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

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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.

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	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
—	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/mm^2 [d]	Upper yield strength
19	R_{eL}	N/mm^2	Lower yield strength
20	R_m	N/mm^2	Tensile strength
21	R_p	N/mm^2	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/mm^2 = 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 $L_0 = k\sqrt{S_0}$. 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_0) is taken independently of the original cross-sectional area (S_0).

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).

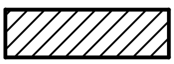
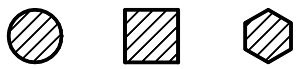
7.1.3 Unmachined test pieces

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_0)

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_0)

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.

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

NOTE Some materials are not notch sensitive. Gauge marking by notches on these materials should be allowed.

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.

If the parallel length (L_c) is much longer than the original gauge length, e.g., with unmachined test pieces, a series of overlapping gauge lengths may be drawn; some of these lengths may extend up to the grips, but the gauge marks shall be within the heated zone.

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.

On an automatic testing machine, the gauge length is defined by the distance between the two knife-edges of the extensometer.

9.3 Determination of percentage elongation after fracture (A)

Percentage elongation after fracture shall be determined in accordance with the definition given in 3.6.2.

For this purpose, the two broken pieces of the test piece are carefully fitted back together so that their axes lie in a straight line.

Special precautions shall be taken to ensure proper contact between the broken parts of the test piece when measuring the final gauge length. This is particularly important when dealing with small cross-sections and low elongation values.

Elongation after fracture ($L_u - L_o$) shall be determined to the nearest 0,25 mm with a measuring device having sufficient resolution and the value of percentage elongation after fracture shall be rounded to the nearest 0,5 %. When using this International Standard to determine percent elongations less than 5 %, measuring of the elongation should be restricted to an extensometer.

This measurement is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one third of the original gauge length (L_o). However the measurement is valid, irrespective of the position of the fracture, if the percentage elongation after fracture is equal to or greater than the specified value.

If so permitted by the product standard, elongation may be measured over a fixed gauge length and converted to proportional gauge length using conversion formulae or tables similar to those given in ISO 2566-1 and ISO 2566-2.

When using an extensometer to measure the elongation after fracture and the total elongation at fracture, the extensometer gauge length, L_e, shall be equal to the original gauge length, L_o.

If the data acquisition system is capable of automatically measuring elongation, gauge marks are not needed. In this case, the elongation measured is the total elongation and the elastic elongation shall be deducted to obtain the percent elongation at fracture.

NOTE Comparisons of percentage elongation are possible only when the gauge length or extensometer gauge length, the shape and area of the cross-section are the same or when the coefficient of proportionality (k) is the same.

9.4 Determination of proof strength non proportional extension (R_p)

The proof strength (non-proportional extension) is determined from the force/extension diagram by drawing a line parallel to the straight portion of the curve and at a distance from this equivalent to the prescribed non-proportional percentage, e.g. 0,2 %. The point at which this line intersects the curve gives the force corresponding to the desired proof strength (non-proportional extension). The latter is obtained by dividing this force by the original cross-sectional area of the test piece (S_o) (see Figure 3).

Accuracy in drawing the force/extension diagram is essential. The curve may be drawn by an automatic recording or a manual method.

If the straight portion of the force/extension diagram is not clearly defined, thereby preventing drawing the parallel line with sufficient precision, the following procedure is recommended (see Figure 4).

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 origin of the curve, measured along the abscissa, equal to the prescribed non-proportional percentage. 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_o) (see Figure 4).

This property may be obtained without plotting the force/extension curve by using automatic devices (e.g.microprocessor, etc.).

Where the extensometer gauge length, L_e, differs from the original gauge length, L_o, the elongation measured shall be expressed as a percentage of the extensometer gauge length, L_e.

9.5 Verification of specified percentage permanent elongation (R_r)

After the test piece has been heated to the specified temperature (see 8.1), monotonically apply the force specified in the product standard, if this verification is required, in accordance with the conditions defined in 8.3.1. Maintain this force, as a general rule, for 10 s to 12 s unless otherwise specified in the product standard. After the force has been removed, verify that the permanent elongation (see 3.6.1) is not more than the specified percentage.

10 Test report

The test report shall contain at least the following information.

a) reference to this International Standard, i.e. ISO 783;

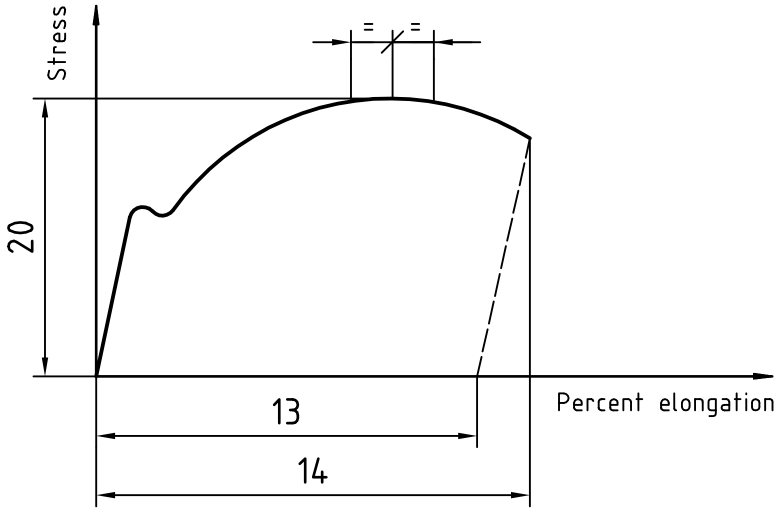
b) identification of the test piece;

c) nature of the material, if known;

d) type of test piece;

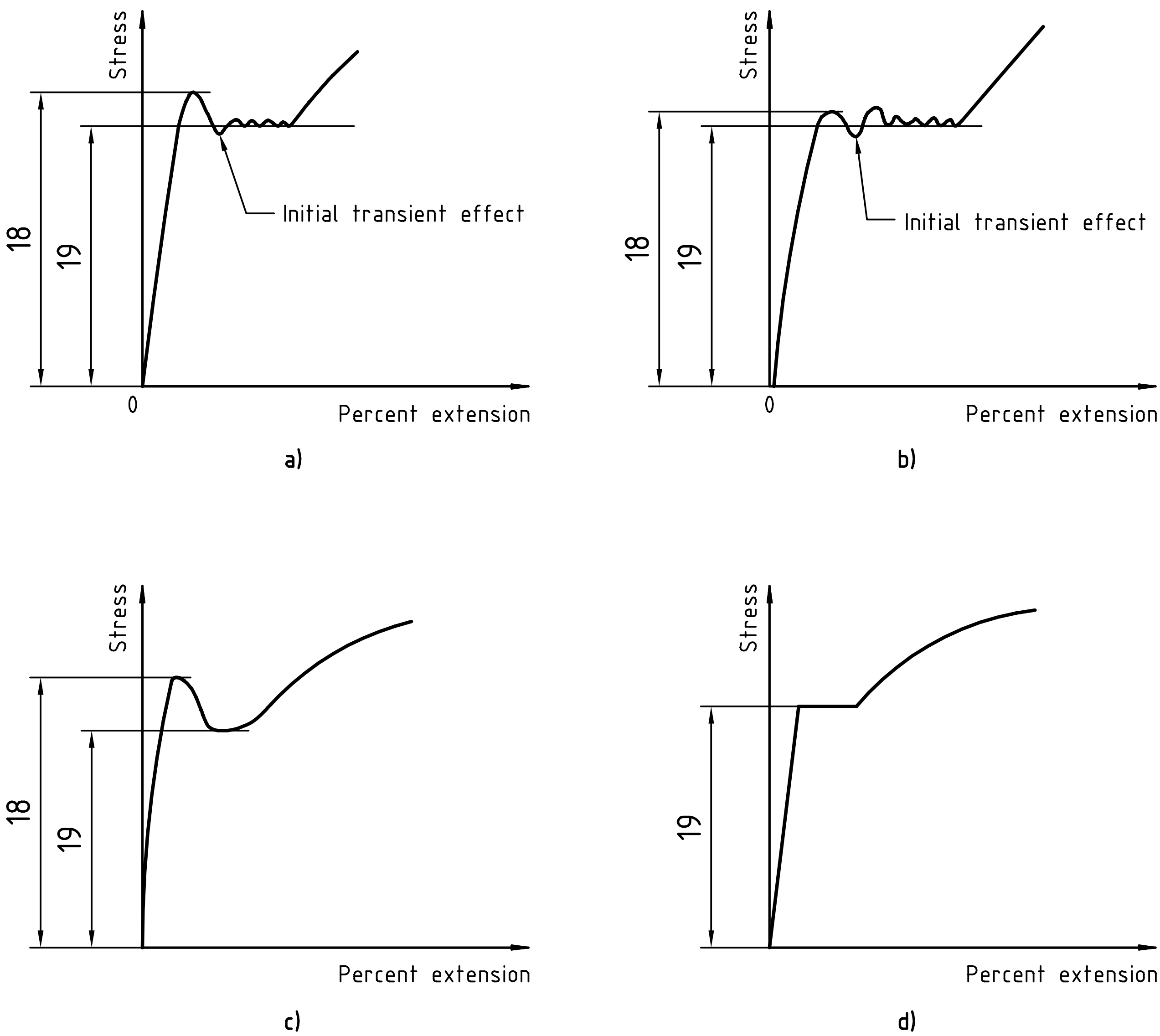
e) specified temperature, indicated temperatures and/or the gradient, if outside the permitted limits;

f) measured properties and results.



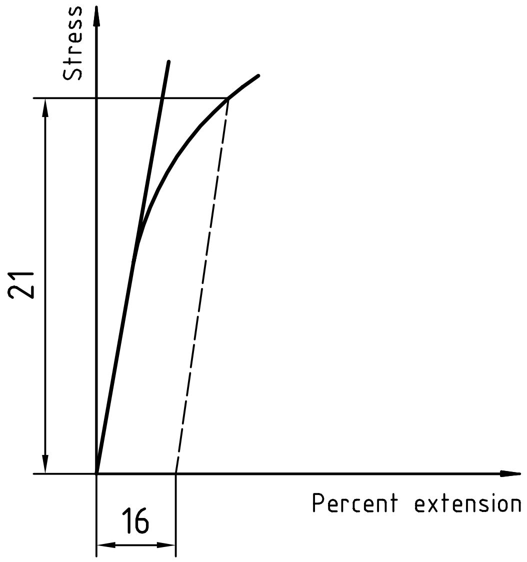
NOTE For the explanation of reference numbers see Table 1.

Figure 1 — Definitions of elongation



NOTE For the explanation of reference numbers see Table 1.

Figure 2 — Definitions of upper and lower yield strength for different types of curve



NOTE For the explanation of reference numbers see Table 1.

Figure 3 — Proof strength, non-proportional extension (R_p)

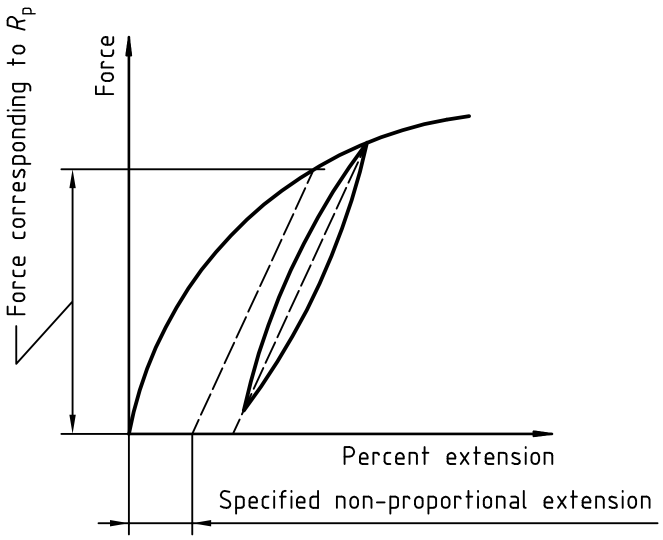
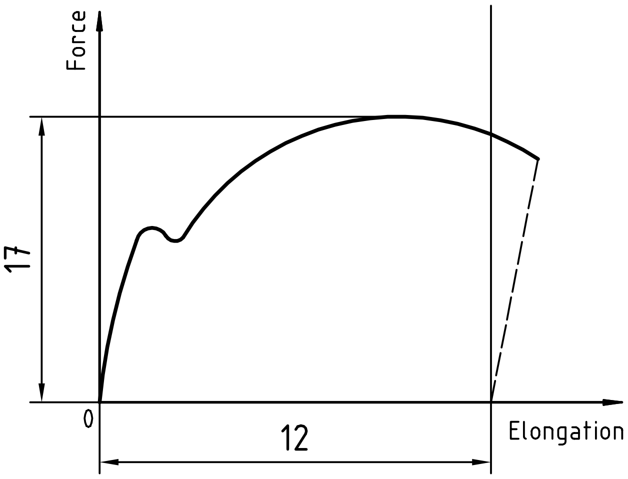
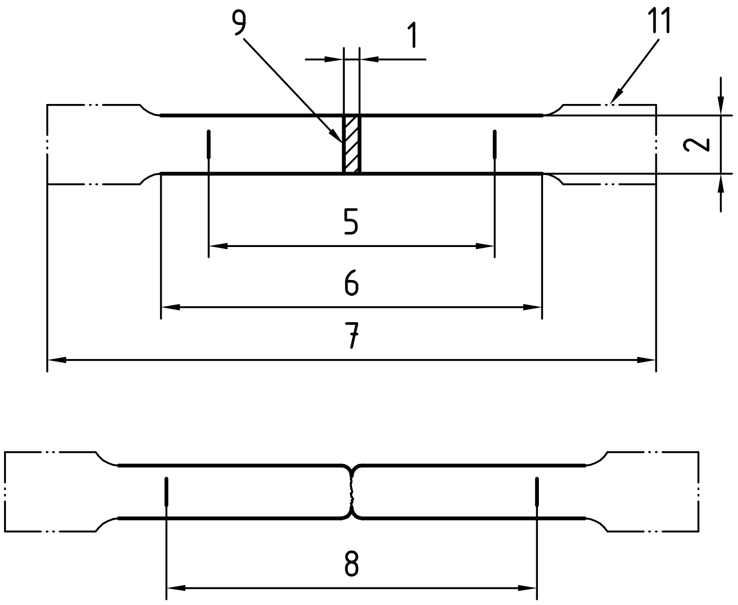


Figure 4 — Proof strength, non-proportional extension (R_p) (see 9.4)



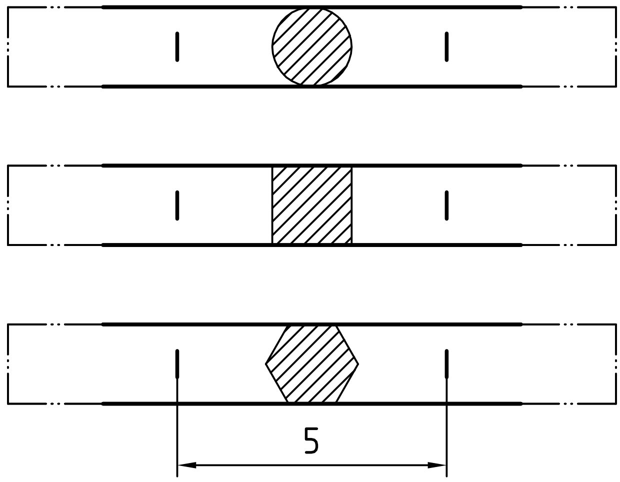
NOTE For the explanation of reference numbers see Table 1.

Figure 5 — Maximum force



NOTE For the explanation of reference numbers see Table 1.

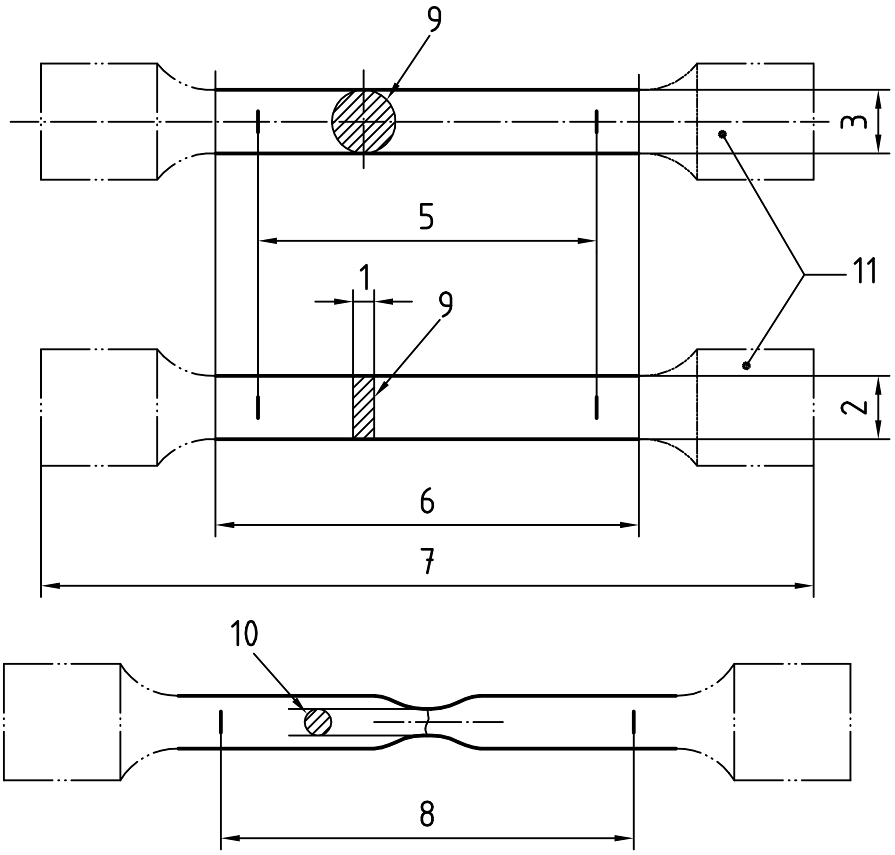
Figure 6 — Machined test pieces of rectangular cross section (see annex A)



NOTE 1 The shape of the test piece heads is given only as a guide.

NOTE 2 For the explanation of reference numbers see Table 1.

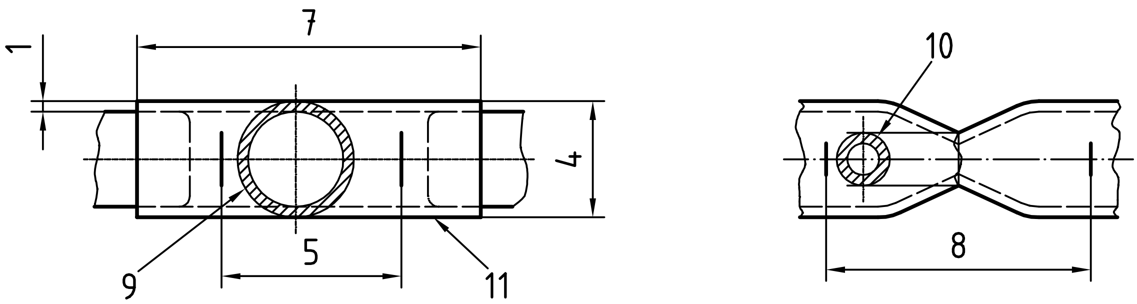
Figure 7 — Test pieces comprising a non-machined portion of the product (see annex B)



NOTE 1 The shape of the test piece heads is given only as a guide.

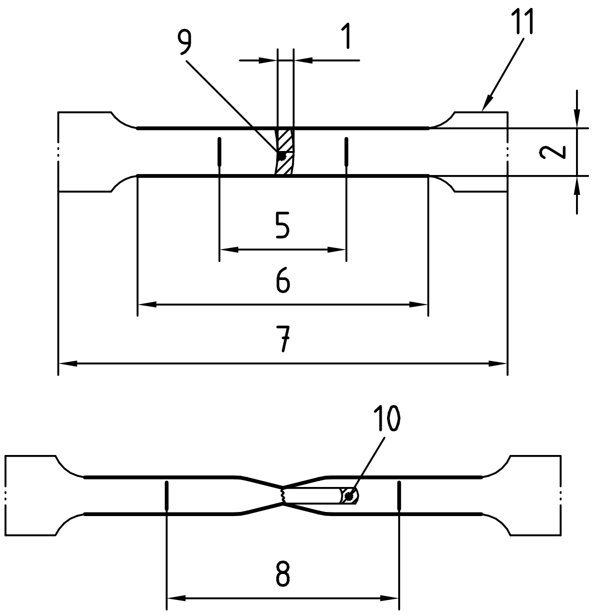
NOTE 2 For the explanation of reference numbers see Table 1.

Figure 8 — Proportional test pieces (see annex C)



NOTE For the explanation of reference numbers see Table 1.

Figure 9 — Test pieces comprising a length of tube (see annex D)



NOTE 1 The shape of the test piece heads is given only as a guide.

NOTE 2 For the explanation of reference numbers see Table 1.

Figure 10 — Test piece cut from a tube (see annex D)

Annex A
(normative)

Types of test piece to be used for thin products: sheets, strips and flats between 0,1 mm and 3 mm thick

For products of less than 0,5 mm thickness, special precautions may be necessary.

A.1 Shape of the test piece

Generally, the test piece has gripped ends which are wider than the parallel length. The parallel length (L_c) shall be connected to the ends by means of transition curves with a radius of at least 20 mm (see Figure 6). The width of these ends shall be at least 20 mm and not more than 40 mm.

By agreement, the test piece may also consist of a strip with parallel sides. For products of width equal to or less than 20 mm, the width of the test piece may be the same as that of the product.

A.2 Dimensions of the test piece

The parallel length shall not be less than $L_o + \frac{b}{2}$.

In case of dispute, the length $L_o + 2b$ shall always be used unless there is insufficient material.

In the case of parallel-sided test pieces less than 20 mm wide, and unless otherwise specified in the product standard, the original gauge length (L_o) shall be equal to 50 mm. For this type of test piece, the free length between the grips shall be equal to $L_o + 3b$.

There are two types of non-proportional test pieces, with dimensions as given in Table A.1.

When measuring the dimensions of each test piece, the tolerances on shape given in Table A.2 shall apply.

In the case of test pieces where the width is the same as that of the product, the original cross-sectional area (S_o) is to be calculated on the basis of the measured dimensions of the test piece.

To avoid measuring the width of the test piece at the time of the test, the nominal width may be used provided the test piece meets the machining tolerances and tolerances on shape given in Table A.2.

Table A.1 — Dimensions of test pieces

Dimensions in millimetres

Test piece type	Width b	Original gauge length L_o	Parallel length L_c	Free length between the grips for parallel side test piece
1	12,5 ± 1	50	75	87,5
2	20 ± 1	80	120	140

Table A.2 — Tolerances on the width of the test piece

Dimensions and tolerances in millimetres

Nominal width of the test piece	Machining tolerance [a]	Tolerance on shape [b]
12,5	± 0,09	0,04
20	± 0,1	0,05

[a] Tolerances js12 are in accordance with ISO 286-2. These tolerances are applicable if the nominal value of the original cross-sectional area (S_o) is to be included in the calculation without having to measure it.

[b] Tolerances IT9 (see ISO 286-2).

A.3 Preparation of test pieces

The test pieces are prepared so as not to affect the properties of the metal. Any areas which have been hardened by shearing or pressing shall be removed by machining.

For very thin materials, it is recommended that strips of identical widths be cut and assembled into a bundle with intermediate layers of a paper which is resistant to the cutting oil. It is recommended that each small bundle of strips be assembled with a thicker strip on each side, before machining to the final dimensions of test piece.

A.4 Determination of the original cross-sectional area (S_o)

The original cross-sectional area shall be calculated from measurements of the dimensions of the test piece.

The error in determining the original cross-sectional area shall not exceed ± 2 %. Since greatest part of this error normally results from the measurement of the thickness of the test piece, the error in measurement of the width shall not exceed ± 0,2 %.

Annex B
(normative)

Types of test piece to be used for wire, bars and sections with a diameter or thickness of less than 4 mm

B.1 Shape of the test piece

The test piece generally consists of an unmachined portion of the product (see Figure 7).

B.2 Dimensions of the test piece

The original gauge length (L_o) shall be taken as 200 mm ± 2 mm or 100 mm ± 1 mm. The distance between the grips of the machine shall be equal to at least $L_o + 50$ mm, i.e. 250 mm and 150 mm respectively, except in the case of small diameter wires where this distance can be taken as equal to L_o.

NOTE In cases where the percentage elongation after fracture is not to be determined, a distance between the grips of at least 50 mm may be used.

B.3 Preparation of test pieces

If the product is delivered coiled, care shall be taken in straightening it.

B.4 Determination of the original cross-sectional area (S_o)

The original cross-sectional area (S_o) shall be determined to an accuracy of ± 1 %.

For products of circular cross-section, the original cross-sectional area may be calculated from the arithmetic mean of two measurements carried out in two perpendicular directions.

The original cross-sectional area (S_o) may also be determined from the mass of a known length and its density.

Annex C
(normative)

Types of test piece to be used for sheets and flats of thickness equal to or greater than 3 mm, and wire, bars and sections of diameter or thickness equal to or greater than 4 mm

C.1 Shape of the test piece

In general, the test piece is machined and the parallel length shall be connected by means of transition curves to the gripped ends which may be of any suitable shape for the grips of the test machine (see Figure 8). The minimum transition radius between the grip ends and the parallel length shall be:

— 0,75d (d being the diameter of the parallel length) for the cylindrical test pieces;

— 12 mm for the prismatic test pieces.

Sections, bars, etc., may be tested unmachined, if required.

The cross-section of the test piece may be circular, square, rectangular or, in special cases, of another shape.

For test pieces with a rectangular cross-section, it is recommended that the width to thickness ratio should not exceed 8:1.

In general, the diameter of the parallel length of machined cylindrical test pieces shall be not less than 4 mm.

C.2 Dimensions of the test piece

C.2.1 Parallel length of machined test piece

The parallel length (L_c) shall be at least equal to

a) $L_o + \frac{d}{2}$ in the case of test pieces with circular cross-section;

b) $L_o + 1{,}5\sqrt{S_o}$ in the case of prismatic test pieces.

Depending on the type of test piece, the length $L_o + 2d$ or $L_o + 2\sqrt{S_o}$ shall be used in cases of dispute, unless there is insufficient material.

C.2.2 Length of unmachined test piece

The free length between the grips of the machine shall be adequate for the gauge marks to be at a reasonable distance from these grips.

C.2.3 Original gauge length (L_o)

C.2.3.1 Proportional test pieces

As a general rule, proportional test pieces are used where the original gauge length (L_o) is related to the original cross-sectional area (S_o) by the equation:

$$L_o = k\sqrt{S_o}$$

where k = 5,65.

Test pieces of circular cross-section preferably have the dimensions given in Table C.1.

Table C.1 — Dimensions of circular cross-section test pieces

   k	Diameter d mm	Original cross sectional area S_o mm^2	Original gauge length $L_o = k\sqrt{S_o}$ mm	Minimum parallel length L_c mm	Total length L_t
5,65	20 ± 0,15	314	100 ± 1	110	Depends on the method of fixing the test piece in the machine grips. In principle: $L_t > L_c + 2d$ or $4d$
	10 ± 0,075	78,5	50 ± 0,5	55	
	5 ± 0,04	19,6	25 ± 0,25	28	

C.2.3.2 Non-proportional test pieces

Non-proportional test pieces may be used if specified by the product standard.

C.3 Preparation of test pieces

The tolerances on the transverse dimensions of machined test pieces are given in Table C.2.

An example of the application of these tolerances is given below.

a) Machining tolerances:

The value given in Table C.2, for example ± 0,075 mm for a nominal diameter of 10 mm, means that no test piece shall have a diameter outside the two values given below, if the nominal value of the original cross-sectional area (S_o) is to be included in the calculation without having to measure it.

10 + 0,075 = 10,075 mm

10 − 0,075 = 9,925 mm

b) Tolerances on shape:

The value given in Table C.2 means that, for a test piece with a nominal diameter of 10 mm which satisfies the machining conditions given above, the deviation between the smallest and largest diameters measured shall not exceed 0,04 mm.

Consequently, if the minimum diameter of this test piece is 9,99 mm, its maximum diameter shall not exceed 9,99 + 0,04 = 10,03 mm.

Table C.2 — Tolerances relating to the transverse dimensions of test pieces

Dimensions and tolerances in millimetres

Designation	Nominal transverse dimension	Machining tolerance on the nominal dimension [a]	Tolerance on shape
Diameter of machined test pieces of circular cross-section	3	± 0,05	0,025 [b]
	> 3 ≤ 6	± 0,06	0,03 [b]
	> 6 ≤ 10	± 0,075	0,036 [b]
	> 10 ≤ 18	± 0,09	0,043 [b]
	> 18 ≤ 30	± 0,105	0,052 [b]
Transverse dimensions of test pieces of rectangular cross-section machined on all four sides		Same tolerance as on the diameter of test pieces of circular cross-section	
Transverse dimensions of test pieces of rectangular cross-section machined on only two opposite sides	3		0,14 [c]
	> 3 ≤ 6		0,18 [c]
	> 6 ≤ 10		0,22 [c]
	> 10 ≤ 18		0,27 [c]
	> 18 ≤ 30		0,33 [c]
	> 30 ≤ 50		0,39 [c]

[a] Tolerances js12 are in accordance with ISO 286-2. These tolerances are applicable if the nominal value of the original cross-sectional area (S_o) is to be included in the calculation without having to measure it.

[b] Tolerances IT9:
[c] Tolerances IT13:
} Maximum deviation between the measurements of a specified transverse dimension along the entire parallel length (L_c) of the test piece.

C.4 Determination of the cross-sectional area (S_o)

The nominal diameter can be used to calculate the original cross-sectional area of test pieces of circular cross-section which satisfy the tolerances given in Table C.2. For all other shapes of test piece, the original cross-sectional area shall be calculated from measurements of the appropriate dimensions, with an error not exceeding ± 0,5 % on each dimension.

Annex D
(normative)

Types of test piece to be used for tubes

D.1 Shape of the test piece

The test piece consists either of a length of tube or a longitudinal or transverse strip cut from the tube and having the full thickness of the wall tube (see Figures 9 and 10), or of a test piece of circular cross-section machined from the wall of the tube.

Machined transverse, longitudinal and circular cross-section test pieces are described in annex A for tube wall thickness less than 3 mm and in annex C for thickness equal to or greater than 3 mm. The longitudinal strip is generally used for tubes with a wall thickness of more than 0,5 mm.

D.2 Dimensions of the test piece

D.2.1 Length of tube

The length of tube may be plugged at both the ends. The free length between each plug and the nearest gauge marks shall exceed $D/4$. In cases of dispute, the value D shall be used, as long as there is sufficient material.

The length of the plug projecting relative to the grips of the machine in the direction of the gauge marks shall not exceed D, and its shape shall be such that it does not interfere with the gauge length elongation.

D.2.2 Longitudinal or transverse strip

The parallel length (L_c) of the longitudinal strips shall not be flattened but the gripped ends may be flattened for gripping in the testing machine.

Transverse or longitudinal test piece dimensions other than those given in annexes A and C can be specified in the product standard.

Special precautions shall be taken when straightening the transverse test pieces.

D.2.3 Circular cross-section test piece machined in tube wall

The sampling of the test pieces is specified in the product standard.

D.3 Determination of the original cross-sectional area (S_o)

The original cross-sectional area (S_o) of the test piece shall be determined to the nearest ± 1 %.

The original cross-section area (S_o) may be determined from the measured length and measured mass of the test piece, and from its density.

The original cross-sectional area (S_o) of a test piece consisting of a longitudinal or transverse strip shall be calculated according to the following equation:

$$S_o = \frac{b}{4}(D^2 - b^2)^{1/2} + \frac{D^2}{4} \arcsin\frac{b}{D} - \frac{b}{4}[(D-2a)^2 - b^2]^{1/2} - \left(\frac{D-2a}{2}\right)^2 \arcsin\frac{b}{D-2a}$$

where

a is the thickness of the tube wall;

b is the average width of the strips;

D is the external diameter.

The following simplified equations can be used for longitudinal or transverse test pieces:

$$S_o = ab\left[1 + \frac{b^2}{6D(D-2a)}\right] \text{ when } \frac{b}{D} < 0{,}25$$

$$S_o = ab \text{ when } \frac{b}{D} < 0{,}17$$

In the case of length of tube, the original cross-sectional area (S_o) shall be calculated as follows:

$$S_o = \pi\, a(D - a)$$

Annex E
(normative)

Measurement of percentage elongation after fracture based on subdivision of the original gauge length

To avoid having to reject test pieces where the position of the fracture does not comply with the conditions of 9.3, the following method may be used, by agreement:

a) before the test, subdivide the original gauge length (L_o) into N equal parts;

b) after the test, use the symbol X to denote the gauge mark on the shorter piece and the symbol Y to denote on the longer piece, the subdivision of which is at the same distance from the fracture as mark X.

If n is the number of intervals between X and Y, the elongation after fracture is determined as follows:

1) if $N - n$ is an even number [see Figure E.1 a)], measure the distance between X and Y and the distance from Y to the graduation mark Z located at:

$\frac{N-n}{2}$ intervals beyond Y

calculate the percentage elongation after fracture using the equation:

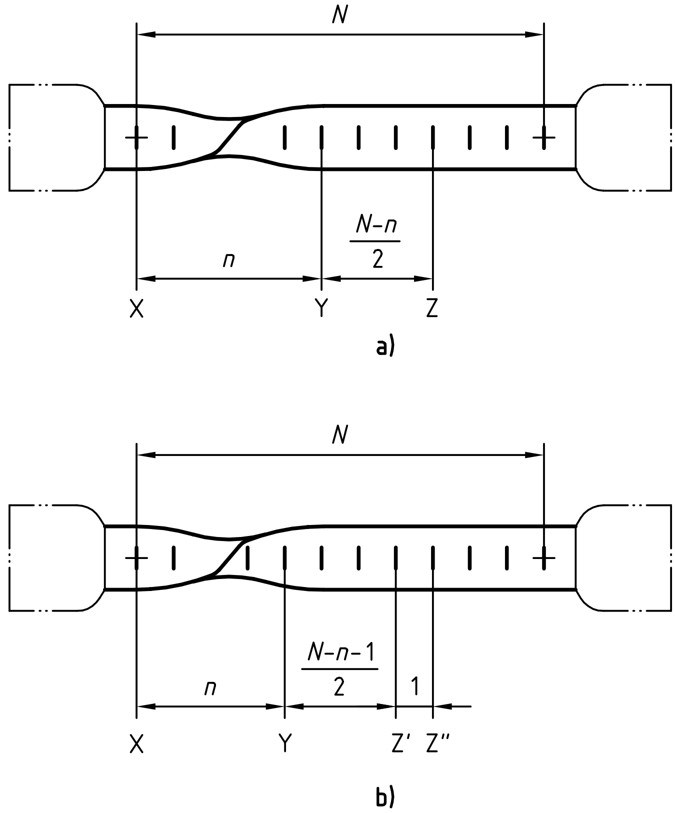
$$A = \frac{\mathrm{XY} + 2\mathrm{YZ} - L_o}{L_o} \times 100$$

2) if $N - n$ is an odd number [Figure E.1 b)], measure the distance between X and Y and the distance from Y to the graduation marks Z' et Z'' located respectively at:

$\frac{N-n-1}{2}$ and $\frac{N-n+1}{2}$ intervals beyond Y

calculate the percentage elongation after fracture using the equation:

$$A = \frac{\mathrm{XY} + \mathrm{YZ'} + \mathrm{YZ''} - L_o}{L_o} \times 100$$



NOTE The shape of the test piece heads is given only as a guide.

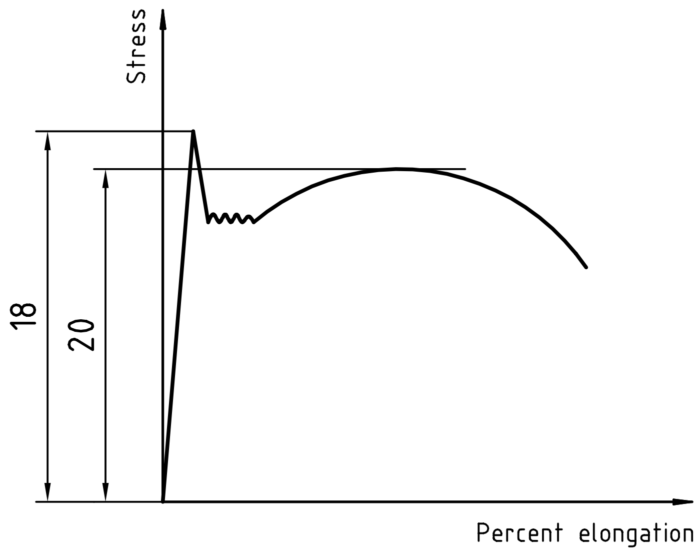
Figure E.1 — Measurement of percentage elongation after fracture based on subdivision of the original gauge length

Annex F
(informative)

Precautions recommended when measuring the tensile strength of materials showing a special yield phenomenon

For materials showing a special yield phenomenon the stress corresponding to the upper yield point, R_{eH}, may be higher than any value of the stress after that point (second maximum, see Figure F.1). In such a case; it is necessary to select one of the two maximum values for the calculation of the tensile strength.

The chosen maximum should be that specified in the product standard or by agreement between the parties concerned.



NOTE For the explanation of reference numbers see Table 1.

Figure F.1 — Tensile strength of materials showing a special yield phenomenon

Bibliography

[1] ASTM E1012-97, *Standard Practice for Verification of Specimen Alignment Under Tensile Loading.*

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