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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*

ISO 11403-3:1999

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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.

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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<sup>1)</sup> 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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<sup>1)</sup> 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.

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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:—<sup>2)</sup>, *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.*

<sup>2)</sup> To be published. (Revision of ISO 175:1981)

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

ISO 1268:1974<sup>3)</sup>, *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.*

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### 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<sup>2</sup>).

<sup>3)</sup> 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<br>Mould temperature<br>Injection velocity                     |
| Thermoplastic             | Compression, ISO 293                            | Moulding temperature<br>Moulding time<br>Cooling rate<br>Demoulding temperature |
| Thermosetting             | Injection, ISO 10724-1 and -2                   | Injection temperature<br>Mould temperature<br>Injection velocity<br>Cure time   |
| Thermosetting             | Compression, ISO 295                            | Mould temperature<br>Moulding pressure<br>Cure time                             |
| Plastics composites       | Test plate production, ISO 1268                 | Fibre content<br>Mould temperature<br>Moulding pressure<br>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  $(50 \pm 5) \% \text{ RH}$  at  $23^\circ\text{C}$  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  $23^\circ\text{C} \pm 2^\circ\text{C}$  and  $(50 \pm 10) \% \text{ RH}$  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  $\sigma_Y$  or, for brittle materials, the stress at break  $\sigma_B$  (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  $3 \text{ mm} \pm 0,1 \text{ mm}$  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  $3 \text{ mm} \pm 0,1 \text{ mm}$  (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  $\varepsilon_B$  less than or equal to 10 % when tested at a speed of 50 mm/min (see ISO 527-1), a test speed of  $5 \text{ mm/min} \pm 1 \text{ mm/min}$  shall be used with the multipurpose test specimen and  $1 \text{ mm/min} \pm 0,2 \text{ mm/min}$  with the small tensile specimen. For materials that yield, or where  $\varepsilon_B > 10 \%$  before exposure, these speeds shall be  $50 \text{ mm/min} \pm 10 \text{ mm/min}$  and  $10 \text{ mm/min} \pm 2 \text{ mm/min}$  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  $\sigma_Y$  or  $\sigma_B$  (see 6.2);
- 2 the tensile work to break  $W_{tB}$  (see 6.2).

Determine reference values of each indicative property at  $23 \text{ °C} \pm 2 \text{ °C}$ , using a minimum of five specimens (see also 6.4).

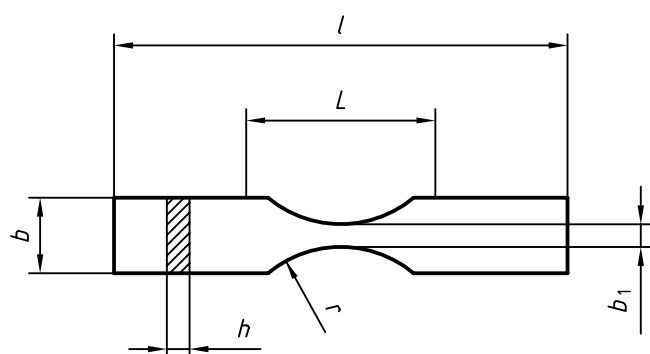
Expose specimens to elevated temperatures selected to enable thermal endurance profiles to be determined.



After exposure, specimens shall be stored at  $23\text{ °C} \pm 2\text{ °C}$  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.



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

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

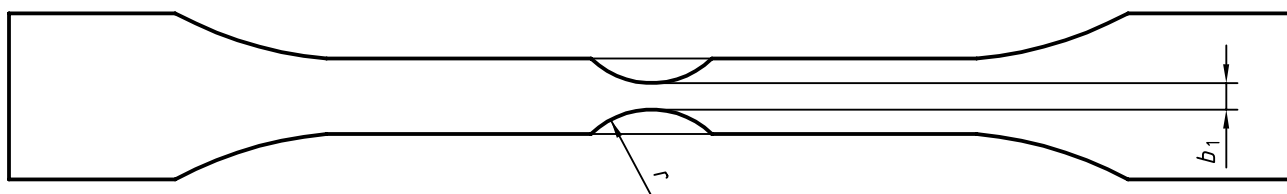


Figure 2 — Test specimen for the measurement of environmental stress cracking resistance under tensile stress, prepared by machining the central waist so that it is identical to that in the small tensile specimen (see figure 1)

## 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  $\sigma_Y$  or  $\sigma_B$  (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  $23\text{ °C} \pm 2\text{ °C}$  (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  $23\text{ °C}$ , measure indicative properties immediately after exposure. If the exposure has been carried out at an elevated temperature, immerse the specimens in fresh chemical at  $23\text{ °C}$  for  $20\text{ min} \pm 10\text{ min}$  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  $\sigma_Y$  or  $\sigma_B$  (see 6.2);
- 2 the work to break  $W_{tB}$  (see 6.2).

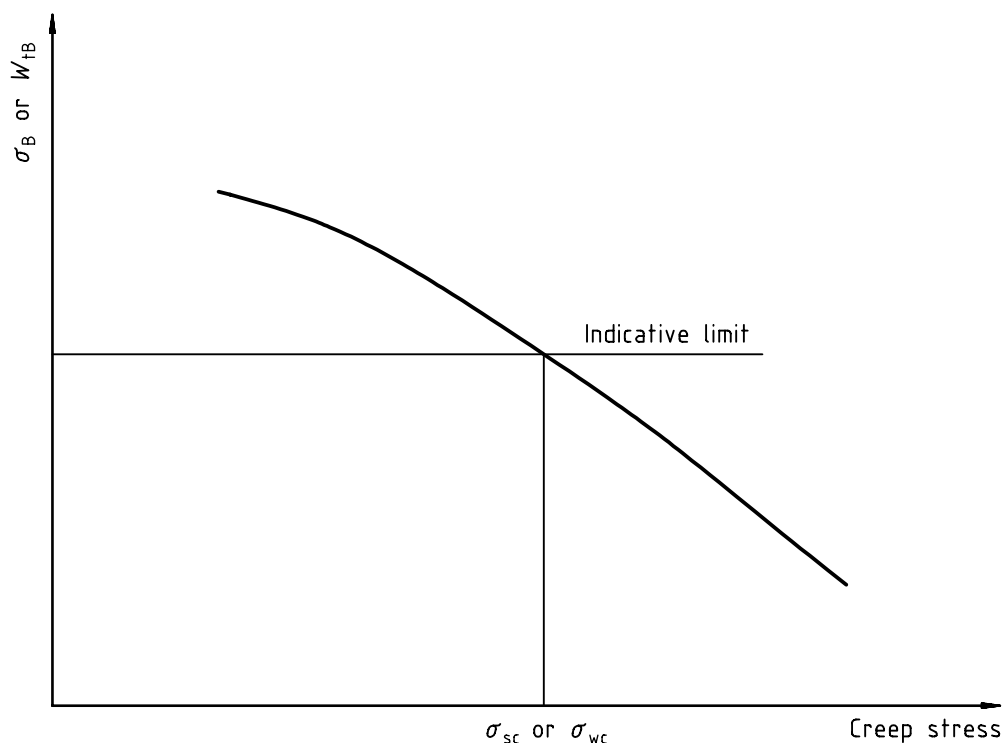
Determine reference values for the indicative properties at  $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ , using a minimum of five specimens (see also 6.4). The reference tensile strength value is  $\sigma_{u0}$ . Conduct creep tests in the chemical at the temperature specified in annex 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  $\sigma_{sc}^{100}$  and  $\sigma_{wc}^{100}$  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  $\sigma_{sc}^{1000}$  and  $\sigma_{wc}^{1000}$ .

Record the ratios  $\sigma_{sc}/\sigma_{u0}$  and  $\sigma_{wc}/\sigma_{u0}$  for 100 h and 1 000 h exposures as shown by table 5, where  $\sigma_{u0}$  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  $\sigma_{sc}$  and  $\sigma_{wc}$  are determined**