ISO 148-1

Third edition

2016-10-15

Metallic materials — Charpy pendulum impact test — Part 1: Test method

Matériaux métalliques — Essai de flexion par choc sur éprouvette Charpy — Partie 1: Méthode d'essai

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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.

The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 4, *Toughness testing — Fracture (F), Pendulum (P), Tear (T)*.

This third edition cancels and replaces the second edition (ISO 148-1:2009), which has been technically revised.

ISO 148 consists of the following parts, under the general title *Metallic materials — Charpy pendulum impact test*:

— *Part 1: Test method*

— *Part 2: Verification of testing machines*

— *Part 3: Preparation and characterization of Charpy V-notch test pieces for indirect verification of pendulum impact machines*

1 Scope

This part of ISO 148 specifies the Charpy (V-notch and U-notch) pendulum impact test method for determining the energy absorbed in an impact test of metallic materials. This part of ISO 148 does not cover instrumented impact testing, which is specified in ISO 14556.

Annexes B and C are based on ASTM E23 and are used with the permission of ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, USA.

2 Normative references

The following referenced documents, in whole or in part, are normatively referenced in this document and are indispensable for the application 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 148-2, *Metallic materials — Charpy pendulum impact test — Part 2: Verification of testing machines*

ISO 286-1, *Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 1: Basis of tolerances, deviations and fits*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 Definitions pertaining to energy

3.1.1

initial potential energy
potential energy
K_p
potential energy of the pendulum hammer prior to its release for the impact test, as determined by direct verification

3.1.2

absorbed energy
K
energy required to break a test piece with a pendulum impact testing machine, after correction for friction

Note 1 to entry: The letter V or U is used to indicate the notch geometry, that is: KV or KU. The number 2 or 8 is used as a subscript to indicate the radius of the striker, for example KV_2.

3.1.3

nominal initial potential energy
nominal energy
K_N
energy assigned by the manufacturer of the pendulum impact testing machine

3.2 Definitions pertaining to test piece

3.2.1

width
W
distance between the notched face and the opposite face

Note 1 to entry: See Figure 1.

Note 2 to entry: In previous versions of the ISO 148 series (prior to 2016), the distance between the notched face and the opposite face was specified as “height”. Changing this dimension to “width” makes this part of ISO 148 consistent with the terminology used in other ISO fracture standards.

3.2.2
thickness

B

dimension perpendicular to the width and parallel to the notch

Note 1 to entry: See Figure 1.

Note 2 to entry: In previous versions of the ISO 148 series (prior to 2016), the dimension perpendicular to the width that is parallel to the notch was specified as “width”. Changing this dimension to “thickness” makes this part of ISO 148 consistent with the terminology used in other ISO fracture standards.

3.2.3
length

L

largest dimension perpendicular to the notch

Note 1 to entry: See Figure 1.

4 Symbols and abbreviated terms

The symbols and designations applicable to this part of ISO 148 are indicated in Tables 1 and 2, and are illustrated in Figure 2.

Table 1 — Symbols and their unit and designation

Symbol	Unit	Designation
B	mm	thickness of test piece
α	°	angle of fall of the pendulum
β_1	J or °	angle of rise when the machine is operated in the normal manner without a test piece in position
β_2	J or °	angle of rise when the machine is operated in the normal manner without a test piece in position and without resetting the indication mechanism
L	mm	length of test piece
LE	mm	lateral expansion
K	J	absorbed energy (expressed as KV_2, KV_8, KU_2, KU_8, to identify specific notch geometries and the radius of the striking edge)
K_1	J or °	indicated absorbed energy when the machine is operated in the normal manner without a test piece in position
K_2	J or °	indicated absorbed energy when the machine is operated in the normal manner without a test piece in position and without resetting the indication mechanism
K_N	J or °	nominal initial potential energy
K_p	J	initial potential energy (potential energy)
KV_2	J	absorbed energy for a V-notch test piece using a 2 mm striker
KV_8	J	absorbed energy for a V-notch test piece using a 8 mm striker

KU_2	J	absorbed energy for a U-notch test piece using a 2 mm striker
KU_8	J	absorbed energy for a U-notch test piece using an 8 mm striker
M	N·m	moment equal to the product $F{\cdot}l_2$
p	J	absorbed energy loss caused by pointer friction
p'	J	absorbed energy loss caused by bearing friction and air resistance
p_β	J	correction of absorbed energy losses for an angle of rise β
SFA	%	shear fracture appearance
T_t	°C	transition temperature
W	mm	width of test piece
T_{t27}	°C	transition temperature defined at a specific value of absorbed energy; for example, 27 J
$T_{t50\,\%\mathrm{US}}$	°C	transition temperature defined at a particular percentage of the absorbed energy of the upper shelf; for example, 50 %
$T_{t50\,\%\mathrm{SFA}}$	°C	transition temperature defined at a particular proportion of shear fracture; for example, 50 %
$T_{t0,9}$	°C	transition temperature defined at a particular amount of lateral expansion; for example, 0,9 mm

5 Principles of the test

This test consists of breaking a notched test piece with a single blow from a swinging pendulum, under the conditions defined in Clauses 6, 7 and 8. The notch in the test piece has a specified geometry and is located in the middle between two supports, opposite to the location which is impacted in the test. The energy absorbed in the impact test, the lateral expansion and the shear fracture appearance are normally determined.

Because the impact values of many metallic materials vary with temperature, tests shall be carried out at a specified temperature. When this temperature is other than ambient, the test piece shall be heated or cooled to that temperature, under controlled conditions.

The Charpy pendulum impact test is often used in routine, high-throughput pass/fail acceptance tests in industrial settings. For these tests, it may not be important whether the test sample is completely broken, partially broken, or simply plastically deformed and dragged through the anvils. In research, design, or academic settings, the measured energy values are studied in more detail, in which case it can be highly relevant whether the sample is broken or not.

It is important to note that not all Charpy pendulum impact test results can be directly compared. For example, the test can be performed with hammers having strikers with different radii, or with different test piece shapes. Tests performed with different strikers can give different results,[7] and test results obtained with differently shaped test pieces can as well. This is why not only the adherence to ISO 148 but also a clear and complete reporting of the type of instrument, the test piece and the details of the post-test test pieces are crucial for comparability of results.

6 Test pieces

6.1 General

The standard test piece shall be 55 mm long and of square section, with 10 mm sides. In the centre of the length, there shall be either a V-notch or a U-notch, as described in 6.2.1 and 6.2.2, respectively.

If the standard test piece cannot be obtained from the material, one of the subsize test pieces, having a thickness of 7,5 mm, 5 mm or 2,5 mm (see Figure 2 and Table 2), shall be used, if not otherwise specified.

NOTE 1 Direct comparison of results is only of significance when made between test pieces of the same form and dimensions.

NOTE 2 For low energies, the use of shims to better position subsize test pieces relative to the centre of strike is important to avoid excess energy absorption by the pendulum. For high energies, this might not be as important. Shims can be placed on or under the test piece supports, with the result that the mid-thickness of the specimen is 5 mm above the 10 mm supports. Shims can be temporarily fixed to the supports using tape or another means.

When a heat-treated material is being evaluated, the test piece shall be finish-machined and notched after the final heat treatment, unless it can be demonstrated that machining before heat treatment does not affect test results.

6.2 Notch geometry

The notch shall be carefully prepared so that the root radius of the notch is free of machining marks which could affect the absorbed energy.

The plane of symmetry of the notch shall be perpendicular to the longitudinal axis of the test piece (see Figure 2).

6.2.1 V-notch

The V-notch shall have an included angle of 45°, a depth of 2 mm and a root radius of 0,25 mm [see Figure 2 a) and Table 2].

6.2.2 U-notch

The U-notch shall have a depth of 5 mm (unless otherwise specified) and a root radius of 1 mm [see Figure 2 b) and Table 2].

6.3 Tolerance of the test pieces

The tolerances on the specified test piece and notch dimensions are shown in Figure 2 and Table 2.

6.4 Preparation of the test pieces

Preparation shall be executed in such a way that any alteration of the test piece, for example due to heating or cold working, is minimized.

6.5 Marking of the test pieces

The test piece may be marked on any face not in contact with supports, anvils or striker and at a position where plastic deformation and surface discontinuities caused by marking do not affect the absorbed energy (see 8.8).

7 Test equipment

7.1 General

The measurements of the instrument and test piece details shall be traceable to national or international standards. Equipment used for measurements shall be calibrated within suitable intervals.

7.2 Installation and verification

The testing machine shall be installed and verified in accordance with ISO 148-2.

7.3 Striker

The striker geometry shall be specified as being either the 2 mm striker or the 8 mm striker. It is recommended that the radius on the striker be shown as a subscript as follows: KV_2 or KV_8 and KU_2 or KU_8.

Reference shall be made to the product specification for striker geometry guidance.

NOTE Tests carried out with 2 mm and 8 mm strikers can give different results.[7]

8 Test procedure

8.1 General

The test piece shall lie squarely against the anvils of the testing machine, with the plane of symmetry of the notch within 0,5 mm of the mid-plane between the anvils. It shall be struck by the striker in the plane of symmetry of the notch and on the side opposite the notch (see Figure 1).

8.2 Friction measurement

The energy absorbed by friction shall be checked on every testing day prior to the first test. The friction losses may be estimated as explained below, but other methods may also be applied.

NOTE The energy absorbed by friction includes, but is not limited to, air resistance, bearing friction and the friction of the indicating pointer. Increases in friction on a machine can influence the measure of absorbed energy.

8.2.1 To determine the loss caused by pointer friction the machine is operated in the normal manner, but without a test piece in position, and the angle of rise, β_1, or energy reading, K_1, is noted. A second test is then carried out without resetting the indication pointer and the new angle of rise, β_2, or energy reading, K_2, is noted. Thus, the loss due to friction in the indicating pointer during the rise is equal to

$$p = M(\cos\beta_1 - \cos\beta_2) \tag{1}$$

when the scale is graduated in degrees, or

$$p = K_1 - K_2 \tag{2}$$

when the scale is graduated in energy units.

NOTE For machines without a pointer, this friction measurement is not necessary.

8.2.2 The procedure to determine the losses caused by bearing friction and air resistance for one half swing is as follows.

After determining β_2 or K_2, the pendulum is returned to its initial position. Without resetting the indicating mechanism, release the pendulum without shock and vibration and permit it to swing 10 half swings. After the pendulum starts its 11th half swing, move the indicating mechanism to about 5 % of the scale-range capacity and record the value as β_3 or K_3. The losses by bearing friction and air resistance for one half swing are equal to

$$p' = 1/10\ M(\cos\beta_3 - \cos\beta_2) \tag{3}$$

when the scale is graduated in degrees, or

$$p' = 1/10\ (K_3 - K_2) \tag{4}$$

when the scale is graduated in energy units.

The number of swings can be changed at the discretion of machine users, and p' should be corrected on account of the applied number of swings.

NOTE 1 If it is required to take into account these losses in an actual test giving an angle of rise, β, the quantity can be subtracted from the value of the absorbed energy.

$$p_\beta = p\frac{\beta}{\beta_1} + p'\frac{\alpha + \beta}{\alpha + \beta_2} \tag{5}$$

Because β_1 and β_2 are nearly equal to α, the angle of fall, for practical purposes Formula (5) can be reduced to:

$$p_\beta = p\frac{\beta}{\alpha} + p'\frac{\alpha + \beta}{2\alpha} \tag{6}$$

For machines graduated in energy units, the value of β can be calculated as follows:

$$\beta = \arccos[1 - 1/M(K_\mathrm{P} - K_\mathrm{T})] \tag{7}$$

The total friction loss, $p + p'$, so measured, shall not exceed 0,5 % of the nominal energy, K_N. If it does, and it is not possible to bring the friction loss within the tolerance by reducing the pointer friction, the bearings shall be cleaned or replaced.

8.3 Test temperature

8.3.1 Unless otherwise specified, tests shall be carried out at 23 °C ± 5 °C (ambient temperature). If a temperature is specified, the test piece shall be conditioned to a temperature within ±2 °C.

8.3.2 For conditioning (heating or cooling) using a liquid medium, the test piece shall be positioned in a container on a grid that is at least 25 mm above the bottom of the container and covered by at least 25 mm of liquid, and be at least 10 mm from the sides of the container. The medium shall be constantly agitated and brought to the specified temperature by any convenient method. The device used to measure the temperature of the medium should be placed in the centre of the group of test pieces. The temperature of the medium shall be held at the specified temperature within ±1 °C for at least 5 min.

NOTE When a liquid medium is near its boiling point, evaporative cooling can dramatically lower the temperature of the test piece during the interval between removal from the liquid and fracture.[8]

8.3.3 For conditioning (heating or cooling) using a gaseous medium, the test piece shall be positioned in a chamber at least 50 mm from the nearest surface. Individual test pieces shall be separated by at least 10 mm. The medium shall be constantly circulated and brought to the specified temperature by any convenient method. The device used to measure the temperature of the medium should be placed in the centre of the group of test pieces. The temperature of the gaseous medium shall be held at the specified temperature within ±1 °C for at least 30 min before the test piece is removed from the medium for testing.

8.3.4 Other methods for heating or cooling are allowed, if the other pertinent requirements of 8.3 are fulfilled.

8.4 Specimen transfer

When testing is performed at other than ambient temperature, not more than 5 s shall elapse between the time the test piece is removed from the heating or cooling medium and the time it is impacted by the striker. An exception is made if the difference between the ambient or instrument temperature and the test piece temperature is less than 25 °C, in which case the time for specimen transfer shall be less than 10 s.

The transfer device shall be designed and used in such a way that the temperature of the test piece is maintained within the permitted temperature range.

The parts of the device in contact with the specimen during transfer from the medium to the machine shall be conditioned with the specimens.

Care should be taken to ensure that the device used to centre the test piece on the anvils does not cause the fractured ends of low-energy, high-strength test pieces to rebound off the device into the pendulum. This pendulum/test piece interaction results in erroneously high indicated energy. It has been shown that clearance between the end of a test piece in the test position and the centring device, or a fixed portion of the machine, shall be equal to or greater than 13 mm to avoid the ends of the test pieces rebounding into the pendulum during the test.

NOTE Self-centring tongs, similar to those shown in Annex A for V-notched test pieces, are often used to transfer the test piece from the temperature-conditioning medium to the proper test position. Tongs of this nature eliminate potential clearance problems due to interference between the fractured specimen halves and a fixed centring device.

8.5 Exceeding machine capacity

The absorbed energy, K, should not exceed 80 % of the initial potential energy, K_p. If the absorbed energy exceeds this value, the absorbed energy shall be reported as approximate and it shall be noted in the test report as exceeding 80 % of the machine capacity.

NOTE Ideally, an impact test would be conducted at a constant impact velocity. In a pendulum-type test, the velocity decreases as the fracture progresses. For specimens with impact energies approaching the capacity of the pendulum, the velocity of the pendulum decreases during fracture to the point that accurate impact energies are no longer obtained.

8.6 Incomplete fracture

Test pieces do not always break into two pieces during the test.

For material acceptance testing, it is not required to report information concerning incomplete fracture.

For tests, other than material acceptance testing, it is required that unbroken test pieces are reported.

NOTE 1 In the case where individual specimens are not identified within test records, the group can be identified as broken or unbroken.

NOTE 2 A test piece that is not fully separated in two half test pieces upon impact can be considered broken if the two halves can be separated by pushing the hinged halves together without the aid of mechanical tools and without fatiguing the specimen.

NOTE 3 A material acceptance test is a test which is used to asses a minimum acceptance requirement.

8.7 Test piece jamming

If a test piece jams in the machine, the results shall be disregarded and the machine thoroughly checked for damage that would affect its state of calibration.

NOTE Jamming occurs when a broken test piece is caught between moving and non-moving parts of the testing machine. It can result in significant energy absorption. Jamming can be differentiated from secondary strike marks, because jamming is associated with a pair of opposing marks on the specimen.

8.8 Post-fracture inspection

If post-fracture inspection shows that any portion of the test specimen identification marking is in a portion of the test piece which is visibly deformed, the test result might not be representative of the material and this shall be noted in the test report.

9 Test report

9.1 Mandatory information

The test report shall contain the following information or, when agreed by the customer, it shall be possible to retrieve this information based on a traceable coding of the test report by the test laboratory:

a) reference to this part of ISO 148, i.e. ISO 148-1;

b) identification of the test piece (e.g. type of steel and cast number);

c) size of the test piece, if other than the standard test piece;

d) temperature of the test or the conditioning temperature of the test specimens;

e) absorbed energy, KV_2, KV_8, KU_2, or KU_8, as appropriate;

f) whether the specimen, or the majority of specimens in a group of specimens were broken (not required for material acceptance tests);

g) any abnormalities that could have affected the test.

9.2 Optional information

The test report may optionally include, in addition to the information in 9.1:

a) test piece orientation (see ISO 3785);

b) initial potential energy of the testing machine, in joules;

c) lateral expansion (see Annex B);

d) shear fracture appearance (see Annex C);

e) absorbed energy/temperature curve (see D.1);

f) lateral expansion/temperature curve;

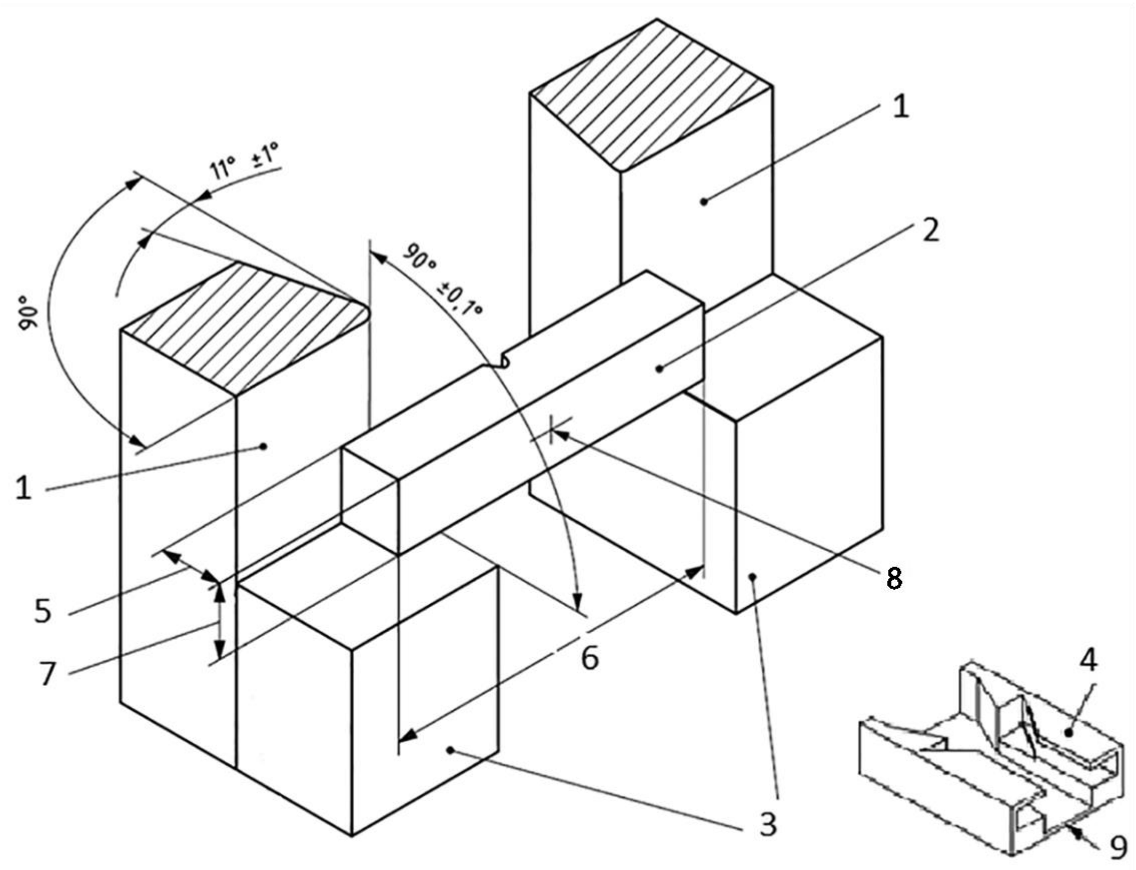
g) shear fracture appearance/temperature curve;

h) transition temperature(s) and the criteria used for its (their) determination (see D.2);

i) number of test pieces which were not completely broken in the test;

j) date (month and year) of the most recent full direct and indirect verifications;

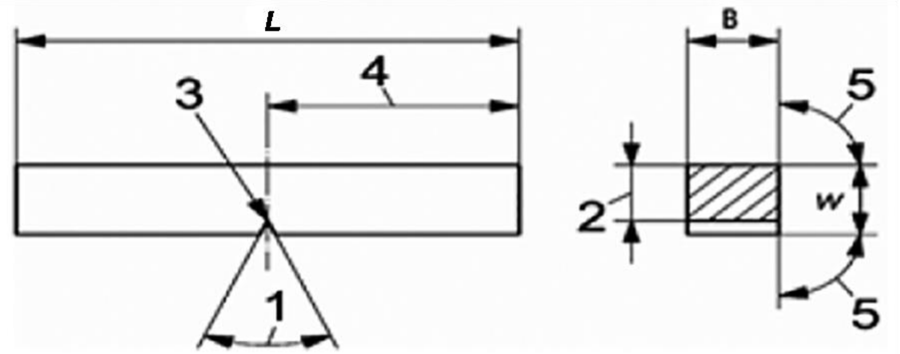
k) measurement uncertainty of the absorbed energy (see Annex E).



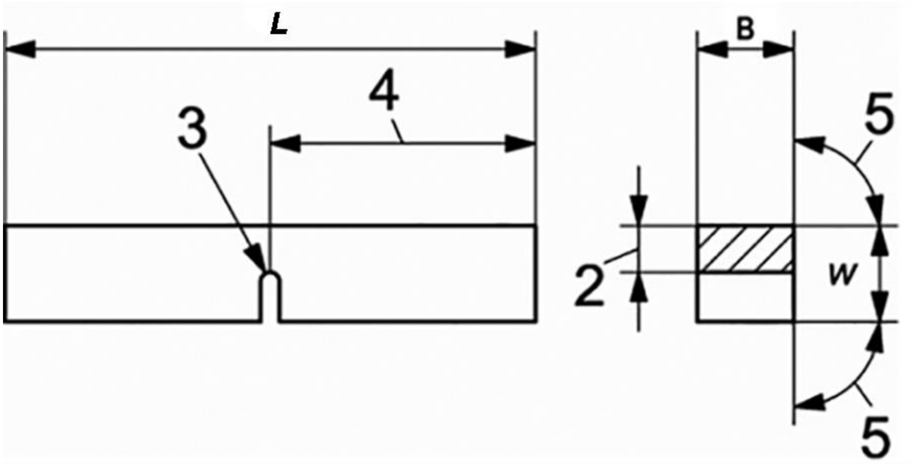
Key

1	anvil
2	standardized test piece
3	test piece supports
4	shroud
5	width of test piece, *W*
6	length of test piece, *L*
7	thickness of test piece, *B*
8	centre of strike
9	direction of pendulum swing

Figure 1 — Test piece terminology showing configuration of test piece supports and anvils of a pendulum impact testing machine



a) V-notch geometry



b) U-notch geometry

NOTE For the symbols *L*, *W*, *B* and the numbers 1 to 5, refer to Table 2.

Figure 2 — Charpy pendulum impact test piece

Table 2 — Tolerances on specified test piece dimensions

Designation	**Symbol and no.**	**V-notch test piece**			**U-notch test piece**		
		Nominal dimension	**Machining tolerance**		**Nominal dimension**	**Machining tolerance**	
				Tolerance class[a]			**Tolerance class**[a]
Length	*L*	55 mm	±0,60 mm	js15	55 mm	±0,60 mm	js15
Width	*W*	10 mm	±0,075 mm	js12	10 mm	±0,11 mm	js13
Thickness[c]	*B*	10 mm	±0,11 mm	js13	10 mm	±0,11 mm	js13
— standard test piece — subsize test piece — subsize test piece — subsize test piece		10 mm 7,5 mm 5 mm 2,5 mm	±0,11 mm ±0,11 mm ±0,06 mm ±0,05 mm	js13 js13 js12 js12	10 mm 7,5 mm 5 mm —	±0,11 mm ±0,11 mm ±0,06 mm —	js13 — — —
Angle of notch	1	45°	±2°	—	—	—	—
Ligament	2	8 mm	±0,075 mm	js12	5 mm	±0,09 mm	js13
Notch radius	3	0,25 mm	±0,025 mm	—	1 mm	±0,07 mm	js12
Notch position (centering)	4	27,5 mm	±0,42 mm [d]	js15	27,5 mm	±0,42 mm[d]	js15
Angle between plane of symmetry of notch and longitudinal axis of test piece		90°	±2°	—	90°	±2°	—
Angle between adjacent longitudinal faces of test piece	5	90°	±2°	—	90°	±2°	—
Surface roughness[b]	NA	<5 µm			<5 µm		

[a] In accordance with ISO 286-1.

[b] The test pieces shall have a surface roughness better than *Ra* 5 µm except for the ends.

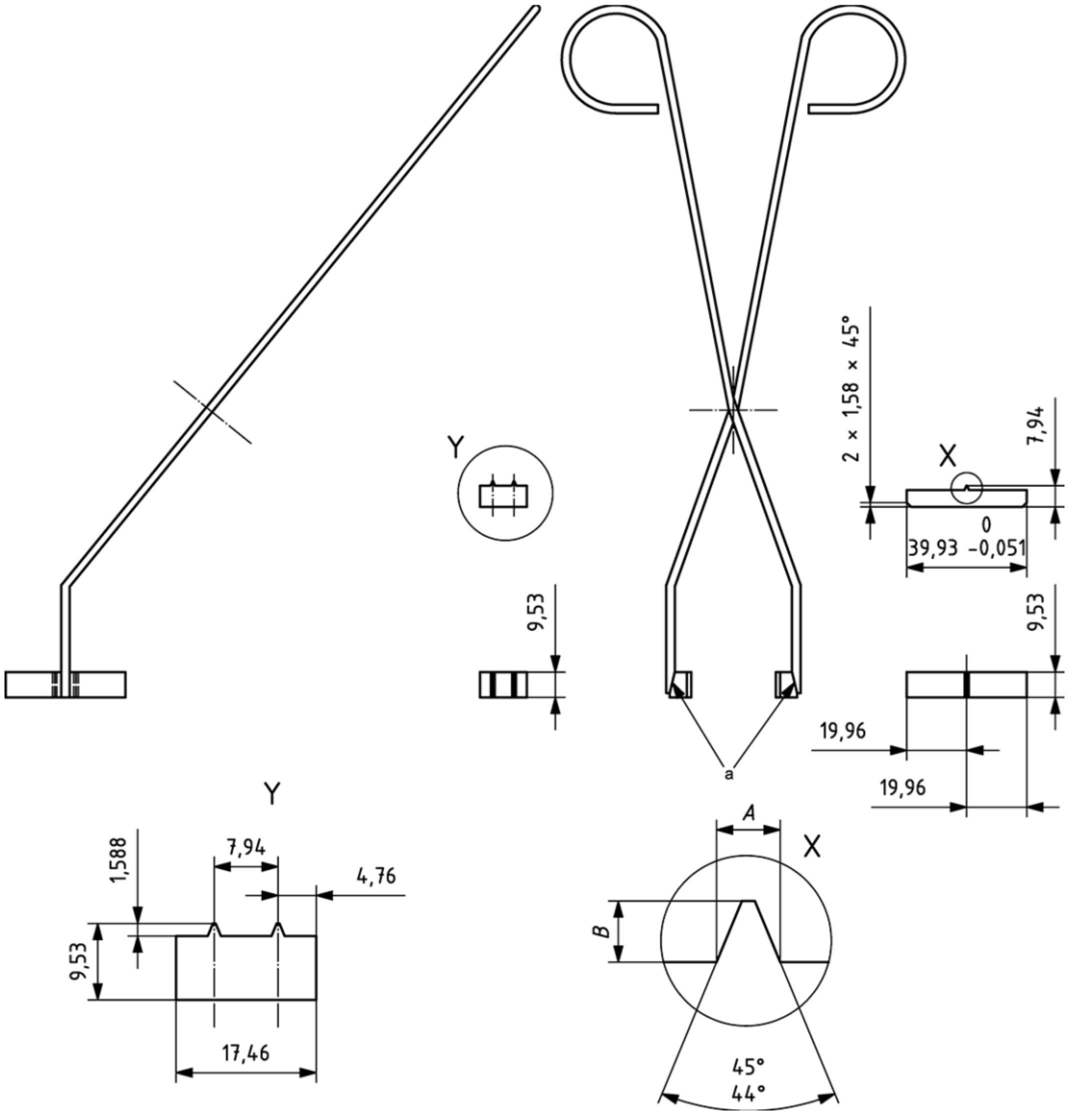
[c] If another thickness (2 mm or 3 mm) is specified, the corresponding tolerances shall also be specified.

[d] For machines with automatic positioning of the test piece, it is recommended that the tolerance be taken as ±0,165 mm instead of ±0,42 mm.

Annex A
(informative)
Self-centring tongs

Tongs similar to the example shown in Figure A.1 are often used to transfer the test piece and properly position it in the pendulum impact testing machine.

Dimensions in millimetres



Specimen thickness	*A*	*B*
10	1,60 to 1,70	1,52 to 1,65
5	0,74 to 0,80	0,69 to 0,81
3	0,45 to 0,51	0,36 to 0,48

[a] Steel pieces silver soldered to tongs parallel to each other.

Figure A.1 — Centring tongs for V-notched Charpy specimens

Annex B
(informative)
Lateral expansion

B.1 General

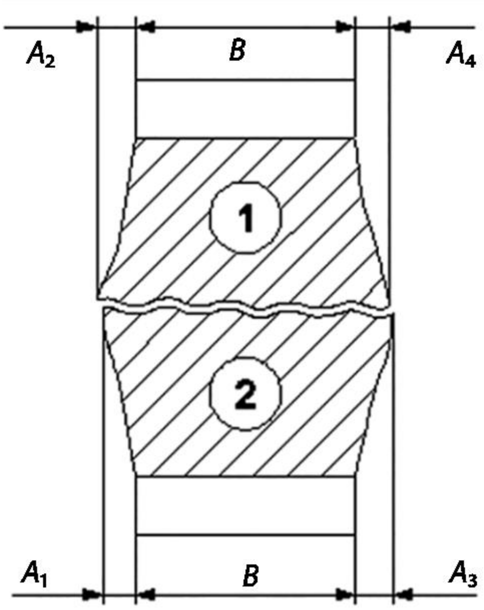
A measure of the ability of the material to resist fracture when subjected to triaxial stresses, such as those at the root of the notch in a Charpy test piece, is the amount of deformation that occurs at this location. The deformation in this case is contraction. Because of the difficulties in measuring this deformation, even after fracture, the expansion that occurs at the opposite end of the fracture plane is customarily measured and used as a proxy for the contraction.

B.2 Procedure

The method of measuring lateral expansion should take into account the fact that the fracture plane seldom bisects the point of maximum expansion on both sides of a test piece. One half of a broken test piece might include the maximum expansion for both sides, one side only, or neither. The techniques used should therefore provide an expansion value, equal to the sum of the higher of the two values obtained for each side, by measuring the two halves separately. The amount of expansion on each side of each half shall be measured relative to the plane defined by the undeformed portion of the side of the test piece (see Figure B.1). Contact and non-contact methods can be used for these measurements.

Lateral expansion may be measured by using a gauge similar to that shown in Figures B.2 and B.3. Measure the two broken halves individually. First, however, check the sides perpendicular to the notch to ensure that no burrs were formed on these sides during impact testing; if such burrs exist, they shall be removed, for example by rubbing with an emery cloth, making sure that the protrusions to be measured are not rubbed during the removal of the burr. Next, place the half-specimens together so that the surfaces originally opposite the notch are facing one another. Take one of the half-specimens (see Figure B.1) and press it firmly against the reference supports, with the protrusions against the gauge anvil. Note the reading, and then repeat this step with the other half-specimen (see Figure B.1), ensuring that the same side is measured. The larger of the two values is the expansion of that side of the test piece. Repeat this procedure to measure the protrusions on the opposite side, and then add the larger values obtained for each side. For example if $A_1 > A_2$ and $A_3 = A_4$, consequently $LE = A_1 + (A_3$ or $A_4)$. If $A_1 > A_2$ and $A_3 > A_4$, consequently, $LE = A_1 + A_3$.

If one or more protrusions of a test piece have been damaged by contacting the anvil, machine mounting surface, etc., the test piece shall not be measured and the condition shall be indicated in the test report.



Key

1	side one of fractured test piece
2	side two of fractured test piece
B	thickness of test piece, mm
A_1, A_2, A_3, A_4,	distance measured, mm

Figure B.1 — Halves of broken Charpy V-notched impact specimen, illustrating the measurement of lateral expansion

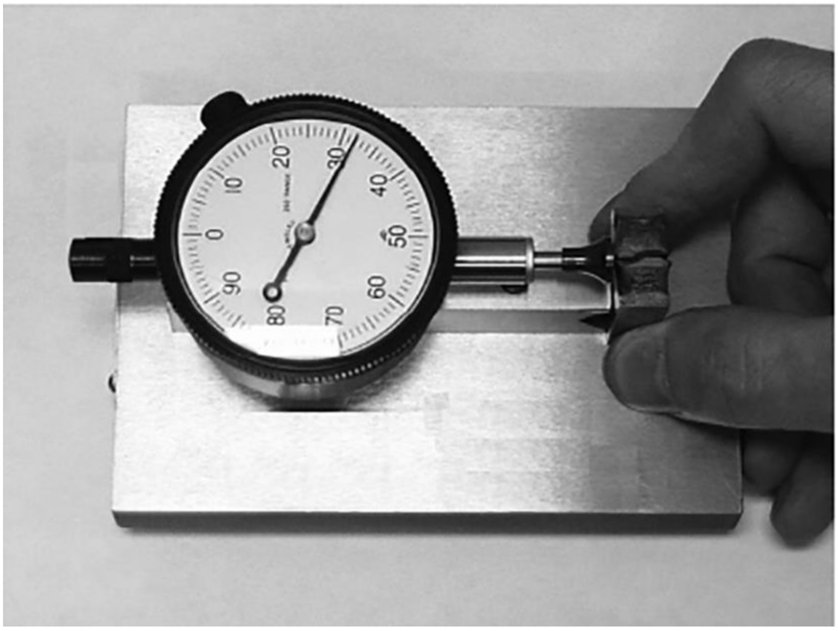
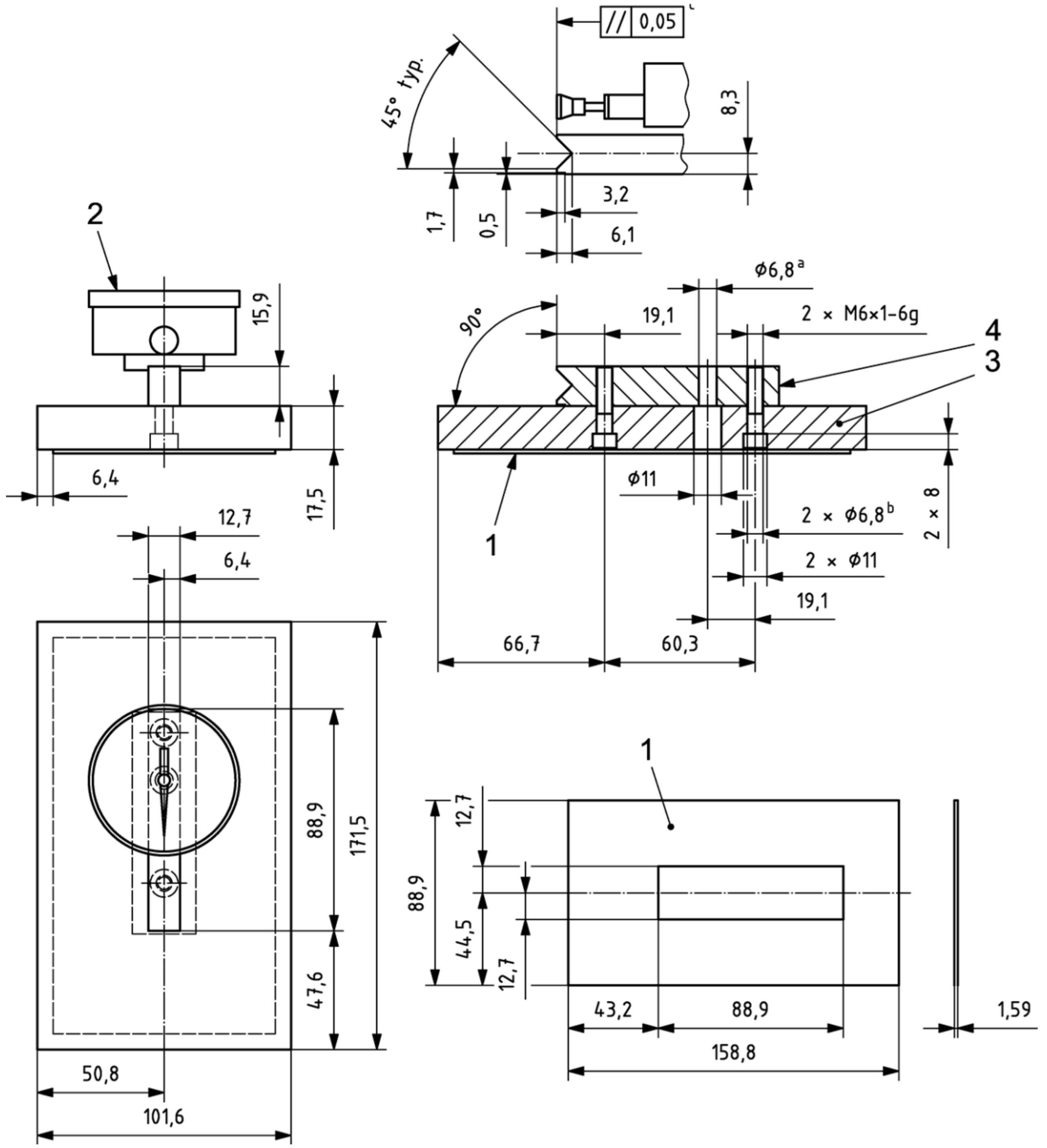


Figure B.2 — Lateral expansion gauge for Charpy specimens showing both halves of a Charpy specimens being measured on one side, rather than each half individually

Dimensions in millimetres



Key

1 pad made of rubber

2 indicator, 10 mm range, graduations in 1/100 mm

3 base plate made of stainless steel or chrome-plated steel

4 dial mount made of stainless steel or chrome-plated steel

[a] For 1/4-20 UNC screw with 7/8” long socket head to mount the indicator.

[b] For M6 × 1 screw with 25 mm socket head.

[c] Lap at assembly.

Figure B.3 — Assembly and details for lateral expansion gauge

Annex C
(informative)
Fracture appearance

C.1 General

The fracture surface of Charpy test pieces is often rated by the percentage of shear fracture which occurs. The greater the percentage of shear fracture, the greater the notch toughness of the material. The fracture surface of most Charpy specimens exhibits a mixture of shear and flat fracture regions. The shear regions are assumed to be fully ductile, but the flat fracture regions can be ductile, brittle, or a combination of these fracture modes. Because the rating is extremely subjective, it is recommended that it is not to be used in specifications.

NOTE The term fibrous-fracture appearance is often used as a synonym for shear fracture appearance. The terms cleavage fracture appearance and crystallinity are often used to express the opposite of shear fracture.

C.2 Procedures

The percentage of shear fracture is commonly determined by any one of the following methods:

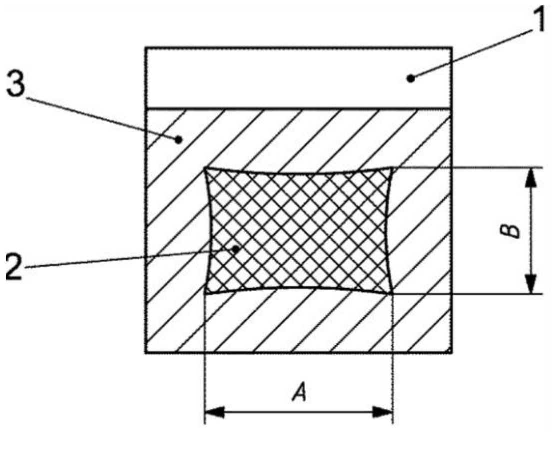
a) measuring the length and width of the cleavage portion (the “shiny” portion) of the flat fracture region, as given in Figure C.1, and determining the percent shear from Table C.1;

b) comparing the appearance of the fracture of the test piece with a fracture appearance chart, such as that given in Figure C.2;

c) magnifying the fracture surface and comparing it to a precalibrated overlay chart, or measuring the per cent cleavage fracture by means of a planimeter, then calculating per cent shear fracture (as 100 % cleavage fracture);

d) photographing the fracture surface at a suitable magnification and measuring the per cent cleavage fracture by means of a planimeter, then calculating per cent shear fracture (as 100 % cleavage fracture);

e) measuring the per cent shear fracture by image analysis techniques.



Key

1 notch

2 cleavage area (brittle)

3 shear area (dull)

A dimension measured to estimate the cleavage area

B dimension measured to estimate the cleavage area

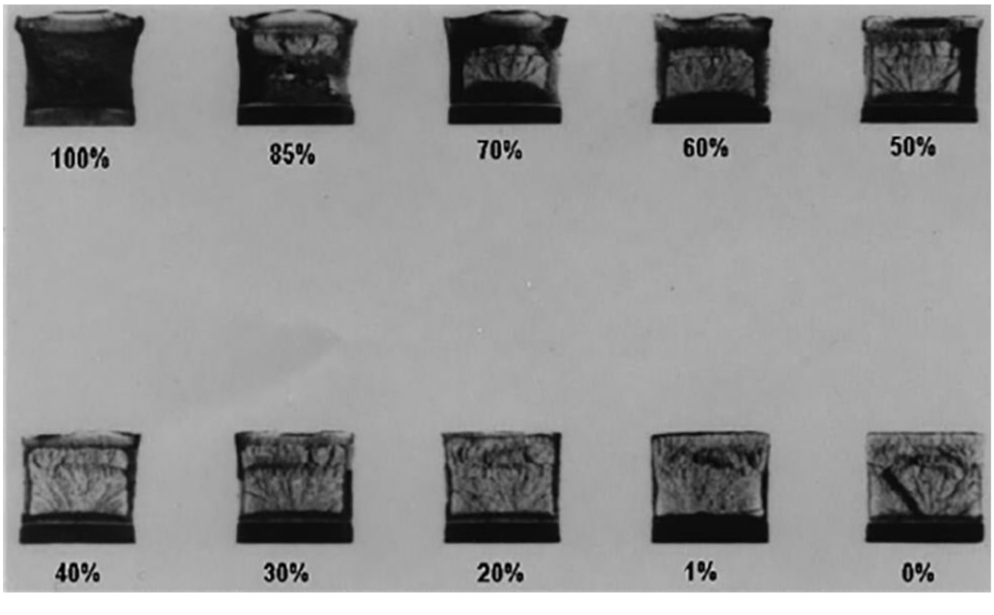
NOTE 1 Measure dimensions *A* and *B* to the nearest 0,5 mm.

NOTE 2 Determine the per cent shear fracture using Table C.1.

Figure C.1 — Determination of per cent shear fracture

Table C.1 — Per cent shear for measurements in millimetres

B mm	*A* mm																		
	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0	6,5	7,0	7,5	8,0	8,5	9,0	9,5	10
	Per cent shear																		
1,0	99	98	98	97	96	96	95	94	94	93	92	92	91	91	90	89	89	88	88
1,5	98	97	96	95	94	93	92	92	91	90	89	88	87	86	85	84	83	82	81
2,0	98	96	95	94	92	91	90	89	88	86	85	84	82	81	80	79	77	76	75
2,5	97	95	94	92	91	89	88	86	84	83	81	80	78	77	75	73	72	70	69
3,0	96	94	92	91	89	87	85	83	81	79	77	76	74	72	70	68	66	64	62
3,5	96	93	91	89	87	85	82	80	78	76	74	72	69	67	65	63	61	58	56
4,0	95	92	90	88	85	82	80	77	75	72	70	67	65	62	60	57	55	52	50
4,5	94	92	89	86	83	80	77	75	72	69	66	63	61	58	55	52	49	46	44
5,0	94	91	88	85	81	78	75	72	69	66	62	59	56	53	50	47	44	41	37
5,5	93	90	86	83	79	76	72	69	66	62	59	55	52	48	45	42	38	35	31
6,0	92	89	85	81	77	74	70	66	62	59	55	51	47	44	40	36	33	29	25
6,5	92	88	84	80	76	72	67	63	59	55	51	47	43	39	35	31	27	23	19
7,0	91	87	82	78	74	69	65	61	56	52	47	43	39	34	30	26	21	17	12
7,5	91	86	81	77	72	67	62	58	53	48	44	39	34	30	25	20	16	11	6
8,0	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
NOTE 100 % shear shall be reported when *A* and *B* are zero.																			



a) Fracture appearance charts and per cent shear fracture comparator

b) Guide for estimating fracture appearance

Figure C.2 — Fracture appearance

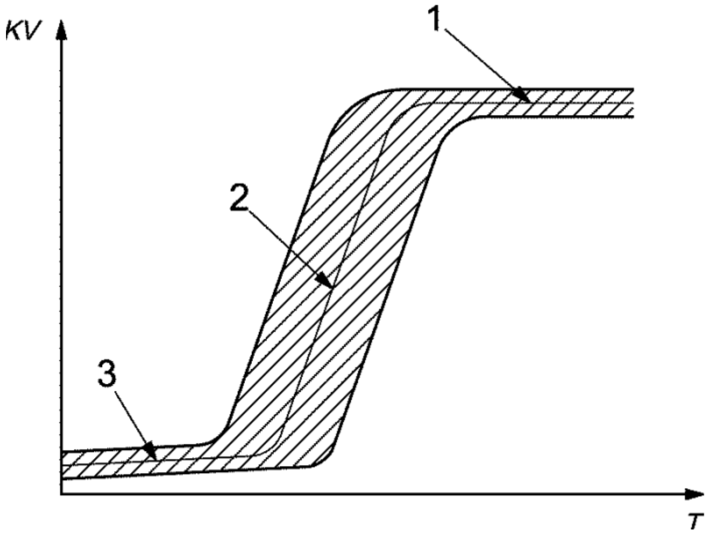
Annex D

(informative)

Absorbed energy vs. temperature curve and the transition temperature

D.1 Absorbed energy/temperature curve

The absorbed energy/temperature curve (K/T curve) shows the energy absorbed as a function of the test temperature for a given type of test piece (see Figure D.1). In general, the curve is obtained by drawing a fitted curve through the individual values. The shape of the curve and the scatter of the test values are dependent on the material, the specimen shape and the impact velocity. In the case of a curve with a ductile-to-brittle transition zone, a distinction is made between the upper-shelf zone, transition zone and the lower-shelf zone.



Key

T	temperature
K	absorbed energy
1	upper-shelf zone
2	transition zone
3	lower-shelf zone

NOTE Transition curves for shear fracture area and for lateral expansion are also common, but are not shown here.

Figure D.1 — Absorbed energy/temperature curve shown schematically

D.2 Transition temperatures

The transition temperature, T_t, characterizes the position of the steep rise in the absorbed energy/temperature curve. Since the steep rise usually extends over a fairly wide temperature range, there can be no generally applicable definition of the transition temperature. The following criteria have, among others, been found useful for determining the transition temperature:

a) T_{t27}, corresponding to a specific value of absorbed energy, e.g. $KV_8 = 27$ J;

b) $T_{t50\ \%\mathrm{US}}$, corresponding to a particular percentage of the absorbed energy of the upper-shelf value, e.g. 50 %;

c) $T_{t50\ \%\mathrm{SFA}}$, corresponding to a particular proportion of shear fracture, e.g. 50 %;

d) $T_{t0,9}$, corresponding to a particular amount of lateral expansion, e.g. 0,9 mm.

The method used to define the transition temperature should be specified in the product standard or specification, or established by agreement.

NOTE The most commonly used fitting model for transition curves is the hyperbolic tangent fitting model.

Annex E
(informative)
Measurement uncertainty of an absorbed energy value, K

E.1 Symbols and units

The symbols and units used in this annex are given in Table E.1. KV is used for example purposes only, where the letter V or U indicates notch geometry.

Table E.1 — Symbols and units

Symbol	Unit	Definition
B_V	J	bias of the pendulum impact testing machine, as determined through indirect verification
k		coverage factor
KV	J	absorbed energy as measured in accordance with this International Standard on V-notched sample
$\overline{KV}$	J	reported average KV value of a set of samples from a test material
KV_R	J	certified KV value of the reference material used in the indirect verification
$\overline{KV}_V$	J	mean KV value of the reference test pieces tested for indirect verification
n		number of tested samples
r	J	instrument scale resolution
s_x	J	standard deviation of the values obtained on the n test samples
T_x	J	error of measured KV value due to temperature effects
$u\left(\overline{KV}\right)$	J	standard uncertainty of $\overline{KV}$
$U(\overline{KV})$	J	expanded uncertainty of $\overline{KV}$ with a confidence level of about 95 %
$u(r)$		standard uncertainty due to machine resolution
u_T	K	standard uncertainty of the test temperature
u_V	J	standard uncertainty of the indirect verification result
$u\left(\bar{x}\right)$	J	standard uncertainty of $\bar{x}$
$\bar{x}$	J	observed average KV value of a set of n samples from a test material without correction for bias
$\nu_{\overline{KV}}$		degrees of freedom corresponding with $u\left(\overline{KV}\right)$
ν_V		degrees of freedom corresponding with u_V
$\nu_{\bar{x}}$		degrees of freedom corresponding with $u\left(\bar{x}\right)$

E.2 Determination of measurement uncertainty

E.2.1 General

This Annex specifies a robust method for determining the uncertainty, $u\left(\overline{KV}\right)$, associated with the mean absorbed energy, $\overline{KV}$, of a set of specimens of a test material. Other methods of assessing $u\left(\overline{KV}\right)$ can be developed and are acceptable, if they meet the requirements of the GUM.[4]

This approach requires input from the "indirect verification" of the Charpy pendulum impact testing machine, which is a normative method of assessing the performance of the instrument with reference test pieces (see ISO 148-2).

NOTE 1 The ISO 148 series requires Charpy pendulum impact testing machines to successfully meet the requirements for both indirect and direct verification. The latter consists of a check of all individual geometric and mechanical requirements imposed on the construction of the instrument (see ISO 148-2).

The roles of direct and indirect verification in the metrological traceability chain of Charpy measurements are given in Figure E.1. The chain starts at the international level with the definition of the measurand, *KV*, or absorbed energy, in the standard procedures described in the ISO 148 series. Global comparability relies on international comparisons of Charpy reference machines and of the certified values of the certified reference test pieces produced by national or international bodies using sets of reference machines.

Calibration laboratories use the certified reference test pieces to verify their reference machine and can use their pendulum to characterize and produce reference test pieces. At the user level, Charpy test laboratories can verify their pendulum with reference test pieces to obtain reliable *KV* values.

NOTE 2 Users can choose to acquire certified reference test pieces from national or international organizations, by-passing the calibration laboratory level.

NOTE 3 For additional information on the difference between certified reference test pieces and reference test pieces, see ISO 148-3:2016, Annex A.

E.2.2 Uncertainty disclaimer

Measurement uncertainty analysis is useful in identifying major sources of inconsistencies in measured results.

Product standards and material property databases based on this part of ISO 148 have an inherent contribution from measurement uncertainty. It is therefore inappropriate to apply further adjustments for measurement uncertainty and thereby risk a product which fails compliance. For this reason, the estimates of uncertainty derived from following this procedure are for information only, unless specifically instructed otherwise by the customer.

The test conditions and limits defined in this part of ISO 148 should not be adjusted to take account of uncertainties of measurement, unless specifically instructed otherwise by the customer. The estimated measurement uncertainties should not be combined with measured results to assess compliance to product specifications, unless specifically instructed otherwise by the customer. Instead, the indicated tolerances are to be interpreted as acceptance intervals.[5] This approach assumes that measurements are made with a tacitly accepted maximum measurement uncertainty. Where possible, this maximum measurement uncertainty has been specified in the current version of the ISO 148 series. Measurement uncertainties of the measured values should be smaller than the indicated values.

E.3 General procedure

E.3.1 Factors contributing to uncertainty

The principal factors contributing to uncertainty are associated with

a) machine bias deduced from the indirect verification,

b) homogeneity of the test material and machine repeatability, and

c) test temperature.

The measurement equation for the mean absorbed energy $\overline{KV}$ is Formula (E.1):

$$\overline{KV} = \overline{x} - B_\mathrm{V} - T_\mathrm{x} \tag{E.1}$$

where

$\overline{x}$ is the observed mean absorbed energy of *n* test specimens;

B_V is the instrument bias based on the indirect verification;

T_x is the bias due to temperature.

E.3.2 Machine bias

As a rule (see Reference [5]), measured values should be corrected for known bias. Indirect verification is one way to establish the value of bias. The machine bias determined by indirect verification is defined in ISO 148-2, as given in Formula (E.2):

$$B_\mathrm{V} = \overline{KV}_\mathrm{V} - KV_\mathrm{R} \tag{E.2}$$

where

$\overline{KV}_\mathrm{V}$ is the mean value of the reference test pieces broken during the indirect verification;

KV_R is the certified value of the reference test pieces.

Depending on how well the value of B_V is known, different actions are proposed in ISO 148-2 which deals with the uncertainty associated with the results of indirect verification.

a) B_V is well known and stable. In this exceptional case, the observed value $\overline{x}$ is corrected by a term equal to B_V to obtain $\overline{KV}$.

b) Most often, there is no firm evidence about the stability of the value of B_V. In this case, the bias is not corrected for, but it contributes to u_V, the uncertainty of the indirect verification result.

In both cases, an uncertainty, u_V, associated with the indirect verification result and the machine bias is calculated in accordance with procedures described in ISO 148-2. The outcome of the uncertainty analysis of the indirect verification is the value u_V.

If there is a significant difference between the values of $\overline{KV}_\mathrm{V}$ and $\overline{KV}$, then the values B_V and u_V should be multiplied by the ratio $\overline{KV}\big/\overline{KV}_\mathrm{V}$.

E.3.3 Machine repeatability and material heterogeneity

The uncertainty of $\overline{x}$, the mean observed absorbed energy of *n* test specimens, is determined using Formula (E.3):

$$u(\overline{x}) = \frac{s_x}{\sqrt{n}} \tag{E.3}$$

where s_x is the standard deviation of the values obtained on the *n* test samples.

The value s_x is caused by two factors:

— machine repeatability;

— sample-to-sample material heterogeneity.

These factors are confounded, and therefore, are both included in this term. It is recommended to report the total measurement uncertainty with the value of s_x as a conservative measure for the variation in K_V due to material heterogeneity.

The value of $\nu_{\bar{x}}$, the number of degrees of freedom of $u(\bar{x})$, is calculated as n-1.

E.3.4 Temperature bias

The effect of temperature bias, T_x, on the absorbed energy is extremely material dependent. If steel is tested in the brittle-to-ductile transition region, small changes in temperature can correspond to large differences in absorbed energy. At the time of publication, it is not possible to present a generic and accepted approach to the calculation of the contribution to absorbed energy uncertainty corresponding with the uncertainty of the measured test temperature. Instead, it is proposed to complement the statement of the measurement uncertainty in terms of absorbed energy with a separate statement on u_T, the uncertainty of the test temperature at which the absorbed energy was measured (see E.5 for example).

E.3.5 Machine resolution

The effect of machine resolution is in most cases negligible in comparison with the other factors contributing to uncertainty (see E.3.1 to E.3.4). An exception is the case where machine resolution is large and the measured energy is low. In that case, the corresponding uncertainty contribution is calculated using Formula (E.4):

$$u\left(r\right) = \frac{r}{\sqrt{3}} \tag{E.4}$$

where r is the machine resolution.

The corresponding number of degrees of freedom is ∞.

E.4 Combined and expanded uncertainty

To calculate $u\left(\overline{KV}\right)$, the factors contributing to uncertainty (see E.3) should be combined. Since u_T is treated separately, and since the terms $u(\bar{x})$, u_V and $u_{(r)}$ are independent of each other, the combined standard uncertainty is determined using Formula (E.5):

$$u(\overline{KV}) = \sqrt{u^2(\bar{x}) + u_\mathrm{V}^2 + u^2(r)} \tag{E.5}$$

To calculate the expanded uncertainty, the combined standard uncertainty is multiplied by the appropriate coverage factor, k. The value of k depends on $\nu_{\overline{KV}}$, the effective degrees of freedom of $u\left(\overline{KV}\right)$, which can be computed using the simple Welch-Satterthwaite[4] approximation, by combining the degrees of freedom, ν_V and ν_x, and evaluating the corresponding uncertainty contributions, u_V and $u\left(\bar{x}\right)$. Since the value of the degrees of freedom corresponding to $u(r)$ is ∞, the machine resolution does not contribute to $\nu_{\overline{KV}}$, see Formula (E.6):

$$\nu_{\overline{KV}} = \frac{u^4\left(\overline{KV}\right)}{\dfrac{u^4\left(\bar{x}\right)}{\nu_{\bar{x}}} + \dfrac{u_V^4}{\nu_V}} \tag{E.6}$$

NOTE In the case of Charpy tests, the number of samples is often limited to 5 or even 3. In addition, the heterogeneity of the samples often leads to a significant value of $u\left(\bar{x}\right)$. This is why the number of effective degrees of freedom is most often not sufficiently large to use a coverage factor of k equal to 2.

The coverage factor, k, corresponding to a confidence level of about 95 % is obtained from the GUM t-table as $t_{95}\left(\nu_{\overline{KV}}\right)$. (For selected t-values, see Table E.5.) The expanded uncertainty of $\overline{KV}$ is determined using Formula (E.7):

$$U\left(\overline{KV}\right) = k \times u\left(\overline{KV}\right) = t_{95}\left(\nu_{\overline{KV}}\right) \times u\left(\overline{KV}\right) \tag{E.7}$$

E.5 Example

In this example, the measurement uncertainty is calculated for the mean value, $\bar{x}$, of a set of n = 3 samples from a particular test material. The results in Table E.2 were obtained on a pendulum which was successfully checked with both direct and indirect verification procedures. As a first step, the mean observed KV value, $\bar{x}$, is calculated, as well as the standard uncertainty, $u\left(\bar{x}\right)$, which is calculated using Formula (E.3).

Table E.2 — Raw Charpy test results

Dimensions in joules

Test results	
KV, Sample 1	105,8
KV, Sample 2	109,3
KV, Sample 3	112,2
Mean *KV*, $\bar{x}$	109,1
Standard deviation of $n = 3$ *KV*-values, s_x	3,2
Standard uncertainty of the mean observed *KV*, $u(\bar{x})$, calculated according to Formula (E.3)	1,9

In the second step, the raw results (without correction for bias) were combined with the results of the most recent indirect verification test, for which reference test pieces of different energy levels (e.g. 20 J, 120 J and 220 J) were used. The test material had an absorbed energy level closest to the 120 J level ($\bar{x}$ = 109,1 J). Therefore, the indirect verification results obtained at this energy level were used in the uncertainty assessment. The bias value, B_V, met the verification criteria in accordance with ISO 148-2. Since there is no firm evidence about the stability of B_V, the measured value was not corrected for the bias. Therefore, the reported KV value, $\overline{KV}$, is equal to the mean value, $\bar{x}$, of the measured values. Since the measured value was not corrected for the bias, it contributed to the uncertainty of the indirect verification result, u_V. The resulting standard uncertainty of the indirect verification result at 120 J was u_V = 5,2 J, with a number of degrees of freedom equal to 7 (see ISO 148-2). This information should be available in the instrument dossier, which is updated after each verification.

Table E.3 gives the measurement uncertainty calculation procedure.

Table E.3 — Calculation scheme of expanded measurement uncertainty, $U\left(\overline{KV}\right)$

Raw test results		Results from indirect verification at 120 J	
$u(\bar{x})$	1,9 J	u_V	5,2 J
Degrees of freedom ν_X for tests on $n = 3$ samples, calculated as $n-1$	2	Degrees of freedom of indirect verification ν_V, taken from calibration certificate	7
Combined standard uncertainty $u\left(\overline{KV}\right)$, from Formula (E.5)			5,5 J
$\nu_{\overline{KV}}$, the effective degrees of freedom of $u\left(\overline{KV}\right)$, from Formula (E.6)			8
t-factor corresponding with a $\nu_{\overline{KV}}$ of 8 and a 95 % confidence level, $t_{95}\left(\nu_{\overline{KV}}\right)$			2,3
Expanded uncertainty $U\left(\overline{KV}\right)$			12,6 J

Table E.4 can be used to report the test results and measurement uncertainty.

Table E.4 — Summary table of the result, $\overline{KV}$, with expanded measurement uncertainty, $U\left(\overline{KV}\right)$

n	s_X [a] J	$\overline{KV}$ J	$\nu_{\overline{KV}}$	$t_{95}\left(\nu_{\overline{KV}}\right)$	$U\left(\overline{KV}\right)$ [b, c] J
3	3,2	109,1	8	2,3	12,6

[a] This standard deviation is a conservative estimate of the test material heterogeneity (its value also contains a contribution from the machine repeatability, which cannot be separately assessed).

[b] The expanded uncertainty, calculated in accordance with this procedure, corresponds to a confidence level of about 95 %.

[c] The uncertainty quoted is subject to an uncertainty of the test temperature, which was measured to an uncertainty of 2 K (confidence level of 95 %). The uncertainties quoted do not consider contributions that can be introduced by particular characteristics of the test material.

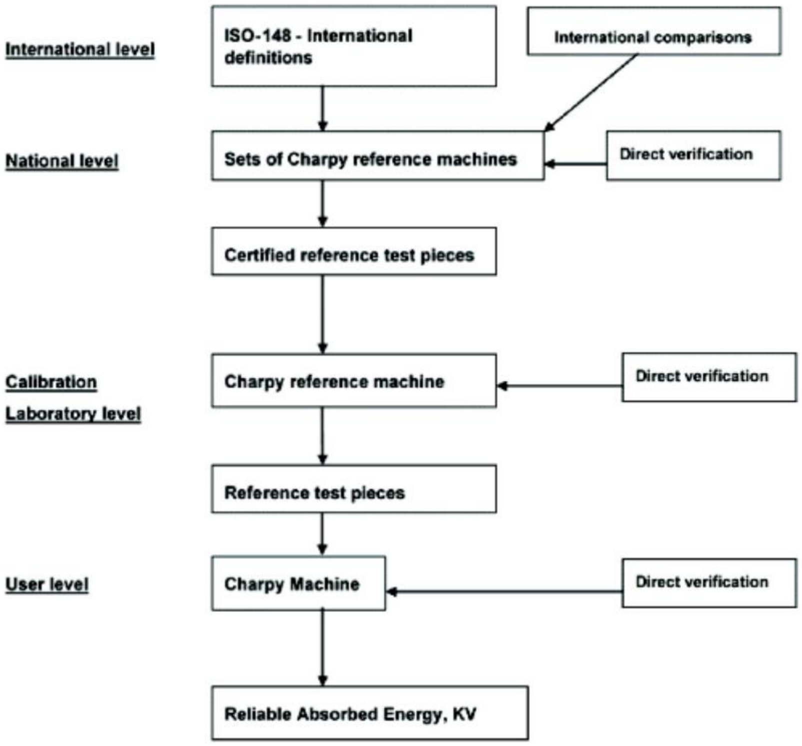


Figure E.1 — Structure of the metrological traceability chain for the definition and dissemination of the absorbed energy scales of the Charpy impact test

Table E.5 — Value of $t_p(\text{v})$ from the t-distribution for v degrees of freedom that defines an interval $-t_p(\text{v})$ to $+t_p(\text{v})$ that encompasses the fraction, p, of the distribution[5]

Degrees of freedom, v	$t_p(\text{v})$ **for fraction** $P = 95\ \%$
1	12,71
2	4,30
3	3,18
4	2,78
5	2,57
6	2,45
7	2,36
8	2,31
9	2,26
10	2,23
11	2,20
12	2,18
13	2,16
14	2,14
15	2,13
16	2,12
17	2,11
18	2,10
19	2,09
20	2,09
25	2,06
30	2,04
35	2,03
40	2,02
45	2,01
50	2,01
100	1,98
∞	1,96

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