INTERNATIONAL STANDARD

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

Reference number
ISO 148-1:2016(E)

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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*

Metallic materials — Charpy pendulum impact test —

Part 1:
Test method

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

Table 1 *(continued)*

Symbol	Unit	Designation
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

$$p = M(\cos \beta_1 - \cos \beta_2) \quad (1)$$

when the scale is graduated in degrees, or

$$p = K_1 - K_2 \quad (2)$$

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

$$p' = 1/10\, M(\cos \beta_3 - \cos \beta_2) \qquad (3)$$

when the scale is graduated in degrees, or

$$p' = 1/10\, (K_3 - K_2) \qquad (4)$$

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.

$$p_\beta = p\frac{\beta}{\beta_1} + p'\frac{\alpha + \beta}{\alpha + \beta_2} \qquad (5)$$

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

$$p_\beta = p\frac{\beta}{\alpha} + p'\frac{\alpha + \beta}{2\alpha} \qquad (6)$$

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

$$\beta = \arccos[1 - 1/M(K_P - K_T)] \qquad (7)$$

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;

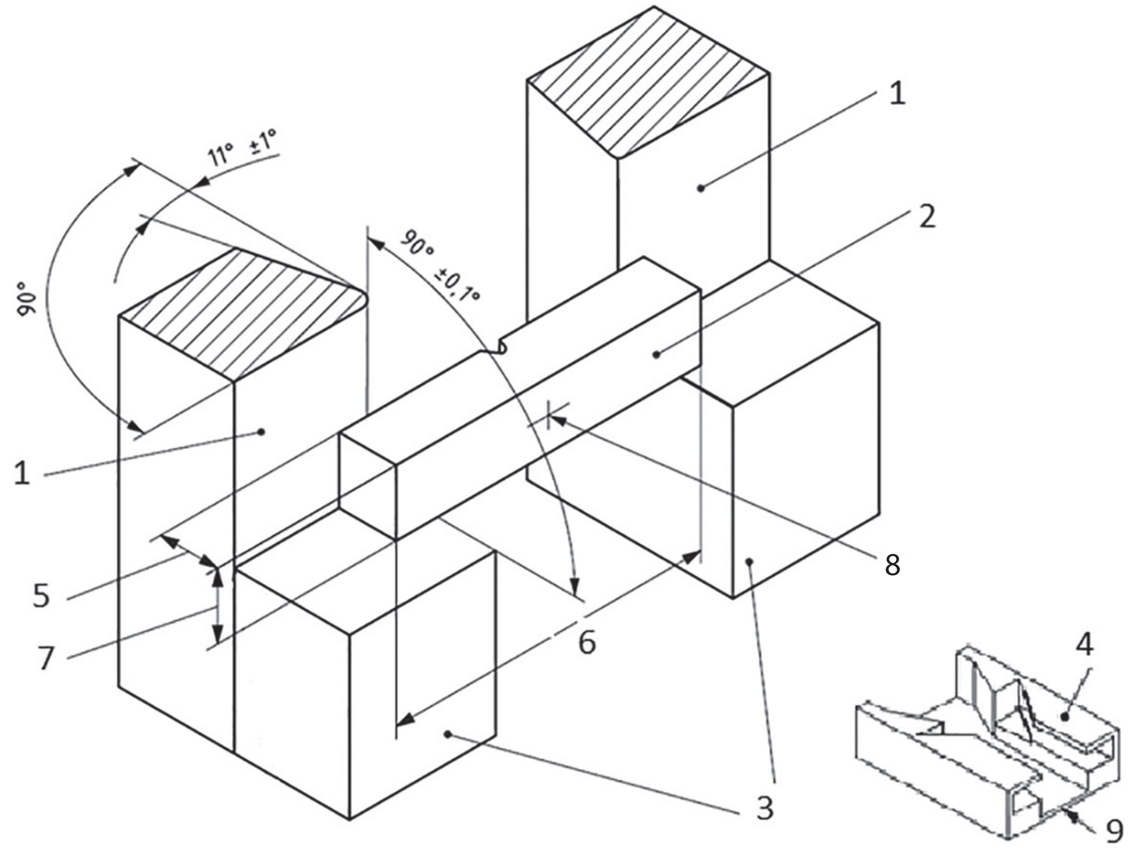
g) shear fracture appearance/temperature curve;

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;

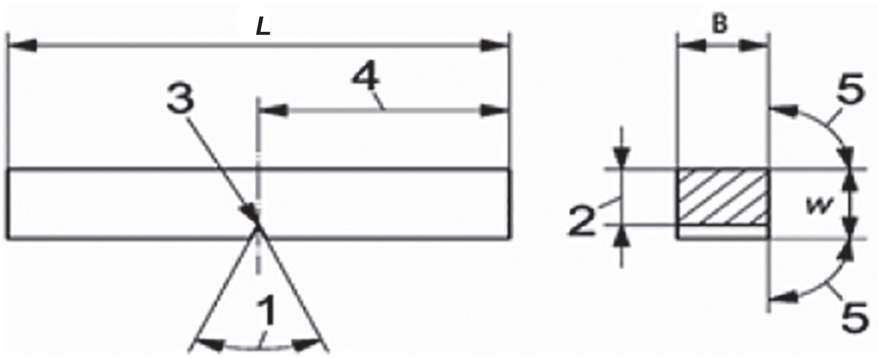
k) measurement uncertainty of the absorbed energy (see Annex E).



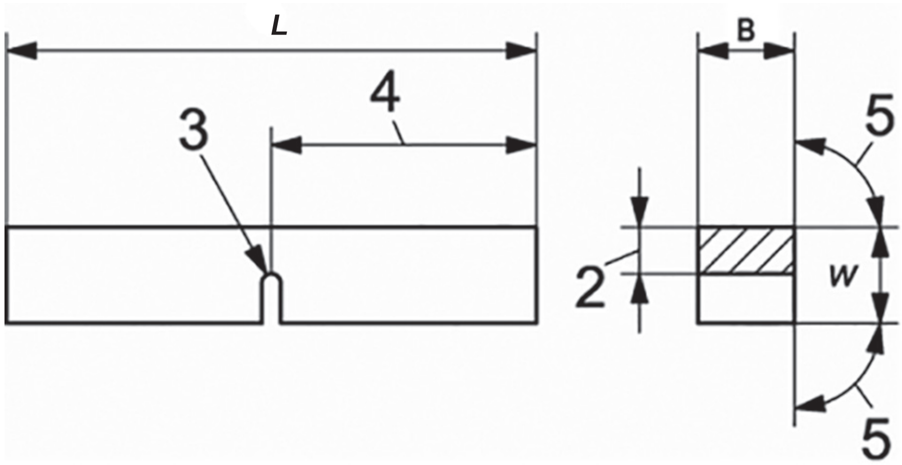
Key

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.

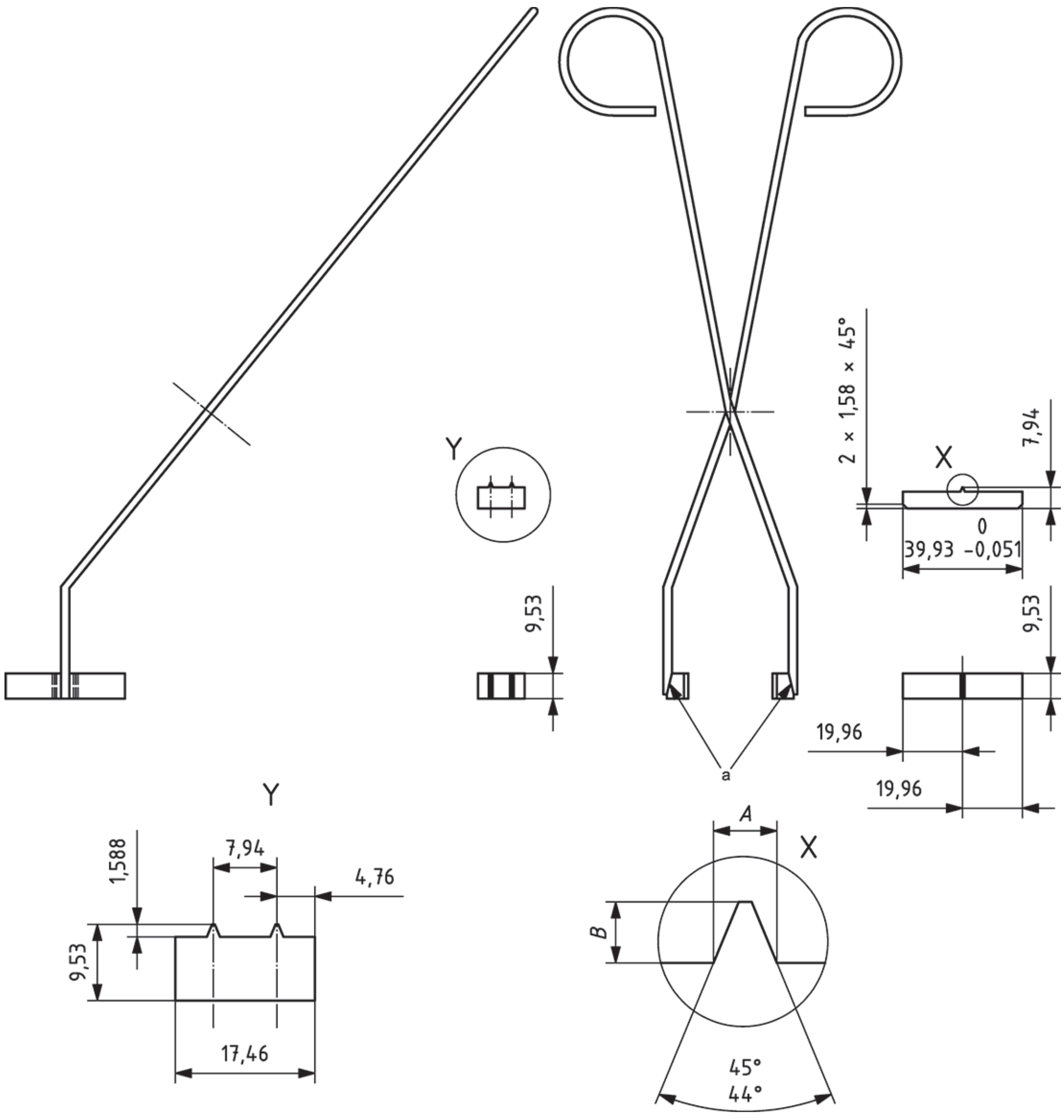
[d] For machines with automatic positioning of the test piece, it is recommended that the tolerance be taken as ±0,165 mm instead of ±0,42 mm.

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



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

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

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

Annex B
(informative)

Lateral expansion

B.1 General

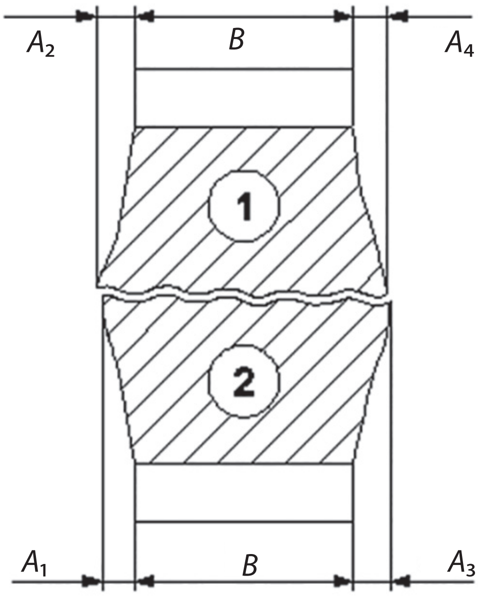
A measure of the ability of the material to resist fracture when subjected to triaxial stresses, such as those at the root of the notch in a Charpy test piece, is the amount of deformation that occurs at this location. The deformation in this case is contraction. Because of the difficulties in measuring 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

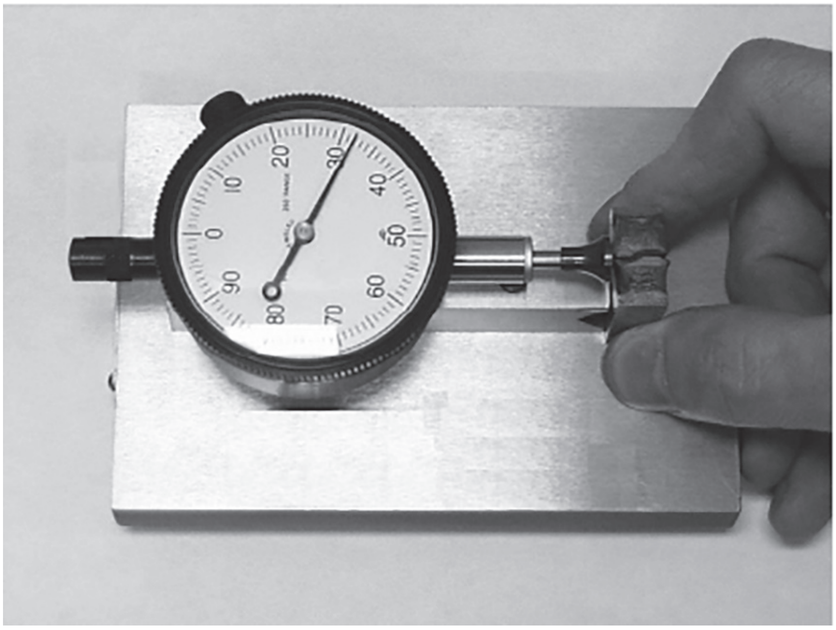
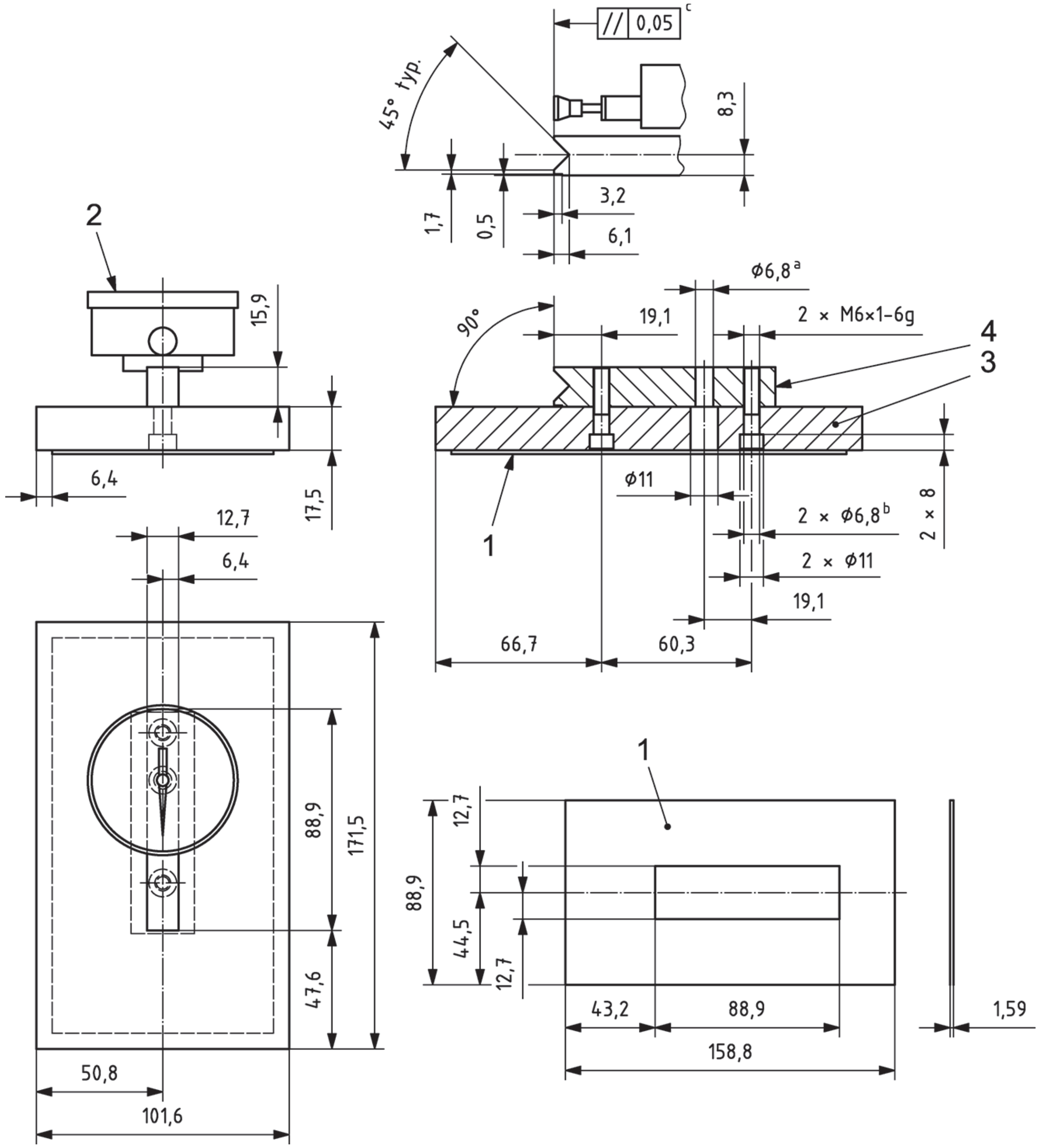


Figure B.2 — Lateral expansion gauge for Charpy specimens showing both halves of a Charpy specimens being measured on one side, rather than each half individually

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:

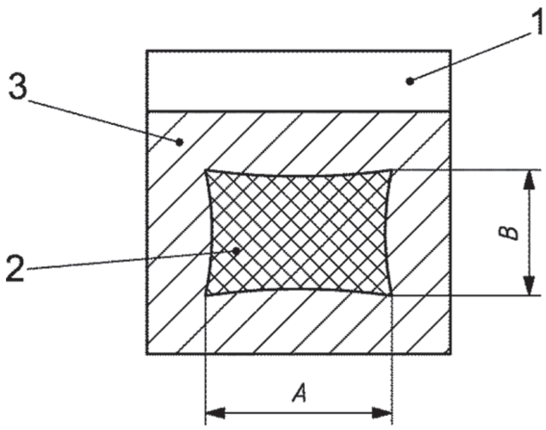
a) measuring the length and width of the cleavage portion (the "shiny" portion) of the flat fracture region, as given in Figure C.1, and determining the percent shear from Table C.1;

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

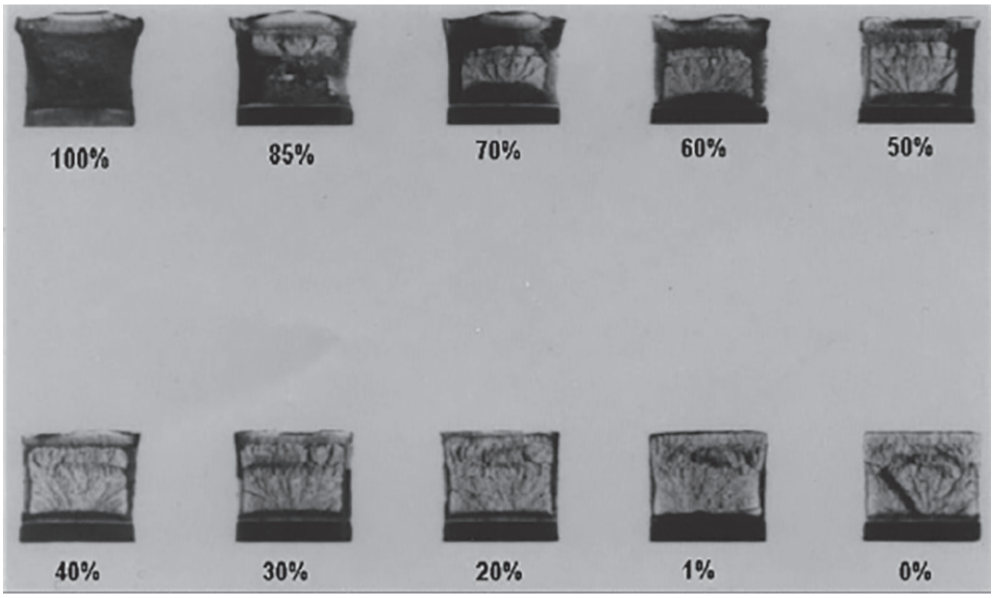
NOTE 1 Measure dimensions *A* and *B* to the nearest 0,5 mm.

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

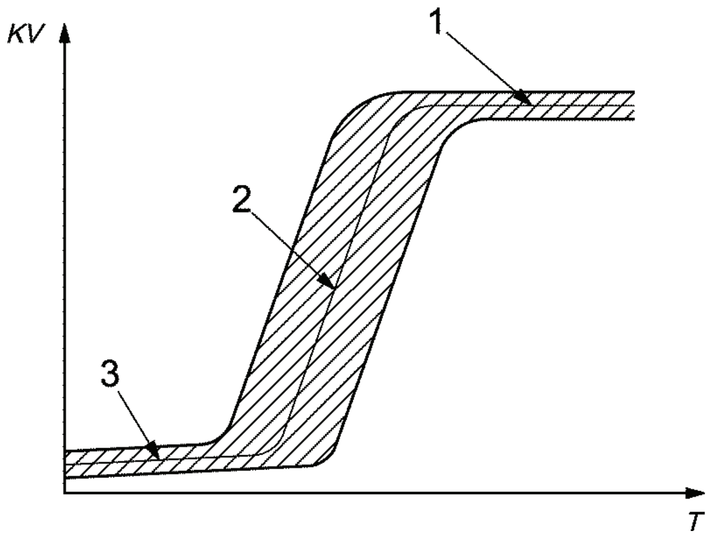
Figure C.2 — Fracture appearance

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

c) $T_{t50\ \%SFA}$, 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
$u\left(\overline{x}\right)$	J	standard uncertainty of $\overline{x}$
$\overline{x}$	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
$\nu_{\overline{x}}$		degrees of freedom corresponding with $u\left(\overline{x}\right)$

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):

$$\overline{KV} = \bar{x} - B_V - T_x \tag{E.1}$$

where

$\bar{x}$ 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):

$$B_V = \overline{KV}_V - KV_R \tag{E.2}$$

where

$\overline{KV}_V$ 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 $\bar{x}$ 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 $\overline{KV}_V$ and $\overline{KV}$, then the values B_V and u_V should be multiplied by the ratio $\overline{KV} / \overline{KV}_V$.

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):

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

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 $\nu_{\overline{x}}$, the number of degrees of freedom of $u(\overline{x})$, 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 $u(\overline{x})$, u_V and $u_{(r)}$ are independent of each other, the combined standard uncertainty is determined using Formula (E.5):

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

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 $u\left(\overline{x}\right)$. 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):

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

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 $u\left(\overline{x}\right)$. 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, $\overline{x}$, 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, $\overline{x}$, is calculated, as well as the standard uncertainty, $u\left(\overline{x}\right)$, 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	
$u\left(\bar{x}\right)$	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.

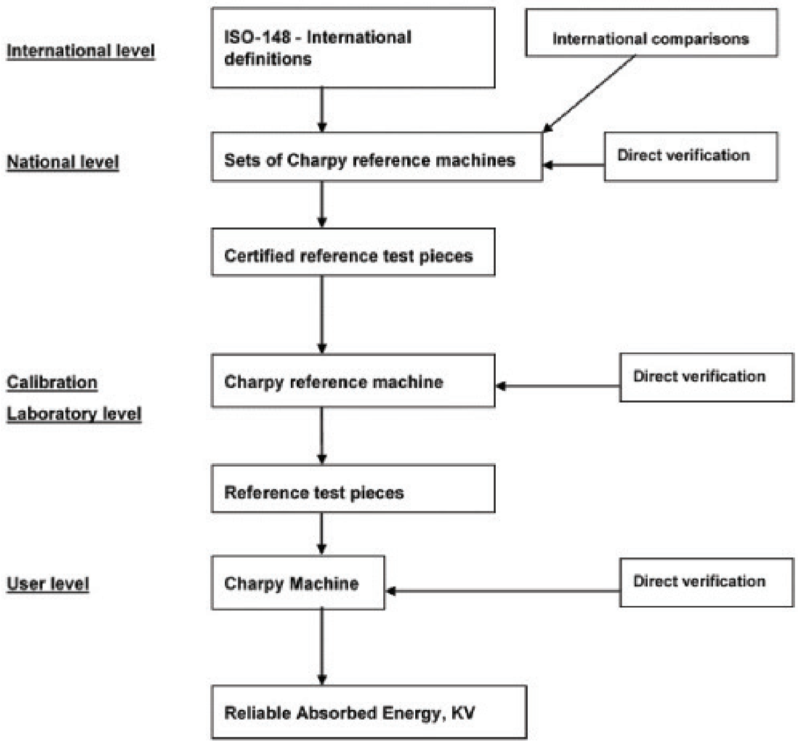


Figure E.1 — Structure of the metrological traceability chain for the definition and dissemination of the absorbed energy scales of the Charpy impact test

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

Degrees of freedom, v	$t_p(\mathrm{v})$ 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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Metallic materials — Charpy pendulum impact test —

Part 2: **Verification of testing machines**

Matériaux métalliques — Essai de flexion par choc sur éprouvette Charpy —

Partie 2: Vérification des machines d'essai (mouton-pendule)

Reference number
ISO 148-2:2016(E)

Contents

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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).

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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 148-2:2008), 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*

Introduction

The suitability of a pendulum impact testing machine for acceptance testing of metallic materials has usually been based on a calibration of its scale and verification of compliance with specified dimensions, such as the shape and spacing of the anvils supporting the specimen. The scale calibration is commonly verified by measuring the mass of the pendulum and its elevation at various scale readings. This procedure for evaluation of machines had the distinct advantage of requiring only measurements of quantities that could be traced to national standards. The objective nature of these traceable measurements minimized the necessity for arbitration regarding the suitability of the machines for material acceptance tests.

However, sometimes two machines that had been evaluated by the direct-verification procedures described above, and which met all dimensional requirements, were found to give significantly different impact values when testing test pieces of the same material.

This difference was commercially important when values obtained using one machine met the material specification, while the values obtained using the other machine did not. To avoid such disagreements, some purchasers of materials added the requirement that all pendulum impact testing machines used for acceptance testing of material sold to them are to be indirectly verified by testing reference test pieces supplied by them. A machine was considered acceptable only if the values obtained using the machine agreed, within specified limits, with the value furnished with the reference test pieces.

This part of ISO 148 describes both the original direct verification and the indirect verification procedures.

Metallic materials — Charpy pendulum impact test —

Part 2: Verification of testing machines

1 Scope

This part of ISO 148 covers the verification of pendulum-type impact testing machines, in terms of their constructional elements, their overall performance and the accuracy of the results they produce. It is applicable to machines with 2 mm or 8 mm strikers used for pendulum impact tests carried out, for instance, in accordance with ISO 148-1.

It can be applied to pendulum impact testing machines of various capacities and of different design.

Impact machines used for industrial, general or research laboratory testing of metallic materials in accordance with this part of ISO 148 are referred to as industrial machines. Those with more stringent requirements are referred to as reference machines. Specifications for the verification of reference machines are found in ISO 148-3.

This part of ISO 148 describes two methods of verification.

a) The direct method, which is static in nature, involves measurement of the critical parts of the machine to ensure that it meets the requirements of this part of ISO 148. Instruments used for the verification and calibration are traceable to national or international standards.

b) The indirect method, which is dynamic in nature, uses reference test pieces to verify points on the measuring scale for absorbed energy. The requirements for the reference test pieces are found in ISO 148-3.

A pendulum impact testing machine is not in compliance with this part of ISO 148 until it has been verified by both the direct and indirect methods and meets the requirements of Clause 6 and Clause 7.

This part of ISO 148 describes how to assess the different components of the total energy absorbed in fracturing a test piece. This total absorbed energy consists of

— the energy needed to fracture the test piece itself, and

— the internal energy losses of the pendulum impact testing machine performing the first half-cycle swing from the initial position.

NOTE Internal energy losses are due to the following:

— air resistance, friction of the bearings of the rotation axis and of the indicating pointer of the pendulum which can be determined by the direct method (see 6.4.5);

— shock of the foundation, vibration of the frame and pendulum for which no suitable measuring methods and apparatus have been developed.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 148-3, *Metallic materials — Charpy pendulum impact test — Part 3: Preparation and characterization of Charpy V-notch test pieces for indirect verification of pendulum impact machines*

3 Terms and definitions

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

3.1 Definitions pertaining to the machine

3.1.1
anvil
portion of the machine that serves to properly position the test piece for impact with respect to the striker and the test piece supports, and supports the test piece under the force of the strike

3.1.2
base
part of the framework of the machine located below the horizontal plane of the supports

3.1.3
centre of percussion
point in a body at which, on striking a blow, the percussive action is the same as if the whole mass of the body were concentrated at the point

Note 1 to entry: When a simple pendulum delivers a blow along a horizontal line passing through the centre of percussion, there is no resulting horizontal reaction at the axis of rotation.

Note 2 to entry: See Figure 4.

3.1.4
centre of strike
point on the striking edge of the pendulum at which, in the free hanging position of the pendulum, the vertical edge of the striker meets the upper horizontal plane of a test piece of half standard thickness (i.e. 5 mm) or equivalent gauge bar resting on the test piece supports

Note 1 to entry: See Figure 4.

3.1.5
industrial machine
pendulum impact machine used for industrial, general or most research-laboratory testing of metallic materials

Note 1 to entry: Industrial machines are not used to establish reference values, unless they also meet the requirements of a reference pendulum (see ISO 148-3).

Note 2 to entry: Industrial machines are verified using the procedures described in this part of ISO 148.

3.1.6
reference machine
pendulum impact testing machine used to determine certified values for batches of *reference test pieces* (3.3.4)

Note 1 to entry: Reference machines are verified using the procedures described in ISO 148-3.

3.1.7
striker
portion of the pendulum that contacts the test piece

Note 1 to entry: The edge that actually contacts the test piece has a radius of 2 mm (the 2 mm striker) or a radius of 8 mm (the 8 mm striker).

Note 2 to entry: See Figure 2.

3.1.8
test piece supports
portion of the machine that serves to properly position the test piece for impact with respect to the *centre of percussion* (3.1.3) of the pendulum, the *striker* (3.1.7) and the *anvils* (3.1.1)

Note 1 to entry: See Figure 2 and Figure 3.

3.2 Definitions pertaining to energy

3.2.1
total absorbed energy
K_T
total absorbed energy required to break a test piece with a pendulum impact testing machine, which is not corrected for any losses of energy

Note 1 to entry: It is equal to the difference in the *potential energy* (3.2.2) from the starting position of the pendulum to the end of the first half swing during which the test piece is broken (see 6.3).

3.2.2
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

Note 1 to entry: See 6.4.2.

3.2.3
absorbed energy
K
energy required to break a test piece with a pendulum impact testing machine, after correction for friction as defined in 6.4.5

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

3.2.4
calculated energy
K_{calc}
energy calculated from values of angle, length and force measured during direct verification

3.2.5
nominal initial potential energy
nominal energy
K_N
energy assigned by the manufacturer of the pendulum impact testing machine

3.2.6
indicated absorbed energy
K_S
energy indicated by the display/dial of the testing machine, which may or may not need to be corrected for friction and air resistance to determine the *absorbed energy*, *K* (3.2.3)

3.2.7
reference absorbed energy
K_R
certified value of *absorbed energy* (3.2.3) assigned to the *reference test pieces* (3.3.4) used to verify the performance of pendulum impact machines

3.3 Definitions pertaining to test pieces

3.3.1
width
W
distance between the notched face and the opposite face

Note 1 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 ISO 148-2 consistent with the terminology used in other ISO fracture standards.

3.3.2
thickness
B
dimension perpendicular to the *width* (3.3.1) and parallel to the notch

Note 1 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 ISO 148-2 consistent with the terminology used in other ISO fracture standards.

3.3.3
length
L
largest dimension perpendicular to the notch

3.3.4
reference test piece
impact test piece used to verify the suitability of a pendulum impact testing machine by comparing the *indicated absorbed energy* (3.2.3) measured by that machine with the *reference absorbed energy* (3.2.7) associated with the test pieces

Note 1 to entry: Reference test pieces are prepared in accordance with ISO 148-3.

4 Symbols and abbreviated terms

Table 1 — Symbols/abbreviated terms and their designations and units

Symbol/ abbreviated term[a]	Unit	Designation
B_V	J	Bias of the pendulum impact machine as determined through indirect verification
b	J	Repeatability
F	N	Force exerted by the pendulum when measured at a distance l_2
F_g	N	Force exerted by the pendulum due to gravity
g	m/s[2]	Acceleration due to gravity
GUM	—	Guide to the expression of uncertainty in measurement[1]
h	m	Height of fall of pendulum
H_1	m	Height of rise of pendulum
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_T	J	Total absorbed energy
K_S	J	Indicated absorbed energy
K_{calc}	J	Calculated energy
KV_R	J	Certified *KV* value of the reference material used in the indirect verification

[a] See Figure 4.

Table 1 *(continued)*

Symbol/ abbreviated term[a]	Unit	Designation
$\overline{KV}_V$	J	Mean *KV* value of the reference test pieces tested for indirect verification
K_N	J	Nominal initial potential energy (nominal energy)
K_P	J	Initial potential energy (potential energy)
K_R	J	Reference absorbed energy of a set of Charpy reference test pieces
K_1 or β_1	J or °	Indicated absorbed energy or angle of rise when the machine is operated in the normal manner without a test piece in position
K_2 or β_2	J or °	Indicated absorbed energy 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
K_3 or β_3	J or °	Indicated absorbed energy or angle of rise after 11 half swings when the machine is operated in the normal manner without a test piece in position and without resetting the indication mechanism
l	m	Distance to centre of test piece (centre of strike) from the axis of rotation (length of pendulum)
l_1	m	Distance to the centre of percussion from the axis of rotation
l_2	m	Distance to the point of application of the force *F* from the axis of rotation
M	N·m	Moment equal to the product $F \cdot l_2$
n_V	—	Number of reference samples tested for the indirect verification of a pendulum impact testing machine
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
r	J	Resolution of the pendulum scale
RM	—	Reference material
s_V	J	Standard deviation of the *KV* values obtained on n_V reference samples
S	J	Bias in the scale mechanism
t	s	Period of the pendulum
T	s	Total time for 100 swings of the pendulum
T_{max}	s	Maximum value of *T*
T_{min}	s	Minimum value of *T*
u	—	Standard uncertainty
$u\left(\overline{KV}_V\right)$	J	Standard uncertainty of $\overline{KV}_V$
$u(B_V)$	J	Standard uncertainty contribution from bias
$u(F)$	J	Standard uncertainty of the measured force, *F*
$u(F_{ftd})$	J	Standard uncertainty of the force transducer
$u(r)$	J	Standard uncertainty contribution from resolution
u_{RM}	J	Standard uncertainty of the certified value of the reference material used for the indirect verification
u_V	J	Standard uncertainty of the indirect verification result
α	°	Angle of fall of the pendulum
β	°	Angle of rise of the pendulum

[a] See Figure 4.

Table 1 *(continued)*

Symbol/ abbreviated term[a]	Unit	Designation
υ_B	—	Degrees of freedom corresponding to $u(B_V)$
υ_V	—	Degrees of freedom corresponding to u_V
υ_{RM}	—	Degrees of freedom corresponding to u_{RM}

[a] See Figure 4.

5 Testing machine

A pendulum impact testing machine consists of the following parts (see Figure 1 to Figure 3):

a) foundation/installation;

b) machine framework: the structure supporting the pendulum, excluding the foundation;

c) pendulum, including the hammer;

d) anvils and supports (see Figure 2 and Figure 3);

e) indicating equipment for the absorbed energy (e.g. scale and friction pointer or electronic readout device).

6 Direct verification

6.1 General

Direct verification of the machine involves the inspection of the items a) to e) listed in Clause 5.

Uncertainty estimates are required under Clause 6 for direct verification measurements to harmonize the accuracy of the applied verification procedures. Uncertainty estimates required in Clause 6 are not related to product standards or material property databases in any way.

The uncertainty of dial gauges, micrometres, callipers, and other commercial instrumentation used for the direct verification measurements shall be estimated once, by the producer.

Uncertainty of a method to measure a direct verification parameter is assessed as part of the method validation. Once method validation is completed, the uncertainty can be routinely used (provided the same method is followed, the same instrumentation is used, and the operators are trained).

6.2 Foundation/installation

6.2.1 The foundation to which the machine is fixed and the method(s) of fixing the machine to the foundation are of the utmost importance.

6.2.2 Inspection of the machine foundation can usually not be made once the machine has been installed; thus, documentation made at the time of installation shall be produced to provide assurance that the mass of the foundation is not less than 40 times that of the pendulum.

6.2.3 Inspection of the installed machine shall consist of the following.

a) Ensuring that the bolts are torqued to the value specified by the machine manufacturer. The torque value shall be noted in the document provided by the manufacturer of the machine (see 6.2.1). If other mounting arrangements are used or selected by an end user, equivalency shall be demonstrated.

b) Ensuring that the machine is not subject to external vibrations transmitted through the foundation at the time of the impact test.

NOTE This can be accomplished, for example, by placing a small container of water on any convenient location on the machine framework. The absence of ripples on the water surface during an impact test indicates that this requirement has been met.

6.3 Machine framework

6.3.1 Inspection of the machine framework (see Figure 1) shall consist of determining the following items:

a) free position of the pendulum;

b) location of the pendulum in relation to the supports;

c) transverse and radial play of the pendulum bearings;

d) clearance between the hammer and the framework.

Machines manufactured after 1998 shall have a reference plane from which measurements can be made.

Annex C is provided for information.

6.3.2 The axis of rotation of the pendulum shall be parallel to the reference plane to within 2/1 000. This shall be certified by the manufacturer.

6.3.3 The machine shall be installed so that the reference plane is horizontal to within 2/1 000.

For pendulum impact testing machines without a reference plane, the axis of rotation shall be established to be horizontal to within 4/1 000 directly or a reference plane shall be established from which the horizontality of the axis of rotation can be verified as described above.

6.3.4 When hanging free, the pendulum shall hang so that the striking edge is within 2,5 mm of the position where it would just touch the test specimen.

NOTE This condition can be determined using a gauge in the form of a bar that is approximately 55 mm in length and of rectangular section 7,5 mm by 12,5 mm (see Figure 3).

6.3.5 The plane of swing of the pendulum shall be 90,0° ± 0,1° to the axis of rotation (u < 0,05°).

6.3.6 The striker shall make contact over the full thickness of the test piece.

One method of verifying this is to use a test piece having dimensions of 55 mm × 10 mm × 10 mm that is tightly wrapped in thin paper (e.g. by means of adhesive tape) and a striking edge that is tightly wrapped in carbon paper with the carbon side outermost (i.e. not facing the striker). From its position of equilibrium, the pendulum is raised a few degrees, released so that it contacts the test piece, and prevented from contacting the test piece a second time. The mark made by the carbon paper on the paper covering the test piece should extend completely across the paper. This verification can be performed concurrently with that of checking the angle of contact between the striker and the test piece (see 6.4.8).

6.3.7 The pendulum shall be located so that the centre of the striker and the centre of the gap between the anvils are coincident to within 0,5 mm (u < 0,1 mm).

6.3.8 Axial play in the pendulum bearings shall not exceed 0,25 mm (u < 0,05 mm) measured at the centre-of-rotation under a transverse force of approximately 4 % of the effective weight of the pendulum, F_g [see Figure 4 b)], applied at the centre of strike.

6.3.9 Radial play of the shaft in the pendulum bearings shall not exceed 0,08 mm (u < 0,02 mm) when a force of 150 N ± 10 N is applied at a distance l perpendicular to the plane of swing of the pendulum.

NOTE The radial play can be measured, for example, by a dial gauge mounted on the machine frame at the bearing housing in order to indicate movement at the end of the shaft (in the bearings) when a force of about 150 N is applied to the pendulum perpendicularly to the plane of the swing.

6.3.10 It is recommended that the mass of the base of the machine framework be at least 12 times that of the pendulum.

6.4 Pendulum

6.4.1 The verification of the pendulum (including striker) shall consist of determining the following quantities:

a) potential energy, K_P;

b) error in the indicated absorbed energy, K_S;

c) velocity of the pendulum at the instant of impact;

d) energy absorbed by friction;

e) position of the centre of percussion (i.e. distance from the centre of percussion to the axis of rotation);

f) radius of the striking edge of the striker;

g) angle between the line of contact of the striker and the horizontal axis of the test piece.

6.4.2 The potential energy, K_P, shall not differ from the nominal energy, K_N, by more than ±1 %. The potential energy, K_P, shall be determined as follows.

The moment of the pendulum is determined by supporting the pendulum at a chosen distance, l_2, from the axis of rotation by means of a knife edge on a balance or dynamometer in such a manner that the line through the axis of rotation that joins the centre of gravity of the pendulum is horizontal within 15/1 000 [see Figure 4 a)] (u < 5/1 000).

The force, F, and the length, l_2, shall each be determined to an accuracy of ±0,2 %. The moment, M, is the product of $F \cdot l_2$.

NOTE Length l_2 can be equal to length l.

The angle of fall, α, shall be measured to an accuracy of ±0,2°; this angle can be greater than 90°.

The potential energy, K_P, is then calculated by Formula (1):

$$K_P = M(1 - \cos\alpha) \quad (1)$$

6.4.3 The graduation marks on the scale corresponding approximately to values of absorbed energy of 0 %, 10 %, 20 %, 30 %, 50 % and 80 % of the nominal energy shall be verified.

For each of these graduation marks, the pendulum shall be supported so that the graduation mark is indicated by the pointer, and the angle of rise, β, then determined to ±0,2°. The calculated energy is given by Formula (2):

$$K_{calc} = M(\cos\beta - \cos\alpha) \quad (2)$$

NOTE 1 The measurement uncertainty of l_2, F and β, as specified, yields a mean total measurement uncertainty of K_{calc} of approximately ±0,3 % of the full-scale value.

The difference between the indicated absorbed energy, K_S, and the calculated energy from the measured values shall not be greater than ±1 % of the energy reading or ±0,5 % of the nominal energy, K_N. In each case, the greater value is permitted, i.e.

$$\left| \frac{K_{calc} - K_S}{K_S} \right| \cdot 100 \le 1\ \% \text{ at between 50 \% and 80 \% of the nominal energy, } K_N \tag{3}$$

$$\left| \frac{K_{calc} - K_S}{K_N} \right| \cdot 100 \le 0{,}5\ \% \text{ at less than 50 \% of the nominal energy, } K_N \tag{4}$$

NOTE 2 Attention is drawn to the fact that the accuracy of the absorbed energy reading is inversely proportional to its value, and this is important when K is small in comparison with K_N.

NOTE 3 For machines with scales and readout devices that are corrected for energy losses, K_{calc} should be corrected in order to compare the results properly.

6.4.4 The velocity at impact can be determined from Formula (5):

$$v = \sqrt{2gl(1 - \cos\alpha)} \tag{5}$$

where

g is the local acceleration of gravity known to 1 part in 1 000 or better, in m/s^2.

The velocity at impact shall be 5 m/s to 5,5 m/s (u < 0,1 m/s); however, for machines manufactured prior to 1998, any value within the range of 4,3 m/s to 7 m/s is permissible and the value shall be stated in the report.

6.4.5 The energy absorbed by friction includes, but is not limited to, air resistance, bearing friction and the friction of the indicating pointer. These losses shall be estimated as follows.

6.4.5.1 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 as indicated by the pointer. 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 as given by Formula (6):

$$p = M\left(\cos\beta_1 - \cos\beta_2\right) \tag{6}$$

when the scale is graduated in degrees, or as given by Formula (7):

$$p = K_1 - K_2 \tag{7}$$

when the scale is graduated in energy units.

6.4.5.2 Determination of the losses caused by bearing friction and air resistance for one half swing is performed as follows.

After determining β_2 or K_2 in accordance with 6.4.5.1, the pendulum is put into 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 eleventh 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 as given by Formula (8):

$$p' = 1/10\, M\left(\cos\beta_3 - \cos\beta_2\right) \tag{8}$$

when the scale is graduated in degrees, or as given by Formula (9):

$$p' = 1/10\left(K_3 - K_2\right) \tag{9}$$

when the scale is graduated in energy units.

NOTE If it is required to take into account these losses in an actual test giving an angle of rise, β, the quantity as given by Formula (10) can be subtracted from the value of the absorbed energy.

$$p_\beta = p\frac{\beta}{\beta_1} + p'\frac{\alpha + \beta}{\alpha + \beta_2} \tag{10}$$

Because β_1 and β_2 are nearly equal to α, Formula (10) can be reduced to Formula (11):

$$p_\beta = p\frac{\beta}{\alpha} + p'\frac{\alpha + \beta}{2\alpha} \tag{11}$$

For machines graduated in energy units, the value of β can be calculated as given in Formula (12):

$$\beta = \arccos\left[\frac{1}{M\left(K_\mathrm{P} - K_\mathrm{T}\right)}\right] \tag{12}$$

6.4.5.3 The values of β_1, β_2, and β_3, and the values of K_1, K_2, and K_3 shall be the mean values from at least two determinations. 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.

6.4.6 The distance from the centre of percussion to the axis of rotation, l_1, is derived from the period (time of swing) of the pendulum, and it shall be 0,995 l ± 0,005 l. The measurement uncertainty of the calculated value of l_1 shall be <0,5 mm.

The distance can be determined by swinging the pendulum through an angle not exceeding 5° and measuring the time, t, of a complete swing in seconds.

l_1 is derived from Formula (13):

$$l_1 = \frac{g \cdot t^2}{4\pi^2} \tag{13}$$

where

g is the acceleration of gravity, taken as equal to 9,81 m/s^2;

π^2 is taken as equal to 9,87.

Therefore, in metres, $l_1 = 0{,}2485 \cdot t^2$.

The value of t shall be determined to within 0,1 %.

With a pendulum having a period of approximately 2 s, this accuracy may be achieved as follows. Determine the time, T, of 100 complete swings, three times. An accurate measure of t is the average of the three values of T divided by 100, provided the quantity (T_{max} − T_{min}), which represents the repeatability, is not more than 0,2 s.

6.4.7 The dimensions of the striker shall be checked. Either of two types of striker may be used, the 2 mm striker or the 8 mm striker. The values for the radius of curvature and the angle of the tip for both types are shown in Table 3.

The maximum width of that portion of the striker passing between the anvils shall be at least 10 mm but not greater than 18 mm (u < 0,2 mm).

NOTE An example of a method of verifying the geometry of the striker is to make a replica for examination.

6.4.8 The angle between the line of contact of the striker and the horizontal axis of the test piece shall be 90° ± 2° (see 6.3.6) (u < 0,2°).

6.4.9 The mechanism for releasing the pendulum from its initial position shall operate freely and permit release of the pendulum without initial impulse, retardation or side vibration.

6.4.10 If the machine has a brake mechanism, means shall be provided to prevent the brake from being accidentally engaged. In addition, there shall be provision to disengage the brake mechanism, for example during the measurement of period and friction losses.

6.4.11 Machines with automated lifting devices shall be constructed so that direct verification can be performed.

6.5 Anvil and supports

6.5.1 Inspection of the anvils and supports should consist of determining the following items (see Figure 2 and Figure 3 and Table 3):

a) configuration of the supports;

b) configuration of the anvils;

c) distance between the anvils;

d) taper of the anvils;

e) radius of the anvils;

f) clearance for the broken test piece to exit the machine.

6.5.2 The planes containing the support surfaces shall be parallel and the distance between them shall not exceed 0,1 mm (u < 0,05 mm). Supports shall be such that the axis of the test piece is parallel to the axis of rotation of the pendulum within 3/1 000 (u < 1/1 000).

6.5.3 The planes containing the anvil surfaces facing the test piece shall be parallel and the distance between them shall not exceed 0,1 mm (u < 0,05 mm). The two planes containing the supports and the anvils shall be 90° ± 0,1° relative to each other (u < 0,05°). Additional requirements for the configuration of the anvils are given in Table 3.

6.5.4 Sufficient clearance shall be provided to ensure that fractured test pieces are free to leave the machine with a minimum of interference and not rebound into the hammer before the pendulum completes its swing. No part of the pendulum that passes between the anvils shall exceed 18 mm in width (u < 0,2 mm).

Hammers are often of one of two basic designs (see Figure 1). When using the C-type hammer, the broken test pieces will not rebound into the hammer if the clearance at each end of the test piece is greater than 13 mm. If end stops are used to position test pieces, they shall be retracted prior to the instant of impact. When using the U-type hammer, means shall be provided to prevent the broken test pieces from rebounding into the hammer. In most machines using U-type hammers, shrouds (see Figure 3) should be designed and installed with the following requirements:

a) a thickness of approximately 1,5 mm;

b) a minimum hardness of 45 HRC;

c) a radius of at least 1,5 mm at the underside corners;

d) a position in which the clearance between them and the hammer overhang does not exceed 1,5 mm.

In machines where the opening within the hammer permits a clearance between the ends of the test piece (resting in position ready to test) and the shrouds of at least 13 mm, the requirements of a) and d) need not apply.

6.6 Indicating equipment

6.6.1 The verification of the analogue indicating equipment shall consist of the following examinations:

a) examination of the scale graduations;

b) examination of the indicating pointer.

The scale shall be graduated in units of angle or of energy.

The thickness of the graduation marks on the scale shall be uniform and the width of the pointer shall be approximately equal to the width of a graduation mark. The indicating pointer shall permit a reading free from parallax.

The resolution, r, of the indicator is obtained from the ratio between the width of the pointer and the centre-to-centre distance between two adjacent scale-graduation marks (scale interval). The recommended ratios are 1:4, 1:5, or 1:10; a spacing of 2,5 mm or greater is required to estimate a tenth of a division on the scale.

The scale interval shall be at most 1 % of the nominal energy and shall permit an estimation of energy in increments of less than or equal to 0,25 % of the nominal energy.

6.6.2 The verification of digital indicating equipment shall ensure that the following requirements are met.

— The scale shall be graduated in units of angle or of energy.

— The resolution of the scale is considered to be one increment of the last active number of the digital indicator provided that the indication does not fluctuate by more than one increment. When the readings fluctuate by more than one increment, the resolution is taken to be equal to half the range of fluctuation.

— The resolution shall be less than or equal to 0,25 % of the nominal energy.

7 Indirect verification by use of reference test pieces

7.1 Reference test pieces used

Indirect verification consists of verifying points on the measuring scale using reference test pieces. The following reference test pieces are used:

a) for comparison between test results obtained with the machine under consideration and test results obtained with a particular reference machine or set of reference machines, or with an SI traceable K_R value obtained in full accordance with ISO 148-1;

b) to monitor the performance of a machine over a period of time, without reference to any other machine.

7.2 Absorbed energy levels

The indirect verification shall be performed at a minimum of two absorbed energy levels within the range of use of the machine. A set for each energy level shall consist of at least five reference test pieces. The reference test piece absorbed energy levels shall be as close as possible to the upper and lower limits of the range of use, subject to the availability of reference test pieces for these absorbed energy levels.

When more than two reference test piece absorbed energy levels are used, the other level(s) should be distributed as uniformly as possible between the upper and lower limits subject to the availability of reference test pieces.

7.3 Requirements for reference test pieces

Reference test pieces shall be obtained from a reference material producer who has prepared the test pieces as specified in ISO 148-3. Whether or not test pieces that do not break shall be taken into account, the calculation of pendulum bias and repeatability is decided by the reference material producer.

7.4 Limited direct verification

A limited direct verification shall be performed before each indirect verification. This limited direct verification includes the following:

a) inspection of the machine in accordance with 6.2.3 a) and of the machine framework in accordance with 6.3.4 and 6.3.6;

b) inspection (visual at least) of the striker and anvils for excessive wear (see Table 3);

c) measurement of the distance between the anvils (see Table 3);

d) when the striker or supports or anvils are changed: measurement of items 6.3.4, 6.3.6, 6.3.7, 6.4.7, 6.4.8, 6.5.2, 6.5.3 and 6.5.4;

e) measurement of the losses due to bearing friction and air resistance;

f) measurement of the loss due to pointer friction.

7.5 Bias and repeatability

7.5.1 Repeatability

KV_1, KV_2, ..., KV_{n_V} are the absorbed energies of the n_V reference test pieces used for the indirect verification at a particular energy level. The repeatability of the machine under the particular controlled conditions is characterized by b, the difference between the highest and lowest of the n_V KV values, as given by Formula (14):

$$b = KV_{max} - KV_{min} \tag{14}$$

The maximum allowed repeatability values are given in Table 2.

7.5.2 Bias

The bias of the machine under the particular controlled conditions is characterized by the number, as given by Formula (15):

$$B_V = \overline{KV}_V - KV_R \tag{15}$$

where

$$\overline{KV}_V = \frac{\sum KV_1 + \ldots + KV_{n_V}}{n_V} \tag{16}$$

The maximum allowed bias values are given in Table 2.

Table 2 — Maximum allowed values for repeatability and bias

Dimensions in joules

Absorbed energy level	**Repeatability** b	**Bias** $\lvert B_V \rvert$
<40	≤6	≤4
≥40	≤15 % KV_R	≤10 % KV_R

8 Frequency of verification

8.1 A full direct verification followed by an indirect verification shall be performed at the time of installation and after moving the machine.

8.2 Indirect verifications, including a limited direct verification, shall be performed at intervals not exceeding 12 months. More frequent indirect verifications may be necessary based on the wear observed.

8.3 When anvils and/or striker are replaced, a direct verification in accordance with clauses describing the affected part(s) shall be performed. An indirect verification shall also be performed.

8.4 If the results of a first indirect verification are unsatisfactory and if limited corrective interventions on the instrument fail to lead to a satisfactory result of the repeated indirect verification, then a full direct verification shall be performed.

9 Verification report

9.1 General

The verification report shall include at least the following information:

a) reference to this part of ISO 148, i.e. ISO 148-2;

b) identification of the machine: manufacturer's name, model and serial number;

c) radius of the striking edge;

d) name of owner and address of place of installation;

e) name or mark of organization performing the verification;

f) date of the verification.

9.2 Direct verification

The following information on the direct verification of the machine shall be included:

a) nominal energy of the pendulum;

b) velocity of pendulum at impact;

c) absorbed energy lost due to air resistance and friction.

9.3 Indirect verification

The following information on indirect verification of the machine shall be included:

a) identification of the reference test pieces used in the indirect verification, including the reference values and the actual observed absorbed energy values for these test pieces;

b) results of the indirect verification:

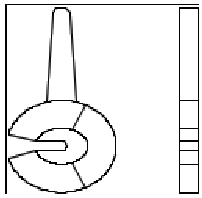
   1) repeatability;

   2) bias;

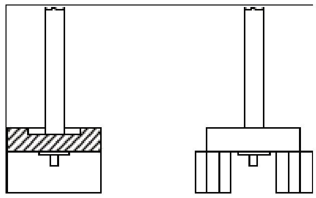
   3) a statement that the machine does or does not conform to the requirements of this part of ISO 148.

10 Uncertainty

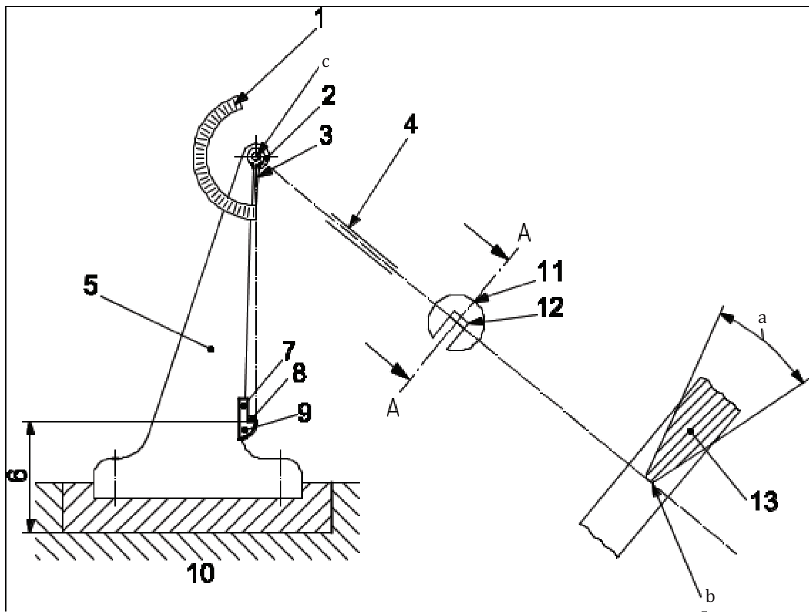
A method for establishing the uncertainty of the indirect verification results is given in Annex A. Annex B gives methods for calculating measurement uncertainty for several of the measurements occurring in the direct verification.



a) C-type hammer



b) U-type hammer

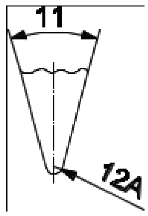


c) Test machine

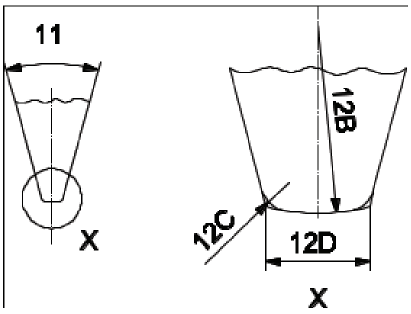
Key

1	scale	9	test-piece supports
2	pendulum bearings	10	foundation
3	friction pointer	11	C-type hammer
4	pendulum rod	12	edge of striker
5	machine framework	13	striker
6	base	a	Angle of striker.
7	anvil	b	Radius of striking edge.
8	test piece	c	Axis of rotation.

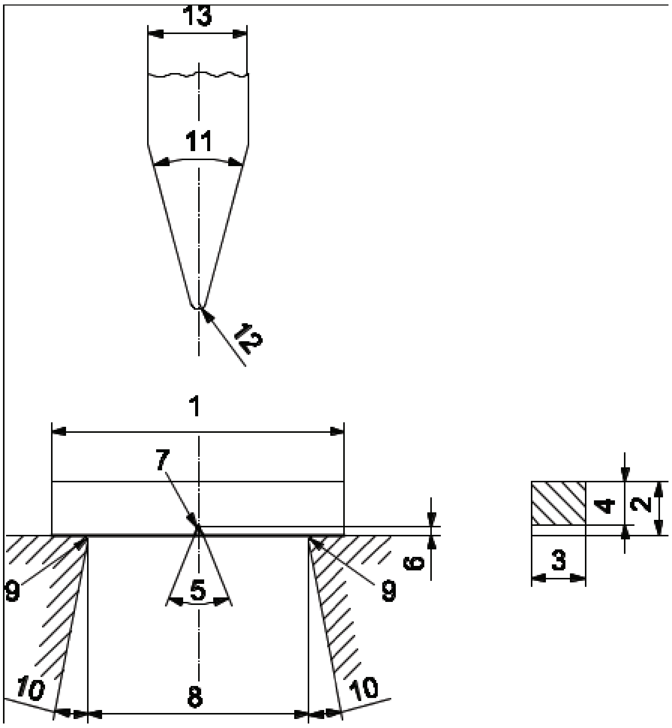
Figure 1 — Parts of a pendulum-type impact test machine



a) 2 mm striker



b) 8 mm striker



c) Overview

NOTE See Table 3 for geometrical characteristics.

Figure 2 — Strikers, test-piece supports and anvils of pendulum-type impact test machines

Table 3 — Geometrical characteristics

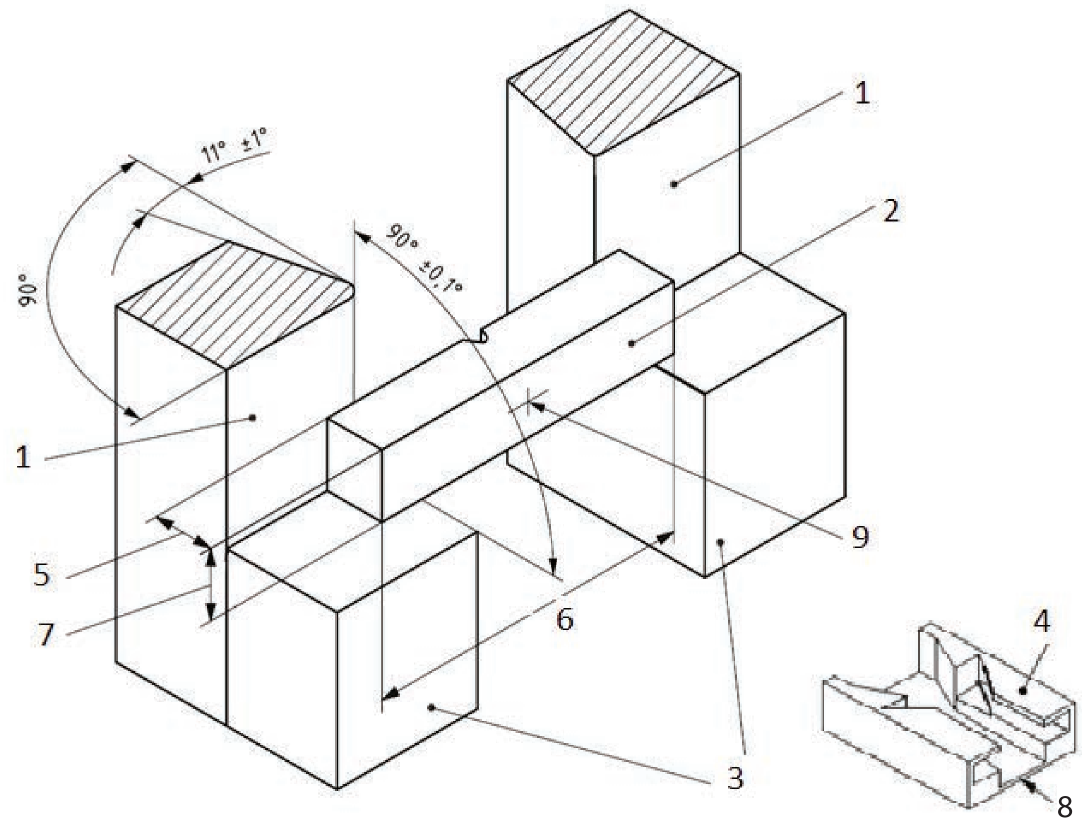
Number[a]	Designation	Dimension
1	Length of test piece	see ISO 148-1
2	Width of test piece	see ISO 148-1
3	Thickness of test piece	see ISO 148-1
4	Width of test piece minus depth of notch (ligament)	see ISO 148-1
5	Angle of notch	see ISO 148-1
6	Depth of notch	see ISO 148-1
7	Notch root radius	see ISO 148-1

[a] See Figure 2.

Table 3 *(continued)*

Number[a]	Designation	Dimension
8	Distance between anvils	$40,00\ \text{mm}\ {}^{+0,20\ \text{mm}}_{-0,00\ \text{mm}}$
9	Radius of anvils	$1,00\ \text{mm}\ {}^{+0,50\ \text{mm}}_{-0,00\ \text{mm}}$
10	Angle of taper of anvil	11° ± 1°
11	Angle of striker	30° ± 1°
12	Radius of striking edge	
12A	2 mm striker	$2,00\ \text{mm}\ {}^{+0,50\ \text{mm}}_{-0,00\ \text{mm}}$
12B	8 mm striker	8,00 mm ± 0,05 mm
12C	Radius of shoulder of 8 mm striker	$0,25\ \text{mm}\ {}^{+0,50\ \text{mm}}_{-0,05\ \text{mm}}$
12D	Width of edge of 8 mm striker	4,00 mm ± 0,05 mm
13	Width of striker	10 mm to 18 mm

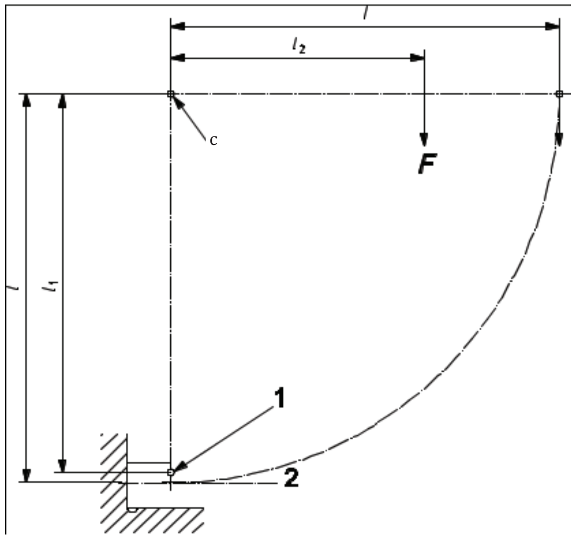
[a] See Figure 2.



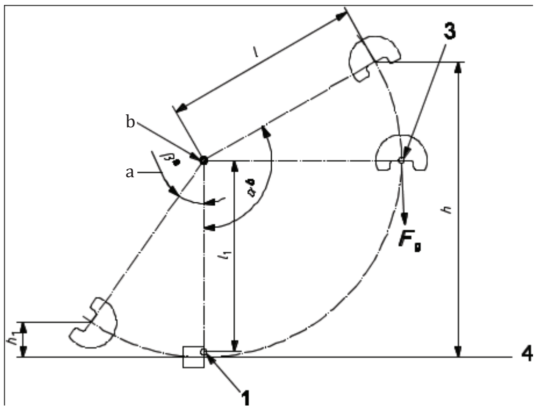
Key

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

Figure 3 — Configuration of test piece supports and anvils of an industrial pendulum-type impact test machine



a) Determination of moment, *M*



b) Designation of terms used to determine energy

Key

1 centre of percussion

2 centre of test piece

3 centre of strike of pendulum

4 centre of standard-size test piece

a Angle of rise, *β*.

b Angle of fall, *α*.

c Axis of rotation.

Figure 4 — Determination of the initial potential energy

Annex A
(informative)

Measurement uncertainty of the result of the indirect verification of a Charpy pendulum impact machine

A.1 Overview and general requirements

A.1.1 General

This Annex provides a method for determining the uncertainty associated with the results of indirect verification tests of a Charpy pendulum impact machine. Other methods for assessing the uncertainty of these tests can be developed and are acceptable, if they meet the requirements of the GUM (see Reference [1]).

This Annex proposes a systematic approach, which leads to estimates for B_V (the bias of the machine) and u_V (the uncertainty of the overall indirect verification result). The values of these parameters are required for the calculation of the measurement uncertainty of the results of tests performed with the pendulum impact testing machine after the verification, as described in ISO 148-1.

NOTE ISO 148-1:2016, Annex E, also provides a general scheme of the metrological chain used to disseminate absorbed energy scales through indirect verification using reference test pieces.

A.1.2 Uncertainty disclaimer

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

Product standards and material property databases based on this and earlier versions of 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 failing product compliance. For this reason, the estimates of uncertainty derived by 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.[2] 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.

A.2 Contributions to the uncertainty of the indirect verification result

A.2.1 Bias

The primary result of an indirect verification is the estimate of the instrument bias, B_V, as given by Formula (A.1):

$$B_V = \overline{KV}_V - KV_R \tag{A.1}$$

where

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

KV_R is the certified KV value of the reference test pieces.

The absolute value of B_V should meet the criteria set in Clause 7.

A.2.2 Uncertainty of the bias value

The standard uncertainty of the bias value is equal to the combined standard uncertainties of the two terms in Formula (A.1).

u_{RM}, the standard uncertainty of the certified reference value, KV_R, is calculated from the expanded uncertainty, U_{RM}, indicated on the certificate of the reference test pieces, by dividing U_{RM} by the appropriate coverage factor (also indicated on the certificate).

The uncertainty associated with $\overline{KV}_V$ is calculated as given by Formula (A.2):

$$u(\overline{KV}_V) = \frac{s_V}{\sqrt{n_V}} \tag{A.2}$$

where

s_V is the standard deviation of the results of the n_V reference test pieces.

7.2 prescribes the use of at least five reference test pieces for the indirect verification.

NOTE Formula (A.2) shows that choosing a larger number n_V can be used to reduce the measurement uncertainty.

Therefore, $u(B_V)$, the standard uncertainty of B_V, is calculated as given by Formula (A.3):

$$u\left(B_V\right) = \sqrt{\left(\frac{s_V}{\sqrt{n_V}}\right)^2 + u_{RM}^2} \tag{A.3}$$

A.3 Determining the combined uncertainty of the indirect verification result, u_V

As a general rule, bias should be corrected for. However, due to wear of the anvils and hammer parts, it is difficult to obtain a perfectly stable bias value throughout the period between two indirect verifications. This is why the measured bias value is often considered an uncertainty contribution, to be combined with its own uncertainty to obtain the uncertainty of the indirect verification result, u_V, as given by Formula (A.4):

$$u_V = \sqrt{u^2\left(B_V\right) + B_V^{\ 2}} \tag{A.4}$$

To correct the absorbed energy values measured with a pendulum impact testing machine, add a term equal to B_V. This requires that the bias value be firmly established and stable. Such a level of knowledge on the performance of a particular pendulum impact testing machine can only be achieved after a series of indirect verification and control chart tests, which should provide the required evidence about the stability of the instrument bias. Therefore, the practice is likely to be limited to reference pendulum impact testing machines.

A.4 Expanding the combined uncertainty

The value of u_V is used in ISO 148-1:2016, Annex E, as one of the contributions to the total measurement uncertainty. To expand a combined standard uncertainty, the degrees of freedom of the respective uncertainty contributions need to be combined into effective degrees of freedom. The degrees of freedom of u_V are calculated using the Welch-Satterthwaite approximation, as given by Formula (A.5):

$$\nu_V = \frac{u_V^4}{\dfrac{u^4\left(\overline{KV}_V\right)}{\nu_B} + \dfrac{u_{RM}^4}{\nu_{RM}} + \dfrac{B_V^4}{\nu_B}} \tag{A.5}$$

The value of ν_B equals $n_V - 1$; the value of ν_{RM} is taken from the reference materials' certificate.

The number of verification test pieces is at least five, but the heterogeneity of the samples is not insignificant. This is why the number of effective degrees of freedom is most often not large enough to use a coverage factor of k equal to 2. Other values of k may be used if interested parties are in agreement.

A.5 Examples of B_V and u_V calculation and reporting

This subclause presents an example of an indirect verification result and its analysis. The indirect verification is executed after a direct verification, using reference test pieces of three different energy levels. The results presented in Table A.1 are those obtained on reference test pieces with a certified KV_R value of 123,8 J, and an expanded uncertainty of 3,4 J, with 30 degrees of freedom (values taken from the RM certificate).

Table A.1 — Example — Results of the indirect verification tests

Test results and data from certificates		Calculation of bias and uncertainty values	
Sample 1	123,1 J	$\overline{KV}_V$	119,4 J
Sample 2	116,1 J	s_V	4,7 J
Sample 3	112,8 J	n_V	5
Sample 4	123,6 J	From Formula (A.2): $u\left(\overline{KV}_V\right)$	2,1 J
Sample 5	121,3 J		
From certificate: degrees of freedom, ν_{RM}	30	From Formula (A.1): B_V	−4,4 J

Table A.1 *(continued)*

Test results and data from certificates		Calculation of bias and uncertainty values	
From certificate: expanded uncertainty at a confidence level of about 95 %, U_{RM}	3,4 J	From Formula (A.3): $u(B_V)$	2,7 J
Since ν_{RM} > 10, u_{RM}, the standard uncertainty, can be calculated as $U_{RM}/2$	1,7 J	From Formula (A.4): u_V	5,2 J
Degrees of freedom for five samples, ν_B	4	From Formula (A.5): ν_V	7

The primary result of the indirect verification is good: the absolute value of the bias (B_V = −4,4 J) is below the upper threshold set in Clause 7. The value of B_V needs to be combined with its uncertainty to obtain u_V, unless its value is well established, which we do not consider to be the case here. From Formula (A.5), the number of degrees of freedom corresponding to u_V is calculated to be 7. The verification results can be reported as shown in Table A.2.

Table A.2 — Summary table of the result with expanded measurement uncertainty, $U\left(\overline{KV}\right)$

KV_R J	B_V J	$u(BV)$ J	ν_V	u_V J
123,8	−4,4	2,7	7	5,2
	B_V is not firmly established			
... [a]	...	...	...	...
	...			

[a] This summary table contains one row for each of the energy levels at which the pendulum was indirectly verified.

A graphical representation of the example is given in Figure A.1, together with the results obtained if the measured absorbed energy values are corrected for the measured bias. The uncertainty of the indirect verification is relatively large (u_V = 5,2 J) as it consists of the combination of $u(B_V)$ and B_V. If the bias value had been better established, and the measured value corrected for its value, a considerably smaller uncertainty could have been obtained [$u(B_V)$ = 2,7 J].

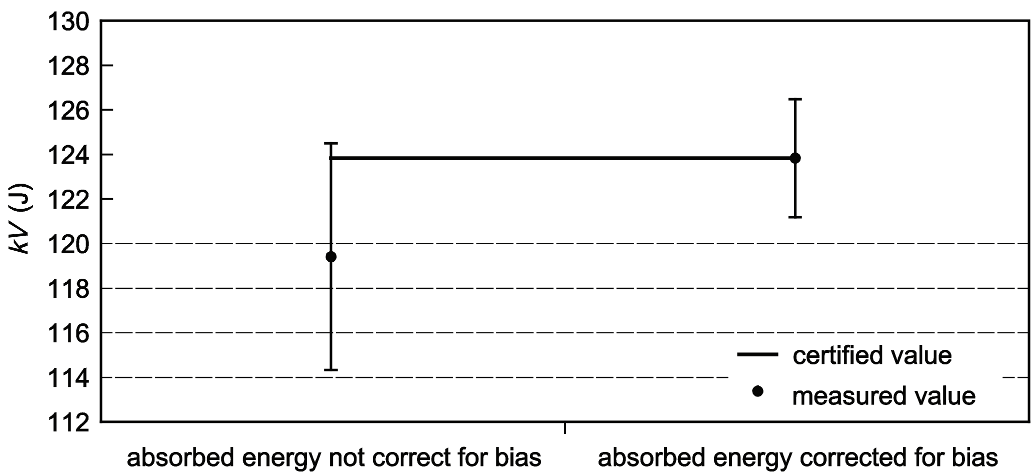


Figure A.1 — Graphical representation of the default approach (left) with an uncorrected absorbed energy and the associated uncertainty, u_V, as well as the case where the measured value is corrected for the bias (right), giving a smaller uncertainty, $u(B_V)$

Annex B
(informative)

Measurement uncertainty of the results of the direct verification of a Charpy pendulum impact testing machine

B.1 General

Direct verification consists of a series of checks of geometrical and mechanical features of a pendulum impact testing machine. Deviation from the nominal values of these features contributes to the bias in the instrument with respect to the expected behaviour of a pendulum impact testing machine fulfilling the requirements of Clause 6.

In theory, one can use a formula such as Formula (B.1) for the estimation of z, the combined instrument bias:

$$z = R + A + C + E + V + (l - l_1) + H + S \tag{B.1}$$

where

R	is the bias in K (in energy units) due to bias in the radius of the edge of the striker;
A	is the bias in K (in energy units) due to bias in anvil and supports geometry;
C	is the bias in K (in energy units) due to bias of the centre of strike;
E	is the bias in K (in energy units) due to the energy calculation from measured angles;
V	is the bias in K (in energy units) due to bias in the impact velocity;
$(l - l_1)$	is the bias in K (in energy units) due to bias in the difference between pendulum length and centre of percussion;
H	is the bias in K (in energy units) due to the correction for friction loss;
S	is the bias in K (in energy units) due to the bias in the energy read from an analogue or digital scale.

The effects of the factors (R, A, C, E, V, $l - l_1$, H, S) on the absorbed energy are assumed to be small if they are within the tolerances required for direct verification of the machine (see Clause 6) and if the pendulum impact test is performed according to the standard procedure (see ISO 148-1). However, there are uncertainties associated with the assessment of the individual factors contributing to z. Assuming that all quantities are independent, the combined standard uncertainty of z would be as given by Formula (B.2):

$$u_c(z) = \sqrt{u^2(R) + u^2(A) + u^2(C) + u^2(E) + u^2(V) + u^2(l - l_1) + u^2(H) + u^2(S)} \tag{B.2}$$

Not all the elements from Formula (B.1) and Formula (B.2) can be reliably and quantitatively assessed. Instead, indirect verification of the instrument, with reference materials, is used to assess the bias in a pendulum and the associated uncertainty.

Nevertheless, it remains important to consider the reliability of the different steps in the mandatory direct verification. This is why this Annex discusses state-of-the-art methods to determine the uncertainties associated with the results of a number of measurements performed during the direct verification of a Charpy pendulum impact machine.

Usually, the uncertainty of a certified value on the certificate of a certified reference material is specified for a confidence level of about 95 %. Therefore, the standard combined uncertainty, u_{RM}, has to be expanded using an appropriate coverage factor, k. The coverage factor to be used depends on the number of degrees of freedom associated with the combined uncertainty, which can be computed using the Welch-Satterthwaite approximation. For a typical case, the number of effective degrees of freedom is larger than 20 and a coverage factor of $k = 2$ can be used.

NOTE Other methods to assess the measurement uncertainties can be developed and are acceptable if they meet the requirements of the GUM (see Reference [1]).

The ultimate aim is to achieve a reliable estimate of the measurement uncertainty for the directly verified features so as to verify whether the sum of the deviation between the nominal and the measured value and the measurement uncertainty of this deviation is within the tolerances allowed by Clause 6.

Uncertainty disclaimer note: Measurement uncertainty analysis is useful for identifying major sources of inconsistencies of measured results. Product standards and material property databases based on this and the previous version of 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 failing product compliance. For this reason, the estimates of uncertainty derived by 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 with product specifications, unless specifically instructed otherwise by the customer. Instead, the indicated tolerances are to be interpreted as acceptance intervals.[2] 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.

B.2 Uncertainty for particular instrument parameters

B.2.1 Centre of percussion

The pendulum is constructed in a way that makes pendulum length, l, equal to the distance between the centre of percussion and the axis of rotation, l_1.

For the determination of l_1, Formula (B.3) is valid:

$$l_1 = \frac{gt^2}{4\pi^2} \quad \text{(B.3)}$$

where

l_1 is the distance between the position of the centre of percussion and the axis of rotation (reduced pendulum length), in metres;

t is the average period of swing of pendulum from three measurements at 100, 50 or 25 swings.

The time measurement T, e.g. for 50 swings, is carried out manually or by a calibrated time-measuring device. In this example, a realistic measurement uncertainty of $u(T)$ = 0,1 s will be used. The uncertainty of l_1 can then be calculated as given by Formula (B.4):

$$u(l_1) = \frac{2gT}{(4\pi^2)\cdot 50^2}\cdot u(T) \tag{B.4}$$

The pendulum length, l, is measured with callipers. Because l can often not be measured directly, it is determined by three partial measurements L_1, L_2 and L_3, which means:

$$u(l) = \sqrt{u^2(L_1) + u^2(L_2) + u^2(L_3)} \tag{B.5}$$

Callipers for smaller lengths (e.g. L_1 and L_3) usually have a measurement uncertainty of 0,1 mm. Callipers for the larger length (here L_2) typically have a measurement uncertainty of 0,3 mm. In this case, the combined uncertainty $u(l)$ = 0,3 mm.

NOTE These values are typically included on the calibration certificate of the instrument used.

The measurement uncertainty of the deviation of the position of the centre of percussion from the measured pendulum length, $(l - l_1)$, is calculated with the above-given uncertainties as given by Formula (B.6):

$$u(l - l_1) = \sqrt{u^2(l) + u^2(l_1)} \tag{B.6}$$

EXAMPLE See also Table B.1.

For a measured pendulum length l = 800,0 mm, a measured T (50 swings) = 89,7 s, and the resulting calculated value for l_1 = 799,75 mm, and using the above uncertainties for length and time measurements, an uncertainty $u(l - l_1)$ of 1,07 mm is obtained. This shows that the measured $(l - l_1)$ is within the allowed tolerance (0,5 %), also taking into account measurement uncertainty.

Table B.1 — Measurement uncertainty of position of centre of percussion

Quantity	Estimated value	Uncertainty		Standard uncertainty	Sensitivity coefficient	Contribution to uncertainty of $(l - l_1)$
		Value	Distribution type			
l	800,0 mm	0,3 mm	Normal	0,3 mm	1 mm/mm	0,3 mm
T	89,7 s	0,1 s	Rectangular	0,058 s	17,83 mm/s	1,03 mm
Combined measurement uncertainty $u(\overline{l - l_1})$						1,07 mm
Expanded measurement uncertainty using k = 2 for a 95 % confidence level						2,14 mm

B.2.2 Impact velocity

The impact velocity is calculated from the pendulum length and the fall angle and is a typical parameter of the testing machine. The permissible errors specified in this part of ISO 148 for the direct verification are relatively large. Since the relative uncertainties of the measurements needed to calculate impact velocity are very small, a specific calculation of the uncertainty of its value is not required.

B.2.3 Absorbed energy calculation

For the calculation of the absorbed energy, Formula (B.7) measurement formulae is valid:

$$KV = F \times l_2 \times \left(\cos\beta - \cos\alpha\right) \tag{B.7}$$

where

- KV is the absorbed energy as calculated from measured fall and rise angles, in joules;
- F is the force exerted by the pendulum in the horizontal position on the force-proving device for distance l_2, in newtons;
- l_2 is the distance between the point of application of force F and the axis of rotation, in metres;
- β is the angle of fall, in degrees;
- α is the angle of rise, in degrees.

The above parameters are not bound by certain nominal values or ranges in the standard. Therefore, there is no bias associated with these parameters, only a measurement uncertainty. The uncertainty of the energy calculated from the measured values is expressed as given in Formula (B.8):

$$u_1^2 = \left(\frac{\partial KV}{\partial F}\right)^2 u^2\left(F\right) + \left(\frac{\partial KV}{\partial l_2}\right)^2 u^2\left(l_2\right) + \left(\frac{\partial KV}{\partial \beta}\right)^2 u^2\left(\beta\right) + \left(\frac{\partial KV}{\partial \alpha}\right)^2 u^2\left(\alpha\right) \tag{B.8}$$

From Formula (B.7), the following can be derived:

$$\frac{\partial KV}{\partial \alpha} = F \cdot l_2 \cdot \sin\alpha \tag{B.9}$$

$$\frac{\partial KV}{\partial \beta} = -F \cdot l_2 \cdot \sin\beta \tag{B.10}$$

$$\frac{\partial KV}{\partial F} = l_2 \cdot \left(\cos\beta - \cos\alpha\right) \tag{B.11}$$

$$\frac{\partial KV}{\partial l_2} = F \cdot \left(\cos\beta - \cos\alpha\right) \tag{B.12}$$

With respect to the individual uncertainty contributions:

$$u\left(F\right) = \sqrt{u^2\left(F_{\text{ftd}}\right) + u^2\left(t\right) + u^2\left(S\right) + u^2\left(D\right)} \tag{B.13}$$

where

$$u(t) = \frac{\delta \cdot a_{\text{temp}}}{\sqrt{3}} \tag{B.14}$$

where

δ is the temperature coefficient of the working standard (given by the manufacturer);

a_{temp} is the deviation from the reference temperature.

$$u(S) = \frac{a_{\text{stab}}}{\sqrt{3}} \tag{B.15}$$

where

a_{stab} is the long-term stability of the working standard;

$$u(D) = a_{\text{int-dev}} \tag{B.16}$$

where

$a_{\text{int-dev}}$ is the interpolation deviation of the working standard;

$$u(l_2) = \frac{\Delta l_2}{l_2} \tag{B.17}$$

where

Δl_2 is the uncertainty of the distance measurement between the point of application of the force and the axis of rotation.

NOTE A minimum estimate for Δl_2 can be taken from the certificate of the instrument used to measure l_2.

EXAMPLE See also Table B.2.

a) **Force**

Measurement uncertainty of the force transducer: U_{ftd} = 0,12 % (k = 2)

Long-term stability of the force transducer: a_{stab} = 0,05 %

Temperature coefficient of the force transducer: δ = 0,01 %

Deviation from the reference temperature: a_{temp} = 5,0 °C

Measurement uncertainty due to linear interpolation of the force exerted by the pendulum on the force-proving device: $a_{\text{int-dev}}$ = 0,05 %

Force exerted by the pendulum on the force-proving device at a 750,1 mm length of the pendulum: F = 206,70 N

The combined contributions to the force uncertainty reach 0,1 %. For a force F of 206,70 N, the combined standard uncertainty, $u(F)$, is therefore 0,21 N.

b) **Pendulum length**

Uncertainty of the distance measurement: l_2 = 0,3 mm

Length of the pendulum: $l = l_2 = 750{,}1$ mm

The uncertainty of the distance l_2, over which the force measurement is carried out, can be applied with $\Delta l_2 = \pm 0{,}3$ mm for careful use.

c) **Angles**

Uncertainty of the angle measurement: $\Delta\alpha = \Delta\beta = 0{,}2°$; rise angle: $\beta = 120°$; fall angle: $\alpha = 160°$

Care should be taken to convert degrees into radians and millimetres into metres prior to applying the formulae.

Table B.2 — Budget of measurement uncertainty for the absorbed energy calculation

Quantity	Estimated value	Uncertainty		Standard uncertainty	Sensitivity coefficient	Contribution to uncertainty of *KV*
		Value	Distribution type			
F	206,7 N	0,21 N	Normal	0,21 N	0,33 J/N	0,07 J
L	750,1 mm	0,3 mm	Rectangular	0,17 mm	91 J/m	0,016 J
β	120°	0,2°	Rectangular	0,12°	134 J/rad	0,27 J
α	160°	0,2°	Rectangular	0,12°	53 J/rad	0,11 J
Combined measurement uncertainty						0,30 J
Expanded measurement uncertainty using $k = 2$ for a 95 % confidence level						0,6 J

B.2.4 Absorbed energy readings from an analog or a digital scale

S is the bias in the scale mechanism; it indicates the difference between the reading of an absorbed energy from the instrument analog scale or a digital value displayed on the instrument PC, and the calculated energy. S can be deduced for a particular pendulum using the results of direct verification, as given by Formula (B.18):

$$S = K_S - K_{calc} \tag{B.18}$$

where

S is the deviation of the indicated energy;

K_S is from the calculated energy, K_{calc}, both in joules.

The effective uncertainty, $u(S)$, is calculated as given by Formula (B.19) and Formula (20):

$$u(S) = \sqrt{u^2(K_S) + u^2(K_{calc})} \tag{B.19}$$

where

$$u(K_S) = \frac{a}{2 \cdot \sqrt{3}} \tag{B.20}$$

where

a is the resolution of the scale (i.e. the smallest distinguishable difference between two measured values).

EXAMPLE See also Table B.3.

Value read from analog scale: $K_S = 68{,}0$ J

Resolution of the indicator: a = 0,5 J

Energy value calculated from measured angles: K_{calc} = 68,17 J

Uncertainty of the energy calculated from measured angles: $u(K_{calc})$ = 0,38 J

Table B.3 — Measurement uncertainty of the deviation of the indicated absorbed energy

Quantity	Estimated value	Uncertainty		Standard uncertainty	Sensitivity coefficient	Contribution to uncertainty of S
		Value	Distribution type			
K_S	68,0 J	0,5 J	Rectangular	0,14 J	1	0,14 J
K_{calc}	68,17 J	0,3 J	Normal	0,3 J	1	0,3 J
Combined measurement uncertainty						0,33 J
Expanded measurement uncertainty using k = 2 for a 95 % confidence level						0,7 J

Annex C
(informative)

Direct method of verifying the geometric properties of pendulum impact testing machines using a jig

C.1 Field of application

This Annex describes a direct method for verifying the geometric properties of pendulum impact testing machines using a jig.

The properties which can be verified are the following:

— position of the striker in the plane of symmetry of the anvils;

— horizontality of the axis of rotation of the pendulum;

— perpendicularity between the arm of the pendulum and the axis of rotation;

— alignment of the striker and the arm of the pendulum;

— perpendicularity between the plane of the striker and the test piece.

This method may be applied to all machines and, in particular, to machines without a reference plane on the framework.

C.2 Jig

The shape and the dimensions of the jig are specified in Figure C.1. The jig has two ends (A and B) corresponding to two positions of use (A and B).

C.3 Procedure

Before using the jig, the following two properties should be verified using a level:

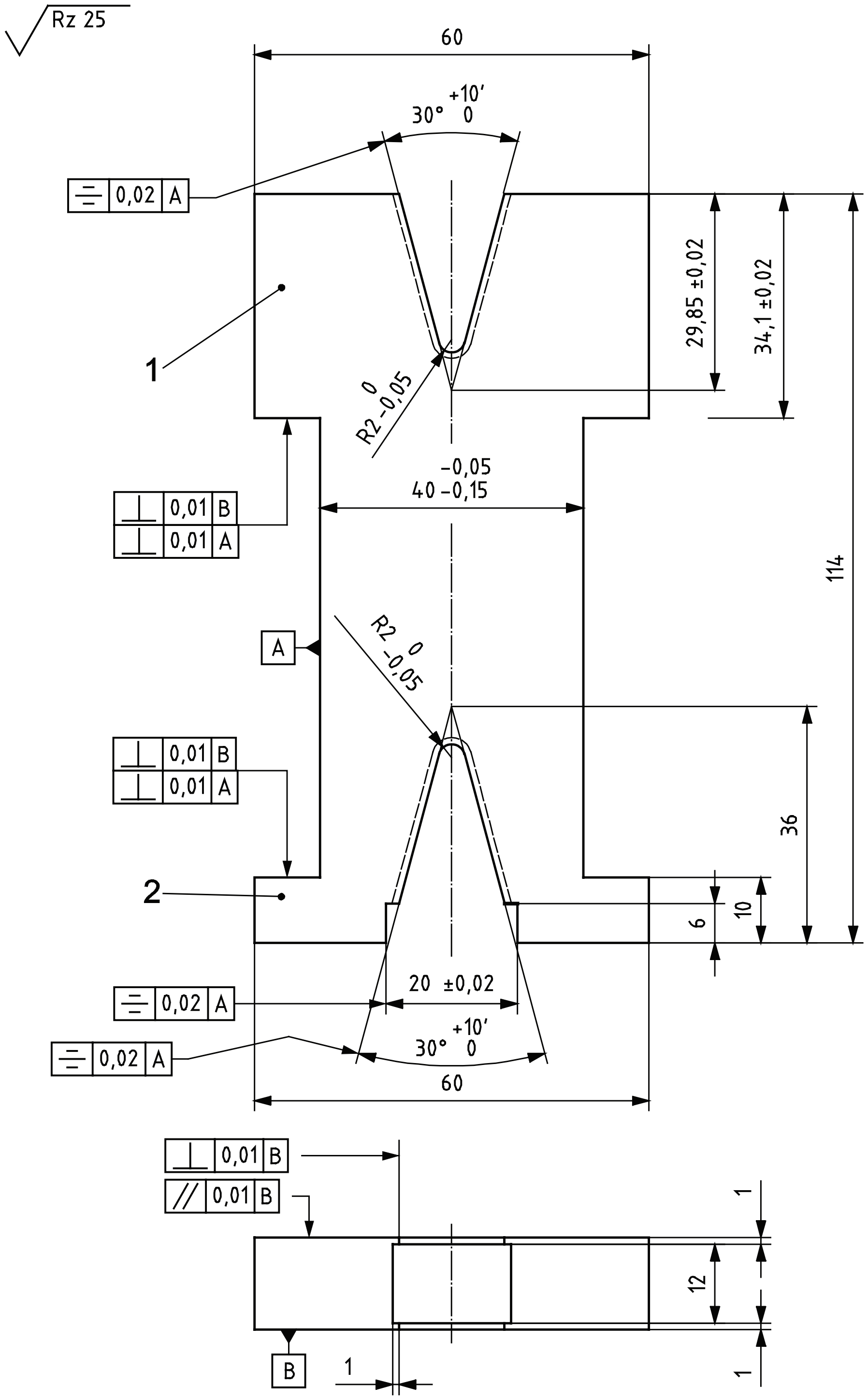
— the horizontality of the plane of the supports;

— the perpendicularity between the plane of the anvils and the plane of the supports.

The jig should be used in the two positions (A and B). As shown in Figure C.2, passing from position A to position B corresponds to the striker travelling 30 mm.

Figure C.3 and Figure C.4 illustrate the way in which to use the jig for verifying the properties defined in C.1.

Dimensions in millimetres



Key

1 end A of jig

2 end B of jig

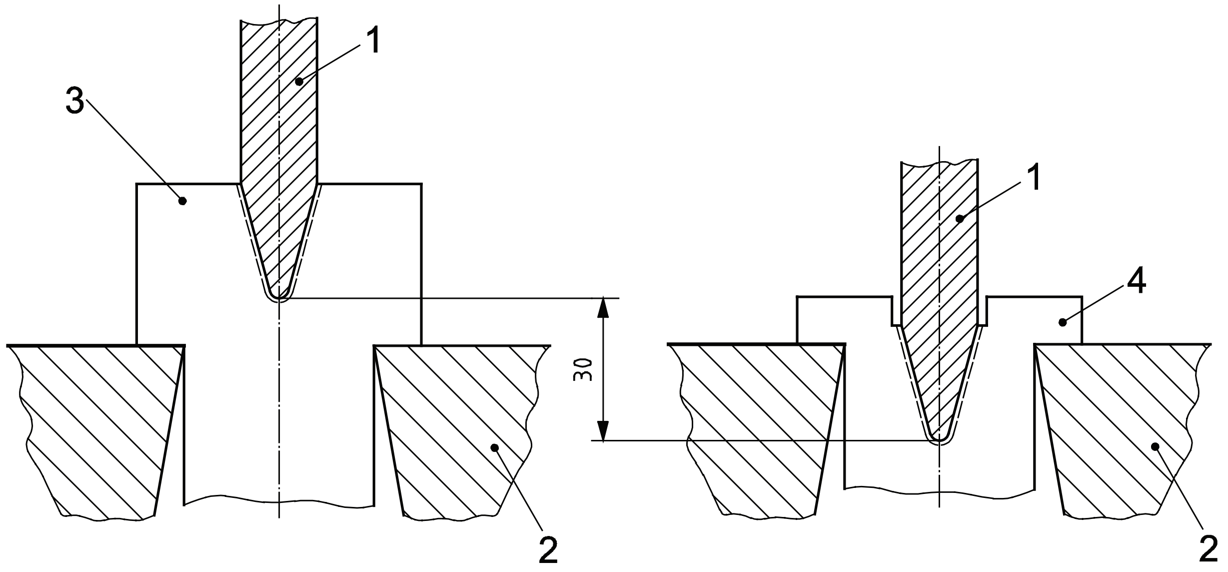
EXAMPLE X46Cr13 (55 HRC), 100Cr6 (62 HRC).

NOTE 1 Material: Stainless steel or steel with improved corrosion resistance, with low thermal expansion.

NOTE 2 All the dimensional tolerances should be ±0,2 mm unless otherwise specified.

Figure C.1 — Jig

Dimensions in millimetres



a) Position A **b) Position B**

Key

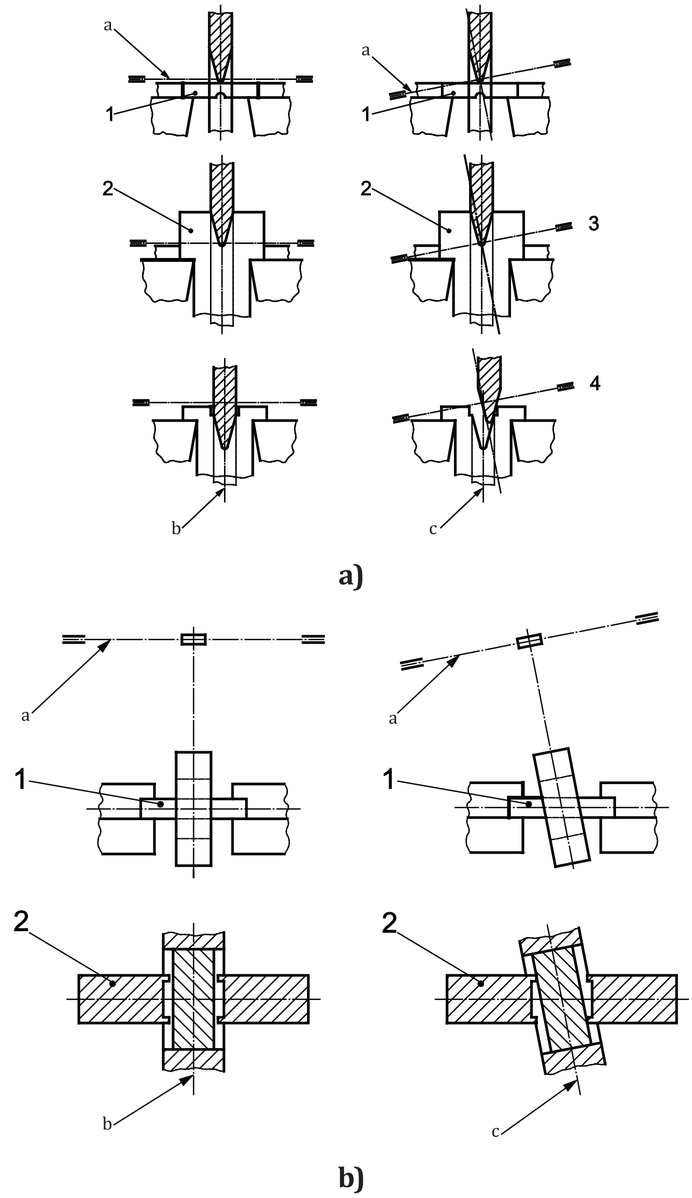
1 striker

2 anvil

3 end A of jig

4 end B of jig

Figure C.2 — Change of position from A to B corresponding to the striker travelling 30 mm



Key

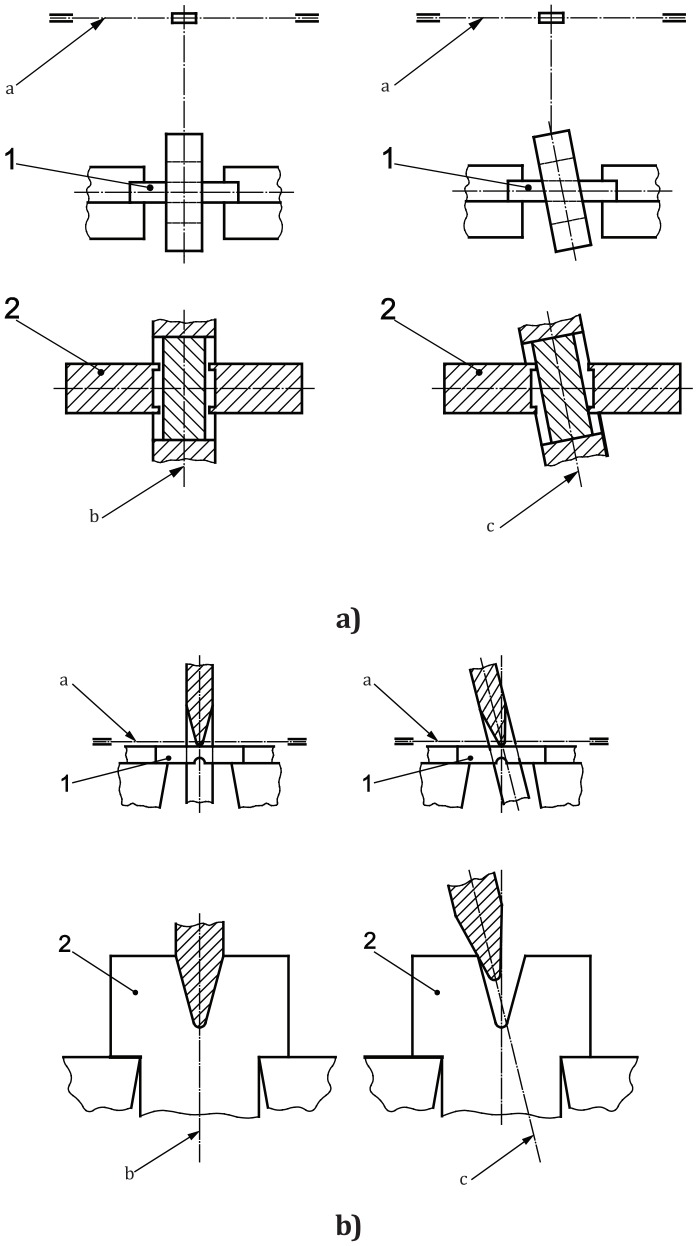
1 test piece
2 jig
3 end A
4 end B
a Pendulum axis.
b Plane of swing of the pendulum perpendicular to the longitudinal axis of the test piece.
c Plane of swing of the pendulum not perpendicular to the longitudinal axis of the test piece.

Figure C.3 — Example of application of the jig illustrated in Figure C.1

In Figure C.3:

a) the plane of swing of the pendulum is not perpendicular to the longitudinal axis of the test piece (right-hand figures);

b) the error is characterized by the fact that the striking edge is in contact with the sides of the jig: top left and bottom right parts of end A of the jig.



Key

1 test piece

2 jig

a Pendulum axis.

b Plane of symmetry of the hammer in the plane of swing of the pendulum.

c Plane of symmetry of the hammer not in the plane of swing of the pendulum.

Figure C.4 — Example of application of the jig illustrated in Figure C.1

In Figure C.4:

a) the plane of symmetry of the hammer is not in the plane of swing of the pendulum (right-hand figures);

b) the error is characterized by the fact that the striking edge is in contact with the sides of the jig: top left and bottom right parts of end A of the jig;

c) the error is characterized by the fact that the striking edge is not in contact with the bottom of the V of the jig.

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INTERNATIONAL STANDARD

ISO 148-3

Third edition
2016-10-15

Metallic materials — Charpy pendulum impact test —

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

Matériaux métalliques — Essai de flexion par choc sur éprouvette Charpy —

Partie 3: Préparation et caractérisation des éprouvettes Charpy à entaille en V pour la vérification indirecte des machines d'essai mouton-pendule

Reference number
ISO 148-3:2016(E)

Contents

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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).

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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 148-3:2008), 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*

Introduction

The suitability of a pendulum impact testing machine for acceptance testing of metallic materials has usually been based on a calibration of its scale and verification of compliance with specified dimensions, such as the shape and spacing of the anvils supporting the test piece. The scale calibration is commonly verified by measuring the mass of the pendulum and its elevation at various scale readings. This procedure for evaluation of machines had the distinct advantage of requiring only measurements of quantities that could be traced to national standards. The objective nature of these traceable measurements minimized the necessity for arbitration regarding the suitability of the machines for material acceptance tests.

However, sometimes two machines that had been evaluated by the direct-verification procedures described above, and which met all dimensional requirements, were found to give significantly different impact values when testing test pieces of the same material.

This difference was commercially important when values obtained using one machine met the material specification, while the values obtained using the other machine did not. To avoid such disagreements, some purchasers of materials added the requirement that all pendulum impact testing machines used for acceptance testing of material sold to them should be indirectly verified by testing reference test pieces supplied by them. A machine was considered acceptable only if the values obtained using the machine agreed, within specified limits, with the value furnished with the reference test pieces.

Successful experience in the use of reference test pieces led to the requirement in ISO 148-2 that indirect verification should be performed using reference test pieces in addition to direct verification. Other standards and codes also require indirect verification using reference test pieces; for example, EN 10045-2[1] (now obsolete) and ASTM E23[2] require the use of reference test pieces. The purpose of this part of ISO 148 is to specify the requirements, preparation and methods for qualifying test pieces used for the indirect verification of pendulum impact testing machines.

Metallic materials — Charpy pendulum impact test —

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 requirements, preparation and methods for qualifying test pieces used for the indirect verification of pendulum impact testing machines in accordance with ISO 148-2.

It specifies notched test pieces with nominal dimensions identical to those specified in ISO 148-1; however, the tolerances are more stringent.

NOTE 1 The chemical composition or heat treatment, or both, are varied according to the energy level desired.

NOTE 2 Reference test pieces are qualified on reference pendulum impact testing machines which are also described in this part of ISO 148.

2 Normative references

The following referenced documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 148-2, *Metallic materials — Charpy pendulum impact test — Part 2: Verification of testing machines*

3 Terms and definitions

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

3.1 Definitions pertaining to the machine

3.1.1
industrial machine
pendulum impact testing machine used for industrial, general or most research-laboratory testing of metallic materials

Note 1 to entry: These machines are not used to establish reference values.

3.1.2
reference machine
pendulum impact testing machine used to determine certified values for batches of reference test pieces

3.2 Definitions pertaining to energy

3.2.1
total absorbed energy
K_T
total absorbed energy required to break a test piece with a pendulum impact testing machine, which is not corrected for any losses of energy

Note 1 to entry: It is equal to the difference in the potential energy from the starting position of the pendulum to the end of the first half swing during which the test piece is broken.

3.2.2
absorbed energy
K
energy required to break a test piece with a pendulum impact testing machine, after correction for energy losses

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

3.2.3
reference absorbed energy
K_R
certified value of absorbed energy assigned to the test pieces used to verify the performance of pendulum impact testing machines

3.3 Definitions related to groups of test pieces

3.3.1
batch
definite quantity of reference test pieces manufactured under identical conditions of production, with a common certified absorbed energy

3.3.2
set
group of test pieces chosen at random from a batch

3.3.2.1
characterization set
set of test pieces taken from a batch and used to determine the reference energy of the batch

3.3.2.2
reference set
set of test pieces used to verify a pendulum impact testing machine

3.4 Definitions pertaining to test pieces

3.4.1
width
W
distance between the notched face and the opposite face

Note 1 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 ISO 148-1 consistent with the terminology used in other ISO fracture standards.

3.4.2
thickness
B
dimension perpendicular to the width and parallel to the notch

Note 1 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 ISO 148-1 consistent with the terminology used in other ISO fracture standards.

3.4.3
length
L
largest dimension perpendicular to the notch

3.4.4
reference test piece
impact test piece used to verify the suitability of a pendulum impact testing machine by comparing the indicated absorbed energy measured by that machine to the reference absorbed energy associated with the test pieces

3.4.5
certified reference test piece
impact test piece accompanied by a certificate providing the certified absorbed energy value, K_R, and its uncertainty at a stated level of confidence

Note 1 to entry: The certified reference value is the value determined by a certified national or international body, or by an organization accredited for the production of certified Charpy reference test pieces in accordance with ISO Guide 34[3], following the procedures described in this part of ISO 148.

4 Symbols and abbreviated terms

Table 1 — Symbols/abbreviated terms and their designations and units

Symbol/ abbreviated term	Unit	Designation
CRM	—	certified reference material
GUM	—	guide to the expression of uncertainty in measurement
k	—	coverage factor
K	J	absorbed energy
K_T	J	total absorbed energy
K_R	J	reference absorbed energy of a set of Charpy reference test pieces
K_V	J	absorbed energy as measured in accordance with ISO 148-1 on a V-notched sample
KV_{char}	J	KV value as determined for a batch of V-notched Charpy reference materials in a batch certification characterization exercise
KV_{PB}	J	certified K_V value of a PB reference material
KV_R	J	certified K_V value of a Charpy reference material
KV_{SB}	J	certified K_V value of an SB reference material
n_{hom}	—	number of samples tested for the homogeneity assessment
n_{PB}	—	number of PB specimens used to compare SB with PB
n_{SB}	—	number of SB specimens used to compare SB with PB
n_V	—	number of reference samples tested for the indirect verification of a pendulum impact testing machine
p	—	number of laboratories/instruments participating in a laboratory comparison

Table 1 *(continued)*

Symbol/ abbreviated term	Unit	Designation
PB	—	primary batch
REMCO	—	ISO Committee on Reference Materials
RM	—	reference material
SB	—	secondary batch
s_p	J	standard deviation of the mean K_V values obtained at p laboratories
s_{PB}	J	standard deviation of results obtained on n_{PB} PB samples when comparing them with n_{SB} SB samples
s_{RM}	J	standard deviation of the K_V values obtained on n_{hom} samples in the homogeneity assessment of the batch of reference material
u_{char}	J	standard uncertainty of KV_{char}
$u_{char,PB}$	J	standard uncertainty of KV_{char} for a PB
$u_{char,SB}$	J	standard uncertainty of KV_{char} for an SB
u_{hom}	J	standard uncertainty of the homogeneity assessment of the reference material
u_{lts}	J	standard uncertainty of the long-term-stability assessment of the reference material
u_{RM}	J	standard uncertainty of the certified value of a reference material used for indirect verification
U_{RM}	J	expanded uncertainty of the certified value of a reference material at a confidence level of about 95 %
u_{sts}	J	standard uncertainty of the short-term-stability assessment of a reference material
$u_{\bar{X}PB}$	J	standard uncertainty of $\bar{X}_{PB}$
$u_{\bar{X}SB}$	J	standard uncertainty of $\bar{X}_{SB}$
$\bar{X}_{PB}$	J	mean of n_{PB} specimens used to compare SB with PB
$\bar{X}_{SB}$	J	mean of n_{SB} specimens used to compare SB with PB
δKV_{hom}	J	part of the error of the measured KV value due to batch heterogeneity
δKV_{lts}	J	part of the error of the measured KV value due to long-term instability
δKV_{sts}	J	part of the error of the measured KV value due to short-term instability
v_{char}	—	degrees of freedom corresponding to u_{char}
v_{hom}	—	degrees of freedom corresponding to u_{hom}
v_{RM}	—	degrees of freedom corresponding to u_{RM}

5 Reference testing machine

5.1 Characteristics

5.1.1 General

The characteristics of reference machines used to determine the reference energy of reference test pieces shall comply with the requirements of ISO 148-2 except as modified below.

5.1.2 Geometrical characteristics (see Table 2 and Figures 1 and 2)

The following geometrical characteristics apply:

a) the radius of the anvils shall be $\left(1^{+0,10}_{0,00}\right)$ mm ;

b) the distance between the anvils shall be $\left(40^{+0,10}_{0,00}\right)$ mm ;

c) the striking edge shall be within ±0,25 mm of the plane of symmetry of the anvils.

Table 2 — Geometrical characteristics

Reference number[a]	Designation	Value	Tolerance		Units
1	Length of test piece	55,00	+0,00 −0,30	*	mm
2	Half-length of test piece	27,5	±0,2	*	mm
3	Width of test piece	10,00	±0,06		mm
4	Thickness of test piece	10,00	±0,07	*	mm
5	Ligament length	8,00	±0,06		mm
6	Angle of notch	45,0	±1,0	*	°
7	Radius at base of notch	0,250	±0,025		mm
8	Angle between adjacent faces	90,00	±0,15	*	°
9	Angle between plane of symmetry of notch and longitudinal axis	90	±2		°
10	Radius of anvils	1,00	+0,10 −0,00	*	mm
11	Angle of taper of anvils	11	±1,0		°
12	Distance between anvils	40,00	+0,10 −0,00	*	mm
13	Distance of striking edge from plane of symmetry of anvils	—	±0,25	*	mm
14	Angle of striker	30	±1		°
15A	Radius of striking edge of 2 mm striker	2,00	+0,20 −0,00	*	mm
15B	Radius of striking edge of 8 mm striker	8,00	±0.05		mm
15C	Radius of shoulder of 8 mm striker	0,25	+0,50 −0,05		mm
15D	Width of striking edge of 8 mm striker	4,00	±0,20		mm

NOTE 1 Tolerances followed by an asterisk * are tighter than those in ISO 148-1 or ISO 148-2.

NOTE 2 See Figures 1 and 2.

[a] See Figure 1.

5.1.3 Capacity

The capacity of a reference machine (nominal initial potential energy) shall be appropriate for the specimens to be tested and certified with it. Certified energies shall not exceed 80 % of the machine capacity.

5.1.4 Hardness

The portions of the striker and the anvils (see Figure 1) that contact the specimen and apply or react to the impacting force shall have a minimum hardness of 56 HRC.

5.1.5 Vibration

Ensure that the reference machine is not subjected to external vibrations induced by other equipment in close proximity, such as forging hammers, presses, moving vehicles. The machine shall also be free of excessive vibrations during an impact test.

NOTE Such vibrations can be detected by placing a small container of water at any convenient location on the machine framework; the absence of ripples on the water surface during an impact test indicates that this requirement has been met. Excessive vibration in a machine firmly fastened to the floor indicates the need for a separate foundation and/or the use of vibration isolators.

5.1.6 Energy-indicating mechanism

The resolution shall be at least 1/400 of the nominal energy.

5.2 Verification of reference testing machine

Direct verification shall be carried out in accordance with ISO 148-2 and with the additional requirements of 5.1.

Indirect verification shall be carried out using certified reference test piece. The repeatability and the bias shall be as specified in Table 3.

All equipment used for inspection and verification of a reference testing machine shall be calibrated and shall have a certified traceability to the SI System (the international system of units). The body performing the verification shall maintain calibration records for all inspection, measurement and test equipment.

The dates and details of all inspections and repairs shall be documented and maintained for each reference machine by the owner of the machine.

Table 3 — Repeatability and bias of reference pendulum impact testing machines

Absorbed energy K	Repeatability	Allowed bias
<40 J	≤2 J	±2 J
≥40 J	≤5 % of K_R	±5 % of K_R

Repeatability is the standard deviation of the K_R values measured on a least 10 reference test pieces.

Bias is given by $\overline{K} - K_R$

where

$$\overline{K} = \frac{K_1 + K_2 + K_3 + \ldots + K_n}{n}$$

where $n \geq 10$.

6 Reference test pieces

6.1 General

Guidelines for the preparation, certification, and use of (certified) reference materials have been drawn up by ISO REMCO, the ISO Committee on reference materials (see References [3] to [7]). The procedures described below provide more details, specific to the case of Charpy reference test pieces.

6.2 Material

All the test pieces from a batch shall come from a single ingot or melt.

All test pieces shall be made of steel. The composition of the test pieces is not specified. Batches with different energy levels may have different compositions.

All test pieces from a batch shall receive the same heat treatment.

For each batch, the level for the reference absorbed energy is characterized by using one of the following ranges:

— Low: <30 J

— Medium: ≥30 J to 110 J

— High: ≥110 J to 200 J

— Ultra-high: ≥200 J

6.3 Dimensions

The reference test pieces shall meet the dimensional requirements given in Table 2.

NOTE These dimensions are identical with those in ISO 148-1, except that some of the tolerances are tighter.

The radius at the base of the notch shall be tangential to the notch angle.

The surface finish, *Ra*, shall not exceed 1,6 µm on the notched surface and 3,2 µm on the other surfaces.

6.4 Marking

All test pieces shall be permanently marked so that each test piece can be distinguished from all the others.

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

6.5 Qualification of a batch of reference test pieces

6.5.1 Any group of test pieces meeting the requirements of 6.2, 6.3 and 6.4 may be used as the batch from which reference test pieces are randomly selected.

6.5.2 To determine the reference energy of a batch, draw one or more sets of at least 25 test pieces at random from the batch and test them on one or more reference machine(s). Take the reference absorbed energy of the batch as the grand average of the values obtained for the 25 or more test pieces, or as the average of the mean values obtained on the different reference machines.

NOTE The certified values can be determined using other methods, providing the method used conforms to ISO Guide 34 and ISO Guide 35[7].

6.5.3 Also calculate the standard deviation. The standard deviation shall be as specified in Table 4.

Table 4 — Maximum allowable standard deviations permitted for Charpy reference test pieces

Energy K_R	Standard deviation
<40 J	≤2,0 J
≥40 J	≤5 % of K_R

6.5.4 The report on the impact tests of the reference test pieces shall include the following information:

a) striker geometry;

b) temperature at which the tests were performed;

c) all details necessary for the identification of each test piece;

d) energy value, K, of each test piece, corrected for air resistance and friction, with the striker radius and specimen type indicated (KV_2, KV_8, KU_2, or KU_8);

e) value of the reference absorbed energy and the associated standard deviation;

f) uncertainty associated with the reference absorbed energy value measured for the set.

NOTE Information on calculating uncertainty is given in Annex A.

6.6 Reference test piece sets

After the characterization set(s) to be tested by the reference machine(s) have been drawn from the batch, draw the remaining test pieces in sets of five. These are the test piece sets. Each test piece set shall remain intact with no substitution permitted.

7 Certificates for reference test pieces

Each set of reference test pieces shall be accompanied by a certificate which provides the following information:

a) reference to this part of ISO 148, i.e. ISO 148-3;

b) name, trademark or reference number of the producer;

c) reference absorbed energy value of the set and its uncertainty at the stated level of confidence;

d) striker geometry;

e) temperature at which the reference specimen should be tested;

f) necessary information for appropriate use of the reference test pieces;

g) name and general description of the material;

h) producer's code for the batch;

i) intended use (making reference to ISO 148-2);

j) description of the (metrologically valid) procedure used to determine the certified value;

k) statement on the metrological traceability of the certified value;

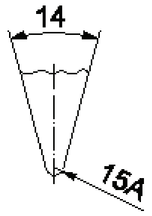
l) storage conditions and shelf-life (period of validity).

8 Notes for using sets of reference test pieces

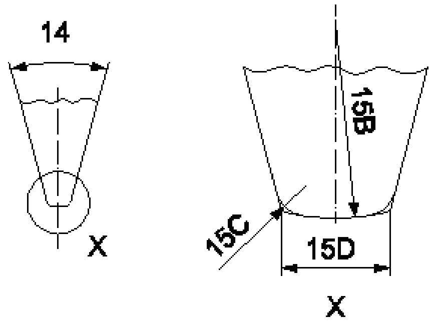
8.1 Indirect verification of an industrial machine shall be performed in accordance with ISO 148-2 using the reference test pieces, the striker and the temperature specified by the producer of the test pieces.

8.2 All the reference test pieces in each set shall be used for a single, indirect verification of the pendulum impact testing machine, testing the test pieces in random order and including all the results in the average. Substitution or replacement of individual test pieces by test pieces from another reference set is not permitted.

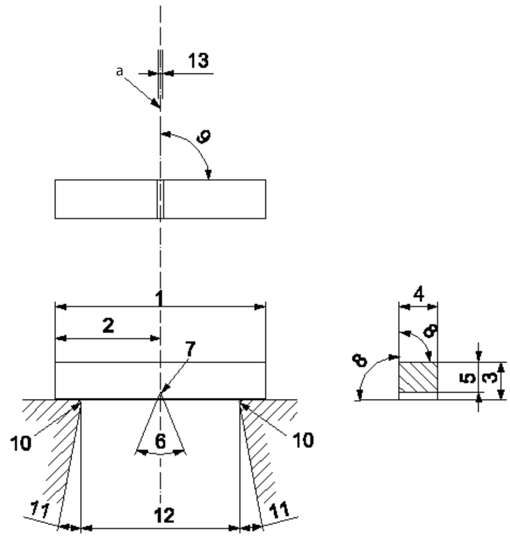
Dimensions in millimetres



a) 2 mm striker



b) 8 mm striker

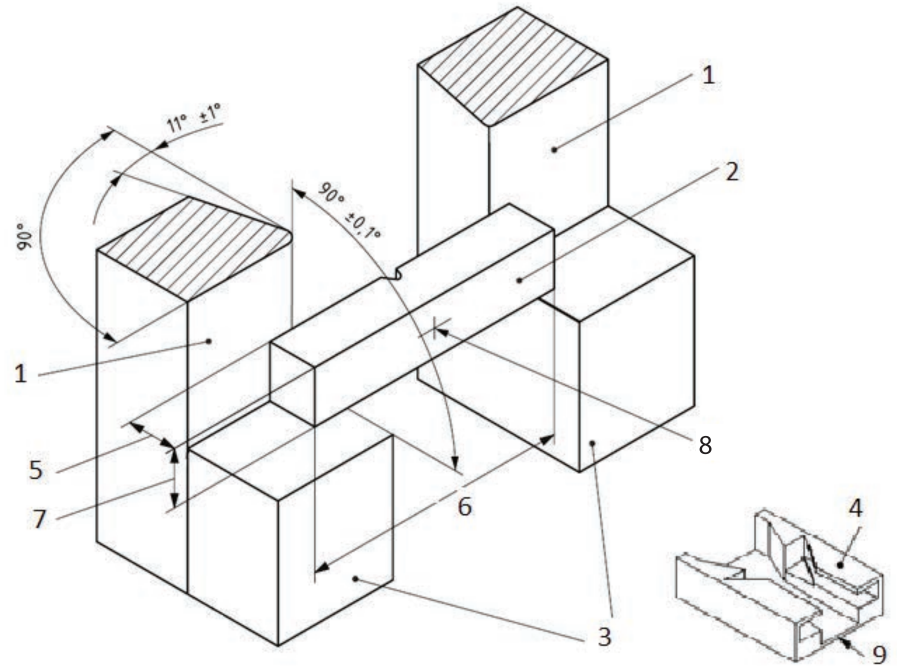


c) Overview

NOTE See Table 2 for geometrical characteristics.

a Line of strike.

Figure 1 — Dimensions of test pieces, anvils and strikers



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 2 — Configuration of test-piece supports and anvils in a reference pendulum impact testing machine

Annex A
(informative)

Uncertainty of the certified *KV* value of Charpy reference materials

A.1 Background

When performing an indirect verification of a pendulum impact testing machine, one compares the reference *KV* value of the reference test pieces with values measured on the pendulum impact testing machine under verification. To determine the measurement uncertainty of this indirect verification exercise and, later, the measurement uncertainty of Charpy measurements on the verified pendulum impact testing machine, one needs the uncertainty of the reference value. Therefore, this uncertainty should be assessed and provided by the reference material (RM) producer.

The ISO Committee on reference materials (REMCO) has drawn up a series of documents on reference materials production and use, which are released as ISO Guides (see References [3] to [7]). Approaches to tackling the uncertainty aspect of RM production are described in generic terms in ISO Guide 34 and in more technical-statistical detail in ISO Guide 35. This Annex provides an ISO-Guides-compliant practical framework for the calculation of the uncertainty of the certified absorbed energy value of a Charpy RM. The text is based on current approaches followed by national metrology institutes (NMIs) active in the Charpy field. The approaches presented here can be used as a guideline by potential new Charpy RM producers, as well as by the users of Charpy RMs who require more insight into the uncertainty stated by the RM producer on the RM certificate.

A.2 The GUM-compliant uncertainty budget

ISO Guide 35 provides a basic, GUM[8]-compliant, model for the certification of batches of certified reference materials (CRMs). In Charpy terms, the model can be expressed as follows:

$$KV_R = KV_{char} + \delta KV_{hom} + \delta KV_{lts} + \delta KV_{sts} \tag{A.1}$$

where

KV_{char}	is the *KV* value obtained from the characterization of the batch (comparing results from different machines);
KV_{hom}	is an error term due to variation between samples (comparing results in repeatability conditions on a single pendulum);
KV_{lts}, KV_{sts}	are error terms due to the long-term and short-term instability of the RM (comparing results of samples exposed to different ageing periods).

Homogeneity and stability studies are most often designed in such a way that the values of the corresponding error terms are zero. However, the uncertainties of the error terms are not (always) zero. Assuming independence of the variables, the uncertainty of the certified value of the Charpy RM, therefore, can be expressed as:

$$u_{RM} = \sqrt{u_{char}^2 + u_{hom}^2 + u_{lts}^2 + u_{sts}^2} \tag{A.2}$$

The better the within-instrument repeatability and the between-instrument reproducibility, the smaller u_{char} will be. The better the between-sample homogeneity, the smaller u_{hom} will be. Sometimes, the material homogeneity is very good, and u_{hom} is dominated by within-instrument repeatability. This is not the case for typical Charpy RMs. The better the stability of the RM microstructure, under the appropriate transport and storage conditions, the smaller u_{sts} and u_{lts} will be.

A.3 KV_R, the certified KV of a batch of Charpy RMs

Charpy RMs are produced batch-wise. The KV values of samples from a single batch vary from sample to sample. Yet, the whole batch will be assigned a single certified KV value. Obviously, this could be best estimated by testing all samples. However, since the impact test is destructive, there would be no samples left for distribution as reference materials. Instead, a representative selection of samples is taken from the batch and tested. An average value will become the certified value, KV_R. This can be the average of all samples tested, or the average of the mean values of a number of subgroups of the samples tested.

A.4 u_{char}, the uncertainty of the average KV of a batch of Charpy RMs

A.4.1 Differences between pendulum impact testing machines

Even if one would break all samples of a batch to determine the average KV of the batch, still the question remains whether the average value obtained under the particular test conditions is affected by inaccuracies in the tests performed. To reduce this uncertainty, RM producers generally try to measure the property to be certified in different independent ways. For properties such as the chemical composition of an RM, one can often use different methods. However, in the case of pendulum impact tests, the only way to measure the "method-defined" KV value is to do Charpy pendulum impact tests in accordance with the applicable standard procedure (ISO 148-1), to which the certified values will be metrologically traceable.

To reduce the effect of machine-specific bias from the standard procedure on the certified reference values, one often performs pendulum impact tests on several pendulum impact testing machines. The larger the number of pendulum impact testing machines used to assess the average of a single batch of samples, the more likely it is that the average of the values obtained is true and unbiased. Of course, this is only true at the condition that individual participating pendulums are good quality instruments. This is the approach of both inter- and intralaboratory comparisons, currently followed in Charpy reference material certification, and recommended in ISO Guide 35.[7]

A.4.2 Intercomparison among p pendulum impact testing machines ($p \geq 6$)

When a sufficient number of machines participate in a comparison, the standard uncertainty of the average value is calculated as:

$$u_{char} = \frac{s_p}{\sqrt{p}} \tag{A.3}$$

where

u_{char} is the uncertainty from the characterization of the batch;

p is the number of laboratories or instruments participating in the intercomparison;

s_p is the standard deviation of the laboratory mean values.

This approach assumes that the individual laboratory mean values are normally distributed, and that the instruments or laboratories participating are a representative sample from the population of Charpy pendulum impact testing machines that meet the dimensions and performance criteria specified in ISO 148-2. The number of degrees of freedom, ν_{char}, associated with this way of calculating u_{char} is p−1. ISO Guide 35 recommends a minimum number of six laboratories or instruments for this approach (ISO Guide 35:2006, 9.4.2.3.1).

A.4.3 Intercomparison among *p* pendulum impact testing machines ($p < 6$)

When the number of instruments participating to the comparison is limited, the value s_p is not a reliable estimate of the standard deviation of the mean values between instruments. To assess u_{char}, other methods should be used. These methods combine the systematic differences observed between the instruments participating in the intercomparison (between-instrument uncertainty) and the measurement uncertainty assessed for the individual instruments (within-instrument uncertainty). An example is the so-called “BOB” or Type-B-on-bias-approach (see Reference [9]).

To have better control over the quality of the impact pendulums participating in the certification exercise, some CRM producers prefer to limit the number of impact pendulums to those in their own laboratory (intralaboratory). This approach offers the benefit of better defining the range for acceptable machine performance. However, it can be argued that it affects the independence of the averaged values. This is why the interlaboratory comparison is generally preferred in ISO Guide 35.

A.5 Uncertainty due to material instability

The stability of the certified value of a CRM is typically threatened by two possible effects: degradation of the material during transport from producer to user (short-term stability), and degradation of the material during storage between the moment of production and the distribution to the CRM user (long-term stability). In the case of the steels currently used for the production of Charpy CRMs, neither short- nor long-term stability has presented problems (see References [10], [11] and [12]). However, this should remain a subject of investigation, especially when selecting new types of steel for the production of Charpy CRMs. Until then, the values for u_{lts} and u_{sts} are considered negligibly small.

A.6 Uncertainty due to sample-to-sample variation — Homogeneity of the batch

Due to the heterogeneity of the steel microstructure, and the nature of the impact fracture process, samples from the same batch often have measurably different *KV* values. This implies that the average value of the set of verification test pieces tested by the CRM user is not exactly the same as the average of the RM batch from which the set was drawn.

For a single sample, the standard uncertainty, u_{hom}, associated with this homogeneity issue equals the standard deviation of the batch, s_{RM}. To assess this standard deviation, tests are performed on a representative number of samples n_{hom}, selected from the batch. The tests are performed in repeatability conditions, excluding or at least minimizing the contributions to the standard deviation coming from machine, operator or other factors.

NOTE The value of s_{RM} can also be deduced from the results of the interlaboratory comparison (see A.4). In this case, the within-laboratory and the between-laboratory variance of the results are separated using ANOVA (analysis of variance). The within-laboratory variance is related to s_{RM}.

Experience has shown that it is difficult to obtain large batches of Charpy reference test pieces with a standard deviation smaller than 3 %. At least, this is the case for the hardenable kind of steels needed for the production of samples at different energy levels with a minimum hardness, so as to truly put the pendulum to a test during verification. To reduce this relatively large contribution to the overall uncertainty of the certified value, it is common practice that the CRM user tests a set of samples of the batch, rather than a single sample, to verify a pendulum. (Actually, ISO 148-2 prescribes the use of at least five test pieces.) The chances that the average of a set of test pieces equals the average of the whole batch increases with n_V, the number of test pieces used in the indirect verification, reducing the corresponding uncertainty contribution according to Formula (A.4):

$$u_{hom} = \frac{s_{RM}}{\sqrt{n_V}} \qquad \text{(A.4)}$$

The number of degrees of freedom of this uncertainty contribution, ν_{hom}, equals ($n_{hom} - 1$).

A.7 Combined and expanded uncertainty of the certified value, and how to report them

If the uncertainty contributions from material instability can be neglected, the combined standard uncertainty, u_{RM}, is calculated from the remaining standard uncertainty contributions, u_{char} and u_{hom}, as follows:

$$u_{RM} = \sqrt{u_{char}^2 + u_{hom}^2} \quad (A.5)$$

Usually, the uncertainty of a certified value on the certificate is specified for a confidence level of about 95 %. Therefore, the standard combined uncertainty, u_{RM}, has to be expanded using an appropriate coverage factor, k. The coverage factor to be used depends on the number of degrees of freedom associated with the combined uncertainty, which can be computed using the Welch-Satterthwaite approximation (see Reference [8]). For a typical case (see example in A.8), the number of effective degrees of freedom is larger than 20 and a coverage factor of $k = 2$ can be used. If the number of degrees of freedom, ν_{RM}, is smaller, the coverage factor can be calculated as:

$$k = t_{95}(\nu_{RM}) \quad (A.6)$$

with t values taken from the non-standard GUM table (see Reference [8]). The certified value, KV_{RM}, of reference test pieces always has to be reported together with the corresponding expanded uncertainty, U_{RM}, and the coverage factor and/or confidence level (see Reference [5]). For the case of Charpy reference test pieces, the user will benefit from the following additional information (see ISO 148-2, Annex A):

1) ν_{char}, the number of degrees of freedom of u_{char}, or the number p of laboratories/instruments participating in the laboratory comparison;

2) standard deviation, s_{RM}, of the homogeneity test results, as a measure for the reference material inhomogeneity, as well as n_{hom}, the number of samples used to determine the homogeneity;

3) value of u_{char}, which is required for transferring the certified value from one batch of Charpy RMs to another batch (see A.9).

A.8 Example

An RM producer has processed a batch of Charpy test pieces. To assess the homogeneity of the batch, one laboratory is chosen to test 25 test pieces in repeatability conditions. Table A.1 shows the results.

First, the data are screened for statistical outliers (as described, for example, in ISO 5725-2[13]). Grubbs' test reveals that the result of sample 22 is a statistical outlier at the 95 % confidence level. An inspection of the sample reveals no abnormal anvil or striker traces, indicating that the sample was correctly positioned during the test. Also, no trivial error was detected when inspecting the test report. Since there is no technical explanation indicating that the result is an outlier due to reasons external to the sample, the result cannot be excluded from the homogeneity analysis. If one had detected a technical explanation in the sample itself (such as a significant microstructural flaw on the fracture surface), the result could not have been eliminated either, since this flaw is related to the material homogeneity, which is the object of the homogeneity assessment.

When comparing the obtained value, s_{RM}, (3,57 J) with the average value of KV (124,74 J), it is confirmed that the batch meets the criterion imposed in Table 4 on batches of Charpy reference materials ($s_{RM} \leq 5$ % of the average value). Based on the intended use of the samples, the CRM producer chooses to distribute the samples in sets of 5, and calculates the corresponding value for the uncertainty contribution using Formula (A.4):

$$u_{hom} = \frac{s_{RM}}{\sqrt{n_V}} = \frac{3{,}57}{\sqrt{5}} = 1{,}60 \quad \text{(A.7)}$$

Then, 11 accredited test laboratories receive 10 test pieces each, randomly selected from the full batch.

NOTE The RM producer is free to choose the number of test pieces per test laboratory. Larger numbers will reduce the uncertainty of the certified value.

The results of the interlaboratory comparison are examined by the RM producer. Grubbs' test does not reveal any statistical outlier among the laboratory mean values. Table A.2 summarizes the results and the RM relevant parameters.

Table A.1 — Results of homogeneity tests

Sample	*KV* J	**Sample**	*KV* J	**Sample**	*KV* J
1	127,7	10	127,9	18	127,3
2	122,2	11	120,7	19	123,8
3	123,5	12	127,5	20	126
4	125,6	13	122,1	21	128,7
5	122,5	14	126,3	22	114,5
6	122,9	15	128,9	23	121,3
7	126,7	16	125,4	24	128,1
8	123,2	17	119,1	25	127
9	129,5	—	—	—	—
Average *KV* = 124,74 J		s_{RM} = 3,57 J		n_{hom} = 25	

Table A.2 — Results of interlaboratory comparison

Laboratory	*KV* J	**Laboratory**	*KV* J	
1	122,2	7	126,8	
2	120,9	8	125,1	
3	125,5	9	123,7	
4	122,0	10	124,0	
5	123,8	11	124,9	
6	122,8	—	—	
KV_R = 123,8 J	s_p = 1,73 J	P = 11	u_{char} = 0,52 J	ν_{char} = 10

The certified value (123,8 J) is obtained as the rounded average of the laboratory mean values. A standard uncertainty, u_{char}, of 0,52 J is calculated from the standard deviation of the laboratory mean values, using Formula (A.3).

Table A.3 shows the standard uncertainty contributions, u_{char} and u_{hom}, the combined standard uncertainty, u_{RM} and ν_{RM}, and the number of degrees of freedom calculated from the Welch-Satterthwaite equation. Since ν_{RM} is larger than 20, a coverage factor of k = 2 can be used to calculate the expanded uncertainty, U_{RM}, for a confidence level of about 95 %. Its value is rounded up to one decimal, in agreement with the precision of the certified value.

Table A.3 — Certification-related uncertainty contributions and associated degrees of freedom

u_{char} = 0,52 J	v_{char} = 10	u_{hom} = 1,60 J	v_{hom} = 24
Standard uncertainty of the certified value calculated from u_{char} and u_{hom} using Formula (A.5)			u_{RM} = 1,68 J
Degrees of freedom calculated using the Welch-Satterthwaite approximation			v_{RM} = 28
Expanded uncertainty of the certified value			U_{RM} = 3,4 J

To report the certification results, the certified value and its uncertainty, Table A.4 can be used.

Table A.4 — Summary table of the certified KV_R with expanded uncertainty, U_{RM}

p	s_{RM} [a] J	n_{hom}	KV_R J	u_{char} J	U_{RM} [b] J
11	3,57	25	123,8	0,52	3,4

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

[b] The expanded uncertainty, calculated according to the procedure described in this annex, corresponds to a confidence level of about 95 %.

A.9 Additional uncertainty contributions when transferring the certified value from a primary batch to a secondary batch

A.9.1 Aim

Charpy RMs of a particular batch can be used to determine the certified value of another batch of Charpy test pieces. The assignment of the certified value of the new batch to be certified is based on a comparison of KV values of previously certified samples and new samples to be certified. In the following, the originally certified batch is called the “Primary Batch (PB)”, which has a certified value KV_{PB}. The new batch to be certified is called the “Secondary Batch (SB)”. The comparison necessarily results in an additional uncertainty contribution in comparison with the uncertainty of the PB.

A.9.2 Practice — Repeatability, bias and commutability requirements

The additional uncertainty contribution from the transfer of the certified value from PB to SB can be kept reasonably small if the comparison occurs under strict repeatability conditions. In the case of Charpy pendulum impact tests, this means ideally that SB and PB samples are tested in one single series of tests on one single pendulum, with a mixed order for testing SB and PB samples. The following values are the results of these tests:

$\bar{X}_{PB}$, mean of n_{PB} specimens used to compare SB with PB, standard deviation = s_{PB}

$\bar{X}_{SB}$, mean of n_{SB} specimens used to compare SB with PB, standard deviation = s_{SB}

This approach is reliable only if the pendulum used to compare PB and SB performs well. In other words, the ratio $KV_{PB} / \bar{X}_{PB}$ should be close to 1; the allowed difference is 20 % ($KV_{PB} \geq 40$ J) or 2 J ($KV_{PB} < 40$ J), corresponding to the level of bias allowed for reference pendulums specified in Table 3.

In addition, the batches SB and PB should be comparable to ensure that the pendulum responds in a similar manner to samples from both batches. In practice, this means that the same base material should be used, and the values of $\bar{X}_{PB}$ and $\bar{X}_{SB}$ should be close (within ±20 %). In terms of CRM production, this is a commutability requirement, the basis for which is discussed in ISO Guide 33.

The certified value of the secondary batch, KV_{SB}, is obtained by correcting $\overline{X}_{SB}$ by a kind of punctual calibration of the pendulum on which the SB and PB were compared, using the ratio $KV_{PB} / \overline{X}_{PB}$:

$$KV_{SB} = \frac{KV_{PB}}{\overline{X}_{PB}} \cdot \overline{X}_{SB} \tag{A.8}$$

where KV_{PB} is the certified KV value of the primary batch.

A.9.3 The resulting uncertainty

To calculate the uncertainty of KV_{SB}, one needs to combine the uncertainties of the factors KV_{PB}, $\overline{X}_{SB}$ and $\overline{X}_{PB}$ from Formula (A.8).

a) The value of KV_{PB} links the SB with the results of the PB. In terms of uncertainty, only $u_{char,PB}$ is relevant, and not u_{hom}, because Formula (A.7) makes the link to the average KV value of the primary batch, not to a set of five samples from the PB.

b) The values $\overline{X}_{SB}$ and $\overline{X}_{PB}$ are estimates of the average of SB and PB on the particular pendulum in the particular repeatability conditions, used for the comparison. The standard uncertainty contributions from both factors are

$$u_{\overline{X}SB} = \frac{s_{SB}}{\sqrt{n_{SB}}} \tag{A.9}$$

$$u_{\overline{X}PB} = \frac{s_{PB}}{\sqrt{n_{PB}}} \tag{A.10}$$

NOTE The resolution of the pendulum used contributes to the uncertainties of $\overline{X}_{SB}$ and $\overline{X}_{PB}$ as well. However, the pendulums used for this type of comparison are chosen to have a good resolution (0,1 J or better), in which case the resolution does not significantly contribute to $u_{\overline{X}SB}$ and $u_{\overline{X}PB}$.

Since the partial derivatives of Formula (A.8) are all equal to 1 or −1, the uncertainty of the characterization of the SB is obtained by combining the contributions $u_{char,PB}$, $u_{\overline{X}SB}$ and $u_{\overline{X}PB}$. Determine $u_{char,SB}$ as follows (see H.6.2 of Reference [8]):

$$u_{char,SB} = \sqrt{u_{char,PB}^2 + u_{\overline{X}_{SB}}^2 + u_{\overline{X}_{PB}}^2} \tag{A.11}$$

This uncertainty contribution can be combined with the uncertainty contributions of homogeneity and/or stability, as described in A.8.

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