Designation: G137 – 97 (Reapproved 2009)

Standard Test Method for Ranking Resistance of Plastic Materials to Sliding Wear Using a Block-On-Ring Configuration[1]

This standard is issued under the fixed designation G137; 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 to measure the resistance of plastic materials under dry sliding conditions. The test utilizes a block-on-ring geometry to rank materials according to their sliding wear characteristics under various conditions.

1.2 The test specimens are small so that they can be molded or cut from fabricated plastic parts. The test may be run at the load, velocity, and temperature which simulate the service condition.

1.3 Wear test results are reported as specific wear rates calculated from volume loss, sliding distance, and load. Materials with superior wear resistance have lower specific wear rates.

1.4 This test method allows the use of both single- and multi-station apparatus to determine the specific wear rates.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *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]

D618 Practice for Conditioning Plastics for Testing

D3702 Test Method for Wear Rate and Coefficient of Friction of Materials in Self-Lubricated Rubbing Contact Using a Thrust Washer Testing Machine

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

G40 Terminology Relating to Wear and Erosion

G77 Test Method for Ranking Resistance of Materials to Sliding Wear Using Block-on-Ring Wear Test

G117 Guide for Calculating and Reporting Measures of Precision Using Data from Interlaboratory Wear or Erosion Tests

3. Terminology

3.1 *Definitions:*

3.1.1 *wear*—damage to a solid surface, generally involving progressive loss of material, due to relative motion between that surface and a contacting substance or substances.

3.1.2 Additional definitions relating to wear are found in Terminology G40.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *specific wear rate*—the volume loss per unit sliding distance, divided by the load. It can be calculated as the volume loss per unit time, divided by the load and the sliding velocity.

3.2.2 *steady state specific wear rate*—the specific wear rate that is established during that part of the test when the specific wear rate remains substantially constant (the specific wear rate versus sliding distance curve flattens out considerably with less than 30 % difference between the specific wear rates) during a minimum of three time intervals spanning a total time duration of at least 18 h, with ideally no single interval exceeding 8 h. However, one time interval during the steady state can be as long as 16 h.

4. Summary of Test Method

4.1 A plastic block of known dimensions is brought into contact with a counterface ring (usually metal) under controlled conditions of contact pressure and relative velocity. This is achieved using a block-on-ring configuration as illustrated in Fig. 1. Periodic weighing of the polymer block results in a number of mass-time data points where the time relates to the time of sliding. The test is continued until the steady state wear rate is established. Mass loss measurements made after the steady state is established are used to determine the steady state specific wear rate, which is the volume loss per unit sliding

[1] This test method is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.40 on Non-Abrasive Wear.

Current edition approved May 1, 2009. Published May 2009. Originally approved in 1995. Last previous edition appeared in 2003 as G137–97(2003). DOI: 10.1520/G0137-97R09.

[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.

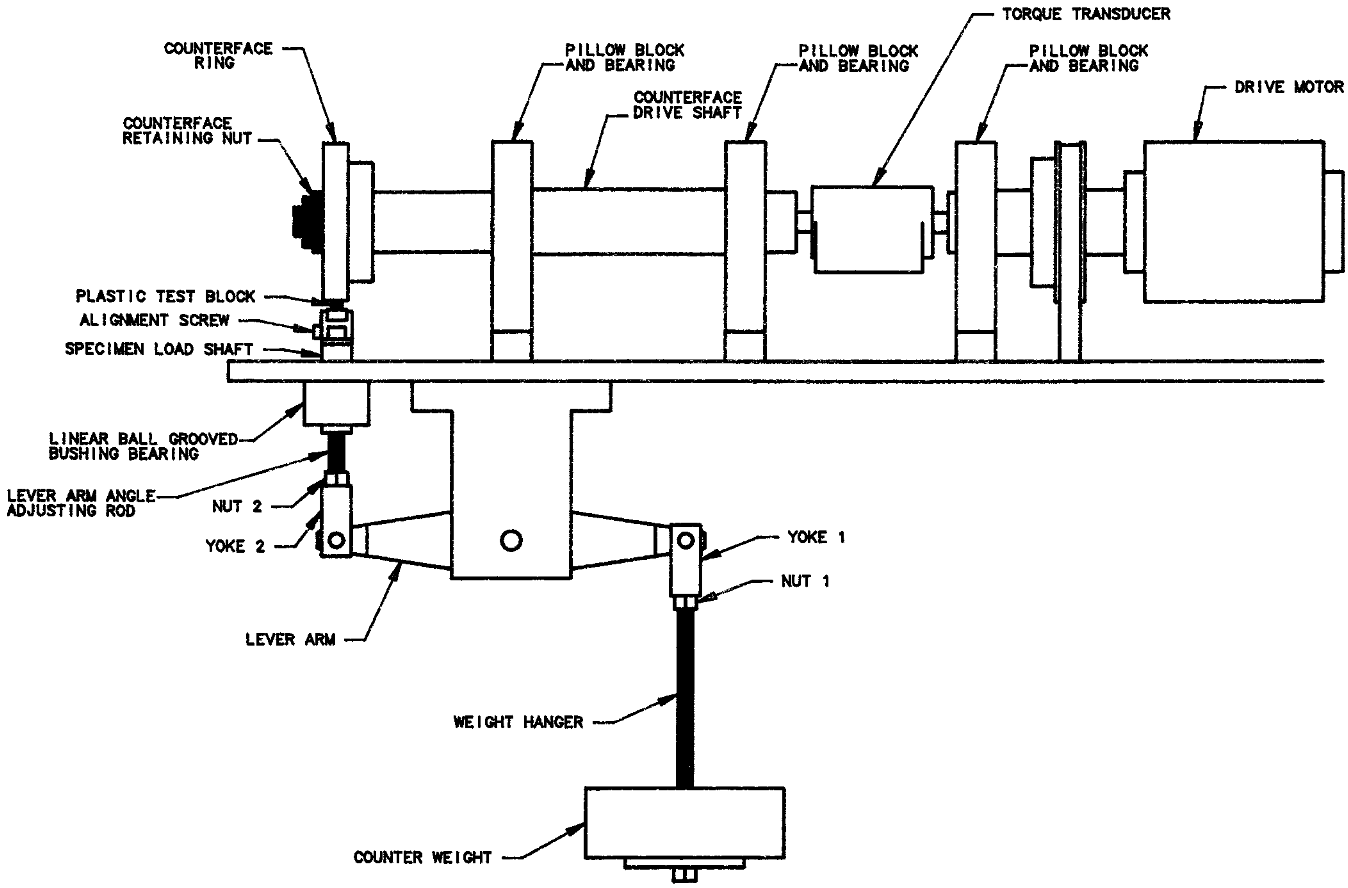


FIG. 1 Single Station Block-on-Ring Arrangement

distance per unit load. The frictional torque may also be measured during the steady state using a load cell. These data can be used to evaluate the coefficiency of friction for the test combination.

NOTE 1—Another test method that utilizes a block-on-ring test configuration for the evaluation of plastics is Test Method G77.

5. Significance and Use

5.1 The specific wear rates determined by this test method can be used as a guide in ranking the wear resistance of plastic materials. The specific wear rate is not a material property and will therefore differ with test conditions and test geometries. The significance of this test will depend on the relative similarity to the actual service conditions.

5.2 This test method seeks only to describe the general test procedure and the procedure for calculating and reporting data.

NOTE 2—This test configuration allows steady state specific wear rates to be achieved very quickly through the use of high loads and speeds. The thrust washer configuration described in Test Method D3702 does not allow for the use of such high speeds and loads because of possible overheating (which may cause degradation or melting, or both) of the specimen. Despite the differences in testing configurations, a good correlation in the ranking of wear resistance is achieved between the two tests (Table X2.1).

6. Apparatus and Materials

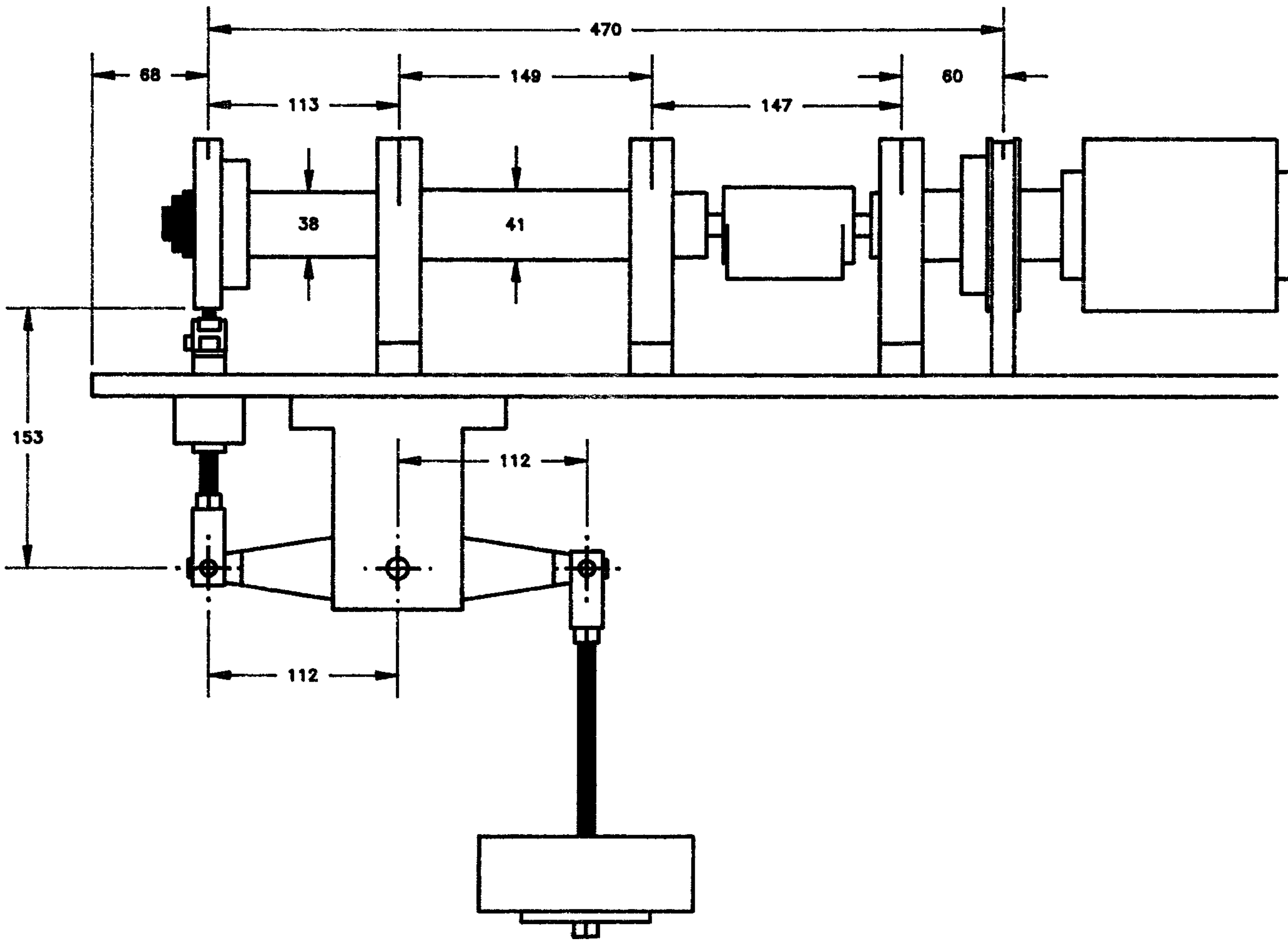
6.1 *Test Setup*—An example of the basic test configuration and part names are shown in Fig. 1. The recommended dimensions of the test apparatus are shown in Fig. 2. The figures shown in this test method represent one example of a block-on-ring test apparatus. The mandatory elements are: the capability to change load and sliding speed, the ability to reposition the specimen after weighing as before, and a counterface ring with acceptable eccentricity. All other design elements can be varied according to the user preference.

6.1.1 Bearings recommended for counterface drive shafts are industrial-grade tapered roller bearings.

6.1.2 Required centerline alignment limits of the counterface drive shafts are ±0.41 mm (±0.016 in.) from the center of a counterface ring. Allowable eccentricity of the counterface ring is no greater than ±0.06 mm (±0.002 in.).

6.1.3 Bearings recommended for the linear ball grooved bushing bearing are industrial-grade linear bearings.

6.2 *Counterface Ring*—The recommended dimensions for the counterface ring are 100 + 0.05, − 0.00-mm diameter and 15.88 + 0.30, − 0.13-mm width. Often a hardened tool steel ring with a hardness of 50 to 60 HRC and a surface roughness of 0.102 to 0.203 µm (4 to 8 µin.) R_a in the direction of sliding is used for the general evaluation of plastics. The requirement for the ring material is that it should not wear appreciably or change dimensions during the course of the test. Therefore, other materials and surface conditions may also be used. It should be noted that test results will be influenced by the choice of ring material and surface roughness.



NOTE 1—All dimensions are given in millimetres.

FIG. 2 Recommended Dimensions of Block-on-Ring Apparatus

6.3 *Test Block*—The recommended dimensions of the test block are 6.35 + 0.00, − 0.03-mm (0.250 + 0.000, − 0.001-in.) width, 6.00 + 0.00, − 0.03-mm (0.236 + 0.000, − 0.001-in.) depth, and 12.70 ± 0.2-mm height. For materials where surface condition is not a parameter under study, a ground surface with the grinding marks running parallel to the depth direction of the block and a roughness of 0.102 to 0.203 µm (4 to 8 µin.) R_a in the direction of motion is recommended. However, other surface conditions may be evaluated as desired.

6.4 *Test Parameters:*

6.4.1 The recommended range for the normal load is from 20 to 40 N.

6.4.2 The recommended range for the velocity is from 0.5 to 1 m/s.

6.5 *Apparatus:*

6.5.1 *Analytical Balance,* capable of measuring to the nearest 0.01 mg.

7. Reagents

7.1 Suitable cleaning procedures should be used to clean counterface ring and test block. Reagents proven suitable for some materials are:

7.1.1 *Acetone,* for steel rings, and

7.1.2 *Methanol,* for test block surface and specimen holder.

7.2 Both solvents are flammable and toxic. Refer to the relevant Material Safety Data Sheet (MSDS) before using the solvents.

8. Preparation and Calibration of Apparatus

8.1 Perform calibration of torque transducers[3] by applying NIST traceable dead weight standards and using a reference load cell.

8.2 Perform calibration of tachometer by comparison to a handheld tachometer which has been calibrated with NIST traceable standards.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 40 h prior to testing in accordance with Procedure A of Practice D618 for those samples where conditioning is required.

[3] The interlaboratory tests were conducted using the torque transducers manufactured by Key Transducers, Inc., Sterling Heights, MI.

9.2 *Test Conditions*—The recommended conditions are the standard laboratory atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity.

10. Procedure

10.1 Clean the counterface ring using mild soap and water so as to remove bulk dirt and corrosion-inhibiting oil. Afterwards, clean the counterface ring in an ultrasonic acetone bath for 2 h (43 kHz 95 W) to remove the remaining contaminants. Allow the ring to dry completely. Handle the ring from this point on with lint-free cotton gloves.

10.2 Mount the counterface ring on the drive shaft and secure with a counterface retaining nut (Fig. 1).

10.3 Clean the test block and specimen holder with methanol. Handle the test block and the specimen holder with lint-free cotton gloves from this point.

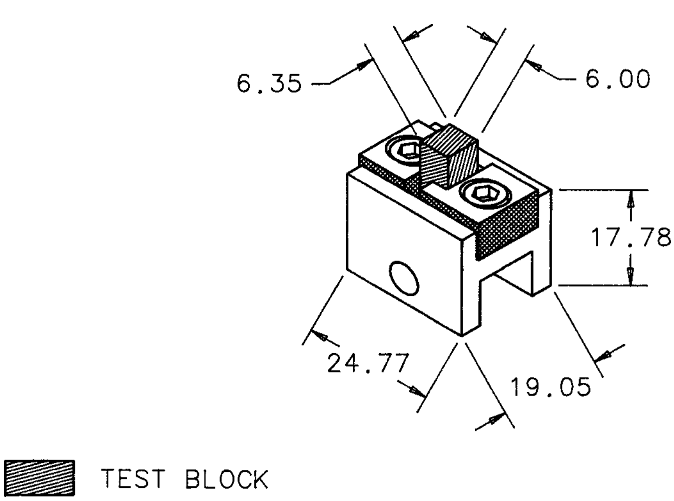
10.4 Measure the width and the depth of the test block to ensure that the surface dimensions fall within the specifications.

10.5 Mount the test block into the specimen holder and tighten so that the test block does not move within the specimen holder (Fig. 3).

10.6 Weigh the test block and specimen holder to the nearest 0.01 mg.

10.7 Position the specimen holder with the test block under the counterface ring. Repositioning is possible with the use of a guide that the specimen load shaft slides on and an alignment screw which secures the specimen holder to the specimen load shaft. The linear ball grooved bushing bearing prevents the specimen load shaft from rotating.

10.8 Apply the required load. Yokes 1 and 2, and Nuts 1 and 2 in Fig. 1 are of equal weight and will not figure into calculations. The weight of the weight hanger will be included in the total weight needed. The weight of specimen, specimen holder, specimen load shaft, and lever arm angle adjusting rod will have to be countered to equal the desired force. To ensure that the proper load has been applied, a small load cell can be mounted between the specimen and the counterface ring with the load being applied. The lever arm should be maintained horizontally by adjusting the height of the lever arm angle adjusting rod. The required load can be applied by other mechanisms.



NOTE 1—All dimensions are given in millimetres.

FIG. 3 Specimen Holder With a Test Block

10.9 Frictional torque values produced by the machine itself (should not be more than ±0.05 Nm) should be zeroed as follows:

10.9.1 The block-on-ring tester is turned on without any load being applied to the specimen. This gives a stable torque reading which should be zeroed. After zero marker is obtained, load may be applied to run the test.

10.10 Bring the lever arm angle adjusting rod gently into contact with the specimen load shaft to apply the load.

10.11 Start the motor and adjust to a desired speed. The speed should preferably not exceed 1 m/s.

10.11.1 Frictional torque values may be recorded so that an average value for the test period may be obtained. Values for the frictional force can be obtained from these measurements by dividing the frictional torque by an appropriate moment arm.

10.12 The test should be interrupted a minimum of six times to determine mass loss as a function of time, though more may be required to ensure that steady state is established. The intervals need not be uniform. Shorter intervals should be used during the initial portion of the test and longer intervals during the latter portion of the test. The test should be continued until three or more of the intervals occur in the steady state range.

10.12.1 Halt the speed controlling motor for weight measurements.

10.12.2 Remove the load from the test block by removing the lever arm angle adjusting rod from the specimen load shaft.

10.12.3 Remove the specimen holder with the test block from the specimen load shaft.

10.12.4 Use compressed air to blow off the worn particles from the test block and from within the specimen holder.

10.12.5 Weigh the specimen holder with the test block on a balance to the nearest 0.01 mg.

10.12.6 Reload the specimen holder with the test block following the procedure in 10.7 – 10.11.

11. Calculation

11.1 *Calculation of Specific Wear Rate:*

11.1.1 Periodic weighing of the specimen holder and the test block results in a number of mass-time data points where the time relates to the time of sliding.

11.1.2 The specific wear rate for each interval can be calculated from (Eq 1):

$$W_s = \frac{1}{F_N v \rho} \cdot \frac{\Delta m}{\Delta t} \quad (1)$$

where:

W_s = specific wear rate, $mm^3/N \cdot m$, dimensions, (L^2/F),
F_N = applied normal force, N,
v = velocity, m/s,
ρ = density, kg/mm^3,
Δm = mass loss, kg, and

Δt = time interval, s.

11.1.3 The specific wear rate reported is the average value within the steady state region.

11.2 *Calculation of Coefficient of Friction:*

11.2.1 The dynamic coefficient of friction is calculated as follows:

$$\mu = F_f / F_N \quad (2)$$

where:

μ = coefficient of friction,
F_f = frictional force calculated from measured frictional torque, and
F_N = applied normal force.

11.2.2 The dynamic coefficient of friction which may be reported is the average value in the steady state region.

12. Report

12.1 Report the following test parameters:

12.1.1 Counterface ring material, hardness, and roughness,
12.1.2 Test block material,
12.1.3 Counterface ring RPM and surface speed, m/s,
12.1.4 Applied normal force, N, and
12.1.5 Temperature and humidity.

12.2 Report the following results:

12.2.1 A table of sliding times and the corresponding mass losses,

12.2.2 A table of sliding times and the corresponding specific wear rates, $mm^3/N{\cdot}m$,

12.2.3 The number of replicates (a minimum of three replicates is recommended), and

12.2.4 The steady state specific wear rate and the standard deviation.

13. Precision and Bias

13.1 The precision of the measurements obtained with this test procedure will depend upon the strict adherence to the stated test procedure.

13.2 The consistency of agreement in repeated tests on the same material will depend upon material homogeneity, test apparatus and material interaction, and close observation of the test by a competent operator.

13.3 Tables X1.1 and X1.2 show representative data and coefficients of variation which were obtained from interlaboratory tests following Guide G117.

13.4 In order to achieve a high confidence level in evaluating test results, it is desirable to run a large number of replicate tests. However, this can be quite expensive and time-consuming. One must, therefore, determine an acceptable sample size, balancing cost and time against allowable sampling error and taking into account the coefficient of variation of the test procedure. Because the coefficients of variation run rather high in this test method, a minimum of three duplicate tests is required for meaningful test results. Sampling error may be reduced by increasing sample size. The relationship in Practice E122 between sample size (n), sampling error (e), and test coefficient of variation (V) is expressed by the following formula:

$$n = (1.96\, V/e)^2 \quad (3)$$

13.5 The 95 % confidence levels for repeatability (within a laboratory) and reproducibility (between laboratories) can vary with the material being evaluated. Based on the results of interlaboratory testing, the nominal 95 % confidence level for repeatability (within a laboratory) is 80 % (coefficient of variation), ranging from 45 to 106 %, and for reproducibility (between laboratories) is 95 %, ranging from 84 to 106 %.

13.6 This test method has no bias since the values determined are specific to this test.

14. Keywords

14.1 block-on-ring; friction; plastics; wear

APPENDIXES

(Nonmandatory Information)

X1. INTERLABORATORY TEST RESULTS AND STATISTICAL RELATIONSHIPS

X1.1 An interlaboratory test was conducted involving two laboratories and three materials, with each laboratory performing four replicate tests for each material. A set of replicate test results for a particular parameter or variable, as measured in a single laboratory for a single material is defined as a cell. All tests were conducted under the identical testing conditions of: 30-N load, 1-m/s speed, using an A2-type tool steel counterface ring with R_c 58 to 60 hardness and 0.102 to 0.203-µm (R_a) initial surface roughness. Mass measurements were taken after 30, 60, 120, 240, 480, 1440, 1680, 1920, and 2880 min. Results are presented in Tables X1.1 and X1.2.

X1.2 *Statistical Symbols:*

p number of laboratories
n number of replicate
x_j an individual test result
$\bar{x}_j$ average of a cell
$\bar{\bar{x}}$ the average of cell averages for a material
d deviation of a cell = $\bar{x}_j - \bar{\bar{x}}$
S_j standard deviation of a cell,
$S_{\bar{x}}$ standard deviation of cell averages
S_r repeatability standard deviation
S_R reproducibility standard deviation
V_r estimated relative standard deviation or coefficient of variation within a laboratory for the parameter measured (repeatability) = $100(S_r/\bar{\bar{x}})$ %

V_R	estimated relative standard deviation or coefficient of variation between laboratories for the parameter measured (reproducibility) = $100(S_R/\bar{x})$ %
2.8 V_r	estimated 95 % confidence limit on the difference between two test results in the same laboratory
2.8 V_R	estimated 95 % confidence limit on the difference between two test results from different laboratories

X1.3 *Statistical Relationships:*

$$S^2 = \sum_1^n (x_j - \bar{x}_j)^2/(n-1)$$

$$S_{\bar{x}}^2 = \sum_1^p d^2/(p-1)$$

$$S_r^2 = \sum_1^p S_j^2/p$$

$$S_R^2 = S_{\bar{x}}^2 + S_r^2(n-1)/n$$

TABLE X1.1 Provisional Summary of Interlaboratory Test Number 1

NOTE—Test conditions:
Load: 30 N
Speed: 1 m/s
Counterface Material: Type: A2 Tool Steel
Hardness: 58 to 60 HRC
Roughness: 0.102 to 0.203 µm (R_a)
Number of replicate: 4
Material 1—Nylon 6,6 with 20 % PTFE.
Material 2—Polycarbonate with 15 % PTFE and 30 % glass fibers.
Material 3—Polycarbonate with 15 % PTFE.

$mm^3/N·m \times 10^{-6}$

Material	Laboratory	Average ($\bar{x}_j$)	Deviation from Average (d_j)	Standard Deviation (s_j)
1	A	0.648	–0.0886	0.120
	B	0.825	0.0886	0.378
		($\bar{x}$)	($S_{\bar{x}}$)	(S_r)
	Column Average	0.737	0.125	0.281
2	A	1.533	–0.4575	0.285
	B	2.448	0.4575	0.359
		($\bar{x}$)	($S_{\bar{x}}$)	(S_r)
	Column Average	1.991	0.016	0.324
3	A	2.450	–0.0588	0.633
	B	2.568	0.0588	0.872
		($\bar{x}$)	($S_{\bar{x}}$)	(S_r)
	Column Average	2.509	0.083	0.762

TABLE X1.2 Statistical Analyses of the Test Results from Interlaboratory Test Number 1

Material	($mm^3/N·m \times 10^{-6}$)			%	
	$\bar{x}$	S_r	S_R	V_r	V_R
1	0.737	0.281	0.281	38	38
2	1.991	0.324	0.705	16	35
3	2.509	0.762	0.762	30	30

X2. CORRELATION WITH TEST METHOD D3702

X2.1 Table X2.1 presents a correlation with Test Method D3702.

TABLE X2.1 Correlation with Test Method D3702 Steady State Specific Wear Rate ($mm^3/N·m \times 10^{-6}$)

Material	Block-on-Ring	Test Method D3702 Thrust Washer
1	0.737	0.684
2	1.991	1.710
3	2.509	4.280