Designation: F 1790 – ~~97~~04

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

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 (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 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, or for materials greater than 3 mm~~ 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.*

[1] This test method is under the jurisdiction of ASTM Committee F-23 on Protective Clothing and is the direct responsibility of Subcommittee F23.20 on Physical Properties.

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2. Referenced Documents

2.1 *ASTM Standards:* [2]
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 ~~demonstrated by~~ that hinders cut through when a material~~,~~ or a combination of ~~materials, when~~ materials is exposed to a sharp-edged ~~device initiates cut through.~~ device.

3.1.2 *cut through, n*—in blade cut resistance tests, the penetration of the cutting edge entirely through material, a~~f~~s indicated by electrical contact ~~is made with a material.~~ 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*~~—any material, or combination of materials, used in an item of clothing~~—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, the intercept of the reference force to the~~ 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 ~~25~~ 20 mm ~~(1 in.).~~ [0.8 in.].

3.1.6 *~~reference~~rating force, n*—in cut resistance testing, the load required to cause a cutting edge to ~~traverse~~ produce a ~~specific~~ cut through when it traverses the reference distance across the material being tested.

3.1.6.1 *Discu~~l~~ssion*—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 resist~~h~~ant.

3.2 *Additional Termino~~u~~logy*—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 ~~reference forces.~~ 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.

5.2 This test method only addresses that range of cutting hazards ~~which~~ 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 ~~Protection Tester:~~ Test Apparatus:*

6.1.1 The cut ~~protection tester~~ test apparatus is designed to measure the distance traveled by the cutting edge as it is maintained under a known load during the test, ~~and then generate~~ so that force distance ~~data. Apparatus, such as~~ data can be generated. A schematic of the cut test principle is shown in Fig. 1~~, consists of a~~. A motor-driven balanced arm (A) holding the cutting edge (B) in contact with the specimen mounted on a mandrel (C). ~~As the~~ The arm ~~is driven downward,~~ propels the blade ~~moves~~ 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 ~~(E)~~ mounted on the lever arm ~~assembly, causes the specimen to sustain a~~ assembly. See Annex for details on available cut ~~through.~~ protection test equipment.

6.1.1.1 The cut test apparatus is powered by a ~~1/50-hp AC~~ 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 ~~sample holder.~~ 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 ~~(E)~~ 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).~~ [33 lb].

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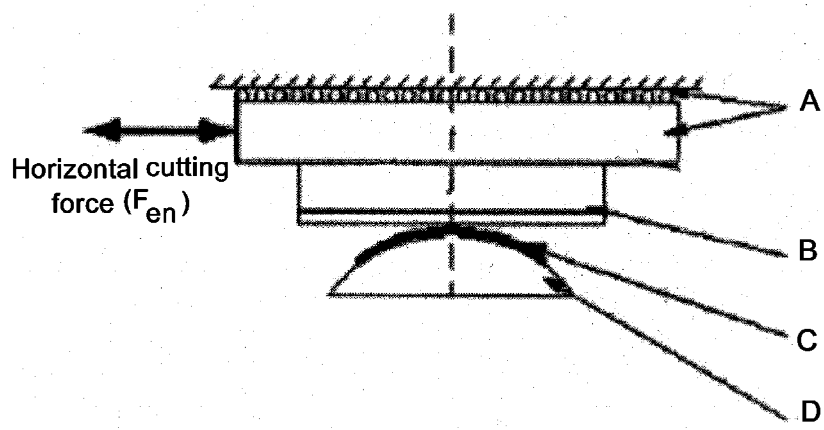
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards*~~,~~ ~~Vol 07.01.~~ volume information, refer to the standard's Document Summary page on the ASTM website.



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

FIG. 1 Schematic of Cut Testing Principle

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. Double-faced tape is used to secure the specimens to the electroconductive surface.~~ material.

6.3 *Blade* ~~.~~[3]—Blades shall be made of stainless steel with a hardness ~~greater than 45~~ 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 ~~blades~~ shall ~~be more~~ have a width greater than 18 mm ~~wide.~~ [0.71 in.].

6.4 *Calibration Material* ~~.~~[4]—Calibration material is a ~~1.6-mm (0.0625-in.)~~ Neoprene sheet having a hardness of 50 ± 5 Shore A and a thickness of 1.57 mm ~~(~~ [0.062 in.~~)~~] ± ~~10 %.~~ 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 ~~exponential regression analysis.~~ the best method to fit the curve.

7. Hazards

7.1 Th~~is~~e cut test equipment can pose a potential hazard to the technician if proper safety precautions are not followed. ~~This instrument~~ The cut test apparatus is to be used only by authorized personnel that have ~~had hands-on training.~~ been properly trained.

7.2 Remove weights when installing or removing a blade.

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 NEVER MOUNT TEST SAMPLE WITH~~

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.

~~*Annual Book*~~

[3] Blade 88-0121 TYPE: GRU-GRU, supplied by American Safety Razor Co., Razor Blade Lane, Vernona, VA 24482, has proven satisfactory for this test method. Its specifications include a cutting edge length greater than 69 mm, width of ~~ASTM Standards, Vol 11.03.~~ 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.

[4] ~~C~~Neoprene, Style NS-5550, or equivalent supplied by Reeves Brothers, Inc. Highway 29 South, Spartanburg, SC has proven satisfactory for this test ~~equipment is~~ 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 Quebec, 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.

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

9. Conditioning

9.1 Condition test specimens as indicated in Practice D 1776.

10. Procedure

10.1 *Test Specimens*:

8.3.1 Cut three

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

8.3.2 On each specimen, make five determinations at three different loads

10.2 *Preparation for a total of 15 determinations for each laboratory sampling unit.*

9. Calibration

9.1 *Calibration of Blade Supply*—Calibrate the cutting edge supply by using a load of 4 N (0.88 lbf) on the calibration material at the beginning and end of each sample being tested, or when changing to a blade supply from a different manufacturing lot number. The length of the calibration cut through must be between 18 and 38 mm (0.70 and 1.5 in.). The cut through lengths at the beginning and end of each sample test should not differ in length by more than 10 mm (0.40 in.).

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

9.1.2 The cutting edges being used are new.

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

9.1.4 The calibration procedure for the lever arm indicates that the force at point of contact is 4 N (0.88 lbf).

9.2 *Calibration of Lever Arm Balance*— With no weights on the lever arm, and a used blade mounted in the blade holder, adjust the position of the counterweight until the edge of the blade touches the curved surface of the mandrel without exerting any visible force on the mandrel.

9.2.1 This neutral position may be verified with gentle taps on the stand next to the machine.

9.2.2 Any disturbance should cause the counterweight to fall away from the mandrel as the lever arm pivots.

9.3 *Calibration of Lever Arm Load Testing*:

9.3.1 To calibrate force, an alternate mandrel fitted with an electronic load cell is required.

9.3.2 Place a known weight of less than 1 kg on the lever arm and record the force indicated by the load cell. Repeat this procedure using different weights between 50 and 1000 g.

9.3.2.1 The load cell is delicate. Do not exceed its rating. Stressing a load cell more than 1.5 times its maximum rating will result in damage.

9.3.3 Perform a linear regression analysis using the actual (known) weight values on the *x*-axis and the force indicated by the load cell on the *y*-axis, Eq 1.

$$y = ax + b \quad (1)$$

10.2.1 *Test apparatus*:

where:

y = force,
x = known weight,
a = slope (correction factor), and
b = intercept

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 slope.

9.3.3.1 The coefficient conductive foil centered down the length of *x* is the correction factor mandrel on the double-face tape. Clip the end of this foil to be applied the mandrel, or attach it securely to the electrical circuit that detects cut through in some other fal wshion.

10.2.2.3 Without stretching or distorting it, place a specimen over the tape with the surface to determine 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 blade.

9.3.4 Calibration 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 specimed an.

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 whenever 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 moved.

10. Conditioning

10.1 Condition test specimens within the acceptable range from 5 to 50 mm [0.2 to 2 in.].

10.4.12 Continue adjusting loads as i needed and retesting to caollect five data points in Practice D 1776. 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. Procedure

11.1 Plug in cut protection tester without weights or blades in operating position.

11.2 Turn machine on and adjust motor speed to approximately 5 rpm in the forward position. Stop the machine with the motor-driven balanced arm at top position.

11.3 Calibrate lever arm balance.

11.4 Cover mandrel face with double-face tape.

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

NOTE 1—For those materials which can be cut through with a load of less than 250 g (8.8 oz), the technician must remove the tape from under the immediate cut area.

NOTE 2—For electrically conductive materials, take care to avoid premature electrical contact.

11.6 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.

11.7 Verify position of cutting arm at the top.

11.8 Insert a new blade in arm slot. Keep it straight and fully seated in its mounting slot and tighten the thumb screw.

11.9 Place lever arm on the arm rest.

11.10 Select and install weights.

11.11 Press the zeroing button on the distance meter.

11.12 Lift the lever arm assembly, drop the rest support, carefully ease the blade into contact with the specimen, and immediately start the machine.

11.12.1 If no cut through occurs within one 50-mm (2-in.) traverse of the blade, stop the machine, set the cutting arm on the rest support, and remove the weights and blade. Move the specimen 6 mm (0.25 in.) to a new spot, install a new blade, increase the load, zero the distance meter, return the motor-driven balanced arm to the top position, 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 calculated force if the cut through is within the acceptable range from 5 to 50 mm (0.2 to 2 in.). Continue as directed in 11.12.2.1.

11.12.2 If a cut through occurs within one 50-mm (2-in.) traverse of the blade, the machine will stop automatically. Read the distance meter, and record the distance and calculated load if the cut through is within the length range from 5 to 50 mm (0.2 in. to 2.0 in.).

11.12.2.1 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.

12. Calculation

121.1 Using the collected database, calculate the reference rating force as follows:

121.1.1 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 bellows:

TDM – 100 or modified

arm CPP sharpness correction factor (SC)

$$= \frac{20}{\text{CB mm}} \left(\text{or } \frac{0.8}{\text{CB in.}}\right) \tag{1}$$

$$\text{correction factor } = \frac{25}{\text{CB mm}} \left(\text{or } \frac{1}{\text{CB in.}}\right) \tag{2}$$

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

where:

CB = blade calibration validation cut through distance in mm (in.) [in.] under a force load of 4 N (0.88 lbf). 500 g. This is the average distance to cut through of the calibration material before and after test for the lot of specimens. blades being used.

121.1.23 PMultiply 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 on linear graph paper.

12.1.3 Draw data.

11.1.5 Draw best curve fit using an exponential appropriate regression analysis program.

12.1.4 Extract reference 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 25 20 mm (1 in.), [0.8 in.], or by using Eq 3.

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

AB

where:

y = distance, 25 20 m,
x = force,
a = constant factor, and
A

~~*b*~~ = constant factor.
B

1~~2~~1.2 Correct the reference force by multiplication by factor ~~*a*~~*A* *determined in ~~9.3.3.1.~~ A1.14.2.5. This will correct for lever arm calibration.*

1~~3~~2. Interpretation of Results

1~~3~~2.1 Materials that can do either of the following are capable of delivering better cut resistance:

1~~3~~2.1.1 Provide higher cut resistance by demonstrating a longer distance traveled when equal loads are mounted.

1~~3~~2.1.2 Provide higher cut resistance by demonstrating resistance to higher loads at the same distance traversed.

1~~3~~2.2 This test method establishes the different loads ~~which~~ that various materials can carry to a fixed distance.

1~~3~~2.2.1 For this test method, the ~~reference~~ rating force is the ~~mass~~ load required for the cutting edge to travel ~~25~~ 20 mm ~~(1 in.)~~ [0.8 in.] and ~~initiate~~ achieve cut through.

1~~3~~2.2.2 The 2~~5~~0-mm ~~(1~~ [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.

1~~3~~2.3 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.

1~~3~~2.3.1 A reliable determination of the load versus distance curve is required to define the reference force that characterizes a test material.

1~~3~~2.3.2 This determination requires that a ~~total~~ minimum of 15 data points be collected, five data points at both extremes of the curve and five in the middle.

1~~3~~2.3.2.1 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.

1~~3~~2.3.3 While sections of the curve may appear to be linear, exponential analysis offers the most reliable process for identification of the ~~reference~~ rating force.

1~~4~~3. Report

1~~4~~3.1 Report the following using the Cut Performance Protection Report Form as shown in Fig. ~~4~~ 2.

1~~4~~3.1.1 Test was performed in accordance with Test Method F 1790-04.

1~~4~~3.1.2 *Sample Identification*—Sample Identification-Product description of fabric to indicate construction, fiber (or blends), and areal density in g/m^2(oz/yd^2),

1~~4~~3.1.3 Identification of blade designation and lot number,

Cut Protection Performance Test
Data Sheet

Date: ____________ **Technician:** ____________
Sample ID: ____________
Areal density of Sample: ____________ **gm/sq m (oz/sq yd)**
Blade lot #: ____________

Blade validation(Cut through distance for 1.57 mm (0.062 in.) thick Neoprene sheet with 500 g load):
Cut-through distances ____________ **mm (in)**

Average cut-through distance ____________ **mm (in)**

Column	1	2	3
Reading #	Rating Force, g	Cut length mm (in)	Normalized cut length mm (in)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Determine normalized reference load " RL " @ 20 mm (0.8 in.) using regression with data from columns 1 and 3:
Corrected load ____________
R-squared: ____________

Comments:

FIG. 2 Cut Performance Protection Report Form

14.1.4 Calibration,

14.1.5 Data point measurements showing five cut-through determinations between the following distances:

5 to 20 mm	(0.2 to 0.8 in.)
21 to 32 mm	(0.83 to 1.26 in.)
33 to 50 mm	(1.3 to 2.0 in.)

14.1.6 Calculation
13.1.4 Calibration,
13.1.5 Load and distance data,
13.1.6 Calculation and report of normalized distances, and
14.1.7 Reference distances,
13.1.7 Rating force and coefficient of correlation determination (R^2), and
13.1.8 Report any variations in procedure from this standard.

154. Precision and Bias

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

154.1.1 Ten different materials were used in this that interlaboratory program, these were tested in seven laboratories. Samples of ten materials were supplied to each laboratory and cut resistance was determined. Duplicate determinations of one-inch reference force were made in each of seven laboratories.

154.1.2 The results of the precision calculations for repeatability and reproducibility are given in Table 1.

154.1.3 An interlaboratory test program was conducted in 2002 to obtain precision data for the modified arm CPP and the TDM.

14.1.4 Eight different materials were used in that interlaboratory program. Duplicate determinations of 20-mm rating force were made in each of six laboratories. [Two laboratories had the TDM, two laboratories had the modified CPP, and two laboratories had both devices.]

14.1.5 Data were calibrated using neoprene samples that bracketed each set of fifteen sample cuts. Calibration and test materials were mounted using double-sided tape, but without the conductive foil mentioned in 10.2.2.

14.1.6 A statistically significant bias was not seen between the two test device types for any of the eight samples. All eight pieces of test equipment were therefore combined for a single analysis.

14.1.7 The results of the precision calculations for repeatability and reproducibility are given in Table 2.

14.1.8 The precision of this test method may be expressed in the format of the following statements that use what is called an appropriate value of *r* or *R* , that is, that value to be used in decisions about test results (obtained with the test method). The appropriate value is that value of *r* or *R* associated with a mean level in Table 1, closest to the mean level under consideration at any given time, for any given material in routine testing operations.

154.1.49 *Repeatability*—The repeatability, *r*, of this test method has been established as the appropriate value tabulated in Table 1. Two single test results, obtained under normal test method procedures, that differ by more than this tabulated *r* (for any given level) must be considered as derived from different or non-identical sample populations.

154.1.510 *Reproducibility*—The reproducibility, *R*, of this test method has been established as the appropriate value tabulated in Table 1. Two single test results obtained in two different laboratories, under normal test method procedures, that differ by more than the tabulated *R* (for any given level) must be considered to have come from different or nonidentical sample populations.

TABLE 1 Type 1Precision of the Test MethodNote 1— : CPP

Sr = repeatability standard deviation,
r = repeatability = 2.80 times the square root of the repeatability variance,
SR = reproducibility standard deviation, and
R = reproducibility = 2.80 times the square root of the reproducibility variance.

NOTE 2—
S_r = repeatability standard deviation,
r = repeatability = 2.80 times the square root of the repeatability variance,
S_R = reproducibility standard deviation, and
R = reproducibility = 2.80 times the square root of the reproducibility variance.

Material	Average, N	Within Laboratories		Between Laboratories	
		S_r	r	S_R	R
1	1.41	0.128	0.353	0.526	1.471
2	3.51	0.161	0.451	0.617	1.667
3	3.83	0.183	0.509	0.308	0.853
4	4.74	0.138	0.382	0.548	1.471
5	6.53	0.450	1.274	0.889	2.451
6	8.85	0.468	1.274	1.333	3.726
7	8.85	0.959	2.647	1.010	2.844
8	12.86	0.679	1.863	1.765	4.903
9	30.87	1.245	3.432	3.687	10.199
10	39.56	3.285	9.120	7.423	20.594

TABLE 2 Precision of the Test Method: modified-CPP and TDM

Material	Rating Force Average (g)	Within Laboratories S_r	Within Laboratories r	Between Laboratories S_R	Between Laboratories R
Cotton	446	40.2	112	103.0	286
Leather	184	30.2	84	57.9	160
Woven HMWPE	482	14.6	41	71.5	198
Knit Reinforced HMWPE	3427	111.8	310	172.2	477
Neoprene	504	31.3	87	59.8	166
Neoprene	1050	160.7	446	287.8	798
Woven p-Aramid	376	32.7	91	106.3	295
Knit p-Aramid	1190	40.7	113	150.4	417

154.2 *Bias*—In test method terminology, bias is the difference between an average test value and the reference (or true) test property value. Reference values do not exist for this test method since value (of the test property) is exclusively defined by the test method. Bias, therefore, cannot be determined.

165. Keywords

165.1 cut resistance; cut through; protective clothing

ANNEX

(Mandatory Information)

A1.

INTRODUCTION

Two types of equipment suitable for carrying out this test are now commercially available: the Cut Protection Performance (CPP) tester and the Tomodynamometer (TDM-100). The CPP tester can be used with a straight or a modified arm. Comparisons of the cut protection performance of materials must be made using equivalent test procedures and devices. There may be a bias between the cut testers; this subject is currently being investigated in a round robin.

These are the only sources of supply of this apparatus known to the committee at this time. If you are aware of alternative suppliers, please provide this information to ASTM headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

A1.1 Cut Protection Performance Tester (CPP)

The Cut Protection Performance testing instrument is designed to assess the cut resistance of a material when exposed to a cutting edge under specified loads. A straight and a modified motor driven balanced arm are available options for the Cut Protection Performance Test equipment. See Fig. A1.1 for CPP tester with straight arm attachment. See Fig. A1.2 for CPP tester with modified arm attachment (mCPP). This instrument and the method 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.

A1.1.1 *Source*

The CPP tester is available from Red Clay, Inc., 2388 Brackenville Rd., Hockessin, DE 19707 E-mail: redclay@magpage.com

A1.1.2 *Limitations*

A1.1.2.1 This cut tester is not valid for high porosity materials that allow cutting edge contact with the mounting surface prior to cutting or for materials greater than 3 mm in thickness.

A1.1.2.2 Materials having a high frictional coefficient such as elastomers can bias the results obtained using the CPP tester. A modified arm assembly satisfactorily measures the cut resistance of these materials and should be used instead of the original straight arm assembly.

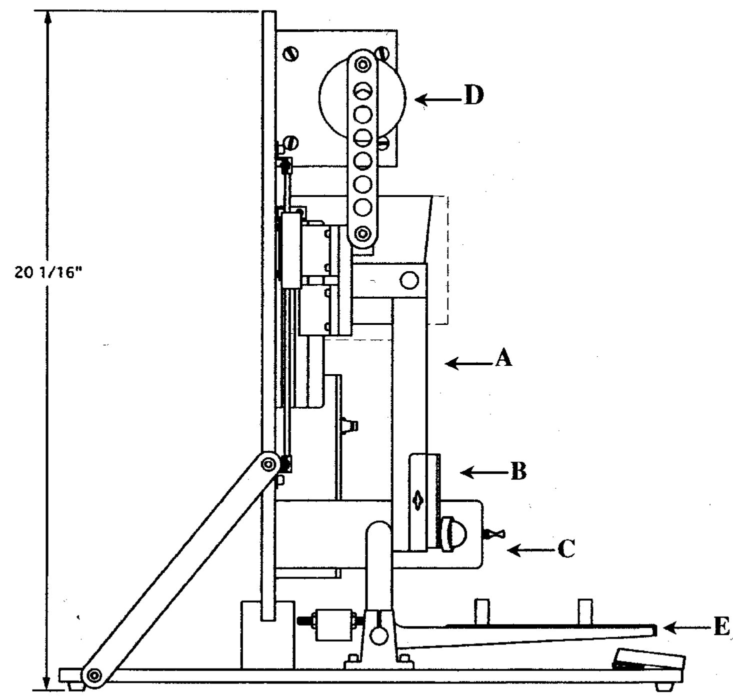
A1.1.3 *Precautions*

A1.1.3.1 Blades are extremely sharp and should be handled with cut resistant gloves.

A1.1.3.2 New blades should be kept in their box until they are to be used, and removed only when the test is to begin.

A1.1.3.3 If a new blade is dropped, discard it and use a new one.

A1.1.3.4 A container should be provided to place the used blades in once they are removed from the machine. Do not leave used blades on the instrument or the work surface. Used blades are still extremely sharp.



NOTE 3—Legend:
A—motor-driven balanced arm
B—cutting edge
C—mandrel
D—motor/drive wheel
E—weights

FIG. A1.1 Schematic of CPP Test Equipment (Side View)

A1.1.3.5 Never remove or install a mandrel with a blade mounted on the arm.

A1.1.3.6 Never mount a sample to the mandrel while the mandrel is locked in position.

A1.1.3.7 Never leave a blade in the instrument when it is not in use.

A1.1.3.8 Keep hands and fingers away from moving parts when operating the instrument.

A1.1.3.9 Turn off power to the instrument when unattended.

A1.1.3.10 As soon as the instrument stops, place the Weight Arm on the Rest.

A1.1.4 *Lever Arm Balancing and Load Calibration Procedure*

A1.1.4.1 *Calibration of Lever Arm Balance*

With no weights on the lever arm, and a used blade mounted in the blade holder, adjust the position of the counterweight until the edge of the blade touches the curved surface of the mandrel without exerting any visible force on the mandrel.

A1.1.4.1.1 This neutral position may be verified with gentle taps on the stand next to the machine.

A1.1.4.1.2 Any disturbance should cause the counterweight to fall away from the mandrel as the lever arm pivots.

A1.1.4.2 *Calibration of Lever Arm Load* :

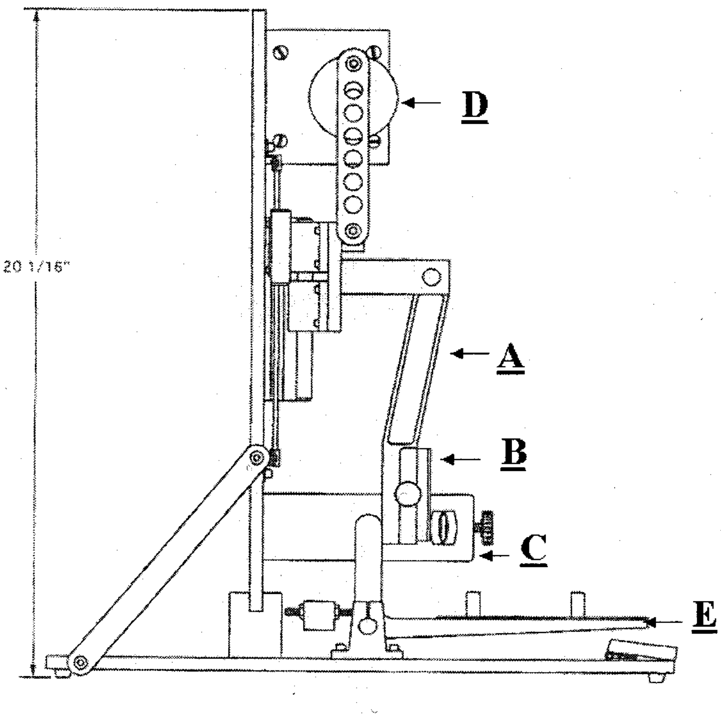
A1.1.4.2.1 To calibrate force, an alternate mandrel fitted with an electronic load cell is required.

A1.1.4.2.2 Place a known weight of less than 1 kg on the lever arm and record the force indicated by the load cell. Repeat this procedure using different weights between 50 and 1000 g.

A1.1.4.2.3 The load cell is delicate. Do not exceed its rating. Stressing a load cell more than 1.5 times its maximum rating will result in damage.

A1.1.4.2.4 Perform a linear regression analysis using the actual (known) weight values on the x-axis and the force indicated by the load cell on the y-axis,

$$y = Ax + B \quad \text{(A1.1)}$$



NOTE 4—Legend:
A—motor-driven balanced arm
B—cutting edge
C—mandrel
D—motor/drive wheel
E—weights

FIG. A1.2 Schematic of mCPP Test Equipment (Side View)

where:

y = force,
x = Known weight,
A = slope (correction factor), and
B = intercept of slope.

A1.1.4.2.5 The coefficient of x is the correction factor to be applied to the actual weights to determine the load on the blade.

A1.1.4.3 Calibration of the lever arm load should be performed at least once a month and whenever the machine is moved.

A1.2 Tomodynamometer (TDM-100)

The TDM-100 is capable of measuring the entire range of cut resistant materials through a horizontal constant speed of blade movement. A constant perpendicular force is applied to the specimen throughout blade movement. See Fig. A1.3 for schematic of TDM-100.

A1.2.1 *Source*

The TDM-100 is available from RGI Industrial Products, Inc., 755 Pierre Caisse, St-Jean-sur Richelieu, Quebec, Canada J3B 7Y5 E-mail: lapointe.louis@rgicanada.com

A1.2.2 *Limitations*

This cut tester is not valid for high porosity materials that allow cutting edge contact with the mounting surface prior to cutting or for materials greater than 20 mm in thickness.

A1.2.3 *Precautions*

A1.2.3.1 Never try to push or pull the sample holder without having locked the vertical movement of the sample holder with the cam lock device.

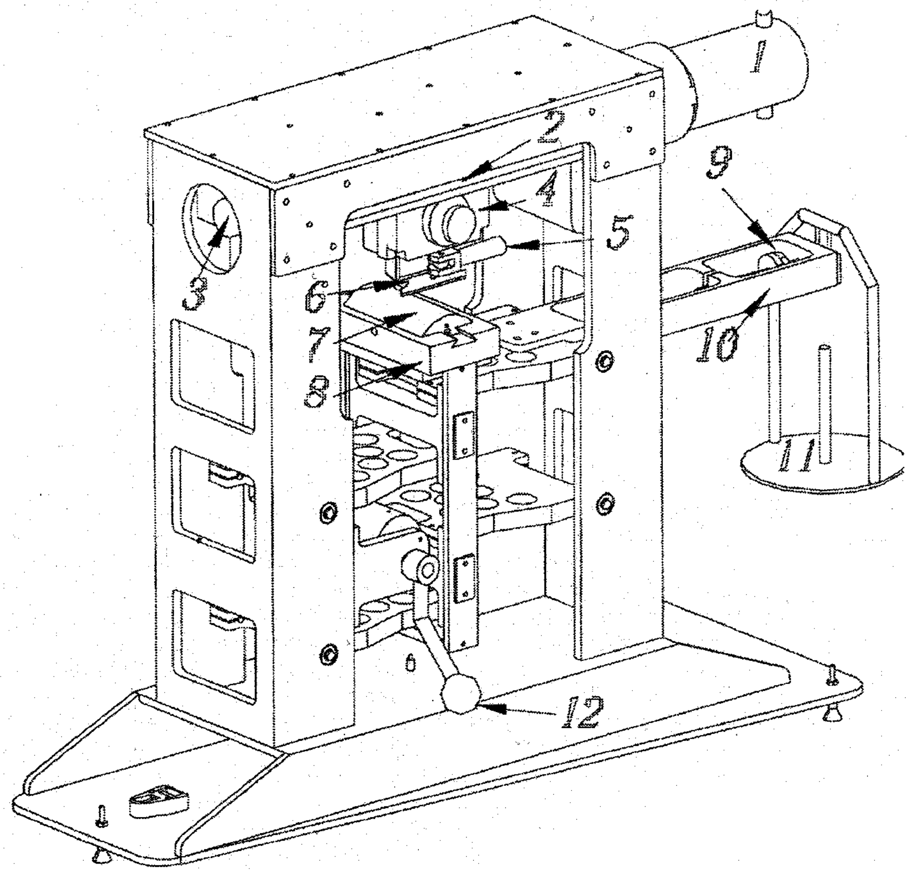
A1.2.3.2 Always remove blade holder using quick release ball lock device for every blade change.

A1.2.4 *Beam Balancing Procedure*

A1.2.4.1 Periodically check that the beam is balanced.

A1.2.4.2 *Verifying beam balancing*:

A1.2.4.2.1 Remove any sample or tape from the sample holder.



Note 5-Legend

1. Motor and gearhead
2. Slide system
3. Encoder
4. Blade support
5. Blade clamp
6. Blade
7. Mandrel
8. Mandrel holder
9. Calibration weights
10. Beam
11. Platen
12. Loading/unloading handle

FIG. A1.3 Schematic of TDM-100 Test Equipment (Front View)

A1.2.4.2.2 Install sample holder on the base.

A1.2.4.2.3 Unlock slowly the vertical movement of the sample holder with cam lock device.

A1.2.4.2.4 Place the mechanism horizontally.

A1.2.4.2.5 If mechanism stays in equilibrium, the apparatus is correctly balanced. If mechanism loses equilibrium, follow the next procedure for beam balancing.

A1.2.4.3 *Beam balancing procedure*:

A1.2.4.3.1 Lock movement of the beam in the higher position with cam lock device.

A1.2.4.3.2 Remove blade holder with the quick release ball lock device.

A1.2.4.3.3 Place the mechanism horizontally.

A1.2.4.3.4 Counterbalance with the two fine adjustment nuts until the mechanism stays in equilibrium.

A1.2.5 *Effective Loading*

A1.2.5.1 In installing weights, allow for any differences in lever arm length between the weight platform and the blade holder.