Designation: F2992 – 23

Standard Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing with Tomodynamometer Test Equipment[1]

This standard is issued under the fixed designation F2992; 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 covers the measurement of the cut resistance of a material when mounted on a specimen holder and subjected to a cutting edge under a specified load using a tomodynamometer.[2]

1.1.1 This procedure is not valid for high-porosity materials which allow cutting edge contact with the mounting surface prior to cutting.

1.1.2 Test apparatus may have limitations in testing materials with a thickness greater than 20 mm.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D123 Terminology Relating to Textiles

D1000 Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications

D1776/D1776M Practice for Conditioning and Testing Textiles

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

F1494 Terminology Relating to Protective Clothing

2.2 *ISO Standards:*[4]

ISO 13997 Protective Clothing—Mechanical Properties—Determination of Resistance to Cutting by Sharp Objects

3. Terminology

3.1 *Definitions:*

3.1.1 *calculated cutting load, n*—in cut resistance testing, the load required to cause a cutting edge to produce a cut-through when it traverses the reference distance across the material being tested.

3.1.1.1 *Discussion*—The calculated cutting load is determined by performing a series of tests at three or more loads as described in Section 11. A material with a higher calculated cutting load is considered to be more cut resistant.

3.1.2 *cut resistance, n*—in blade cut testing, the property that hinders cut-through when a material or a combination of materials is exposed to a sharp-edged device.

3.1.3 *cut-through, n*—in blade cut resistance tests, the penetration of the cutting edge entirely through material as indicated by electrical contact of the cutting edge and the conductive strip or substrate.

3.1.4 *cut-through distance, n*—in cut resistance testing, the distance of required travel by the cutting edge to cut through the specimen.

3.1.5 *cutting edge, n*—in cut resistance tests, a sharp-edged device used to initiate cut-through of a planar structure.

3.1.6 *no cut, n*—in cut resistance testing, a trial for which the load used is insufficient to cause a cut-through in the maximum allowable blade travel of the apparatus.

[1] This test method is under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and is the direct responsibility of Subcommittee F23.20 on Physical.

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[2] Derived from the Greek *tomo*, to cut or slice, *dynamo*, force or energy, and *meter*, to measure. From Masse, S., Lara, J., Sirard, C., and Daigle, R., "Basic Principles Used in the Development of a New Cut-Test Machine for Standardization," ASTM Special Technical Publication No. 1273, 1997, pp. 66–83.

[3] 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.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

3.1.6.1 *Discussion*—For this test method, the maximum allowable blade travel is 50 mm (1.97 in.).

3.1.7 *protective clothing, n*—an item of clothing that is specifically designed and constructed for the intended purpose of isolating all or part of the body from a potential hazard; or, isolating the external environment from contamination by the wearer of the clothing.

3.1.7.1 *Discussion*—In this test method, the potential hazard is cutting.

3.1.8 *reference distance, n*—in cut resistance testing, a standardized distance for a blade to travel across a material to produce a cut-through.

3.1.8.1 *Discussion*—For this test method, the reference distance is 20 mm (0.8 in.).

3.2 *Additional Terminology*—Terms relevant to textiles are defined in Terminology D123. Terms relevant to protective clothing are defined in Terminology F1494.

4. Summary of Test Method

4.1 A cutting edge under a specified load is moved one time across a specimen mounted on a specimen holder.

4.2 The cut-through distance from initial contact to cut-through is determined for each load.

4.2.1 A series of tests, at a minimum of three different loads, must be performed to establish a range of cut distance at these different loads.

4.3 The test method is repeated using multiple loads to determine the calculated cutting load for the material.

5. Significance and Use

5.1 This test method assesses the cut resistance of a material when exposed to a cutting edge under specified loads. Data obtained from this test method can be used to compare the cut resistance of different materials.

5.2 This test method only addresses that range of cutting hazards that are related to a cutting action by a smooth sharp edge across the surface of the material. It is not representative of any other cutting hazard to which the material may be subjected, such as serrated edges, saw blades, or motorized cutting tools. Nor is it representative of puncture, tear, or other modes of fabric failure.

6. Apparatus

6.1 *Test Principle*—The principle of the cut test is to measure the distance traveled by a cutting edge as it is maintained under a load during the test. The cut test apparatus consists of the following primary components (see Fig. 1): blade holder (A) and straight line mechanism, a cutting edge (B), a specimen (C) with conductive strip (D), and double-sided mounting tape (E) mounted to a fixed specimen holder (F). The apparatus should propel the cutting edge across the specimen until sufficient work is applied to cause the specimen to cut through.

6.2 *Test Apparatus*—A tomodynamometer is capable of measuring the entire range of cut-resistant materials through a horizontal constant speed of blade movement. The maximum linear displacement of the blade is 70 mm (2.75 in.) for the cutting edge. A constant perpendicular force is applied to the specimen throughout blade movement. The test apparatus (see Fig. 2) consists of a motor and gearhead (*1*) with slide system (*2*) and blade support/clamp mechanism (*3*) and blade (*4*) in contact with the specimen mounted on a cantilevered specimen holder and specimen holder mount (*5*). The beam (*6*) is connected to the specimen holder mount. Cutting edge displacement is measured by a distance meter (*7*) capable of measuring to 0.1 mm (0.004 in.). Weights are placed on the platen (*8*). These weights generate the load needed to penetrate the moving edge into the specimen and produce a cut-through. In this example, the resulting load applied to the specimen against the blade equals twice the total weight placed on the platen. The calibration weights (*9*) are used to balance the beam with sample prior to adding weight to the lever arm. Movement of the specimen holder and specimen holder mount mechanism is facilitated by use of the loading/unloading handle (*10*). Leveling adjustment is facilitated by the level mechanism (*11*). The apparatus should be capable of loads ranging from 10 g to 15 kg (0.35 oz to 33 lb).

6.2.1 *Cutting Speed*—The apparatus shall propel the cutting edge across the specimen at a constant speed of 2.5 ± 0.5 mm/s (0.10 in./s).

6.2.2 *Cut-Through Distance*—Cut-through is detected by an electrical contact between the cutting edge and conductive strip.

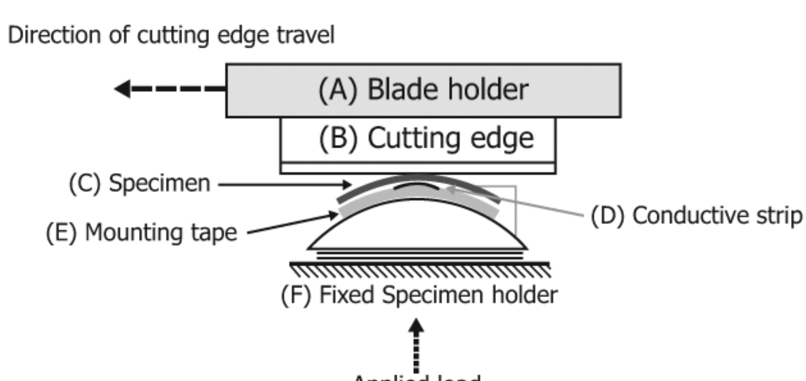

FIG. 1 Schematic of Cut Test Principle

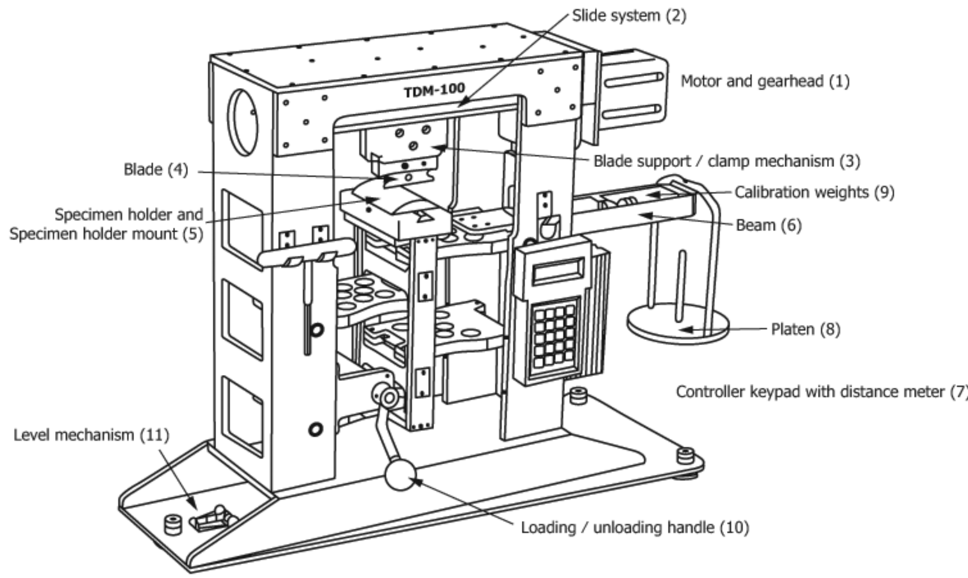

FIG. 2 Schematic of the Test Apparatus (Front View)

6.2.3 *Specimen Holder*—The top surface of the specimen holder is a rounded form which has an arc of at least 32 mm (1.25 in.) in a circle having a radius of 38 mm (1.5 in.). The surface of the specimen holder shall be conductive and made of metal.

6.3 *Cutting Edge*—Single-edged razor blades[5] shall be used as the cutting edge. The blades shall be made of stainless steel with a hardness greater than 45 HRC. Blades shall be 1.0 ± 0.5 mm (0.039 ± 0.020 in.) thick and ground to a bevel width of 2.5 ± 0.2 mm (0.098 ± 0.008 in.) along a straight edge resulting in a primary bevel angle of 22° ± 2°. The blade should also contain a honed secondary bevel at the cutting edge with an inclined angle of 36° ± 2°. Blades shall have a cutting edge length greater than 65 mm (2.56 in.) and shall have a width greater than 18 mm (0.71 in.).

6.4 *Conductive Strip*—A 6 mm (0.26 in.) wide copper or aluminum conductive strip with adhesive backing will be used that is no thicker than 0.3 mm (0.01 in.). The conductive strip will be centered down the length of the specimen holder between the sample and mounting tape. For samples that contain electrically conductive materials, elimination of the conductive metal strip is permitted.

6.5 *Mounting Tape*—Double-sided tape[6] shall be used to secure the test specimen to the apparatus. The tape should have a cloth carrier and rubber-based adhesive on both sides with a total thickness of 0.38 ± 0.25 mm, weight of 473 ± 33 g/m^2, and a minimum tensile strength of 90 N/cm (see Test Methods D1000 for details on test methods for adhesive tape).

7. Hazards

7.1 The cut test equipment can pose a potential hazard to the technician if proper safety precautions are not followed. The cut test apparatus is to be used only by authorized personnel that have been properly trained. Wear appropriate protective gloves while operating the cut test equipment.

7.2 Store used blades in a sealed container.

7.3 Remove blades from the apparatus at the end of each test or when the apparatus is not in use.

7.4 Keep hands out of cutting area when a blade is installed in the apparatus and when the apparatus is operating.

7.5 Turn off machine before making instrument adjustments to avoid the chance of a low-voltage shock.

8. Sampling and Test Specimens

8.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of shipping units directed in an applicable material specification.

8.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, take at random from each shipping unit in the lot sample the number of packages or pieces directed in an applicable material specification or other agreement between the purchaser and the supplier.

8.3 *Protective Clothing Sample*—A sample of the actual protective clothing article.

8.4 *Test Specimens:*

8.4.1 Take test specimens at random from each sample.

8.4.1.1 When performing up to 15 cut tests per specimen, as when determining the reference load of the material, the specimen shall have a minimum dimension of 25.4 by 100 mm (1.0 by 4.0 in.).

8.4.1.2 For textile materials, cut the specimen on the bias as to create an angle of 0.785 rad (45°) between the machine and

[5] Blade 88-0121 Type GRU-GRU textile blade available from Accutec, Inc. (formerly American Safety Razor Company), One Razor Blade Lane, Verona, VA 24482 has proven satisfactory for this test method. It is the sole source of supply of the apparatus known to the committee at this time. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[6] Polyken 108Fr Double-Coated Cloth Tape manufactured by Berry Plastics Corporation or equivalent has proven satisfactory for this test method.

cross-machine directions of the material (see Terminology D123 for the definition of machine directions of textile materials).

8.4.1.3 For gloves and sleeves, cut the specimen from the primary protective area of the glove, usually the palm area or other area claiming to be cut resistant. Cut the specimen on the bias as to create an angle of 0.785 rad (45°) between the machine and cross-machine directions of the material.

NOTE 1—For small samples of insufficient width to cut the sample on the bias, such as protective clothing, cut the test specimen parallel to the machine direction up to the maximum allowable width and then rotate it 0.785 rad (45°) when mounting it on the apparatus.

9. Calibration and Standardization

9.1 *Beam Balancing Procedure – #1:*

9.1.1 Remove any sample or tape from the sample holder.

9.1.2 Install sample holder on the base.

9.1.3 Carefully control the vertical movement of the sample holder when unlocking the cam lock device with the loading/unloading handle.

9.1.4 Place the mechanism horizontally.

9.1.5 If mechanism stays in equilibrium, the apparatus is correctly balanced. If mechanism loses equilibrium, follow procedure #2 (9.2) for beam balancing.

9.2 *Beam Balancing Procedure – #2:*

9.2.1 Lock movement of the beam in the higher position with cam lock device.

9.2.2 Remove blade holder with the quick release ball lock device.

9.2.3 Place the mechanism horizontally.

9.2.4 Counterbalance with the two fine adjustment nuts until the mechanism stays in equilibrium.

9.3 *Validation of Cutting Edge Supply:*

9.3.1 *Calibration Material*—Calibration material is a neoprene sheet,[7] having a hardness of 50 ± 5 Shore A and a thickness of 1.57 ± 0.05 mm (0.062 ± 0.002 in.).

9.3.1.1 Store the calibration material under controlled laboratory conditions described in Practice D1776/D1776M in an opaque container to prevent deterioration by heat or ultraviolet light.

9.3.2 *Blade Validation Procedure:*

9.3.2.1 Take a specimen of the calibration material and follow the mounting procedure as described in 11.1.

9.3.2.2 Calculate the average cut-through distance using a minimum of one blade cut out of 20 for each blade supply by performing a cut test with each blade following the test procedure described in 11.2 using a cutting load of 500 gf.

9.3.2.3 To be a valid blade supply, the average cut-through distance for the blade supply must be between 15.0 and 25.0 mm (0.6 and 1.0 in.), and the cut-through distances for all the tested blades in the supply should not differ by more than 10 mm (0.4 in.).

[7] Product reference #NS5550-062-010 black (comparable to NS-5550 Neoprene Sheet Stock Material) manufactured by Gindor, Inc., 66101 US 33, Goshen, IN 46526-9483 (website: www.gindor.com) has proven satisfactory for this method. If you are aware of alternative suppliers, please provides this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

10. Conditioning

10.1 Condition test specimens as indicated in Practice D1776/D1776M.

11. Procedure

11.1 *Specimen Mounting:*

11.1.1 Cover the specimen holder surface with double-sided tape and place a 6 mm (0.25 in.) conductive strip with the adhesive side up centered down the length of the specimen holder on the double-sided tape. Clip the end of this strip to the specimen holder, or attach it securely to the electrical circuit that detects cut-through. Without stretching or distorting the material, place the test specimen over the tape with the surface to be cut facing up. Apply firm pressure on the specimen to secure it to the specimen holder. For samples that contain electrically conductive materials, the conductive strip can be eliminated.

NOTE 2—The tape and strip can also be applied directly to the sample before the test specimen is cut and then mounted directly to the specimen holder. This procedure is helpful for materials that curl or distort when being cut from the sample.

11.1.2 Insert the specimen holder in the specimen holder mount with the sample facing the blade and position the specimen holder in place.

11.1.3 Balance the beam with sample prior to adding weights to the platen. This can be done either by adjusting the calibration weights or by adding half of the sample mounting weight to the platen.

11.2 *Test Procedure for Measuring the Cut-Through Distance:*

11.2.1 Insert a new blade from a validated blade supply in the blade clamp and tighten the blade clamping system.

NOTE 3—Refer to 9.3 for instructions on how to validate the blade supply.

11.2.2 Verify that the cutting arm is at the ready position, making certain that only the blade edge and not the corner of the blade will touch the specimen. All cuts should be made with the blade moving right to left.

11.2.3 Select and install weights to produce the desired cutting load.

11.2.4 Zero the blade travel distance meter.

11.2.5 Carefully ease the specimen into contact with the blade and immediately start the apparatus.

11.2.6 After cut-through is detected and the motor arm stops, record the cut-through distance.

11.2.6.1 If no cut-through occurs within 50.0 mm (1.97 in.) of blade travel, stop the machine and indicate that the load was insufficient to cut through the specimen by reporting a *no cut*.

11.2.7 Lock the lever arm with blade retracted from the specimen, remove the weights, and discard the used blade.

11.3 *Test Procedure for Determining the Calculated Cutting Load:*

11.3.1 Repeat the test procedure described in 11.2 to obtain a minimum of 15 data points using a minimum of three different loads. The loads should be distributed to produce cut-through distances in the range of 5.0 to 50.0 mm (0.2 to

1.97 in.). When performing multiple cut tests per specimen, each cut should be spaced a minimum of 6.35 (0.25 in.) from the previous cut.

11.3.1.1 Five replicated tests at each of three different loads have been found to be adequate; however, an alternate allocation of test loads may be considered for highly reinforced materials. If possible, the loads should be selected as to produce five data points in the 5 to 20 mm (0.2 to 0.8 in.) cut-through distance range, five data points in the 20 to 33 mm (0.8 to 1.3 in.) cut-through distance range, and five data points in the 33 to 50.0 mm (1.3 to 1.97 in.) cut-through distance range. For more details on selecting the different loads to use with this procedure, see Appendix X1.

12. Calculation of Results

12.1 *Blade Sharpness Correction:*

12.1.1 Calculate the blade sharpness correction factor, C_s, of the blade supply by dividing 20 mm (0.8 in.) by the average cut-through distance determined in the blade validation procedure described in 9.3.2.

12.1.2 Multiply the measured cut-through distances recorded during the test by C_s to create normalized distance data.

12.2 *Calculated Cutting Load Determination:*

12.2.1 When testing specimens using multiple loads for the purposes of determining the calculated cutting load (see 11.3), perform an inverse regression analysis (see Note 4 and Note 1) of the cutting loads and the log of the normalized cut-through distances to estimate the calculated cutting load required to produce cut-through at the reference distance of 20 mm (0.8 in.). For more details about performing the regression analysis and an example calculation, refer to Annex A1.

NOTE 4—The use of the common logarithm of the cut-through distance when performing the regression analysis has been found to provide the most reliable method for estimating the calculated cutting load.

13. Interpretation of Results

13.1 Materials that can do either of the following are capable of delivering better cut resistance:

13.1.1 Provide higher cut resistance by demonstrating a longer distance traveled when equal loads are mounted.

13.1.2 Provide higher cut resistance by demonstrating resistance to higher loads at the same cut-through distance, which can be accomplished by determining the calculated cutting load for the material.

14. Report

14.1 Report the following:

14.1.1 Test was performed in accordance with Test Method F2992 for tomodynamometer.

14.1.2 Date when test was performed.

14.1.3 Name and model number of the cut testing device used.

14.1.4 *Sample Identification*—Sample description of fabric or material to indicate construction, fiber (or blends), and areal density in g/m^2 (oz/yd^2).

14.1.5 Identification of blade supply designation and lot number.

14.1.6 Results of the blade validation indicating that the blade supply is valid and indicate the blade sharpness correction factor (C_s).

14.1.7 *Test Result:*

14.1.7.1 Report the loads used, the measured cut-through distances at each load, the calculated cutting load, the standard deviation, and the coefficient of determination, R^2, of the regression analysis.

14.1.7.2 Plot the regression curve using the normalized distances and weights used (see Annex A1, Fig. A1.2).

14.1.8 Report any variations in procedure from this test method.

15. Precision and Bias

15.1 The precision of this test method is based on an interlaboratory study of ASTM F2992, Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing with Tomodynamometer Test Equipment, conducted in 2022. Eight volunteer laboratories were asked to test seven different materials. Every "test result" represents an individual determination, and all participants were instructed to report three replicate test results for each material. Practice E691 was followed for the design of study and analysis of the data; the details are given in ASTM Research Report No. RR:F23-2001.[8]

15.1.1 *Repeatability Limit (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would, in the long run, in the normal and correct operation of the test method, exceed the determined values only in one case in 20.

15.1.1.1 Repeatability limit can be interpreted as the maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

15.1.1.2 Repeatability limits are listed in Table 1.

15.1.2 *Reproducibility Limit (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

15.1.2.1 Reproducibility limit can be interpreted as the maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

15.1.2.2 Reproducibility limits are listed in Table 1.

15.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

15.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method; therefore, no statement on bias is being made.

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F23-2001. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Cut Resistance (gf)

Material	Number of Laboratories n	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Reproducibility Standard Deviation S_R	Repeatability Limit	Reproducibility Limit
Polyester Nylon PU Palm Dip	7	216	11	86	30	240
Neoprene	7	497	18	34	51	96
UHMWPE Knit	7	370	31	64	88	179
Knit p Aramid	7	1349	61	129	171	362
Glass UHMWPE Polyester	7	1677	58	368	161	1030
2500–3500 g Composite Steel UHMWPE Polyester	7	3123	119	600	332	1679
Composite Steel UHMWPE Polyester	7	9384	362	1468	1015	4111

[A] The average of the laboratories' calculated averages.

15.3 The precision statement was determined through statistical examination of 147 results, from seven laboratories, on seven materials.

16. Keywords

16.1 calculated cutting load; cut protection; cut resistance; cut-through distance; protective clothing

ANNEX

(Mandatory Information)

A1. CALCULATED CUTTING LOAD DETERMINATION

A1.1 Regression Analysis

A1.1.1 Using the loads as the independent variable, *x*, and cut-through distances as the dependent variable, *y*, perform an inverse linear regression analysis[9] by first performing a log transformation of the cut-through distances and then calculating the slope and intercept of the regression line as indicated in Eq A1.1.

$$y' = b_0 + b_1 x \quad (A1.1)$$

where:

y' = log transformation of the normalized cut-through distance, log10y,
X = applied load,
b_0 = intercept of the regression line, and
b_1 = slope of the regression line.

A1.1.2 The load required to produce a cut-through at the reference distance, y_r, of 20 mm can then be estimated from Eq A1.2. This load, known as the calculated cutting load, x_r, can be used to compare the cut resistance of samples.

A1.1.2.1 Calculated cutting load equation:

$$x_r = (\log_{10}(y_r) - b_0)/b_1 \quad (A1.2)$$

where:

x_r = calculated cutting load, gf, and
y_r = reference distance, 20 mm.

[9] Neter, J., Kunter, M. H., and Wasserman, W., *Applied Linear Statistical Models*, Irwin Homewood, IL, 1990.

A1.1.3 The standard deviation, *s*, and 95 % confidence interval of the calculated load estimate can be calculated using Eq A1.3 and A1.4.

A1.1.3.1 Standard deviation of the calculated cutting load:

$$s = \sqrt{\frac{MSE}{b_1^{\,2}}\left(1 + \frac{1}{n} + \frac{(x_r - X)^2}{\Sigma(x_i - X)^2}\right)} \quad (A1.3)$$

where:

MSE = mean square error,
X = mean load, and
N = number of measurements.

A1.1.3.2 95 % confidence interval of the calculated cutting load:

$$x_r \pm t_{\left(1-\frac{a}{2};\,n-2\right)} s \quad (A1.4)$$

A1.2 Example Calculation

A1.2.1 An example dataset of loads and normalized cut-through distances is provided in Table A1.1. The calculated cutting load, x_r, of the dataset is 435 gf with a standard deviation of 45.4 gf resulting in a 95 % confidence limit of ±98 gf ($337 \le x_r \le 533$ gf). The R^2 of regression line is 0.94.

A1.2.2 The results of the regression analysis using standard MS Excel formulas are shown in Table A1.2 with the corresponding cell formulas shown in Table A1.3. The application of the regression analysis is shown graphically in Fig. A1.1. A plot of the untransformed (normalized) cut-through distances versus applied load is shown in Fig. A1.2 illustrating the

TABLE A1.1 Example Cut Test Data Used to Determine the Calculated Cutting Load

Load, x, gf	Cut-Through Distance, y, mm
200	45.8
200	49.2
200	42.3
200	41
200	45.4
400	20.1
400	22.2
400	18.6
400	20.4
400	24.6
600	12.4
600	15.5
600	13.3
600	10.8
600	8.9

logarithmic shape of the trend line. The results of the step-wise calculations and parameters are as follows:

A1.2.2.1 Regression parameters:

n = 15
b_0 = 1.922
b_1 = –1.43E-3
MSE = 3.95E-3
X = 400
$\Sigma(x_i - X)^2$ = 400 000
C_s = 1.000

A1.2.2.2 Regression equation:

$$y' = 1.922 - 0.00143x \quad (A1.5)$$

A1.2.2.3 Calculated cutting load:

$$y_r = 20.0 \text{ mm} \quad (A1.6)$$

$$x_r = \frac{\log_{10}20.0 - 1.922}{-0.00143} = 435\ gf \quad (A1.7)$$

$$s^2 = \frac{0.00395}{-0.00143^2}\left[1 + \frac{1}{15} + \frac{(435 - 400)^2}{400000}\right] = 2065 \quad (A1.8)$$

$$s = \sqrt{2065} = 45.4\ gf \quad (A1.9)$$

A1.2.2.4 95 % confidence limit and interval:

$$t_{\left(1 - \frac{0.95}{2};\, 13\right)} = 2.16 \quad (A1.10)$$

$$x_r \pm 2.16(45.4) = 435 \pm 98\ gf \quad (A1.11)$$

$$337 \leq x_r \leq 533\ gf \quad (A1.12)$$