INTERNATIONAL STANDARD

ISO 148-3

Second edition
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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
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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 148-3 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 4, *Toughness testing — Fracture (F), Pendulum (P), Tear (T)*.

This second edition cancels and replaces the first edition (ISO 148-3:1998) 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 must 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 must be performed using reference test pieces in addition to direct verification. National standards and codes also require indirect verification using reference test pieces; for example, EN 10045-2 and ASTM E 23 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 covers 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 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 148-1, *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 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 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 friction

NOTE 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 striker radius, 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 in accordance with Clause 6 and used to determine the reference energy of the batch

3.3.2.2
reference set
set of test pieces chosen in accordance with Clauses 6 and 8 and used to verify a pendulum impact testing machine

3.4 Definitions pertaining to test pieces

3.4.1
height
distance between the notched face and the opposite face

3.4.2
width
dimension perpendicular to the height that is parallel to the notch

3.4.3
length
largest dimension perpendicular to the notch

3.4.4
reference test piece
impact test piece used to verify the suitability of pendulum impact testing machines 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 the certified absorbed energy value, K_R, accompanied by an uncertainty at a stated level of confidence

NOTE The certified reference value is the value determined by a certified national or international body.

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in Table 1 are applicable.

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
ISO	—	International Organization for Standardization
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
KV	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 KV value of a PB reference material
KV_R	J	Certified KV value of a Charpy reference material
KV_{SB}	J	Certified KV 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
PB	—	Primary batch
REMCO	—	ISO Committee on reference materials
RM	—	Reference material
SB	—	Secondary batch
s_p	J	Standard deviation of the mean KV 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

Table 1 (*continued*)

Symbol/ abbreviated term	Unit	Designation
s_{RM}	J	Standard deviation of the KV 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
$u_{\overline{X}PB}$	J	Standard uncertainty of $\overline{X}_{PB}$
$u_{\overline{X}SB}$	J	Standard uncertainty of $\overline{X}_{SB}$
$\overline{X}_{PB}$	J	Mean of n_{PB} specimens used to compare SB with PB
$\overline{X}_{SB}$	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
ν_{char}	—	Degrees of freedom corresponding to u_{char}
ν_{hom}	—	Degrees of freedom corresponding to u_{hom}
ν_{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 remain 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	Height of test piece	10,00	± 0,06	mm
4	Width of test piece	10,00	± 0,07 *	mm
5	Ligament length	8,00	± 0,06	mm
6	Angle of notch	45,0	± 1,0 *	degree
7	Radius of curvature at base of notch	0,250	± 0,025	mm
8	Angle between adjacent faces	90,00	± 0,15 *	degree
9	Angle between plane of symmetry of notch and longitudinal axis	90	± 2	degree
10	Radius of anvils	1,00	$^{+0,10}_{-0,00}$ *	mm
11	Angle of taper of anvils	11	± 1,0	degree
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	degree
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	± 0,05	mm
15D	Width of striking edge of 8 mm striker	4,00	± 0,05	mm

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

NOTE 2 Subsize specimens may be used, but the tolerance should change proportionally.

NOTE 3 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 300 J or greater.

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.

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 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 1/400th 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 pieces. 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) through the national standards Bodies. 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

Values in joules

Absorbed energy K	Repeatability	Bias
< 40	$\leqslant 3$	$\leqslant 2$
$\geqslant 40$	$\leqslant$ 7,5 % of KV_R	$\leqslant$ 5 % of KV_R

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

Bias is given by $\overline{KV} - KV_R$

where

$$\overline{KV} = \frac{KV_1 + KV_2 + KV_3 + \ldots + KV_n}{n}$$

where

$n \geqslant 10$

5.3 Use of reference testing machine

5.3.1 The procedure for the operation of the reference machine shall conform to the requirements of ISO 148-1 and to the following additional requirements.

5.3.2 The angular position of the pendulum at the extremes of its swing or the impact energy calculated therefrom shall be automatically recorded in digital or graphical form. These records shall be in permanent form, available for evaluation at any time until one year after the entire batch of reference test pieces has been distributed.

5.3.3 The combined air resistance and friction loss resulting from 11 successive half swings shall be measured and the values recorded before and after testing each characterization set.

5.3.4 The anvils and striker shall be inspected and measured for compliance annually. If any parts are found to be damaged, they shall be replaced and the machine shall be re-qualified (see 5.1 and 5.2).

During the annual inspection of the reference machine, the flatness of the anvil surfaces (which absorb the force transmitted through the test piece) and the adjacent radii shall be examined for wear or damage. The results of this examination shall be retained until the anvils are replaced or re-machined.

NOTE This examination can be done, for example, by making a replica of the surfaces in silicone rubber or another low-shrinkage material, or by holographic methods.

The radius (radii) of the striking edge of the striker and the radii of the anvil surfaces which are contacted by the test piece shall be measured and documented in the same manner.

If it becomes necessary to repair the recording system, it shall be recalibrated before additional tests are made (see 5.2).

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 [1] to [5]). 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 the following ranges:

— Low: < 30 J

— Medium: $\geqslant 30$ J to 110 J

— High: $\geqslant 110$ J to 200 J

— Ultra-high: $\geqslant 200$ 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 that avoids the effects of plastic deformation and surface discontinuities on 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 Guides 34 and 35.

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

Table 4 — Standard deviation permitted for reference test pieces

Values in joules

Energy KV_R	Standard deviation
< 40	$\leqslant 2{,}0$
$\geqslant 40$	$\leqslant 5$ % of KV_R

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

a) the striker geometry;

b) the temperature at which the tests were performed;

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

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

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

f) the 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 gives the following information:

a) a reference to this part of ISO 148, i.e. ISO 148-3:2008;

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

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

d) the striker geometry;

e) the temperature at which the reference absorbed energy was determined;

f) all details necessary for the identification of the reference machine(s) used to determine the reference energy (and necessary information concerning the 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;

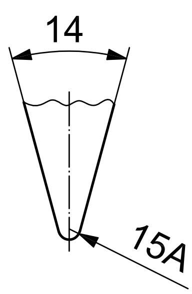
k) statement on the metrological traceability of the certified value;

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

8 Notes for using sets of reference test pieces

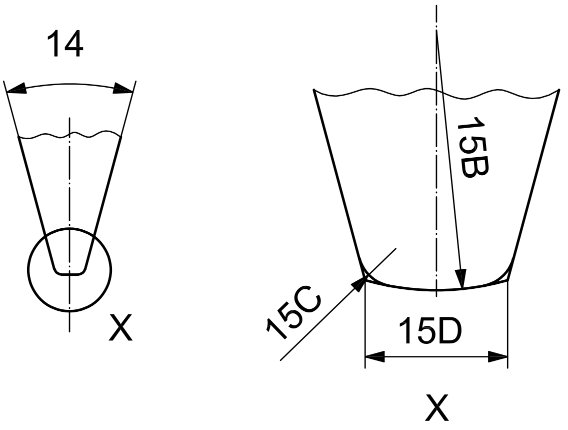
8.1 Indirect verification of an industrial machine shall be performed in accordance with ISO 148-2 using the reference test pieces, the striker and the temperature specified by the producer of the test pieces.

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.

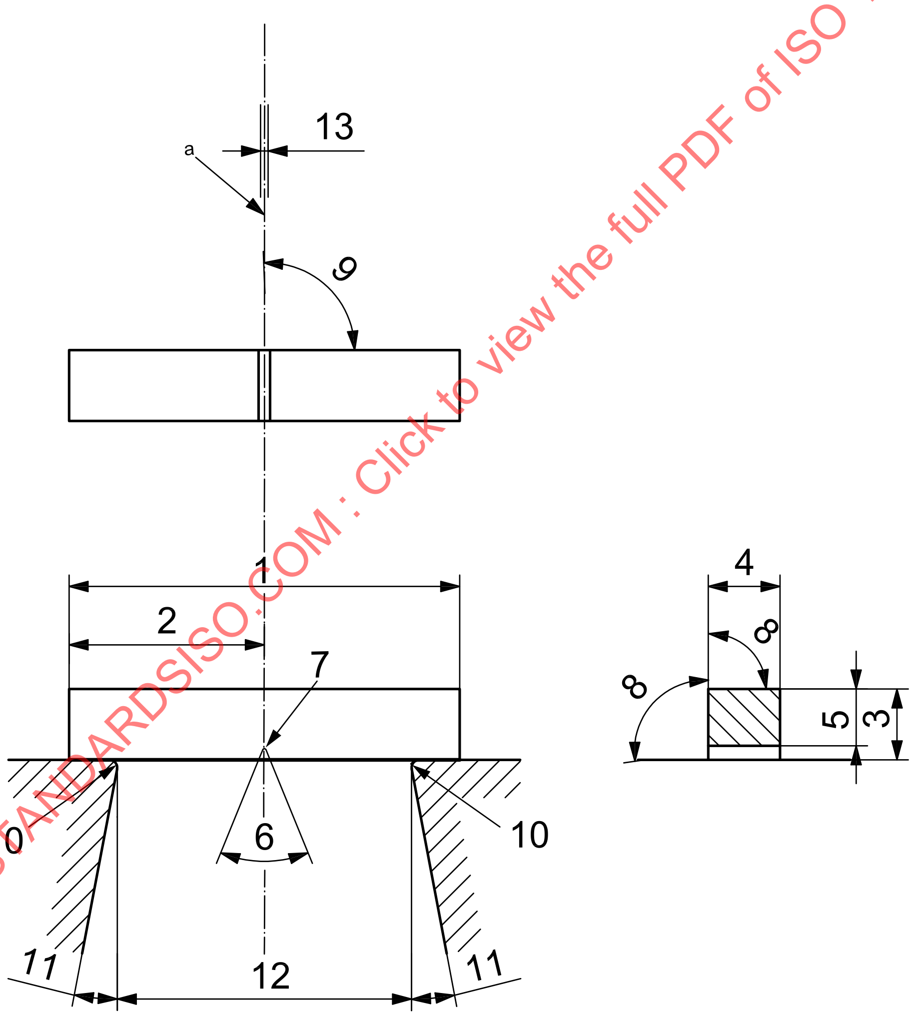


a) 2 mm striker

Figure 1 (*continued*)



b) 8 mm striker

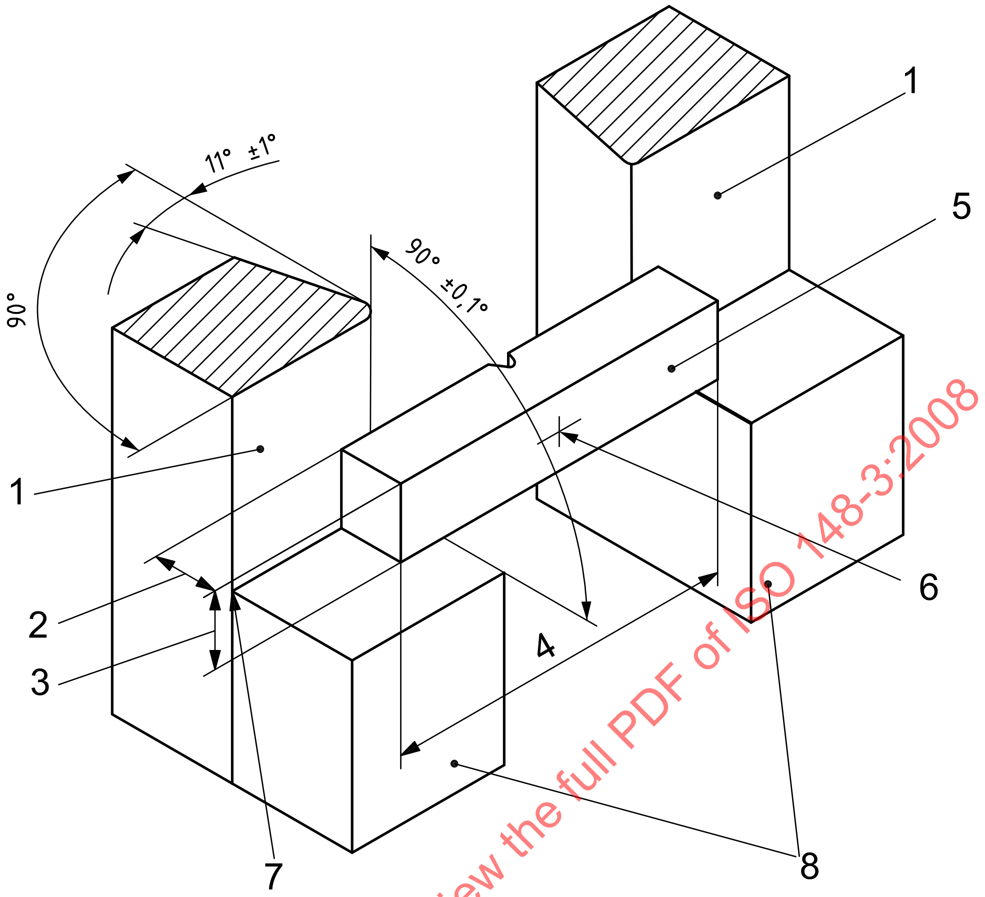


c) Overview

NOTE See Table 2 for geometrical characteristics.

[a] Line of strike.

Figure 1 — Dimensions of test pieces, anvils and strikers



Key

1 anvil
2 height of test piece
3 width of test piece
4 length of test piece
5 reference test piece
6 centre of strike
7 recess
8 test-piece supports

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 (see for example the procedures proposed in Reference [1]), 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 must 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 [1] to [5]). Approaches to tackling the uncertainty aspect of RM production are described in generic terms in ISO Guide 34 [4] and in more technical-statistical detail in ISO Guide 35 [5]. This informative 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 [5] provides a basic, GUM [7]-compliant model for certification of batches of certified reference materials (CRMs). In Charpy terms, the model can be expressed as follows:

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

where

KV_{char} is the KV value obtained from the characterization of the batch (comparing results from different instruments);

δKV_{hom} is an error term due to variation between samples (comparing results in repeatability conditions on a single pendulum);

δKV_{lts}, δKV_{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:

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

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 [5].

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

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 [5] 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 have to 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 [5].

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] and [11]). 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 the 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 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 Equation (A.4):

$$u_{\mathrm{hom}} = \frac{s_{\mathrm{RM}}}{\sqrt{n_{\mathrm{V}}}} \tag{A.4}$$

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

