Designation: G 115 – 04

Standard Guide for Measuring and Reporting Friction Coefficients[1]

This standard is issued under the fixed designation G 115; 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 guide covers information to assist in the selection of a method for measuring the frictional properties of materials. Requirements for minimum data and a format for presenting these data are suggested. The use of the suggested reporting form will increase the long-term usefulness of the test results within a given laboratory and will facilitate the exchange of test results between laboratories. It is hoped that the use of a uniform reporting format will provide the basis for the preparation of handbooks and computerized databases.

1.2 This guide applies to most solid materials and to most friction measuring techniques and test equipment.

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]

B 460 Test Method for Dynamic Coefficient of Friction and Wear of Sintered Metal Friction Materials Under Dry Conditions[3]

B 461 Test Method for Frictional Characteristics of Sintered Metal Friction Materials Run in Lubricants[3]

B 526 Test Method for Coefficient of Friction and Wear of Sintered Metal Friction Materials Under Dry-Clutch Conditions[3]

C 808 Guideline for Reporting Friction and Wear Test Results of Manufactured Carbon and Graphite Bearing and Seal Materials

D 1894 Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting

D 2047 Test Method for Static Coefficient of Friction of Polish-Coated Floor Surfaces as Measured by the James Machine

D 2394 Methods for Simulated Service Testing of Wood and Wood-Base Finish Flooring

D 2714 Test Method for Calibration and Operation of the Falex Block-on-Ring Friction and Wear Testing Machine

D 3028 Test Method for Kinetic Coefficient of Friction of Plastic Solids[3]

D 3108 Test Method for Coefficient of Friction, Yarn to Solid Material

D 3247 Test Method for Coefficient of Static Friction of Corrugated and Solid Fiberboard (Horizontal Plane Method)[3]

D 3248 Test Method for Coefficient of Static Friction of Corrugated and Solid Fiberboard (Inclined Plane Method)[3]

D 3334 Methods of Testing Fabrics Woven from Polyolefin Monofilaments[3]

D 3412 Test Method for Coefficient of Friction, Yarn-to-Yarn

D 4103 Practice for Preparation of Substrate Surfaces for Coefficient of Friction Testing

E 122 Practice for Choice of Sample Size to Estimate, With a Specified Tolerable Error, the Average of a Lot or Process

E 303 Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester

E 510 Practice for Determining Pavement Surface Frictional and Polishing Characteristics Using a Small Torque Device

E 670 Test Method for Side Force Friction on Paved Surfaces Using the Mu-Meter

E 707 Test Method for Skid Resistance Measurements Using the North Carolina State University Variable-Speed Friction Tester

F 489 Test Method for Static Coefficient of Friction of Shoe Sole and Heel Materials as Measured by the James Machine

F 609 Test Method for Static Slip Resistance of Footwear, Sole, Heel, or Related Materials by Horizontal Pull Slipmeter (HPS)

F 695 Practice for Evaluation of Test Data Obtained by Using the Horizontal Pull Slipmeter (HPS) or the James

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[1] This guide is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.50 on Friction.

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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] Withdrawn.

Machine for Measurement of Static Slip Resistance of Footwear, Sole, Heel, or Related Materials
F 732 Practice for Reciprocating Pin-on-Flat Evaluation of Friction and Wear Properties of Polymeric Materials for Use in Total Joint Prosthesis
G 40 Terminology Relating to Wear and Erosion
G 65 Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus
G 99 Test Method for Wear Testing with a Pin-on-Disk Apparatus
G 133 Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear
G 143 Test Method for Measurement of Web/Roller Friction Characteristics

3. Terminology

3.1 *Definitions:*

3.1.1 *coefficient of friction, μ or f, n—in tribology*—the dimensionless ratio of the friction force (F) between two bodies to the normal force (N) pressing these bodies together. (See also *static coefficient of friction* and *kinetic coefficient of friction*.) **G 40**

3.1.2 *friction force*, *n*—the resisting force tangential to the interface between two bodies when, under the action of external force, one body moves or tends to move relative to the other. (See also *coefficient of friction*.) **G 40**

3.1.3 *kinetic coefficient of friction*, *n*—the coefficient of friction under conditions of macroscopic relative motion between two bodies. **G 40**

3.1.4 *static coefficient of friction*, *n*—the coefficient of friction corresponding to the maximum friction force that must be overcome to initiate macroscopic motion between two bodies. **G 40**

3.1.5 *stick-slip*—a relaxation oscillation usually associated with decrease in coefficient of friction as the relative velocity increases. (The usual manifestation is a cycling (decrease and subsequent increase) in the friction force as sliding proceeds (Fig. 1).)

3.1.6 *triboelement*, *n*—one of two or more solid bodies that comprise a sliding, rolling, or abrasive contact, or a body subjected to impingement or cavitation. (Each triboelement contains one or more tribosurfaces.) **G 40**

3.1.7 *tribosystem*, *n*—any system that contains one or more triboelements, including all mechanical, chemical, and environmental factors relevant to tribological behavior. (See also *triboelement*.) **G 40**

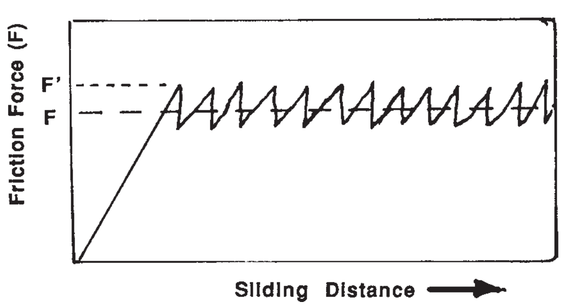


FIG. 1 Typical Force versus Distance Behavior for a System that Exhibits Stick-Slip Behavior

4. Summary of Guide

4.1 Current ASTM friction test standards are tabulated in this document so that users can review available test methods and determine which method may be most applicable for a particular application. Any of the listed tests or other accepted tests may be used. General friction testing precautions are cited and a prescribed method of recording friction data is recommended. This guide is intended to promote the use of this standard reporting system and standard friction test methods.

5. Significance and Use

5.1 This guide points out factors that must be considered in conducting a valid test for determination of the coefficient of friction of a tribosystem, and it encourages the use of a standard reporting format for friction data.

5.1.1 The factors that are important for a valid test may not be obvious to non-tribologists, and the friction tests referenced will assist in selecting the apparatus and test technique that is most appropriate to simulate a tribosystem of interest.

5.2 The tribology literature is replete with friction data that cannot readily be used by others because specifics are not presented on the tribosystem that was used to develop the data. The overall goal of this guide is to provide a reporting format that will enable computer databases to be readily established. These databases can be searched for material couples and tribosystems of interest. Their use will significantly reduce the need for each laboratory to do its own testing. Sufficient information on test conditions will be available to determine applicability of the friction data to the engineer's specific needs.

6. Apparatus

6.1 Any of the devices shown schematically in Table 1 can be used to measure the friction forces in a sliding system. Wear test machines are often equipped with sensors to measure friction forces also. The appropriate device to use is the one that closely simulates a tribosystem of interest.

6.2 The key part of simulating a tribosystem is to use specimen geometries that resemble the components in the system of interest. Other important factors to simulate are normal force (contact pressure), velocity, type of motion (reciprocating versus unidirectional), and environment. For example, if an application involves flat surfaces in contact under relatively light loads and with low slip velocities, a sled device may be applicable. If an application involves materials such as friction composites, one of the brake type dynamometer tests may be appropriate.

6.3 A very important consideration in selecting a test apparatus is stiffness of the friction force measuring system. If the sliding member in a test couple is set into motion by a metal rod, chain, or similar device, there will be very little elastic strain in the pulling device prior to initiation of motion, and the force measuring transducer may not record a "breakaway" force, a force spike that is higher than the mean force measured during steady state sliding. This breakaway force is commonly used to calculate static friction (Fig. 2). If initial friction is of interest in a test, it is advisable to use a force measuring system with substantial elasticity. In sled type devices this is often

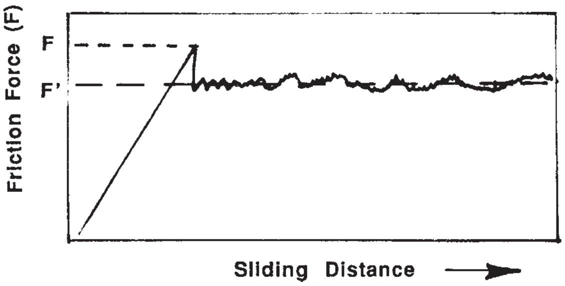
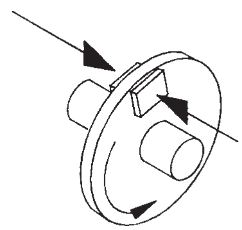
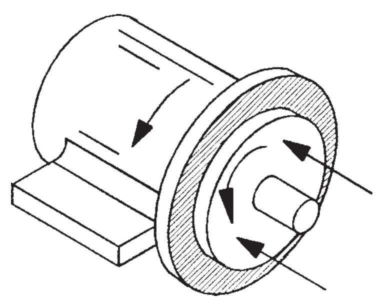
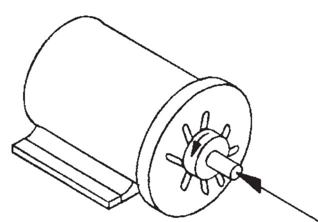


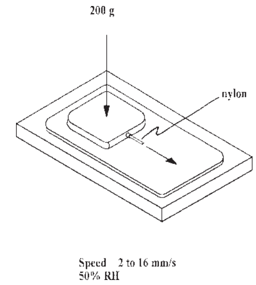
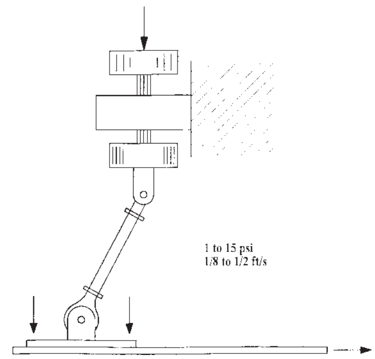
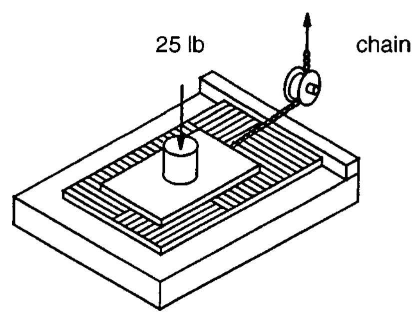
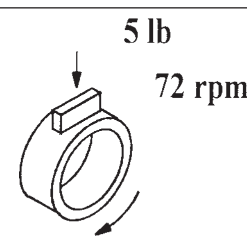
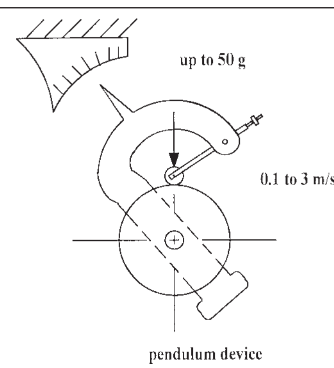
FIG. 2 Typical Force versus Distance Recording for a System that has a Static Friction that is Higher than its Kinetic Friction

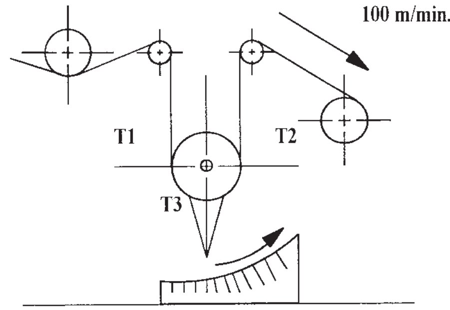
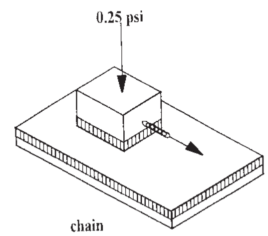
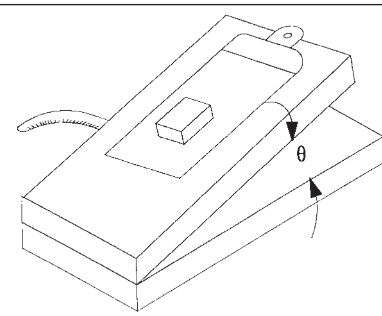
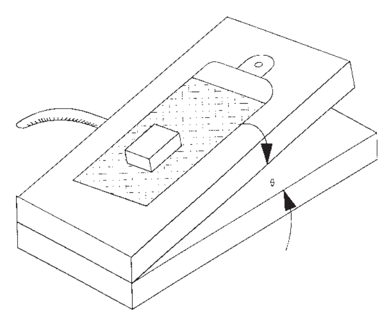
accomplished by using a nylon or similar plastic filament to produce motion of the sliding member. The appropriate force measuring system to use is the one that best simulates the tribosystem of interest; pulling plastic film over a roll probably involves significant elasticity in the system (from the low elastic modulus of the plastic). In this case an elastic friction measuring system would be appropriate. (**Warning—**More "elastic" systems may be more prone to produce stick-slip behavior. In addition, elastic beams containing strain gages may produce different friction responses than a more rigid load cell even if used on the same friction testing machine.) When pulling a steel cable over the same roll, it would be more appropriate to use a stiff testing system.

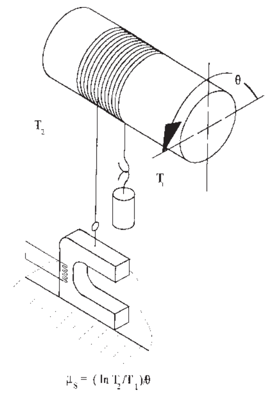
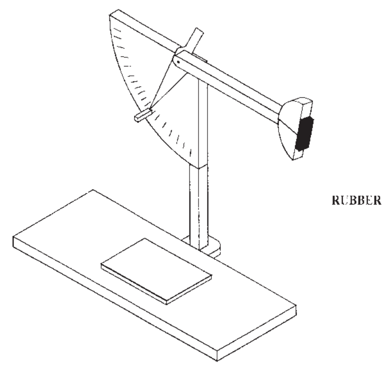
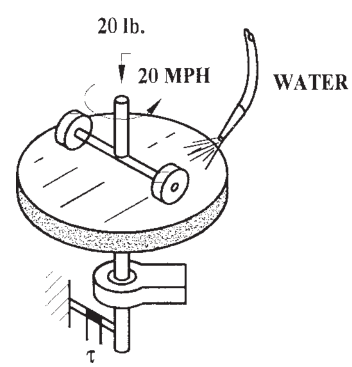
6.4 Initial friction force spikes will occur in many test systems. Test surfaces that are prone to blocking or interlocking of surface features are particularly prone to showing a breakaway force spike. (Blocking is a term used to describe the tendency of some plastic materials to stick to each other after long periods of contact.) Plasticized vinyl materials often block when self mated. Plasticizer migration can be the cause.

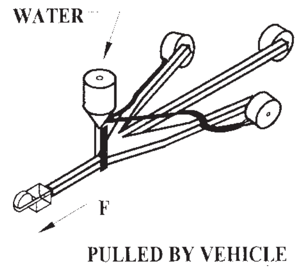
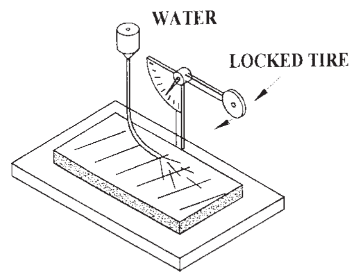
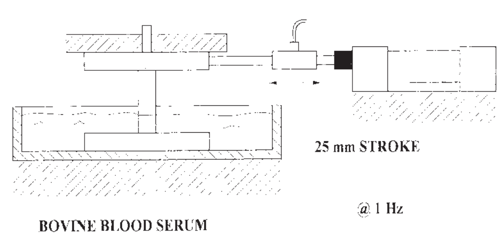
TABLE 1 ASTM Friction Tests and Applicable Materials

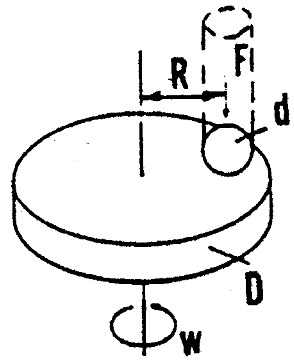
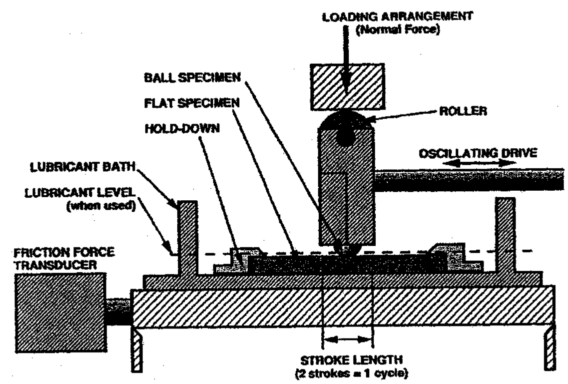
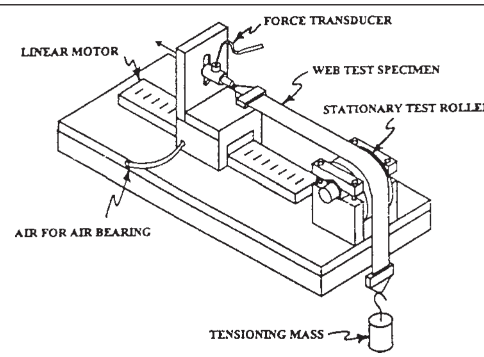
Standard/Committee	Title	Measured Parameters	Test Configuration
B 460 B09 on Metal Powders and Metal Powder Products	Dynamic Coefficient of Friction and Wear of Sintered Metal Friction Materials Under Dry Conditions	Friction materials versus metal (μ_k versus temperature)	
B 461 B09 on Metal Powders and Metal Powder Products	Frictional Characteristics of Sintered Metal Friction Materials Run in Lubricants	Friction materials versus metal (μ_k versus number of engagements) (μ_k versus velocity)	
B 526 B09 on Metal Powders and Metal Powder Products	Coefficient of Friction and Wear of Sintered Metal Friction Under Dry-Clutch Conditions	Friction materials versus gray cast iron (μ_s and μ_k)	
C 808 D02 on Petroleum Products and Lubricants	Reporting Friction and Wear Test Results of Manufactured Carbon and Graphite Bearing and Seal Materials	Carbon versus other materials (μ_s and μ_k)	any

Standard/Committee	Title	Measured Parameters	Test Configuration
D 1894 D20 on Plastics	Static and Kinetic Coefficients of Friction of Plastic Films and Sheeting	Plastic film versus stiff or other solids (μ_s and μ_k)	
D 2047 D21 on Polishes	Static Coefficient of Friction of Polish-Coated Floor Surfaces as Measured by the James Machine	Walking materials versus shoe heels and soles (μ_s and μ_k)	
D 2394 D07 on Wood	Simulated Service Testing of Wood and Wood-Base Finish Flooring	Wood and wood base flooring versus sole leather (μ_s and μ_k)	
D 2714 D02 on Petroleum Products and Lubricants	Calibration and Operation of the Falex Block-on-Ring Friction and Wear Testing Machine	Steel ring versus steel block (lubricated with standard oil) (μ_k)	
D 3028 D20 Plastics	Kinetic Coefficients of Friction of Plastic Solids	Plastic Sheets or solids versus other solids (μ_s and μ_k)	

Standard/Committee	Title	Measured Parameters	Test Configuration
D 3108 D13 on Textiles	Coefficient of Friction, Yarn to Solid Material	Textile yarn versus solids (μ_k)	 $\mu = (\ln T_2 - \ln T_1)/ \phi$
D 3247 D06 on Paper and Paper Products	Coefficient of Static Friction of Corrugated and Solid Fiberboard (Horizontal Plane Method)	Cardboard self-mated (μ_s)	
D 3248 D06 on Paper and Paper Products	Coefficient of Static Friction of Corrugated and Solid Fiberboard (Inclined Plane Method)	Cardboard self-mated (μ_s)	 $\mu_s = \tan\theta$
D 3334 D13 on Textiles	Testing Fabrics Woven from Polyolefin Monofilaments	Woven fabric self-mated (μ_s)	 $\mu_s = \tan\theta$

Standard/Committee	Title	Measured Parameters	Test Configuration
D 3412 D13 on Textiles	Coefficient of Friction, Yarn-to-Yarn	Continuous filament and spun yarns self-mated (μ_s and μ_k)	
D 4103 D21 on Polishes	Preparation of Substrate Surfaces for Coefficient of Friction Testing	Vinyl and wood tiles (preparation only)	any
E 303 E17 on Vehicle- Pavement Systems	Measuring Surface Frictional Properties Using the British Pendulum Tester	Rubber versus pavement (BPN British Pendulum Number)	
E 510 E17 on Vehicle- Pavement Systems	Determining Pavement Surface Frictional and Polishing Characteristics using a Small Torque Device	Rubber versus pavement (TN, Torque Number)	

Standard/Committee	Title	Measured Parameters	Test Configuration
E 670 E17 on Vehicle-Pavement Systems	Side Force Friction on Paved Surfaces Using the Mu-Meter	Tires versus pavement mu Number (F dry − F wet)	
E 707 E17 Vehicle-Pavement Systems	Skid Resistance Measurements Using the North Carolina State University Variable-Speed Friction Tester	Rubber tire versus pavement (VSN—variable speed number)	
F 489 F13 on Safety and Traction for Footwear	Static Coefficient of Friction of Shoe Sole and Heel Materials as Measured by the James Machine	Leather and rubber sole and heel material versus walking surfaces (μ_s)	Same as D 2047
F 609 F13 on Pedestrian/ Walkway Safety and Footwear	Static Slip Resistance of Footwear, Sole, Heel, or Related Materials by Horizontal Pull Slipmeter (HPS)	Footwear materials versus walking surfaces (μ_s)	Same as D 2047
F 695 F13 on Pedestrian/ Walkway Safety and Footwear	Evaluation of Test Data Obtained by Using the Horizontal Pull Slipmeter (HPS) or the James Machine for Measurements of Static Slip Resistance of Footwear, Sole, Heel, or Related Materials	Footwear materials vs walking surfaces (reliable ranking of footwear for slip resistance) (μ_k)	Same as D 2047
F 732 F04 Medical and Surgical Materials and Devices	Reciprocating Pin-on Flat Evaluation of Friction and Wear Properties of Polymeric Materials for Use in Total Joint Prosthesis	Materials for human joints (μ_k)	

Standard/Committee	Title	Measured Parameters	Test Configuration
G 99 G02 Wear and Erosion	Wear Testing with a Pin-on-Disk Apparatus	(μ_k)	
G 133 G02 Wear and Erosion	Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear	(μ_k)	
G 143 G02 Wear and Erosion	Test Method for Measurement of Web Web Roller Friction Characteristics	(μ_s)	

7. General Precautions

7.1 The precautions listed below are provided to supplement those included in any ASTM or other friction test.

7.1.1 Avoid skin contact with the test surfaces. Fingerprints can leave a film several micrometres thick that can affect results.

7.1.2 Test in ambient conditions (atmosphere, temperature, humidity) that are the same as the tribosystem of interest. Samples should be in equilibrium with their environment. It is advisable to incubate test samples that can be affected by humidity (plastics and other non-metals) for 24 h in the desired ambient conditions prior to testing.

7.1.3 Use test samples with the same surface texture and directionality as the tribosystem of interest. A nondirectional lapped surface is sometimes preferred for research studies.

7.1.4 Be meticulous in cutting test samples, and eliminate burred edges and errors of form (dents, scratches, bow, and so forth).

7.1.5 Thoroughly document the test specimens: material designation, composition, heat treatment, processing, manufacturer.

7.1.6 If friction is measured in a wear test, be aware that the measured friction coefficient is for altered counterfaces; the surfaces are probably separated by wear debris. Friction characteristics of virgin surfaces may be significantly different from those of a system involving surfaces separated by wear debris. If worn surfaces are likely in the tribosystem of interest, then it is appropriate to measure friction coefficients in a wear test.

7.1.7 The frictional characteristics of many couples can be affected by sliding velocity and normal force. It is advisable to check systems for sensitivity to these factors. Hold normal force constant and vary velocity and vice versa.

7.1.8 Run-in may cause friction force transitions. Therefore, a steady-state value of friction force may or may not be achieved under given test conditions. The reported friction coefficient (μ_k) should be the steady-state value unless specific reference to transient behavior is to be reported.

7.1.9 Inspect surfaces after testing to determine if the surfaces are altered by the test (are they scratched, worn, deformed, and so forth). If the test goal is to test virgin surfaces, it may be necessary to use less severe test conditions. If unexpected damage occurs under all test conditions of interest, this should be noted in the test results. The occurrence of surface damage may be a significant test output.

7.1.10 When using a digital acquisition system to record friction force, results can be affected by the sampling rate or the duration of the sampling period.

8. Test Specimens and Sample Preparation

8.1 Friction measurements are extremely dependent on the condition of the contacting surfaces on the test specimens. The surfaces should be in exactly the same condition as the tribosystem under study or as prescribed in an applicable ASTM or test standard. If the subject tribosystem involves molded surfaces, do not test with machined surfaces.

8.2 *Cleaning*:

8.2.1 Avoid cleaning surfaces with solvents that may leave films that may not be present in the tribosystem of interest. If perfectly clean metal surfaces are to be tested for friction characteristics, cleaning with refluxed solvent vapors is very effective. Trichlorethylene is commonly used in a vapor degreaser for this purpose. There is some evidence that cleaning in chlorinated solvents can leave films that affect friction results. If this is a consideration, acetone or a similar non-chlorinated solvent can be used.

8.2.2 Plastics, ceramics, and other non-metals can have their surface characteristics significantly affected by solvent cleaning. Many plastics can be effectively cleaned with commercial glass detergents (except those containing wax) followed by a distilled water rinse. This same procedure will work on many ceramics. Alcohols should be avoided on ceramics since there is some evidence that they alter surface properties. Alcohols should be avoided for cleaning in general because they may not effectively remove common surface contaminants such as fingerprints and oil.

8.2.3 The cleaning method that has shown to produce uniformly clean surfaces on metals and most rigid materials is abrasive cleaning with bonded abrasive. Abrading with a fresh sheet of abrasive paper on a flat surface plate (use a grit size that will produce the desired surface roughness) will usually be sufficient to produce a surface that is free of contaminating films. Frequent changes in sample orientation can be used to generate a multidirectional scratch pattern. Debris from abrasion should be removed by a blast from an aerosol can of laboratory-grade, clean, dry air. Abrasion is the only effective way of removing silicones, graphite, molybdenum disulfide, and similar materials. Any abrasion or lapping process produces some risk of embedding abrasive. If it is felt that a test material is prone to embedding, surface analysis techniques (X-ray fluorescence and so forth) can be used to confirm if a particular surface preparation process is producing embedding. Usually embedding is not a concern unless fine abrasives (<10 µm) are used. In any case, specimens must be checked for embedding.

8.2.4 In summary, cleaning of friction test surfaces is one of the most important considerations, and the best system to use is the one that produces surface conditions that will be present in tribosystems of interest. For research studies, freshly abraded surfaces are likely to be clean and free from the contaminant films that may affect results.

9. Testing

9.1 Simulate the velocity, type of motion, normal force, and environment of the tribosystem of interest. If a standard test is being used (ASTM, and so forth), use designated test conditions. Try to use fresh samples for replicate tests. If this is impractical, examine samples for wear after each test; discontinue testing if there is an upward or downward trend or if the surface texture is altered in any way (unless worn surfaces are of interest). For example, it may be possible to do a dozen replicate tests on hard steel samples without alteration of surfaces, but plastic samples may wear (by surface deformation, scratching, and so forth) after only one test. Statistical techniques can be used to determine the number of replicates required (Practice E 122) but usually 5 to 10 replicates are adequate. The variability of the test will often determine how many replicates are needed, but it is usually desirable to have a coefficient of variation less than 0.1 for a valid test.

9.2 The sliding distance employed in a friction test should be adequate to ensure equilibrium friction conditions. If the friction force increases and decreases continuously through a test, this may be an indication that a longer sliding distance is needed. If friction is measured in a wear test, this should be stated in the data sheet.

10. Calculation of Coefficient of Friction

10.1 The equations commonly used to calculate coefficients of friction are shown in Fig. 3. The inclined plane test (Fig. 3a) only yields the static coefficient of friction. It is recommended that the term static friction coefficient, μ_s, be used to describe a coefficient calculated using a breakaway force in a friction test rig that moves a specimen with a mechanism other than gravity.

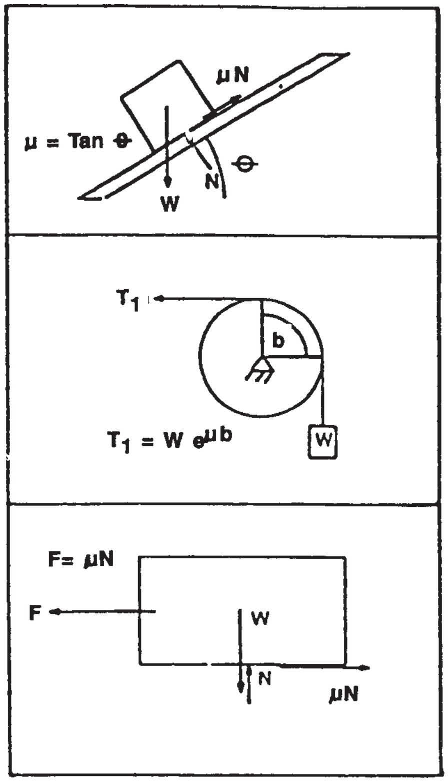


FIG. 3 Formulas for Calculation of Friction Coefficients, μ

F = Friction force, w = mass, N = Normal force
b = angle of wrap (radians)

10.2 The kinetic coefficient of friction, μ_k, may not be constant for a given time of sliding. It is common to calculate μ_k from averaged force readings for the duration of sliding, but other techniques may be used. It is strongly recommended that friction force readings be taken from continuously recorded (analog or digital) force data. If a test is very fast and initial friction is of concern, a recording oscilloscope or high-speed data acquisition system can be used to optimize recorder response. If suitable equipment is available to record friction force and normal force at pre-set time intervals (instantaneous), these values can be averaged to yield a μ_k for a test. Whatever the method used, the technique should be described in sufficient detail so that it can be reproduced by others.

10.3 *Interpretation of Friction Force Recordings*:

10.3.1 Stick-slip behavior occurs in many sliding systems, and when it does, the coefficient of friction of the system is so variable that it is common practice to simply report "stick-slip behavior" for the test result rather than a numerical result. Typical friction force versus time (distance) recordings are presented in Fig. 1, Fig. 2, and Fig. 4.

10.3.2 In the examples of typical friction force traces (Fig. 1, Fig. 2, and Fig. 4), the kinetic coefficient of friction is usually calculated from the friction force F. The static coefficient is usually calculated from force F′; the behavior in the example in Fig. 1 is usually reported as stick-slip. This type of behavior may not be apparent if the moving body is translated by a rigid screw mechanism or similar device. Tribosystems that display stick-slip behavior often produce vibration or noise. Stick-slip usually occurs in tribosystems in which there is considerable elasticity. It usually does not occur if the static coefficient of friction (μ_s) is equal to the kinetic coefficient of friction (μ_k), and it often occurs in systems where there is a negative slope to the coefficient of friction versus velocity curve.

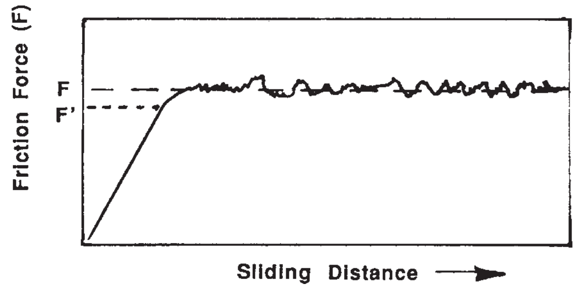


FIG. 4 Typical Force versus Distance Recording for a System that Does Not Exhibit a High Breakaway Force

11. Report

11.1 The minimum data for tabulation in friction database is included in items 11.1.1 to 11.1.8.

11.1.1 Material Couple (A) ________________________
(B) ____________________ (generic names of materials)[4]

11.1.2 Specimen Description (A) ______________________
(B)____

11.1.2.1 Examples of specimen descriptions are: pin, disk, shaft, bushing, block, and so forth)

11.1.3 Kinetic Coefficient of Friction

μ_k ______________________________

Static Coefficient of Friction

μ_s ______________________________

11.1.4 System Configuration (see Fig. 5 for options)____

11.1.5 ASTM or other procedure______________________

11.1.6 *Comments*—In addition to the above it is always advisable to include a "comments" section in a data sheet to prompt inclusion of important tribological behavior that may not show up in making the above measurements. For example, some couples may show stick-slip behavior, some may squeal, some materials may deform, and so forth. Note here if sample surfaces were visibly altered during the friction test.

[4] Many plastics, ceramics, and cermets are proprietary in nature; for these materials, use tradenames but reference the manufacturer.

11.1.7 *Test Conditions—(Starting)*, for conforming surfaces (Fig. 5), this is the normal force/apparent area of contact; Hertz stress equations can be used for nonconformal geometries.

Apparent Contact Pressure (MPa)	______________
Normal force (N)	______________
Velocity (m/s)	______________
Type of motion	____________ (reciprocating, steady sliding, and so forth)
Total sliding distance (m)	______________
Sample bulk	______________
Temperature (°C)	______________
Temperature measurement technique (location of sensor, and so forth)	
Test atmosphere	____________(surrounding gases, ambient pressure, and so forth)
Relative humidity (%)	______________
Lubricant	______________
Generic type (petroleum oil)	Specifics: (Mobil 10/60, and so forth)
Friction measured as part of a wear test _____ yes _____ no	

11.1.8 *Test Materials*—Complete description of stationary members and moving members should include:

generic name	— (1020 steel, acetal homopolymer, aluminum oxide, and so forth)
specification	— (AISI, ASTM, UNS)
form	— (wrought, cast, extruded, hot pressed, and so forth)
treatments	— (hardened to 60 HRC, annealed, as extruded, carburized, plated with 1 µm-thick hard chromium, and so forth)
surface texture	— (Ra, Rz, lay, method of surface preparation) relationship of lay to sliding direction, and so forth)

NOTE 1—If one or both members are coated or subject to some surface treatment, the details of this process should be noted. If a coating is the subject of a friction test, the coating(s) may be listed as a test member(s).

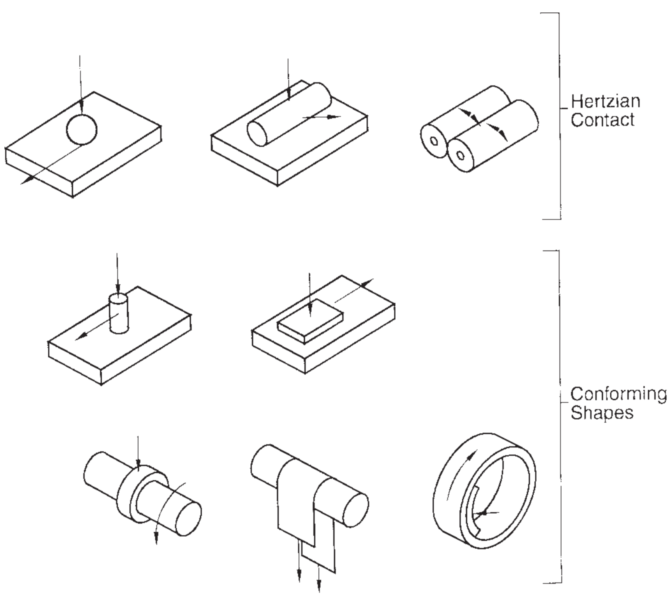


FIG. 5 Friction Testing Specimen Configuration Options

12. Precision and Bias

12.1 Since this guide encompasses the use of many types of test methods and types of apparatus, no specific data for precision and bias can be given. Some general comments on values that might be expected, and on factors that can affect precision, are given in the following paragraphs.

12.2 The repeatability of tests on the same material will depend upon material homogeneity, machine and material interaction, and careful adherence to the specified procedure by the machine operator.

12.3 Industrial experience has shown that carefully conducted unlubricated inclined plane and sled friction tests have produced within-laboratory coefficient of variation of 10 % or less for friction coefficients on an identical tribosystem. Coefficients of variation may be 25 % or higher when friction measurements are derived from wear tests. Precision is worst on systems where test conditions produce surface damage. It is the responsibility of the user to determine acceptable coefficients of variation, but the above reflect observations made in unlubricated metal-to-metal and metal-to-plastic friction tests.

12.4 Sample wear during friction tests can result in unacceptable test variability. Care should be taken to prevent surface alteration during friction testing caused by wear unless wear is part of the tribosystem of interest.

12.5 Friction coefficients of material couples obtained on one type of test apparatus may be significantly different from coefficients of the same material couples tested on a different apparatus. A friction coefficient is a system effect, so appropriate caution must be used when comparing or using data from different sources and systems.

13. Summary

13.1 The use of one of the test methods (Table 1) cited in this guide will give assurance of a testing procedure that has been agreed-to for a particular application. In addition, it is important to keep in mind that friction is a system property. The coefficient of friction of polystyrene on mild steel measured on a sled test (Test Method D 1894) will probably be different than the coefficient of the same couple measured on a pendulum friction tester (Methods D 3334).

13.1.1 Data developed by others can be useful if sufficient information is presented to characterize the tribosystem used in testing. Conformance with this guide in testing and reporting should produce data that can be reviewed for applicability to a particular tribosystem.