 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, which you may attend.

TABLE 2 Formula for Neoprene Rubber[A]

NOTE 1—The rubber will conform to Classification D2000.

NOTE 2—The 60 Durometer wheel will be in accordance with 2BC615K11Z1Z2Z3Z4, where Z1–Elastomer–Neoprene GW, Z2–Type A Durometer hardness 60 ± 2, Z3–Not less than 50 % rubber hydrocarbon content, and Z4–Medium thermal black reinforcement.

NOTE 3—The wheels are molded under pressure. Cure tiems of 40 to 60 min at 153°C (307°F) are used to minimize "heat-to-heat" variations.

Materials	Proportions by Weight
Neoprene GW	100
Magnesia[B]	2
Zinc Oxide[C]	10
Octamine	2
Stearic Acid	0.5
SRF Carbon Black[D]	37
ASTM #3 Oil	10

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[B] Maglite D (Merck)
[C] Kadox 16 (Ner Jersey Zinc)
[D] ASTM Grade N762

to the sand hopper using plastic tubing. In new nozzles, the rate of sand flow is adjusted by grinding the orifice of the nozzle to increase the width of the opening to develop a sand flow rate of 300 to 400 g/min. During use, the nozzle opening must be positioned as close to the junction of the test specimen and the rubber wheel as the design will allow. (See Fig. 8.)

6.4.1 Any convenient material of construction that is available as welded or seamless pipe may be used for the construction of the fabricated nozzle. Stainless steel is preferred because of its corrosion resistance and ease of welding. Copper and steel are also used successfully.

6.4.2 *Formed Nozzle*—Nozzles formed from tubing may be used only when they duplicate the size and shape (rectangular orifice and taper), and the sand flow characteristics (flow rate and streamlined flow) of the fabricated nozzle. (See Fig. 7 and Fig. 9.)

6.4.3 *Sand Flow*—The nozzle must produce a sand flow rate of 300 to 400 g/min (0.66 to 0.88 lb/min).

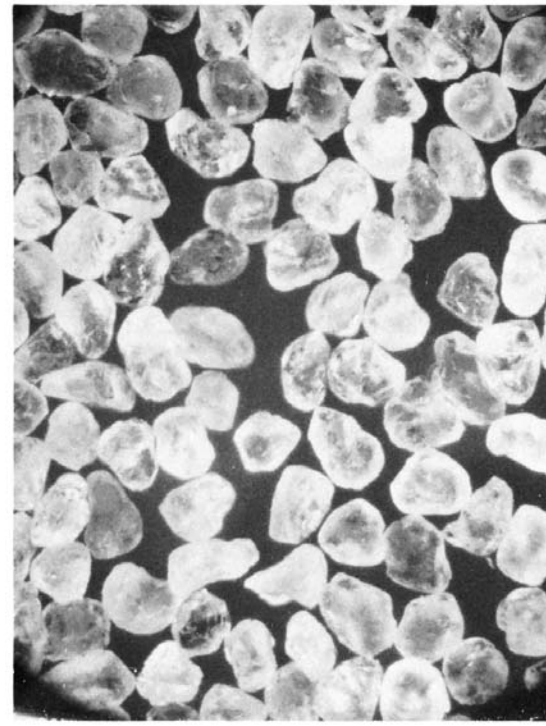

FIG. 6 25X Magnification AFS 50/70 Test Sand Ottawa Silica Co.

6.4.4 *Sand Curtain*—Fig. 9 shows the proper stream-lined flow and the narrow shape of the sand curtain as it exits from the sand nozzle. A turbulent sand flow as depicted in Fig. 10 will tend to produce low and inconsistent test results. It is intended that the sand flows in a streamlined manner and passes between the specimen and rubber wheel.

6.5 *Motor Drive*—The wheel is driven by a nominally 0.7-kW (1-hp) dc motor through a 10/1 gear box to ensure that full torque is delivered during the test. The rate of revolution (200 ± 10 rpm) must remain constant under load. Other drives producing 200 rpm under load are suitable.

6.6 *Wheel Revolution Counter*—The machine shall be equipped with a revolution counter that will monitor the number of wheel revolutions as specified in the procedure (Section 9). It is recommended that the incremental counter have the ability to shut off the machine after a preselected number of wheel revolutions or increments up to 12 000 revolutions is attained.

6.7 *Specimen Holder and Lever Arm*—The specimen holder is attached to the lever arm to which weights are added, so that a force is applied along the horizontal diametral line of the wheel. An appropriate number of weights must be available to apply the appropriate force (Table 3) between the test specimen and the wheel. The actual weight required should not be calculated, but rather should be determined by direct measurement by noting the load required to pull the specimen holder away from the wheel. A convenient weight system is a can filled with sand (see Fig. 2).

6.8 *Analytical Balance*—The balance used to measure the loss in mass of the test specimen shall have a sensitivity of 0.001 g. Procedure C requires a sensitivity of 0.0001 g.

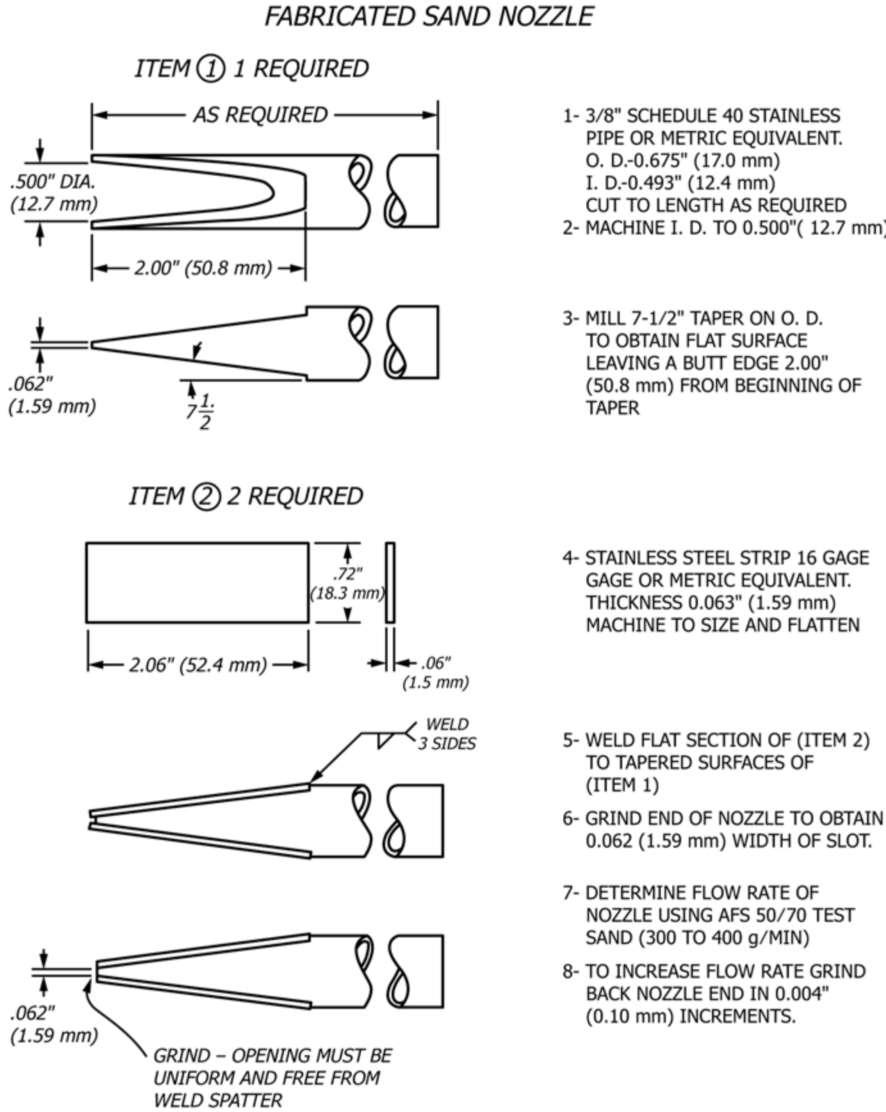

FIG. 7 Sand Nozzle

6.9 *Enclosure, Frame, and Abrasive Hopper*—Fig. 3 and Fig. 4 are photographs of a typical test apparatus. The size and shape of the support elements, enclosure, and hopper may be varied according to the user's needs.

7. Specimen Preparation and Sampling

7.1 *Materials*—It is the intent of this test method to allow for the abrasion testing of any material form, including wrought metals, castings, forgings, gas or electric weld overlays, plasma spray deposits, powder metals, metallizing, electroplates, cermets, ceramics and so forth. The type of material will, to some extent, determine the overall size of the test specimen.

7.2 *Typical Specimen,* a rectangular shape 25 by 76 mm (1.0 by 3.0 in.) and between 3.2 and 12.7 mm (0.12 and 0.50 in.) thick. The size may be varied according to the user's need with the restriction that the length and width be sufficient to show the full length of the wear scar as developed by the test. The test surface should be flat within 0.125 mm (0.005 in.) maximum.

7.3 *Wrought, Cast, and Forged Metal*—Specimens may be machined to size directly from the raw material.

7.4 *Electric or Gas Weld Deposits* are applied to one flat surface of the test piece. Double-weld passes are recommended to prevent weld dilution by the base metal. The heat of welding may distort the test specimen. When this occurs, the specimen may be mechanically straightened or ground, or both. In order to develop a suitable wear scar, the surface to be abraded must be ground flat to produce a smooth, level surface at least 63.4 mm (2.50 in.) long and 19.1 mm (0.75 in.) for the test. (See 7.5.) Note that the welder technique, heat input of welds, and the flame adjustment of gas welds will have an effect on the abrasion resistance of a weld deposit.

7.5 *Finish*—Test specimens should be smooth, flat, and free of scale. Surface defects such as porosity and roughness may bias the test results, and such specimens should be avoided unless the surface itself is under investigation. Typical suitable surfaces are mill-rolled surfaces such as are present on cold-rolled steel, electroplated and similar deposits, ground

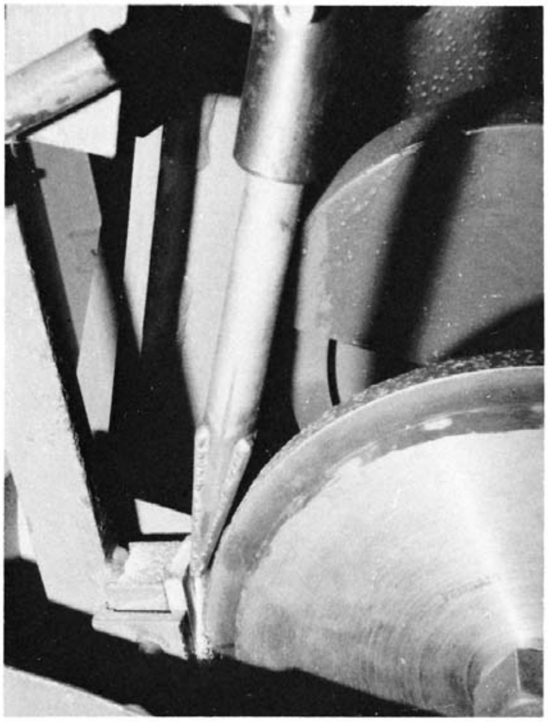

FIG. 8 Position of Sand Nozzle

surfaces, and finely machined or milled surfaces. A ground surface finish of approximately 0.8 µm (32 µin.) or less is acceptable. The type of surface or surface preparation shall be stated in the data sheet.

8. Test Parameters

8.1 Table 3 indicates the force applied against the test specimen and the number of wheel revolutions for test Procedures A through E.

8.2 *Sand Flow*—The rate of sand flow shall be 300 to 400 g/min (0.66 to 0.88 lb/min).

8.3 *Time*—The time of the test will be about 30 min for Procedures A and D, 10 min for Procedure B, 5 min for Procedure E, and 30 s for Procedure C, depending upon the actual wheel speed. In all cases the number of wheel revolutions and not the time shall be the controlling parameter.

8.4 *Lineal Abrasion*—Table 3 shows the lineal distance of scratching abrasion developed using a 228.6-mm (9-in.) diameter wheel rotating for the specified number of revolutions. As the rubber wheel reduces in diameter the number of wheel revolutions shall be adjusted to equal the sliding distance of a new wheel (Table 3) or the reduced abrasion rate shall be taken into account by adjusting the volume loss produced by the worn wheel to the normalized volume loss of a new wheel. (See 10.2.)

9. Procedure

9.1 *Cleaning*—Immediately prior to weighing, clean the specimen with a solvent or cleaner and dry. Take care to remove all dirt or foreign matter or both from the specimen. Dry materials with open grains (some powder metals or ceramics) to remove all traces of the cleaning solvent, which may have been entrapped in the material. Steel specimens having residual magnetism should be demagnetized or not used.

9.2 Weigh the specimen to the nearest 0.001 g (0.0001 g for Procedure C).

9.3 Seat the specimen securely in the holder and add the proper weights to the lever arm to develop the proper force pressing the specimen against the wheel. This may be measured accurately by means of a spring scale which is hooked around the specimen and pulled back to lift the specimen away from the wheel. A wedge should be placed under the lever arm so that the specimen is held away from the wheel prior to start of test. (See Fig. 2.)

9.4 Set the revolution counter to the prescribed number of wheel revolutions.

9.5 *Sand Flow and Sand Curtain*—The rate of sand flow through the nozzles shall be between 300 g (0.66 lb)/min and 400 g (0.88 lb)/min. Do not start the wheel rotation until the proper uniform curtain of sand has been established (see Fig. 9 and Note 3).

9.5.1 The dwell time between tests shall be the time required for the temperature of the rubber wheel to return to room temperature. For Procedure B the dwell time shall be at least 30 min.

9.6 Start the wheel rotation and immediately lower the lever arm carefully to allow the specimen to contact the wheel.

9.7 When the test has run the desired number of wheel revolutions, lift the specimen away from the wheel and stop the sand flow and wheel rotation. The sand flow rate should be measured before and after a test, unless a consistent flow rate has been established.

9.8 Remove the specimen and reweigh to the nearest 0.001 g (0.0001 g for Procedure C).

9.8.1 *Wear Scar*—Observe the wear scar and compare it to the photographs of uniform and nonuniform wear scars in Fig. 11. A nonuniform pattern indicates improper alignment of the rubber rim to the test specimen or an unevenly worn rubber wheel. This condition may reduce the accuracy of the test.

9.9 *Preparation and Care of Rubber Wheels*—Dress the periphery of all new rubber wheels and make concentric to the bore of the steel disk upon which the rubber is mounted. The concentricity of the rim shall be within 0.05 mm (0.002 in.) total indicator reading on the diameter. Follow the same dressing procedure on used wheels that develop grooves or that wear unevenly so as to develop trapezoidal or uneven wear scars on the test specimen (Fig. 11). The intent is to produce a uniform surface that will run tangent to the test specimen without causing vibration or hopping of the lever arm. The wear scars shall be rectangular in shape and of uniform depth at any section across the width. The rubber wheel may be used until the diameter wears to 215.9 mm (8.50 in.). New rubber rims may be mounted on steel disks by the qualified source (6.2).

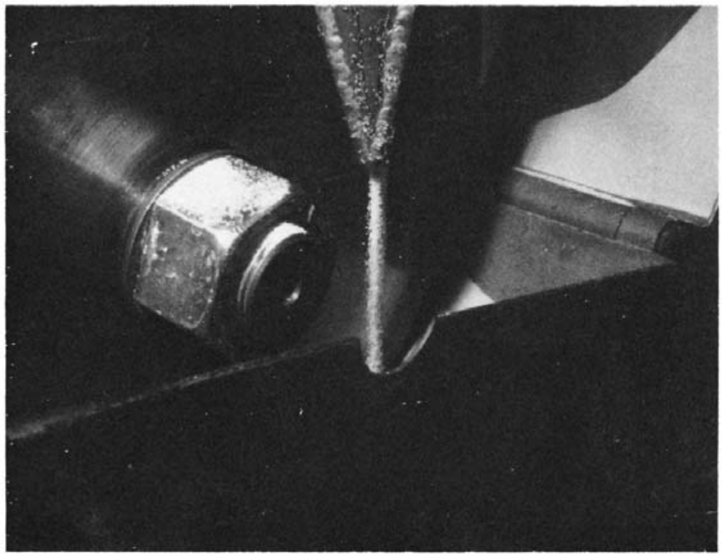

FIG. 9 Sand Flow—Streamlined

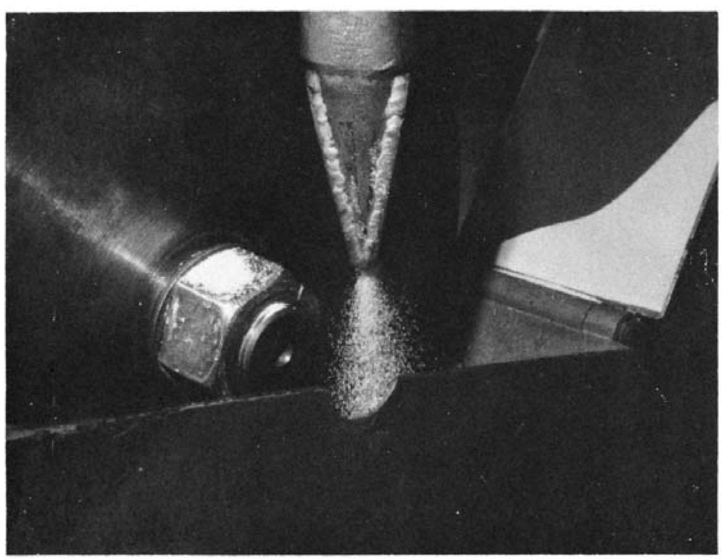

FIG. 10 Sand Flow—Turbulence

TABLE 3 Test Parameters

Specified Procedure	Force Against Specimen,[B] N (lb)	Wheel Revolutions	Lineal Abrasion[A] m	(ft)
A	130 (30)	6000	4309	(14 138)
B	130 (30)	2000	1436	(4 711)
C	130 (30)	100	71.8	(236)
D	45 (10.1)	6000	4309	(14 138)
E	130 (30)	1000	718	(2 360)

[A] See 8.4.
N = Newton (SI metric term for force)
1 lbf = 4.44822 N
1 Kgf = 9.806650 N
[B] Force tolerance is ±3 %.

9.10 *Wheel Dressing Procedure*—The preferred dressing procedure for the periphery of the rubber rim is to mount a diamond-cut file[8], stone or soft metal in place of the specimen in the holder and run the machine with load until the wheel is clean. Another dressing procedure for the periphery of the rubber rim is to mount the wheel on a lathe, and machine the surface with a tool bit especially ground for rubber applications. Grind a carbide or high-speed steel tool bit to very deep rake angles (Fig. 12). Feed the tool across the rubber surface in the opposite direction from that normally used for machining steel. This allows the angular surface of the tool bit to shear away thin layers of rubber without tearing or forming grooves

[8] The sole source of supply 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 Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

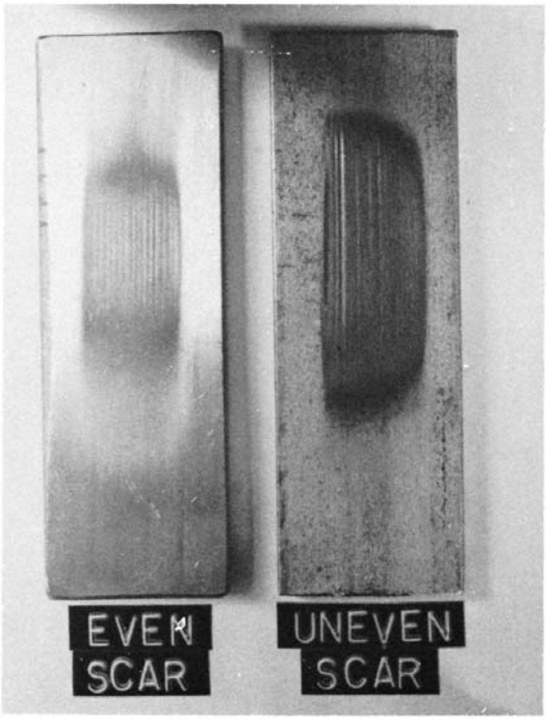

FIG. 11 Typical Wear Scars Uneven and Nonuniform Wear Scars Indicate Improper Alignment or Wear of Rubber Wheel

in the rubber as would occur when using the pointed edges of the tool. The recommended machining parameters are: *Feed*—25 mm/min (1.0 in./min); *Speed*—200 rpm; *Depth of Cut*—0.254 mm (0.010 in.) to 0.762 mm (0.030 in.). The dressed wheel should be first used on a soft carbon steel test specimen (AISI 1020 or equivalent) using Procedure A. This results in a smooth, uniform, non-sticky surface. An alternative dressing method involves the use of a high-speed grinder on the tool post of a lathe. Take great care since grinding often tends to overheat and smear the chlorobutyl rubber, leaving a sticky surface. Such a surface will pick up and hold sand particles during testing. If the grinding method is used, not more than 0.05 mm (0.002 in.) may be ground from the surface at one time so as to prevent overheating on the chlorobutyl rubber wheel.

10. Calculating and Reporting Results

10.1 The abrasion test results should be reported as volume loss in cubic millimetres in accordance with the specified procedure used in the test. For example, ___mm^3 per ASTM__ Procedure ___. While mass loss results may be used internally in test laboratories to compare materials of equivalent densities, it is essential that all users of this test procedure report their results uniformly as volume loss in publications or reports so that there is no confusion caused by variations in density. Convert mass loss to volume loss as follows:

$$\text{Volume loss, mm}^3 = \frac{\text{mass loss (g)}}{\text{density (g/cm}^3\text{)}} \times 1000 \quad (1)$$

10.2 *Adjusting the Volume Loss*—As the rubber wheel decreases in diameter the amount of scratching abrasion developed in a given practice will be reduced accordingly. The actual volume loss produced by these slightly smaller wheels will, therefore, be inaccurate. The "adjusted volume loss" value takes this into account and indicates the actual abrasion rate that would be produced by a 228.6-mm (9.00-in.) diameter wheel. Calculate the adjusted volume loss (AVL) as follows:

$$\text{AVL} = \text{measured volume loss} \times \frac{228.6 \text{ mm (9.00 in.)}}{\text{wheel diameter after use}} \quad (2)$$

10.3 *Reporting Test Results*—All significant test parameters and test data as noted in Tables 3 and 4 shall be reported, including wheel rubber type. Any variation from the recommended procedure must be noted in the comments. The report shall include a statement of the current precision and accuracy of the test apparatus as qualified by the testing of Reference Materials. The volume loss data developed by the initial qualification tests or the volume loss data developed by the periodic re-qualification tests should be listed on the data sheet (Table 4).

11. Precision and Bias[9]

11.1 The precision of this test method is based on an interlaboratory study of ASTM G65, Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus, as conducted in 2013. Six laboratories participated in this study, each testing three different materials. Every "test result" represents an individual determination. The laboratories were asked to report replicate test results for each material. Practice E691 was followed for the basic design and analysis of the data; the details are given in ASTM Research Report No. RR:G02-1016.

11.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

11.1.1.1 Repeatability limits are listed in Tables 5 and 6 below.

11.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

11.1.2.1 Reproducibility limits are listed in Tables 5 and 6 below.

11.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

11.1.4 Any judgment in accordance with 11.1.1 would normally have an approximate 95 % probability of being correct; however, the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number

[9] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:G02-1016. Contact ASTM Customer Service at service@astm.org.

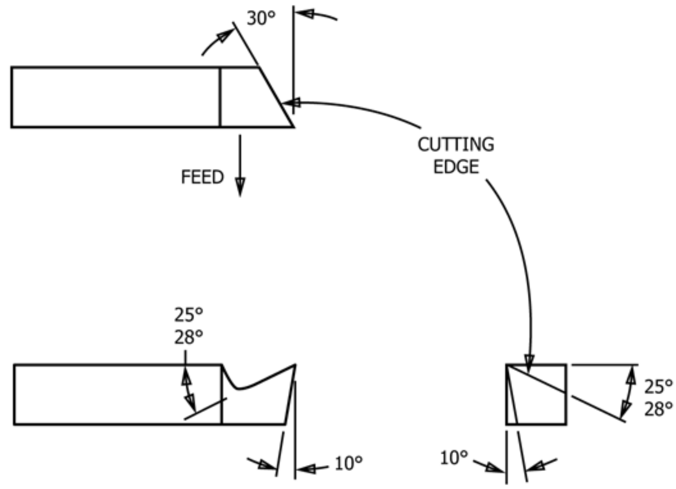

FIG. 12 Typical Wheel Dressing Tool

TABLE 4 Data Sheet

Dry Sand/Rubber Wheel Test
ASTM G-65 Procedure ____

Qualification of Apparatus (11.4): Date ____
Reference Materials ____ Quantity ____
Adjusted Volume Loss (avg) ____ mm³ Coefficient of Variation ____ %

Test Data

Material Description: ____ Wheel diameter: ____
Heat Treatment: ____ Wheel width: ____
Hardness: ____ Wheel hardness: ____
Surface Preparation ____

Test No.						
Rubber Type						
Test load						
Wheel revolutions						
Sand flow, g/min						
Initial mass, g						
Final mass, g						
Mass loss, g						
Density, g/cm³ᴬ						
Volume loss, mm³ (mass loss/density) x 1000						
Adjusted volume loss, mm³						

Comments: ____

Company Name ____ Tested by ____ Date ____

ᴬ Density of materials may be obtained from *ASM Metals Handbook*, Vol 1, 8th ed. or suppliers of materials.

TABLE 5 Procedure A (Volume Loss mm³)

Material	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
D2	42.70	1.10	2.61	3.09	7.31
Carbide	9.28	0.86	1.04	2.40	2.92

of laboratories reporting usable results for Procedure A indicates that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95 % probability limit would imply. Consider the precision limits listed for those abrasives with fewer than six reporting laboratories as a

TABLE 6 Procedure B (Volume Loss mm³)

Material	Average $\bar{x}$	Repeatability Standard Deivation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
H13	54.16	3.66	6.80	10.26	19.04

general guide, and the associated probability of 95 % as only an indicator of what can be expected.

11.2 The precision statement was determined through statistical examination of 30 test results, from a total of six laboratories, on three different materials labeled as:

D2:	High carbon-chromium tool steel
Carbide:	Nickel matrix hardfacing containing spherical carbide with a 60/40 carbide/matrix density percentage
H13:	Low carbon medium chromium tool steel

It is recommended to choose the listed material closest in characteristics to your test material when considering precision.

APPENDIX

(Nonmandatory Information)

X1. SOME STATISTICAL CONSIDERATIONS IN ABRASION TESTING

X1.1 Background

X1.1.1 The Dry Sand/Rubber and Wheel Abrasion Test as developed and described by Haworth, Avery, and others (**1-7**) has been in various stages of evolution and use since 1960. A number of variations of this test procedure have been used by several research and industrial laboratories in the United States who were faced with the problem of evaluating hard surfacing alloys, castings, and wrought products for their resistance to abrasive wear. Individual laboratories set their own test parameters with the goal being the generation of reproducible test data within the laboratory. As the need for standardization became apparent, Subcommittee G02.30 formed a task group to study the effect of each test parameter on the overall results within individual laboratories and among all laboratories as a group. While standardization of test parameters was attained, it became evident that the variability or experimental error inherent in each laboratory was a factor that must be considered. Not only must the test method, apparatus, and individual operator generate repeatable results, but the test results must be consistently reproducible within an acceptable range. Another important consideration in establishing repeatable and reproducible test results was the selection of an adequate sample size. More specifically this was the need for laboratories to agree on the number of times a test should be repeated on a given homogeneous material in order to obtain a meaningful average result. While single test results and simple arithmetic averaging may in some few cases be useful in individual laboratories, it is essential that statistical techniques and multiple testing of specimens be utilized for the qualification of each test apparatus, and for the comparison of materials. Further information on statistical methods may be found in Practice E122, MNL 7, and in the references.

X1.2 Statistical Equations

X1.2.1 Several equations for the calculation of standard deviation and coefficient of variation are used in the statistical analysis of data shown in Table X1.1. To ensure uniformity among laboratories using the dry sand/rubber wheel test, the standard deviation and coefficient of variation of results produced from a series of tests should be calculated by the following equations:

$$S_r = \sqrt{\frac{1}{p}\left(\sum S_j^{\,2}\right)} \quad \text{(X1.1)}$$

TABLE X1.1 Statistical Analyses of Interlaboratory Test Results

Round-Robin Test Conditions	Specified Procedure	Number of Samples	Average, mm³	Standard Deviation Within, mm³	Standard Deviation Between, mm³	Coefficient of Variation Within, %	Coefficient of Variation Between, %	Coefficient of Variation Total,%	Standard Deviation Total, mm³
RR No. 15 4340 steel	E	3	51.63	1.67	0.75	3.2	1.5	3.5	1.83
RR No. 14A and 14B 4340 steel	E	3	47.74	1.84	2.46	3.9	5.2	6.04	3.07
RR No. 14A and 14B 4340 steel	B	3	91.08	2.18	4.98	2.4	3.5	6	5.44
RR No. 12 WC-14 weight % CO 0.010 in. thick	A	4	2.18	0.14	0.42	6.4	19.3	20.4	0.44
RR No. 14 hard-chrome plating 0.010 in. thick	C	3	1.33	0.1	0.25	7.4	19.1	20.5	0.27

d	=	deviations from average, $(\bar{x}_j - \bar{x})$
$S_{\bar{x}}$	=	$\sqrt{\sum(d^2)/p-1}$
S_L	=	$\sqrt{(S_{\bar{x}}^2)-(S_r^2)}$
S_L	=	0 if the quantity under the root sign is negative.
S_R	=	$\sqrt{(S_r^2)+(S_L^2)}$ is the reproducibility standard deviation of the test method for the parameter measured.
$V_r(\%)$	=	$100(S_r)/(\bar{x})$, the estimated relative standard deviation or coefficient of variation within a laboratory for the parameter measured (repeatability).
$V_L(\%)$	=	$100(S_L)/(\bar{x})$, the estimated relative standard deviation or coefficient of variation between laboratories for the parameter measured (reproducibility).

where:

p	=	number of laboratories,
n	=	number of replicate tests,
$\bar{x}_j$	=	average of n number of replicate tests of each, laboratory of parameter j,
S_j	=	standard deviation,
$\bar{x}$	=	average of $\bar{x}_j$'s for all laboratories of each parameter,
S_r	=	estimated repeatability standard deviation within, and a laboratory for each parameter measured.

X1.3 Typical Volume Loss Values

X1.3.1 Procedure A of the Dry Sand/Rubber Wheel Test will produce volume losses in metallic materials ranging from 0.25 to 250 mm^3. The more abrasion-resistant materials will develop the least volume loss. Table X1.2 shows typical volume loss ranges that may be expected in the metals listed. They are offered as guidelines only and not as purchasing specifications or as standard reference specimens. Any material specifications involving this test method must be by agreement between the seller and the purchaser. When volume losses exceed 100 mm^3, greater accuracy in material ranking is obtained by using Procedure D (see Table 3). Procedure A should be used for the more abrasion-resistant materials. Procedure E or B can be used for materials with volume losses in the range from 50 to 100 mm.

X1.4 ILS for Alternate Rubber Wheel

X1.4.1 Due to supply issues of the original chlorobutyl rubber wheel formulation, an alternate rubber was selected that is both previously accepted (G105) for tribological abrasion testing and readily available. G105 neoprene rubber, formulation for 60 durometer hardness was selected for prototype and Inter-Laboratory Study. The results show consistency of the neoprene rubber between laboratories (Table X1.3).

TABLE X1.2 Volume Loss Range

	Practice A, mm³	Practice B, mm³	Practice C, mm³	Practice D, mm³	Practice E, mm³
	Standard Values (Mean ± Standard Deviation)[A]				
AISI Tool Steel D-2 Reference Material No. 1[B]	35.6 ± 5.2	...	...	...	...
AISI Tool Steel H-13 Reference Material No. 2[B]	...	55.6 ± 4.2	...	...	...
AISI 4340 Steel Reference Material No. 3[B]	...	...	...	91.1 ± 5.4	49.2 ± 2.9
	Nonstandard Values				
316 stainless bar annealed RB-80	260 ± 20	...	...	58.5 ± 26.6	...
AISI 1090 plate-normalized 900°C (1600°F) air-cooled 24-26 HRc	80.7 ± 8.0	...	...	33.0 ± 6.0	...
17-4PH stainless-aged 500°C (925°F)-4 h at temperature, air-cooled-43 HRc	220 ± 20	122.1 ± 15.3	...	70.9 ± 6.1	...
Stellite 1016 hard surfacing overlay 57-58 HRc applied by oxyacetylene welding process (35 flame)	17 ± 4	...	...	...	...
Sintered tungsten carbide (Kennametal K-714, Valenite 2889)	1.9 ± 0.3	...	...	....	...
WC-Co flame spray coatings	2.2 ± 0.4	...	...	...	...
Hard-chrome plating	...	...	1.3 ± 0.3		

[A]The mean values and standard deviation for volume loss reported were calculated from the values in Research Report RR: RR:G02-1006.
[B]See 11.6.2 for heat treat.

TABLE X1.3 ILS Round Robin Data—Neoprene Rubber Wheel on D2, H13, and Composite Carbide Coupons

D2

Test Lab	A	A	B	B	C	C	D	D	E	E
Mass Loss (g)	0.3220	0.3369	0.3207	0.3207	0.3154	0.3338	0.3070	0.3060	0.3644	0.3519
Volume Loss (mm³)	41.82	43.75	41.65	41.65	40.96	43.35	39.87	39.74	47.32	45.70
D2 Avg Mass Loss	0.4187				Variance	0.000359				
D2 Std Dev	0.01896				Variance Population	0.000324				

H13

Test Lab	A	A	B	B	C	C	D	D	E	E
Mass Loss (g)	0.4271	0.4375	0.3385	0.3385	0.4958	0.4362	0.4273	0.3524	0.4772	0.4568
Volume Loss (mm³)	55.04	56.38	43.62	43.62	63.89	56.21	55.06	45.41	61.49	58.87
H13 Avg Mass Loss	0.4187				Variance	0.003209				
H13 Std Dev	0.056649				Variance Population	0.002888				

Carbide

Test Lab	A	A	B	B	C	C	D	D	E	E
Mass Loss (g)	0.1140	0.1032	0.1265	0.1090	0.1028	0.1065	0.0838	0.1071	0.1209	0.1226
Volume Loss (mm³)	9.60	8.69	10.65	9.18	8.65	8.96	7.05	9.02	10.18	10.32
Carbide Avg Mass Loss	0.1096				Variance	0.000152				
Carbide Std Dev	0.012341				Variance Population	0.000137				

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