



Designation: F 1790 – 04

# Standard Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing<sup>1</sup>

This standard is issued under the fixed designation F 1790; 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 ( $\epsilon$ ) 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 mandrel and subjected to a cutting edge under a specified load.

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 thicker materials; see the Annex, or the equipment manufacturer's specifications.

1.2 The values stated in SI units or in other units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

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:*<sup>2</sup>

D 123 Terminology Relating to Textiles

D 1776 Practice for Conditioning Textiles for Testing

F 1494 Terminology Relating to Protective Clothing

## 3. Terminology

3.1 *Definitions:*

3.1.1 *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.

3.1.2 *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.

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

3.1.4 *protective clothing, n*—a product which is specifically designed and constructed for the intended purpose of isolating parts of the body from a potential hazard; or as a barrier to prevent the body from being a source of contamination.

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

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

3.1.5.1 *Discussion*—For this test method, the reference distance is 20 mm [0.8 in.].

3.1.6 *rating force, 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.

3.1.6.1 *Discussion*—The rating force is the final result of this test method, the force required to produce a cut through in 20 mm of blade travel. A material with a higher rating force is considered to be more cut resistant.

3.2 *Additional Terminology*—Terms relevant to textiles are defined in D 123. Terms relevant to protective clothing are defined in F 1494.

## 4. Summary of Test Method

4.1 A cutting edge, with a specified load, is moved one time across a specimen mounted on a mandrel.

4.2 The distance is recorded, from initial contact to cut through, for each load.

4.2.1 A series of tests, at a minimum of three different loadings must be performed to establish a range and to determine the rating force.

4.3 The resulting load versus distance curve can be used to determine cut resistance of the specimen.

## 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.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee F23 on Protective Clothing and is the direct responsibility of Subcommittee F23.20 on Physical Properties.

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<sup>2</sup> 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.

5.2 This test method only addresses that range of cutting hazards that are related to a cutting action 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 *Cut Test Apparatus:*

6.1.1 The cut test apparatus is designed to measure the distance traveled by the cutting edge as it is maintained under a known load during the test, so that force distance data can be generated. A schematic of the cut test principle is shown in Fig. 1. A motor-driven balanced arm (A) holding the cutting edge (B) in contact with the specimen mounted on a mandrel (C). The arm propels the blade across the specimen until sufficient force is applied to cause the specimen to sustain a cut through. The force is generated entirely by the weights mounted on the lever arm assembly. See Annex for details on available cut protection test equipment.

6.1.1.1 The cut test apparatus is powered by a constant speed electric motor. The motor speed is adjusted by a power controller. The cut through is electronically recorded as the cutting edge cuts through the specimen and makes electrical contact with the conductive strip or substrate. The distance traveled is recorded on a distance meter capable of recording to 0.1 mm [0.004 in.].

6.1.2 Weights are mounted on the lever arm assembly. The apparatus must be capable of handling loads ranging from 10 g [0.35 oz] to 15 kg [33 lb].

6.2 *Mandrel*—The top surface of the mandrel 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 mandrel should either be made of electroconductive material or be covered with an electroconductive material.

6.3 *Blade*<sup>3</sup>—Blades shall be made of stainless steel with a hardness of 78-80 on the 30N scale or approximately 59-64 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. This is an included angle of approximately 22° at the cutting edge. 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 *Calibration Material*<sup>4</sup>—Calibration material is a Neoprene sheet having a hardness of 50 ± 5 Shore A and a thickness of 1.57 mm [0.062 in.] ± 0.05 mm [0.002 in.].

6.4.1 This calibration material shall be stored under controlled laboratory conditions in an opaque container to prevent deterioration by heat or ultraviolet light.

6.5 *Data Analysis*—Data analysis can be accomplished by a computer, capable of analyzing the data collected using the best method to fit the curve.

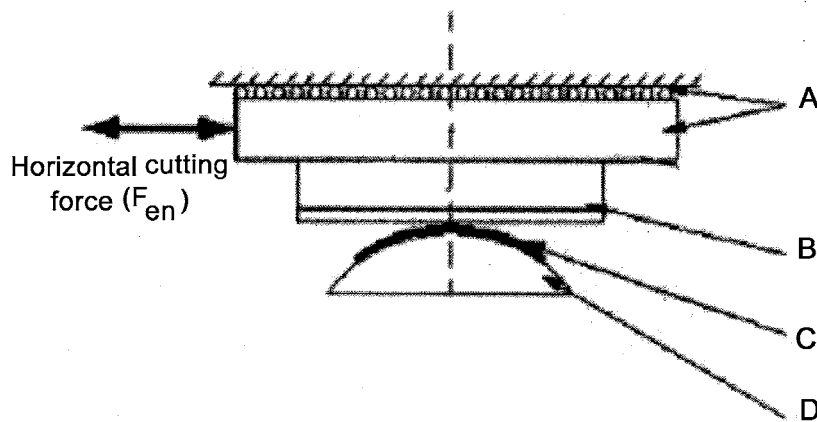
**7. Hazards**

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.

7.2 Remove weights when installing or removing a blade.

<sup>3</sup> Blade 88-0121 TYPE: GRU-GRU, supplied by American Safety Razor Co., Razor Blade Lane, Verona, VA 24482, has proven satisfactory for this test method. Its specifications include a cutting edge length greater than 69 mm, width of greater than 18 mm, and a thickness of 0.85 to 0.93 mm. Steel hardness is designated using the Rockwell C hardness number (HRC) and the Rockwell Superficial Hardness number on the 30 N scale.

<sup>4</sup> Neoprene, Style NS-5550, or equivalent supplied by Reeves Brothers, Inc. Highway 29 South, Spartanburg, SC has proven satisfactory for this test method. Stocks of this neoprene are available for purchase from Red Clay, Inc., 2388 Brackenville Rd., Hockessin, DE 19707 or IRSST (Institut de recherche en santé et en sécurité du travail du Québec, 505 boulevard de Maisonneuve Ouest, Montreal, Quebec, Canada H3A 3C2) with certificate of conformity. This material may be used to establish secondary calibration materials from local suppliers.



NOTE 1—Legend:  
 A—Blade holder and straight line mechanism  
 B—Blade  
 C—Sample  
 D—Mandrel

FIG. 1 Schematic of Cut Testing Principle

7.3 Store used blades in a sealed container.

7.4 Remove blades at the end of each test or when not in use.

7.5 **KEEP HANDS OUT OF CUTTING AREA WHEN A BLADE IS IN CUT POSITION.**

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

7.7 Keep hands and fingers away from moving parts when machine is operating.

## 8. Sampling

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.

## 9. Conditioning

9.1 Condition test specimens as indicated in Practice D 1776.

## 10. Procedure

### 10.1 *Test Specimens:*

Cut a 50 mm by 100-mm [2 in. by 4-in.] specimen at random from each laboratory sampling unit. Cut all woven and knit structures on the bias with the goal of making an angle of 0.785 rad (45°) between the warp and filling (wale and course) directions of the fabric and the blade.

### 10.2 *Preparation for Testing:*

#### 10.2.1 *Test apparatus:*

10.2.1.1 Plug in cut test apparatus without weights or blades in operating position.

10.2.1.2 Turn machine on and adjust the motor driven balanced arm to ready position.

10.2.1.3 Calibrate lever arm balance. See Annex or instrument manufacturer's operating instructions.

#### 10.2.2 *Specimen mounting:*

10.2.2.1 Cover mandrel face with double-face tape.

10.2.2.2 Place a 6-mm [0.25-in.] strip of conductive foil centered down the length of the mandrel on the double-face tape. Clip the end of this foil to the mandrel, or attach it securely to the electrical circuit that detects cut through in some other fashion.

10.2.2.3 Without stretching or distorting it, place a specimen over the tape with the surface to be cut facing up. Apply firm pressure on the specimen.

10.2.2.4 Insert the mandrel in the support column with the rounded side facing the motor-driven balanced arm and align so that the blade contact is centered on the rounded surface. Tighten mandrel in place, if appropriate.

### 10.3 *Validation of cutting edge supply:*

10.3.1 Calibrate the cutting edge supply using the Neoprene sheet calibration material.

10.3.2 Cut a 50 mm by 100-mm [2 in. by 4-in.] specimen of the calibration material and follow mounting procedure detailed in 10.2.2.

10.3.3 Validate the cutting edge supply by using a load of 500 g on the calibration material at the beginning and end of each sample being tested, or validate one blade out of 20 for each blade supply or manufacturing lot number. If using the TDM-100 tester or CPP tester with modified arm, the cut through length for the calibration material must be between 15 and 25 mm [0.6 and 1.0 in.]. If using the CPP tester with the straight arm, the cut through length for the calibration material must be between 10 and 15 mm [0.4 and 0.6 in.]. The cut through lengths for all the blades in a lot should not differ in length by more than 10 mm [0.40 in.]. Read the distance meter and record the distance if the cut through is within the acceptable range.

10.3.4 When the length of cut through is outside these distances, check for the following:

10.3.4.1 The cutting edges being used are new.

10.3.4.2 The Neoprene material is the same as that specified in Section 6.

10.3.4.3 The calibration procedure for the lever arm indicates that the force at point of contact is generated by an effective weight of 500 g, allowing for any lever-arm effects.

### 10.4 *Test procedure:*

10.4.1 Cut the test specimen and follow mounting procedure detailed in 10.2.2.

10.4.2 Verify that the cutting arm is at the ready position. All cuts will be made with the blade moving in the same direction.

10.4.3 Insert a new blade in arm slot. Keep it straight and fully seated in its mounting slot and tighten the blade clamping system.

10.4.4 Ensure that the blade does not touch the specimen.

10.4.5 Select and install weights.

10.4.6 Press the zeroing button on the distance meter.

10.4.7 Carefully ease the blade into contact with the specimen, and immediately start the machine. Make certain that only the blade edge and not the corner of the blade is touching the specimen.

10.4.8 A cut through should occur within one full traverse of the blade. The machine will stop automatically. Read the distance meter, and record the distance and corresponding load if the cut through is within the length range from 5 mm to 50 mm [0.2 to 2.0 in.].

10.4.9 For electrically conductive materials, take care to avoid premature electrical contact. An 8-mm [0.38-in.] strip of tissue paper may need to be carefully aligned on top of the conductive foil strip before positioning the specimen.

10.4.10 If no cut through occurs within one full traverse of the blade, stop the machine. Lock the cutting arm with blade off the specimen, and remove the weights and blade. Move the specimen 6 mm [0.25 in.] to a new spot, install a new blade, return the motor-driven balanced arm to the ready position, increase the load, zero the distance meter, and retest.

10.4.11 Lock the cutting arm with blade off the specimen, and remove the weights and blade. Move the specimen 6 mm [0.25 in.] to a new spot, install a new blade, increase or decrease the load, return the motor-driven balanced arm to the ready position, zero the distance meter, and retest. Continue testing with changes in loads until a cut through is observed

within one traverse that causes the machine to stop. Read the distance meter and record the distance and loading weight if the cut through is within the acceptable range from 5 to 50 mm [0.2 to 2 in.].

10.4.12 Continue adjusting loads as needed and retesting to collect five data points in the 5 to 20-mm [0.2 to 0.8-in.] cut-through length range, five data points in the 33 to 50-mm [1.3 to 2-in.] cut-through length range, and five additional points at any loading selection in between those used for the upper and lower cut-through length ranges. An alternate allocation of test loads for the 15 cuts may be considered for highly reinforced materials. Additional tests can be performed at the discretion of the technician.

## 11. Calculation

11.1 Using the collected database, calculate the rating force as follows:

11.1.1 Calculate the average cut through distance for cutting edge supply validation tests on the calibration material described in 10.3.

11.1.2 Calculate the blade sharpness correction factor (SC) using the cut test apparatus specific equations shown below:

$$\begin{aligned} & \text{TDM} - 100 \text{ or modified} \\ & \text{arm CPP sharpness correction factor (SC)} \\ & = \frac{20}{\text{CB mm}} \left( \text{or } \frac{0.8}{\text{CB in.}} \right) \end{aligned} \quad (1)$$

$$\text{CPP sharpness correction factor (SC)} = \frac{12.7}{\text{CB mm}} \left( \text{or } \frac{0.5}{\text{CB in.}} \right) \quad (2)$$

where:

CB = blade validation cut through distance in mm [in.] under a load of 500 g. This is the average distance to cut through the calibration for the lot of blades being used.

11.1.3 Multiply the measured cut through distances for the experimental materials by SC to create normalized distance data.

11.1.4 Obtain a plot of recorded load versus normalized distance data.

11.1.5 Draw best curve fit using an appropriate regression analysis program to provide the best method of fit.

11.1.6 Extract rating force either by interpolating the value that intercepts the distance axis at 20 mm [0.8 in.], or by using Eq 3.

$$y = a10^{bx} \text{ or } x = \frac{(\log(y/a))}{b} \quad (3)$$

where:

y = distance, 20 m,  
x = force,  
A = constant factor, and  
B = constant factor.

11.2 Correct the reference force by multiplication by factor A determined in A1.14.2.5. This will correct for lever arm calibration.

## 12. Interpretation of Results

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

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

12.1.2 Provide higher cut resistance by demonstrating resistance to higher loads at the same distance traversed.

12.2 This test method establishes the different loads that various materials can carry to a fixed distance.

12.2.1 For this test method, the rating force is the load required for the cutting edge to travel 20 mm [0.8 in.] and achieve cut through.

12.2.2 The 20-mm [0.8-in.] distance was selected because it is the middle point of the useful section of the blades used in this test method. The blades are never used twice so that edge retention is ensured when using the procedure.

12.3 At very small loads, infinite distances are anticipated while heavier loads will generate distances approaching zero. Exponential analysis represents the asymptotic value of a load versus distance ratio.

12.3.1 A reliable determination of the load versus distance curve is required to define the reference force that characterizes a test material.

12.3.2 This determination requires that a minimum of 15 data points be collected, five data points at both extremes of the curve and five in the middle.

12.3.2.1 The extremes are defined as the heavier loads that lead to shorter travel distances, between 5 and 20 mm [0.2 and 0.8 in.] and the lighter loads that allow longer travel distances of 33 to 50 m [1.3 to 2 in.]. For most materials a good load versus distance curve is obtained when the ratio between the light and heavy loads is approximately a factor of two. This correlation is lower when measuring materials which can be cut with a load greater than 3 kg.

12.3.3 While sections of the curve may appear to be linear, exponential analysis offers the most reliable process for identification of the rating force.

## 13. Report

13.1 Report the following using the Cut Performance Protection Report Form as shown in Fig. 2.

13.1.1 Test was performed in accordance with Test Method F 1790-04.

13.1.2 *Sample Identification*—Sample Identification-Product description of fabric to indicate construction, fiber (or blends), and areal density in g/m<sup>2</sup>(oz/yd<sup>2</sup>),

13.1.3 Identification of blade designation and lot number,

13.1.4 Calibration,

13.1.5 Load and distance data,

13.1.6 Calculation and report of normalized distances,

13.1.7 Rating force and coefficient of determination (*R*<sup>2</sup>), and

13.1.8 Report any variations in procedure from this standard.

## 14. Precision and Bias

14.1 An interlaboratory test program was conducted in 1995 to obtain precision data for the CPP.

14.1.1 Ten different materials were used in that interlaboratory program, these were tested in seven laboratories. Samples of ten materials were supplied to each laboratory and cut