BS ISO 16260:2016

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# Paper and board — Determination of internal bond strength

**National foreword**

This British Standard is the UK implementation of ISO 16260:2016.

The UK participation in its preparation was entrusted to Technical Committee PAI/11, Methods of test for paper, board and pulps.

A list of organizations represented on this committee can be obtained on request to its secretary.

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BS ISO 16260:2016

INTERNATIONAL STANDARD

# ISO 16260

First edition
2015-06-01

# Paper and board — Determination of internal bond strength

*Papier et carton — Détermination de la force de cohésion interne*

Reference number
ISO 16260:2015(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).

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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 WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 6, *Paper, board and pulps*, Subcommittee SC 2, *Test methods and quality specifications for paper and board*.

# Introduction

Paper and board sheets may, during printing, conversion, or specific product applications, be subjected to impulses, impacts, or shock loads of sufficient magnitude to cause structural failure of the sheet. Commonly observed in-plane structural failures include surface picking, blistering, and interior delimitation.

This International Standard describes one method for determining the internal bond strength of a sheet of paper or board. There are other published methods[2],[4] for determining "Z" or thickness direction tensile strength but in this method, the delaminating force is applied at a rate very much higher than in other methods. This method may, therefore, be preferred for predicting sheet performance under printing or converting conditions.

# Paper and board — Determination of internal bond strength

## 1 Scope

This International Standard describes a method to measure the energy required to rapidly delaminate a test piece of paper or board. Rupture of the test piece in the "Z" or thickness direction is initiated by a pendulum having a defined mass, moving at a defined velocity.

The procedure is suitable for both single- and multi-ply papers and boards, including coated sheets and those that are laminated with synthetic polymer films. It is particularly suitable for papers and boards that may be subjected to Z-direction[2],[5] rapid impacts, impulses, or shock loads during printing or conversion.

The test procedure entails the adherence of double-sided adhesive tape to both sides of the test piece under pressure. For this reason, the method may be unsuitable for materials that might be structurally damaged by compression or are porous enough to permit migration of the tape adhesive into or through the test piece.

## 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 186, *Paper and board — Sampling to determine average quality*

ISO 187, *Paper, board, and pulps — Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples*

ASTM D3330/D3330M-04(2010), *Standard Test Method for Peel Adhesion of Pressure-Sensitive Tape*

## 3 Terms and definitions

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

**3.1**
**internal bond strength**
average energy, expressed as Joules per square metre of surface, required to delaminate a test piece under the conditions of the test

**3.2**
**test assembly**
test piece, mounted ready for the test

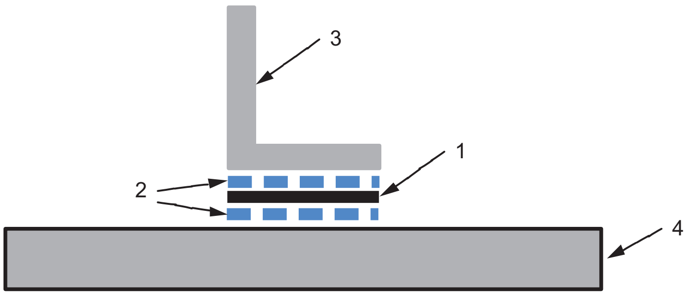
Note 1 to entry: The test assembly consists of the test piece, laminated between two pieces of double-sided adhesive tape, with the bottom side of the lower tape layer adhered to a rigid metal anvil and the upper side of the upper tape layer adhered to an "L"-shaped aluminium platen.

## 4 Principle

A square test piece is adhered to a flat metal anvil by means of double sided adhesive tape. An "L"-shaped aluminium platen with the same surface area as the test piece is then adhered to the upper surface of the test piece, again using double sided adhesive tape. The assembly is shown in Figure 1. The assembly is secured in position and a pendulum allowed to impact the upper inside surface of the platen, causing it to rotate about its outside corner, splitting the test piece in the "Z" or thickness direction (Figure 2)

The energy absorbed in rupturing the test piece is calculated from the measurement of the subsequent over-swing of the pendulum and the known masses and dimensions of the system components.




**Key**

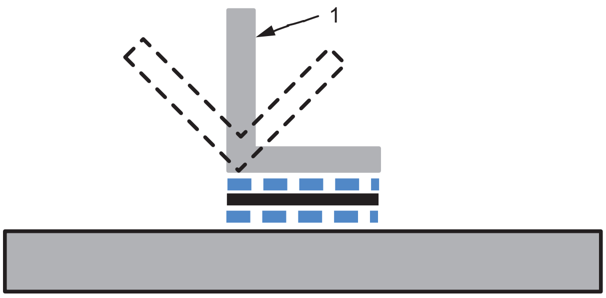
1 test piece

2 double sided adhesive tape

3 aluminium platen

4 metal anvil

**Figure 1 — Components of a test assembly**




**Key**

1 pendulum strike point and direction

**Figure 2 — Pendulum to anvil strike point**

## 5 Apparatus

**5.1** A device for the pressing of the test assembly of dimensions 25,4 mm ± 0,1 mm × 25,4 ± 0,1 mm for testing by pressing the components of the test assembly together at a controlled pressure for a controlled time. Any device employed to apply pressure should be capable of doing so in the range of 345 kPa to 1 034 kPa and for a period of at least 3 s. During the pressure cycle, the aluminium platen (5.5) should be securely clamped in position to prevent flexing.

NOTE Most commercially available preparation stations are capable of simultaneously preparing five test assemblies.

**5.2** Ensure that the test instrument is levelled in the front–back and left–right directions and the pendulum is horizontal when in the latched position.

**5.3** A pendulum, mounted on a pedestal by means of a horizontal spindle supported on low-friction bearings, whose centre of mass lies on the centreline of the pendulum shaft at a point 127 mm ± 0,6 mm from the centreline of the spindle. The pendulum shall be free to rotate from a horizontal position through at least 180 degrees. At its free end, the pendulum carries a metal striker ball which contacts the inside face of the aluminium angle on the test assembly when the pendulum reaches the vertical position. To minimize energy losses due to vibration, the centre of gravity of the pendulum should be at the point of impact of the striker ball with the aluminium angle. There should be no looseness in the construction of pendulums that have augmented weight assemblies.

**5.4** A means for securing the pendulum in a horizontal position with provision for a rapid, vibration-free release.

**5.5** The test assembly is formed from a stationary anvil (base) and a separable aluminium angle (platen) that is a right angle in cross section together with the test piece and adhesive tape. See Figure 1.

Anvils intended for use in multiple test piece preparation stations should be indelibly marked to ensure that they are always placed in the same position in the preparation station. The test assembly is securely held in position so that the pendulum strikes the centre of percussion of the aluminium platen when the axis of rotation is at the outside corner of the right angle of the platen. See Figure 2.

**5.6** A means of registering the peak angular swing of the pendulum after impact with the test assembly.

**5.7** A means to convert the peak angular swing of the pendulum to an internal bond strength value. Commonly employed methods include optical encoder/digital computers and mechanical scale/friction pointer. The minimum range of the instrument shall be 0 Joules/$m^2$ – 525 Joules/$m^2$.

**5.8** An optional means to extend the range of the instrument. This may be achieved by fitting pendulums of different masses, or by adding augmenting weights to the pendulum, or reducing the surface area of the test piece by an amount not exceeding 50 %. The user of this International Standard should consult the manufacturer of the test instrument regarding the installation and verification of such options. Any such modifications to the instrument must be included in the test report.

**5.9** A device suitable for cutting strips of the test material 25,4 mm ± 0,1 mm wide and of sufficient length to mount in the test assembly preparation device.

**5.10** A knife or multi-blade cutting device for separating test assemblies prepared in multi-station test assembly preparation devices.

**5.11** Double-sided adhesive paper tape 25,4 mm ± 0,08 mm wide with a creped release liner. The tape should have a nominal thickness of 0,15 mm and should exhibit a minimum adhesion to steel of 56 N/100 mm when measured in accordance with ASTM D3330/D3330M-04.

NOTE A suitable tape is 3M™ Double Coated Paper Tape 410M[1].

**5.12** A supply of solvent suitable for removing adhesive residue from the anvils and platens.

## 6 Sampling

If tests are being made to evaluate a lot, the sample shall be selected in accordance with ISO 186. If the tests are made on another type of sample, make sure that the specimens taken are representative of the sample received.

## 7 Conditioning

Conditioning shall be carried out in accordance with ISO 187.

1) 3M™ Double Coated Paper Tape 410M is an example of a suitable product available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

## 8 Preparation of test pieces

**8.1** From each test specimen, cut strips 25,4 mm ± 0,1 mm wide of sufficient length to fit the preparation device in use.

NOTE Commercially available preparation stations typically require strips 140 mm – 178 mm long.

Handle the strips by the extreme ends only and discard any that exhibit creases, wrinkles, or other abnormalities.

**8.2** Load the preparation station with adhesive tape, test strip, anvils, and platens in accordance with the manufacturer's instructions, ensuring that the anvils and platens are free from adhesive and fibre residue from previous tests.

**8.3** Operate the preparation station so as to apply a pressure of 690 kPa ± 20 kPa to each test assembly for a period of 3 s.

**8.4** Use a knife or inbuilt cutting device to separate the individual test assemblies. If necessary, trim the edges of the test piece/tape sandwich to remove any overlap.

## 9 Calibration

Calibrate the preparation station and the test instrument at required intervals in accordance with the manufacturer's instructions and/or the procedures given in Annex A.

## 10 Procedure

**10.1** Carry out the tests under the same atmospheric conditions as those used to condition the test pieces.

**10.2** Latch the pendulum in the horizontal position. On instruments with mechanical indication, ensure that the pointer is swung in a direction opposite to that of the swing of the pendulum at the time of impact until it comes to rest against the pendulum latch pin.

**10.3** Take the first test assembly, consisting of an anvil, test piece/tape sandwich, and aluminium platen, and place it in position in the pendulum strike zone. Secure the test assembly firmly in position using the fixtures provided.

**10.4** Operate the pendulum release mechanism and allow the pendulum to strike the aluminium platen, rupturing the test piece. If possible, capture the platen to prevent damage to it by contact with hard objects.

**10.5** Examine both surfaces of any test piece rupture. Discard results of tests that exhibit partial delamination, tape to tape bonding, tape show-through, or tape to metal peel at the leading edge of the rupture.

**10.6** Note the test value, if appropriate, re-latch the pendulum, remove the test assembly, and reset the instrument for the next test.

**10.7** Make at least five valid tests in each principal direction of the test material.

**10.8** If tape to metal peel is observed with samples of high internal bond strength, it may be necessary to increase the clamping pressure (8.3) above 690 kPa or pressing time above 3 s. In either case, care shall be taken to ensure that adhesive does not migrate from the tape into the test piece.

## 11 Expression of results

**11.1** For each direction tested, calculate the mean value of internal bond strength to three significant figures.

**11.2** For each direction tested, calculate the standard deviation or coefficient of variation of results to two significant figures.

NOTE Comparisons of test data from the mechanical Scott Internal Bond Tester with data from later electronic versions pose two problems. First, the upper and lower ranges on earlier instruments that use removable weights to increase the range of the pendulum do not agree. The weight additions shift the pendulum's centre of percussion, thereby, affecting both its range and internal vibrational losses. To correct this problem, later electronic instruments use an extrapolated lower range scale when extending the range of the instrument. While correlations and agreement with low range scale (without additional pendulum weights) data are straightforward, it is not possible to correlate electronic instrument test results with data taken on a mechanical instrument that is in the high range configuration.[5]

## 12 Test report

The test report shall include the following particulars:

a) reference to this International Standard;

b) date and place of testing;

c) all the information necessary for complete identification of the sample;

d) type of instrument used;

e) temperature and relative humidity used for the test;

f) number of test pieces tested in each direction;

g) pressure used in preparing the test pieces, in kPa;

h) time that pressure was applied in s;

i) type of tape used;

j) arithmetic mean results, as calculated in 11.1;

k) standard deviations or coefficients of variation, as calculated in 11.2;

l) any deviations from the procedure described in this International Standard that may have influenced the results.

# Annex A
(normative)

# Maintenance and calibration

## A.1 Test assembly preparation station

**A.1.1** Inspect the aluminium angle pieces. They shall be free from dents, scratches, and adhesive residue. Contact surfaces shall be flat and edges free from burrs. Verify that the dimensions of the tape contact faces are 25,4 mm × 25,4 mm ± 0,1 mm. The physical properties of aluminium vary with different alloys, thus, affecting the coefficient of restitution between the aluminium angle piece and the steel sphere impact point on the pendulum. Use only aluminium angle pieces supplied by the manufacturer of the instrument and designated for use on that instrument.

**A.1.2** Use a load cell, pressure gauge, or other suitable device to verify that any device employed to prepare the test assembly can apply a pressure of 690 kPa ± 20 kPa.

## A.2 Pendulum and associated fixtures

During the test, the kinetic energy of the pendulum is distributed in several ways as follows:

a) energy to rupture the test piece;

b) energy in the pendulum excess swing;

c) frictional losses proportional to the excess swing;

d) vibrational losses due to pendulum construction; and

e) energy to move the aluminium angle.

**A.2.1** Ensure that the pendulum spindle is horizontal and the bearings are maintained according to the manufacturer's instructions.

**A.2.2** Verify that the centre of mass of the pendulum is located at 127 mm ± 0,6 mm from the centre line of the spindle.

**A.2.3** Determine the mass of the pendulum by weighing or reference to the manufacturer's specifications.

**A.2.4** In the case of pendulums fabricated from multiple components, verify that there is no relative movement between components.

**A.2.5** Verify that the pendulum is horizontal when held in the latched position and that the release operates smoothly without imparting any upward displacement to the pendulum on release.

**A.2.6** Verify that, when at rest in the vertical position, the pendulum striker just contacts the face of the aluminium angle.

**A.2.7** Verify that the instrument is equipped with mechanical or electronic means to subtract energy loss through friction, vibration, and moving the aluminium angle from the total energy lost during the test.

**A.2.8** Instruments in current use calculate energy losses from measurements of pendulum angular displacement and constants such as the pendulum mass and centre of mass location. Angular displacement is determined by a mechanical friction pointer or now more commonly by an optical encoder.

Ideally, the instrument should be verified by independent measurement of the pendulum displacement and calculation, comparing the calculated values of internal bond strength with those indicated by the instrument. In practice, the average user may not have the required equipment available.

An alternative calibration system offered by some equipment manufacturers consists of sets of metal weights of various sizes and a mounting fixture designed to replace the normal test assembly. A weight is placed in the fixture and struck by the pendulum. The indicated value of internal bond strength from the instrument is compared with the value assigned to the weight by the manufacturer. Such verification systems, which imply the existence of a master instrument, are usually specific to one maker of instrument.

# Annex B
(informative)

# Precision

## B.1 General

The precision statement was obtained from a round robin test that was conducted over the months of June thru September 2012 using four grades of paperboard and a uniform source of double-sided tape. The results are as follows:

Each laboratory was instructed to run 10 tests on each sample for both machine and cross-machine directions for a total of 20 test results per sample.

Sample A: Manila envelope stock, 108 g/m$^2$, pulp – virgin kraft.

Sample B: Liner board, 205 g/m$^2$, pulp – virgin kraft.

Sample C: Coated cylinder board, 384 g/m$^2$, pulp – recycled old newsprint.

Sample D: Coated folding box board, 303 g/m$^2$, pulp – unbleached sulfate.

## B.2 Results

The data represented in Tables B.1 and B.2.

The calculations were made according to ISO/TR 24498 and TAPPI T 1200.

The repeatability standard deviation reported is the "pooled" repeatability standard deviation that is, the standard deviation is calculated as the root-mean-square of the standard deviations of the participating laboratories. This differs from the conventional definition of repeatability in ISO 5725-1.

The repeatability and reproducibility limits reported are estimates of the maximum difference which should be expected in 19 of 20 instances, when comparing two test results for material similar to those described under similar test conditions. These estimates may not be valid for different materials or different test conditions. Repeatability and reproducibility limits are calculated by multiplying the repeatability and reproducibility standard deviations by 2,77.

NOTE 1 The repeatability standard deviation and the within-laboratory standard deviation are identical. However, the reproducibility standard deviation is NOT the same as the between-laboratories standard deviation. The reproducibility standard deviation includes both the between-laboratories standard deviation and the standard deviation within a laboratory, as follows:

$$s_{\text{repeatability}}^2 = s_{\text{within lab}}^2 \quad \text{but} \quad s_{\text{reproducibility}}^2 = s_{\text{within lab}}^2 + s_{\text{between lab}}^2$$

NOTE 2 $2,77 = 1,96\sqrt{2}$, provided that the test results have a normal distribution and that the standard deviation, $s$, is based on a large number of tests.

**Table B.1 — Estimation of the repeatability**

| Sample | Number of laboratories | Mean internal bond strength<br>J/m² | Repeatability standard deviation<br>$s_r$<br>J/m² | Coefficient of variation<br>$C_{V,r}$<br>% | Repeatability limit<br>$r$<br>J/m² |
|---|---|---|---|---|---|
| A | 7 | 539 | 65,5 | 12,2 | 182,0 |
| B | 10 | 389 | 33,3 | 8,6 | 92,3 |
| C | 10 | 160 | 17,2 | 10,8 | 47,7 |
| D | 10 | 157 | 10,4 | 6,6 | 28,8 |

**Table B.2 — Estimation of the reproducibility**

| Sample | Number of laboratories | Mean internal bond strength<br>J/m² | Reproducibility standard deviation<br>$s_R$<br>J/m² | Coefficient of variation<br>$C_{V,r}$<br>% | Reproducibility limit<br>$R$<br>J/m² |
|---|---|---|---|---|---|
| A | 7 | 539 | 85,0 | 15,8 | 235,6 |
| B | 10 | 389 | 41,2 | 10,6 | 114,2 |
| C | 10 | 160 | 21,1 | 13,2 | 58,5 |
| D | 10 | 157 | 17,9 | 11,4 | 49,6 |

# Annex C
(informative)

# Instrument/Pendulum ranges and measurement of impact energies

## C.1 General

See Table C.1.

**Table C.1 — Instrument/Pendulum ranges: Table of technical data**

| | Range 0 | Range 1<br>SB low | Range 2<br>SB high | Range 3 |
|---|---|---|---|---|
| Measuring range (J/m$^2$) (recommendation, otherwise manufacturers' instructions) | 50 to 400 | 100 to 600 | 200 to 1 200 | 300 to 2 400 |
| Corresponds to Scott-Bond (SB) -scale. | | Low-range<br>0 to 525 | High-range<br>210 to 1 050 | |
| Pendulum length, h, in millimetres (mm), to ±0,2 mm | 228,6 | 228,6 | 228,6 | 228,6 |
| Reduced pendulum length[a], length millimetres (mm) | 130 to 140 | 145 to 170 | 170 to 190 | 180 to 200 |
| Mass at 90° deflection of pendulum ±4 g | 133 | 190 | 380 | 760 |
| Range of tolerance potential energy[a] Potential Energy [Nm] calculated from m(90°)*g*h | 0,29 to 0,31 | 0,41 to 0,44 | 0,84 to 0,88 | 1,60 to 1,72 |

[a] The decisive factor is the potential energy that is stored in the pendulum at the start of the test. Once the pendulum is released, the potential energy is converted into kinetic energy as the pendulum impacts the aluminium angle. The determination of the reduced pendulum length serves the user for a fast check-up of the device's condition. A more accurate examination is possible by applying the method described at the end of this annex.

## C.2 Angle/Anvil/Tape considerations

Angle — Alloy: AlMgSiO, 5 F22 for new devices/Standard: EN AW 6060 T66

For "old" devices, only original angle shall be used.

Compensation: The scales of the Scott-Bond devices contain a compensation that takes account of the original angle's alloy. This could lead to deviating measuring values. This correction factor shall not apply for digital devices of this International Standard.

Surface: Surface roughness: Rz ≤ 3,8 µm

Weight of the set of angles: 5 g × (11,3 ± 0,2) g

Wear and tear: Replacement after 10 000 measurements or when there are significant traces of deformation and pendulum markings.

Contact pressure: (400 kPa to 500 kPa) ≙ (4,0 bar to 5,0 bar)

Pressing time: 10 s to 20 s

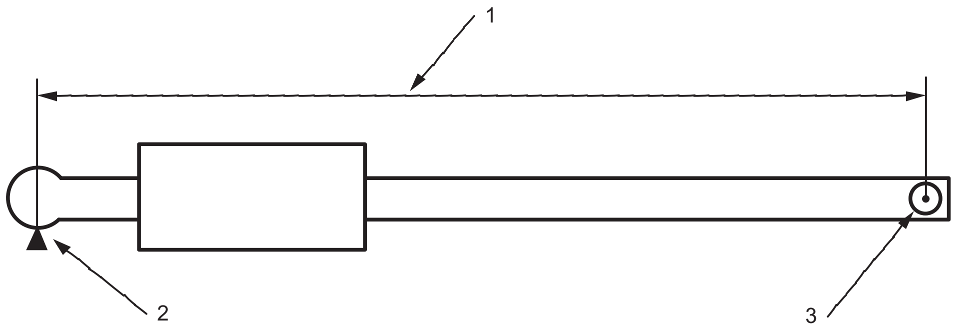
 

## C.3 Pendulum

Pendulum point of impact onto the angle: Placed centred on the anvil and 21 mm ± 0,2 mm from the angle's lower edge without a sample and without adhesive tape.

Quality of the pendulum bearing: Energy loss at empty oscillation < 1 %.

Pendulum length: To measure as indicated in Figure C.1, 228,6 mm ± 0,2 mm (≙9 in).




**Key**

1 distance between contact point and centre of pendulum rotation, 228,6 mm ± 0,2 mm (≙9 in)

2 contact point for m(90°) total mass at 90° deflection

3 centre of rotation

**Figure C.1 — Reduced pendulum length, *Lred***

This calculation determines the position of the centre mass on the centreline of the pendulum shaft. It must be determined by measuring the average period, $t_S$, of one oscillation. The measurement is determined by deflecting the pendulum ≤3° and measuring the time for at least 10 oscillations to get a reliable average. Calculation of *Lred*:

$$Lred = \left(\frac{t_S}{2\pi}\right)^2 * g \quad \text{(C.1)}$$

where

$t_S$ is the average period of one oscillation (s);

$g$ is the gravity of earth (m/s$^2$).

Adhesive tape — FINAT FTM1 = 15 N/(25,4 mm ± 0,2 mm), Tesa tesafix4961, Permacell P-50, and 3MTM type 410M. Customer and supplier should agree on one adhesive tape.

Sample size — 25,4 mm ± 0,2 mm edge length.

## C.4 Verification of device compliance with a standard

An impact device for checking the standard is shown in the form of a drawing in Figure C.2 and in the form of a photograph in Figure C.3. Pre-defined cylindrical mass pieces are positioned in the device such that, at the centre of percussion, the tip of the pendulum bob strikes the centre of the circle at 0° deflection. This absorbs the pendulum energy which the impact then transfers to the test piece.

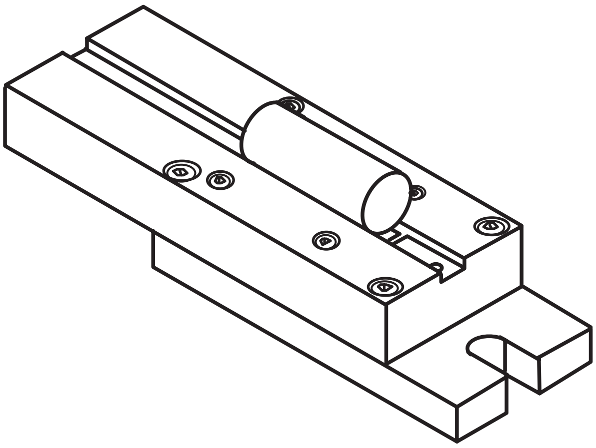


**Figure C.2 — Impact device with a cylindrical mass piece in 3D**

**Figure C.3 — Mounted impact device with a cylindrical mass piece and pendulum bob**

For devices from different manufacturers, there is an adapter that ensures that the cylindrical mass pieces will be reliably struck in the centre by the pendulum bob at 0° deflection. The test pieces are available in gradations of 10 g, the weight being determined by the length of the cylinder.

Similar pendulum designs must supply the same values when the same mass pieces are struck. This circumstance gives rise to the values in Table C.2 which, for physical reasons, differ for measuring range 1 and measuring range 2.

Identical results of measurement will never be obtained when the same material is tested in two measuring ranges.

**Table C.2 — Table of values for measuring rates 1 and 2**

| Test piece weight<br>g | Measuring range 1<br>J/m² | Measuring range 2<br>J/m² |
|---|---|---|
| 20 | 130 | |
| 30 | 205 | 230 |
| 40 | 260 | 320 |
| 50 | 310 | 400 |
| 60 | 360 | 460 |
| 70 | 400 | 510 |
| 80 | 440 | 580 |
| 90 | 465 | 630 |
| 100 | 500 | 680 |
| 110 | | 710 |
| 120 | | 740 |
| 130 | | 770 |
| 140 | | 800 |
| 150 | | 815 |
| 160 | | 830 |
| 180 | | 870 |
| 200 | | 910 |
| 220 | | 950 |
| 230 | | 970 |

To check a measuring instrument to determine whether it complies with this International Standard, measurements are conducted in the measuring range using the impact device and the test pieces cited in the respective table, the measured values being noted.

Five measurements are to be performed using each test piece and the results averaged. Obvious faulty measurements conducted with mechanical devices equipped with a scale must be discarded and replaced by a repetition of the test with a new value.

A device complies with the present standard if, and only if, the average values from five single measurements coincide with the values in Table C.2 while observing a tolerance.

Deviations of ±3 % of the value in Table C.2 are permissible for devices built in 2011 or later. Deviations of ±10 % of the value in Table C.2 are permissible for older models.

The tendency of any deviations from the values in Table C.2 is the same for all test pieces. This means that the results obtained with one device and in one measuring range will always tend to be higher or lower than the corresponding values in Table C.2.

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