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## Plastics — Ultra-high-molecular-weight polyethylene (PE-UHMW) moulding and extrusion materials —

### Part 2: Preparation of test specimens and determination of properties

*Plastiques — Matériaux à base de polyéthylène à très haute masse moléculaire (PE-UHMW) pour moulage et extrusion —*

*Partie 2: Préparation des éprouvettes et détermination des propriétés*

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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](http://www.iso.org/directives)).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 9, *Thermoplastic materials*, 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 first edition of ISO 21304-2 cancels and replaces ISO 11542-2:1998, which has been technically revised. It also incorporates the Technical Corrigendum ISO 11542-2:1998/Cor 1:2007.

The main changes compared to the previous edition are as follows:

- updated the normative references to the latest version;
- added terms and definitions (see [Clause 3](#));
- revised the contents and structures of [Table 2](#) and [Table 3](#) according to the revised ISO 10350-1;
- added new [Annex A](#);
- revised the masses of weights used to load specimen in [Table B.1](#) (former Table A.1);
- revised [Figure B.1](#), [Figure B.2](#), [Figure B.3](#) and [Figure C.1](#) (former Figures A.1, A.2, A.3 and B.1).

A list of all parts in the ISO 21304 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](http://www.iso.org/members.html).

# Plastics — Ultra-high-molecular-weight polyethylene (PE-UHMW) moulding and extrusion materials —

## Part 2:

# Preparation of test specimens and determination of properties

## 1 Scope

This document specifies the methods of preparation of test specimens and the test methods to be used in determining the properties of PE-UHMW moulding and extrusion materials. It gives the requirements for handling test material and for conditioning both the test material before moulding and the specimens before testing.

This document gives the procedures and conditions for the preparation of test specimens and procedures for measuring properties of the materials from which these specimens are made. Properties and test methods which are suitable and necessary to characterize PE-UHMW moulding and extrusion materials are listed.

The properties have been selected from the general test methods in ISO 10350-1. Other test methods in wide use for or of particular significance to these moulding and extrusion materials are also included in this document, as are the designatory properties specified in ISO 21304-1. This document specifies the materials with MFR less than 0,1 g/10 min at 190 °C / 21,6 kg based on ISO 17855-1.

The methods of preparation and conditioning, the specimen dimensions and the test procedures specified in this document are used in order to obtain reproducible and comparable test results. Values determined will not necessarily be identical to those obtained using specimens of different dimensions or prepared using different procedures.

## 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 62, *Plastics — Determination of water absorption*

ISO 75-1, *Plastics — Determination of temperature of deflection under load — Part 1: General test method*

ISO 75-2, *Plastics — Determination of temperature of deflection under load — Part 2: Plastics and ebonite*

ISO 178, *Plastics — Determination of flexural properties*

ISO 179-1, *Plastics — Determination of Charpy impact properties — Part 1: Non-instrumented impact test*

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

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

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

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ISO 527-4, *Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastics composites*

ISO 899-1, *Plastics — Determination of creep behaviour — Part 1: Tensile creep*

ISO 1133-1, *Plastics — Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics — Part 1: Standard method*

ISO 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pycnometer method and titration method*

ISO 1183-2, *Plastics — Methods for determining the density of non-cellular plastics — Part 2: Density gradient column method*

ISO 1628-3, *Plastics — Determination of the viscosity of polymers in dilute solution using capillary viscometers — Part 3: Polyethylenes and polypropylenes*

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

ISO 4589-2, *Plastics — Determination of burning behaviour by oxygen index — Part 2: Ambient-temperature test*

ISO 8256, *Plastics — Determination of tensile-impact strength*

ISO 10350-1, *Plastics — Acquisition and presentation of comparable single-point data — Part 1: Moulding materials*

ISO 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and step height*

ISO 11357-3, *Plastics — Differential scanning calorimetry (DSC) — Part 3: Determination of temperature and enthalpy of melting and crystallization*

ISO 11359-2, *Plastics — Thermomechanical analysis (TMA) — Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*

ISO 15527, *Plastics — Compression-moulded sheets of polyethylene (PE-UHMW, PE-HD) — Requirements and test methods*

ISO 20753, *Plastics — Test specimens*

ISO 21304-1, *Plastics — Ultra-high-molecular-weight polyethylene (PE-UHMW) moulding and extrusion materials — Part 1: Designation system and basis for specifications*

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60243-1, *Electrical strength of insulating materials — Test methods — Part 1: Tests at power frequencies*

IEC 60296, *Fluids for electrotechnical applications — Unused mineral insulating oils for transformers and switchgear*

ISO/IEC 60695-11-10, *Fire hazard testing — Part 11-10: Test flames — 50 W horizontal and vertical flame test methods*

IEC 62631-2-1, *Dielectric and resistive properties of solid insulating materials-Part 2-1:Relative permittivity and dissipation factor-Technical frequencies (0,1 Hz to 10 MHz)-AC Methods*

IEC 62631-3-1, *Dielectric and resistive properties of solid insulating materials — Part 3-1: Determination of resistive properties (DC methods) — Volume resistance and volume resistivity — General method*

IEC 62631-3-2, *Dielectric and resistive properties of solid insulating materials — Part 3-2: Determination of resistive properties (DC methods) — Surface resistance and surface resistivity*

### 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 <http://www.electropedia.org/>

#### 3.1

##### elongational stress

$F_{(150/10)}$

tensile stress (force divided by initial cross-sectional area) required to increase the measured length of a test specimen by 600 % at 150 °C over a 10 min period

#### 3.2

##### Charpy double-notched impact strength

impact energy absorbed in breaking a double-notched specimen, referred to the original cross-sectional area of the specimen, at double notches (see [Figure C.1](#))

Note 1 to entry: It is expressed in kilojoules per square metre.

### 4 Preparation of test specimens

#### 4.1 Treatment of the material before moulding

Before processing, no pretreatment of the material sample is normally necessary.

#### 4.2 Compression moulding

Compression-moulded sheets shall be prepared in accordance with ISO 293 using the conditions specified in [Table 1](#). The test specimens for the determination of the properties shall be machined from the compression-moulded sheets in accordance with ISO 2818 or stamped.

**Table 1 — Compression-moulding conditions**

Material	Moulding temperature °C	Preheating pressure MPa	Preheating time min	Full pressure MPa	Full-pressure time min	Average cooling rate °C/min	Demoulding temperature °C
All grades	210	5	5 to 15	10	30 ± 1	15	≤ 40

A flash mould (see ISO 293) may be used, but it is necessary to start cooling while simultaneously applying the full pressure. This avoids the melt being pressed out of the frame and also avoids sink marks.

For thicker sheet (≥4 mm), a positive mould (see ISO 293) shall be used. The preheating time depends on the type of mould and the type of energy input (steam, electricity).

For frame moulds, 5 min is usually sufficient but for positive moulds, due to the bigger mass, a preheating time of 5 min to 15 min can be necessary, especially if electric heating is used.



## 5 Conditioning of test specimens

Unfilled PE-UHMW test specimens shall be conditioned in accordance with ISO 291 for at least 40 h at 23 °C ± 2 °C, with no relative humidity requirement. Test specimens containing fillers and / or additives that are susceptible to moisture uptake shall be conditioned for at least 40 h at 23 °C ± 2 °C and 50 % ± 10 % relative humidity.

## 6 Determination of properties

In the determination of properties and the presentation of data, the standards, supplementary instructions and notes given in ISO 10350-1 shall be applied. Unless specifically stated in [Table 2](#) and [Table 3](#), testing of unfilled PE-UHMW test specimens shall be carried out at a standard temperature of 23 °C ± 2 °C with no relative humidity requirement. Specimens made from materials containing fillers and / or additives that are susceptible to moisture uptake shall be tested in a standard atmosphere of 23 °C ± 2 °C and 50 % ± 10 % relative humidity.

[Table 2](#) is compiled from ISO 10350-1, and the properties listed are those which are appropriate to PE-UHMW moulding and extrusion materials. These properties are those considered useful for comparisons of data generated for different thermoplastics.

[Table 3](#) contains those properties, not found specifically in [Table 2](#), which are in wide use or of particular significance in the practical characterization of PE-UHMW moulding and extrusion materials.

**Table 2 — General properties and test conditions (selected from ISO 10350-1)**

Property		Symbol	Standard	Specimen type (dimensions in mm)	Specimen Preparation <sup>a</sup>	Unit	Test conditions and supplementary instructions
<b>1 Mechanical properties</b>							
1.1	Tensile modulus	$E_t$	ISO 527-1 ISO 527-2 ISO 527-4	ISO 20753 Type A2	Q	MPa	Test speed 1 mm/min
1.2	Yield stress	$\sigma_y$					Failure with yielding
1.3	Yield strain	$\epsilon_y$				%	Test speed 50 mm/min
1.4	Nominal strain at break	$\epsilon_{tb}$					
1.5	Stress at 50 % strain	$\sigma_{50}$				MPa	Failure without yielding
1.6	Stress at break	$\sigma_b$					$\epsilon_b \leq 10$ %: test speed 5 mm/min
1.7	Strain at break	$\epsilon_b$				%	$\epsilon_b > 10$ %: test speed 50 mm/min
1.8	Tensile creep modulus	$\frac{E_{tc}1}{E_{tc}10^3}$	ISO 899-1	MPa	At 1 h		Strain ≤ 0,5 %
1.9					At 1 000 h		
1.10	Flexural modulus	$E_f$	ISO 178	80 × 10 × 4	MPa	Test speed 2 mm/min	
1.11	Tensile-impact strength	$\alpha_{tN}$	ISO 8256	80 × 10 × 4 Machined double V-notch, r = 1		kJ/m <sup>2</sup>	
<sup>a</sup> Q = Compression moulding.							
<sup>b</sup> Electrical properties are generally affected by the relative humidity. Therefore, they shall be measured in a standard atmosphere of 23 °C ± 2 °C and 50 % ± 10 % relative humidity.							



Table 2 (continued)

Property		Symbol	Standard	Specimen type (dimensions in mm)	Specimen Preparation <sup>a</sup>	Unit	Test conditions and supplementary instructions	
<b>2 Thermal properties</b>								
2.1	Melting temperature	$T_m$	ISO 11357-3	Powder	-	°C	Record peak melting temperature. Use 10 K/min heating/cooling rate.	
2.2	Glass transition temperature	$T_g$	ISO 11357-2				Record the method used for determination of $T_g$ . Use 10 K/min heating rate.	
2.3	Temperature of deflection under load	$T_f$ 1,8	ISO 75-1	80 × 10 × 4	Q	°C	1,8 MPa	Use flatwise loading
2.4		$T_f$ 0,45	ISO 75-2				0,45 MPa	
2.5	Coefficient of linear thermal expansion	$\alpha_p$	ISO 11359-2	Prepared from ISO 20753 type A2	Q	°C <sup>-1</sup>	Parallel	Record the secant value over the temperature range 23 °C to 55 °C.
2.6		$\alpha_n$					Transverse	
2.7	Flammability-Burning behaviour	B50/3	ISO/IEC 60695-11-10	125 × 13 × 3	Q		Record one of the classifications V-0, V-1, V-2, HB, HB40 or HB75.	
2.8		B50/h		Additional thickness, $h$				
2.9	Ignitability-Oxygen index	OI	ISO 4589-2	80 × 10 × 4	Q	%	Use procedure A (top surface ignition).	
<sup>a</sup> Q = Compression moulding. <sup>b</sup> Electrical properties are generally affected by the relative humidity. Therefore, they shall be measured in a standard atmosphere of 23 °C ± 2 °C and 50 % ± 10 % relative humidity.								

Table 2 (continued)

Property		Symbol	Standard	Specimen type (dimensions in mm)	Specimen Preparation <sup>a</sup>	Unit	Test conditions and supplementary instructions		
<b>3 Electrical properties<sup>b</sup></b>									
3.1	Relative permittivity	$\epsilon_r$ 100	IEC 62631-2-1	$\geq 60 \times \geq 60 \times 2$	Q	-	100 Hz		
3.2		$\epsilon_r$ 1M					1 MHz		
3.3	Dissipation factor	$\tan \delta$ 100					100 Hz		
3.4		$\tan \delta$ 1M					1 MHz		
3.5	Volume resistivity	$\rho_e$	IEC 62631-3-1	$\geq 60 \times \geq 60 \times 2$	Q	$\Omega \cdot m$	Measure value at 1 min.		
3.6	Surface resistivity	$\sigma_e$	IEC 62631-3-2				$\Omega$	Voltage 500V	Use contacting line electrodes 1 mm to 2 mm wide, 50 mm long and 5 mm apart.
3.7	Electric strength	$E_B$ 1	IEC 60243-1				$\geq 60 \times \geq 60 \times 1$	$kV/mm$	Use 20 mm diameter spherical electrodes.
3.8		$E_B$ 2		$\geq 60 \times \geq 60 \times 2$	Immerse in transformer oil in accordance with IEC 60296. Use a voltage application rate of 2 kV/s.				
3.9	Comparative tracking index	CTI	IEC 60112	$\geq 20 \times \geq 20 \times 4$	-	Use solution A.			
<b>4 Other properties</b>									
4.1	Water absorption	$W_w$	ISO 62	$60 \times 60 \times 1$	Q	%	Saturation value in water at 23 °C.		
4.2		$W_H$					Equilibrium value at 23 °C, 50 % RH.		
4.3	Density	$\rho$	ISO 1183-1	$10 \times 10 \times 4$	Q	$kg/m^3$	Test specimen to be taken from moulded specimen.		
4.4			ISO 1183-2	$5 \times 5 \times 4$					
<sup>a</sup> Q = Compression moulding.									
<sup>b</sup> Electrical properties are generally affected by the relative humidity. Therefore, they shall be measured in a standard atmosphere of 23 °C ± 2 °C and 50 % ± 10 % relative humidity.									