Designation: D 3330/D 3330M – 02ε1

Standard Test Method for Peel Adhesion of Pressure-Sensitive Tape [1]

This standard is issued under the fixed designation D 3330/D 3330M; 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.

ε[1] NOTE—The US Customary units were corrected in the last sentence of 6.5 in December 2003.

1. Scope

1.1 These test methods cover the measurement of the peel adhesion of pressure-sensitive tapes.

1.1.1 Test Method A gives a measure of the adherence, when peeled at 180° angle, to a standard steel panel or to other surface of interest for a single-coated tape.

1.1.2 Test Method B gives a measure of the adherence to the backing of a single-coated tape.

1.1.3 Test Method C gives a measure of the adherence of double-coated tape to a standard steel panel or other surface of interest.

1.1.4 Test Method D gives a measure of the adherence of the release liner to the adhesive of either single- or double-coated tape.

1.1.5 Test Method E gives a measure of the adherence of an adhesive transfer tape to a standard steel panel or other surface of interest.

1.1.6 Test Method F gives a measure of the adherence, when peeled at 90° angle, to a standard steel panel or other surface of interest for a single-coated tape.

1.2 These test methods provide a means of assessing the uniformity of the adhesion of a given type of pressure-sensitive adhesive tape. The assessment may be within a roll of tape, between rolls, or between production lots.

1.3 Variations in either the tape backing or the adhesive, or both, affect the response. Therefore, these test methods cannot be used to pinpoint the specific cause(s) of non-uniformity.

1.4 These test methods may not be appropriate to test tapes having relatively stiff backings, stiff liners, or backings showing high stretch at low forces. These characteristics will result in a high variability for the test response which is not a true indication of the real nature of the adhesive bond.

1.5 Values stated in either SI or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents, therefore, each system must be used independently without combining values in any way.

1.6 These test methods are intended to replace AFERA 4001, EN 1939, PSTC-1, PSTC-2, PSTC-3 and PSTC-4.

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:*

A 666 Specification for Austenitic Stainless Steel, Sheet, Strip, Plate and Flat Bar[2]

D 996 Terminology of Packaging and Distribution Environments[3]

D 3715/D 3715M Practice for Quality Assurance of Pressure-Sensitive Tapes[3]

D 4332 Practice for Conditioning Containers, Packages or Packaging Components for Testing[3]

D 5750 Guide for Width and Lengths of Pressure-Sensitive Tape[3]

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[4]

2.2 *AFERA Standard:*[5]

4001 Self adhesive tapes – Measurement of peel adhesion

2.3 *European Norm:*[6]

EN 1939 Self adhesive tapes – Measurement of peel adhesion from stainless steel or from its own backing

[1] These test methods are under the jurisdiction of ASTM Committee D-10 on Packaging and are the direct responsibility of Subcommittee D10.14 on Tape and Labels.

Current edition approved Oct. 10, 2002. Published December 2002. Originally published in 1976. Last previous edition approved in 2000 as D 3330/D 3330M – 00.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 15.09.

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

[5] Association des Fabricants Européens de Rubans Auto Adhesifs (AFERA), LAM, Laan Copes van Cattenburch 79, NL-2858 EW, The Hauge, Netherlands.

[6] European Norm, (EN); available from Comité Européen de Normalisation (CEN), Rue de Stassart, 36, B-1050, Brussels, Belgium.

2.4 *Pressure Sensitive Tape Council Standards:*[7]

PSTC-1 Peel Adhesion of Single Coated Pressure-Sensitive Tapes at 180°Angle

PSTC-2 Peel Adhesion for Single Coated Pressure-Sensitive Tapes at 90° Angle

PSTC-3 Peel Adhesion of Double Coated Pressure-Sensitive Tapes at 180° Angle

PSTC-4 Adhesion to Liner of Presure-Sensitive Tapes at 180° Angle

3. Terminology

3.1 *Definitions*—Terminology found in Terminology D 996 shall apply.

4. Summary of Test Method

4.1 *Test Method A—Single-Coated Tapes, Peel Adhesion at 180° Angle*—A strip of tape is applied to a standard test panel (or other surface of interest) with controlled pressure. The tape is peeled from the panel at 180° angle at a specified rate, during which time the force required to effect peel is measured.

4.2 *Test Method B—Adhesion to Backing, Single-Coated Tapes*—A strip of the tape under test is applied to a rigid panel. A strip of the tape under test is applied to the backing of the first strip of tape and tested for peel adhesion as described in Test Method A.

4.3 *Test Method C—Double-Coated Tapes*:

4.3.1 *Face Side Adhesion*—The double-coated tape is adhered to a stainless steel panel (or other surface of interest), liner side up. The liner is removed and the exposed adhesive covered with a strip of 0.025-mm [0.001-in.] thick polyester film. The resulting tape is then tested as described in Test Method A.

4.3.2 *Liner Side Adhesion*—The face side adhesive is adhered to a 0.025-mm [0.001-in.] polyester film. The liner is removed and the tape is applied adhesive down to a stainless steel panel (or other surface of interest). Testing is conducted as described in Test Method A.

4.4 *Test Method D—Adhesion to Liner*—The tape is adhered to a standard steel test panel with the liner side up. The liner is peeled from the adhesive in the same manner as in peeling a single-coated tape from a standard panel as described in Test Method A.

4.5 *Test Method E—Adhesion of Adhesive Transfer Tapes*:

4.5.1 *Face Side*—The tape is adhered to a standard panel (or other surface of interest). The liner is removed and a 0.025-mm [0.001-in.] thick strip of polyester is adhered to form a film-backed strip of tape. The adhesion is measured as described in Test Method A.

4.5.2 *Linear Side*—The transfer tape is applied to a strip of 0.025-mm [0.001-in.] thick polyester film, the liner is removed and the resulting tape's adhesion is measured as described in Test Method A.

4.6 *Test Method F—Single-Coated Tapes, 90° Peel*—A strip of tape is applied to a standard test panel (or other surface of interest) with controlled pressure. The tape is peeled from the panel at 90° angle at a specified rate, during which time the force required to effect peel is measured.

5. Significance and Use

5.1 These test methods are tools for quality assurance use. Given specific pressure-sensitive tape and a requirement in terms of the minimum or maximum peel value expected for this tape, the data from the test can be used in conjunction with acceptance criteria.

5.2 Test Method A, B, C, E, or F can show the relative bond strength of a given tape to one or more surfaces (material and texture) as compared to the standard stainless steel panel. Substitution of representative samples of materials in question for the standard steel panel would suffice to do this.

5.3 Test Methods A, B, C, E or F cannot be used to compare two pressure-sensitive tapes of the same type but of different manufacture for their ability to adhere to a surface. This is because the measured peel force is not normalized for a fixed area of stress. The area under stress varies with backing stiffness and adhesive rheology (firmness). Two different tapes seldom agree in these properties.

5.4 Test Method D can show the amount of force required to remove a liner that covers the adhesive side of a tape at a specified peel rate. The force will be different at other peel rates.

5.5 These test methods may not provide design information as there is usually no direct relationship between peel adhesion and any functional requirement.

6. Apparatus

6.1 *Specimen Cutter*[8]—The specimen cutter shall hold two single-edged razor blades in parallel planes, a precise distance apart, to form a cutter of exact specimens widths. Two cutters, 12- and 24-mm [0.05- and 1-in.] cutting width, shall be available. Appropriate alternates which will not cause edge damage may be used.[9]

NOTE 1—The 12-mm [0.5-in.] cutter shall consist of a 12-mm [0.5-in.] thick by 220-mm [8-in.] length aluminum bar stock 12-mm [0.05-in.] wide. The edges for about 125 mm [5 in.] from one end shall be slightly rounded to form a handle. The width of the bar for 75 mm [3 in.] from the opposite end shall be narrowed to exactly 12 mm [0.5 in.] minus the thickness of a single razor blade (one of two used as cutting edges). The razor blades shall be held in position using side plates. The end of the cutter shall be cut away at 45° angle to expose the cutting edge at one end of the blades. The edges shall be separated by 12 ± 0.10 mm [0.5 in.]. The 24-mm [1-in.] cutter shall follow the same description except the bar stock shall be 24.0 mm [1 in.] and shall be narrowed exactly 24 mm [1 in.] minus the thickness of a single razor blade.

6.2 *Dispensing System*—For solvents, such as a wash bottle.

6.3 *Panel*[8]—A stainless steel panel, 50 by 125 mm [2 by 5 in.] no less than 1.1 mm [0.043 in.] thickness, conforming to Type 302 or 304 of Specification A 666, having a bright

[7] Pressure Sensitive Tape Council (PSTC), 400 North Michigan Ave., #2200, Chicago, IL 60611–4267.

[8] Available from Chemsultants International, 9349 Hamilton Dr., Mentor, OH 44061-1118, and PSTC, 400 North Michigan Ave., #2200, Chicago, IL 60611–4267.

[9] These widths correspond to the primary metric (SI) units described in Guide D 5750. These so-called "modular metric" units are used throughout the world, except for Europe. If it is desirable to test slightly different widths (for example, 25 mm) of specimens than those described in 9.1, this should be noted (see 18.1.7) and calculations must also account for the difference (see 17.1).

annealed finish. The surface roughness height shall be 50 ± 25 nm [2.0± 1.0 µin.] arithmetical average deviation from the mean line. Panels showing stains, discoloration, or many scratches are not acceptable. New panels should be cleaned prior to use as described in 11.1, except with ten washes of the final solvent. Between uses, the panel test surface shall be protected from scratches and contamination, and the panels stored at conditions described in Section 10.

6.4 *Roller*—Mechanically or hand operated.[8]

6.4.1 A steel roller 85 ± 2.5 mm [3.25 ± 0.1 in.] in diameter and 45 ± 1.5 mm [1.75 ± 0.005 in.] in width, covered with rubber approximately 6 mm [0.25 in.] in thickness, having a Shore scale A durometer hardness of 80 ± 5. The surface shall be a true cylinder void of any convex or concave deviations. The mass of the roller shall be 2040 ± 45 g [4.5 ± 0.1 lb].

6.4.2 No part of the apparatus shall increase the mass of the roller during use. The roller shall move either mechanically or by hand at the rate of 10 ± 0.5 mm/s [24 ± 0.5 in./min]. A mechanically operated roller is recommended for referee purposes.

NOTE 2—A simple check to determine if the rubber surface is cylindrical is to wrap the roller in a very thin paper (onionskin) and drag it across a flat glass plate on which is placed carbon paper, face up. The carbon rubs off onto the thin paper wrapper to reveal high spots or hollows on the rubber surface.

6.5 *Adhesion Tester*—A constant-rate-of-extension (CRE) tension tester shall be used. It is proposed to use an electronic machine taking at least one reading per mm [0.1 in.] of tape peeled. The tester shall have two clamps with centers in the same plane, parallel with the direction of the motion on the stressing clamp, and so aligned that they will hold the specimen wholly in the same plane; a means of moving the stressing clamp at a uniform rate of 5.0 ± 0.2 mm/s [12 ± 0.5 in./min] and a device for recording load. The instrument shall be calibrated to an accuracy of 0.5 % of full scale and the scale range used for any test shall be such that the mean test level falls within 20 to 80 % of full scale.

6.6 *Fixture*—90° peel for Test Method F.[8]

7. Reagents and Materials

7.1 *Purity of Reagents*—Reagent grade chemicals should be used in all tests. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening accuracy of the determination.

7.2 *Solvents*:

7.2.1 Any of the following solvents may be used for cleaning:

7.2.1.1 Diactone alcohol non-residual, technical grade or better,

7.2.1.2 Methanol (95 %),

7.2.1.3 Methyl ethyl ketone (MEK),

7.2.1.4 n-Heptane, or

7.2.1.5 Acetone.

7.2.2 For referee testing, the final cleaning shall be with MEK or acetone.

7.2.3 Before selecting or using these solvents for cleaning test panels, be sure to read and follow all precautions on the chemical Material Safety Data Sheets (MSDS) and consult with Environmental, Health, and Safety (EHS) professionals.

7.3 *Cleaning Material*—Absorbent, surgical gauze, cotton wool or tissue may be used. To be suitable, materials must be lint-free during use, absorbent, contain no additives that are soluble in the solvents listed in 7.2 and made exclusively from virgin materials.

8. Sampling

8.1 *Acceptance Sampling*—Sampling shall be in accordance with Practice D 3715/D 3715M.

8.2 *Sampling for Other Purposes*—The sampling and the number of test specimens depends on the purpose of the testing. Practice E 122 is recommended. It is common to test at least five specimens of a particular tape. Test specimens should be taken from several rolls of tape, and whenever possible, among several production runs of tape. Strong conclusions about a specific property of a tape cannot be based on tests of a single unit (roll) of a product.

9. Test Specimen

9.1 The specimen shall be 24-mm [1-in.] wide. If the specimen is of a different width, refer to Note 4. A tolerance of± 0.5 mm [±1/64 in.] shall be allowed. The length shall be approximately 300 mm [12 in.].

9.2 Discard at least three but no more than six outer wraps of tape from the sample roll before taking the specimens for testing.

9.3 Remove one specimen per sample roll for each test to be performed. Remove the specimen from a freely rotating roll at the rate of 500 to 750 mm/s [20 to 30 in./s]. Where width or other factors causing a high adherence to backing makes it impossible to remove the specimen at the prescribed rate, remove it at a rate as close to 500 mm/s [20 in./s] as possible.

9.4 When tape is wider than 24 mm [1 in.], specimens of the widest specified width are to be cut from the center of a strip removed from the roll in accordance with 9.3.

9.5 Apply specimen within 5 min after unwinding.

10. Conditioning

10.1 Condition the sample rolls of tape in the standard conditioning atmosphere as described in Practice D 4332 for a period of not less than 24 h. Test at these conditions. **Warning**—The tester should know that by prolonged handling heat is transmitted to the stainless steel test panel. Therefore, during and after application of the adhesive tape to the test panel, the panel should be handled as little as possible.

11. Test Method A—Single-Coated Tapes at 180° Angle

11.1 Dispense one of the solvents listed in 7.2.1 onto the panel, wiping it to dryness with fresh absorbent cleaning material. Repeat for a total of three washes with this solvent. The panel shall be allowed to dry at standard conditions for at least 10 min. If cleaned panel is not used within 10 h, it should be recleaned.

NOTE 3—Discard panels showing stains, discoloration, or many scratches. Avoid contacting panel surface with fingers. During storage, panels should be protected from damage or contamination.

11.2 Remove a 300-mm [12-in.] specimen of the tape to be tested, as described in 9.3. Fold 12 mm [0.5 in.] at one end, adhesive to adhesive to form a tab. Touch other end of the specimen to an end of the test panel. Hold the other end of the specimen so that it does not make contact with the panel but is positioned loosely above it. Roll mechanically or by hand twice in each lengthwise direction, causing the roller to apply the tape to the panel. This prevents entrapment of air between the adhesive and the panel. Should this occur, discard the specimen.

NOTE 4—Where the width of the specimen is less than 24 mm [1 in.], prior to applying test specimen, apply a strip or strips of the tape, to give an equivalent width of 24 mm [1 in.] for rolling purposes or use roller of appropriate weight to obtain a line pressure equal to 2040 g [4.5 lb] for 24 mm [1 in.] width ± 35 %.

11.3 Individually prepare each specimen and test within 1 min.

NOTE 5—Longer dwell time will give different results. Peel adhesion increases with dwell time at different rates for various tapes. A longer dwell time may be chosen purposely.

11.4 Double back the folded end of the tape at an angle of 180° and peel 25 mm [1 in.] of the tape from the panel. Clamp that end of the panel into the movable jaw of the adhesion testing machine and the free end of the tape into the other jaw. Operate the movable jaw at 5.0 ± 0.2 mm/s [12 ± 0.5 in./min].

11.5 After the movable jaw is started in motion, disregard the values obtained while the first 25 mm [1 in.] of tape is mechanically peeled. Use the average force obtained during peeling of the next 50 mm [2 in.] as the adhesion value.

12. Test Method B—Adhesion to Backing of Single-Coated Tapes

12.1 Apply a sample of the tape under test to a rigid panel such as the standard stainless steel panel. Roll firmly. Apply a second strip of the tape to the backing of the strip on the test panel as described in 11.2 taking care to align the edges of the second specimen with those of the strip in the test panel. Complete testing as described in 11.3-11.5.

13. Test Method C—Adhesion of Double-Coated Tape

13.1 *Face Side*—Follow the procedure of 11.1-11.3, then remove the liner and superimpose on the test strip a strip of 0.025-mm [0.001-in.] thick polyester film, as wide as or slightly wider than the double-coated tape. Apply this film in the manner of applying the double-coated test strip to the panel so that the roller makes the actual application of the film to the double-coated tape.

NOTE 6—The two passes of the roller in applying polyester film may be made using the hand roller. The rolling rate may be increased to 50 mm/s [2 in.]/s. Continue in accordance with 11.4 and 11.5.

13.2 *Liner Side*—Adhere the face side of the specimen to a strip of 0.025-mm [0.001-in.] thick polyester film in the manner described in 11.2 so that the roller makes actual application of the tape to the film. Trim the film to be as wide as or slightly wider than the tape. Remove the liner. Continue in accordance with 11.1-11.5.

14. Test Method D—Adhesion to Liner of Double-Coated and Single-Coated Tapes

14.1 *Double-Coated Tapes*—Follow 11.1. Apply 125 mm [5 in.] of one end of the specimen to the panel with the adhesive side (face side) down. Make four passes with the roller, twice in each direction at a rate of 10 ± 0.5 mm/s [24± 0.5 in./min]. Separate the liner from the tape at the free end and cut away the free tape. Do not disturb the line adhered to the tape on the panel. Double back the liner and proceed in accordance with 11.4 and 11.5.

14.2 *Single-Coated Tapes*—Follow 11.1. Apply a strip of double-coated tape as wide as the specimen, the full length of the panel. Remove the liner from the single-coated tape. Superimpose 125 mm [5 in.] of one end of the specimen, backing side down, against the double-coated tape on the panel. Make four passes with the roller, twice in each direction at a rate of 10 ± 0.5 mm/s [12 ± 0.5 in./min]. Separate the liner from the tape at the free end and cut away the free tape. Do not disturb the liner adhered to the tape on the panel. Double back the liner and proceed in accordance with 11.4 and 11.5.

15. Test Method E—Adhesion of Adhesive Transfer Tapes

15.1 *Face Side*—Follow procedure of 11.1-11.3, then remove the liner and superimpose on the test strip a strip of 0.025-mm [0.001-in.] thick polyester film, as wide as or slightly wider than the adhesive transfer tape. Apply this film in the manner of applying described in 11.2 so that the roller makes the actual application of the film to the adhesive transfer tape. Proceed as described in 11.4 and 11.5.

15.2 *Liner Side*—Apply to the face side of the adhesive transfer tape a trip of 0.025-mm [0.001-in.] thick polyester film. Make two passes of the roller using a hand roller of the same size. The roller rate may be increased to 50 mm/s [2 in.]/s. Remove the liner from the tape and apply to a standard test panel as described in 11.2 and 11.3. Proceed as described in 11.4 and 11.5.

NOTE 7—In spite of its apparent simplicity, the use of this test method is rather delicate and involves the use of great care in following the procedure as written to give coherent and identical results between one laboratory and another, as well as between one operator and another.

16. Test Method F—Single Coated Tapes at 90° Angle

16.1 Prepare specimen for testing as described in 11.1-11.3.

16.2 Double back the folded end of the tape at a 90° angle and peel 25 mm [1 in.] of the tape from the panel. Place the panel into a fixture clamped to the moving jaw of the adhesion tester so that it will maintain a peeling angle at 90° during the peeling of the next 75 mm [3 in.] of tape and the free end of the tape into the other jaw. Operate the moving jaw at 5.0 ± 0.2 mm/s [12 ± 0.5 in./min].

16.3 Proceed as described in 11.5.

17. Calculation

17.1 In the SI system, if observed pull value is not in Newtons (N), convert to N per 10 mm by converting the pull value to N and dividing by the width of the tape, mm, and

multiplying by 10. In the English System, if the observed value is not in ounces, convert to ounces and divide by the specimen width.

18. Report

18.1 Report the following information:

18.1.1 Statement that these test methods were used and indication of any deviations from the test methods as written,

18.1.2 Identification of the source of each roll of tape tested,

18.1.3 Description of any anomalous behavior during testing (such as adhesive transfer or splitting),

18.1.4 Peel adhesion value, N/10 mm to the nearest 0.1 N/10 mm [oz/in. to the nearest 1 oz/in.]. Use actual specimen width in calculations,

18.1.5 Identification of the test method used (A, B, C, D or E) and, if C or E, whether face side or liner side,

18.1.6 Dwell time, if less or greater than the standard 1 min,

18.1.7 Test specimen widths, if different from 9.1, and

18.1.8 Conditions of test, if other than 23 ± 1°C [73.4 ± 3.5°C] or 50 ± 5 % RH.

19. Precision and Bias

19.1 *Summary*—The difference between two single observations should not exceed 18.8 % of the average of the two observations in 95 out of 100 cases when both observations are taken by the same well-trained operator using the same piece of test equipment and the specimens randomly drawn from the same sample of material. Larger differences may occur under all other circumstances. The true value of peel adhesion at 180° angle can only be defined in terms of a specified test method. Within this limitation, Test Methods D 3330/D 3330M has no known bias. The bias for this summary and for evaluations made under other conditions are explained in 19.2-19.5.

NOTE 8—Of the six methods in these test methods only Test Method A was used in determining the precision. It is believed that the precision for the other test methods would be similar. It would probably not apply to Test Method C.

19.2 *Interlaboratory Test Data*[10]—An interlaboratory study was made in 1980 in which randomly drawn samples of two materials were tested in each of six laboratories. Two operators in each laboratory each tested 3 specimens from each of 3 rolls of each material. The components of variance for peel adhesion at 180° results expressed as coefficients of variation (see Note 8) and were calculated to be as follows:

	Specimens of the Same Material	Specimens of Different Material
Single-operator component	4.8 % of the average	9.7 % of the average
Within-Laboratory component	2.1 % of the average	0 % of the average
Between-Laboratory component	9.0 % of the average	3.7 % of the average
Replication component	4.9 % of the average	4.9 % of the average

19.3 *Critical Differences*—For the components of variance reported in 19.2, two averages of observed values should be considered significantly different in the 95 % probability level if the difference equals or exceeds the critical difference shown in Table 1.

TABLE 1 Critical Difference, Percent of Grand Average for the Conditions Noted[A,B]

Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Specimens of the Same Material:			
1	18.8	19.7	42.5
5	14.5	15.6	29.4
10	13.9	15.0	29.1
Specimens of Different Material:			
1	30.1	30.1	31.8
5	28.0	28.0	29.4
10	27.3	27.3	29.1

[A]The critical differences were calculated using t = 1.960 which is based on infinite degrees of freedom.

[B]To convert the values of the critical differences to units of measure, multiply the average of the two specific sets of data being compared by the critical differences expressed as a decimal fraction.

NOTE 9—The tabulated values of the critical differences and confidence limits should be considered to be general statements particularly with respect to between-laboratory precision. Before a meaningful statement can be made about two specific laboratories, the amount of statistical bias between them, if any, must be established with each comparison being based on recent data obtained on specimens randomly drawn from one sample of the material to be evaluated.

19.4 *Confidence Limits*—For components of variance reported in 19.2, single averages of observed values have the following 95 % confidence limits. See Note 9 and Table 2.

19.5 *Bias*—No justifiable statement can be made on the bias of Test Method D 3330/D 3330M for testing peel adhesion since the true value cannot be established by accepted referee method.

20. Keywords

20.1 adhesion to backing; adhesion to liner; peel adhesion at 90° angle; peel adhesion at 180° angle; pressure sensitive tape

TABLE 2 Width of 95 % Confidence Limits, Percent of the Grand Average for the Conditions Noted[A,B]

Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Specimens of the Same Material:			
1	±13.3	±13.9	±30.0
5	±10.3	±11.0	±20.8
10	±9.8	±10.6	±20.6
Specimens of Different Material:			
1	±21.3	±21.3	±22.5
5	±19.8	±19.8	±20.8
10	±19.3	±19.3	±20.6

[A]The confidence limits are calculated using t = 1.960 which is based on infinite degrees of freedom.

[B]To convert the values of the confidence limits to units of measure, multiply the average of the specific set of data which is of interest by the confidence limits expressed as a decimal fraction.

[10] Supporting data are available from ASTM headquarters. Request RR: D-1–1002.