Designation: G115 – 04

Standard Guide for Measuring and Reporting Friction Coefficients[1]

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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]

B460 Test Method for Dynamic Coefficient of Friction and Wear of Sintered Metal Friction Materials Under Dry Conditions[3]

B461 Test Method for Frictional Characteristics of Sintered Metal Friction Materials Run in Lubricants[3]

B526 Test Method for Coefficient of Friction and Wear of Sintered Metal Friction Materials Under Dry-Clutch Conditions[3]

C808 Guide for Reporting Friction and Wear Test Results of Manufactured Carbon and Graphite Bearing and Seal Materials

D1894 Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting

D2047 Test Method for Static Coefficient of Friction of Polish-Coated Flooring Surfaces as Measured by the James Machine

D2394 Test Methods for Simulated Service Testing of Wood and Wood-Base Finish Flooring

D2714 Test Method for Calibration and Operation of the Falex Block-on-Ring Friction and Wear Testing Machine

D3028 Test Method for Kinetic Coefficient of Friction of Plastic Solids[3]

D3108 Test Method for Coefficient of Friction, Yarn to Solid Material

D3247 Test Method for Coefficient of Static Friction of Corrugated and Solid Fiberboard (Horizontal Plane Method)[3]

D3248 Test Method for Coefficient of Static Friction of Corrugated and Solid Fiberboard (Inclined Plane Method)[3]

D3334 Methods of Testing Fabrics Woven from Polyolefin Monofilaments[3]

D3412 Test Method for Coefficient of Friction, Yarn to Yarn

D4103 Practice for Preparation of Substrate Surfaces for Coefficient of Friction Testing

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

E303 Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester

E510 Practice for Determining Pavement Surface Frictional and Polishing Characteristics Using a Small Torque Device[3]

E670 Test Method for Testing Side Force Friction on Paved Surfaces Using the Mu-Meter

E707 Test Method for Skid Resistance Measurements Using the North Carolina State University Variable-Speed Friction Tester[3]

F489 Test Method for Using a James Machine[3]

F609 Test Method for Using a Horizontal Pull Slipmeter (HPS)

F695 Practice for Ranking of Test Data Obtained for Measurement of Slip Resistance of Footwear Sole, Heel, and Related Materials

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

G40 Terminology Relating to Wear and Erosion

G65 Test Method for Measuring Abrasion Using the Dry

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

Sand/Rubber Wheel Apparatus
G99 Test Method for Wear Testing with a Pin-on-Disk Apparatus
G133 Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear
G143 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*.) G40

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*.) G40

3.1.3 *kinetic coefficient of friction*, *n*—the coefficient of friction under conditions of macroscopic relative motion between two bodies. G40

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. G40

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).) G40

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.) G40

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*.) G40

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.

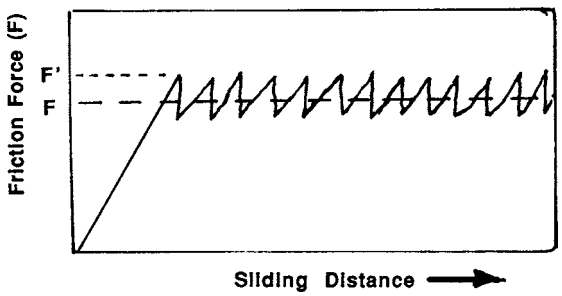


FIG. 1 Typical Force versus Distance Behavior for a System that Exhibits Stick-Slip Behavior

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 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

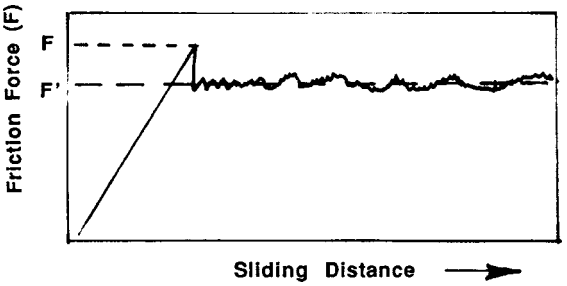
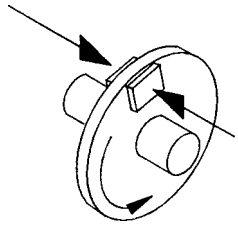
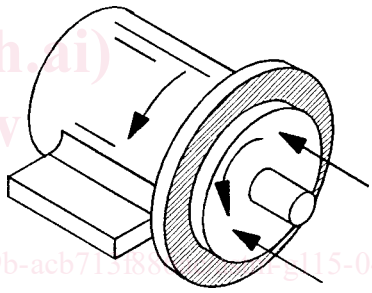
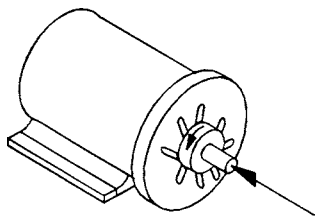


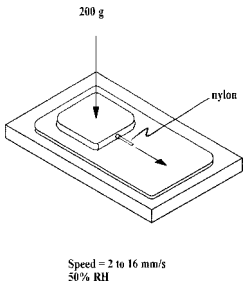
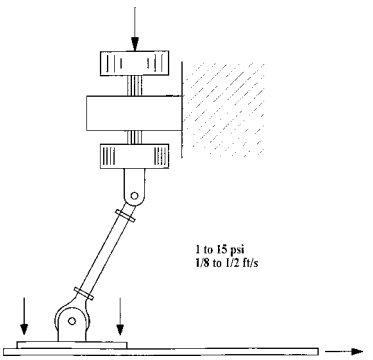
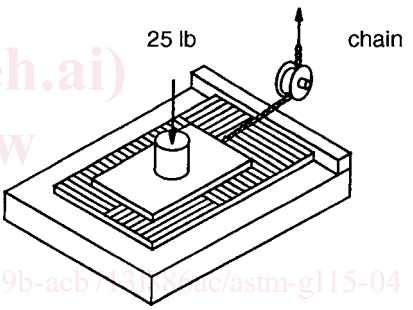
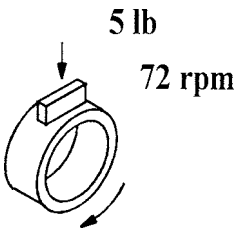
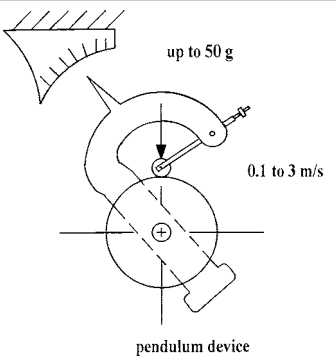
FIG. 2 Typical Force versus Distance Recording for a System that has a Static Friction that is Higher than its Kinetic Friction

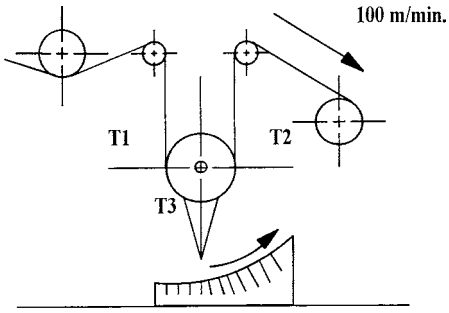
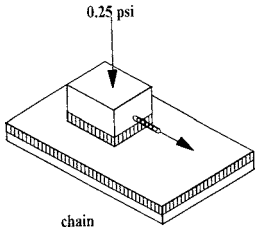
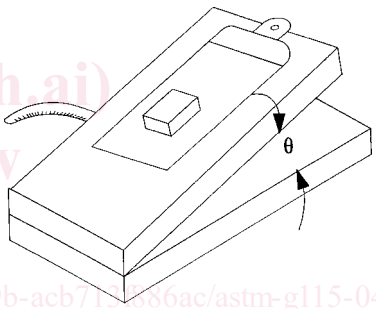
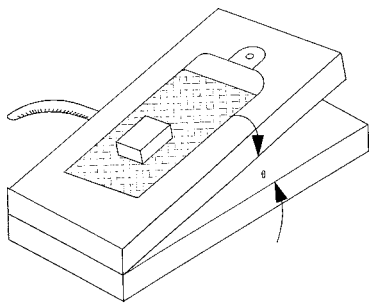
"elastic" systems may be more prone to produce stick-slip behavior. In addition, elastic beams containing strain gages may produce different friction responses than a more rigid load cell even if used on the same friction testing machine.) When pulling a steel cable over the same roll, it would be more appropriate to use a stiff testing system.

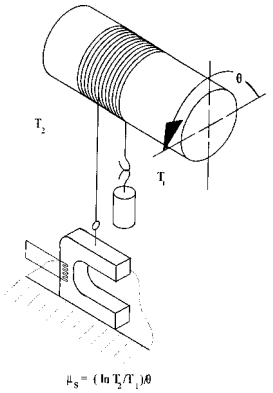
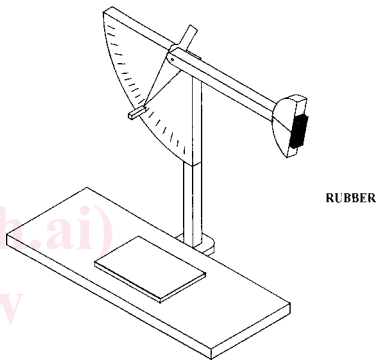
6.4 Initial friction force spikes will occur in many test systems. Test surfaces that are prone to blocking or interlocking of surface features are particularly prone to showing a breakaway force spike. (Blocking is a term used to describe the tendency of some plastic materials to stick to each other 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
B460	Dynamic Coefficient of Friction and Wear of Sintered Metal	Friction materials versus metal	
B09 on Metal Powders and Metal Powder Products	Friction Materials Under Dry Conditions	(μ_k versus temperature)	
B461	Frictional Characteristics of Sintered Metal Friction Materials Run in Lubricants	Friction materials versus metal (μ_k versus number of engagements) (μ_k versus velocity)	
B09 on Metal Powders and Metal Powder Products			
B526	Coefficient of Friction and Wear of Sintered Metal Friction Under Dry-Clutch Conditions	Friction materials versus gray cast iron (μ_s and μ_k)	
B09 on Metal Powders and Metal Powder Products			
C808	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
D02 on Petroleum Products and Lubricants			

Standard/Committee	Title	Measured Parameters	Test Configuration
D1894 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)	
D2047 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)	
D2394 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)	
D2714 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)	
D3028 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
D3108 D13 on Textiles	Coefficient of Friction, Yarn to Solid Material	Textile yarn versus solids (μ_k)	 $\mu = (\ln T_2 - \ln T_1) / \phi$
D3247 D06 on Paper and Paper Products	Coefficient of Static Friction of Corrugated and Solid Fiberboard (Horizontal Plane Method)	Cardboard self-mated (μ_s)	
D3248 D06 on Paper and Paper Products	Coefficient of Static Friction of Corrugated and Solid Fiberboard (Inclined Plane Method)	Cardboard self-mated (μ_s)	 $\mu_s = \tan\theta$
D3334 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
D3412 D13 on Textiles	Coefficient of Friction, Yarn-to-Yarn	Continuous filament and spun yarns self-mated (μ_s and μ_k)	
D4103 D21 on Polishes	Preparation of Substrate Surfaces for Coefficient of Friction Testing	Vinyl and wood tiles (preparation only)	any
E303 E17 on Vehicle-Pavement Systems	Measuring Surface Frictional Properties Using the British Pendulum Tester	Rubber versus pavement (BPN British Pendulum Number)	
E510 E17 on Vehicle-Pavement Systems	Determining Pavement Surface Frictional and Polishing Characteristics using a Small Torque Device	Rubber versus pavement (TN, Torque Number)