Metallic materials-Tensile testing Method of test at room temperature

Contents

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Introduction

This Standard has been prepared based on the first edition of ISO 6892-1 published in 2009 with some modifications of the technical contents.

The portions given side-lines or dotted underlines are the matters in which the contents of the corresponding International Standard have been modified. A list of modifications with the explanations is given in Annex JC.

1 Scope

This Standard specifies the method for tensile testing of metallic materials and defines the mechanical properties thereof which can be measured at room temperature (between 10 °C and 35 °C).

NOTE: The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

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

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and JIS are IDT (identical), MOD (modified), and NEQ (not equivalent) according to ISO/IEC Guide 21-1.

Warning: Persons carrying out tests based on this Standard should be familiar with normal laboratory practice. This Standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this Standard to establish appropriate safety and health practices.

2 Normative references

The following standards contain provisions which, through reference in this text constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 7721 Tension/compression testing machines-Verification and calibration of the force-measuring system.

NOTE: Corresponding International Standard: ISO 7500-1:2004 Metallic Materials-Verification of static uniaxial testing machines-Part 1: Tension/compression testing machines Verification and calibration of the force
measuring system (MOD)

JIS B 7741 Verification of extensometers used in uniaxial testing

NOTE: Corresponding International Standard: ISO/DIS 9513:1996 Metallic Materials-Verification of extensometers used in uniaxial testing (MOD)

<u>**JIS G 0202**</u> <u>Glossary of terms used in iron and steel (testing)</u>

<u>**JIS Z 8401**</u> <u>Guide to the rounding of numbers</u>

3   Terms and definitions

For the purposes of this Standard, the terms and definitions given in JIS G 0202 and the following definitions apply.

3.1 gauge length L

length of the parallel portion of the test piece on which elongation is measured, <u>which is particularly classified as follows</u>

3.1.1   original gauge length L_0

gauge Length (3.1) marked on the test piece measured at room temperature before the test.

3.1.2   final gauge length after rupture, final gauge length after fracture L_u

gauge length (3.1) marked on the test piece measured at room temperature after rupture.

At the measurement, two fractured parts of the test piece shall be carefully fitted back together so that their axes lie in a straight line.

3.2   parallel length L_e

length of the parallel portion where the cross-sectional area of the test piece is reduced

NOTE: For the unmachined test pieces, the parallel length is replaced by the distance between grips.

3.3   elongation

increase in the original gauge length L_0 (3.1.1) at any moment during the test

3.4   percentage elongation

increase in the original gauge length L_0 (3.1.1), expressed as a percentage of the original gauge length

3.4.1   percentage permanent elongation

increase in the original gauge length L_0 (3.1.1) after removal of a specified stress, expressed as a percentage of the original gauge length

3.4.2 **percentage** elongation after fracture A

permanent elongation (L_u.-L_0), expressed as a percentage of the original gauge length L_0 (3.1.1)

NOTE: For proportional test pieces, if the original gauge length is not equivalent to $5.65 \sqrt{S_0}$[1], (where, S_0 is the original cross-sectional area of parallel portion), the symbol A should be supplemented by a subscript indicating the coefficient of proportionality used.

Ans: percentage elongation after fracture of gauge length of $11.3 \sqrt{S_0}$

Note [1] $5.65 \sqrt{S_0} = 5 \sqrt{\dfrac{4S_0}{\pi}}$

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.

$A_{80\,mm}$: percentage elongation after fracture of gauge length of 80 mm.

3.4.3 percentage total extension at fracture A$_1$

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

See figure 1.

NOTE: In **ISO 6892-1,** the definitions in **3.4.3** to **3.4.6** of this Standard are described in 3.6 of ISO 6892-1 as that relevant to the extension.

3.4.4 percentage total extension at maximum force A$_{gt}$

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

See figure 1.

3.4.5 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.
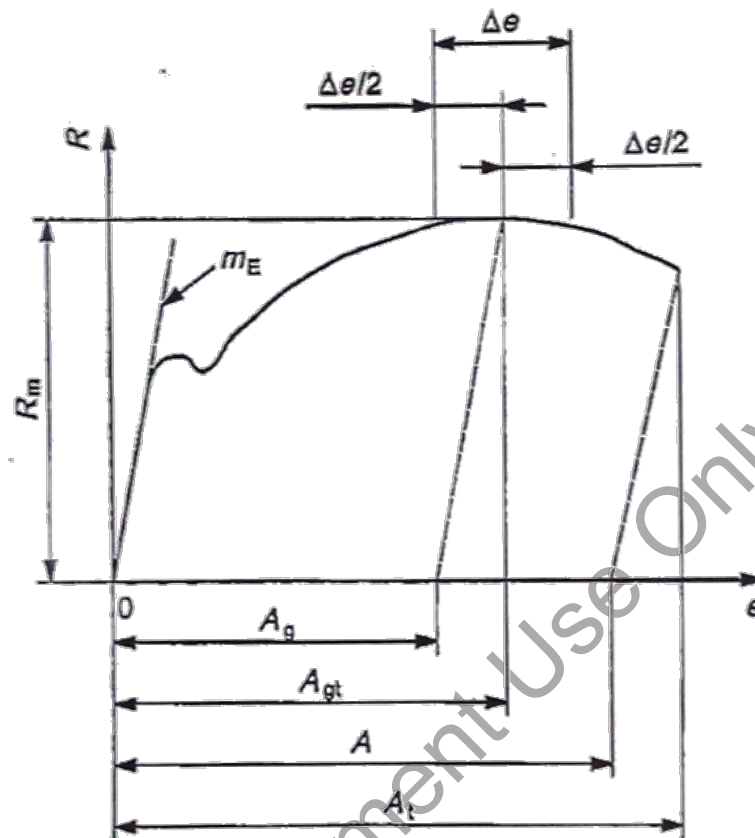
A: percentage elongation after fracture [measured by extensometer or directly from test piece (see 20.1)]

A_g: percentage plastic extension at maximum force

A_{gt} percentage total extension at maximum force

A_t percentage total extension at fracture

e   percentage extension

m_E: slope of elastic part of stress-percentage extension curve

R: stress

Rm   tensile strength

Δe plateau extent (for definitions, see clause 17 for A_g and clause 18 for A_{gt})

Figure 1 Definitions of extension

3.4.6 percentage yield point extension A_e.

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

See figure 7.

3.5 extensometer gauge length L_e

extensometer gauge length before the test used for measurement of extension by means of an extensometer

NOTE: For the measurement of yield point and proof strength, the extensometer gauge length L_e should span as much of the parallel portion of the test piece as possible. Ideally, as a minimum of Le should be greater than $0.50 \, L_o$ but less than approximately $0.90 \, L_e$. 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

3.6.1 percentage extension

increase in the extensometer gauge length L_e (3.5), expressed as a percentage of the extensometer gauge length

3.6.2 percentage permanent extension

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

3.7 testing rate

3.7.1 strain rate e_{Lg}

increase of strain per time measured from the extensometer gauge length L_e. **(3.5)**

NOTE: See **3.5.**

3.7.2 estimated strain rate over the parallel length $\grave{e}_{Le}$

increase of strain per time over the parallel length L_e (**3.2**) of the test piece obtained based on the crosshead separation rate v_c (3 7.3) and the parallel length of the test piece

(3.7.3) crosshead separation rate v_c.

displacement of the crosshead per time

3.7.4 stress rate R

increase of stress per time

NOTE: The stress rate should be applied only in the elastic part.

3.8 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

$$Z = \frac{S_o - S_u}{S_0} \times 100$$

3.9 maximum force

NOTE 1   When specifying the maximum force for the materials exhibiting discontinuous yielding but

subjected to no workhardening, it shall be <u>upon the agreement between the parties concerned with delivery.</u>

NOTE 2   See figure 8 c).

3.9.1 maximum force F_m

highest force that the test piece withstands during the test for the case of materials exhibiting no discontinuous yielding

NOTE: See figure 8 a).

3.9.2 maximum force F_m

highest force that the test piece withstands after the beginning of workhardening for the case of materials exhibiting discontinuous yielding.

NOTE: See figure 8 b).

3.10 stress R

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

NOTE 1   All references to stress in this Standard are to engineering stress.

NOTE 2   In what follows, the designations of "force" and "stress", or "extension", "percentage extension" and "strain", respectively, are used on various occasions (as figure axis labels or in explanations for the definition 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**)

3.10.2 yield strength (yield point)

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

3.10.2.1 upper yield strength (upper yield point) R_{eH}

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

See figure 2.

3.10.2.2 lower yield strength (lower yield point) R_{eL}

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

See figure 2.
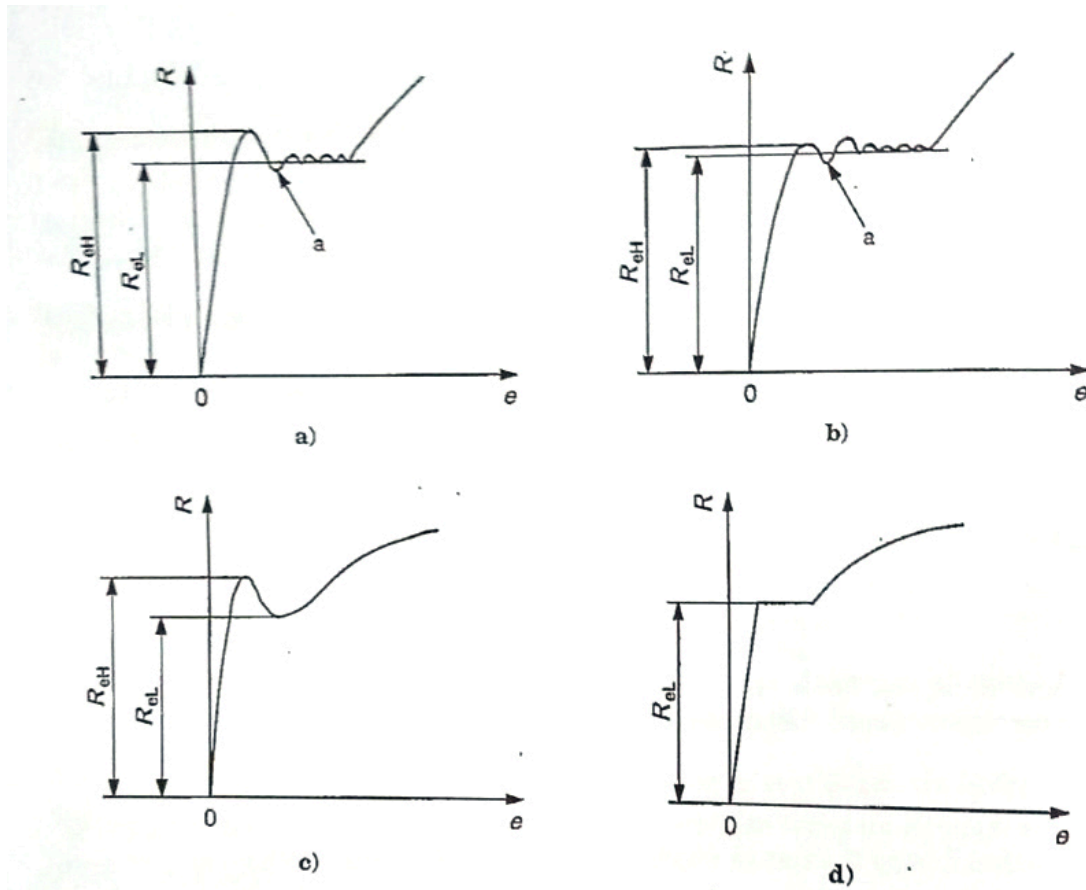
e	:	percentage extension
R	:	stress
R_{eH}	:	upper yield strength (upper yield point)
R_{eH}	:	lower yield strength (lower yield point)
a	:	initial transient effect

Figure 2   Upper yield strength (upper yield point) and lower yield strength (lower yield point)

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   :   a suffix is added to the subscript to indicate the prescribed percentage (e.g., $R_{P0.2}$)

See figure 3,
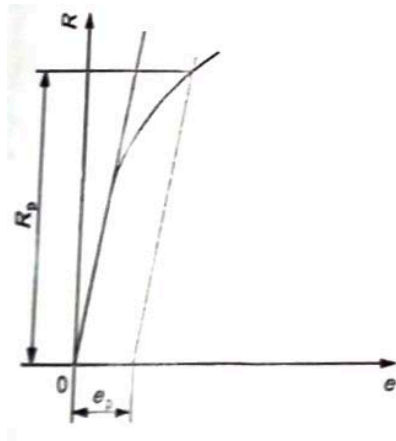
e	:	percentage extension
e_p	:	specified percentage plastic extension
R	:	stress
R_p	:	proof strength (plastic extension)

e	:	percentage extension
e_1	:	specified percentage total extension
R	:	stress
R_1	:	proof strength (total extension)

Figure 3   Proof strength (plastic extension)   **Figure 4   Proof strength (total extension)**

3.10.4 proof strength, total extension R_t.
stress at which total extension (elastic extension plus plastic extension of extensometer) is equal to a specified percentage of the extensometer gauge length L_0 (**3.5**) (**see figure 4**)

> **NOTE:**   A suffix is added to the subscript to indicate the prescribed percentage (e.g., $R_{t0.5}$)

3.10.5 permanent set strength R_r.
stress at which the plastic deformation of the specified percentage permanent elongation or the percentage permanent extension or under occurs, after removal of force

The percentage permanent elongation or the percentage permanent extension are expressed as a percentage of the original gauge length L_0 (**3.1.1**) and the extensometer gauge length L_e (**3.5**), respectively (see figure 5).

> **NOTE:** A suffix is added to the subscript to indicate the specified percentage of the original gauge length L_0 (**3.1.1**) or the extensometer gauge length L_e (**3.5**) (e.g., $R_{ro}.2$).
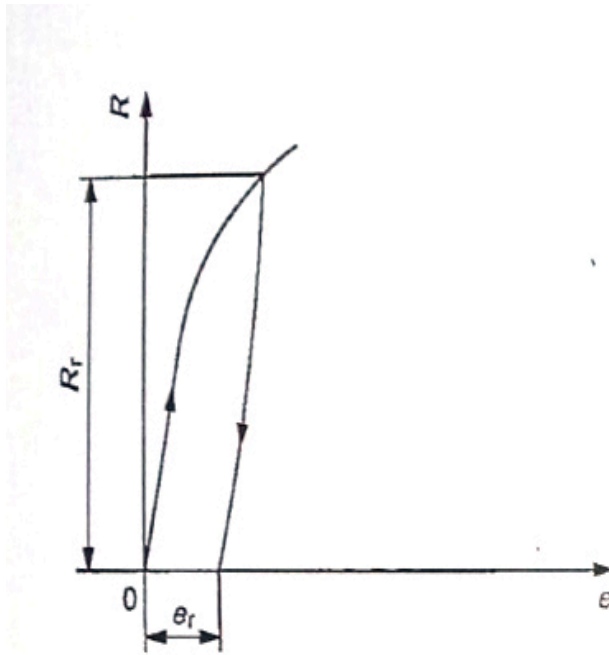
e   :   percentage extension   e   :   percentage extension

e_r :   percentage permanent set extension e_p :   specified percentage plastic extension

R   :   stress   R   :   stress

R_r :   permanent set strength R_p :   proof strength (plastic extension)

Figure 5   Permanent set strength   **Figure 6 Proof strength (plastic extension)**

(See 13.1)

3.11 fracture, rupture

phenomenon which is deemed as the occurrence of total separation of the test piece

>   NOTE: Criteria for fracture which may be used for computer-controlled tests are given in figure A.2 of
>   **ISO 6892-1.**

4 Symbols and designations

The symbols and corresponding designations are given in table 1.

Table 1 Symbol and designation

Symbol	Unit	Designation
		Test piece
a_0	mm	Thickness of flat-form test piece or wall thickness of tube before test
b_0	mm	Width of parallel portion of flat-form test piece, average width of strip form test piece taken from tube or width of flat wire before test
d_0	mm	Diameter (or width across flats) of parallel portion of bar-form test piece, diameter of wire or inside diameter of tube before test
D_0	mm	Outside diameter of tube before test
L_0	mm	Original gauge length
L'_0	mm	Initial gauge length at measurement of A_{wn} (see Annex I).
L_e	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 at measurement of A_{wn} (see Annex I)
S_n	mm^2	Original cross-sectional area of parallel portion
S_u	mm^2	Minimum cross-sectional area after fracture
K		Coefficient of proportionality (see 6.1.1)
Z	%	Percentage reduction of area
		Elongation
A	%	Percentage elongation after fracture (see 3.4.2)
A_{wn}	%	Percentage plastic elongation without necking (see Annex I)
		Extension
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
ΔL_m	mm	Extension at maximum force
ΔL_r	mm	Extension at fracture
		Testing rate
$\dot{e}_{Le}$	s^{-1}	Strain rate
$\dot{e}_{Le}$	s^{-1}	Estimated strain rate over parallel portion
R	MPa.s^{-1}	Stress rate
V_e	mms^{-1}	Crosshead separation rate
		Force
F_m	N	Maximum force

Table 1 (concluded)

Symbol	Unit	Designation
		Yield strength-proof strength-tensile strength
E	MPa [a)]	Modulus of elasticity
m	MPa	Slope of stress-percentage extension curve at any moment of test
m_E	MPa	Slope of elastic part of stress-percentage extension curve [b)]
R_{eH}	MPa	Upper yield strength (upper yield point)
R_{el}	MPa	Lower yield strength (lower yield point)
R_m	MPa	Tensile strength
R_p	MPa	Proof strength (plastic extension)
R_r	MPa	Permanent set strength
R_t	MPa	Proof strength (total extension)

NOTE   The factor 100 is necessary, if percentage values are used.

Notes a) 1 MPa = 1 N/mm^2

b) 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.

a) Horizontal line method   **b) Regression method**
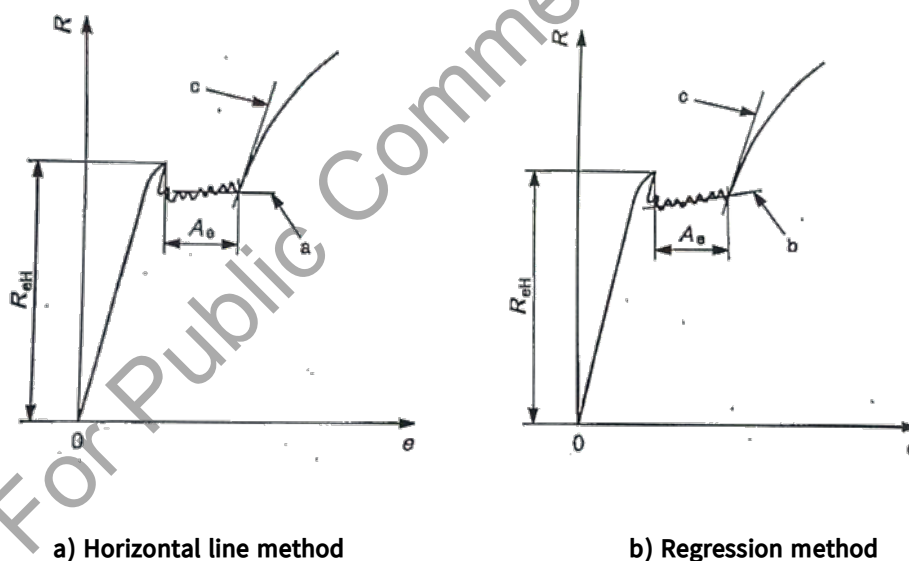
A_0: percentage yield point extension

e : percentage extension

R: stress

R_{eH}: upper yield strength (upper yield point)

a : horizontal line through the last local minimum point prior to uniform workhardening

b : regression line thorough the range of yielding prior to uniform workhardening

c : line corresponding to the highest slope of the curve occurring at the start of uniform work hardening

Figure 7 Different evaluation methods for percentage yield point extension A$_e$.
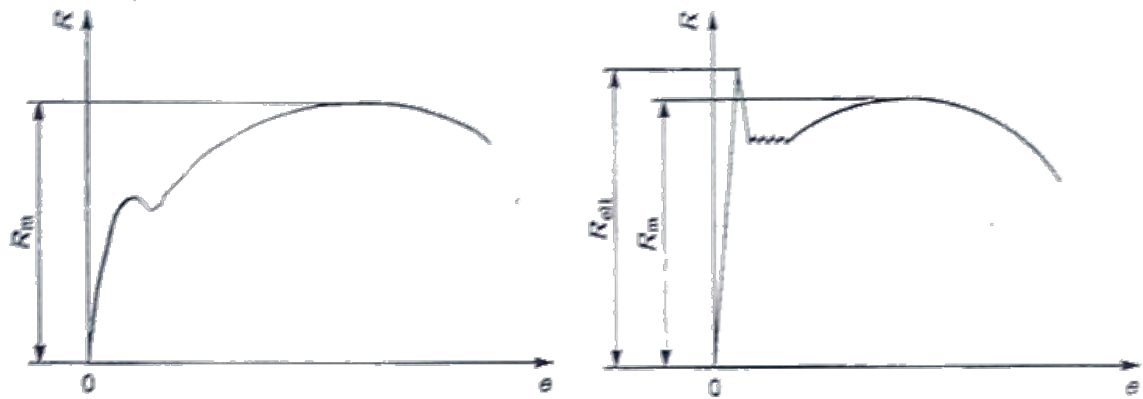
a) $R_{eH} < R_m$ b) $R_{eH} > R_m$
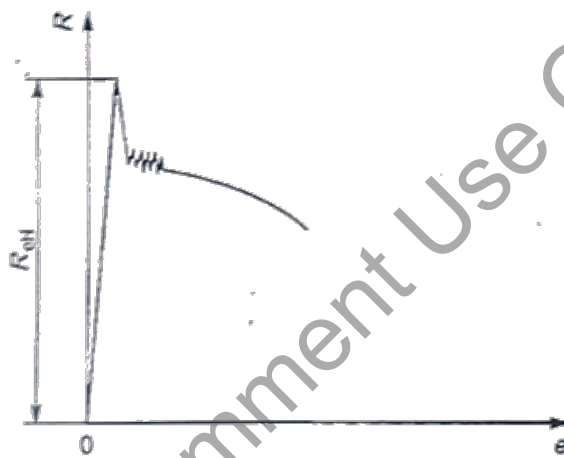
c) Special case of stress-percentage extension behaviour [a]

e :   percentage extension

R :   stress

R_{eH}: upper yield strength (upper yield point)

R_m : tensile strength

NOTE [a] For materials which exhibit this behaviour, the tensile strength is not specified in this Standard. If necessary, this may be determined upon the agreement between the parties concerned with delivery.

Figure 8   Different types of stress-percentage extension curve for determination of tensile strength R_m
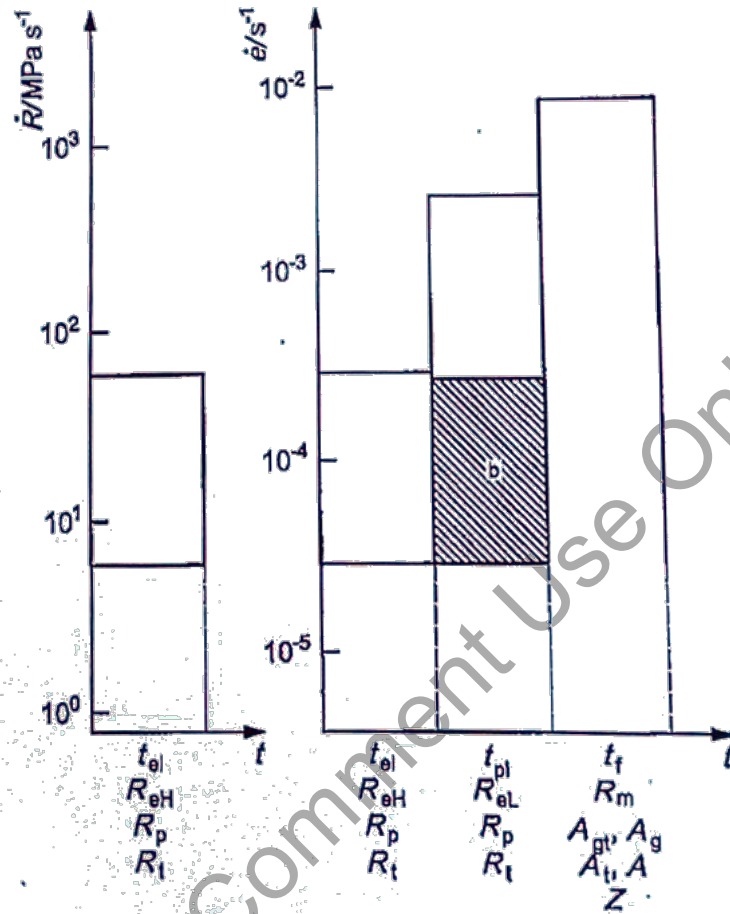
$\dot{e}$: strain rate

$\dot{R}$: stress rate

t : time progress of the tensile test

t_{el} : time range of elastic behaviour for measurement of the parameters listed in table 1

t_r : time range (usually up to fracture) for measurement of the parameters listed in table 1

t_{pl}: time range of plastic behaviour for measurement of the parameters listed in table 1

b: expanded range to lower rates, if testing machine is not capable of controlling the strain rate

NOTE: Strain rate in the elastic part obtained from stress rate using a young modulus of 210 000 MPa (steel) (see 10.3.2.5)

Figure 9 Illustration of strain rate to be used during test if R_{eH}, R_{eL}, R_p, R_t, R_m, A_g, A_{gt}, A, A_t and Z are measured
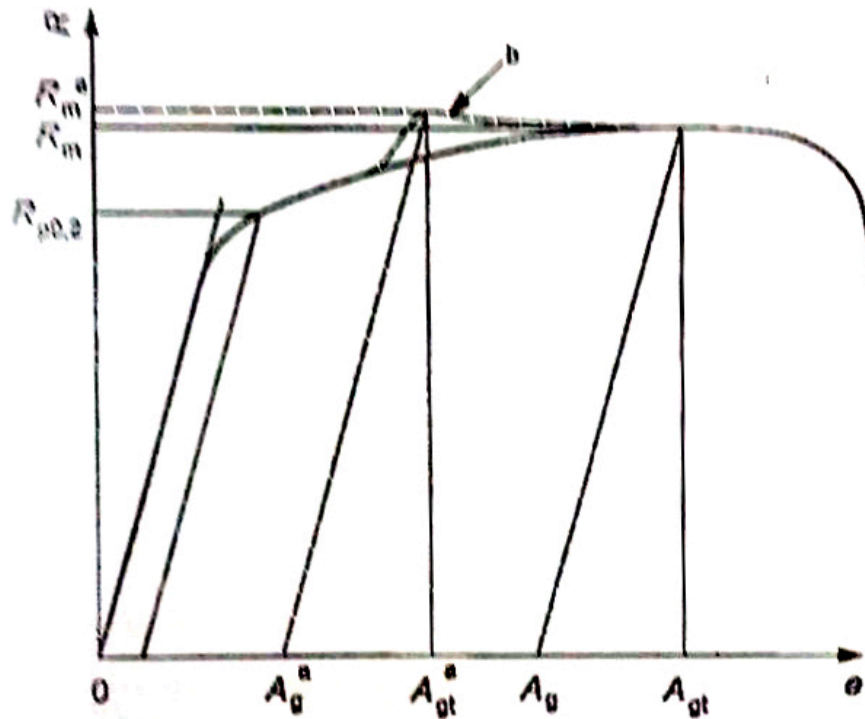
e: percentage extension

R: stress

a: false value resulting from abrupt strain rate increase

b: stress-strain behaviour if strain rate is abruptly increase

NOTE: For the definitions of parameters, see table 1.

Figure 10 Illustration of inadmissible discontinuity in stress-extension curve

a) Before test

b) After test
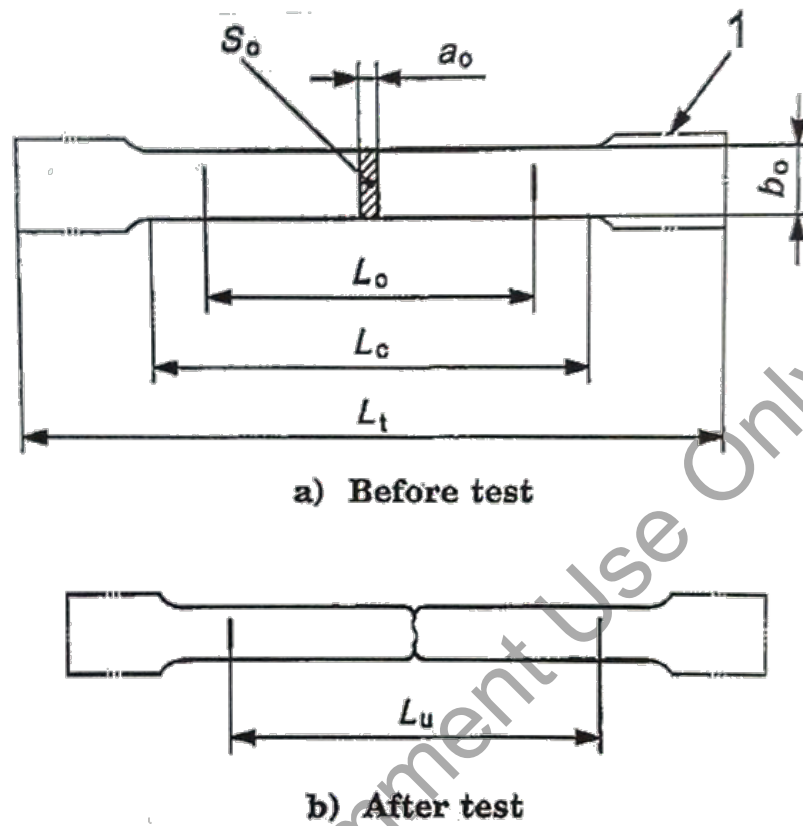
a_o : thickness of flat-form test piece before test

b_o : width of parallel portion of flat-form test piece before test

L_c : parallel length

L_o : original gauge length

L_t : total length of test piece

L_u : final gauge length after fracture

S_o : original cross-sectional area of parallel portion

1 : gripped end

NOTE: The shape of gripped ends of test piece is only given as a guide.

Figure 11 Flat-form test piece (see Annex B and Annex D)
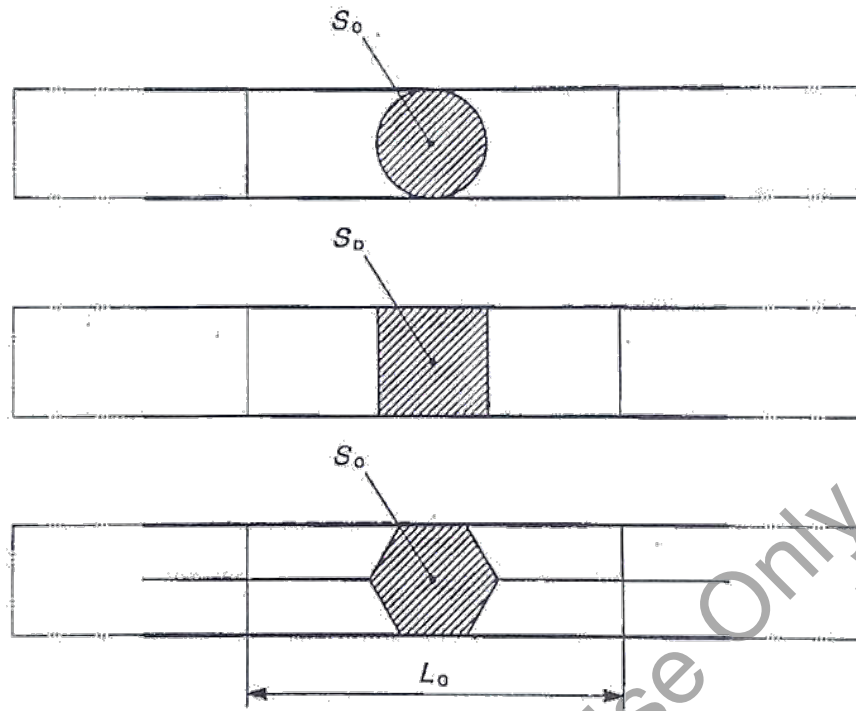
L_0: original gauge length

S_0: original cross-sectional area

Figure 12 Bar-form and wire-form test pieces (unmachined) (see Annex C)

a) Before test

b) After test
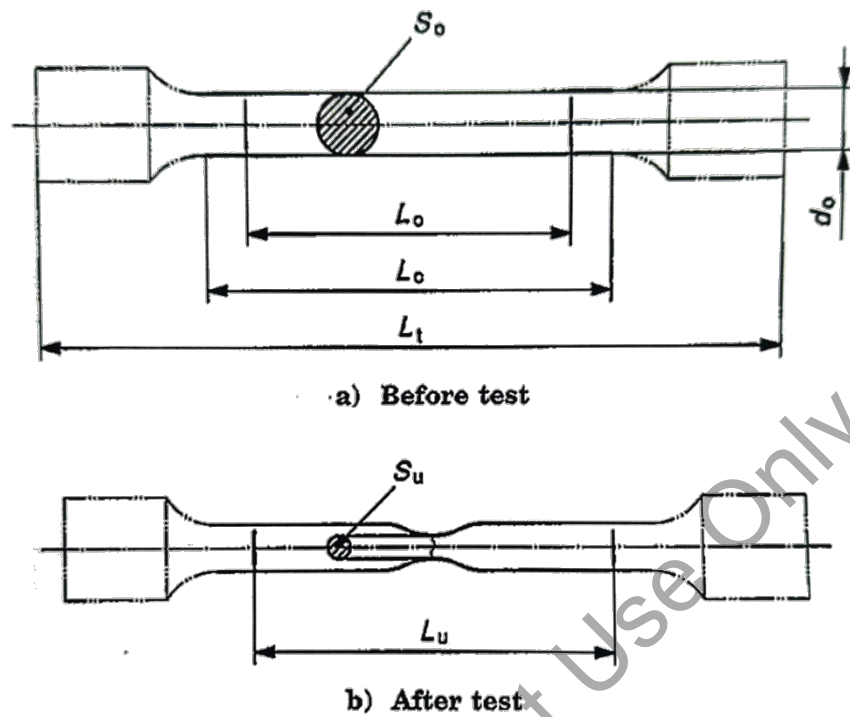
d_o : diameter of the parallel portion of a bar-form test piece before test

L_c : parallel length

L_o : original gauge length

L_t : total length of test piece

L_u : final gauge length after fracture:

S_o : original cross-sectional area of parallel portion

S_u : minimum cross-sectional area after fracture

NOTE: The shape of gripped ends of test piece is only given as a guide.

Figure 13 Bar-form test piece (machined) (see Annex D)

a) Before test

b) After test
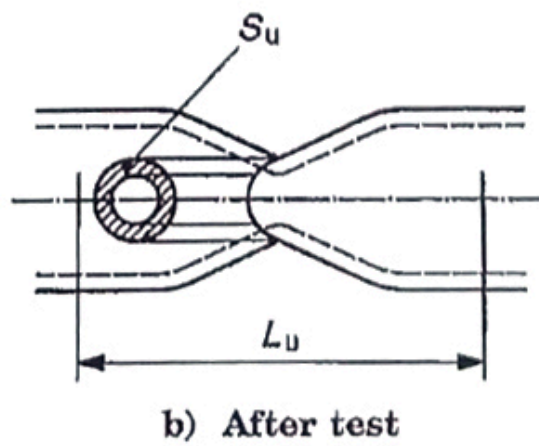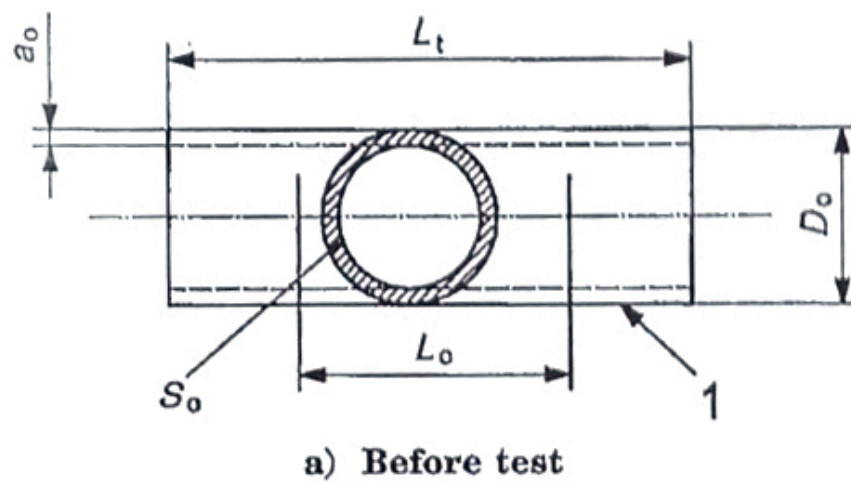
a_o : wall thickness of a tube before test

D_o : outside diameter of a tube before test

L_o : original gauge length

L_t : total length of test piece

L_u : final gauge length after fracture

S_o : original cross-sectional area of the parallel portion

S_u : minimum cross-sectional area after fracture

1 : gripped end

Figure 14 Tube-form test piece (see Annex E)

a) Before test

b) After test
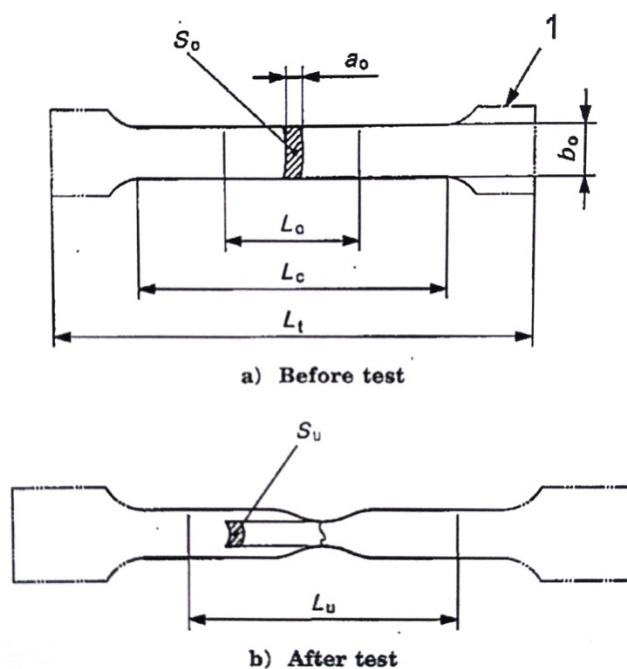
a_o : wall thickness of tube before test

b_o : average width of strip-form test piece taken from tube

L_c : parallel length

L_o : original gauge length

L_t : total length of test piece.

L_u : final gauge length after fracture

S_o : original cross-sectional area of parallel portion

S_u : minimum cross-sectional area after fracture

1 : gripped end

NOTE: The shape of gripped ends of test piece is only given as a guide.

Figure 15 Strip-form test piece (see Annex E)

5 Principle

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

The test shall be carried out at a 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 material from which the test pieces are taken.

The test piece shall be usually prepared by machining a sample from the metallic material, or punching or casting. However, the metallic materials of uniform cross section (sections, bars, wires, etc.) and also as-cast test pieces (i.e., for cast iron and non ferrous metals) 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.

The straightening of the test piece shall be avoided as far as practicable; however when it is necessary, it shall be done by such a method that might not effect the mechanical properties of the test piece as far as practicable.

The proportional test piece shall be that having a relationship of $L_o = k\sqrt{S_o}$ between the original gauge length L_o and the original cross-sectional area S_o. The internationally adopted value for k, which is the coefficient of proportionality, 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 (e.g., 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 and the original cross-sectional area S_o are independently determined.

The dimensional tolerances of the test pieces shall be in accordance with Annex B to Annex E (see 6.2), unless otherwise specified.

6.1.2 Machined test pieces

The machined test pieces shall incorporate a transition radius between the gripped ends and the parallel portion, if these have different cross-sectional dimensions. The dimensions of transition radius are important and it is recommended that they be defined in product standard, 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 L_c or, in the case where the test piece has no transition radius, the length between the grips shall always be greater than the original gauge length L_o.

The parallel portion of a test piece may be tapered towards the middle within the tolerances on the dimensional change of the parallel portion specified in Annex B to Annex E.

6.1.3 Unmachined test pieces

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

As-cast test pieces shall incorporate a transition radius between the gripped ends and the parallel potion. The dimension of this transition radius is 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 of test pieces

The main types of test pieces are defined in Annex B to Annex E according to the shape and type of product, as given in table 2.1 and table 2.2. Other types of test pieces may be specified in product standards.

Table 2.1 Main types of test piece according to type of product

Unit: mm

Type of product		Corresponding Annex
strip-sheet-plate thickness a_o	wire-bar-section diameter or width across flats	
$0.1 \leq a_o < 3$	-	Annex B
-	<4	Annex C
$a_o \geq 3$	≥4	Annex D
Tube		Annex E

Table 2.2 Classification of test pieces

Shape of test piece	Flat-form test piece	Bar-form test piece	Tube-form test piece	Strip-form test piece	Wire-form test piece
Proportional test piece	No. 14B	No. 2, No. 14A	No. 14C	No. 14B	
Non-proportional test piece	No. 1A, No. 1B, No. 5, No. 13A, No. 13B	No. 4, No. 10, No. 8A, No. 8B, No. 8C, No. 8D	No. 11	No. 12A, No. 12B, No. 12C	No. 9A, No. 9B
NOTE: No. 1B test pieces shall be used in the case where the test pieces shown in table 2.3 are not suitable to be used.					

The selection of the test piece to be used shall be in accordance with the requirements of respective product standards; however, the division of use in table 2.3 should be referred to.

Table 2.3 Division of use of test pieces

Division	dimension	Test piece Proportional	Test piece Non proportional	NOTE	Corresponding Annex
Sheet, plate, section, strip	Over 40 mm in thickness	No. 14A	No. 4, No. 10	For bar-form test piece	Annex D
		No. 14B	-	For flat-form test piece	
	Over 20 mm to and incl. 20 mm in thickness	No. 14A	No. 4, No. 10	For bar-form test piece	
		No. 14B	No. 1A	For flat-form test piece	
	Over 6 mm to and incl. 20 mm in thickness	No. 14B	No. 1A, No. 5	For flat-form test piece	
	Over 30 mm to al incl. 6 mm in thickness	-	No. 5, No. 13A, No. 13B		-
	3mm or under in thickness	-			Annex B
Bar	-	No. 2, No. 14A	No. 4, No. 10	-	Annex C
Wire	-	-	No. 9A, No. 9B	-	Annex D
Tube	Tube of small outside diameter	No. 14C	No. 11	For tube-form test piece	Annex E
	50 mm or under in outside diameter	No. 14B	No. 12A	For strip-form test piece	
	Over 50 mm to and incl. 170mm outside diameter		No. 12B		
	Over 170 mm in outside diameter		No. 12C		
	200 mm or over in tube diameter	No. 14B	No. 5	For flat-form test piece or strip-form test piece	
	Tube of thick wall	No. 14A	No.4	For bar-form test piece	
Casting	-	No. 14A	No. 4, No. 10	-	-
	-	-	No. 8A, No. 8B, No. 8C, No. 8D	Used when elongation value is not required. Taken from specimen casted for test piece	
Forging	-	No. 14A	No. 4, No. 10	-	-

6.3 Preparation of test piece

The test piece shall be taken and prepared in accordance with the requirements of the relevant standards for respective products (e.g.; **JIS G 0416**).

7. Measurement of original cross-sectional area

The respective dimensions of the test piece should be measured at sufficient points between gauge marks.

A minimum of three cross-sections are recommended.

NOTE: Nominal dimensions are specified in Annex B and Annex D. The concept where the measuring position is made to one point is given in Annex JA.

Respective dimensions of the test piece shall be measured at least to the nearest 0.5% of the numerical values, provided that the dimensions of 2 mm or under maybe limited to the nearest 0.01 mm.

The original cross-sectional area S, is the average cross-sectional area, and shall be calculated from the measurements of appropriate dimensions. However, for the test piece tapered for a proper reason, the original cross-sectional area shall be that measured at the smallest cross section.

Examples of the calculation method are as follows.

Example 1 The original cross-sectional area S_o of the parallel portion of the test piece except the tube-form test piece is obtained from the average of three measurements at the both ends and the centre between the gauge marks.

For the tube-form test piece, the original cross-sectional area S_o is measured at the end part of the test piece.

Example 2 The diameter used for obtaining the original cross-sectional area S_o of the test piece with circular cross section and the tube-form test piece is the average of measurements in two orthogonal directions.

The wall thickness for obtaining the original cross-sectional area S_o of the tube-form test piece is the average of not less than three measurements at the points on the circumference of the tube end part equally divided.

NOTE: The average of the difference between inside and outside diameters of a tube-form test piece when measured in two orthogonal directions may be substituted by the twice of average of the thickness at four points.

The accuracy of this calculation depends on the type and shape of the test piece. The evaluation method of the original cross-sectional area S_o for different types of test pieces is given in Annex B to Annex E.

8 Marking of original gauge length

Each end of the original gauge length L. shall be marked by means of fine marks (e.g., punches, scribed lines), but not by notches which could result in premature fracture. For the test piece whose material is sensitive to scratch on the surface or extremely hard, the marks may be scribed on the surface of coating applied on the test piece.

For the 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 Lo. The original gauge length shall be marked to an accuracy of = 1%.

The original gauge length shall be measured at least to the nearest 0.1 mm. The extensometer gauge length may be used as the designated original gauge length when the error to the designated original gauge length is within 1.0 %

24

If the parallel length L$_e$ is much greater than the original gauge length, for instance, as 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.

NOTE : It is unnecessary to put the gauge marks, if the required elongation is measured by an employment of the extensometer (see 20.2).

9 Accuracy of testing machine

9.1 Testing machine

The testing machine used for the tensile test shall be Class 1 or better specified in JIS B 7721.

9.2 Extensometer

For the measurement of proof strength (plastic extension or total extension), the extensometer to be used shall be Class 2 or better specified in JIS B 7741 within the application range of extension.

10. Conditions of testing

10.1 Setting of zero point of force

The force-measuring system shall be set to zero after the force 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 the weight of the gripping device is compensated for in the force measurement and also, any force resulting from the clamping operation does not affect this measurement.

10.2 Method of gripping

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

It shall be ensured that test pieces are held in such a way that the force is applied as axially as possible to minimize the bend (more information is given in ASTM E 1012, for example). This is the particular importance when testing brittle materials or when measuring the proof strength (Plastic extension or 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 that it does not exceed 5% of the specified yield strength 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:

> **NOTE:** In ISO 6892-1, the method based on the strain rate control is made as method A, and the method based on the stress rate control is made as method B. In this Standard, method A is described as Annex JB.

10.3.1 General

The testing rates shall conform to the following requirements depending on the materials. Unless otherwise specified, any convenient speed of testing may be used up to the force equivalent to half of the specified yield strength. The testing rates above this point shall be as follows (see figure 9).

10.3.2 Yield strength and proof strength

10.3.2.1 Upper yield strength R_{eH}

The stress rate shall be as given in table 3. If it is controlled by the crosshead separation rate, the rate shall be kept as constant as possible within the limits corresponding to the stress rate of 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 iron, steel, tungsten, and nickel-based alloys.

Table 3 Stress rate

Modulus of elasticity of material E MPa		Stress rate $\dot{R}$ MPa . s^{-1}	
System		Min.	Max.
<150 000		2	20
	≥ 150 000	3	30
NOTE: In ISO 6992-1, the stress rate for the modulus of elasticity ≥ 150 000 is specified so as to be 6 MPa·s^{-1} to 60 MPa·s^{-1}.			

10.3.2.2 Lower yield strength R_{eL}

If only the lower yield strength is being measured, the strain rate during yield of the parallel portion of the test piece shall be between 0.000 25 s^{-1} and 0.002 5 s^{-1}. The strain rate within the parallel portion shall be kept as constant as possible. If the strain rate cannot be regulated directly, the crosshead separation rate shall be fixed within the limits corresponding to the stress rate just before yield begins, the controls of the machine not being further adjusted until the completion of yield.

In no case shall the stress rate in the elastic part exceed the range given in table 3.

10.3.2.3 Upper yield strength and lower yield strength R_{eH} and R_{eL}

If both the upper yield strength and the lower yield strength are measured, the conditions for measuring the lower yield strength shall be conformed to (see 10.3.2.2).

10.3.2.4 Proof strength (plastic extension) and proof strength (total extension) R_p and R_t.

The stress rate shall be as given in table 3. If it is controlled by the crosshead separation rate, the rate shall be kept as constant as possible within the limits corresponding to the stress rate of table 3.

Within the plastic part and up to the proof strength (plastic extension or total extension), the strain rate shall not exceed $0.0025\ s^{-1}$.

10.3.2.5 Crosshead separation rate

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

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

After the measurement of the required yield strength/proof strength, the testing rate (the strain rate or the crosshead separation rate) shall be as given in table 4.

If only the tensile strength of the material is to be measured, table 4 shall be applied.

Table 4 Testing rate when measuring only tensile strength after measuring yield strength/proof strength.

Unit: s^{-1}

Material	Minimum rate	Maximum rate
Steel	0.003	0.008
Others	-	0.008

The application of the strain rate (or crosshead separation rate) over $0.008\ s^{-1}$ shall be in accordance with the product standards of **JIS.**

The tensile strength shall be calculated according to the following equation.

$$R_m = \frac{F_m}{S_0} \tag{1}$$

where, R_m : tensile strength (MPa)

F_m : maximum force (N)

S_0 : original cross-sectional area (mm^2)

11 Measurement of upper yield strength R_{eH}.

R_{eH} shall be measured from the force-extension curve or the peak load indicator, and defined as the maximum value prior to the first decrease in force. The upper yield strength is obtained by dividing this force by the original cross-sectional area S_o of the test piece.

The upper yield strength shall be calculated according to the following equation.

$$R_{eH} = \frac{F_{eH}}{S_o} \quad (2)$$

where, R_{eH} : upper yield strength (MPa)

F_m : maximum force corresponding to upper yield strength (N)

S_o : original cross-sectional area (mm^2)

NOTE: The maximum force F_{eH} (N) prior to the first decrease is obtained according the force-extension curve for obtaining the upper yield strength.

Also, the measurement by the peak load indicator is applicable (see figure 2).

12 Measurement of lower yield strength R_{eL}.

R_{eL} shall be measured from the force-extension curve, and defined as the minimum value of stress during the plastic yielding, ignoring any initial transient effect. The lower yield strength is obtained by dividing this force by the original cross-sectional area S_o of the test piece.

The lower yield strength shall be calculated according to the following equation.

$$R_{eL} = \frac{F_{eL}}{S_o} \quad (3)$$

where, R_{eL} : lower yield strength (MPa)

F_{eL} : maximum force corresponding to lower yield strength (N)

S_o : original cross-sectional area (mm^2)

NOTE: The minimum force F_{eL} (N), ignoring any initial transient effect, is obtained according the force-extension curve for obtaining the lower yield strength (see figure 2).

For the productivity of testing, R_{eL} may be reported as the minimum stress within 0.25% strain after R_{eH} ignoring any initial transient effect. After measuring R_{eL}. by this procedure, the testing rate may be increased in accordance with 10.3.2.6. Use of this shorter procedure should be recorded on the test report.

NOTE: This clause only applies to materials having yield phenomena, when A_e is not to be measured.

13   Proof strength (plastic extension)R_p

13.1 R_p, shall be obtained from the force-extension curve by drawing a line parallel to the linear portion of the curve and at a distance from this equivalent to the prescribed plastic percentage extension, e.g., 0.2%. The point at which this line intersects the force-extension curve gives the force corresponding to the desired proof strength (plastic extension). The proof strength is obtained by dividing this force by the original cross-sectional area S_o, of the test piece (see figure 3).

NOTE :   In ISO 6892-1, as the method when the straight portion of the force... extension curve is not clearly defined, the method given in figure 6 is specified.

13.2 This property (R_p) may be obtained by using automatic devices without plotting the force-extension curve.

14   Proof strength (total extension) R_t

14.1 R_t, shall be obtained from the force-extension curve by drawing a line parallel to the ordinate axis (force axis) and at a distance from this equivalent to the prescribed total extension, and the point at which this line intersects the force-extension curve gives the force corresponding to the desired proof strength (total extension). The proof strength (total extension) is obtained by dividing this force by the original cross-sectional area S_o, of the test piece (see figure 4).

14.2 This property (R_t) may be obtained by using automatic devices without plotting the force-extension curve.

15 Method of verification of permanent set strength R_r,

The test piece shall be subjected to a force corresponding to the specified stress for 10s to 12s. This force shall be obtained by multiplying the specified stress by the original cross-sectional area S_o of the test piece. After removing the force, it is then confirmed that the permanent set extension or elongation is not more than the percentage specified for the original gauge length (see figure 5).

NOTE: This is a pass/fail test, which is not normally carried out as a part of the standard tensile test. The stress applied to the test piece and the permissible permanent set extension or elongation are specified either by the product standards or the requester of the test. For example, reporting "$R_{r0.5}$=750 MPa, Pass" indicates that a stress of 750 MPa was applied to the test piece and the resulting permanent set was 0.5 % or under.

16 Measurement of percentage yield point extension A_e

For materials exhibiting discontinuous yielding, A_e shall be obtained from the force extension curve by subtracting the extension at R_{eH} from the extension at the start of uniform workhardening. The extension at the start of uniform workhardening shall be defined by the intersection of a horizontal line through the last local minimum point, or a regression line through the range of yielding, prior to uniform workhardening, and a line corresponding to the highest slope of the curve occurring at the start of uniform workhardening (see figure 7). A_e shall be expressed as a percentage of the extensometer gauge length.

The measurement method equivalent to this may be used.

The method used [see figure 7 a) or figure 7 b)] should be recorded in the test report.

17   Measurement of percentage plastic extension at maximum force Ag

The method consists of obtaining the extension at maximum force on the force extension curve obtained with an extensometer and subtracting the elastic strain.

The percentage plastic extension at maximum force A_g shall be calculated according to the following equation.

$$A_g = \left[\frac{\Delta L_m}{L_c} - \frac{R_m}{M_E} \right] \times 100 \quad\text{---}\quad (4)$$

where, L_e : extensometer gauge length

         m_E : slope of elastic part of stress-percentage extension curve

         R_m : tensile strength

         ΔL_m : extension at maximum force

NOTE: For materials which exhibit a plateau at maximum force, the percentage plastic extension at maximum force shall be the extension at the mid-point of the plateau (see figure 1).

18 Measurement of percentage total extension at maximum force A_{gt}

The method consists of obtaining the extension at maximum force on the force extension curve obtained with an extensometer.

The percentage total extension at maximum force A_{gt} shall be calculated according to the following equation.

$$A_{gt} = \frac{\Delta L_m}{L_c} \times 100 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (5)$$

where, L_c : extensometer gauge length

         ΔL_m : extension at maximum force

NOTE: For materials which exhibit a plateau at maximum force, the percentage total extension at maximum force shall be the extension at the mid point of the plateau (see figure 1).

19 Measurement of percentage total extension at fracture A_t

The method consists of obtaining the extension at fracture on the force-extension curve obtained with an extensometer.

The percentage total extension at fracture A_t shall be calculated according to the following equation.

$$A_t = \frac{\Delta L_f}{L_e} \times 100 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (6)$$

where, L_e : extensometer gauge length

         ΔL_f : extension at maximum fracture

20 Measurement of percentage elongation after fracture A

20.1 The percentage elongation after fracture A shall be obtained according to the definition of **3.4.2**.

For this purpose, the two fractured parts of the test piece shall be carefully fitted back together so that their axes lie in a straight line.

Special precautions shall be taken to ensure proper contact between the fractured parts of the test piece when measuring the final gauge length. This is particularly important for test pieces of small cross section and those having low elongation values.

The percentage elongation after fracture A shall be calculated according to the following equation.

$$A = \frac{L_u - L_0}{L_0} \times 100 \qquad\qquad\qquad\qquad\qquad\qquad\qquad (7)$$

where, L_0 original gauge length.

 L_u final gauge length after fracture

Elongation after fracture (L_u - L_0) shall be measured to the nearest 0.25 mm or better using a measuring device with sufficient resolution.

If the specified minimum percentage elongation is less than 5 %, it is recommended that special precautions be taken (see Annex G). The result of this measurement is valid only if the distance between the fracture and the nearest gauge mark is not less than 1/4 the original gauge length L_o. However, the test is valid, irrespective of the fracture location, if the percentage elongation after fracture is equal to or greater than the specified value.

   NOTE 1 ISO 6892-1 describes that the result is valid only if the distance between the fracture and the
          nearest gauge mark is not less than 1/3 the original gauge length.

   NOTE 2 If required, the fracture location of the test piece shall be identified by adding the following
symbols.

          A: fracture at 1/4 or more of original gauge length (L_o) apart from nearest gauge mark (location A
          in figure 16)
          B: fracture at less than 1/4 of original gauge length (L_o) within nearest gauge mark (location B in
          figure 16)
          C: fracture outside gauge marks (location C in figure 16)
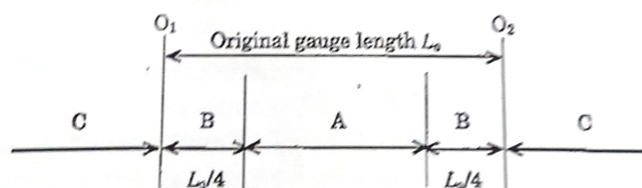
Figure 16 Fracture location and symbol of test piece

   NOTE 3 If the crevice (CP) exists in the middle of breadth (figure 17), when the fractured parts of a flat-form test
          piece are fitted together, the elongation after fracture shall be calculated with the whole length between
          the gauge marks $O_1 O_2$ including this distance CP of the crevice.
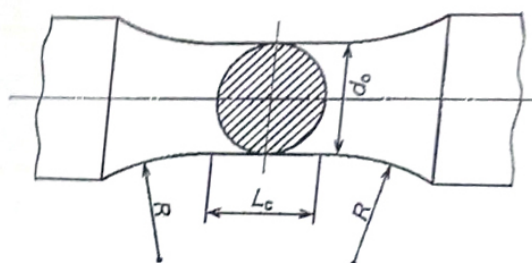
Figure 17 Example of breadth fitted together

20.2 When the extension at fracture is measured using an extensometer, it is not necessary to put the gauge marks on the test piece. The percentage elongation after fracture should be obtained with the elastic elongation subtracted the extension at fracture. However, unless otherwise specified, the length between gauge marks at fracture of the test piece may be used for L_U. To obtain comparable values with the method of fitting the fractured parts of the test piece together, additional adjustments may be applied.

Principally, the test is valid only if the fracture has occurred within the extensometer gauge length L_e. The test is valid regardless of the fracture location, if the percentage elongation after fracture is equal to or greater than the specified value.

The extensometer to be used in this case shall have a gauge length equal to the original gauge length of the test piece, and shall be able to measure the extension with an accuracy of = 0.5% of the gauge length.

20.3 If the elongation of the non-proportional test piece is measured over the original gauge length thereof, it may be converted to the elongation of the proportional gauge length using the conversion formulae or tables upon the agreement between the parties concerned with delivery **(e.g., ISO 2566-1 and ISO 2566-2).**

NOTE: The comparison of percentage elongation is possible only when the original gauge length or the extensometer gauge length, the shape and the cross-sectional area are same or when the coefficient of proportionality k is same.

21 Measurement of percentage reduction of area Z

The percentage reduction of area shall be measured according to the definition of 3.8.

If necessary, the two fractured parts of the test piece shall be carefully fitted back together so that their axes lie in a straight line.

The percentage reduction of area Z shall be calculated according to the following equation.

$$Z = \frac{S_0 - S_U}{S_0} \times 100 \qquad (8)$$

where, S_0: original cross-sectional area of parallel portion

S_U: minimum cross-sectional area after fracture

NOTE: ISO 6892-1 describes that the minimum cross-sectional area after fracture S_u shall be measured with an accuracy of ± 2 %; however, on small bar-form test pieces or test pieces with other cross-sectional geometries, this may not be possible.

32 Test Report

The test report shall contain at least the following items unless otherwise agreed between the parties concerned with delivery.

However, a part of the following items may be omitted upon the agreement between the parties concerned with delivery.

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a) Reference to this Standard: **JIS Z 2241**

b) Identification of test piece

c) Type of material (if known)

d) Shape of test piece

e) Sampling position and sampling direction of test pieces (if known)

f) Test results Test results should be rounded to the following accuracies or better, if not specified in the product standards. The rounding method of numerical values shall be in accordance with **JIS Z 8401.**

     − value of strength: whole number in unit of MPa[2]

     − percentage yield point extension A_e : 0.1%

     − percentage elongation after fracture: 1%

     − other percentage extension and elongation: 0.5%

     − percentage reduction of area: 1%

     − Note 1 MPa-1 N/mm²

23 Measurement uncertainty

23.1 General

The measurement uncertainty analysis is useful for identifying major sources of inconsistencies of measured results.

Product standards, and material property databases based on this Standard and earlier edition of this Standard have an inherent contribution from measurement un certainty. It is therefore inappropriate to apply further adjustments for measurement uncertainty and thereby risk failing product which is compliant. For this reason, the estimates of uncertainty derived by following this procedure are for information only, unless otherwise specifically instructed by the customer.

23.2 Conditions of testing

The conditions of testing and limits defined in this Standard shall not be adjusted to take account of uncertainties of measurement, unless otherwise specifically instructed by the customer.

23.3 Test results

The estimated measurement uncertainties shall not be used to assess compliance to product standards, unless otherwise specifically instructed by the customer.

    NOTE: In ISO 6892-1, the guidance for the determination of uncertainty related to metrological parameters and the values obtained from the interlaboratory tests on a group of steels and aluminium alloys are provided in Annex J and Annex K.

Annex A (informative)

Recommendations concerning the use of

computer-controlled tensile testing machine

(The description of the corresponding International Standard is not adopted).

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Annex B (normative)
Types of test pieces used for thin products of 0.1 mm or
over to and excluding 3 mm in thickness

NOTE: For products of less than 0.5 mm in thickness, special precautions may be necessary.

B.1 Shape of test piece

Generally, the thickness of the test piece shall be the original thickness of the product, and the gripped ends shall be wider than the parallel length. The parallel length L_o shall be connected to the gripped ends by means of transition radius as given in table B.1. The width of gripped ends should be 1.2 times or more of the width of the parallel portion b_0

Upon the agreement between the parties concerned with delivery, the test piece may also consist of a strip with parallel sides (parallel sided test piece). 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 (see figure 11).

B.2 Dimensions of test piece

Three different non-proportional test pieces are widely used (see table B.1).

The parallel length L_e shall not be less than $L_0 + b_0/2$ except No. 5 test piece in table B.1.

In case of dispute, the parallel length L. should be $L_0 + 2b_0$, unless there is insufficient length of the product. For the parallel sided test pieces of under 20 mm in width, unless otherwise specified in the product standards, the original gauge length L, of the test piece shall be equal to 50 mm. For this type of test piece, the free length between the grips shall be equal to $L_0 + 3b_0$, or more.

When measuring the dimensions of the test piece, the tolerances on dimensional change given in table B.1 shall apply.

For the parallel sided test pieces where the width is the same as that of the sample, the original cross-sectional area S, shall be calculated on the basis of the measured dimensions of the test piece.

The nominal width of the test piece may be used, when the tolerances on nominal dimensions conform to table B.2 by avoiding the measurement of the width of the test piece at the time of the test.

Table B.1 Dimensions of test piece

Unit: mm

Type of test piece	Width of parallel portion bo	Tolerances on dimensional change of parallel portion [e]	Original gauge length of test piece L_o	Transition radius R	Parallel length L_e		Minimum free length between grips for parallel sided test piece	Type of test piece in ISO Standard[d]
					Min.	Recommended		
No. 13B	12.5±0.5 [b]	0.06	50	20 to 30	57	75	87.5	1
No. 13A	20 ±0.7 [b]	0.10	80	20 to 30	90	120	140	2
No. 5	25 ±0.7 [b]	0.10	50 [a]	20 to 30	60 [a]	-	Not specified	3

NOTE: In the earlier editions of this Standard, the original gauge length L_o is expressed as the gauge length L. In Annexes hereafter, the expression, the original gauge length L_o is used similarly.

Notes [a] The ratio L_n/b_o of No. 5 test piece is very small compared to that of No. 13B test piece and No. 13A test piece. As a result, the measurement results (absolute values and range of variation) obtained by using this test piece may be different from those of test pieces of other types.

[b] Range of the width permissible to respective types of the test piece (The test piece shall be prepared in the range of these tolerances).

[c] The maximum value of dimensional change permissible on the whole parallel length L_e of the test piece.

[d] The type of test piece specified in Annex B of ISO 6892-1.

Table B.2 Tolerances on width for calculation of original cross-sectional area by using nominal width without measurement

Unit: mm

Nominal width of test piece	Tolerances on nominal width[a]
12.5	± 0.02
20	± 0.02
25	± 0.04

NOTE: In ISO 6892-1, larger tolerances than those on this nominal width are specified.

Note [a] When the tolerances are within these values, the nominal value may be used for the calculation of the original cross-sectional area So without measurement.
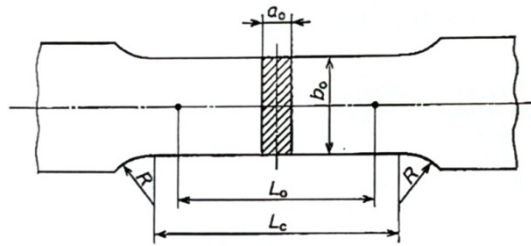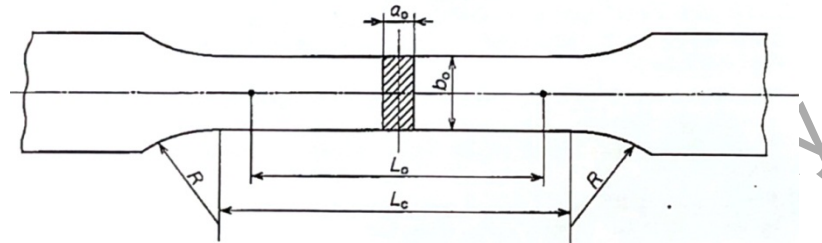
Figure B.1   No. 5 test piece

Figure B.2   No. 13 test piece

B.3 Preparation of test piece

The test pieces shall be prepared so as not to affect the properties of the sample. Any areas which have been hardened by shearing or pressing shall be removed by machining, when the effects thereof on the test results are recognized.

These test pieces are predominantly prepared from the sheet or the strip. If possible, as-rolled surfaces should not be removed.

> **NOTE:** The preparation of these test pieces by punching may result in significant changes to the properties, especially the yield point or proof strength (due to workhardening). Products which exhibit high workhardening should, generally, be prepared by milling, grinding etc.

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

The tolerances given in table B.2, for example, ± 0.02 mm for a nominal width of 12.5 mm, means that no test piece shall have a width 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.

12.5 mm +0.02 mm = 12.52 mm

12.5 mm-0.02 mm =12.48 mm

B.4 Determination of original cross-sectional area S_0

The original cross-sectional area S_o shall be calculated from measurements of the dimensions of the test piece. However, the nominal dimensions may be used in the case of Note[n] of table **B.2.**

> **NOTE:** ISO 6892-1 specifies that the error in determining the original cross-sectional area shall not exceed ±
>
> 2% and the error in measurement of the width shall not exceed ± 0.2%.

In order to achieve test results with a reduced measurement uncertainty, it is recommended that the original cross-sectional area be obtained with an accuracy of ± 1% or better. For thin products, special measurement techniques may be required in some cases.
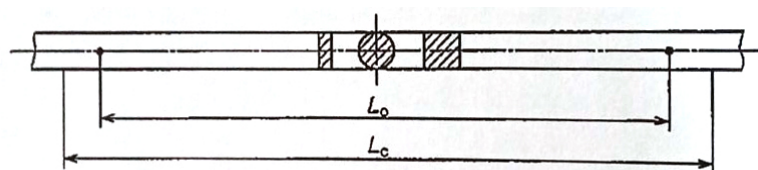
Annex C (normative)

Types of test pieces used for wires and bars with
diameter or traverse of less than 4 mm

C.1 Shape of test piece

The test piece generally consists of an unmachined portion of the product (see figure 12).

C.2 Dimensions of test piece

The dimensions of the test piece shall be as given in figure C.1.

Unit: mm

Type of test piece	Original gauge length of test piece L_o	Distance between grips[n)]
No.9A	100 ±1	150 min.
No. 9B	200±2	250 min.
NOTE: ISO 6892-1 describes that the free length between the grips shall be L_o + 3b, or more.		
Note [a)] When the measurement of the elongation after fracture is not required, the minimum 50 mm may be applied to the distance between grips.		

Figure C.1 Dimensions of test piece

C.3 Preparation of test piece

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

C.4 Determination of original cross-sectional area S_0

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

NOTE: ISO 6892-1 describes that an accuracy of the cross-sectional area shall not exceed ± 1%.

Also, the original cross-sectional area may be calculated from the mass of a known length and its density according to equation (C.1).

$$S_0 = \frac{1.000 \times m}{p \times L_t} \qquad (C.1)$$

where, m : mass of test piece (g)

L_t : total length of test piece (mm)

p : density of material of test piece (g.cm^{-3})

Annex D (normative)

Types of test pieces of sheets of 3 mm or more

in thickness, and wires and bars of 4 mm or more

in diameter or width across flats

D.1 Shape of test piece)

In the case where the test piece is machined, the parallel portion shall be connected by means of transition having a certain radius to the gripped ends which may be of any suitable shape for the grips of the testing machine (see figure 13). The minimum transition radius between the gripped ends and the parallel portion shall be as follows.

a) 0.75 d_o (d_o is the diameter of parallel portion): wire-form or bar-form cylindrical test pieces

b) 12 mm: other test pieces

Wires and bars may be tested using the unmachined parallel sided test piece. The cross section of the test piece may be circular, square, rectangular or, in special cases, some other shape.

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

In general, the diameter of wire-form or bar-form test pieces with circular cross section which has been machined shall not be less than 3 mm.

D.2 Dimensions of test piece

D.2.1 Parallel portion of machined test piece

The parallel length L shall be as follows.

a) $L_0 + d_0/2$ or more for cylindrical wire-form or bar-form test pieces

b) $L_o + 1.5\sqrt{S_0}$ or more for other test pieces

In cases of dispute, the length $L_o + 2d_0$, or $L_o + 2\sqrt{S_o}$, should be used depending on the type of test piece, unless there is insufficient length of the sample.

D.2.2 Length of unmachined test piece

The free length between the grips of the testing machine shall be adequate for the gauge marks to be at least a distance of $\sqrt{S_o}$, from the grips.

D.2.3 Original gauge length of test piece L_0

D.2.3.1 Proportional test pieces

In general, the proportional test pieces are used where L_o is related to the original cross-sectional area S_o, according to equation (D.1).

$$L_o = k \sqrt{S_o} \quad\text{(D.1)}$$

where, L_o: original gauge length

        k: 5.65

        S_o: original cross-sectional area of parallel portion

Alternatively, 11.3 may be used as the value of k.

The wire-form or bar-form test pieces with circular cross section are shown in figure D.1. They should preferably have one set of dimensions given in table D.1.

Table D.1   Wire-form or bar-form test pieces with circular cross section

K	Diameter of parallel portion d_o Mm	Original gauge length of test piece $L_o = k\sqrt{S_o}$ Mm	Minimum parallel length L_e mm
5.65	20 ±0.7 [n]	100	110
	14 ±0.7 [a]	70	77
	10 ±0.7 [a]	50	55
	5 ±0.5 [n]	25	28
NOTE: The parallel length L_e means the distance between the grips.
Note[a] Range of the diameter permissible to respective types of the test piece (The test piece shall be prepared in the range of these tolerances)

D.2.3.1.1 No. 14 test piece

The shape and dimensions of No. 14A test piece shall be as given in figure D.1.
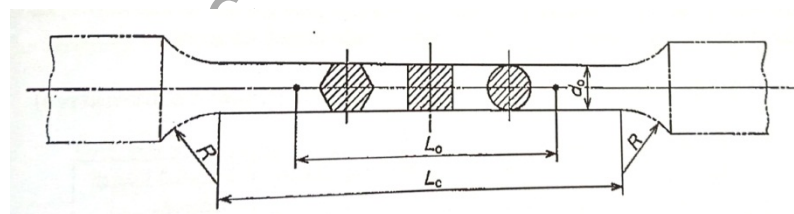
Unit: mm

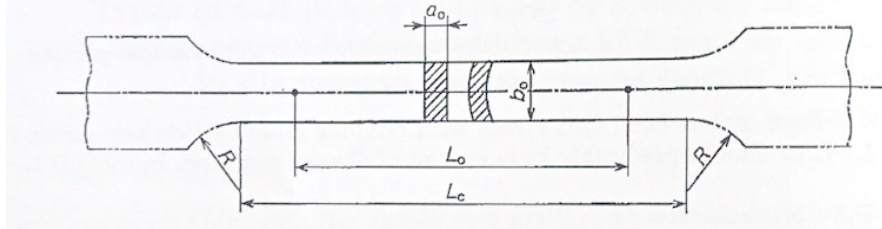| The Original gauge length of test piece L_o	Parallel length L_e	Transition radius R
5.65 $\sqrt{S_o}$	5.5d, to 7 d_o	15 min

Figure D.1 No. 14A test piece

For the parallel portion with the square cross section, the parallel length may be made as $L_o = 5.65\ d_o$, and for that with the hexagonal cross section, $L_o = 5.26\ d_o$

The parallel length should be made as $L_{e = 7d_o}$ as far as practicable.

The diameter of gripped ends of No. 14A test piece may be made the same dimension as that of the parallel portion . In this case , the distance between grips shall be $L_e \geq 8\ d_0$

The shape and dimensions of No. 14B test piece shall be as given in figure D.2.

Unit: mm

Width b_o	Original gauge length of test piece L_o	Parallel length L_e	Transition radius R	Thickness a_o
$8a_o$, max.	$5.65\sqrt{S_o}$	$L_0 +1.5\sqrt{S_o}$ to $L_0 +2.5\sqrt{S_o}$	15 min.	Original thickness of product

Figure D.2 No. 14B test piece

The parallel length of No. 14B test piece shall be $L_o+2\sqrt{S_o}$ as far as practicable.

In the case of applying No. 14B test piece to the test of tubes, the cross section of the parallel portion shall be as cut out of the tube.

The width of gripped ends of No. 14B test piece may be the same as that of the parallel portion. In this case, the parallel length shall be $L_0+3\sqrt{S_o}$

No. 14B test piece, the standard dimensions of which are given in table D.2, should be used by grouping by dimension in every reasonable sheet thickness category.

Table D.2 Standard dimensions of No. 14B test piece (informative)

Unit: mm

Thickness	Width b_o	Original gauge length L_o	Parallel length L_e
Over 5.5 to and incl. 7.5	12.5 ±0.5	50	80
Over 7.5 to and incl. 10		60	
Over 10 to and incl. 13	20 ±0.7	85	130
Over 13 to and incl. 19		100	
Over 19 to and incl. 27	40±0.7	170	265
Over 27 to and incl. 40		205	

D.2.3.1.2 No.2 test piece (specific to JIS)

The shape and dimensions of No. 2 test piece shall be as given in figure D.3.

No. 2 test piece shall be used for the bar of not more than 25 mm in nominal diameter (or width across flats).
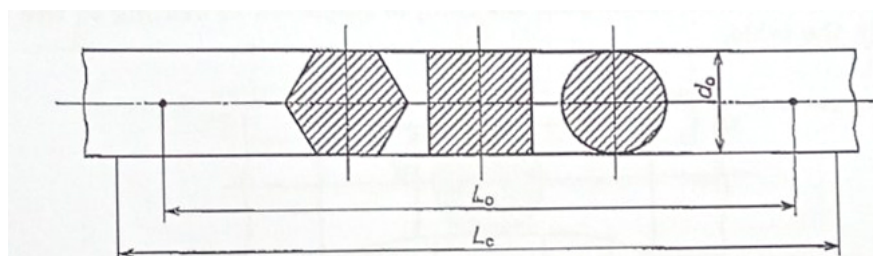
Unit: mm

| Diameter or width across flats	Original gauge length of test piece L_o	Parallel length L_e
Original diameter or width across flats of product	$8\,d_o$	$L_o + 2\,d_o$ min.

Figure D.3 No. 2 test piece

D.2.3.2 Non-proportional test piece

The parallel length L_e shall be $L_o + b_o/2$ or more. In case of dispute, the parallel length L_e-L_o+$2b_o$, should be used unless there is insufficient length of the sample.

D.2.3.2.1 No. 4 test piece (specific to JIS)

The shape and dimensions of No. 4 test piece shall be as given in figure D.4.
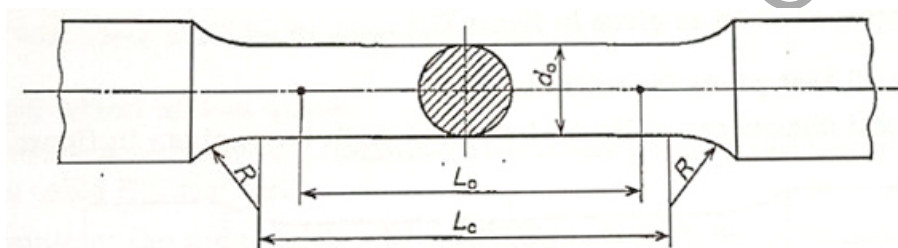
Unit: mm

Diameter d_o	Original gauge length of test piece L_o	Parallel length L_e	Transition radius R
14± 0.5	50	60 min	15 min

Figure D.4 No. 4 test piece

The parallel portion of No. 4 test piece shall be finished by machining. When No. 4 test piece of the dimensions of figure D.4 cannot be prepared, the diameter of the parallel portion and the gauge length may be determined according to $L_o = 4\sqrt{S_0}$

D.2.3.2.2 No. 8 test piece (specific to JIS)

NOTE: No. 8 test piece shall be used for the tensile test of the products such as iron castings which do not require elongation values.

The shape and dimensions of No. 8 test piece shall be as given in figure D.5.

No. 8 test piece shall be taken from the sample subjected to casting to the dimensions given in the table.

Unit: mm
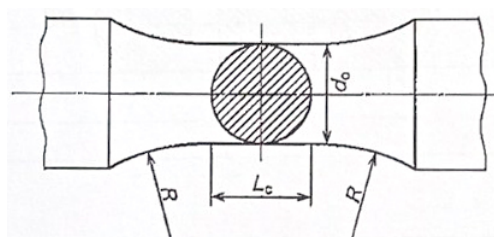
Type of tent piece	Casting dimensions. of sample (diameter)	Parallel length L_e	Diameter d_0	Transition radius R
8A	approx. 13	approx. 8	8	16 min
8B	approx. 20	approx. 12.5	12.5	25 min
8C	approx. 30	approx. 20	20	40 min
8D	approx. 45	approx. 32	32	64 min

Figure D.5 No. 8 test piece

D.2.3.2.3 No.9 test piece

No. 9 test piece shall be as given in figure C.1.

D.2.3.2.4 No. 10 test piece (specific to JIS)

The shape and dimensions of No. 10 test piece shall be as given in figure D.6.

Unit: mm

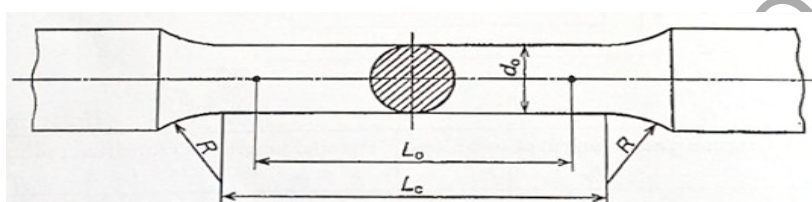| Diameter d_0	Original gauge length of test piece L_o	Parallel length L_e	Transition radius. R
12.5 ± 0.5	50	60 min.	15 min.

Figure D.6 No. 10 test piece

D.2.3.2.5 No. 1 test piece

The shape and dimensions of No. 1 test piece shall be as given in figure D.7.
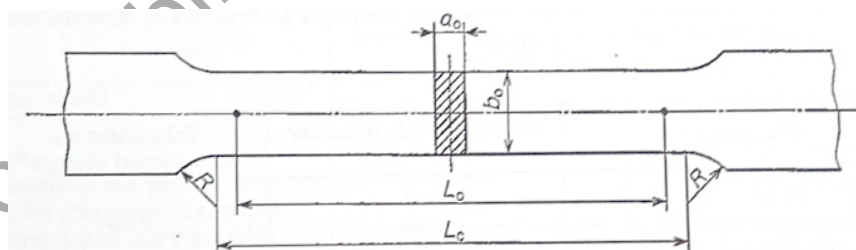
Unit: mm.

Type of test piece	Width b_o	Original gauge length of test piece L_o	Parallel length L_e	Transition radius R	Thickness a_o
1A	40 ± 0.7	200	220 min.	25 min.	Original thickness of product
1B	25 ± 0.7	200	215 min.	25 min.	Original thickness of product
NOTE: In ISO 6892-1, the test piece of 80 mm in the original gauge length is specified.					

Figure D.7 No. 1 test piece

D.2.3.2.6 No. 5 test piece

No. 5 test piece shall be in accordance with B.2; however, the transition radius shall be 15 mm or more.

D.2.3.2.7 No. 13 test piece

No. 13 test piece shall be in accordance with B.2.

D.3 Preparation of test piece

The tolerances on the width, diameter or traverse of machined test pieces shall be as given in table D.3 and table D.4.

An example of the application of these tolerances shall be as follows.

a) Machining tolerances when using nominal dimension for calculation

When using the nominal dimension other than the measured value for the calculation of the original cross-sectional area S_o, no test piece shall have the dimension outside the two values given in table D.4, for example, ± 0.02 mm for a nominal diameter of 10 mm.

10 mm + 0.02 mm = 10.02 mm

10 mm - 0.02 mm = 9.98 mm

b) Tolerances on dimensional change The tolerances given in table D.3 means that, for a test piece with a nominal diameter of 10 mm which satisfies the machining conditions given in a), the deviation between the smallest and largest diameters measured shall not exceed 0.04 mm.

Consequently, if the minimum diameter of the test piece is 9.99 mm, its maximum diameter shall not exceed 9.99 mm +0.04 mm -10.03 mm.

Table D.3   Tolerances on dimensional change for width, diameter or traverse of test piece

Unit: mm

Designation	Nominal width, diameter or traverse	Tolerances on dimensional change [a]
Diameter of test piece with circular cross section and four transverses of test piece with rectangular/square cross section	>3 ≤6	0.03
	>6 ≤10	0.04
	>10 ≤18	0.04
	>18 ≤30	0.05
Width of flat-form test piece machined only on both sides in width direction	>3 ≤6	0.03
	>6 ≤10	0.04
	>10 ≤18	0.06
	>18 ≤30	0.10
	>30 ≤50	0.10
Note[u] Difference between the maximum value and the minimum value of width, diameter or traverse along the entire parallel length (L_e) of the test piece.		

Table D.4 Tolerances when using nominal dimension for calculation of original cross-sectional area

Unit: mm

Designation	Nominal width, diameter or traverse	Machining tolerances on nominal dimension [a]
Diameter of test piece with circular cross section and four transverses of test piece with rectangular/square cross section	>3 ≤6	±0.01
	>6 ≤10	±0.02
	>10 ≤18	±0.03
	>18 ≤30	±0.06
Width of flat-form test piece machined only on both sides in width direction	>3 ≤6	±0.01
	>6 ≤10	±0.02
	>10 ≤18	±0.03
	>18 ≤30	±0.06
	>30 ≤50	±0.10

Note[a] 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. If these machining tolerances are not conformed, every individual dimension of the test piece shall be measured.

D.4 Determination of cross-sectional area S_o.

The nominal dimension of the test piece with circular cross section and that with rectangular/square cross section on which four surfaces are machined, and the width of the flat-form test piece only both sides of which are machined that satisfy the tolerances given in table D.4 may be used for the calculation of the original cross-sectional area. For all other shapes of test pieces, the original cross-sectional area shall be calculated from measurements of the appropriate dimensions.

NOTE: ISO 6892-1 specifies that the measurement shall be carried out with an error not exceeding ±0.5 % on each dimension.

<h1 align="center">Annex E (normative)</h1>
<h2 align="center">Types of test pieces used for tubes</h2>

E.1 Shape of test piece

The shape of test piece shall be a tube-form test piece, longitudinal strip-form test piece having the original wall thickness of the tube or the traverse flat-form test piece (see figure 14 and figure 15). Also, there is the bar-form test piece taken from the cross section of the tube.

Machined longitudinal and transverse, and bar-form test pieces are in accordance with in Annex B for the tube with a wall thickness of less than 3 mm, and Annex D for that with a wall thickness is equal to or greater than 3 mm. The longitudinal test piece is generally used for the tube with a wall thickness of more than 0.5 mm.

E.2 Dimensions of test piece

E.2.1 Tube-form test piece

The tube-form test piece may be plugged at both ends. The interval between each plug and the nearest gauge mark shall be greater than $D_0/4$. In case of dispute, the interval shall be over D_0, unless there is insufficient length of the sample.

The length of the plug projecting beyond the grips of the testing machine in the direction of the gauge marks shall not exceed D_o, and its shape shall be such that it does not interfere with deformation of the tube within the gauge length.

E.2.1.1 Proportional test piece

E.2.1.1.1 No. 14C test piece

The shape and dimensions of No. 14C test piece shall be as given in figure E.1. The cross section of No. 14C test piece shall be as cut out from the product of tube. No. 14C test piece shall be plugged at gripped ends. In this case, the length of the part which is allowed to deform without touching the plugs shall be within the range from

$[L_0 + D_0/2)]$ to $(L_0 + 2D_0)$, but $(L_0 + 2D_n)$ is preferable.
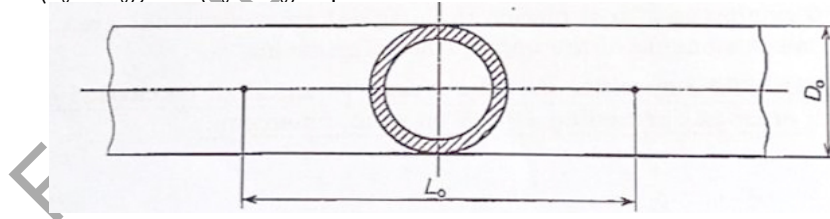
Original gauge length L-5.65$\sqrt{A}$ (where, A is cross-sectional area of test piece)

<p align="center">Figure E.1 No. 14C test piece</p>

E.2.1.2 Non-proportional test piece

E.2.1.2.1 No. 11 test piece (specific to JIS)

The **shape** and dimensions of No. 11 test piece shall be as given in figure E.2.

The cross section of No. 11 test piece shall be as cut out from the product of tube. The gripped ends shall be inserted with metal plugs or pressed flat by hammering.

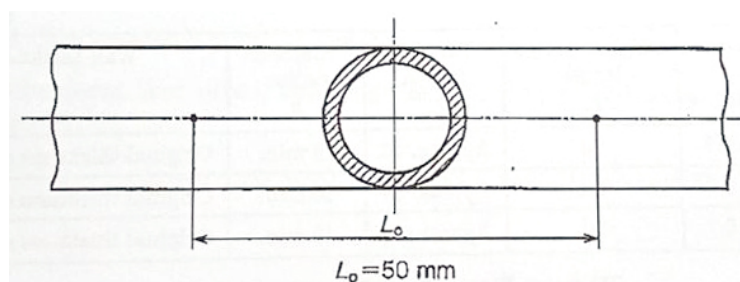In the latter case, the parallel length shall be not less than 100 mm.

Figure E.2 No.11 test piece

E.2.2 Longitudinal strip-form test piece or traverse flat-form test piece

The parallel length L_e of the longitudinal strip-form test piece shall not be flattened; however, the gripped ends of the test piece may be flattened.

Dimensions of longitudinal strip-form test piece or traverse flat-form test piece other than those given in Annex B and Annex D shall be in accordance with the product standards.

Special precautions shall be taken when flattening the transverse flat-form test piece.

### E.2.2.1 Proportional test piece

E.2.2.1.1 No. 14B test piece

No. 14B test piece shall be as given in figure D.2.

E.2.2.2 Non-proportional test piece

E.2.2.1.1 No. 12 test piece (specific to JIS)

The **shape** and dimensions of No. 12 test piece shall be as given in figure E.3.

The cross section of parallel portion of No. 12 test piece shall be as cut out from the product of tube; however, the gripped ends may be flattened by hammering at room temperature.
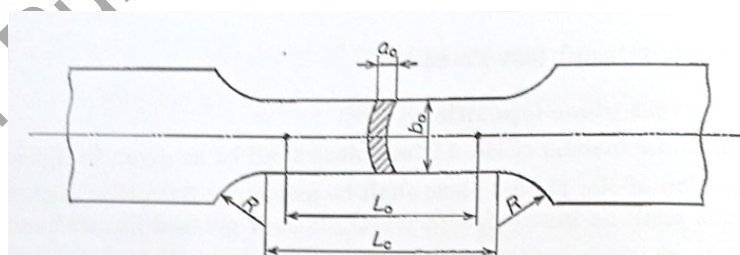
Unit: mm

Type of test piece	Width b_o	Original gauge length L_o	Parallel length L_e	Transition radius R	Wall thickness a_o
12A	19±0.7	50	Approx. 60	15 min	Original thickness of product
12B	25±0.7	50	Approx. 60	15 min	Original thickness of product
12C	38±0.7	50	Approx. 60	15 min	Original thickness of product

Figure E.3 No. 12 test piece

E.2.3 Bar-form test piece

The sampling method of test piece shall be in accordance with the product standards.

E.3 Determination of original cross-sectional area S_o

The original cross-sectional area of the tube-form test piece may be obtained from the mass of test piece, length of test piece measured and density of the material according to equation (E.1).

NOTE: ISO 6892-1 specifies that the error in determining the original cross-sectional area shall not exceed ±1%.

$$S_0 = \frac{1000 \times m}{p \times L_t} \tag{E. 1}$$

where,   m: mass of test piece (g)

L_t: total length of test piece (mm)

p: density of material of test piece (g.cm³)

The original cross-sectional area of longitudinal strip-form test piece should be calculated according to equation (E.2).

If $b_0/D_0 < 0.25$

$$S0 = a_0 b_0 \left[1 + \frac{b_0^2}{6 D_0 (D_0 - 2a_0)} \right] \tag{E. 2}$$

where, a_o: wall thickness of tube

b_0.: average width of test piece

D_0: outside diameter of tube

Or equation (E.3) may be used.

$$S_0 = a_0 (D_0 - a_0) \sin^{-1} \frac{b_0}{D0 - a_0} \tag{E.3}$$

NOTE 1 ISO 6892-1 specifies that the calculation shall be carried out according to the following equation.

$$S_0 = \frac{b_0}{4}(D_0^2 - b_0^2)^{1/2} + \frac{D_0^2}{4} \arcsin\left[\frac{b_0}{D_0}\right] - \frac{b_0}{4}\left[(D_0 - 2a_0)^2 - b_0^2\right]^{1/2} - \left[\frac{D_0 - 2a_0}{2}\right]^2 \arcsin\left[\frac{2}{(D_0 - 2a_0)}\right]$$

NOTE 2 ISO 6892-1 permits the use of equation $S_o = a_o b_o$, if $b_0/D_0 < 0.1$.

For the tube-form test piece, the original cross-sectional area shall be obtained according to equation (E.4).

$$S_0 = \pi a_0 (D_0 - a_0) \tag{E.4}$$

Annex F (informative)

Estimation of crosshead separation rate in consideration
of stiffness of testing machine

Equation (JB.1) in JB.1 does not consider any elastic deformation of the testing equipment (frame, load cell, grips, etc.). This means that the deformation can be separated into the elastic deformation of the testing equipment and the elastic deformation of the test piece. Only a part of the crosshead separation rate is transferred to the test piece. The resulting strain rate at the test piece $\dot{e}_m$ per second is given by equation (F.1).

$$\dot{e}_m = v_c \bigg/ \left(\frac{m \times S_o}{C_M} + L_c \right) \quad\text{--}\quad \text{(F.1)}$$

where, C_M: stiffness of testing equipment (N/mm)

(Around the point of interest such as $R_{p0.2}$, if stiffness is not linear, e.g., when using

wedge grips)

L_c: parallel length of test piece (mm)

m: slope of stress-percentage extension curve at a given moment of test (MPa)

(Around the point of interest such as $R_{p0.2}$

S_o: original cross-sectional area (mm²)

v_c: crosshead separation rate (mm.s⁻¹)

NOTE: The values of m and C_M derived from the linear portion of the stress strain curve cannot be used.

Equation (JB.1) does not compensate for the effects of stiffness of testing equipment (see JB.1). A better approximation of the crosshead separation rate v. (mm s⁻¹) necessary to produce a resulting strain rate at the test piece $\dot{e}_m$ around the point of interest, can be obtained from equation (F.2).

$$v_c = \dot{e}_m \left[\frac{m \times s_o}{C_M} + L_c \right] \quad\text{--}\quad \text{(F.2)}$$
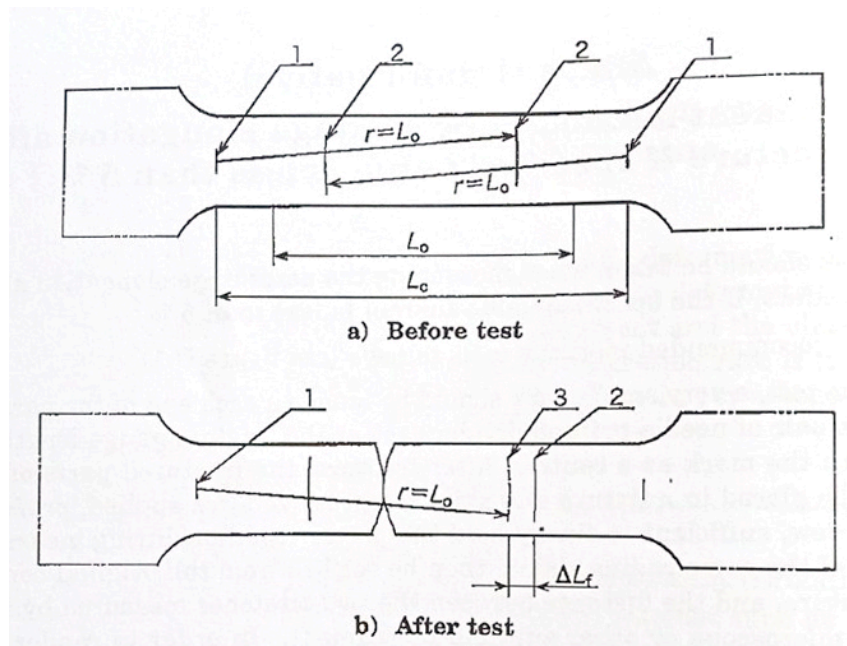
Annex G (informative)
Measurement method of percentage elongation after
fracture if specified value is less than 5%

Precautions should be taken when measuring the percentage elongation after fracture of the product, if the specified value thereof is less than 5 %.

One of the recommended methods is as follows (see figure G.1).

Prior to the test, a very small mark should be made on each end of the parallel portion. Using a pair of needle-pointed dividers set at the original gauge length, an arc is scribed with the mark as a centre. After fracture, the fractured parts of the test piece should be placed in a fixture and axial compressive force applied, preferably by means of a screw, sufficient to firmly hold the pieces together during measurement. A second arc of the same radius should then be scribed from the original centre closest to the fracture, and the distance between the two scratches measured by means of a measuring microscope or other suitable instrument. In order to render the fine scratches more easily visible, a suitable dye film may be applied to the test piece before testing.

NOTE: Another measuring method is described in 20.2 (measuring method of the extension at fracture using an extensometer).

a) Before test

b) After test

L0   original gauge length

Lc   parallel length

ΔL elongation at fracture

r   radius of arc scribed from mark at end of parallel portion ($r = L_0$)

1   mark made at end of parallel portion

2   are scribed by a pair of needle-pointed dividers by making mark at end of parallel portion as the base point and setting to original gauge length after fracture.

3   are scribed by a pair of needle-pointed dividers by making mark at end of parallel portion as the base point and setting to original gauge length after fracture

Figure G.1   Example of measuring method of percentage elongation after fracture if specified value is less than 5%

Annex H (informative)
Measurement method of percentage elongation after
fracture based on subdivision of original gauge length

To avoid having to reject test pieces where the fracture location does not comply with 20.1, the following method may be applied upon the agreement between the parties concerned with delivery.

a) Before the test, the original gauge length is divided into N equal lengths of 5 mm (recommended) to 10 mm.

b) After the test, the gauge mark on the shorter part of the fractured test piece is made as X and the gauge mark on the longer part of the fractured test piece which is at the same distance from the fracture as X is made as Y. If n is the number of intervals between X and Y, the elongation after fracture is obtained as follows.

1) If N-n is an even number [see figure H.1 a)], the distance between X and Y, L_{xy} and the distance from Y to the graduation Z, l_{yz}, which is located at (N-n)/2 are measured.

   The percentage elongation after fracture is obtained according to equation (H.1).

   $$A = \frac{L_{xy} + 2l_{yz} - L_0}{L_0} \times 100 \quad\text{--}\quad (H.1)$$

2) If N-n is an odd number [see figure H.1 b)], the distance between X and Y, l_{xy}, the distance from Y to the graduation Z, l_{yz}, and the distance from Y to the graduation Z", l_{yz}- are measured. The location of Z' and Z" are as follows.
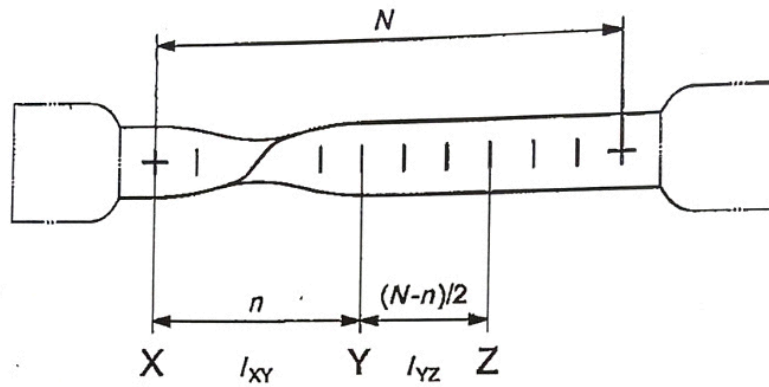
   The graduation Z' is located at (N-n-1)/2
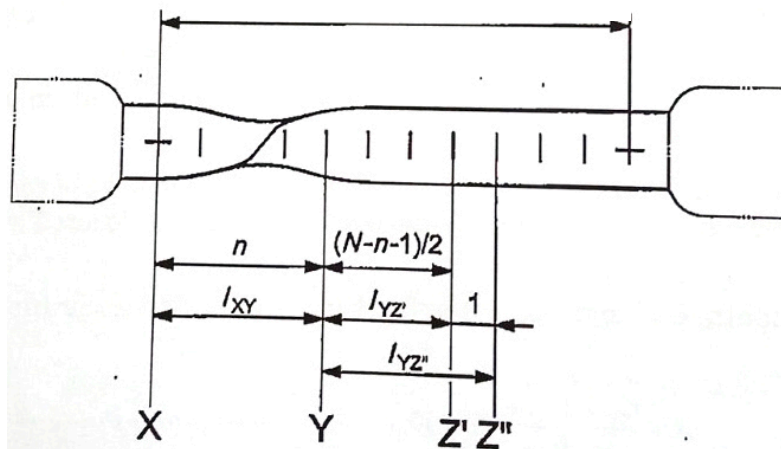
   The graduation Z" is located at (N-n+1)/2

   The percentage elongation after fracture is obtained according to equation (H.2).

   $$A = \frac{L_{xy} + l_{yz} + l_{yz} - L_0}{L_0} \times 100 \quad\text{--}\quad (H.2)$$

(a) If N – n is even number

(b) If N – n is odd number

n: number of graduations between X and Y

N: number of equal lengths

X: gauge mark on shorter part of test piece

Y: gauge mark on longer part of test piece

Z, Z', Z'' : gauge marks

NOTE: The shape of gripped ends is only given as guide.

Figure H.1 Example of measurement method of percentage elongation after fracture

Annex I (informative)
Measurement of percentage plastic elongation without
necking for bar, wire rod and wire

This method is to be carried out on the longer part of a fractured test piece. Before the test, equidistant marks are made between the gauge marks so that the distance between two successive marks becomes equal to a fraction of the initial gauge length L_o. The marking of the initial gauge length L_o'. should be accurate to within ± 0.5 mm. The measurement of the final gauge length after fracture L'_u. is made on the longer fractured part of the test piece, and should be accurate to within ±0.5 mm.

In order for the measurement to be valid, the following two conditions should be met.

a) The measuring zone should be located at least 5d, from the fracture and at least $2.5d_0$, from the grip.

b) The final gauge length measured should be at least equal to the value specified in the product standard.

The percentage plastic elongation without necking is calculated according to equation (I.1).

$$A_{wn} = \frac{L_u' - L_0'}{L_0'} \times 100 \quad\quad\quad\quad (1.1)$$

NOTE: For many metallic materials, the maximum force occurs in the range where necking starts. This means the forces for Ag and Awn for these materials will be nearly equal. Large differences will be found in highly cold deformed material such as double reduced tin plate, irradiated structural steel and tests carried out at elevated temperatures.

Annex JA (informative)

Number of measuring points required for calculation of

cross-sectional area of test piece

JA.1   Obtaining method of original cross-sectional area of parallel portion of test piece

It in specified so that the cross-sectional area of parallel portion of test piece is obtained by the measured values at sufficient positions on the central part. Generally, it is obtained from the average of 3 positions at both ends of gauge length and the central part. However, for the tube-form test piece specified in Annex E, it is obtained from the measurements at the end of the test piece.

JA.2 Concept where dimensional measurement is made to one point

For the case of the parallel portion of the test piece and the unmachined test piece, it is considered acceptable that the position of dimensional measurement in longitudinal direction is one point, if it is sufficiently managed that the cross-sectional area between gripped ends are even over the whole length and the cross-sectional area change (maximum value- minimum value) is within 0.5 %. For respective dimensions, the position of dimensional measurement in longitudinal direction may be made to one point, if the tolerances in table JA-1 to table JA.3 are sufficiently managed so as not to exceed.

Table JA.1 Dimensional tolerances of test piece (test piece with circular cross section)

unit : mm

Nominal diameter	Tolerances
10 or over to and excl 12	0.025
12or over to and excl 16	0.03
16 or over	0.04

Table JA.2 Dimensional tolerances of test piece (test piece of under 6 mm in thickness with rectangular cross section)

Unit: mm

Nominal thickness	Tolerances
0.6 or over to and excl. 1.2	0.002
1.2 or over to and excl. 2.5	0.004
2.5 or over to and excl. 6	0.01

Unit: mm

Nominal width	Tolerances
12.5 or over to and excl. 25	0.02
25 or over	0.04

Table JA.3 Dimensional tolerances of test piece (test piece of 6 mm or over in thickness with rectangular cross section)

Unit: mm

Nominal thickness	Tolerances
6 or over to and excl. 1.2	0.02
12 or over to and excl. 20	0.04
20 or over	0.05

Unit: mm

Nominal width	Tolerances
25 or over to and excl. 40	0.05
40 or over	0.10

Annex JB (informative)
Testing rate based on strain rate control (method A)

In this Annex, the test method in which the testing rate in the elastic part is controlled by the strain rate is specified as method A in ISO 6892-1. This is listed in view of the spread of this method in Japan for the future.

JB.1 General

Method A is intended to minimize the variation of the testing rates during the moment when the strain rate sensitive parameters are measured 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 control of the strain rate itself è that is based on the feedback obtained from an extensometer. The second is the control of the estimated strain rate over the parallel portion e_{Lc} which is achieved by controlling the crosshead separation rate at a velocity equal to the desired strain rate calculated from the parallel length.

If a material shows homogeneous deformation behaviour and the force remains nominally constant, the strain rate $\dot{e}_{Le}$ and the estimated strain rate over the parallel portion $\dot{e}_{Le}$ are approximately equal. Differences exist if the material exhibits discontinuous or serrated yielding (e.g., some steels and AIMg 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 of the parallel portion may be substantially below the target strain rate due to the compliance of the testing machine.

The testing rate conforms to the following requirements.

a) In the range up to and including the measurement of R_{eH}, R_p, or R_t, the specified strain rate $\dot{e}_{Le}$ (**see 3.7.1**) is 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 portion $\dot{e}_{Le}$ may be used.)

b) During discontinuous yielding, the estimated strain rate over the parallel portion $\dot{e}_{Le}$ (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 portion may be maintained in this range sufficiently accurately using a constant crosshead separation rate, v_e. (see 3.7.3).

$$V_e = L_e \times \dot{e}_{Le} \quad\text{-- (JB.1)}$$

where, $\dot{e}_{Le}$ estimated strain rate over parallel portion

L_e parallel length of test piece

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

The strain rates specified JB.2 to JB.4 is maintained during the measurement of the relevant material property (see also figure JB.1).

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 applied should be documented.

JB.2 Measurement of upper yield strength R_{eH} or proof strength R_p and R_t

The strain rate $\grave{e}_{Le}$ is kept as constant as possible up to and including the measurement of R_{eH}. R_p, and R_t. During the measurement of these material properties, the strain rate $\grave{e}_{Le}$, is in one of the two following specified ranges (see figure JB.1).

Range 1: (0.000 07 ± 0.000 014)s^{-1}

Range 2: (0.000 25a ± 0.000 005) s^{-1} (recommended unless otherwise specified)

If the testing machine is not able to control the strain rate directly, the estimated strain rate over the parallel portion $\grave{e}_{Le}$. i.e. constant crosshead separation rate, is used. This rate is calculated using equation (JB.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 thereof is given in Annex F.

JB.3 Lower yield strength R... or percentage yield point extension A_e.

Following the detection of the upper yield strength, the estimated strain rates the parallel portion $\grave{e}_{Le}$, shall be maintained in one of the following two specified ranges until discontinuous yielding has ended (see figure JB.1).

Range 2: (0.000 250.000 05)S^{-1} a (recommended when R_1 is measured)

Range 3: (0.002=0.000 4) S^{-1}

JB.4 Tensile strength R. percentage elongation after fracture A, percentage total extension at the maximum force A_g percentage plastic extension at maximum force A_g, and percentage reduction of area Z

After measurement of the required yield/proof strength properties, the estimated strain rate over the parallel portion $\grave{e}_{Le}$ is changed to one of the following specified ranges.

Range 2: (0.000 25 ± 0.000 05) s^{-1}

Range 3: (0.002 ± 0.000 4) S^{-1}

Range 4: (0.006 7 ± 0.001 33) S^{-1} [(0.4 ± 0.08) min^{-1}] (recommended unless otherwise specified)

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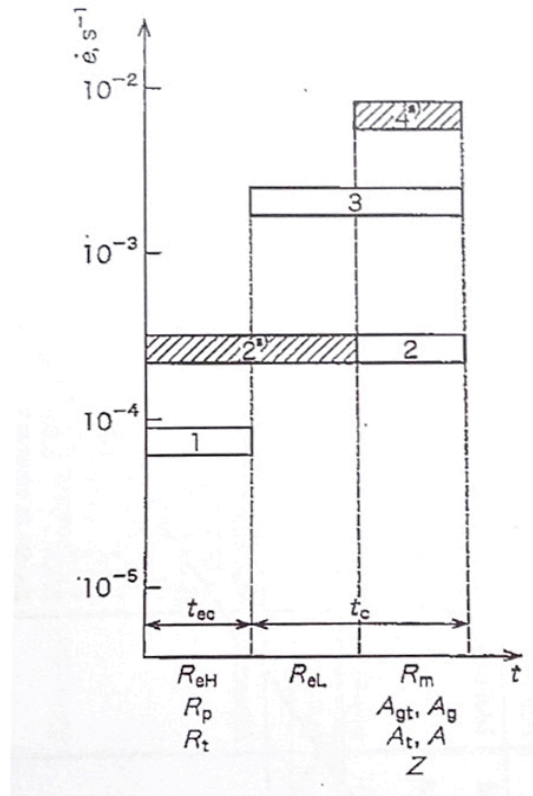
è : strain rate

z : time progress of tensile test

l_{cc}: time range controlled by extensometer or crosshead separation rate

l_c : time range controlled by crosshead separation rate

1 : range 1: è = $(0.000\ 07 \pm 0.000\ 014)$ S^{-1}

2 : range 2: è = $(0.000\ 25 \pm 0.000\ 05)$ S^{-1}

3 : range 3: è = $(0.002 \pm 0.000\ 4)$ S^{-1}

4 : range 4: è = $(0.0067 \pm 0.001\ 33)$ S^{-1} $((0.4 \pm 0.08)$ $min^{-1}]$

Note [a)] Recommended

Figure JB.1 Illustration of strain rate to be used during test if R_{CH}, R_{CL} R_P, R_{eL} R_m A_g, A_{gt}, A,A_t and Z are measured

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Bibliography

JIS G 0416 Steel and steel products-Location and preparation of samples and test pieces for mechanical testing

NOTE   **:** Corresponding International Standard: ISO 377:1997 Steel and steel products-Location and
                preparation of samples and test pieces for mechanical testing (**MOD**)

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

ASTM E 1012 Standard Practice for verification of Test Frame and Specimen Alignment Under Tensile and
                Compressive Axial Force Application