

BS EN ISO 6892-1:2009



BSI Standards Publication

# Metallic materials — Tensile testing

Part 1: Method of test at ambient  
temperature

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### National foreword

This British Standard is the UK implementation of EN ISO 6892-1:2009. It supersedes BS EN 10002-1:2001 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee ISE/NFE/4, Mechanical testing of metals, to Subcommittee ISE/NFE/4/1, Uniaxial testing of metals.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

**Metallic materials - Tensile testing - Part 1: Method of test at  
room temperature (ISO 6892-1:2009)**

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Méthode d'essai à température ambiante (ISO 6892-  
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bei Raumtemperatur (ISO 6892-1:2009)

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## Foreword

This document (EN ISO 6892-1:2009) has been prepared by Technical Committee ISO/TC 164 "Mechanical testing of metals" in collaboration with Technical Committee ECISS/TC 1 "Tensile testing" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2010, and conflicting national standards shall be withdrawn at the latest by February 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 10002-1:2001.

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### Endorsement notice

The text of ISO 6892-1:2009 has been approved by CEN as a EN ISO 6892-1:2009 without any modification.

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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.

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The main task of technical committees is to prepare International Standards. 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.

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.

ISO 6892-1 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This first edition of ISO 6892-1 cancels and replaces ISO 6892:1998.

ISO 6892 consists of the following parts, under the general title *Metallic materials — Tensile testing*:

— *Part 1: Method of test at room temperature*

The following parts are under preparation:

— *Part 2: Method of test at elevated temperature*

— *Part 3: Method of test at low temperature*

The following part is planned:

— *Part 4: Method of test in liquid helium*

## **Introduction**

During discussions concerning the speed of testing in the preparation of ISO 6892:1998, it was decided to recommend the use of strain rate control in future revisions.

In this part of ISO 6892, there are two methods of testing speeds available. The first, method A, is based on strain rates (including crosshead separation rate) and the second, method B, is based on stress rates. Method A is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results.

# Metallic materials — Tensile testing —

## Part 1: Method of test at room temperature

### 1 Scope

This part of ISO 6892 specifies the method for tensile testing of metallic materials and defines the mechanical properties which can be determined at room temperature.

NOTE Annex A indicates complementary recommendations for computer controlled testing machines.

### 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 2566-1, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels*

ISO 2566-2, *Steel — Conversion of elongation values — Part 2: Austenitic steels*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometers used in uniaxial testing*

### 3 Terms and definitions

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

#### 3.1

##### **gauge length**

$L$

length of the parallel portion of the test piece on which elongation is measured at any moment during the test

[ISO/TR 25679:2005<sup>[3]</sup>]

##### 3.1.1

##### **original gauge length**

$L_0$

length between **gauge length** (3.1) marks on the piece measured at room temperature before the test

NOTE Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

### 3.1.2

#### final gauge length after rupture

#### final gauge length after fracture

$L_u$   
length between **gauge length** (3.1) marks on the test piece measured after rupture, at room temperature, the two pieces having been carefully fitted back together so that their axes lie in a straight line

NOTE Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

### 3.2

#### parallel length

$L_c$   
length of the parallel reduced section of the test piece

[ISO/TR 25679:2005<sup>[3]</sup>]

NOTE The concept of parallel length is replaced by the concept of distance between grips for unmachined test pieces.

### 3.3

#### elongation

increase in the **original gauge length** (3.1.1) at any moment during the test

NOTE Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

### 3.4

#### percentage elongation

elongation expressed as a percentage of the **original gauge length**,  $L_o$  (3.1.1)

[ISO/TR 25679:2005<sup>[3]</sup>]

#### 3.4.1

##### percentage permanent elongation

increase in the **original gauge length** (3.1.1) of a test piece after removal of a specified stress, expressed as a percentage of the original gauge length,  $L_o$

[ISO/TR 25679:2005<sup>[3]</sup>]

#### 3.4.2

##### percentage elongation after fracture

$A$   
permanent elongation of the gauge length after fracture,  $(L_u - L_o)$ , expressed as a percentage of the **original gauge length**,  $L_o$

[ISO/TR 25679:2005<sup>[3]</sup>]

NOTE For proportional test pieces, if the original gauge length is not equivalent to  $5,65\sqrt{S_o}$ <sup>1)</sup> where  $S_o$  is the original cross-sectional area of the parallel length, the symbol  $A$  should be supplemented by a subscript indicating the coefficient of proportionality used, e.g.  $A_{11,3}$  indicates a percentage elongation of the gauge length,  $L_o$ , of

$$A_{11,3} = 11,3\sqrt{S_o}$$

For non-proportional test pieces (see Annex B), the symbol  $A$  should be supplemented by a subscript indicating the original gauge length used, expressed in millimetres, e.g.  $A_{80\text{ mm}}$  indicates a percentage elongation of a gauge length,  $L_o$ , of 80 mm.

---

1)  $5,65\sqrt{S_o} = 5\sqrt{(4S_o/\pi)}$ .

### 3.5

#### extensometer gauge length

$L_e$

initial extensometer gauge length used for measurement of extension by means of an extensometer

NOTE 1 Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

NOTE 2 For measurement of yield and proof strength parameters,  $L_e$  should span as much of the parallel length of the test piece as possible. Ideally, as a minimum,  $L_e$  should be greater than  $0,50L_o$  but less than approximately  $0,9L_c$ . This should ensure that the extensometer detects all yielding events that occur in the test piece. Further, for measurement of parameters "at" or "after reaching" maximum force,  $L_e$  should be approximately equal to  $L_o$ .

### 3.6

#### extension

increase in the **extensometer gauge length**,  $L_e$  (3.5), at any moment during the test

[ISO/TR 25679:2005<sup>[3]</sup>]

#### 3.6.1

##### percentage extension "strain"

extension expressed as a percentage of the **extensometer gauge length**,  $L_e$  (3.5)

#### 3.6.2

##### percentage permanent extension

increase in the extensometer gauge length, after removal of a specified stress from the test piece, expressed as a percentage of the **extensometer gauge length**,  $L_e$  (3.5)

[ISO/TR 25679:2005<sup>[3]</sup>]

#### 3.6.3

##### percentage yield point extension

$A_e$

in discontinuous yielding materials, the extension between the start of yielding and the start of uniform workhardening, expressed as a percentage of the **extensometer gauge length**,  $L_e$  (3.5)

NOTE Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

See Figure 7.

#### 3.6.4

##### percentage total extension at maximum force

$A_{gt}$

total extension (elastic extension plus plastic extension) at maximum force, expressed as a percentage of the **extensometer gauge length**,  $L_e$  (3.5)

See Figure 1.

#### 3.6.5

##### percentage plastic extension at maximum force

$A_g$

plastic extension at maximum force, expressed as a percentage of the **extensometer gauge length**,  $L_e$  (3.5)

See Figure 1.

### 3.6.6

#### percentage total extension at fracture

$A_t$   
total extension (elastic extension plus plastic extension) at the moment of fracture, expressed as a percentage of the **extensometer gauge length**,  $L_e$  (3.5)

See Figure 1.

### 3.7 Testing rate

#### 3.7.1

##### strain rate

$\dot{\epsilon}_{L_e}$   
increase of strain, measured with an extensometer, in **extensometer gauge length**,  $L_e$  (3.5), per time

NOTE See 3.5.

#### 3.7.2

##### estimated strain rate over the parallel length

$\dot{\epsilon}_{L_c}$   
value of the increase of strain over the **parallel length**,  $L_c$  (3.2), of the test piece per time based on the **crosshead separation rate** (3.7.3) and the parallel length of the test piece

#### 3.7.3

##### crosshead separation rate

$v_c$   
displacement of the crossheads per time

#### 3.7.4

##### stress rate

$\dot{R}$   
increase of stress per time

NOTE Stress rate should only be used in the elastic part of the test (method B).

### 3.8

#### percentage reduction of area

$Z$   
maximum change in cross-sectional area which has occurred during the test,  $(S_o - S_u)$ , expressed as a percentage of the original cross-sectional area,  $S_o$ :

$$Z = \frac{S_o - S_u}{S_o} \times 100$$

### 3.9 Maximum force

NOTE For materials which display discontinuous yielding, but where no workhardening can be established,  $F_m$  is not defined in this part of ISO 6892 [see footnote to Figure 8 c)].

#### 3.9.1

##### maximum force

$F_m$   
(materials displaying no discontinuous yielding) highest force that the test piece withstands during the test

### 3.9.2

#### maximum force

$F_m$

(materials displaying discontinuous yielding) highest force that the test piece withstands during the test after the beginning of workhardening

NOTE See Figure 8 a) and b).

### 3.10

#### stress

at any moment during the test, force divided by the original cross-sectional area,  $S_0$ , of the test piece

NOTE 1 Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

NOTE 2 All references to stress in this part of ISO 6892 are to engineering stress.

NOTE 3 In what follows, the designations “force” and “stress” or “extension”, “percentage extension” and “strain”, respectively, are used on various occasions (as figure axis labels or in explanations for the determination of different properties). However, for a general description or definition of a well-defined point on a curve, the designations “force” and “stress” or “extension”, “percentage extension” and “strain”, respectively, are interchangeable.

#### 3.10.1

##### tensile strength

$R_m$

stress corresponding to the **maximum force**,  $F_m$  (3.9)

[ISO/TR 25679:2005<sup>[3]</sup>]

#### 3.10.2

##### yield strength

when the metallic material exhibits a yield phenomenon, stress corresponding to the point reached during the test at which plastic deformation occurs without any increase in the force

NOTE Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

##### 3.10.2.1

##### upper yield strength

$R_{eH}$

maximum value of **stress** (3.10) prior to the first decrease in force

NOTE Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

See Figure 2.

##### 3.10.2.2

##### lower yield strength

$R_{eL}$

lowest value of **stress** (3.10) during plastic yielding, ignoring any initial transient effects

[ISO/TR 25679:2005<sup>[3]</sup>]

See Figure 2.

### 3.10.3

#### proof strength, plastic extension

$R_p$   
stress at which the plastic extension is equal to a specified percentage of the **extensometer gauge length**,  $L_e$  (3.5)

NOTE 1 Adapted from ISO/TR 25679:2005, “proof strength, non-proportional extension”.

NOTE 2 A suffix is added to the subscript to indicate the prescribed percentage, e.g.  $R_{p0,2}$ .

See Figure 3.

### 3.10.4

#### proof strength, total extension

$R_t$   
stress at which total extension (elastic extension plus plastic extension) is equal to a specified percentage of the **extensometer gauge length**,  $L_e$  (3.5)

NOTE 1 Adapted from ISO/TR 25679:2005<sup>[3]</sup>.

NOTE 2 A suffix is added to the subscript to indicate the prescribed percentage, e.g.  $R_{t0,5}$ .

See Figure 4.

### 3.10.5

#### permanent set strength

$R_r$   
stress at which, after removal of force, a specified permanent elongation or extension, expressed respectively as a percentage of **original gauge length**,  $L_o$  (3.1.1), or **extensometer gauge length**,  $L_e$  (3.5), has not been exceeded

[ISO/TR 25679:2005<sup>[3]</sup>]

See Figure 5.

NOTE A suffix is added to the subscript to indicate the specified percentage of the original gauge length,  $L_o$ , or of the extensometer gauge length,  $L_e$ , e.g.  $R_{r0,2}$ .

### 3.11

#### fracture

phenomenon which is deemed to occur when total separation of the test piece occurs

NOTE Criteria for fracture which may be used for computer controlled tests are given in Figure A.2.

## 4 Terms and symbols

The symbols used in this part of ISO 6892 and corresponding designations are given in Table 1.

**Table 1 — Symbols and designations**

| Symbol                 | Unit                | Designation                                                                                                                                   |
|------------------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Test piece</b>      |                     |                                                                                                                                               |
| $a_o, T^a$             | mm                  | original thickness of a flat test piece or wall thickness of a tube                                                                           |
| $b_o$                  | mm                  | original width of the parallel length of a flat test piece or average width of the longitudinal strip taken from a tube or width of flat wire |
| $d_o$                  | mm                  | original diameter of the parallel length of a circular test piece, or diameter of round wire or internal diameter of a tube                   |
| $D_o$                  | mm                  | original external diameter of a tube                                                                                                          |
| $L_o$                  | mm                  | original gauge length                                                                                                                         |
| $L'_o$                 | mm                  | initial gauge length for determination of $A_{wn}$ (see Annex I)                                                                              |
| $L_c$                  | mm                  | parallel length                                                                                                                               |
| $L_e$                  | mm                  | extensometer gauge length                                                                                                                     |
| $L_t$                  | mm                  | total length of test piece                                                                                                                    |
| $L_u$                  | mm                  | final gauge length after fracture                                                                                                             |
| $L'_u$                 | mm                  | final gauge length after fracture for determination of $A_{wn}$ (see Annex I)                                                                 |
| $S_o$                  | mm <sup>2</sup>     | original cross-sectional area of the parallel length                                                                                          |
| $S_u$                  | mm <sup>2</sup>     | minimum cross-sectional area after fracture                                                                                                   |
| $k$                    | —                   | coefficient of proportionality (see 6.1.1)                                                                                                    |
| $Z$                    | %                   | percentage reduction of area                                                                                                                  |
| <b>Elongation</b>      |                     |                                                                                                                                               |
| $A$                    | %                   | percentage elongation after fracture (see 3.4.2)                                                                                              |
| $A_{wn}$               | %                   | percentage plastic elongation without necking (see Annex I)                                                                                   |
| <b>Extension</b>       |                     |                                                                                                                                               |
| $A_e$                  | %                   | percentage yield point extension                                                                                                              |
| $A_g$                  | %                   | percentage plastic extension at maximum force, $F_m$                                                                                          |
| $A_{gt}$               | %                   | percentage total extension at maximum force, $F_m$                                                                                            |
| $A_t$                  | %                   | percentage total extension at fracture                                                                                                        |
| $\Delta L_m$           | mm                  | extension at maximum force                                                                                                                    |
| $\Delta L_f$           | mm                  | extension at fracture                                                                                                                         |
| <b>Rates</b>           |                     |                                                                                                                                               |
| $\dot{\epsilon}_{L_e}$ | s <sup>-1</sup>     | strain rate                                                                                                                                   |
| $\dot{\epsilon}_{L_c}$ | s <sup>-1</sup>     | estimated strain rate over the parallel length                                                                                                |
| $\dot{R}$              | MPa s <sup>-1</sup> | stress rate                                                                                                                                   |
| $v_c$                  | mm s <sup>-1</sup>  | crosshead separation rate                                                                                                                     |

Table 1 — Symbols and designations (*continued*)

| Symbol                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Unit             | Designation                                                                     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------------------------------------------------------------------------------|
| <b>Force</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                  |                                                                                 |
| $F_m$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | N                | maximum force                                                                   |
| <b>Yield strength — Proof strength — Tensile strength</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                  |                                                                                 |
| $E$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | MPa <sup>b</sup> | modulus of elasticity                                                           |
| $m$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | MPa              | slope of the stress-percentage extension curve at a given moment of the test    |
| $m_E$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | MPa              | slope of the elastic part of the stress-percentage extension curve <sup>c</sup> |
| $R_{eH}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | MPa              | upper yield strength                                                            |
| $R_{eL}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | MPa              | lower yield strength                                                            |
| $R_m$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | MPa              | tensile strength                                                                |
| $R_p$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | MPa              | proof strength, plastic extension                                               |
| $R_r$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | MPa              | specified permanent set strength                                                |
| $R_t$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | MPa              | proof strength, total extension                                                 |
| <sup>a</sup> Symbol used in steel tube product standards.<br><sup>b</sup> 1 MPa = 1 N mm <sup>-2</sup> .<br><sup>c</sup> In the elastic part of the stress-percentage extension curve, the value of the slope may not necessarily represent the modulus of elasticity. This value can closely agree with the value of the modulus of elasticity if optimal conditions (high resolution, double sided, averaging extensometers, perfect alignment of the test piece, etc.) are used.<br><b>CAUTION — The factor 100 is necessary if percentage values are used.</b> |                  |                                                                                 |

## 5 Principle

The test involves straining a test piece by tensile force, generally to fracture, for the determination of one or more of the mechanical properties defined in Clause 3.

The test is carried out at room temperature between 10 °C and 35 °C, unless otherwise specified. Tests carried out under controlled conditions shall be made at a temperature of 23 °C ± 5 °C.

## 6 Test piece

### 6.1 Shape and dimensions

#### 6.1.1 General

The shape and dimensions of the test pieces may be constrained by the shape and dimensions of the metallic product from which the test pieces are taken.

The test piece is usually obtained by machining a sample from the product or a pressed blank or casting. However, products of uniform cross-section (sections, bars, wires, etc.) and also as-cast test pieces (i.e. for cast iron and non-ferrous alloys) may be tested without being machined.

The cross-section of the test pieces may be circular, square, rectangular, annular or, in special cases, some other uniform cross-section.

Preferred test pieces have a direct relationship between the original gauge length,  $L_o$ , and the original cross-sectional area,  $S_o$ , expressed by the equation  $L_o = k\sqrt{S_o}$ , where  $k$  is a coefficient of proportionality, and are called proportional test pieces. The internationally adopted value for  $k$  is 5,65. The original gauge length shall be not less than 15 mm. When the cross-sectional area of the test piece is too small for this requirement to be met with,  $k = 5,65$ , a higher value (preferably 11,3) or a non-proportional test piece may be used.

NOTE By using an original gauge length smaller than 20 mm, the measurement uncertainty is increased.

For non-proportional test pieces, the original gauge length,  $L_o$ , is independent of the original cross-sectional area,  $S_o$ .

The dimensional tolerances of the test pieces shall be in accordance with the Annexes B to E (see 6.2).

Other test pieces such as those specified in relevant product standards or national standards may be used by agreement with the customer, e.g. ISO 3183<sup>[1]</sup> (API 5L), ISO 11960<sup>[2]</sup> (API 5CT), ASTM A370<sup>[6]</sup>, ASTM E8M<sup>[7]</sup>, DIN 50125<sup>[10]</sup>, IACS W2<sup>[13]</sup>, and JIS Z2201<sup>[14]</sup>.

### 6.1.2 Machined test pieces

Machined test pieces shall incorporate a transition radius between the gripped ends and the parallel length if these have different dimensions. The dimensions of the transition radius are important and it is recommended that they be defined in the material specification if they are not given in the appropriate annex (see 6.2).

The gripped ends may be of any shape to suit the grips of the testing machine. The axis of the test piece shall coincide with the axis of application of the force.

The parallel length,  $L_c$ , or, in the case where the test piece has no transition radii, the free length between the grips, shall always be greater than the original gauge length,  $L_o$ .

### 6.1.3 Unmachined test pieces

If the test piece consists of an unmachined length of the product or of an unmachined test bar, the free length between the grips shall be sufficient for gauge marks to be at a reasonable distance from the grips (see Annexes B to E).

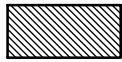
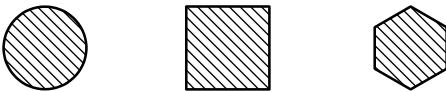
As-cast test pieces shall incorporate a transition radius between the gripped ends and the parallel length. The dimensions of this transition radius are important and it is recommended that they be defined in the product standard. The gripped ends may be of any shape to suit the grips of the testing machine. The parallel length,  $L_c$ , shall always be greater than the original gauge length,  $L_o$ .

## 6.2 Types

The main types of test pieces are defined in Annexes B to E according to the shape and type of product, as shown in Table 2. Other types of test pieces can be specified in product standards.

Table 2 — Main types of test piece according to product type

Dimensions in millimetres

| Type of product                                                                                                                                |                                                                                                                                                | Corresponding Annex |
|------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| <b>Sheets — Plates — Flats</b><br><br><b>Thickness</b><br>$a$ | <b>Wire — Bars — Sections</b><br><br><b>Diameter or side</b> |                     |
| $0,1 \leq a < 3$                                                                                                                               | —                                                                                                                                              | B                   |
| —                                                                                                                                              | $< 4$                                                                                                                                          | C                   |
| $a \geq 3$                                                                                                                                     | $\geq 4$                                                                                                                                       | D                   |
| <b>Tubes</b>                                                                                                                                   |                                                                                                                                                | E                   |

### 6.3 Preparation of test pieces

The test pieces shall be taken and prepared in accordance with the requirements of the relevant International Standards for the different materials (e.g. ISO 377).

## 7 Determination of original cross-sectional area

The relevant dimensions of the test piece should be measured at sufficient cross-sections perpendicular to the longitudinal axis in the central region of the parallel length of the test piece.

A minimum of three cross-sections is recommended.

The original cross-sectional area,  $S_0$ , is the average cross-sectional area and shall be calculated from the measurements of the appropriate dimensions.

The accuracy of this calculation depends on the nature and type of the test piece. Annexes B to E describe methods for the evaluation of  $S_0$  for different types of test pieces and contain specifications for the accuracy of measurement.

## 8 Marking the original gauge length

Each end of the original gauge length,  $L_0$ , shall be marked by means of fine marks or scribed lines, but not by notches which could result in premature fracture.

For proportional test pieces, the calculated value of the original gauge length may be rounded to the nearest multiple of 5 mm, provided that the difference between the calculated and marked gauge length is less than 10 % of  $L_0$ . The original gauge length shall be marked to an accuracy of  $\pm 1$  %.

If the parallel length,  $L_C$ , is much greater than the original gauge length, as, for instance, with unmachined test pieces, a series of overlapping gauge lengths may be marked.

In some cases, it may be helpful to draw, on the surface of the test piece, a line parallel to the longitudinal axis, along which the gauge lengths are marked.

## 9 Accuracy of testing apparatus

The force-measuring system of the testing machine shall be calibrated in accordance with ISO 7500-1, class 1, or better.

For the determination of proof strength (plastic or total extension) the used extensometer shall be in accordance with ISO 9513, class 1 or better, in the relevant range. For other properties (with higher extension) an ISO 9513, class 2 extensometer in the relevant range may be used.

## 10 Conditions of testing

### 10.1 Setting the force zero point

The force-measuring system shall be set to zero after the testing loading train has been assembled, but before the test piece is actually gripped at both ends. Once the force zero point has been set, the force-measuring system may not be changed in any way during the test.

**NOTE** The use of this method ensures, that on one hand the weight of the gripping system is compensated for in the force measurement and on the other hand any force resulting from the clamping operation does not affect this measurement.

### 10.2 Method of gripping

The test pieces shall be gripped by suitable means, such as wedges, screwed grips, parallel jaw faces, or shouldered holders.

Every endeavour should be made to ensure that test pieces are held in such a way that the force is applied as axially as possible, in order to minimize bending (more information is given in ASTM E1012<sup>[8]</sup>, for example). This is of particular importance when testing brittle materials or when determining proof strength (plastic extension), proof strength (total extension) or yield strength.

In order to obtain a straight test piece and ensure the alignment of the test piece and grip arrangement, a preliminary force may be applied provided it does not exceed a value corresponding to 5 % of the specified or expected yield strength.

A correction of the extension should be carried out to take into account the effect of the preliminary force.

### 10.3 Testing rate based on strain rate control (method A)

#### 10.3.1 General

Method A is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results.

Two different types of strain rate control are described in this section. The first is the control of the strain rate itself,  $\dot{\epsilon}_{Le}$ , that is based on the feedback obtained from an extensometer. The second is the control of the estimated strain rate over the parallel length,  $\dot{\epsilon}_{Lc}$ , which is achieved by controlling the crosshead separation rate at a velocity equal to the desired strain rate multiplied by the parallel length.

If a material shows homogeneous deformation behaviour and the force remains nominally constant, the strain rate,  $\dot{\epsilon}_{Le}$ , and the estimated strain rate over the parallel length,  $\dot{\epsilon}_{Lc}$ , are approximately equal. Differences exist if the material exhibits discontinuous or serrated yielding (e.g. some steels and AlMg alloys in the yield point elongation range, or materials which show serrated yielding like the Portevin-Le Chatelier effect) or if

necking occurs. If the force is increasing, the estimated strain rate may be substantially below the target strain rate due to the compliance of the testing machine.

The testing rate shall conform to the following requirements.

- a) In the range up to and including the determination of  $R_{eH}$ ,  $R_p$  or  $R_t$ , the specified strain rate,  $\dot{\epsilon}_{L_e}$  (see 3.7.1), shall be applied. In this range, to eliminate the influence of the compliance of the tensile testing machine, the use of an extensometer clamped on the test piece is necessary to have accurate control over the strain rate. (For testing machines unable to control by strain rate, a procedure using the estimated strain rate over the parallel length,  $\dot{\epsilon}_{L_c}$ , may be used.)
- b) During discontinuous yielding, the estimated strain rate over the parallel length,  $\dot{\epsilon}_{L_c}$  (see 3.7.2), should be applied. In this range, it is impossible to control the strain rate using the extensometer clamped on to the test piece because local yielding can occur outside the extensometer gauge length. The required estimated strain rate over the parallel length may be maintained in this range sufficiently accurately using a constant crosshead separation rate,  $v_c$  (see 3.7.3);

$$v_c = L_c \dot{\epsilon}_{L_c} \quad (1)$$

where

$\dot{\epsilon}_{L_c}$  is the estimated strain rate over the parallel length;

$L_c$  is the parallel length.

- c) In the range following  $R_p$  or  $R_t$  or end of yielding (see 3.7.2),  $\dot{\epsilon}_{L_e}$  or  $\dot{\epsilon}_{L_c}$  can be used. The use of  $\dot{\epsilon}_{L_c}$  is recommended to avoid any control problems which may arise if necking occurs outside the extensometer gauge length.

The strain rates specified in 10.3.2 to 10.3.4 shall be maintained during the determination of the relevant material property (see also Figure 9).

During switching to another strain rate or to another control mode, no discontinuities in the stress-strain curve should be introduced which distort the values of  $R_m$ ,  $A_g$  or  $A_{gt}$  (see Figure 10). This effect can be reduced by a suitable gradual switch between the rates.

The shape of the stress-strain curve in the workhardening range can also be influenced by the strain rate. The testing rate used should be documented (see 10.6).

### 10.3.2 Strain rate for the determination of the upper yield strength, $R_{eH}$ , or proof strength properties, $R_p$ , and $R_t$

The strain rate,  $\dot{\epsilon}_{L_e}$ , shall be kept as constant as possible up to and including the determination of  $R_{eH}$  or  $R_p$  or  $R_t$ . During the determination of these material properties the strain rate,  $\dot{\epsilon}_{L_e}$ , shall be in one of the two following specified ranges (see also Figure 9).

Range 1:  $\dot{\epsilon}_{L_e} = 0,000\ 07\ s^{-1}$ , with a relative tolerance of  $\pm 20\ \%$

Range 2:  $\dot{\epsilon}_{L_e} = 0,000\ 25\ s^{-1}$ , with a relative tolerance of  $\pm 20\ \%$  (recommended unless otherwise specified)

If the testing machine is not able to control the strain rate directly, the estimated strain rate over the parallel length,  $\dot{\epsilon}_{L_c}$ , i.e. constant crosshead separation rate, shall be used. This rate shall be calculated using Equation (1).

The resulting strain rate on the test piece will be lower than the specified strain rate because the compliance of the testing machine is not considered. An explanation is given in Annex F.

### 10.3.3 Strain rate for the determination of the lower yield strength, $R_{eL}$ , and percentage yield point extension, $A_e$

Following the detection of the upper yield strength (see A.4.2), the estimated strain rate over the parallel length,  $\dot{\epsilon}_{L_c}$ , shall be maintained in one of the following two specified ranges (see Figure 9) until discontinuous yielding has ended.

Range 2:  $\dot{\epsilon}_{L_c} = 0,000\ 25\ s^{-1}$ , with a relative tolerance of  $\pm 20\ %$  (recommended, when  $R_{eL}$  is determined)

Range 3:  $\dot{\epsilon}_{L_c} = 0,002\ s^{-1}$ , with a relative tolerance of  $\pm 20\ %$

### 10.3.4 Strain rate for the determination of the tensile strength, $R_m$ , percentage elongation after fracture, $A$ , percentage total extension at the maximum force, $A_{gt}$ , percentage plastic extension at maximum force, $A_g$ , and percentage reduction area, $Z$

After determination of the required yield/proof strength properties, the estimated strain rate over the parallel length,  $\dot{\epsilon}_{L_c}$ , shall be changed to one of the following specified ranges (see Figure 9).

Range 2:  $\dot{\epsilon}_{L_c} = 0,000\ 25\ s^{-1}$ , with a relative tolerance of  $\pm 20\ %$

Range 3:  $\dot{\epsilon}_{L_c} = 0,002\ s^{-1}$ , with a relative tolerance of  $\pm 20\ %$

Range 4:  $\dot{\epsilon}_{L_c} = 0,006\ 7\ s^{-1}$ , with a relative tolerance of  $\pm 20\ %$  ( $0,4\ min^{-1}$ , with a relative tolerance of  $\pm 20\ %$ ) (recommended unless otherwise specified)

If the purpose of the tensile test is only to determine the tensile strength, then an estimated strain rate over the parallel length of the test piece according to range 3 or 4 may be applied throughout the entire test.

## 10.4 Testing rate based on stress rate (method B)

### 10.4.1 General

The testing rates shall conform to the following requirements depending on the nature of the material. Unless otherwise specified, any convenient speed of testing may be used up to a stress equivalent to half of the specified yield strength. The testing rates above this point are specified below.

### 10.4.2 Yield and proof strengths

#### 10.4.2.1 Upper yield strength, $R_{eH}$

The rate of separation of the crossheads of the machine shall be kept as constant as possible and within the limits corresponding to the stress rates in Table 3.

**NOTE** For information, typical materials having a modulus of elasticity smaller than 150 000 MPa include magnesium, aluminium alloys, brass, and titanium. Typical materials with a modulus of elasticity greater than 150 000 MPa include wrought iron, steel, tungsten, and nickel-based alloys.

Table 3 — Stress rate

| Modulus of elasticity of the material<br>$E$<br>MPa | Stress rate<br>$\dot{R}$<br>MPa s <sup>-1</sup> |      |
|-----------------------------------------------------|-------------------------------------------------|------|
|                                                     | min.                                            | max. |
| < 150 000                                           | 2                                               | 20   |
| ≥ 150 000                                           | 6                                               | 60   |

#### 10.4.2.2 Lower yield strength, $R_{eL}$

If only the lower yield strength is being determined, the strain rate during yield of the parallel length of the test piece shall be between 0,000 25 s<sup>-1</sup> and 0,002 5 s<sup>-1</sup>. The strain rate within the parallel length shall be kept as constant as possible. If this rate cannot be regulated directly, it shall be fixed by regulating the stress rate just before yield begins, the controls of the machine not being further adjusted until completion of yield.

In no case shall the stress rate in the elastic range exceed the maximum rates given in Table 3.

#### 10.4.2.3 Upper and lower yield strengths, $R_{eH}$ and $R_{eL}$

If both upper and lower yield strengths are determined during the same test, the conditions for determining the lower yield strength shall be complied with (see 10.4.2.2).

#### 10.4.2.4 Proof strength (plastic extension) and proof strength (total extension), $R_p$ and $R_t$

The rate of separation of the crossheads of the machine shall be kept as constant as possible and within the limits corresponding to the stress rates in Table 3 within the elastic range.

Within the plastic range and up to the proof strength (plastic extension or total extension), the strain rate shall not exceed 0,002 5 s<sup>-1</sup>.

#### 10.4.2.5 Rate of separation

If the testing machine is not capable of measuring or controlling the strain rate, a crosshead separation rate equivalent to the stress rate given in Table 3 shall be used until completion of yield.

#### 10.4.2.6 Tensile strength, $R_m$ , percentage elongation after fracture, $A$ , percentage total extension at the maximum force, $A_{gt}$ , percentage plastic extension at maximum force, $A_g$ , and percentage reduction area, $Z$

After determination of the required yield/proof strength properties, the test rate may be increased to a strain rate (or equivalent crosshead separation rate) no greater than 0,008 s<sup>-1</sup>.

If only the tensile strength of the material is to be measured, a single strain rate can be used throughout the test which shall not exceed 0,008 s<sup>-1</sup>.

### 10.5 Choice of the method and rates

Unless otherwise agreed, the choice of method (A or B) and test rates are at the discretion of the producer or the test laboratory assigned by the producer, provided that these meet the requirements of this part of ISO 6892.

## 10.6 Documentation of the chosen testing conditions

In order to report the test control mode and testing rates in an abridged form, the following system of abbreviation can be used:

ISO 6892 Annn, or ISO 6892 Bn

where 'A' defines the use of method A (strain rate control), and 'B' the use of method B (stress rate based). The symbols 'nnn' are a series of up to 3 characters that refer to the rates used during each phase of the test, as defined in Figure 9, and 'n' may be added to indicate the stress rate (in MPa s<sup>-1</sup>) selected during elastic loading.

EXAMPLE 1 ISO 6892-1:2009 A224 defines a test based on strain rate control, using ranges 2, 2 and 4.

EXAMPLE 2 ISO 6892-1:2009 B30 defines a test based on stress rate, performed at a nominal stress rate of 30 MPa s<sup>-1</sup>.

EXAMPLE 3 ISO 6892-1:2009 B defines a test based on stress rate, performed at a nominal stress rate according to Table 3.

## 11 Determination of the upper yield strength

$R_{eH}$  may be determined from the force-extension curve or peak load indicator and is defined as the maximum value of stress prior to the first decrease in force. The latter is obtained by dividing this force by the original cross-sectional area of the test piece,  $S_0$  (see Figure 2).

## 12 Determination of the lower yield strength

$R_{eL}$  is determined from the force-extension curve and is defined as the lowest value of stress during plastic yielding, ignoring any initial transient effects. The latter is obtained by dividing this force by the original cross-sectional area of the test piece,  $S_0$  (see Figure 2).

For productivity of testing,  $R_{eL}$  may be reported as the lowest stress within the first 0,25 % strain after  $R_{eH}$ , not taking into account any initial transient effect. After determining  $R_{eL}$  by this procedure, the test rate may be increased as per 10.3.4. Use of this shorter procedure should be recorded on the test report.

NOTE This clause only applies to materials having yield phenomena and when  $A_e$  is not to be determined.

## 13 Determination of proof strength, plastic extension

**13.1**  $R_p$  is determined from the force-extension curve by drawing a line parallel to the linear portion of the curve and at a distance from it equivalent to the prescribed plastic percentage extension, e.g. 0,2 %. The point at which this line intersects the curve gives the force corresponding to the desired proof strength plastic extension. The latter is obtained by dividing this force by the original cross-sectional area of the test piece,  $S_0$  (see Figure 3).

If the straight portion of the force-extension curve is not clearly defined, thereby preventing drawing the parallel line with sufficient precision, the following procedure is recommended (see Figure 6).

When the presumed proof strength has been exceeded, the force is reduced to a value equal to about 10 % of the force obtained. The force is then increased again until it exceeds the value obtained originally. To determine the desired proof strength, a line is drawn through the hysteresis loop. A line is then drawn parallel to this line, at a distance from the corrected origin of the curve, measured along the abscissa, equal to the prescribed plastic percentage extension. The intersection of this parallel line and the force-extension curve gives the force corresponding to the proof strength. The latter is obtained by dividing this force by the original cross-sectional area of the test piece,  $S_0$  (see Figure 6).