Designation: D 4917 – 97 (Reapproved 2007)

An American National Standard

Standard Test Method for Coefficient of Static and Kinetic Friction of Uncoated Writing and Printing Paper by Use of the Horizontal Plane Method[1]

This standard is issued under the fixed designation D 4917; 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 describes a horizontal plane procedure for the determination of the coefficient of static and kinetic friction of paper measured when sliding against itself.

1.2 Although this test method is basic in concept, the precision statement has been developed on uncoated writing and printing papers. While the use of this test method is recommended for those grades only, it may be used with other types of papers giving specific attention to special paper characteristics and with the understanding that the precision and bias may not be the same.

1.3 The horizontal instrument requires some means of movement of the specimen in relation to the surface upon which it rests. The coefficient of friction (COF) is measured directly from the resistance to tangential motion and the applied weight pressing two pieces of paper together.

1.4 Static COF relates to the force required to initiate movement between two surfaces while kinetic COF relates to the force required to cause continuation of the movement at uniform speed.

1.5 An inclined plane method is described in Test Method D 4918, which gives similar results for static COF but Test Method D 4918 cannot be used for the determination of kinetic COF. The choice of approach depends on the equipment available and the means of measurement.

1.6 The determination of this characteristic for corrugated and solid fiberboard is described in Test Methods D 4521 and D 3247. These test methods differ in that in Test Methods D 4521 and D 3247, the two specimens are allowed to slip upon one another three times before the force measurement is determined, while in this test method the determination is made on the first slip.

1.7 *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]

D 528 Test Method for Machine Direction of Paper and Paperboard

D 585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, and Related Product

D 685 Practice for Conditioning Paper and Paper Products for Testing

D 725 Method for Identification of Wire Side of Paper[3]

D 828 Test Method for Tensile Properties of Paper and Paperboard Using Constant-Rate-of-Elongation Apparatus

D 1968 Terminology Relating to Paper and Paper Products

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

D 3460 Specification for White Watermarked and Unwatermarked Bond, Reprographic, and Laser Printer Cut-Sized Office Papers[3]

D 4521 Test Method for Coefficient of Static Friction of Corrugated and Solid Fiberboard[3]

D 4918 Test Method for Coefficient of Static Friction of Uncoated Writing and Printing Paper by Use of the Inclined Plane Method

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

[1] This test method is under the jurisdiction of ASTM Committee D06 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.92 on Standard Documents Relating to Paper and Paper Products.

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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.

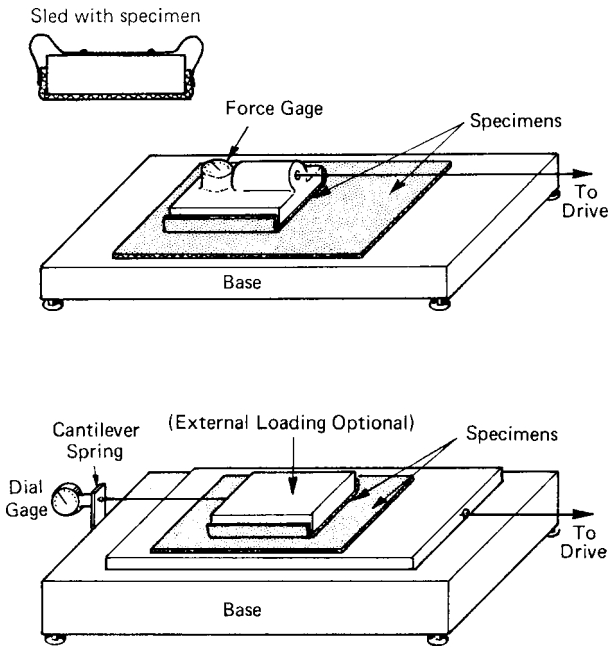

FIG. 1 Schematics for Two Horizontal Plane Instruments

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology D 1968 and the *Dictionary of Paper.*[4]

4. Summary of Test Method

4.1 One specimen of the paper sample is clamped to a horizontal plane surface, the other to a specimen sled. The sled is pulled across the surface, or alternatively, the plane is pulled under the stationary sled by mechanical means, and the force required to do so is measured. The coefficients of both static and kinetic friction can be determined.

5. Significance and Use

5.1 The coefficient of friction of printing and writing papers is an indicator of the ease with which the top or bottom sheet of a stack of paper will slide across the succeeding sheet, such as occurs on the infeed of a printing press or the sheet transport into a copier machine. A minimum coefficient of friction is required to prevent double-feeding of any sheets.

5.2 Since each sheet is removed from the stack only once, a single slide of each pair of specimens is performed and the value recorded.

6. Apparatus (see Fig. 1)

6.1 *Horizontal Plane and Supporting Base*—A horizontal plane surface of a smooth, incompressible material—metal, hardwood, plate glass, or plastic—having a width at least 25 mm (1 in.) wider than the specimen sled (see 6.2). The plane is mounted on a supporting base provided with means of leveling in two directions. A constant rate-of-motion tester, as described in Test Method D 828, has also been found suitable. If this type of tester is used, the horizontal plane and supporting base are one and the same.

6.2 *Specimen Sled*—A sled or specimen block made of an incompressible material with a rubber-faced lower surface or such material with a COF significantly higher than the material being tested. A63.5-mm (2.5-in.) square metal block weighing 200 ± 5 g has been found satisfactory. A means for clamping the specimen to the sled may be provided, but is not necessary if the lower surface is faced with 3-mm (⅛-in.) thick soft rubber. A means for fastening the sled to the force measuring device, such as a wire cable or nylon filament line, is required. Care should be taken in selecting a wire cable or nylon filament line to make certain that its ability to stretch does not interfere with the measurement of force.

6.3 *Mechanical Power Unit*—Providing a means for moving the specimen sled horizontally along the plane surface, or the plane surface under the specimen sled at a uniform speed of 150 ± 30 mm/min (0.5 ± 0.1 ft/min). A constant rate-of-motion tester equipped with a load cell in its upper crosshead and a constant rate-of-motion lower crosshead has been found satisfactory (Test Method D 828).

6.4 *Force Measuring Device*—Means for measuring the force required to move or restrain the specimen sled to the nearest 5 gf (0.01 lbf). A force gage or the load cell of a constant rate-of-motion tester have both been found suitable (Test Method D 828).

6.5 *Paper Cutter*, to cut test specimens.

7. Sampling and Test Specimen Preparation

7.1 For acceptance sampling, obtain the sample in accordance with Practice D 585.

7.2 When sampling for other purposes, use Practice E 122 as an alternative.

7.3 The sample, selected in accordance with Practice D 585 should be in the form of a finished ream or a "lift" sample from a roll. A lift is a stack of sheets about 1.3 cm (0.5 in.) cut from a roll.

7.4 Precondition, condition, and test in the atmospheres described in Practice D 685.

7.5 Cut the sample into test specimen pairs as follows:

7.5.1 *Finished Ream Sample*:

7.5.1.1 *With Machine Direction COF*—Lift off a stack of six consecutive sheets, identify the machine direction (Test Method D 528) and the felt (or top) side (Method D 725) of the top sheet, and cut two specimens from each sheet: one 100 by 215 mm (4 by 8.5 in.) and the other 75 by 130 mm (3 by 5 in.). Cut the specimens so that the machine direction is parallel to the long dimension. Stack the two sets of specimens in separate piles, maintaining the same order of sheets as in the ream. Take the top sheet off the pile of larger specimens and discard. Use the second large specimen with the first small specimen, the third large specimen with the second specimen, and so on, performing the test with five pairs of specimens from consecutive sheets. There will be one left-over small specimen (sixth) which can be discarded.

7.5.1.2 *Across Machine Direction COF*—Follow directions given in 7.5.1.1, except cut the specimens so that the machine direction is parallel to the shorter dimension.

[4] Available from Technical Association of the Pulp and Paper Industry (TAPPI), 15 Technology Parkway South, Norcross, GA 30092, http://www.tappi.org.

7.5.2 *Lift Sample*:

7.5.2.1 *With Grain Direction COF*—Lift off a stack of seven consecutive sheets, identify the machine direction and the felt (or top) side of the top sheet, and cut two specimens from each sheet: one 100 by 215 mm (4 by 8.5 in.) and the other 75 by 130 mm (3 by 5 in.). Cut the specimens so that the machine direction is parallel to the longer dimension. Discard the top sheet from each stack and test five pairs of specimens. Each pair is from the same sheet. Discard the bottom sheets.

7.5.2.2 *Across Grain Direction COF*—Follow directions given in 7.5.2.1 except cut the specimens so that the machine direction is parallel to the shorter dimension. Discard the top sheet from each stack and test five pairs of specimens. Each pair is from the same sheet. Discard the bottom sheets.

8. Procedure

8.1 Place the horizontal plane and its base on a vibration-free table and level it, or set up a constant rate-of-motion tester in accordance with its instructions for coefficient of friction determination. If necessary, adjust the force measuring device to zero.

8.2 *With Grain Direction COF*:

8.2.1 Select the specimens cut with the grain direction parallel to the long dimension (see 7.5.1.1 or 7.5.2.1).

8.2.2 Place the longer of each specimen pair on the horizontal plane with the top (felt) side upward and clamp or otherwise attach the end farthest from the force measuring device to the plane.

8.2.3 Place the smaller specimen on top of the larger with the wire side facing down, and set the rubber-faced sled lightly atop it, or attach the smaller specimen to the sled and position the sled atop the larger specimen.

8.2.4 Attach the cable from the power unit or force gage to the sled.

8.2.5 Start the power unit, making sure the cable remains taut as the drive takes up the load. No immediate relative motion may take place between the sled and the plane until the pull on the sled is equal to, or exceeds, the static frictional force acting at the contact surfaces. Record this initial, maximum reading, or note the maximum peak recorded on the strip chart recorder of the constant rate-of-motion tester, as the force component of the coefficient of static friction.

8.2.6 Continue the motion of the two specimens for a distance of about 130 mm (5 in.). Record the average force reading during this period, or obtain the average force by integrating the recorded trace on the strip chart recorder of the constant rate-of-motion tester, as the force component of the coefficient of kinetic friction.

8.2.7 After the sled has traveled the required distance, stop the power unit, remove the specimens, and return the apparatus to the starting positions. Continue to test the remaining specimen pairs in identical fashion. No specimen pairs shall be tested more than once unless such tests constitute one of the variables to be studied.

8.3 *Across Grain Direction COF*—Select the set of specimens cut with the grain direction parallel to the short dimension (see 7.5.1.2 or 7.5.2.2). Repeat the procedure described in 8.2.2 through 8.2.7.

9. Calculation

9.1 Determine for each specimen pair the coefficient of static friction, U_s, as follows:

$$U_s = A_s/B \quad (1)$$

where:

A_s = force required to initiate motion, gf, and
B = sled weight, gf.

9.2 Determine for each specimen pair the coefficient of kinetic friction, U_k, as follows:

$$U_k = A_k/B \quad (2)$$

where:

A_k = average force reading during uniform sliding, gf, and
B = sled weight, gf.

10. Report

10.1 Report as coefficient of static friction, the average and standard deviation of the five determinations of U_s. Report separately for the with- and across-machine directions.

10.2 Report as coefficient of kinetic friction, the average and standard deviation of the five determinations of U_k. Report separately for the with- and across-machine directions.

10.3 Report whether the sample is taken from a finished ream or a lift.

11. Precision and Bias

11.1 *Repeatability*[5]—The repeatability standard deviation of the procedure in this test method is approximately 0.007 for the coefficient of static friction and 0.005 for the coefficient of kinetic friction. The corresponding 95 % repeatability limits are approximately 0.019 and 0.014, respectively. These estimates of repeatability were developed on writing papers in accordance with Specification D 3460 having coefficients of static friction in the range from 0.40 to 0.70. The repeatability for other uncoated writing and printing papers may be larger or smaller than the values stated here.

11.2 *Reproducibility*— An estimate of the reproducibility standard deviation and the 95 % reproducibility limits is under development.

11.3 *Bias*—No statement about bias of the procedure in this test method is made, because the values measured for static and kinetic coefficient of friction are defined based on the specific testing conditions stated in the test method.

12. Keywords

12.1 coefficient of friction; kinetic friction; printing paper; static friction; uncoated paper; writing paper

[5] A report concerning the within-laboratory precision statement is contained in ASTM files. Request RR: D1000.

APPENDIX

(Nonmandatory Information)

X1. SIGNIFICANCE AND INTERPRETATION OF TEST METHOD

X1.1 In 7.3 the procedure for selecting the sample in two manners depending upon the form of the paper to be tested is described. In 7.5 the procedure for preparing test specimens depending upon the form of the paper to be tested is described. Sampling of a cut size ream of the type commonly used in sheet-fed printing presses and copy machines is described in 7.5.1. Sampling paper from a roll is described in 7.5.2.

X1.2 *Ream Sample:*

X1.2.1 In the manufacturing process of converting paper from rolls to sheets, it is common practice to combine the webs of two or more rolls in the processing equipment. As a result, successive sheets in the stack of cut paper represent the combination of the several rolls that are processed together. By using the sampling procedure described in 7.5.1, the resulting COF values represent the relationships between successive sheets. This is comparable to the manner in which the sheets are fed into the press or copier.

X1.2.2 There is a need to determine the COF of an individual sheet in such a way as to not be influenced by the adjacent sheet from another roll, the operator may select a single sheet, prepare a test specimen pair, and test in accordance with the instructions given.

X1.3 *Roll Sample*—If the paper to be tested is in the form of a roll, the samples are to be selected as described in 7.5.2. The test results will not be influenced by other sheets.