Designation: G 115 – 98

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 presents 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:*

B 460 Test Method for Dynamic Coefficient of Friction and Wear of Sintered Metal Friction Materials Under Dry Conditions[2]

B 461 Test Method for Frictional Characteristics of Sintered Metal Friction Materials Run in Lubricants[2]

B 526 Test Method for Coefficient of Friction and Wear of Sintered Metal Friction Materials Under Dry-Clutch Conditions[2]

C 122 Test Method of Panel Spalling Testing Super–Duty Fireclay Brick[3]

C 808 Guideline for Reporting Friction and Wear Test Results of Manufactured Carbon and Graphite Bearing and Seal Materials[3]

D 1894 Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting[4]

D 2047 Test Method for Static Coefficient of Friction of Polish-Coated Floor Surfaces as Measured by the James Machine[5]

D 2394 Methods for Simulated Service Testing of Wood and Wood-Base Finish Flooring[6]

D 2714 Test Method for Calibration and Operation of the Falex Block-on-Ring Friction and Wear Testing Machine[7]

D 3028 Test Method for Kinetic Coefficient of Friction of Plastic Solids[5]

D 3108 Test Method for Coefficient of Friction, Yarn to Solid Material[8]

D 3247 Test Method for Coefficient of Static Friction of Corrugated and Solid Fiberboard (Horizontal Plane Method)[9]

D 3248 Test Method for Coefficient of Static Friction of Corrugated and Solid Fiberboard (Inclined Plane Method)[9]

D 3334 Method of Testing Fabrics Woven from Polyolefin Monofilaments[10]

D 3412 Test Method for Coefficient of Friction, Yarn-to-Yarn[11]

D 4103 Practice for Preparation of Substrate Surfaces for Coefficient of Friction Testing[12]

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[13]

E 303 Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester[14]

E 305 Practices for Establishing and Controlling Spectrochemical Analytical Curves[15]

E 510 Practice for Determining Pavement Surface Frictional and Polishing Characteristics Using a Small Torque Device[16]

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[2] *Discontinued*—See *1989 Annual Book of ASTM Standards*, Vol 02.05.

[3] *Annual Book of ASTM Standards*, Vol 15.01.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

[6] *Annual Book of ASTM Standards*, Vol 04.10.

[7] *Annual Book of ASTM Standards*, Vol 05.02.

[8] *Annual Book of ASTM Standards*, Vol 07.01.

[9] *Discontinued*—See *1987 Annual Book of ASTM Standards*, Vol 15.09.

[10] *Discontinued*—See *1988 Annual Book of ASTM Standards*, Vol 07.01.

[11] *Annual Book of ASTM Standards*, Vol 07.02.

[12] *Annual Book of ASTM Standards*, Vol 15.04.

[13] *Annual Book of ASTM Standards*, Vol 14.02.

[14] *Annual Book of ASTM Standards*, Vol 04.03.

[15] *Annual Book of ASTM Standards*, Vol 03.05.

[16] *Discontinued*—See *1984 Annual Book of ASTM Standards*, Vol 04.03.

E 670 Test Method for Side Force Friction on Paved Surfaces Using the Mu-Meter[14]

E 707 Test Method for Skid Resistance Measurements Using the North Carolina State University Variable-Speed Friction Tester[16]

F 489 Test Method for Static Coefficient of Friction of Shoe Sole and Heel Materials as Measured by the James Machine[17]

F 609 Test Method for Static Slip Resistance of Footwear, Sole, Heel, or Related Materials by Horizontal Pull Slipmeter (HPS)[17]

F 695 Practice for Evaluation of Test Data Obtained by Using the Horizontal Pull Slipmeter (HPS) or the James Machine for Measurement of Static Slip Resistance of Footwear, Sole, Heel, or Related Materials[17]

F 732 Practice for Reciprocating Pin-on-Flat Evaluation of Friction and Wear Properties of Polymeric Materials for Use in Total Joint Prosthesis[18]

G 40 Terminology Relating to Wear and Erosion[19]

G 65 Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus[19]

G 143 Test Method for Measurement of Web/Roller Friction Characteristics[19]

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 – 93**

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– 93**

3.1.3 *kinetic coefficient of friction*, *n*— the coefficient of friction under conditions of macroscopic relative motion between two bodies. **G 40 – 93**

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 – 93**

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 – 93**

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

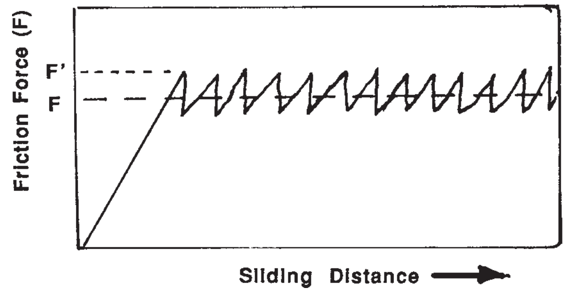


FIG. 1 Typical Force versus Distance Behavior for a System that Exhibits Stick-Slip Behavior

triboelement.) **G 40 – 93**

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

[17] *Annual Book of ASTM Standards*, Vol 15.07.
[18] *Annual Book of ASTM Standards*, Vol 13.01.
[19] *Annual Book of ASTM Standards*, Vol 03.02.

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 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. When pulling a steel cable over the same roll, it would be more appropriate to use a stiff testing system.

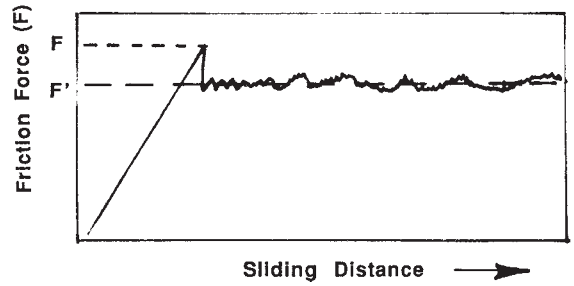
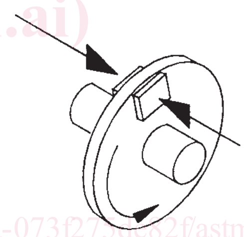
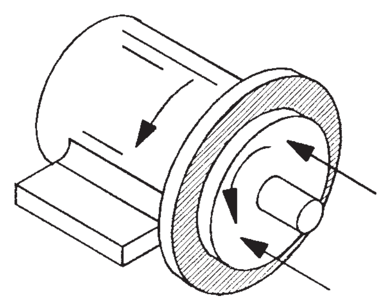
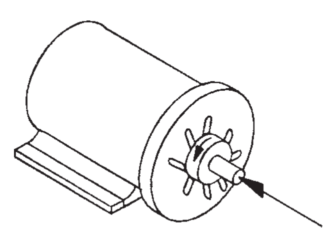


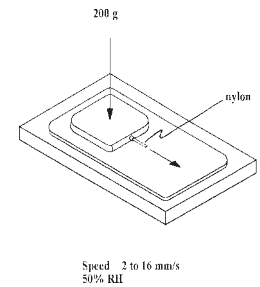
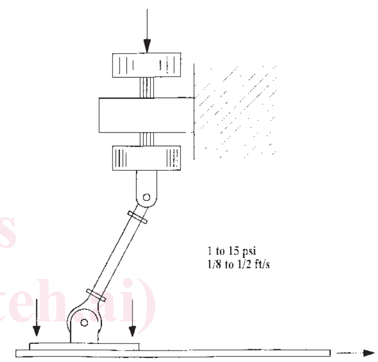
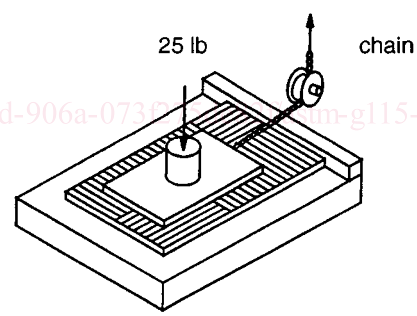
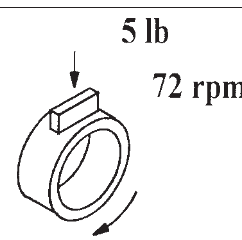
FIG. 2 Typical Force versus Distance Recording for a System that has a Static Friction that is Higher than its Kinetic Friction

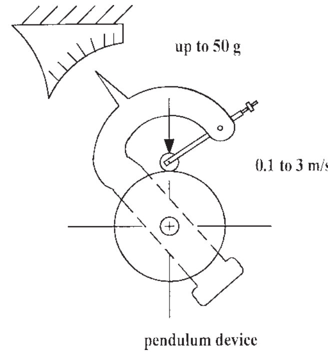
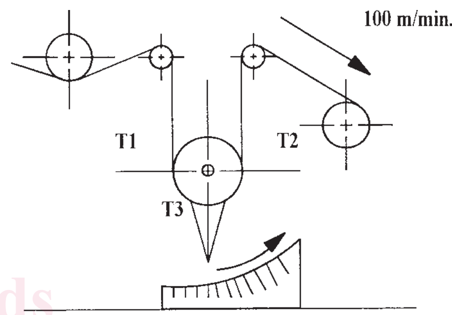
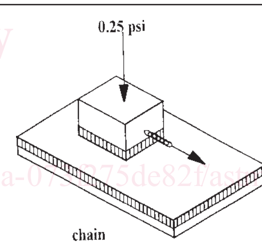
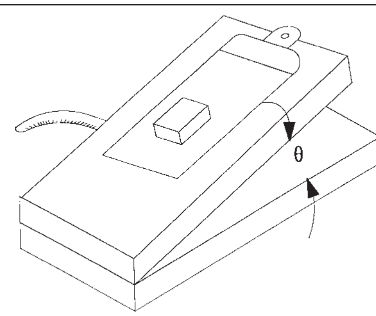
NOTE 1—**Caution:** More "elastic" systems may be more prone to produce stick-slip behavior. In addition, elastic beams containing strain gages may produce different friction responses than a more rigid load cell even if used on the same friction testing machine.

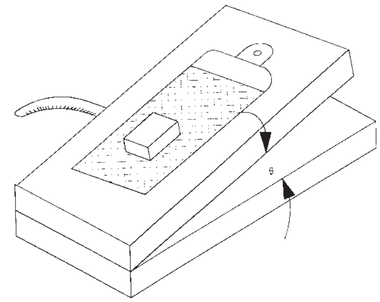
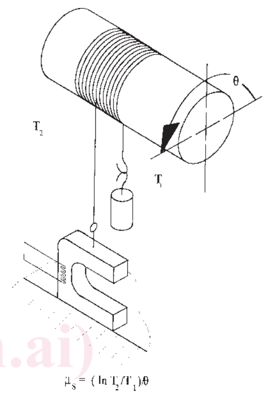
6.4 Initial friction force spikes will occur in many test systems. Test surfaces that are prone to blocking or interlocking of surface features are particularly prone to showing a breakaway force spike. (Blocking is a term used to describe the tendency of some plastic materials to stick to each other 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 B-9 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 B-9 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 B-9 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)	

Standard/Committee	Title	Measured Parameters	Test Configuration
C 808 C-5 on Manufactured Carbon and Graphite Products	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
D 1894 D-20 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 D-21 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 D-7 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 D-2 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)	

Standard/Committee	Title	Measured Parameters	Test Configuration
D 3028 D-20 Plastics	Kinetic Coefficients of Friction of Plastic Solids	Plastic Sheets or solids versus other solids (μ_s and μ_k)	
D 3108 D-13 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 D-6 on Paper and Paper Products	Coefficient of Static Friction of Corrugated and Solid Fiberboard (Horizontal Plane Method)	Cardboard self-mated (μ_s)	
D 3248 D-6 on Paper and Paper Products	Coefficient of Static Friction of Corrugated and Solid Fiberboard (Inclined Plane Method)	Cardboard self-mated (μ_s)	 $\mu_s = \tan\theta$

Standard/Committee	Title	Measured Parameters	Test Configuration
D 3334 D-13 on Textiles	Testing Fabrics Woven from Polyolefin Monofilaments	Woven fabric self-mated (μ_s)	 $\mu_s = \tan\theta$
D 3412 D-13 on Textiles	Coefficient of Friction, Yarn-to-Yarn	Continuous filament and spun yarns self-mated (μ_s and μ_k)	
D 4103 D-21 on Polishes	Preparation of Substrate Surfaces for Coefficient of Friction Testing	Vinyl and wood tiles (preparation only)	any
E 303 E-17 on Pavement Management Technologies	Measuring Surface Frictional Properties Using the British Pendulum Tester	Rubber versus pavement (BPN British Pendulum Number)