INTERNATIONAL STANDARD

ISO 6892

Second edition
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Metallic materials — Tensile testing at ambient temperature

Matériaux métalliques — Essai de traction à température ambiante

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ISO 6892:1998(E)

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

This second edition cancels and replaces the first edition (ISO 6892:1984), which has been technically revised.

Annexes A to D form an integral part of this International Standard. Annexes E to L are for information only.

Introduction

During the preparation of this International Standard and discussion concerning the speed of testing, it was decided to recommend for the future to give a preference to the control of strain rate.

Metallic materials — Tensile testing at ambient temperature

1 Scope

This International Standard specifies the method for tensile testing of metallic materials and defines the mechanical properties which can be determined at ambient temperature.

2 Normative references

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

ISO 286-2:1988, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.*

ISO 377:1997, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing.*

ISO 2566-1:1984, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels.*

ISO 2566-2:1984, *Steel — Conversion of elongation values — Part 2: Austenitic steels.*

ISO 7500-1:1986, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tensile testing machines.*

ISO 9513:—[1], *Metallic materials — Verification of extensometers used in uniaxial testing.*

3 Principle

The test involves straining a test piece by tensile force, generally to fracture, for the purpose of determining one or more of the mechanical properties defined in clause 4.

The test is carried out at ambient 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.

1) To be published. (Revision of ISO 9513:1989)

4 Definitions

For the purpose of this International Standard, the following definitions apply.

4.1 gauge length (L)**:** Length of the cylindrical or prismatic portion of the test piece on which elongation shall be measured. In particular, a distinction is made between:

4.1.1 original gauge length (L_o)**:** Gauge length before application of force.

4.1.2 final gauge length (L_u)**:** Gauge length after rupture of the test piece (see 11.1).

4.2 parallel length (L_c)**:** Parallel portion of the reduced section of the test piece.

NOTE — The concept of parallel length is replaced by the concept of distance between grips for non-machined test pieces.

4.3 elongation: Increase in the original gauge length (L_o) at any moment during the test.

4.4 percentage elongation: Elongation expressed as a percentage of the original gauge length (L_o).

4.4.1 percentage permanent elongation: Increase in the original gauge length of a test piece after removal of a specified stress (see 4.9), expressed as a percentage of the original gauge length (L_o).

4.4.2 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).

In the case of proportional test pieces, only if the original gauge length is other than $5{,}65\sqrt{S_o}$ [2)] where S_o is the original cross-sectional area of the parallel length, the symbol A shall be supplemented by an index indicating the coefficient of proportionality used, for example:

$A_{11,3}$ = percentage elongation of a gauge length (L_o) of $11{,}3\sqrt{S_o}$.

In the case of non-proportional test pieces, the symbol A shall be supplemented by an index indicating the original gauge length used, expressed in millimetres, for example:

$A_{80\ mm}$ = percentage elongation of a gauge length (L_o) of 80 mm.

4.4.3 percentage total elongation at fracture (A_t): Total elongation (elastic elongation plus plastic elongation) of the gauge length at the moment of fracture expressed as a percentage of the original gauge length (L_o).

2) $5{,}65\sqrt{S_o} = 5\sqrt{\frac{4S_o}{\pi}}$

4.4. percentage elongation at maximum force: Increase in the gauge length of the test piece at maximum force, expressed as a percentage of the original gauge length (L_o). A distinction is made between the percentage total elongation at maximum force (A_{gt}) and the percentage non-proportional elongation at maximum force (A_g) (see figure 1).

4.5 extensometer gauge length (L_e)**:** Length of the parallel portion of the test piece used for the measurement of extension by means of an extensometer.

It is recommended that for measurement of yield and proof strength parameter $L_e \geqslant L_o/2$.

It is further recommended that for measurement of parameters "at" or "after" maximum force, L_e be approximately equal to L_o.

4.6 extension: Increase in the extensometer gauge length (L_e) at a given moment of the test.

4.6.1 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).

4.6.2 percentage yield point extension (A_e)**:** In discontinuous yielding materials, the extension between the start of yielding and the start of uniform work hardening. It is expressed as a percentage of the extensometer gauge length (L_e).

4.7 percentage reduction of area (Z)**:** Maximum change in cross-sectional area ($S_o - S_u$), which has occurred during the test expressed as a percentage of the orignal cross-sectional area (S_o).

4.8 maximum force (F_m)**:** The greatest force which the test piece withstands during the test once the yield point has been passed.

For materials, without yield point, it is the maximum value during the test.

4.9 stress: At any moment during the test, force divided by the original cross-sectional area (S_o) of the test piece.

4.9.1 tensile strength (R_m)**:** Stress corresponding to the maximum force (F_m).

4.9.2 yield strength: When the metallic material exhibits a yield phenomenon, a point is reached during the test at which plastic deformation occurs without any increase in the force. A distinction is made between:

4.9.2.1 upper yield strength (R_{eH})**:** Value of stress at the moment when the first decrease in force is observed (see figure 2).

4.9.2.2 lower yield strength (R_{eL})**:** Lowest value of stress during plastic yielding, ignoring any initial transient effects (see figure 2).

4.9.3 proof strength, non-proportional extension (R_p)**:** Stress at which a non-proportional extension is equal to a specified percentage of the extensometer gauge length (L_e) (see figure 3). The symbol used is followed by a suffix giving the prescribed percentage, for example: $R_{p0,2}$.

4.9.4 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) (see figure 4). The symbol used is followed by a suffix giving the prescribed percentage for example: $R_{t0,5}$.

4.9.5 permanent set strength (R_r)**:** Stress at which, after removal of force, a specified permanent elongation or extension expressed respectively as a percentage of the original gauge length (L_o) or extensometer gauge length (L_e) has not been exceeded (see figure 5).

The symbol used is followed by a suffix giving the specified percentage of the original gauge length (L_o) or of the extensometer gauge length (L_e), for example: $R_{r0,2}$.

5 Symbols and designations

Symbols and corresponding designations are given in table 1.

6 Test piece

6.1 Shape and dimensions

6.1.1 General

The shape and dimensions of the test pieces depend on 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 constant cross-section (sections, bars, wires, etc.) and also as-cast test pieces (i.e. cast irons 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, of some other shape.

Test pieces, the original gauge length of which is related to the original cross-sectional area by the equation $L_o = k\sqrt{S_o}$ are called proportional test pieces. The internationally adopted value for k is 5,65. The original gauge length shall be not less than 20 mm. When the cross-sectional area of the test piece is too small for this requirement to be met with the coefficient k value of 5,65, a higher value (preferably 11,3) or a non-proportional test piece may be used.

In the case of non-proportional test pieces, the original gauge length (L_o) is taken independently of the original cross-sectional area (S_o).

The dimensional tolerances of the test pieces shall be in accordance with the appropriate annexes (see 6.2).

Table 1 — Symbols and designations

Reference number [1)]	Symbol	Unit	Designation
			Test piece
1	a [2)]	mm	Thickness of a flat test piece or wall thickness of a tube
2	b	mm	Width of the parallel length of a flat test piece or average width of a longitudinal strip from a tube or width of flat wire
3	d	mm	Diameter of the parallel length of a circular test piece, or diameter of round wire or internal diameter of a tube
4	D	mm	External diameter of a tube
5	L_o	mm	Original gauge length
—	L'_o	mm	Initial gauge length for determination of A_g
6	L_c	mm	Parallel length
—	L_e	mm	Extensometer gauge length
7	L_t	mm	Total length of test piece
8	L_u	mm	Final gauge length
—	L'_u	mm	Final gauge length after fracture for determination of A_g (see annex H)
9	S_o	mm^2	Original cross-sectional area of the parallel length
10	S_u	mm^2	Minimum cross-sectional area after fracture
—	k	—	Coefficient of proportionality
11	Z	%	Percentage reduction of area: $\frac{S_o - S_u}{S_o} \times 100$
12	—	—	Gripped ends

Table 1 *(concluded)*

Reference number [1]	Symbol	Unit	Designation
			Elongation
13	—	mm	Elongation after fracture: $L_u - L_o$
14	A [3]	%	Percentage elongation after fracture: $\frac{L_u - L_o}{L_o} \times 100$
15	A_e	%	Percentage yield point extension
—	ΔL_m	mm	Extension at maximum force
16	A_g	%	Percentage non-proportional elongation at maximum force (F_m)
17	A_{gt}	%	Percentage total elongation at maximum force (F_m)
18	A_t	%	Percentage total elongation at fracture
19	—	%	Specified percentage non-proportional extension
20	—	%	Percentage total extension (see 28)
21	—	%	Specified percentage permanent set extension or elongation
			Force
22	F_m	N	Maximum force
			Yield strength — Proof strength — Tensile strength
23	R_{eH}	N/mm^2	Upper yield strength [4]
24	R_{eL}	N/mm^2	Lower yield strength
25	R_m	N/mm^2	Tensile strength
26	R_p	N/mm^2	Proof strength, non-proportional extension
27	R_r	N/mm^2	Permanent set strength
28	R_t	N/mm^2	Proof strength, total extension
—	E	N/mm^2	Modulus of elasticity

1) See figures 1 to 13.
2) The symbol T is also used in steel tube product standards.
3) See 4.4.2.
4) 1 N/mm^2 = 1 MPa

6.1.2 Machined test pieces

Machined test pieces shall incorporate a transition curve between the gripped ends and the parallel length if these have different dimensions. The dimensions of this transition radius may be 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 or be parallel to the axis of application of the force.

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

6.1.3 Non-machined test pieces

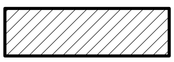
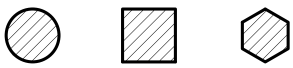
If the test piece consists of an unmachined length of the product or of an unmachined test bar, the free length between the grips shall be sufficient for gauge marks to be at a reasonable distance from the grips (see annexes A and D).

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 piece are defined in annexes A to D according to the shape and type of product, as shown in table 2. Other types of test piece can be specified in product standards.

Table 2 — Main types of test piece

Type of product		Corresponding annex
Sheets — Flats  with a thickness in millimetres of	Wire — Bars — Sections  with a diameter or side in millimetres of	
0,1 ⩽ thickness < 3	—	A
—	< 4	B
⩾ 3	⩾ 4	C
Tubes		D

6.3 Preparation of test pieces

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

7 Determination of original cross-sectional area (S_o)

The original cross-sectional area 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. It is indicated in annexes A to D for the different types of test piece.

8 Marking the original gauge length (L_o)

Each end of the original gauge length 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 off to the nearest multiple of 5 mm, provided that the difference between the calculated and marked gauge length is less than 10 % of L_o. Annex F gives a nomogram for determining the original gauge length corresponding to the dimensions of test pieces of rectangular cross-section. The original gauge length shall be marked to an accuracy of ± 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 drawn.

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 drawn.

9 Accuracy of testing apparatus

The testing machine shall be verified in accordance with ISO 7500-1 and shall be of class 1 or better.

When an extensometer is used it shall be of class 1 (see ISO 9513) for the determination of upper and lower yield strengths and for proof strength (non-proportional extension); for other properties (with higher extension) a class 2 extensometer (see ISO 9513) can be used.

10 Conditions of testing

10.1 Speed of testing

Unless otherwise specified in the product standard, the speed of testing shall conform to the following requirements depending on the nature of the material.

10.1.1 Yield and proof strengths

10.1.1.1 Upper yield strength (R_{eH})

Within the elastic range and up to the upper yield strength, the rate of separation of the crossheads of the machine shall be kept as constant as possible and within the limits corresponding to the stressing rates in table 3.

Table 3 — Rate of stressing

Modulus of elasticity of the material (E) N/mm^2	Rate of stressing N/mm^2·s^{-1}	
	min.	max.
< 150 000	2	20
⩾ 150 000	6	60

10.1.1.2 Lower yield strength (R_{eL})

If only the lower yield strength is being determined, the rate of straining during yield of the parallel length of the test piece shall be between 0,000 25/s and 0,002 5/s. The straining 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 rate of stressing just before yield begins, the controls of the machine not being further adjusted until completion of yield.

In no case shall the rate of stressing in the elastic range exceed the maximum rates given in table 3.

10.1.1.3 Upper and lower yield strengths (R_{eH} and R_{eL})

If the two yield strengths are determined during the same test, the conditions for determining the lower yield strength shall be complied with (see 10.1.1.2).

10.1.1.4 Proof strength (non-proportional extension) and proof strength (total extension) (R_p and R_t)

The rate of stressing shall be within the limits given in table 3.

Within the plastic range and up to the proof strength (non-proportional extension or total extension) the straining rate shall not exceed 0,002 5/s.

10.1.1.5 Rate of separation

If the testing machine is not capable of measuring or controlling the strain rate, a cross head separation speed equivalent to the rate of stressing given in table 3 shall be used until completion of yield.

10.1.2 Tensile strength (R_m)

10.1.2.1 In the plastic range

The straining rate of the parallel length shall not exceed 0,008/s.

10.1.2.2 In the elastic range

If the test does not include the determination of a yield stress (or proof stress), the rate of the machine may reach the maximum permitted in the plastic range.

10.2 Method of gripping