INTERNATIONAL STANDARD

ISO 11403-3

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Plastics — Acquisition and presentation of comparable multipoint data —

Part 3:
Environmental influences on properties

Plastiques — Acquisition et présentation de données multiples comparables —

Partie 3: Effets induits par l'environnement sur les propriétés

Reference number
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Contents

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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.

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.

International Standard ISO 11403-3 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*.

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*

Owing to the wide range of properties that are included in ISO 11403, it has been necessary to develop the standard in stages, dividing the contents into parts. In this way, each part can be further developed separately and further parts can be added when appropriate.

Annex B forms an integral part of this part of ISO 11403. Annex A is for information only.

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. These data are not necessarily suitable for design.

ISO 10350[1)] 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 the 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 standard test specimens, and the polymer structure in these specimens 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. For other properties, however, ISO standards either do not exist or exhibit shortcomings that complicate their use at present for the generation of comparable data (see annex A). 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.

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1) ISO 10350-1:1998, *Plastics — Acquisition and presentation of comparable single-point data — Part 1: Moulding materials.*
ISO 10350-2:—, *Plastics — Acquisition and presentation of comparable single-point data — Part 2: Reinforced plastics.* (To be published)

Plastics — Acquisition and presentation of comparable multipoint data —

Part 3:
Environmental influences on properties

1 Scope

This part of ISO 11403 specifies test procedures for the acquisition and presentation of multipoint data which demonstrate the behaviour of plastics under the following environments:

— prolonged exposure to heat;

— liquid chemicals;

— environmental stress cracking under a constant tensile stress;

— artificial weathering.

The tests are listed in order of increasing severity of the environment. By testing under the least severe environments first, it is possible to make informed judgements regarding whether tests under more severe conditions are worthwhile.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 11403. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 11403 are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 175:—[2)], *Plastics — Methods of test for the determination of the effects of immersion in liquid chemicals*.

ISO 291:1997, *Plastics — Standard atmospheres for conditioning and testing*.

ISO 293:1986, *Plastics — Compression moulding test specimens of thermoplastic materials*.

ISO 294-1:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 1: General principles, and moulding of multipurpose and bar test specimens*.

ISO 294-2:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 2: Small tensile bars.*

ISO 295:1991, *Plastics — Compression moulding of test specimens of thermosetting materials.*

[2)] To be published. (Revision of ISO 175:1981)

ISO 527-1:1993, *Plastics — Determination of tensile properties — Part 1: General principles.*

ISO 1268:1974[3)], *Fibre-reinforced plastics — Preparation of glass fibre reinforced, resin bonded, low-pressure laminated plates or panels for test purposes.*

ISO 1817:1999, *Rubber, vulcanized — Determination of the effect of liquids.*

ISO 2578:1993, *Plastics — Determination of time-temperature limits after prolonged exposure to heat.*

ISO 2818:1994, *Plastics — Preparation of test specimens by machining.*

ISO 3167:1993, *Plastics — Multipurpose test specimens.*

ISO 4892-2:1994, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc sources.*

ISO 6252:1992, *Plastics — Determination of environmental stress cracking (ESC) — Constant-tensile-stress method.*

ISO 10724-1:1998, *Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) — Part 1: General principles and moulding of multipurpose test specimens.*

ISO 10724-2:1998, *Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) — Part 2: Small plates.*

ISO 11403-1:1994, *Plastics — Acquisition and presentation of comparable multipoint data — Part 1: Mechanical properties.*

3 Definitions

For the purposes of this part of ISO 11403, the following 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

3.2
indicative property
a property that has been selected to reveal the influence of an environment on a material through a comparison of measurements of the property before and after exposure

3.3
indicative data
ratios of mean values of indicative properties after and before exposure

NOTE They give a measure of the severity of the influence of an environment on a material for specific exposure conditions (see clause A.1).

3.4
tensile work to break
W_{tB}
the area under a plot of the applied stress against the grip displacement in a tensile test, the applied stress being determined from the ratio of the tensile force to the minimum initial cross-sectional area of the specimen

NOTE It is expressed in kilojoules per square metre (kJ/m^2).

3) Under revision.

4 Specimen preparation

In the preparation of specimens by injection or compression moulding, the procedures described in ISO 293, ISO 294-1, ISO 294-2, ISO 295, ISO 10724-1, ISO 10724-2 or ISO 1268 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.

Table 1 — Moulding parameters

Type of moulding material	**Moulding method and standard** (where applicable)	**Moulding parameters**
Thermoplastic	Injection, ISO 294-1 and -2	Melt temperature Mould temperature Injection velocity
Thermoplastic	Compression, ISO 293	Moulding temperature Moulding time Cooling rate Demoulding temperature
Thermosetting	Injection, ISO 10724-1 and -2	Injection temperature Mould temperature Injection velocity Cure time
Thermosetting	Compression, ISO 295	Mould temperature Moulding pressure Cure time
Plastics composites	Test plate production, ISO 1268	Fibre content Mould temperature Moulding pressure Cure time

5 Conditioning

For materials having properties that are significantly dependent upon the concentration of absorbed water, specimens shall be in equilibrium with an atmosphere of (50 ± 5) % RH at 23 °C before exposure to the environment, and for indicative property measurements prior to exposure (see the note) with the exception of tests for prolonged exposure to heat (see 6.5). For these materials, consult the relevant material standard for procedures for conditioning specimens. For materials that have properties that are not significantly sensitive to absorbed water, specimens shall be conditioned in accordance with the International Standard appropriate to the material. If no materials standard is available, condition test specimens at 23 °C ± 2 °C and (50 ± 10) % RH for a minimum length of time of 88 h (see ISO 291). Reference to the use of any special conditioning shall be recorded with the data in the tables in clause 7.

NOTE The water content may change during exposure to an environment, either through exposure to an elevated temperature or, in the case of exposure to a chemical, through exchange of water with the chemical.

6 Test requirements

6.1 General

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

Where tests are carried out at temperatures other than 23 °C, temperature values shall be chosen from the series of integral multiples of 10 °C.

6.2 Indicative properties and indicative data (see clause A.1)

For each of the test requirements in 6.5 to 6.8, data shall be recorded as ratios of certain indicative property values obtained at 23 °C before and after specified conditions of exposure. The tensile strength and the tensile work to break are indicative properties that are common to each of the environmental exposure tests. The tensile strength is either the yield stress σ_Y or, for brittle materials, the stress at break σ_B (see ISO 527-1) and is determined by dividing the value for the force at yield or break by the minimum initial cross-sectional area of the specimen in the waisted region. The tensile work to break W_{tB} (see 3.4) is determined from a conventional tensile test used to obtain the tensile strength and is normalized with respect to the minimum initial cross-sectional area of the specimen. In this part of ISO 11403, all indicative data are recorded as a ratio of a measurement after exposure to a measurement prior to exposure. It is therefore not necessary to specify units for indicative property measurements but clearly these must be consistent throughout a series of measurements of each property.

6.3 Test specimens (see clauses A.1 and A.2)

For the determination of indicative properties, either the ISO 3167 multipurpose test specimen or the ISO 294-2 small tensile specimen (see figure 1) may be used. The small specimen shall have a thickness of 3 mm ± 0,1 mm and is recommended for materials that exhibit ductile failure prior to exposure (see clause A.1). The small specimen may be prepared by injection moulding (see ISO 294-2 for thermoplastics), or by machining the shape from sheet or compression moulded plates having a thickness of 3 mm ± 0,1 mm (see ISO 2818). Where appropriate, the moulding conditions specified in part 2 of the relevant material standard shall be used. For the determination of environmental stress cracking resistance (6.7), the multipurpose test specimen shall be used, machined where necessary as shown in figure 2 (see also clause A.5).

6.4 Test speed

For polymers that, prior to exposure, show no yielding and have a strain at break ε_B less than or equal to 10 % when tested at a speed of 50 mm/min (see ISO 527-1), a test speed of 5 mm/min ± 1 mm/min shall be used with the multipurpose test specimen and 1 mm/min ± 0,2 mm/min with the small tensile specimen. For materials that yield, or where $\varepsilon_B > 10$ % before exposure, these speeds shall be 50 mm/min ± 10 mm/min and 10 mm/min ± 2 mm/min respectively for the two specimen types.

The test speeds for indicative property measurements after exposure to the environment shall be the same as those adopted for tests prior to exposure and shall be recorded with the data in clause 7.

6.5 Prolonged exposure to heat: ISO 2578

For materials that absorb moisture, specimens shall be as-moulded and contained so as to avoid changes in water content prior to all thermal exposures and reference tests.

The indicative properties are:

1 the tensile strength σ_Y or σ_B (see 6.2);

2 the tensile work to break W_{tB} (see 6.2).

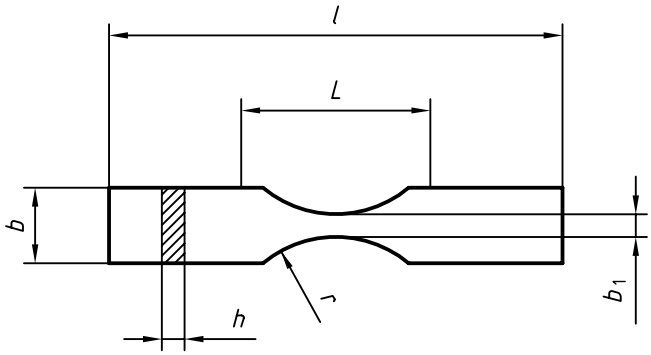
Determine reference values of each indicative property at 23 °C ± 2 °C, using a minimum of five specimens (see also 6.4).

Expose specimens to elevated temperatures selected to enable thermal endurance profiles to be determined.

After exposure, specimens shall be stored at 23 °C ± 2 °C for between 16 h and 96 h before the measurement of indicative properties. For materials that absorb moisture, the specimens shall be sealed during this time interval in order to prevent any change in the moisture content. Determine the thermal endurance graphs corresponding to a threshold value of 50 % of each indicative property. A minimum of five specimens shall be used at each exposure time, a minimum of five exposure times for each indicative property at each temperature and a minimum of four temperatures for determining the profile for each property (see the note).

NOTE Some of the exposure times may yield results that can be used for the determination of both of the property profiles.

Record the temperature index TI corresponding to a time limit of 20 000 h and the halving interval HIC for each indicative property as shown by table 2.



Dimensions in millimetres		
l	Overall length	60
b	Width at ends	10 ± 0,2
b_1	Minimum width	3 ± 0,2
r	Radius	15 ± 1
h	Thickness	3 ± 0,2
L	Initial distance between grips	25 ± 2

Figure 1 — Details of the ISO 294-2 small tensile specimen

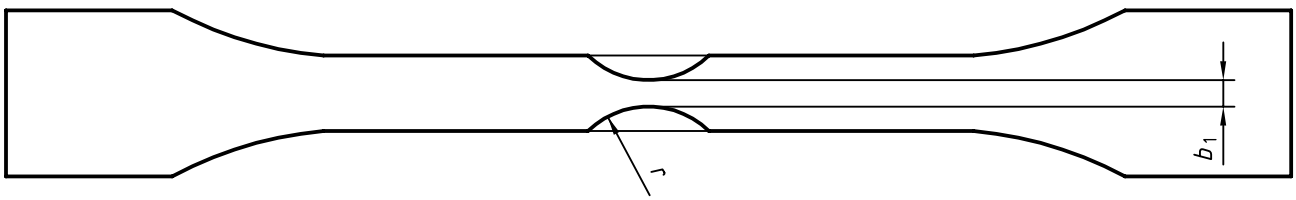


Figure 2 — Test specimen for the measurement of environmental stress cracking resistance under tensile stress, prepared by machining the central waist so that it is identical to that in the small tensile specimen
(see figure 1)

6.6 Liquid chemicals: ISO 175

To aid comparability of data generated for different materials and from different sources, this part of ISO 11403 requires that materials be exposed to the chemicals listed in annex B. If particular materials are not recommended for use, or are not used, in the presence of any of these chemicals at the temperature specified, then the letters NR (not recommended) shall be given in place of experimental data (see table 3).

Although not part of the comparable core data defined above, results for exposure to other chemicals may be presented in addition. It is recommended that, for this purpose, the chemicals be chosen from the list given in ISO 175.

The indicative properties are:

1 the tensile strength σ_Y or σ_B (see 6.2);

2 the tensile work to break W_{tB} (see 6.2);

3 the length l of the specimen and its thickness h in the centre of the waist (see figure 1);

4 the mass m of the specimen.

Measure reference values at 23 °C ± 2 °C (prior to exposure to the chemical), using a minimum of five specimens for properties 1 and 2 (see also 6.4) and, additionally, a minimum of four different specimens for properties 3 and 4.

Immerse specimens in the chemical for periods of 100 h and 1 000 h at the temperature specified in annex B (see the note). For exposure tests carried out at 23 °C, measure indicative properties immediately after exposure. If the exposure has been carried out at an elevated temperature, immerse the specimens in fresh chemical at 23 °C for 20 min ± 10 min and then immediately measure the indicative properties.

NOTE To avoid unnecessary long-term testing, it is recommended that exploratory tests be carried out to determine the influence of the temperature and the chemical acting alone.

Use a minimum of five specimens for each exposure time for properties 1 and 2. Of the four specimens used to determine reference values for properties 3 and 4, use two specimens to determine properties 3 and 4 after 100 h immersion and the remaining two specimens to determine the properties after 1 000 h immersion. The specimens used to obtain properties 3 and 4 may subsequently be used to obtain properties 1 and 2.

The presentation of results at additional temperatures is optional. In each additional test, in order to maximize the precision of indicative data for properties 3 and 4, it is recommended that the measurement of reference values be repeated on four new specimens which are then used to determine indicative properties 3 and 4 at each temperature.

Record the ratio of the mean value of each property after exposure to the mean value prior to exposure as shown by table 4. Also record the letters ST with the ratio of the mass after 1 000 h exposure if, as a result of measurements at other times, it is known that the specimen is saturated with the chemical at this exposure time.

6.7 Environmental stress cracking under constant tensile stress: ISO 6252 (see clauses A.4 and A.5)

Use the ISO 3167 multipurpose test specimen. If convenient, it is acceptable to reduce the length of the specimen by removing the tab regions at each end.

For the preparation of specimens by injection moulding, the central region of the test specimen shall be reduced to a width of 3 mm by machining circular notches of radius 15 mm (see figure 2, ISO 2818 and clause A.5). It is recommended that precautions be taken during machining to avoid introducing stress concentrations perpendicular to the long axis of the specimen by ensuring that the cutting direction is parallel to the length of the specimen.

Where specimens are prepared by compression moulding or by machining from sheet or compression-moulded plates, the machining of the waisted region is optional.

To aid comparability of data generated for different materials and from different sources, this part of ISO 11403 requires that materials be exposed to the chemicals listed in annex B. If particular materials are not recommended for use in the presence of any of these chemicals at the temperature specified, then the letters NR (not recommended) shall be given in place of experimental data in table 5.

Although not part of the comparable core data defined above, results for exposure to other chemicals or at other temperature may be presented in addition. It is recommended that, for this purpose, the chemicals be chosen from the list given in ISO 175.

The indicative properties are:

1 the tensile strength σ_Y or σ_B (see 6.2);

2 the work to break W_{tB} (see 6.2).

Determine reference values for the indicative properties at 23 °C ± 2 °C, using a minimum of five specimens(see also 6.4). The reference tensile strength value is σ_{uo}. Conduct creep tests in the chemical at the temperature specified in annex B at a series of stress levels chosen to give reductions in the tensile strength that are above and below 25 % and in the work to break that are above and below 50 % after 100 h loading time (see the note). A minimum of four stress levels shall be used and a minimum of five specimens at each stress. Plot the indicative property values against the creep stress (see figure 3).

NOTE To avoid any unnecessary long-term testing, it is recommended that exploratory tests be carried out to determine the influence of the temperature, the chemical and the stress acting alone.

Determine, by interpolation, creep stresses σ_{sc}^{100} and σ_{wc}^{100} that give, respectively, a 25 % reduction in the tensile strength and a 50 % reduction in the work to break.

Repeat this procedure for 1 000 h creep loading time and determine the corresponding creep stresses $\sigma_{sc}^{1\,000}$ and $\sigma_{wc}^{1\,000}$.

Record the ratios σ_{sc}/σ_{uo} and σ_{wc}/σ_{uo} for 100 h and 1 000 h exposures as shown by table 5, where σ_{uo} is the reference tensile strength value (see above).

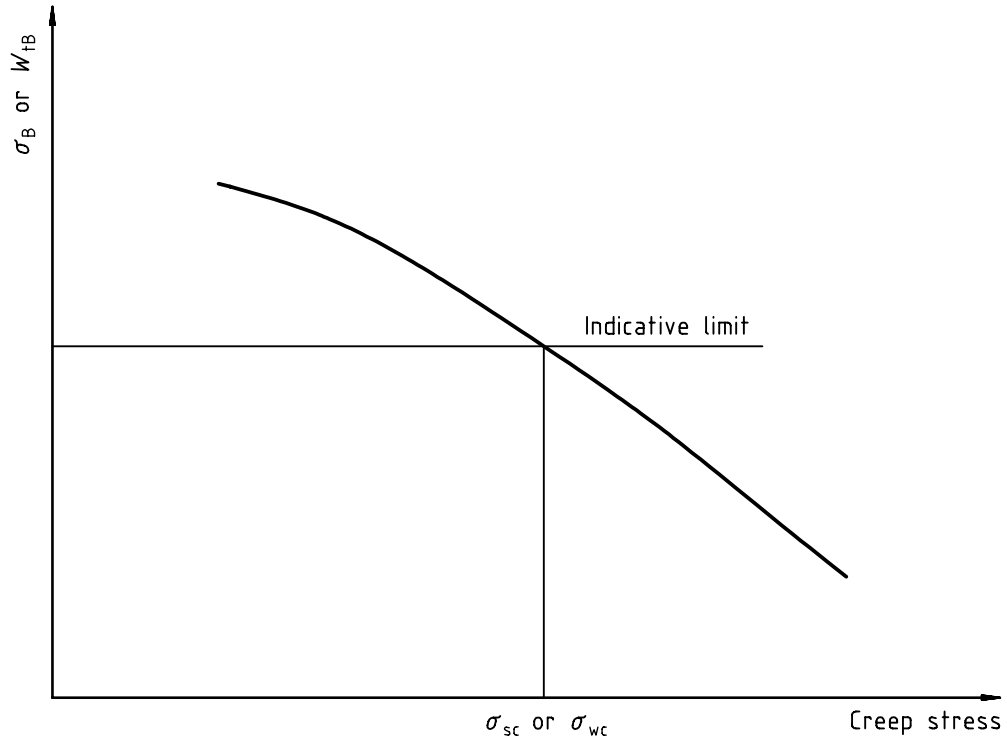


Figure 3 — Plot of indicative property values, measured after creep loading, against the creep stress showing how the quantities σ_{sc} and σ_{wc} are determined

6.8 Artificial weathering: ISO 4892-2 (see clause A.3)

Use a xenon-arc lamp with one or more of the following sets of exposure conditions (see the note).

NOTE Set of conditions 1 is intended to simulate exposure to natural sunlight. Sets of conditions 2 and 3 are intended to simulate exposure behind glass. With set of conditions 3, the ambient temperature is significantly higher than it is under set of conditions 2.

Set of exposure conditions 1: Open air

Use filtering selected to give a relative spectral irradiance complying with method A of ISO 4892-2:1994 and an absolute irradiance of 550 W/m^2 ± 50 W/m^2 in the wavelength range 290 nm to 800 nm.

Use a cycle having a dry period of 102 min followed by a spray period of 18 min. During the dry period, the black standard temperature in the enclosure shall be 65 °C ± 3 °C and the relative humidity (65 ± 5) %. During the spray period, the lamp shall remain on.

Set of exposure conditions 2: Behind glass, low temperature

Use filtering selected to give a relative spectral irradiance complying with method B of ISO 4892-2:1994 and an absolute irradiance of 550 W/m^2 ± 50 W/m^2 in the wavelength range 300 nm to 800 nm.

The black standard temperature in the enclosure shall be 65 °C ± 3 °C and the relative humidity (65 ± 5) %.

Set of exposure conditions 3: Behind glass, high temperature

Use the same filtering and absolute irradiance as with set of conditions 2 above.

The black standard temperature in the enclosure shall be 100 °C ± 3 °C and the relative humidity (50 ± 5) %.

Specimens shall be mounted in the weathering enclosure such that their wide faces are exposed to the radiation. Where the small tensile specimen is used, these may be mounted horizontally in the specimen holders. The specimen holders shall be closed at the back using a matt stainless-steel plate but ensuring that a gap of greater than 2 mm exists between the specimens and the plate to allow free circulation of air. In order to minimize the possibility of fracture of the specimen in the grips during property measurements after exposure, the shoulders of the specimens may be screened using strips of matt stainless steel to prevent exposure to the radiation.

The indicative properties are:

1 the tensile strength σ_Y or σ_B (see 6.2);

2 the tensile work to break W_{tB} (see 6.2).

Determine reference values for the indicative properties measured at 23 °C ± 2 °C using a minimum of five specimens (see also 6.4).

Expose specimens over a range of radiant exposures selected to give reductions in the tensile strength that are above and below 25 % and in the tensile work to break that are above and below 50 %. A minimum of five specimens shall be used at each radiant exposure and a minimum of five exposures shall be selected for each series of indicative property measurements.

Terminate all exposures at the end of an appropriate dry period and store specimens at 23 °C ± 2 °C for between 16 h and 96 h before indicative properties are measured. For materials that absorb moisture, specimens shall be sealed during this time interval in order to prevent any change in the moisture content.

Using mean values of the indicative properties at each exposure, determine, by interpolation, the radiant exposures that cause a 25 % reduction in the tensile strength and a 50 % reduction in the tensile work to break (see the note to 6.5). Record these as shown by table 6.

7 Presentation of data

Record the results in the formats described by the following tables together with information which identifies the material.

The following additional information shall be included with each table:

a) A reference to the International Standard for the material, 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.

b) The specimen type (multipurpose or small tensile) and the method of preparation of the specimen (injection moulding, compression moulding or cut from a sheet).

c) The test speed used for indicative property measurements.

d) Any special conditioning procedure used with water-sensitive materials to achieve equilibrium water content.

Table 2 — Values of the temperature index TI and the halving interval HIC corresponding to an exposure time of 20 000 h and a threshold value of 50 % of the indicative property (see 6.5)

Indicative property	TI	HIC
Tensile strength σ_Y or σ_B		
Work to break W_{tB}		

Table 3 — Availability of data on chemical resistance

(This table shall contain the list of chemicals and temperatures identified in annex B)

Name of chemical	Temperature °C	DA, NR or NA
DA: Data available (see table 4) NR: Not recommended (polymer material either not suitable or not used with this chemical) NA: Not available (data not measured)		

Table 4 — Ratios of indicative property values after exposure to a chemical for a period t at temperature T to values obtained prior to exposure

[The letters ST after the record of the mass ratio for 1 000 h exposure indicate that the specimen is saturated with the chemical by this exposure (see 6.6)]

Name of chemical:	**Exposure temperature**, T (°C)**:**	
Indicative property	**Exposure time**, t (h)	
	100	1 000
Tensile strength σ_Y or σ_B		
Work to break W_{tB}		
Length l		
Thickness h		
Mass m		

Table 5 — Ratios of creep stresses σ_{sc} and σ_{wc} to the reference tensile strength value σ_{uo} at 23 °C for creep loading times t of 100 h and 1 000 h (see 6.7)

(σ_{sc} and σ_{wc} are the creep stresses that, together with the indicated temperature and chemical, produce a 25 % reduction in the reference tensile strength and a 50 % reduction in the reference work to break, respectively.The letters NR in place of data indicate that the material is not recommended or not used under prolonged stress with this chemical. The letters NA indicate that the data have not been measured yet.)

Name of chemical	T °C	**Normalized creep stress**	t h	
			100	1 000
		σ_{sc}/σ_{uo}		
		σ_{wc}/σ_{uo}		

Table 6 — Radiant exposures under artificial weathering resulting in a 25 % reduction in the tensile strength and a 50 % reduction in the tensile work to break (see 6.8)

Exposure conditions:	
Indicative property	**Radiant exposure**, H GJ/m^2
Tensile strength σ_Y or σ_B	
Work to break W_{tB}	

8 Precision

For information on the typical 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, the precision of the data from some tests will depend on the test conditions and the material's behaviour under those conditions. Furthermore the properties considered in this part of ISO 11403 are subject to a greater level of inherent variability than those in the other parts. Data derived using this part, in particular, should not be considered to be absolute. Relatively small differences in the reported properties for materials may not be real, unless supported by statistical evidence.

Annex A
(informative)

Information relating to certain test requirements

The purpose of this annex is to supply information that explains the reasons behind certain of the decisions taken in preparing this part of ISO 11403.

A.1 Indicative properties

The most relevant indicative properties for revealing the resistance of a polymer to a potentially hostile environment are considered to be the tensile strength, the elongation to break and a measure of impact resistance, the tensile-impact strength being commonly preferred for the latter because of its general applicability to both brittle and tough materials. For the first two properties, the ISO 3167 multipurpose test specimen would appear to be the most obvious specimen type to be used for the acquisition of data. However, one important criticism of specifying this specimen for this part of ISO 11403 relates to the presence of a parallel-sided waisted region. For those materials that undergo elongation beyond yield, measurements of the elongation to break obtained using this specimen are very variable owing to the large portion of the specimen that gives rise to yield deformation and within which the onset of failure can originate. The influences of an aggressive environment generally give rise to a reduction in the strain to failure with, initially, only a small change in the strength. Early indications of the effect of the environment are therefore uncertain if data on the failure strain are scattered.

For this reason, with materials that exhibit ductile failure prior to exposure, the specimen geometry shown in figure 1 is specified for the acquisition of indicative property values in this part of ISO 11403. Since the radius of the waisted region is large in comparison with the width of the specimen at the waist, the stress distribution through the cross-section of the specimen in the centre of the waist is effectively uniform, and a valid estimate of the tensile strength of the specimen can be obtained from the ratio of the maximum applied force to the minimum cross-sectional area. Measurements of strain to break cannot be obtained on this specimen, but the work to break can be obtained from the area under a plot of the applied force against the change in grip separation. This quantity is closely related to both the strain at break and the tensile-impact strength, especially when results are expressed as changes in properties relative to values for unexposed material.

For more brittle materials, the multipurpose test specimen should be used, but the indicative properties, tensile strength and work to break, are the same.

Through these selections, estimates of changes in strength and toughness are obtained from a single test and a single test specimen, thereby minimizing the experimental effort and cost involved in data acquisition.

A.2 Specimen preparation

The cost of preparing the small tensile specimen by injection moulding is substantially lower than the cost of preparation by machining the multipurpose test specimen. For this reason, preparation by injection moulding is preferred in this part of ISO 11403. The level of molecular or fibre orientation, however, will probably be somewhat higher than that obtained in the multipurpose specimen. Indicative properties obtained on the small specimen will therefore, in general, not be comparable with results for these properties recorded in the other data presentation standards ISO 10350 and ISO 11403-1 where the multipurpose specimen is used. However, it should be noted that properties in this part of ISO 11403 are presented only as a ratio of measurements made before and after exposure to an environment. This ratio is likely to be less sensitive to specimen structure than the property measurement alone.

A.3 Artificial-weathering tests

There are a number of different artificially accelerated exposure tests that can be used to evaluate the relative durability of plastics. This part of ISO 11403 specifies exposure to a xenon-arc lamp conducted in accordance with ISO 4892-2[4)]. This standard was selected so that all reported data will correspond to exposure to the same well-specified spectral irradiance, which is necessary for the presentation of comparable data.

However it is noted that ISO 4892-3[4)] describes fluorescent UV exposures for plastics and ISO 4892-4[4)] describes filtered open-flame carbon-arc exposures for plastics, and these parts of ISO 4892 provide useful data for other purposes. Exposures in all of these types of device are used by researchers to evaluate the durability of plastics and are often required in product or material specifications. The particular type of exposure device and test conditions that will provide the most relevant results will depend on the polymer being evaluated, the specific material property of interest and the type of outdoor environment that the test is attempting to simulate. Further information regarding the usefulness and limitations of artificial-weathering tests is given in the introduction to ISO 4892-1[4)].

A.4 Environmental stress cracking (ESC) resistance

A variety of test methods exists for determining information on the ESC resistance of plastics. Of these, the more rapid and simple tests to perform identify those chemicals which, in combination with mechanical loading, have a significant influence on the strength of the polymer, and therefore enable the manufacturer to caution the use of their materials in load-bearing applications in the presence of certain chemicals. These tests do not however, in general, give quantitative information on the long-term durability of plastics in the presence of those chemicals that appear, from short-term tests, to have no deleterious effect on properties. Such long-term strength data can be obtained using the tensile test ISO 6252, and this test has the additional feature that the specimen is subjected to a constant applied load which gives a more critical assessment of durability than one in which a constant strain or deformation is imposed. The acquisition of data using this test is however expensive and it is recommended therefore that the data proposed here using this test need only be obtained for the reduced range of chemicals which appear from other tests to have no obvious stress cracking effect on the polymer.

A.5 Test specimens for ESC tests

The ESC resistance of a polymer will be highly sensitive to the direction of the applied stress with respect to the direction of any molecular or fibre orientation in the test specimen. An injection-moulded tensile specimen contains surface regions of relatively high molecular or fibre alignment, and the use of such a test specimen may yield unrealistically high values for ESC resistance. Accordingly, ISO 6252 recommends the use of specimens cut parallel and perpendicular to the flow direction in an injection-moulded plate to reveal the anisotropy of ESC behaviour.

In order to minimize the cost of generating data for ESC resistance in this part of ISO 11403, the ISO 3167 multipurpose specimen is specified with a radiussed waist machined into the central region of the specimen as shown in figure 2 (for compression-moulded specimens, the machined waist is not necessary). The waist serves to expose interior regions of the specimen to the chemical, where the molecular alignment is less than at the surface. This allows possible failure of the test specimen to take place which might otherwise be inhibited or delayed if the chemical had access only to surface material which is oriented in the direction of the applied stress.

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4) ISO 4892:1994, *Plastics — Methods of exposure to laboratory light sources:*

— *Part 1: General guidance*

— *Part 2: Xenon-arc sources*

— *Part 3: Fluorescent UV lamps*

— *Part 4: Open-flame carbon-arc lamps*

Annex B
(normative)

Chemicals for chemical resistance and environmental stress cracking resistance tests

The following list contains chemicals for which information on the chemical resistance and environmental stress cracking resistance of plastics is commonly required. Where it is known that a particular polymer is not recommended or not used for exposure to a chemical at the temperature specified here and under the conditions identified in 6.6 or 6.7, then the letters NR shall be recorded instead of data in the appropriate boxes in tables 3 and 5.

Chemical	**Temperature** °C
Sulfuric acid (38 % by mass)	23
Sodium hydroxide solution (35 % by mass in water)	23
Deionized water	90
Isopropyl alcohol	23
Toluene	23
n-Hexane	23
Acetone	23
n-Butyl acetate	23
Zinc chloride solution (50 % by mass in water)	23
Standard fuel (ISO 1817, liquid 2)	60
SAE 10W40 multigrade motor oil (Oil No. 3 in ISO 1817)	130
SAE 80/90 hypoid-gear oil	130
DOT 4 brake fluid (liquid 103 in ISO 1817)	130
Ethylene glycol (50 % by mass in water)	108

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