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Protective clothing — Mechanical properties — Determination of resistance to cutting by sharp objects

Vêtements de protection — Propriétés mécaniques — Détermination de la résistance à la coupure par des objets tranchants

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 94, *Personal safety — Personal protective equipment*, Subcommittee SC 13, *Protective clothing*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 162, *Protective clothing including hand and arm protection and lifejackets,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 13997:1999), which has been technically revised.

This document has been completely rewritten based on the current practices and experience in cut testing as well as comparing other cut test methods standards around the world. The main changes are as follows:

— new blades and revised range of cutting stroke length for the blades to be valid;

— new neoprene, with calibration data and Annex C;

— new specimen securing clamp;

— new Figure 3;

— new paper sheet in the specimen assembly;

— new data form ILT in Annex A;

— a few new information in Annex B for calculation;

— the neoprene control is only referenced to in Annex C.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Although textiles, composites, leather, rubbers and reinforced materials may resist cutting by sharp edges in different ways, a test method for evaluating the resistance to cut of materials in protective clothing needs to be applicable to all materials. The test described in this document provides a method that allows calculations of the downwards (normal) force required to cause a blade drawn across the sample for a fixed distance to cut through the specimen.

The performance of protective clothing materials may be classified using the numerical values obtained from this test.

Protective clothing — Mechanical properties — Determination of resistance to cutting by sharp objects

1 Scope

This document specifies a tomodynamometer cut test method and related calculations, for use on materials and assemblies designed for protective clothing, including gloves. The test determines resistance to cutting by sharp edges, such as knives, sheet metal parts, swarf, glass, bladed tools and castings.

When this document is cited as a test method in a material or product requirement standard, that standard contains the necessary information to permit the application of this document to the particular product.

This test does not provide data on the resistance to penetration by pointed objects such as needles and thorns, or the point of sharp-edged blades. The test described in this document is not considered suitable for testing materials made from chain mail and metal plates. The text of this document does not include provisions for the safeguard of the operator.

2 Normative reference

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 34-1, *Rubber, vulcanized or thermoplastic — Determination of tear strength — Part 1: Trouser, angle and crescent test pieces*

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 48-4, *Rubber, vulcanized or thermoplastic — Determination of hardness — Part 4: Indentation hardness by durometer method (Shore hardness)*

ISO 2781, *Rubber, vulcanized or thermoplastic — Determination of density*

ISO 11610, *Protective clothing — Vocabulary*

ISO 23388:2018, *Protective gloves against mechanical risks*

ISO 23529, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11610 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org

3.1
cut-through
event which has occurred when the blade edge first contacts the conducting material below the test specimen

3.2
cutting force
calculated force that would be required to be applied to a blade of standard sharpness to cut through a material in a blade stroke of length 20 mm

3.3
cutting stroke length
distance the cutting-edge travels before *cut-through* (3.1) occurs

4 Sampling

4.1 General

Unless otherwise specified, specimen dimensions should not be less than 25 mm by 100 mm as this allows for several cuts on the same sample (see 5.2.4 and 5.2.5). If this specimen size is not possible, the smallest specimen on which single cuts are made shall not be less than 25 mm by 25 mm.

NOTE The test requires at least 15 cuts therefore at least 2 specimens are necessary.

4.2 Textiles and other materials

Specimens shall be taken from regions of the sample product representative of the range of construction present in protective areas or as defined in product requirement standard. In the case of an irregular design, the test specimen shall be taken from the area where the least protection is expected.

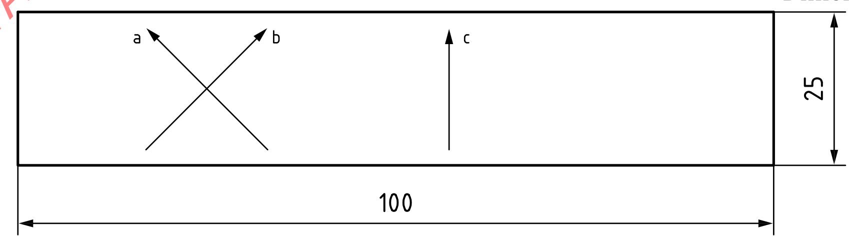
Specimens from textile materials shall be prepared so that test cuts are made at an angle of (45 ± 5)° to the warp and weft direction as defined in Figure 1. Only one result (cutting force see 5.4.4.2) shall be reported.

Materials that have no clear orientation shall be tested in two directions at 90° to each other and both cutting forces (see 5.4.4.2) shall be reported and the final result is the lowest one.

If the material is known to have homogenous properties in all directions, only one result (cutting force see 5.4.4.2) needs to be reported.

NOTE Materials that have no clear orientation are for example, unoriented materials, or those in which the machine direction either does not exist or is uncertain such as some non-woven.

Dimensions in millimetres



a Warp or longitudinal direction.
b Weft or transversal direction.
c Cut test direction.

Figure 1 — Control specimen dimensions and cut direction for garments

4.3 Gloves

For gloves, take the specimen from the palm area cut on the bias such that the size of the specimen is adequate but at an angle as close as possible to 45° as shown in Figure 2.

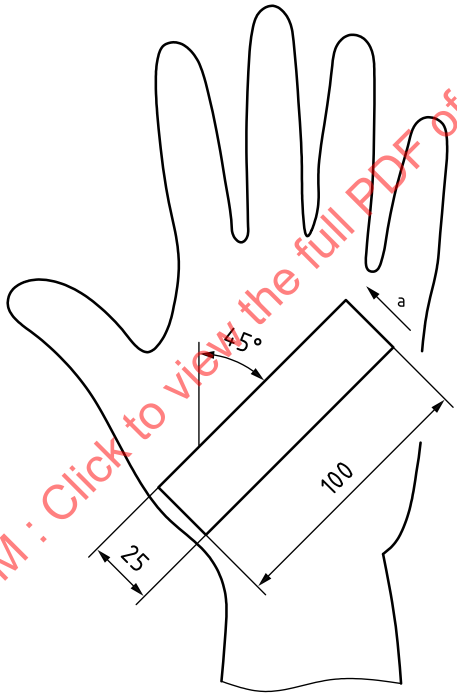
In the case of an irregular design of the palm, the test specimen shall be taken from the palm area where the least protection is expected.

If reinforcement(s) does not uniformly cover the palm area, either the specimen shall be taken without reinforcement or the specimen shall be provided without reinforcement.

If cut protection is claimed for back of the hand or cuff and the materials are different from the palm, they shall be tested and reported.

NOTE There is no tolerance to the angle for the glove as this depends on the size of the glove and its construction to take the correct angle that best represents a 45° angle.

Dimensions in millimetres



[a] Cut test direction.

Figure 2 — Glove sample and cut direction

4.4 Conditioning

Specimens shall be conditioned as defined in product requirement standard or in the following conditioning atmosphere:

— Temperature (23 ± 2) °C and relative Humidity (50 ± 5) %.

Alternatively, the following conditioning should be used, and shall be reported in the test report.

— Temperature (20 ± 2) °C and relative Humidity (65 ± 5) %.

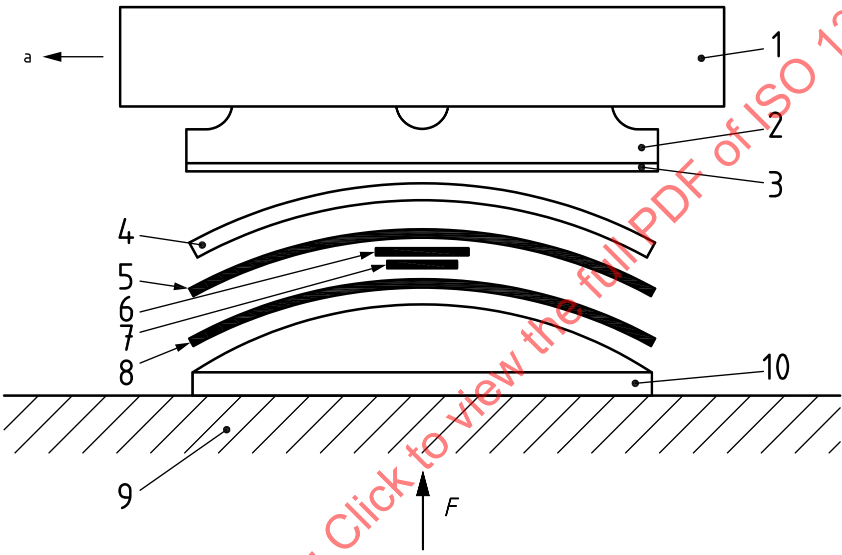
The period of conditioning is at least 24 h. Testing shall be carried out in the conditioning environment or within 30 min of withdrawing the specimens from the conditioning environment.

5 Test method

5.1 Principle

The cut resistance of a material is its ability to resist being cut through by a blade. This is measured in a machine in which a sharp blade is drawn across a specimen. The cuts are achieved in blade movements of 5,0 mm to 50,0 mm length when a range of forces are applied to the blade normal to the specimen surface. The cut resistance of a sample material is expressed as the cutting force that is required to be applied to a blade of standard sharpness to just cut through the material in a 20,0 mm blade stroke. The value of the cutting force may be used to classify materials.

The cut test apparatus consists of the following primary components (see Figure 3): blade holder (1) with a straight line mechanism that holds a blade (2), having a cutting edge (3), a specimen (5) with a paper sheet (6) and conductive strip (7) and double-sided adhesive tape(8) mounted to a specimen holder (10) attached to the specimen holder mount (9) to which the force is applied (F).



Key

1 blade holder
2 blade
3 cutting edge of blade
4 specimen securing clamp (optional)
5 specimen
6 paper sheet
7 conductive strip
8 double-sided adhesive tape
9 Specimen holder mount
10 specimen holder
F applied force
a Cut direction.

Figure 3 — Schematic of the cut test principle

Any apparatus can be used that can maintain a constant force between the cutting edge and the specimen and can accurately measure the distance the blade travels to cut through the specimen. The testing apparatus shall also allow the test to be performed in the conditions specified in the test method, for instance in terms of displacement rate of the blade and geometry of the specimen holder (see 5.2).

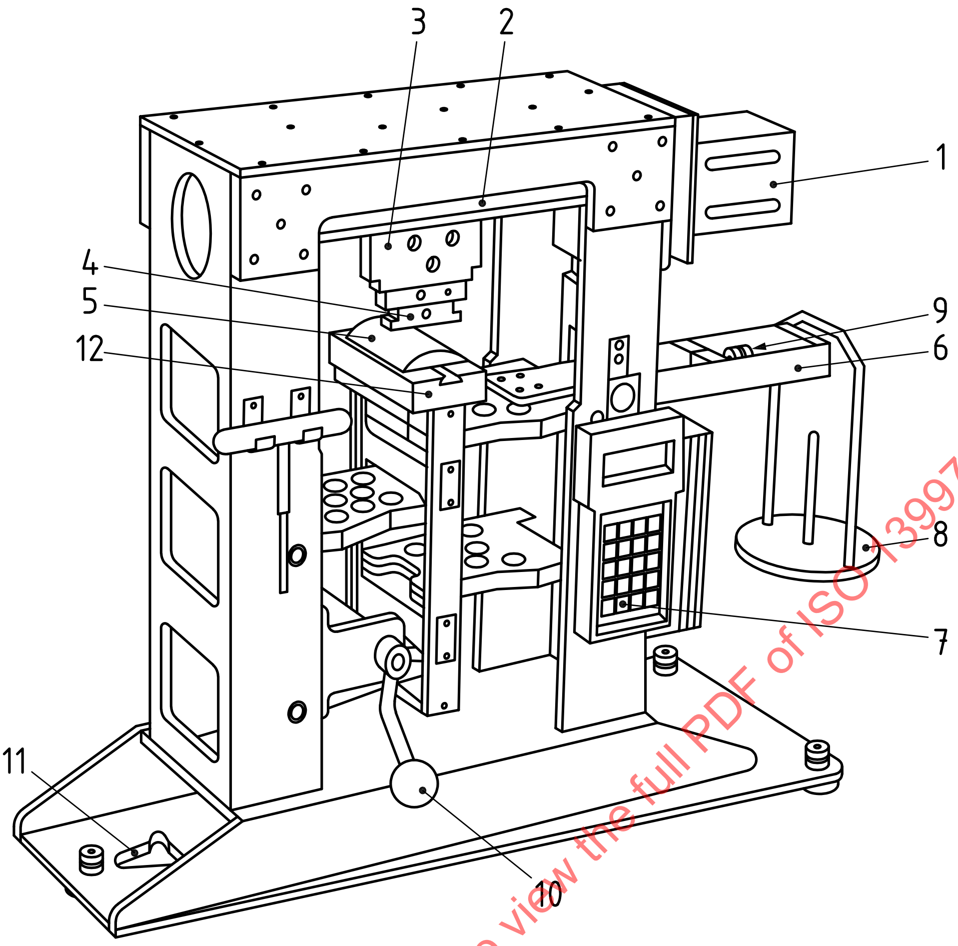
The test apparatus may have limitations in testing materials with a thickness greater than 12 mm (see 5.2.7). When using the specimen securing clamp (4), the maximum thickness may be less than that (see 5.2.5).

NOTE For each of the required measurements performed in accordance with this document, a corresponding estimate of the uncertainty of measurement should be evaluated. One of the following approaches should be used:

- a statistical method, e.g. that given in ISO 5725-2[2];
- a mathematical method, e.g. that given in ISO/IEC Guide 98-3[3];
- uncertainty and conformity assessment as given in ISO/IEC Guide 98-4[4];
- JCGM 100:2008[5].

5.2 Test apparatus

The apparatus shall have the following components (see Figure 4 for the general aspect of the cut testing device).



Key

1	motor and gearhead	5	specimen holder and specimen securing clamp	9	calibration weights
2	slide system	6	beam	10	loading/unloading handle
3	blade support/clamp mechanism	7	controller keypad with distance meter	11	level indicator
4	blade	8	loading device	12	specimen holder mount

Figure 4 — Example of apparatus[1)]

Keep the instrument free of dust and fibers. Don't let lint accumulate on the guide rails and sharps.

5.2.1 Rigid framework

Rigid framework that supports the constituent parts when a force of up to 200 N is exerted between the cutting edge and the specimen.

1) An apparatus known as the tomodynamometer embodying these principles is available from a number of suppliers such as: (1) TDM-100 from RGI Industrial Products, Inc., 755 Pierre Caisse, St-Jean-sur Richelieu, Quebec, Canada J3B 7Y5 (www.rgicanada.com), (2) STM610 from SATRA, Wyndham Way, Telford Way, Kettering, Northamptonshire, NN16 8SD, United Kingdom (www.satra.com), (3) LINEAR CUT RESISTANCE TESTER 3394B from Mesdan, Via Masserino, 6 - 25080 Puegnago del Garda (BS) Italy (www.saviotechnologies.com), and (4) PROCOUPE from EMI Developpement, Rue Alexandre Yersin, Zone Artisanale Coulmet, 10450 Breviandes France (www.emi-developpement.com). This information is given for the convenience of user of this International Standard and does not constitute an endorsement by ISO of this product. Equivalent products may be used if they can be shown to lead to the same results.

5.2.2 Force application system

Force application system to move the specimen holder towards the blade, or the blade towards the specimen holder during operation of the machine such that the force between the cutting edge and the specimen is constant ±5 %.

The force shall be variable between 1,0 N and 200 N. The force may be applied to the blade holder or to the specimen holder.

5.2.3 Specimen holder mount

The specimen holder mount is the part of the apparatus to which the specimen holder is fitted and allows it to be positioned for the execution of the cut test.

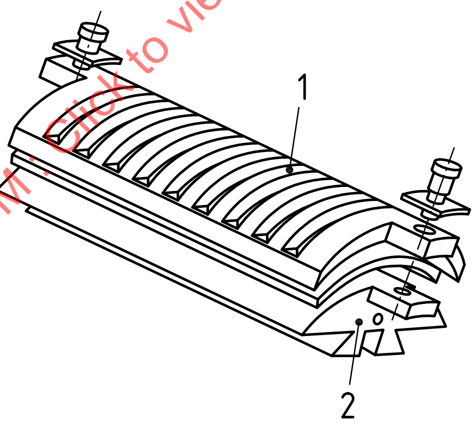
5.2.4 Specimen holder

Specimen holder, with surface made of metal on which the specimen is mounted. The specimen mounting area shall be curved with a radius of (38 ± 0,5) mm. The length of the mounting area shall be greater or equal to 100 mm and the width across the curvature shall be greater than or equal to 32 mm.

5.2.5 Specimen securing clamp

The specimen securing clamp is fitted to the specimen holder to secure the specimen in place during the cut testing and avoid movement of the specimen (see Figure 5). The interior of the specimen securing clamp should not be a smooth surface to ensure that the specimen is held in place with minimum force.

The specimen securing clamp, including the screws, shall be either made of non-conductive rigid material or insulated from conductive samples, to avoid premature stop of the test.



Key

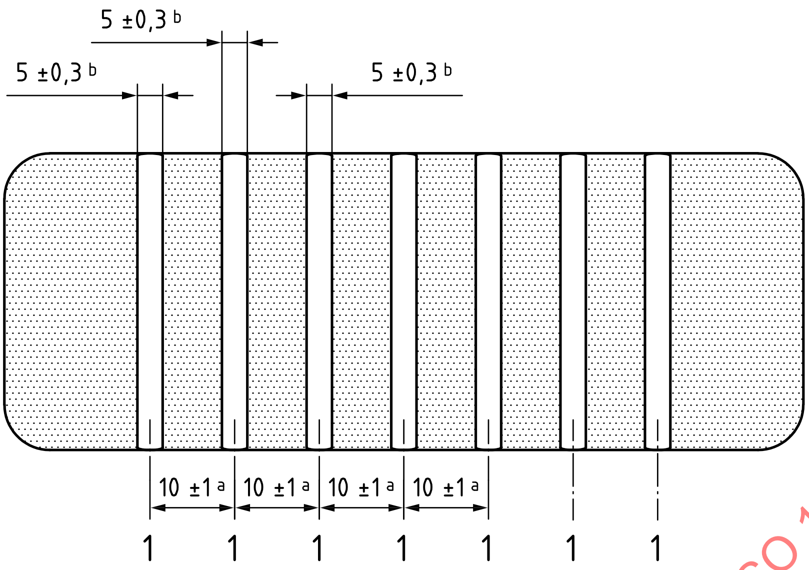
1 specimen securing clamp

2 specimen holder

Figure 5 — Example of specimen holder and specimen securing clamp

The specimen securing clamp shall have opening for the blades of (5,0 ± 0,3) mm and the distance between the adjacent cut tests of the mounting device is (10 ± 1) mm. Screws shall be fastened to put enough pressure on the specimen during the test to avoid slippage while making sure to use the lowest pressure possible to avoid deforming the material loaded on the specimen securing clamp, which may make the material bulge inside the slots and change its cut resistance (see figure 6).

Dimensions in millimetres



Key

1 cut position

a Distance between two cuts (mandatory dimensions).

b Free space for the blade. (mandatory dimensions).

Figure 6 — Example of specimen securing clamp with details of cut positions

If a new blade inadvertently touches the specimen securing clamp, discard it and use a new one.

The use of the specimen securing clamp is mandatory in the following cases:

— specimens that do not stick on the double-sided adhesive tape;

— unbounded multilayer sample;

— materials that curl or distort;

— any other reasons that prevent conducting the test without the specimen securing clamp.

In any other cases, the use of specimen securing clamp is forbidden.

The use of the specimen securing clamp may restrict the maximum thickness of the tested materials as the blade may interfere with the cut through depending on the design of the specimen securing clamp.

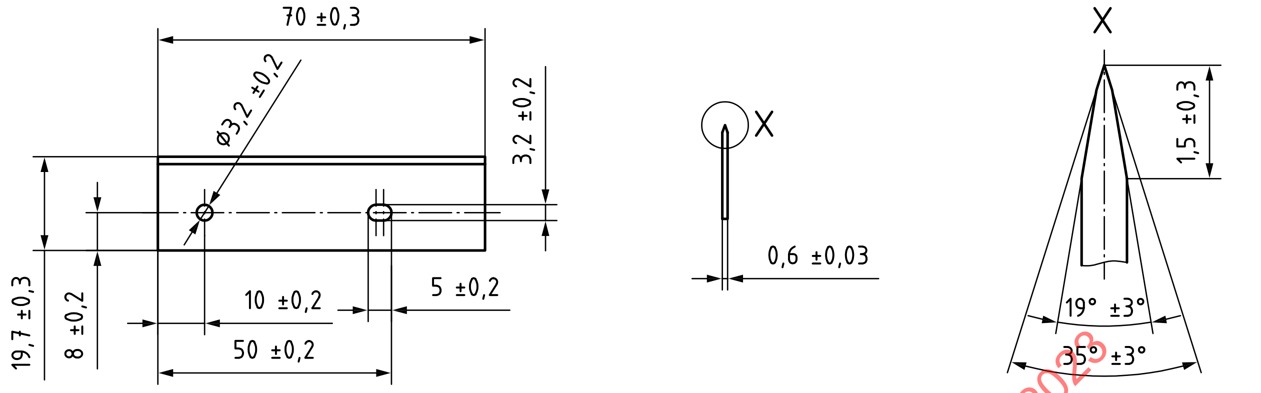
5.2.6 Blades

Blades, made of stainless steel with a hardness greater than 60 HRC.

Blades shall be (0,60 ± 0,03) mm thick, they shall have 2 facets and they shall be ground to a bevel width of (1,5 ± 0,3) mm along a straight edge. This results in an included first angle from the blade centre of approximately (19 ± 3)° and a second angle of approximately (35 ± 3)° at the bevel of the cutting edge. Blades shall have a cutting-edge length equal or greater than 65 mm and a width equal or greater than 18 mm[2]. An example of blade design is given in Figure 7. Blades shall pass the validation procedure in 5.3.3.2.

2) FEATHER Safety Razor Co., Ltd, Address: 3-70, OHYODO-MINAMI 3-CHOME, KITA-KU, OSAKA 531-0075, JAPAN, Phone: 81-6-6458-1631 (website: www.feather.co.jp) Product: KAKEN Blade No. 99727. This information is given for the convenience of users of this International Standard, and does not constitute an endorsement by ISO of this product. Equivalent products may be used if they can be shown to lead to the same results.

Dimensions in millimetres



a) Blade design **b) Blade profile** **c) Blade profile – blade edge**

Figure 7 — Examples of blade design

The finishing of the blade (deburring) shall be done in a way that the blade is homogeneous (same cutting property) in both direction.

5.2.7 Blade holder

Blade holder, capable of holding the blade rigidly and with minimum distortion so that at least 12,0 mm of the blade width is exposed.

The blade shall be held so that it is orientated across the curvature of the specimen holder with the plane of the blade at (90 ± 2)° to the long axis of the specimen holder.

5.2.8 Cutting-motion system

Cutting-motion system to move the specimen holder and cutting edge relative to each other such that the cutting edge moves across the specimen at (90 ± 2)° to the long axis of the specimen holder at a velocity of (2,5 ± 0,5) mm/s.

A screw-thread drive system has been found satisfactory. The bearings in the system shall provide smooth movement with restricted lateral motion. The maximum transverse movement of the cutting edge when it is stationary and not in contact with a specimen shall be 0,5 mm when a force of (5,0 ± 0,5) N is applied alternately to the two sides of the blade at (90 ± 5)° to the long axis of the blade.

5.2.9 Cut-stroke length measurement system

Cut-stroke length measurement system, to measure the length of the cutting edge that is drawn across the specimen to completely cut through it, accurate to 0,1 mm.

The distance to be measured is the blade movement from its initial stationary position in contact with the specimen to the point at which cut-through occurs and the first electrical contact between the blade and the conductive strip mounted on the specimen holder takes place.

5.3 Calibration

5.3.1 Beam balancing procedure

Follow the following procedure:

5.3.1.1 Check and adjust if needed the alignment of the equipment by levelling using the level indicator (as shown in Figure 4, key 11).

5.3.1.2 Remove any load from the platform.

5.3.1.3 Remove any specimen or tape from the specimen holder.

5.3.1.4 Without any specimen or tape onto the specimen holder, 2 cases are possible

— Mount the specimen holder and specimen securing clamp (when used) on the base

— Mount the specimen holder without specimen securing clamp on the base.

5.3.1.5 Move the beam (as shown in Figure 4, key 6) carefully to the neutral position and observe if the platform comes back near to the horizontal. If the mechanism stays in equilibrium, the apparatus is correctly balanced.

5.3.1.6 If the mechanism loses equilibrium, lock the movement of the beam in the higher position with the lever arm (as shown in Figure 4, key 6). Remove the blade from the blade holder. Place the mechanism horizontally. Counterbalance with the two fine adjustment nuts until the mechanism stays in equilibrium.

5.3.1.7 In addition, check the mechanism by adding 0,05 N force. A smooth displacement of the balancing arm should be observed.

5.3.2 Cutting speed adjustment

Check and adjust the speed of advance of the blade by measuring the distance travelled by a blade during a period of time (20 s for example). The speed shall be (2,5 ± 0,5) mm/s. Adjust if necessary.

5.3.3 Validation of blades

5.3.3.1 Calibration material

Calibration material shall be a neoprene sheet[3)] with the following properties when tested according to the conditions defined in Annex C:

— hardness using ISO 48-4 of (53 ± 5) Shore A;

— thickness using ISO 23529 method A of (1,54 ± 0,25) mm;

— density using ISO 2781 of (1,39 ± 0,05) g/cm^3;

— tensile strength using ISO 37 of (10,7 ± 2) N/mm^2;

— tear resistance using ISO 34-1 of (2,8 ± 2,0) N/mm.

NOTE The values of all properties were measured and averaged from an interlaboratory test. The tolerances also come from the same interlaboratory test, except for the hardness and thickness, which are the manufacturing tolerances stated by Gindor.

Store the calibration material in one of the conditioning atmospheres in 4.4 and in the dark (away from any light source).

3) Calibration materials are available from a number of suppliers such as: GINDOR, INC. 66101 US 33, Goshen, IN 46526-9483 USA, Phone: 574.642.4004 (website: www.gindor.com) Product reference #NS5550-062-010 black have proven satisfactory for this method. This information is given for the convenience of user of this International Standard and does not constitute an endorsement by ISO of this product. Equivalent products may be used if they can be shown to lead to the same results.

5.3.3.2 Blade validation procedure

Every box or lot of blades must be calibrated before considered eligible for cut testing. Every 20th blade shall be tested by cutting a (neoprene) calibration material with a force of (4,90 ± 0,02) N. Take a specimen of the calibration material and follow the specimen mounting procedure 5.4.1, without the use of the specimen securing clamp nor the paper sheet.

NOTE To achieve the 4,90 N force, one can use the 500 g mass.

Calculate the average cutting stroke length. To be a valid blade supply, the average cutting stroke length for the blade supply shall be between 15,0 and 25,0 mm, and the cutting stroke lengths for all the tested blades in the supply should not differ by more than 10 mm. Record the cutting distances.

Calculate the average cutting stroke length in mm (L), for every box or lot. This average will be used for the blade sharpness correction factor in 5.4.4.1.

5.4 Test procedure

5.4.1 Specimen mounting

Install a piece of double- sided adhesive tape as defined in ISO 23388:2018, 6.1.2.2, of width (50 ± 2) mm on the specimen holder. The double-sided adhesive shall have a sufficient thickness to avoid the electrical contact between the specimen and the specimen holder.

Place a conductive strip[4] on the double-sided adhesive, centered down the length of the specimen holder. The conductive strip shall be (6 ± 1) mm wide and no thicker than 0,3 mm. Clip the end of this strip to the specimen holder, or attach it securely to the electrical circuit to ensure good electrical contact to detect cut through (see Figure 8).

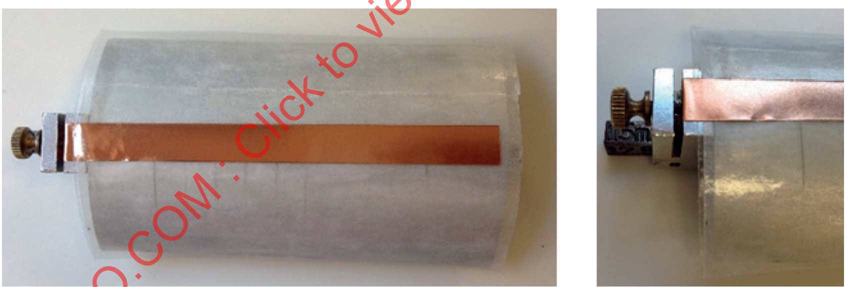


Figure 8 — Specimen mounting

A strip of paper of approximately 10 mm width and 100 mm length shall be placed centrally over the conductive strip. The paper sheet (according to ISO 23388:2018, 6.2.6) shall have an areic mass (grammage) of (65 ± 5) g/m^2 and be less than 0,1 mm thick.

NOTE 1 The paper will avoid any possible electrical contact between the conductive strip and the specimen.

Lay the test specimen over the taped specimen holder, with the surface to be cut facing up, without stretching or distorting the material. Apply firm pressure on the specimen to secure it to the specimen holder.

For multilayer materials, or materials that curl or distort when being cut from the specimen, no additional taping or sewing is allowed. The specimen securing clamp shall be used.

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4) Conductive strip manufactured by 3M 1181 Conductive Copper Tape 6,4 mm x 16m Manufactured part No 1181-6.3, 0,04 mm thick has proven satisfactory for this method. This information is given for the convenience of user of this International Standard and does not constitute an endorsement by ISO of this product. Equivalent products may be used if they can be shown to lead to the same results.

Mount the specimen securing clamp if needed (see 5.2.5). Tighten the specimen securing clamp mechanism gently to avoid any movement of the specimen during the test, but without compressing the specimen.

NOTE 2 For conductive samples, the specimen securing clamp needs to be either made of non-conductive material or insulated from conductive specimens, to avoid premature stopping of the test (see 5.2.5).

Insert the specimen holder (Figure 4, key 5) with the specimen securing clamp (when necessary) onto the specimen holder mount (Figure 4, key 12).

5.4.2 Test procedure for measuring the cutting stroke length

a) Check that the machine is level (see 5.3.1.1).

b) Mount a specimen on the specimen holder and if needed the specimen securing clamp (see 5.4.1, last paragraph).

c) Balance the beam with the specimen and the specimen securing clamp (when used) in place by adjusting the calibration weights to the loading device (Figure 4, key 8.).

d) Fit a new blade, from a validated blade supply, in the blade clamp and tighten the blade clamping system (see 5.3.3.2 for instructions on how to validate the blade). If a new blade is dropped discard, and use a new one.

   New blades should be kept in the box and removed one at the time immediately before use.

e) Verify that the cutting arm is at the ready position.

f) Select and install weights to produce the desired cutting force, and record this cutting force.

g) Zero the blade travel distance meter.

h) Gently and slowly bring the blade into contact with the specimen and start cutting strokes within 5 s. The corner of the blade shall not touch the specimen. All cuts shall be made with the blade moving right to left.

i) After cut-through is detected and the motor arm stops, record the cut-through distance. The cut distance shall be between 5,0 mm and 50,0 mm. Cut distances below 5,0 mm and above 50,0 mm shall be discarded from the calculation. These cut distances are the raw cut distances, not the normalized cut distances.

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

5.4.3 Test procedure for determining the calculated cutting force

a) Repeat the test procedure described in 5.4.2 using a minimum of three different cutting forces. The cutting forces should be distributed to produce cutting stroke lengths in the range of 5,0 to 50,0 mm. When performing multiple cut tests per specimen, each cut should be spaced by a minimum of 10 mm from the previous cut.

b) Five replicated tests at each of three different cutting forces have been found to be adequate. If possible, the cutting forces should be selected as to produce five data points in the 5,0 to 20 mm cutting stroke length range, five data points in the 20 to 33 mm cutting stroke length range, and five data points in the 33 to 50,0 mm cutting stroke length range.

For selecting the different cutting forces to use with this procedure for new or unknown materials a series of increasing or decreasing cutting force can be tested to determine a force range, see Table 1.

Table 1 — Selection or screening example for material

Applied force N	Measured cutting stroke length mm	Selected force
2	No cut	
5	65	Discarded
10	45	Minimum force
20	20	
30	5,5	Maximum force
40	4,0	Discarded

5.4.4 Calculations

5.4.4.1 Blade sharpness correction

Calculate the blade sharpness correction factor using Formula (1).

$$Cs = \frac{20}{L} \quad (1)$$

where

Cs blade sharpness correction factor;

L average cutting stroke length in mm determined in 5.3.3.2.

5.4.4.2 Calculated normalized cut distance and determination of the cutting force of the material

Multiply the measured cutting stroke lengths recorded during the test by the blade sharpness correction factor, C_s, to create normalized distance data.

After testing specimens using multiple loads for the purposes of determining the calculated cutting force (see 5.4.3), plot the normalized cutting stroke length against the applied forces. Obtain a best fit curve (using a regression analysis based on a logarithmic relationship) of the normalized cutting stroke lengths to estimate the calculated cutting force required to produce cut through at the reference distance of 20 mm. The calculation shall be performed using Annex B.

Record the cutting force to the nearest 0,1 N.

NOTE An inter-laboratory trial has been performed on this test method, the results are found in Annex A.

6 Test report

The test report shall contain at least the following information:

a) reference to this document ISO 13997:2023;

b) description of the samples to be tested, their method of preparation, and pre-treatment, if any, and the permitted size and orientation range of the specimens prepared for the samples;

c) the use of specimen securing clamp (if used);

d) date of the test;

e) Conditioning (see 4.4);

f) the cutting force determined from the curve (according to 5.4.4.2), the confidence interval (CI, see Annex B) and the coefficient of determination (R2) of the regression of the curve;

g) the blade sharpness correction factor;

h) the curve plotted through the fifteen or more cut tests;

i) details of any deviation from the method described in this document;

j) any unusual features observed;

Other information should be made available upon request;

1) values of all individual cut tests (force, distance); after calculation according to 5.4.4.2;

2) the normalized cutting stroke lengths;

3) information on the different consumables used (blade, neoprene, etc.).

Annex A
(informative)

Inter-laboratory test data analysis

A.1 Objectives of the inter-laboratory test

The ILT was organized to validate this test method, to confirm the calibration procedure and to include a new specimen securing clamp.

A.2 Materials

5 references of samples were selected for the inter laboratory testing to cover the range of products usually tested using this method and to cover the full range of the test results from a low to a high cut resistance. Sample reference 4 was chosen as it has shown dulling the blade of the circular blade in the cut resistance test carried out in accordance with ISO 23388.

Sample reference 1: Leather sample

Sample reference 2: Woven sample

Sample reference 3: Dipped supported glove

Sample reference 4: HPPE sample

Sample reference 5: Unbonded layer sample

A.3 Participating

Between 10 and 14 test laboratories participated in the inter laboratory trial using a variety of equipment supplied by different manufactures.

A.4 Test results

Clamping mechanism	Results following statistical treatment	Sample reference 1: leather sample	Sample reference 2: woven sample	Sample reference 3: dipped supported glove	Sample reference 4: HPPE sample	Sample reference 5: unbonded layer sample
Without speci-men securing clamp	Average result (N)	9,3	9,8	41,1	25,1	11,0
	Standard deviation	1,5	2,3	11,5	5,2	1,9
With specimen securing clamp	Average result (N)	9,9	10,5	43,2	25,2	9,9
	Standard deviation	2,1	2,2	12,1	4,2	1,8

A.5 Summary

The results show very little difference between the tests carried out with and without the specimen securing clamp. The specimen securing clamp allows testing of multilayer materials.

Annex B
(normative)

Calculated cutting force determination

NOTE Adapted, with permission, from ASTM F2992/F2992M-15[1] Standard Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing with Tomodynamometer (TDM-100) Test Equipment, copyright ASTM International, 100 Barr Harbor Drive, West Conshohoken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

B.1 Regression analysis

B.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[6] 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 Formula (B.1).

$$y' = b_0 + b_1 x \tag{B.1}$$

where

y' is the log transformation of the normalized cutting stroke length, log 10y;

x is the applied load;

b_0 is the intercept of the regression line;

b_1 is the slope of the regression line.

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

Calculated cutting force is given by Formula (B.2):

$$x_r = [\log_{10}(y_r) - b_0] / b_1 \tag{B.2}$$

where

x_r is the calculated cutting force in Newtons;

y_r is the reference distance, 20 mm.

B.1.3 The standard deviation, s, and 95 % confidence interval of the calculated load estimate can be calculated using Formulae (B.3) and (B.4).

Standard deviation of the calculated cutting force is given by Formula (B.3):

$$s = \sqrt{\frac{MSE}{b_1^2}\left[1 + \frac{1}{n} + \frac{(x_r - X)^2}{\Sigma(x_i - X)^2}\right]} \tag{B.3}$$

where

MSE is the mean square error;

X is the mean load;

n is the number of measurements.

95 % Confidence interval of the calculated cutting force is given by Formula (B.4):

$$CI = x_r \pm t_{\left(1-\frac{a}{2};n-2\right)}^{s} \tag{B.4}$$

B.2 Example calculation

B.2.1 An example dataset of loads and normalized cutting stroke lengths is provided in Table B.1. The calculated cutting force, x_r, of the dataset is 4,3 N with a standard deviation of 0,4 N resulting in a 95 % confidence limit of ±0,88 N (3,42 N ≤x_r≤ 5,18 N). The r^2 of the regression line is 0,95.

Table B.1 — Example of cut test data used to determine the calculated cutting force

Load, *x*, N	**Cutting stroke length**, *y*, mm	**Cutting stroke length**, *y*, mm (normalized)
2,0	47,0	45,6
2,0	48,3	46,9
2,0	49,5	48,0
2,0	43,8	42,5
2,0	41,6	40,4
4,0	20,6	20,0
4,0	25,2	24,4
4,0	19,7	19,1
4,0	22,9	22,2
4,0	23,8	23,1
6,0	9,5	9,2
6,0	14,3	13,9
6,0	12,7	12,3
6,0	9,1	8,8
6,0	13,4	13,0

B.2.2 The standard Microsoft Excel® formulae are shown in Table B.2. The application of the regression analysis is shown graphically in Figure B.1. A plot of the untransformed (normalized) cutting stroke lengths versus applied load is shown in Figure B.2 illustrating the logarithmic shape of the trend line. The results of the step-wise calculations and parameters are as follows: