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Plastics — Determination of puncture impact behaviour of rigid plastics —

Part 2: Instrumented impact testing

*Plastiques — Détermination du comportement des plastiques rigides
perforés sous l'effet d'un choc —*

Partie 2: Essais de choc instrumentés

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CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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 of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical behavior*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 249, *Plastics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 6603-2:2000), which has been technically revised.

The main changes are as follows:

- references to ISO 6603-1 have been replaced by the corresponding text;
- normative references and bibliography have been updated and completed;
- requirements for force measurement accuracy have been revised;
- definitions for conditioning and test climate have been updated;
- testing in a clamped situation have been defined as the preferred method;
- precision data has been added to [annex F](#).

A list of all parts in the ISO 6603 series can be found on the ISO website.

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

Plastics — Determination of puncture impact behaviour of rigid plastics —

Part 2: Instrumented impact testing

1 Scope

This document specifies a test method for the determination of puncture impact properties of rigid plastics, in the form of flat specimens, using instruments for measuring force and deflection. It is applicable if a force-deflection or force-time diagram, recorded at nominal constant striker velocity, is necessary for detailed characterization of the impact behaviour.

The test method is applicable to specimens with a thickness between 1 mm to 4 mm.

The method is suitable for use with the following types of material:

- rigid thermoplastic moulding and extrusion materials, including filled, unfilled and reinforced compounds and sheets;
- rigid thermosetting moulding and extrusion materials, including filled and reinforced compounds, sheets and laminates;
- fibre-reinforced thermoset and thermoplastic composites incorporating unidirectional or multi-directional reinforcements such as mats, woven fabrics, woven rovings, chopped strands, combination and hybrid reinforcements, rovings, milled fibres and sheets made from pre-impregnated materials (prepregs).

The method is also applicable to specimens which are either moulded or machined from finished products, laminates and extruded or cast sheet.

The test results are comparable only if the conditions of preparation of the specimens, their dimensions and surfaces as well as the test conditions are the same. In particular, results determined on specimens of different thickness cannot be compared with one another (see [Annex E](#)). Comprehensive evaluation of the reaction to impact stress can be obtained by determinations made as a function of impact velocity and temperature for different material variables, such as crystallinity and moisture content.

The impact behaviour of finished products cannot be predicted directly from this test, but specimens may be taken from finished products (see above) for tests by this method.

Test data developed by this method is not intended to be used for design calculations. However, information on the typical behaviour of the material can be obtained by testing at different temperatures and impact velocities (see [Annex D](#)) by varying the thickness (see [Annex E](#)) and by testing specimens prepared under different conditions.

It is not the purpose of this document to give an interpretation of the mechanism occurring on every particular point of the force-deflection diagram. These interpretations are a task for scientific research.

2 Normative references

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

ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 293, *Plastics — Compression moulding of test specimens of thermoplastic materials*

ISO 294-3, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 3: Small plates*

ISO 295, *Plastics — Compression moulding of test specimens of thermosetting materials*

ISO 1268-1, *Fibre-reinforced plastics — Methods of producing test plates — Part 1: General conditions*

ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*

ISO 2818, *Plastics — Preparation of test specimens by machining*

ISO 16012, *Plastics — Determination of linear dimensions of test specimens*

ISO 20753, *Plastics — Test specimens*

3 Terms and definitions

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

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

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

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

3.1 impact velocity

v_0
velocity of the striker relative to the support at the moment of impact

Note 1 to entry: Impact velocity is expressed in metres per second (m/s).

3.2 force

F
force exerted by the striker on the test specimen in the direction of impact

Note 1 to entry: Force is expressed in newtons (N).

3.3 deflection

l
relative displacement between the striker and the specimen support, starting from the first contact between the striker and the test specimen

Note 1 to entry: Deflection is expressed in millimetres (mm).

3.4 energy

E
energy expended in deforming and penetrating the test specimen up to a deflection l

Note 1 to entry: Energy is expressed in joules (J).

Note 2 to entry: Energy is measured as the integral of the force-deflection curve starting from the point of impact up to a deflection l .

3.5 maximum force

 F_M

maximum force which occurs during the test

Note 1 to entry: See [Figures 1](#) to [4](#).

Note 2 to entry: Maximum force is expressed in newtons (N).

3.6 deflection at maximum force

 l_M

deflection that occurs at maximum force F_M

Note 1 to entry: See [Figures 1](#) to [4](#).

Note 2 to entry: Deflection at maximum force is expressed in millimetres (mm).

3.7 energy to maximum force

 E_M

energy expended up to the deflection l_M at maximum force

Note 1 to entry: See [Figures 1](#) to [4](#).

Note 2 to entry: Energy to maximum force is expressed in joules (J).

3.8 puncture deflection

 l_p

deflection at which the force has dropped to half the maximum force F_M

Note 1 to entry: See [Figures 1](#) to [4](#) and Note 3 to entry of [3.9](#).

Note 2 to entry: Puncture deflection is expressed in millimetres (mm).

3.9 puncture energy

 E_p

energy expended up to the puncture deflection l_p

Note 1 to entry: See [Figures 1](#) to [4](#).

Note 2 to entry: Puncture energy is expressed in joules (J).

Note 3 to entry: When testing tough materials, a transducer mounted at some distance from the impacting tip may record frictional force acting between the cylindrical part of the striker and the punctured material. The corresponding frictional force acting shall not be included in the puncture energy, which, therefore, is restricted to that deflection, at which the force drops to half the maximum force F_M .

3.10 impact failure

mechanical behaviour of the material under test which may be either one of the following types:

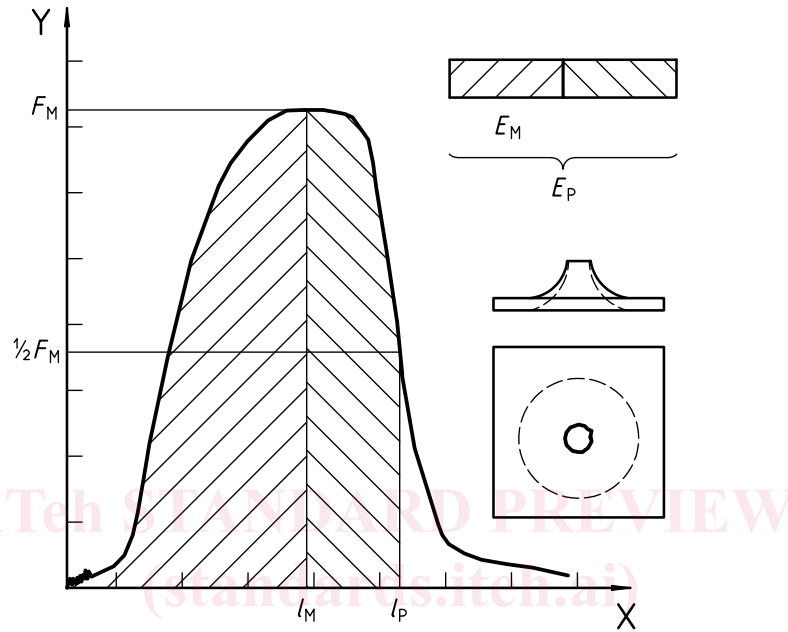
- a) YD yielding followed by deep drawing, see [Figure 1](#)
- b) YS yielding followed by an at least partially stable cracking, see [Figure 2](#)
- c) YU yielding followed by unstable cracking, see [Figure 3](#)
- d) NY no yielding, see [Figure 4](#)

Note 1 to entry: The classification of the type of failure shall take into account the shape of the curve as well as the assessment of the broken specimen.

Note 2 to entry: Yielding is characterised by a zero slope at maximum force in the force deflection diagram, or by whitening of the material in the area of puncture, or by a significant reduction of the material thickness in the area where the break appears.

Note 3 to entry: Comparison of Figures 2 and 3 shows puncture deflection l_p and puncture energy E_p are identical for the failure types YS and YU. As shown in Figure 4, identical values at maximum and at puncture are found for the deflection as well as the energy in the case of failure type NY. For complex behaviour see Annex A.

Note 4 to entry: For more guidance on the classification of failure types, see the informative Annex F.



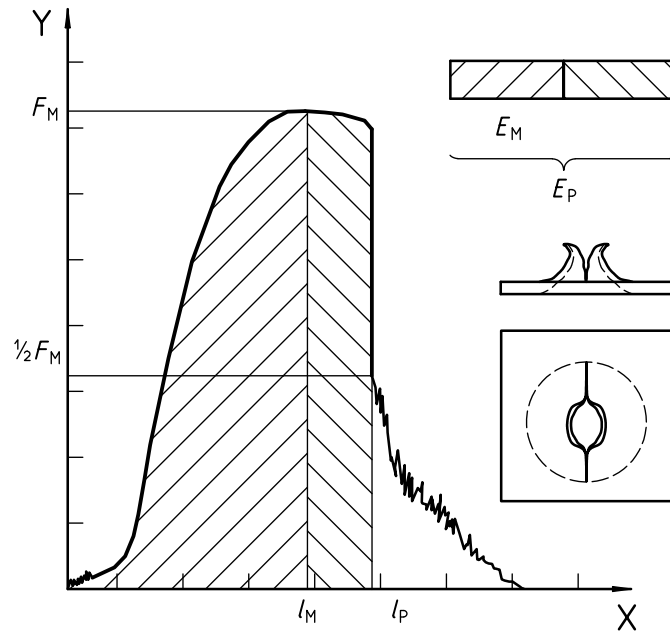
Key

- X deflection
- Y force

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Figure 1 — Example of force-deflection diagram for failure by yielding (zero slope at maximum force) followed by deep drawing, and typical appearance of specimens after testing (with lubrication)

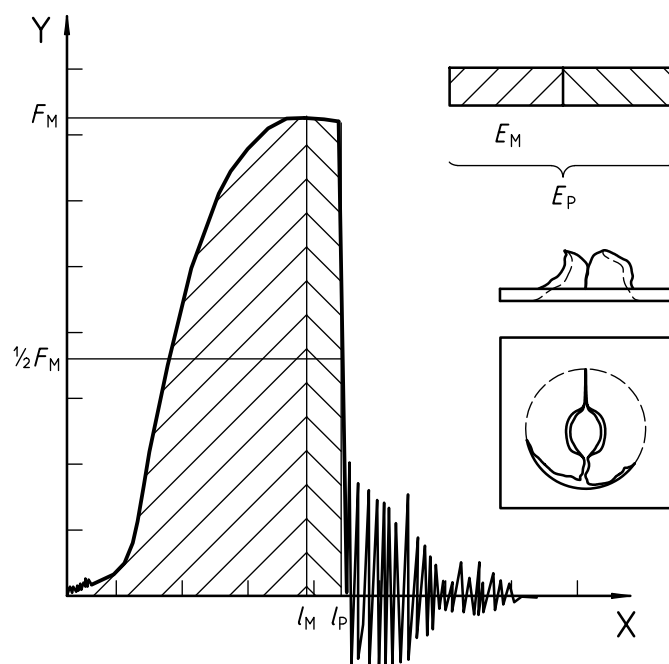
**Key**

- X deflection
- Y force

Figure 2 — Example of force-deflection diagram for failure by yielding (zero slope at maximum force) followed by stable crack growth, and typical appearance of specimens after testing (with lubrication)

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Key

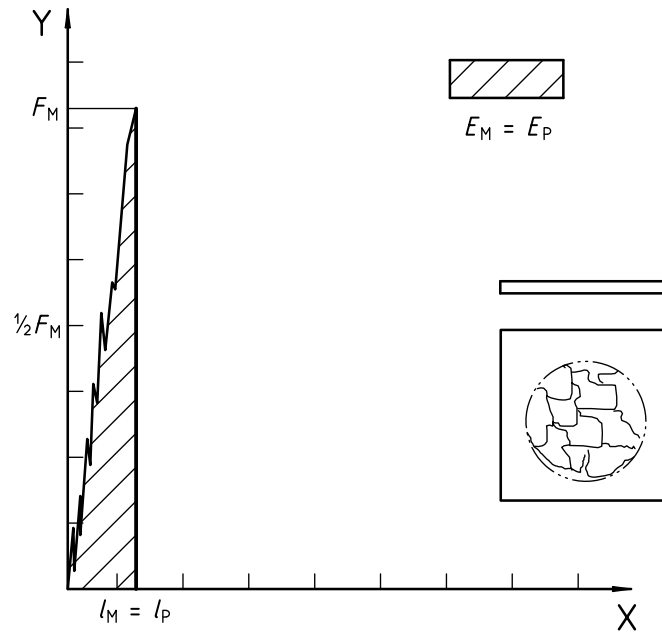
X deflection

Y force

NOTE Natural vibration of the force measurement system appears after unstable cracking (striker and load cell).

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Figure 3 — Example of force-deflection diagram for failure by yielding (zero slope at maximum force) followed by unstable crack growth, and typical appearance of specimens after testing (with lubrication)

**Key**

X deflection

Figure 4 — Example of force-deflection diagram for failure without yielding followed by unstable crack growth, and typical appearance of specimens after testing (with lubrication)

4 Principle

The test specimen is punctured at its centre using a lubricated striker, perpendicularly to the test-specimen surface and at a nominally uniform velocity. The resulting force-deflection or force-time diagram is recorded electronically. The test specimen should be clamped in position (preferred) during the test.

The force-deflection diagram obtained in these tests records the impact behaviour of the specimen from which several features of the behaviour of the material can be inferred.

5 Apparatus

5.1 Testing instrument, consisting of the following essential components:

- energy carrier, which can be falling mass type or hydraulic type (see [5.1.1](#));
- striker, which shall be lubricated;
- specimen support with a recommended clamping device.

The test device shall permit the test specimen to be punctured at its centre, perpendicular to its surface at a nominally constant velocity. The force exerted on the test specimen in the direction of impact and the deflection from the centre of the test specimen in the direction of impact shall be derivable or measurable (see [Figure 5](#)).

The term “falling mass type energy carrier” covers all types of instruments working by the principle of an inertial mass, independent from the direction of movement.

5.1.1 Energy carrier, with a preferred impact velocity v_0 of $(4,4 \pm 0,2)$ m/s (see [3.1](#) and note to [3.1](#)). To avoid results, which cannot be compared due to the viscoelastic behaviour of the material under impact, the decrease of velocity during the test shall not be greater than 20 %.

NOTE For brittle materials, an impact velocity of 1 m/s can be more appropriate because it reduces the level of vibration and noise and improves the quality of the force-deflection diagram (see [annex A](#)).

5.1.1.1 Hydraulic type, consisting of a high-speed testing machine with suitable attachments.

Any deviation of the velocity of the striker relative to the support during impact shall be controlled, for example by recording deflection-time curves and checking the slope.

5.1.1.2 Inertial-mass type, which may be accelerated. Suitable devices are falling-dart machines.

In the case of a gravitationally accelerated mass and neglecting frictional losses; the impact velocity v_0 corresponds to a drop height H_0 of the energy carrier of $(1,0 \pm 0,1)$ m.

For all inertial-mass-type energy carriers the impact velocity shall be measured by velocity-measuring sensors placed close to the point of impact. The maximum decrease of velocity during test results in the minimum mass, m_c , of the carrier according to [Formulae \(1\)](#) and [\(2\)](#) (see NOTE).

$$m_c \geq 6E^* / v_0^2 \tag{1}$$

$$m_c \geq 0,31E^* \text{ for } v_0 = 4,4 \text{ m/s} \tag{2}$$

where

m_c is the mass of the energy carrier, expressed in kilograms;

E^* is the highest puncture energy to be measured, expressed in joules (see [3.9](#));

v_0 is the impact velocity (4,4 m/s, see [3.1](#)).

NOTE In many cases, a weighted energy carrier with a total mass m_c of 20 kg has been found to be sufficient for the larger striker and of 5 kg for the smaller striker (see [5.1.2](#)).

5.1.2 Striker, preferably having a polished hemispherical striking surface of diameter $(20,0 \pm 0,2)$ mm. Alternatively, a $(10,0 \pm 0,1)$ mm diameter striking surface should be used.

NOTE 1 The size and dimensions of the striker and condition of the surface will affect the impact results.

The striker shall be made of any material with sufficient resistance to wear and of sufficiently high strength to prevent plastic deformation. In practice, hardened steel or materials with lower density (i.e. titanium) have been found acceptable.

The hemispherical surface of the striker shall be lubricated to reduce any friction between the striker and the test specimen (see NOTE 2 and [Annex B](#)).

NOTE 2 Test results obtained with a lubricated or dry striker are likely to be different. Below ambient temperatures, condensation can act as a lubricant.

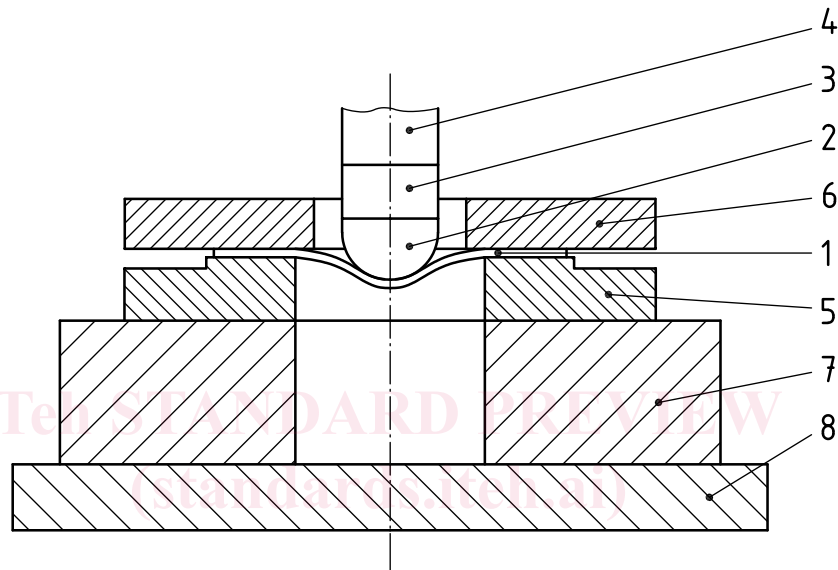
The load cell shall be located within one striker diameter from the tip of the striker, i.e. mounted as closely as possible to the tip to minimize all extraneous forces and sufficiently near to fulfil the frequency-response requirement (see [5.2](#)). An example is shown in [Figure 5](#).

5.1.3 Support ring (see [Figures 5](#) and [6](#)), placed on a rigid base and designed such that air cannot be trapped under the test specimen, thus avoiding a possible spring effect. Below the support ring, there shall be sufficient space for the striker to travel after total penetration of the test specimen. The

recommended inside diameter of the support ring is (40 ± 2) mm, or alternatively (100 ± 5) mm, with a minimum height of 12 mm.

5.1.4 Base for test device, firmly mounted to a rigid structure so that the mass of the base (see [Figure 5](#)) is of sufficient stiffness to minimize deflection of the specimen support.

When calculating the deflection from the kinetics of the accelerated mass, a minimum mass ratio m_B/m_C of 10 between base (m_B) and energy carrier (m_C) shall be used. This prevents the base from being accelerated by more than 1 % of the impact speed up to the end of the test. For directly measured deflections, this minimum ratio is a recommendation only. For the principles of this specification, see ISO 179-2:2020, Annex B^[5].



Key

- | | |
|------------------------------------|-----------------------------------|
| 1 test specimen | 5 test specimen support |
| 2 hemispherical striker tip | 6 clamping ring (optional) |
| 3 load cell (recommended position) | 7 base |
| 4 shaft | 8 acoustical isolation (optional) |

Figure 5 — Example of test device