INTERNATIONAL STANDARD

ISO 11403-1

Third edition
2014-06-15

Plastics — Acquisition and presentation of comparable multipoint data —

Part 1:
Mechanical properties

Plastiques — Acquisition et présentation de données multiples comparables —

Partie 1: Propriétés mécaniques

Reference number
ISO 11403-1:2014(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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. www.iso.org/directives

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

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

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the 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 61, *Plastics*, Subcommittee SC 2, *mechanical properties*.

This third edition cancels and replaces the second edition (ISO 11403-1:2001), which has been technically revised. The main changes are as follows:

— Annex A was deleted;

— ISO 3167 was deleted and ISO 20753 was added in the Clause 2, Normative references.

ISO 11403 consists of the following parts, under the general title *Plastics — Acquisition and presentation of comparable multipoint data*:

— *Part 1: Mechanical properties*

— *Part 2: Thermal and processing properties*

— *Part 3: Environmental influences on properties*

Introduction

This International Standard has been prepared because users of plastics find sometimes that available data cannot be used readily to compare the properties of similar materials, especially when the data have been supplied by different sources. Even when the same standard tests have been used, they often allow the adoption of a wide range of alternative test conditions, and the data obtained are not necessarily comparable. The purpose of this International Standard is to identify specific methods and conditions of test to be used for the acquisition and presentation of data in order that valid comparisons between materials can be made.

ISO 10350 is concerned with single-point data. Such data represent the most basic method for characterizing materials and are useful for the initial stages of material selection. The present International Standard identifies test conditions and procedures for the measurement and presentation of a more substantial quantity of data. Each property here is characterized by multipoint data which demonstrate how that property depends upon important variables such as time, temperature and environmental effects. Additional properties are also considered in this standard. These data therefore enable more discriminating decisions to be made regarding a material's suitability for a particular application. Some data are also considered adequate for undertaking predictions of performance in service and of optimum processing conditions for moulding a component, although it should be recognized that, for purposes of design, additional data will often be needed. One reason for this is that some properties are strongly dependent upon the physical structure of the material. The test procedures referred to in this standard employ, where possible, the multipurpose tensile bar, and the polymer structure in this test specimen may be significantly different from that in specific regions of a moulded component. Under these circumstances, therefore, the data will not be suitable for accurate design calculations for product performance. The material supplier should be consulted for specific information on the applicability of data.

ISO 10350 and the various parts of this International Standard together define the means for acquiring and presenting a core set of comparable data for use in material selection. Use of these standards should result in a rationalization of effort and a reduction of cost associated with provision of these data. Furthermore, reference to these standards will simplify the development of data models for the computerized storage and exchange of data concerning material properties.

Where appropriate, values for test variables have been specified by this standard. For some tests however, owing to the wide range of conditions over which different plastics perform, the standard gives guidance in the selection of certain test conditions so that they cover the operating range for that polymer. Because, in general, the properties and performance specifications for different polymers differ widely, there is no obligation to generate data under all the test conditions specified in this standard.

Data on a wide range of properties are needed to enable plastics to be selected and used in the large variety of applications to which they are suited. ISO standards describe experimental procedures which are suitable for the acquisition of relevant information on many of these properties. The standard has therefore been divided into parts so that each part can be developed independently. In this way, additional properties can be included as new or revised standards become available.

Plastics — Acquisition and presentation of comparable multipoint data —

Part 1: Mechanical properties

1 Scope

This part of ISO 11403 specifies test procedures for the acquisition and presentation of multipoint data on the following mechanical properties of plastics:

— dynamic modulus;

— tensile properties at constant test speed;

— ultimate stress and strain;

— tensile stress-strain curves;

— tensile creep;

— Charpy impact strength;

— puncture impact behaviour.

The test methods and test conditions apply predominantly to those plastics that can be injection- or compression-moulded or prepared as sheets of specified thickness from which specimens of the appropriate size can be machined.

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

ISO 179-2, *Plastics — Determination of Charpy impact properties — Part 2: Instrumented impact test*

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

ISO 294-1, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 1: General principles, and moulding of multipurpose and bar test specimens*

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 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*

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

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

ISO 6603-2, *Plastics — Determination of puncture impact behaviour of rigid plastics — Part 2: Instrumented impact testing*

ISO 6721-2, *Plastics — Determination of dynamic mechanical properties — Part 2: Torsion-pendulum method*

ISO 6721-4, *Plastics — Determination of dynamic mechanical properties — Part 4: Tensile vibration — Non-resonance method*

ISO 10724-1, *Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) — Part 1: General principles and moulding of multipurpose test specimens*

ISO 10724-2, *Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) — Part 2: Small plates*

ISO 20753, *Plastics — Test specimens*

3 Terms and definitions

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

3.1
multipoint data
data characterizing the behaviour of a plastics material by means of a number of test results for a property measured over a range of test conditions

4 Specimen preparation

In the preparation of specimens by injection or compression moulding, the procedures described in ISO 293, ISO 294-1 and 294-3, ISO 295 or ISO 10724-1 and 10724-2 shall be used. The method of moulding and the conditions will depend upon the material being moulded. If these conditions are specified in the International Standard appropriate to the material, then they shall be adopted, where possible, for the preparation of every specimen on which data are obtained using this part of ISO 11403. For those plastics for which moulding conditions have not yet been standardized, the conditions employed shall be within the range recommended by the polymer manufacturer and shall, for each of the processing methods, be the same for every specimen. Where moulding conditions are not stipulated in any International Standard, the values used for the parameters in Table 1 shall be recorded with the data for that material.

Where specimens are prepared by machining from sheet, the machining shall be performed in accordance with ISO 2818.

Table 1 — Moulding parameters

Type of moulding material and moulding method	Standard (where applicable)	Moulding parameters
Thermoplastic Injection	ISO 294-1 and 294–3	Melt temperature Mould temperature Injection velocity[a]
Thermoplastic Compression	ISO 293	Mould temperature Moulding time Cooling rate Demoulding temperature
Thermosetting Injection	ISO 10724-1 and 10724–2	Injection temperature Mould temperature Injection velocity Cure time
Thermosetting Compression	ISO 295	Mould temperature Moulding pressure Cure time

[a] Values specified in materials standards refer to the preparation of the multipurpose test specimen only (see ISO 294-1). For the preparation of small plate specimens (see ISO 294-3), values for the injection velocity shall be chosen to give an injection time comparable to that achieved with the multipurpose test specimen.

5 Conditioning

After moulding, specimens shall be conditioned for 28 d ± 2 d at 23 °C ± 2 °C and (50 ± 10) % relative humidity prior to testing (see note) unless special conditioning is required by the relevant material standards. For those materials whose properties are known to be insensitive to moisture, the control of relative humidity is not necessary. Where it can be demonstrated that the use of a shorter conditioning period has no significant influence on the measured properties, then this shorter period may be used and shall be recorded with the property data in the tables in Clause 7.

NOTE Changes in the molecular structure of a test specimen occur following cooling from the moulding temperature. At elevated temperatures, changes in the size and structure of crystalline regions will take place. In amorphous regions, molecular rearrangements will also occur (physical ageing) and, whereas changes in crystallinity are inhibited at temperatures below the glass transition temperature, physical ageing continues in many polymers at ambient temperatures. These structural changes have a significant influence on certain properties and therefore give rise to a dependence of properties on thermal history. By prescribing an isothermal conditioning period for specimens prior to testing, a reproducible and traceable structural state is established for subsequent measurements carried out in the short-term around, or slightly above, ambient temperatures. However, when measurements are made over a wider and increasing temperature range, or at a constant elevated temperature, further structural changes can take place during the test. Subsequent cooling will establish different structural states and, if the test is non-destructive, repeat measurements will not reproduce previous values.

If special conditioning procedures are specified in material standards which involve heating, to prepare specimens in their dry state or with a more stable structure, then, after conditioning, specimens shall be heated to the glass transition temperature of the polymer and held at that temperature for a period of 20 min and subsequently cooled in still air at 23 °C prior to conditioning for 28 d ± 2 d at 23 °C ± 2 °C. Where data on materials whose properties are sensitive to water content are to be presented for the polymer in its dry state, conditioning shall be carried out at 0 % relative humidity.

Where specimens have been subject to a thermal history under conditions other than 23 °C and 50 % relative humidity, details of this history shall be recorded with the associated property data in the tables in Clause 7.

Subsequent thermal conditioning is required for certain tests and is specified with test requirements in Clause 6.

6 Test requirements

6.1 General

In acquiring data for the properties included in this part of ISO 11403, the test procedures described in the corresponding ISO test standard for each property shall be followed.

Where data are recorded at selected temperatures, values shall be chosen from the series of integral multiples of 10 °C, starting at −40 °C and replacing 20 °C by 23 °C.

For materials whose properties are sensitive to the water content, the results of tests on the polymer after it has been conditioned may change progressively with time when tested at elevated temperatures because of a

continual decrease in water content. The relevance of the data generated is therefore uncertain. Whether such data are worth presenting in accordance with this part of ISO 11403 should be decided by the data supplier.

6.2 Dynamic modulus: ISO 6721-2 or ISO 6721-4

Use a specimen of thickness 1 mm prepared by compression moulding if feasible. If an alternative thickness or method of moulding is necessary, these shall be stated.

Record the real part of the dynamic shear or tensile modulus, G'or E' respectively, and the respective loss factor tan δ_G or tan δ_E measured at a frequency of 1 Hz ± 0,5 Hz and at intervals of 10 °C between −40 °C and the maximum working temperature, as shown by Figure 1 and Table 2 in Clause 7. The measurement at 20 °C shall be replaced by one at 23 °C.

Begin measurements at the lowest temperature and proceed to higher values. Care shall be taken in selecting the heating rate or the dwell time at each temperature to ensure that there is no significant difference between the recorded temperature and the actual temperature of the specimen.

6.3 Tensile properties at constant test speed: ISO 527-1 and ISO 527-2

NOTE Data on the tensile properties of materials other than those covered in ISO 527-2 will be covered in this part of ISO 11403 when additional parts to ISO 527 have been prepared.

6.3.1 General

Use the type A1 specified in ISO 20753. Conduct two tensile tests, the first at a test speed of 1 mm/min up to a strain of 0,25 % to obtain a value for the tensile modulus and the second at a test speed of 5 mm/min to failure (see Note). For this second test, the specimen used to determine the modulus may be used after removing the stress and allowing an appropriate period of time to elapse to permit the specimen to recover from its previous loading.

NOTE The criterion used in the single-point data standard ISO 10350 for selecting the test speed according to the mode of failure of the specimen is not appropriate here because it could lead to the need to change the test speed at different temperatures.

At a constant temperature, T_i, measure the stress-strain curve up to the ultimate values of stress σ_{ui} and strain ε_{ui} which represent the yield point Y or, if no yield is observed, the breaking point B. If no yield or break is observed up to 50 % elongation, then this elongation shall represent the ultimate point on the curve. Repeat the measurements at up to seven temperatures T_i, one of which shall be 23 °C and the others selected between −40 °C and the maximum working temperature of the polymer.

6.3.2 Ultimate stress and strain

At each temperature T_i, record the ultimate values of stress σ_{ui} and strain ε_{ui} as shown by Figure 2 and Table 3 in Clause 7.

6.3.3 Tensile stress-strain curves

At each temperature T_i, record the tensile modulus E_t and the stress at nine values of strain ε_{ki} given by $\varepsilon_{ki} = \varepsilon_{ui} \times k/10$, where k takes all integer values between 1 and 9, as shown by Figure 2 and Table 4 in Clause 7.

6.4 Tensile creep: ISO 899-1

Use the type A1 specified in ISO 20753. Where creep tests are undertaken at temperatures above 23 °C, the specimen shall be held for a period of 24 h at the test temperature prior to load application.

NOTE 1 The creep behaviour of plastics is particularly dependent upon the state of physical ageing of the specimen. If the temperature of the specimen is raised following a period of storage at ambient temperature, significant further changes in age state can take place. These changes become less with increasing time but lead to a dependence of creep behaviour upon the elapsed time at the elevated temperature prior to load application.

Select and record in Table 5 of Clause 7 a value for the maximum stress, σ_{mi} that the polymer could experience for prolonged periods of time at the temperature T_i. Repeat for up to seven temperatures T_i, one of which shall be 23 °C and the others selected to span the useful working range of the polymer.

At each temperature, identify five creep stresses $\sigma_{ki} = \sigma_{mi} \times k/5$ (k = 1 to 5). At each of these stresses, record the creep strain at five times t (in hours) given by lg t = 0, 1, 2, 3 and 4, as shown by Figure 3 and Table 5 in Clause 7.

NOTE 2 The procedure stated in this part of ISO 11403 for presenting creep properties involves the acquisition of a large amount of data, and it will be common practice to generate some of the values for certain materials and grades of a material by calculation. It is not possible at present to describe in this part of ISO 11403 how such calculations should be carried out, implying that each data supplier may use his own method.

Data obtained by extrapolation shall be restricted to no more than one decade in time and shall be labelled with the letter E in the appropriate box in Table 5. Interpolation is permitted as long as the calculated values of strain recorded in Table 5 refer to stress and time values which differ by less than ±20 % from the values of stress and time at which strain measurements were made. Where data for a polymer have been derived by calculation using measured values for similar grades of the polymer, then these data shall be labelled with the letter C in the appropriate box in Table 5. For filled materials, calculated data shall be derived only by interpolation between measured data for materials of higher and lower filler content.

6.5 Charpy impact strength: ISO 179-1 or ISO 179-2

Use the type 1 specimen specified in ISO 179-1 and 179-2, cut from the central part of type A1 specified in ISO 20753. The notched specimen shall have a type A notch (45° V-notch of depth 2 mm and tip radius 0,25 mm) machined into the edge of the specimen (see ISO 2818).

Use edgewise impact.

Measure the impact strength of notched and unnotched specimens, a_{cA} and a_{cU} respectively, at intervals of 10 °C from −40 °C to 23 °C as shown by Figure 4 and Table 6 in Clause 7.

At each temperature, classify test results according to the three types of failure defined in ISO 179-1 and ISO 179-2:

— C: complete break or hinge break;

— P: partial break;

— N: no break.

Select the test result for the type of failure that occurs most frequently, and record in Table 6 the mean value of the impact strength and the corresponding failure type C, P or N.

6.6 Puncture impact behaviour: ISO 6603-2

Use a plate specimen of dimensions 60 mm ± 2 mm square or diameter by 2 mm thick. If these are prepared by injection moulding, then use mould type D2 in ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets. Clamp the specimen sufficiently to prevent any out of plane movement of its outer regions.

Use a striker diameter of 20 mm and lubricate the surface prior to each test.

Use a striker velocity of 4,4 m/s.

NOTE These test conditions are the same as those used to present single-point data in ISO 10350-1.

Measure the maximum force, F_m, and the puncture energy, E_p, up to the point where the force has fallen to 50 % of F_m at intervals of 10 °C from −40 °C to 23 °C. At each temperature, record the mean value of these measurements as shown in Table 7 in Clause 7.

7 Presentation of data

Record the results in the formats described by the following tables together with information that identifies the

material.

Table 2 — Dynamic modulus and loss factor versus temperature (see 6.2 and Figure 1)

T (°C)	- 40	- 30	- 20	- 10	0	10	23	...
G' or E' (MPa)								
tan δ_G or tan δ_E								
NOTE Indicate in the table whether E' and tan δ_E or G' and tan δ_G have been measured.								

Table 3 — Ultimate values of stress and strain and the mode of failure at temperatures T_i (see 6.3.2 and Figure 2)

i	1	2	3	4	5	6	7
T_i (°C)							
σ_{ui} (MPa)							
ε_{ui}							
Y or B							

Table 4 — Values of the tensile modulus and the stress taken from stress-strain curves at temperatures T_i and strains $\varepsilon_{ki} = \varepsilon_{ui} \times k/10$ (see 6.3.3 and Figure 2)

T_i (°C)	E_t (MPa)	Stress levels corresponding to the value of *k* below								
		1	2	3	4	5	6	7	8	9

Table 5 — Creep strains at times t and stresses $\sigma_{ki} = \sigma_{mi} \times k/5$ corresponding to a fixed temperature T_i (see 6.4 and Figure 3)

T_i (°C)			σ_{mi} (MPa)		
lg *t* (*t* in hours)	**Creep strains corresponding to the values for *k* below**				
	1	2	3	4	5
0					
1					
2					
3					
4					
NOTE σ_{mi} is selected appropriate to the creep performance at the temperature T_i					

Table 6 — Notched and un-notched Charpy impact strength, a_{cA} and a_{cU} respectively and type of failure at different temperatures (see 6.5 and Figure 4)

T (°C)	a_{cA} (kJ/m^2)	**Type of failure**	a_{cU} (kJ/m^2)	**Type of failure**
−40				
−30				
−20				
−10				
0				
10				
23				

Table 7 — Maximum force, F_m, and puncture energy, E_p, at different temperatures (see 6.6)

T (°C)	−40	−30	−20	−10	0	10	23
F_m (N)							
E_p (J)							

The following additional information shall be included with each table:

a) The method of preparation of the specimen.

b) A reference to the International Standard which gives the processing conditions used to prepare the specimen, if this was prepared by injection or compression moulding. If these are not given in any standard, then record the appropriate conditions identified in Table 1.

c) Any special conditioning procedure referred to in Clause 5.

d) The number of specimens tested.

8 Precision

For information on the precision of the test methods used to generate the data recorded in the tables in Clause 7, the appropriate ISO test standard should be consulted. However, not all of these standards contain a precision clause and, furthermore, the precision of the data from some tests will depend on the test conditions and on the behaviour of the material under those conditions.

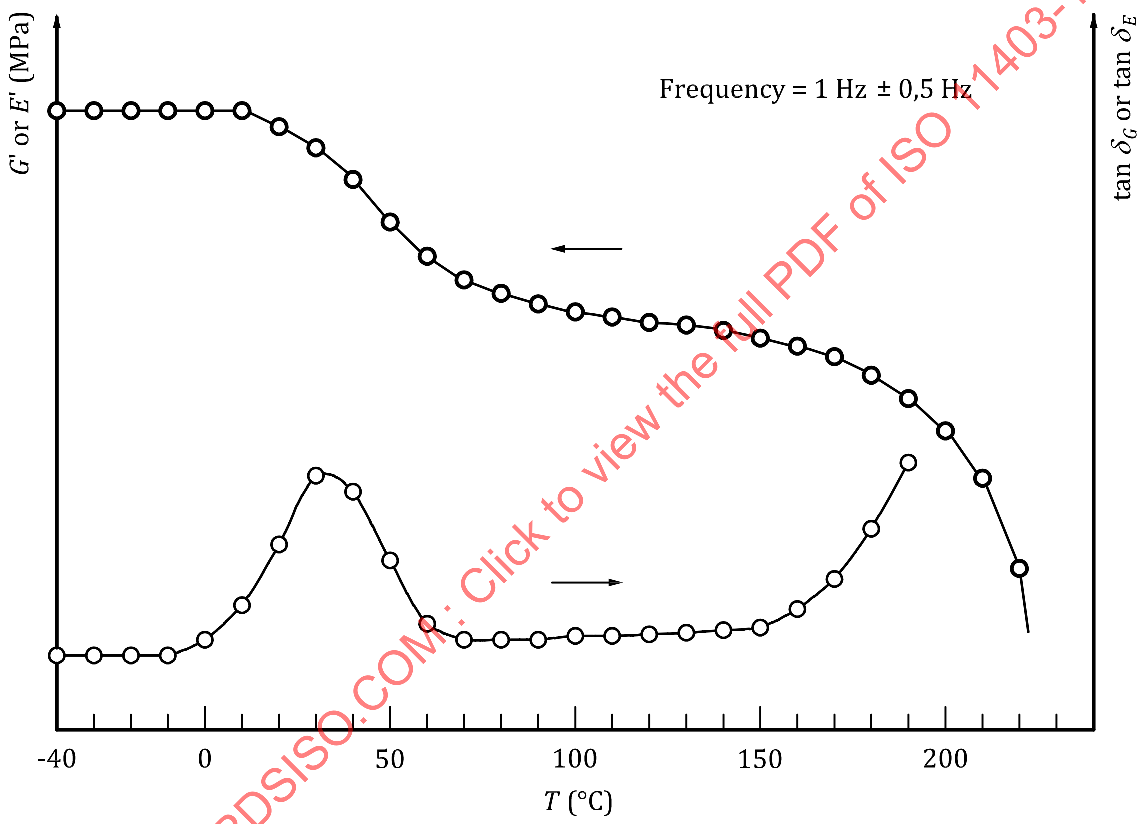

Figure 1 — Schematic diagram depicting the variation of the real part of the dynamic shear or tensile modulus, *G'* or *E'* respectively, and the loss factor of a semi-crystalline polymer with temperature *T* showing the glass-to-rubber relaxation region and the early stages of melting

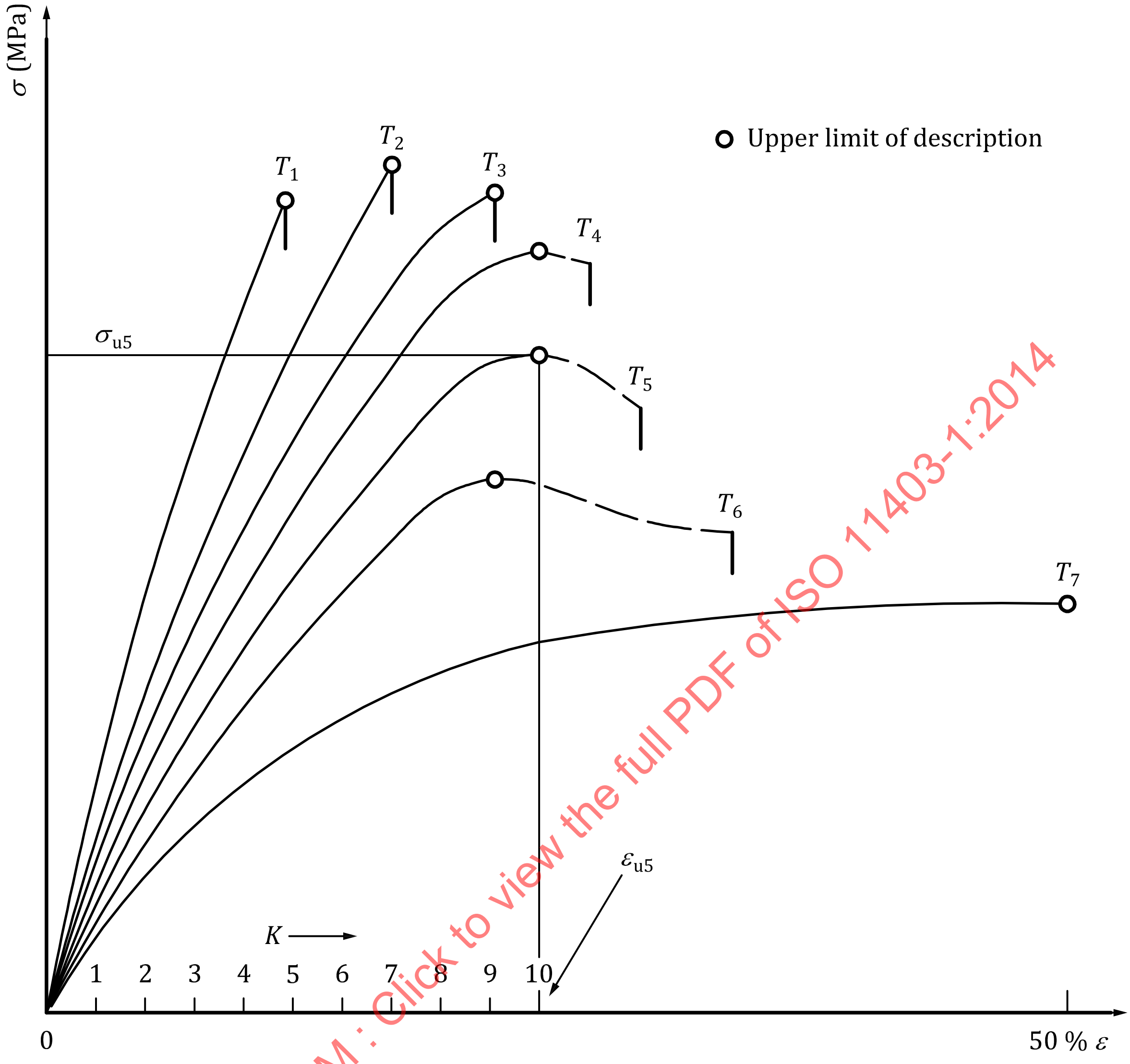

Figure 2 — Stress-strain curves at different temperatures T_i showing ultimate values of stress σ_{ui} and strain ε_{ui} and identifying strains $\varepsilon_{ki} = \varepsilon_{ui} \times k/10$ at which values of stress are to be recorded.

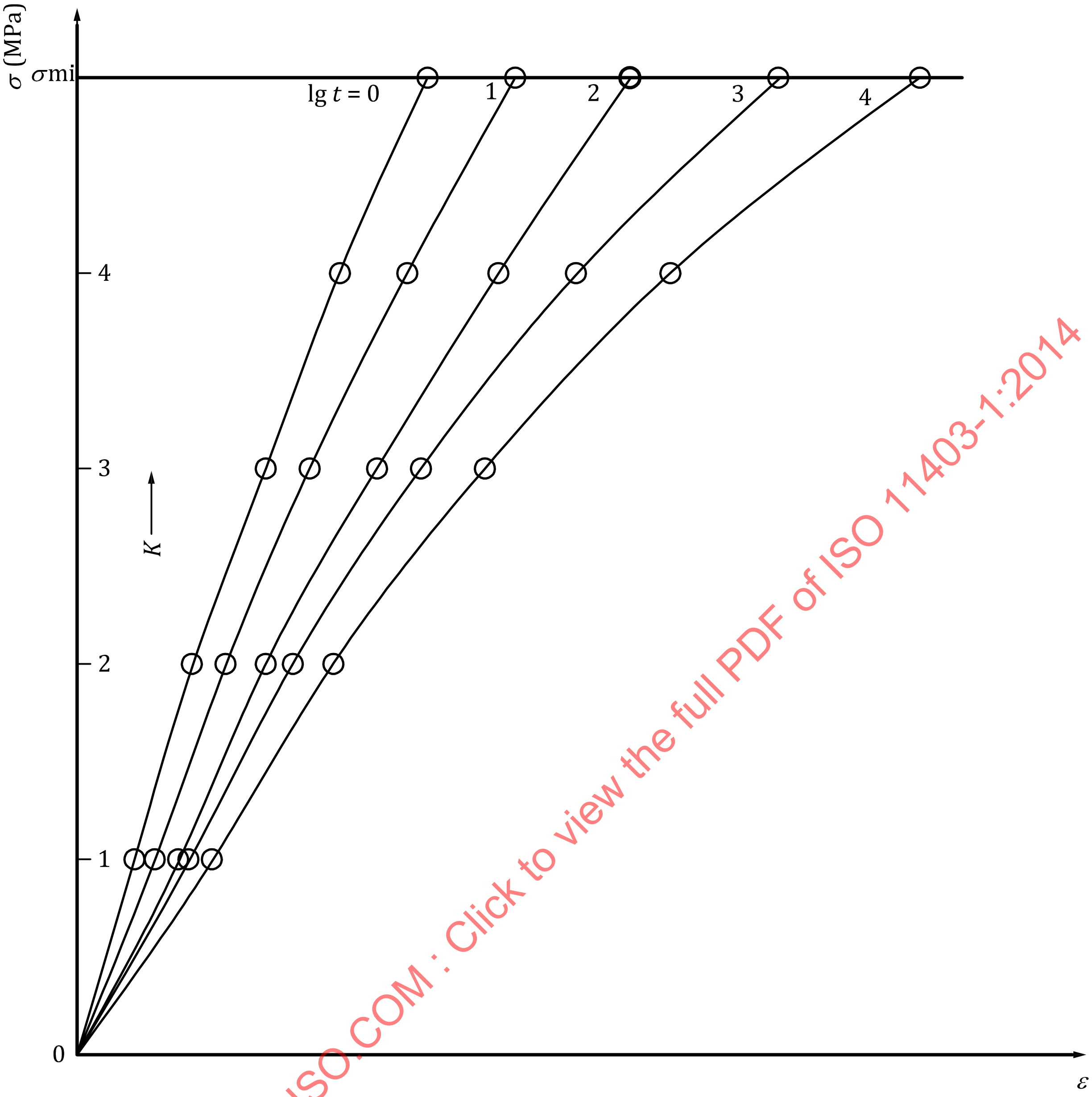

Figure 3 — Isochronous stress-strain curves at a single temperature T_i identifying stresses $\sigma_{ki} = \sigma_{mi} \times k/5$ and times t (in hours) for recording creep strain in a tensile creep test

