INTERNATIONAL STANDARD

ISO 783

Second edition
1999-08-15

Metallic materials — Tensile testing at elevated temperature

Matériaux métalliques — Essai de traction à température élevée

Reference number
ISO 783:1999(E)

Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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

This second edition cancels and replaces the first edition (ISO 783:1989) which has been technically revised.

Annexes A to E form a normative part of this International Standard. Annex F is for information only.

Metallic materials — Tensile testing at elevated temperature

1 Scope

This International Standard specifies a method of tensile testing of metallic materials at a specified temperature greater than ambient temperature and defines the mechanical properties which can be thereby determined.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

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

ISO 2142, *Wrought aluminium, magnesium and their alloys — Selection of specimens 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 International Standard, the following terms and definitions apply.

3.1
gauge length
length of the parallel portion of the test piece on which elongation is measured at any moment during the test

NOTE In particular a distinction is made between the gauge lengths defined in 3.1.1 and 3.1.2.

3.1.1
original gauge length
L_o
gauge length at ambient temperature before heating of the test piece and before application of force

3.1.2
final gauge length
L_u
gauge length after rupture, the two pieces having been carefully fitted back together so that their axes lie in a straight line, measured at ambient temperature

3.2
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.

3.3
extensometer gauge length
L_e
length of the parallel portion of the test piece used for the measurement of elongation by means of an extensometer

NOTE This length may differ from L_o and could have a value greater than b, d or D (see Table 1) but less than L_c.

3.4
extension
increase in the extensometer gauge length (L_e), at any moment during the test

3.5
elongation
increase in the original gauge length (L_o) under the action of the tensile force, at any moment during the test

3.6
percentage elongation
elongation expressed as a percentage of the original gauge length (L_o)

NOTE In particular, a distinction is made between the elongations defined in 3.6.1 to 3.6.3.

3.6.1
percentage permanent elongation
increase in the original gauge length of a test piece after removal of a specified stress (see 3.8), expressed as a percentage of the original gauge length (L_o)

3.6.2
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)

See Figure 1.

3.6.3
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)

See Figure 1.

3.7
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 original cross-sectional area (S_o)

3.8
maximum force
F_m
the greatest force which the test piece withstands during the test

See Figure 5.

NOTE See comments in annex F.

3.9
stress
force at any moment during the test divided by the original cross-sectional area (S_o) of the test piece

3.9.1
tensile strength
R_m
stress corresponding to the maximum force (F_m)

See Figure 5.

3.9.2
yield strength
when the metallic material exhibits a yield phenomenon, point reached during the test at which plastic deformation occurs without any increase in the force

NOTE Distinction is made between the strengths defined in 3.9.2.1 and 3.9.2.2.

3.9.2.1
upper yield strength
R_{eH}
value of stress at the moment when the first decrease in force is observed

See Figure 2.

3.9.2.2
lower yield strength
R_{eL}
lowest value of stress during plastic yielding, ignoring any transient effects

See Figure 2.

3.9.3
proof strength, non-proportional extension
R_p
stress at which a non-proportional extension is equal to a specified proportion e of the extensometer gauge length (L_e).

See Figure 3.

NOTE The symbol used is to be followed by a subscript giving the specified percentage, e.g.: $R_{p0,2}$

4 Symbols and designations

Symbols used throughout this International Standard and their designation are given in Table 1.

Table 1 — Symbols and designations

Reference number[a]	Symbol	Unit	Designation
			Test piece
—	θ	°C	Fixed temperature
—	θ_i	°C	Indicated temperature
1	a [b]	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
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 after fracture
9	S_o	mm²	Original cross-sectional area of the parallel length
10	S_u	mm²	Minimum cross-sectional area after fracture
—	k	—	Coefficient of proportionality
—	Z	%	Percentage reduction of area: $\frac{S_o - S_u}{S_o} \times 100$
11	—	—	Gripped ends
			Elongation
12	—	mm	Elongation after fracture: $L_u - L_o$
13	A [c]	%	Percentage elongation after fracture: $\frac{L_u - L_o}{L_o} \times 100$
14	A_t	%	Percentage total elongation at fracture
15	—	%	Specified percentage permanent elongation
16	—	%	Specified percentage non-proportional elongation
			Force
17	F_m	N	Maximum force
			Yield strength — Proof strength — Tensile strength
18	R_{eH}	N/mm² [d]	Upper yield strength
19	R_{eL}	N/mm²	Lower yield strength
20	R_m	N/mm²	Tensile strength
21	R_p	N/mm²	Proof strength, non-proportional extension

[a] See Figures 1 to 10.

[b] The symbol T is also used in steel tubes product standards.

[c] In the case of proportional test pieces, only if the original gauge length is other than $5{,}65\sqrt{S_o}$, $5{,}65\sqrt{S_o} = 5\sqrt{\frac{4\,S_o}{\pi}}$, where S_o is the original cross-sectional area of the parallel length, shall the symbol A be supplemented by an index indicating the coefficient of proportionality used, e.g.:

$A_{11,3}$ = percentage elongation of an original 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 a subscript designating the original gauge length used, expressed in millimetres, e.g.:

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

[d] 1 N/mm² = 1 MPa

5 Principle

The test consists of 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 3.

The test is carried out at the specified temperature, which is greater than ambient temperature.

6 Apparatus

6.1 Testing machine

The testing machine shall be verified in accordance with ISO 7500-1 and shall be of at least class 1 unless otherwise specified in the product standard.

6.2 Extensometer

When using an extensometer to measure the elongation, the extensometer shall be of class 1 (see ISO 9513) for the upper and lower yield strengths and for the proof strength for non-proportional extension; for the other characteristics (having higher elongations) an extensometer of class 2 (see ISO 9513) can be used.

The extensometer gauge length shall be not less than 10 mm and shall be centrally located in the mid-region of the parallel length. The extensometer should be preferably of a type that is capable of measuring elongation on both sides of a test piece and allowing the two readings to be averaged.

Any part of the extensometer projecting beyond the furnace shall be designed or protected from draughts so that fluctuations in the ambient temperature have only a minimal effect on the readings. It is advisable to maintain reasonable stability of the temperature and speed of the air surrounding the testing machine.

6.3 Heating device

6.3.1 Permitted deviations of temperature

The heating device for the test piece shall be such that the test piece can be heated to the specified temperature θ.

The permitted deviations between the specified temperature, θ, and the indicated temperature, θ_i, and for the temperature gradient are given in Table 2.

Table 2 — Permitted deviations between the specified temperature, θ, and the indicated temperature, θ_i

Specified temperature θ °C	Permitted deviation between θ and θ_i °C	Temperature gradient °C
$\theta \leqslant 600$	± 3	3
$600 < \theta \leqslant 800$	± 4	4
$800 < \theta \leqslant 1\,000$	± 5	5

For specified temperatures greater than 1 000 °C, the permitted deviations shall be defined by a previous agreement between the parties concerned.

The indicated temperatures, θ_i, are the temperatures which are measured at the surface of the parallel length of the test piece.

The permitted deviations in temperature shall be complied with on the original gauge length, L_o, at least until the point corresponding to the proof strength for non-proportional extension is reached.

6.3.2 Measurement of temperature

The temperature-measuring equipment shall have a resolution of a least 1 °C and an accuracy ± 0,004 θ °C or ± 2 °C whichever is greater.

When the gauge length is less than 50 mm, one thermocouple should be placed at each end of the parallel length. When the gauge length is equal to or greater than 50 mm, a third thermocouple should be placed near the centre of the parallel length.

This number may be reduced if the general arrangement of the furnace and the test piece is such that, from experience, it is known that the variation in temperature of the test piece does not exceed the permitted deviation specified in 6.3.1.

Thermocouple junctions shall make good thermal contact with the surface of the test piece and be suitably screened from direct radiation from the furnace wall.

NOTE Heating by induction coils is not recommended because this type of heating is based on the volume of material within the coils and temperature control problems could occur.

6.3.3 Verification of the temperature-measuring system

All components of the temperature-measuring system shall be verified at intervals not exceeding three months over the working temperature range. If the temperature-measuring system is automatically calibrated every day it is used, or if past successive verifications show that no adjustments were made to the temperature-measuring equipment for it to comply with the requirements of this International Standard, the verification interval can be extended. In no case shall this interval exceed one year. Errors shall be recorded on the verification report. The temperature measuring system shall be verified by a method traceable to the international unit (SI unit) of temperature.

7 Test piece

7.1 Shape and dimensions

7.1.1 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.

NOTE Test pieces with collars/annular knife-edge ridges in this parallel length may be used.

Proportional test pieces are those whose original gauge length is related to the original cross-sectional area by the equation $L_o = k\sqrt{S_o}$. 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 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 7.2).

7.1.2 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 given in the material specification if they are not given in the appropriate annex (see 7.2).

The gripped ends may be of any shape to suit the grips of the testing machine. The axis of 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).

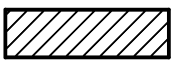
7.1.3 Unmachined test pieces

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).

7.2 Types

The main types of test pieces are defined in annexes A to D according to the shape and type of product, as shown in Table 3. Other types of test piece can be specified in product standards.

Table 3 — Product types

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

7.3 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 (e.g. ISO 377 for steel and steel products, ISO 2142 for wrought aluminium and magnesium and their alloys).

8 Test conditions

8.1 Heating of the test piece

The test piece shall be heated to the specified temperature, θ, and shall be maintained at that temperature for at least 10 min before loading. The loading shall only be started after the indications of the elongation-measuring apparatus have been stabilized.

NOTE Longer times are often required to bring the entire cross section of the material up to the specified temperature.

During heating, the temperature of the test piece shall not, at any moment, exceed the specified temperature with its tolerances, except by special agreement between the parties concerned.

When the test piece has reached the specified temperature, the extensometer shall be reset to zero.

8.2 Loading of the test piece

Force application to the test piece shall be made so as to strain the test piece in a non-decreasing manner, without shock or sudden vibration. The force shall be applied along the specimen axis so as to produce minimum bending or torsion in the specimen gauge length[1)].

8.3 Rate of loading

8.3.1 Determination of yield strength

This deals with upper and lower yield strengths, proof strength non-proportional extension.

The strain rate of the parallel length of the test piece, from the beginning of the test to the yield strength to be determined, shall be between 0,001/min and 0,005/min.

When a test system is incapable of displaying strain rate, the stress rate shall be set so that a strain rate less than 0,003/min is maintained throughout the elastic range. In no case shall the stress rate in the elastic range exceed 300 N/(mm^2·min).

8.3.2 Determination of tensile strength

If only the tensile strength is to be determined, the strain rate of the test piece shall be between 0,02/min and 0,20/min.

If a yield strength is also determined on the same test piece, the change of the stress rate required in 8.3.1 to the rate defined above shall be monotonic.

9 Procedure

9.1 Determination of original cross-sectional area (S_o)

The original cross-sectional area shall be calculated from the measurements of the appropriate dimensions. The precision of the measurement depends on the type of the test piece. The limit of error in determining cross-sectional areas of different types of test piece is given in annexes A to D.

9.2 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 cause premature fracture.

[1)] Examples of methods for verifying alignment can be found in ASTM E1012.