



Metallic materials — Tensile testing — Method of test at room temperature



AS 1391:2020

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Metallic materials — Tensile testing — Method of test at room temperature

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Preface

This Test Method was prepared by the Standards Australia Committee MT-006, Mechanical Testing of Metals to supersede AS 1391—2007 *Metallic materials—Tensile testing at ambient temperature*.

The objective of this Test Method is to specify the method for tensile testing of metallic materials and define the mechanical properties which can be determined at room temperature.

NOTE Annex A contains further recommendations for computer controlled testing machines.

This Test Method is identical with, and has been reproduced from, ISO 6892-1:2019, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*.

As this document has been reproduced from an International Standard or Test Method or Technical Specification or Technical Report, the following applies:

- (a) In the source text “this part of ISO 6892” should read “this Australian Test Method”.
- (b) A full point substitutes for a comma when referring to a decimal marker.

Australian or Australian/New Zealand Standards that are identical adoptions of international normative references may be used interchangeably. Refer to the online catalogue for information on specific Standards.

The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

Contents

Preface	ii
Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Symbols	6
5 Principle	7
6 Test pieces	8
6.1 Shape and dimensions	8
6.1.1 General	8
6.1.2 Machined test pieces	8
6.1.3 Unmachined test pieces	8
6.2 Types	9
6.3 Preparation of test pieces	9
7 Determination of original cross-sectional area	9
8 Original gauge length and extensometer gauge length	9
8.1 Choice of the original gauge length	9
8.2 Marking the original gauge length	10
8.3 Choice of the extensometer gauge length	10
9 Accuracy of testing apparatus	10
10 Conditions of testing	10
10.1 Setting the force zero point	10
10.2 Method of gripping	11
10.3 Testing rates	11
10.3.1 General information regarding testing rates	11
10.3.2 Testing rate based on strain rate (method A)	11
10.3.3 Testing rate based on stress rate (method B)	13
10.3.4 Report of the chosen testing conditions	14
11 Determination of the upper yield strength	15
12 Determination of the lower yield strength	15
13 Determination of proof strength, plastic extension	15
14 Determination of proof strength, total extension	16
15 Method of verification of permanent set strength	16
16 Determination of the percentage yield point extension	16
17 Determination of the percentage plastic extension at maximum force	16
18 Determination of the percentage total extension at maximum force	17
19 Determination of the percentage total extension at fracture	17
20 Determination of percentage elongation after fracture	17
21 Determination of percentage reduction of area	18
22 Test report	19
23 Measurement uncertainty	19
23.1 General	19
23.2 Test conditions	19

23.3	Test results.....	20
Annex A	(informative) Recommendations concerning the use of computer-controlled tensile testing machines	33
Annex B	(normative) Types of test pieces to be used for thin products: sheets, strips, and flats between 0,1 mm and 3 mm thick	39
Annex C	(normative) Types of test pieces to be used for wire, bars, and sections with a diameter or thickness of less than 4 mm	42
Annex D	(normative) Types of test pieces to be used for sheets and flats of thickness equal to or greater than 3 mm and wire, bars, and sections of diameter or thickness equal to or greater than 4 mm	43
Annex E	(normative) Types of test pieces to be used for tubes	47
Annex F	(informative) Estimation of the crosshead separation rate in consideration of the stiffness (or compliance) of the testing equipment	49
Annex G	(normative) Determination of the modulus of elasticity of metallic materials using a uniaxial tensile test	51
Annex H	(informative) Measuring the percentage elongation after fracture if the specified value is less than 5 %	60
Annex I	(informative) Measurement of percentage elongation after fracture based on subdivision of the original gauge length	61
Annex J	(informative) Determination of the percentage plastic elongation without necking, A_{wn}, for long products such as bars, wire, and rods	63
Annex K	(informative) Estimation of the uncertainty of measurement	64
Annex L	(informative) Precision of tensile testing — Results from interlaboratory programmes	68
Bibliography		75

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This second edition cancels and replaces the first edition (ISO 6892-1:2009), which has been technically revised with the following changes:

- a) renumbering of [Clause 10](#);
- b) additional information about the use of Method A and B;
- c) new denomination for:
 - 1) Method A closed loop → A1
 - 2) Method A open loop → A2;
- e) addition of [A.5](#);
- f) addition in Annex F for determination of the stiffness of the testing equipment;
- g) new normative Annex G: Determination of the modulus of elasticity of metallic materials using a uniaxial tensile test;
- h) the old Annex G is renamed to Annex H, Annex H to Annex I, etc.

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

- *Part 1: Method of test at room temperature*
- *Part 2: Method of test at elevated temperature*
- *Part 3: Method of test at low temperature*
- *Part 4: Method of test in liquid helium*

Introduction

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

In this part of ISO 6892, there are two methods of testing speeds available. The first, method A, is based on strain rates (including crosshead separation rate) and the second, method B, is based on stress rates. Method A is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results. Therefore, and out of the fact that often the strain rate sensitivity of the materials is not known, the use of method A is strongly recommended.

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Metallic materials — Tensile testing — Method of test at room temperature

1 Scope

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

NOTE Annex A contains further recommendations for computer controlled testing machines.

2 Normative references

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

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

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

3 Terms and definitions

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

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

3.1

gauge length

L

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

3.1.1

original gauge length

L_0

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

3.1.2

final gauge length after fracture

L_u

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

3.2

parallel length

L_c

length of the parallel reduced section of the test piece

Note 1 to entry: The concept of parallel length is replaced by the concept of distance between grips for unmachined test pieces.

3.3

elongation

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

3.4

percentage elongation

elongation expressed as a percentage of the *original gauge length* ([3.1.1](#))

3.4.1

percentage permanent elongation

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

3.4.2

percentage elongation after fracture

A

permanent elongation of the gauge length after fracture, $(L_u - L_o)$, expressed as a percentage of the *original gauge length* ([3.1.1](#))

Note 1 to entry: For further information, see [8.1](#).

3.5

extensometer gauge length

L_e

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

Note 1 to entry: For further information, see [8.3](#).

3.6

extension

increase in the *extensometer gauge length* ([3.5](#)), at any moment during the test

3.6.1

percentage extension

“strain”

e

extension expressed as a percentage of the *extensometer gauge length* ([3.5](#))

Note 1 to entry: e is commonly called engineering strain.

3.6.2

percentage permanent extension

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

3.6.3

percentage yield point extension

A_e

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

Note 1 to entry: See [Figure 7](#).

3.6.4

percentage total extension at maximum force

A_{gt}

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

Note 1 to entry: See [Figure 1](#).

3.6.5**percentage plastic extension at maximum force** A_g

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

Note 1 to entry: See [Figure 1](#).

3.6.6**percentage total extension at fracture** A_t

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

Note 1 to entry: See [Figure 1](#).

3.7 Testing rate**3.7.1****strain rate** $\dot{\epsilon}_{L_e}$

increase of strain, measured with an extensometer, in *extensometer gauge length* (3.5), per time

3.7.2**estimated strain rate over the parallel length** $\dot{\epsilon}_{L_c}$

value of the increase of strain over the *parallel length* (3.2), of the test piece per time based on the *crosshead separation rate* (3.7.3) and the parallel length of the test piece

3.7.3**crosshead separation rate** v_c

displacement of the crossheads per time

3.7.4**stress rate** $\dot{R}$

increase of stress per time

Note 1 to entry: Stress rate is only used in the elastic part of the test (method B) (see also [10.3.3](#)).

3.8**percentage reduction of area** Z

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

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

3.9 Maximum force**3.9.1****maximum force** F_m

<materials displaying no discontinuous yielding> highest force that the test piece withstands during the test

3.9.2

maximum force

F_m

<materials displaying discontinuous yielding> highest force that the test piece withstands during the test after the beginning of work-hardening

Note 1 to entry: For materials which display discontinuous yielding, but where no work-hardening can be established, F_m is not defined in this part of ISO 6892 [see footnote to [Figure 8 c](#)].

Note 2 to entry: See [Figure 8 a](#)) and b).

3.10

stress

R

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

Note 1 to entry: All references to stress in this part of ISO 6892 are to engineering stress.

3.10.1

tensile strength

R_m

stress corresponding to the *maximum force* ([3.9.2](#))

3.10.2

yield strength

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

3.10.2.1

upper yield strength

R_{eH}

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

Note 1 to entry: See [Figure 2](#).

3.10.2.2

lower yield strength

R_{eL}

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

Note 1 to entry: See [Figure 2](#).

3.10.3

proof strength, plastic extension

R_p

stress at which the plastic extension is equal to a specified percentage of the *extensometer gauge length* ([3.5](#))

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

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

Note 3 to entry: See [Figure 3](#).

3.10.4

proof strength, total extension

R_t

stress at which total extension (elastic extension plus plastic extension) is equal to a specified percentage of the *extensometer gauge length* ([3.5](#))

Note 1 to entry: A suffix is added to the subscript to indicate the prescribed percentage, e.g. $R_{t0,5}$.

Note 2 to entry: See [Figure 4](#).

3.10.5

permanent set strength

R_r

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

Note 1 to entry: A suffix is added to the subscript to indicate the specified percentage of the original gauge length, L_o , or of the extensometer gauge length, L_e , e.g. $R_{r0,2}$.

Note 2 to entry: See [Figure 5](#).

3.11

fracture

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

Note 1 to entry: Criteria for fracture for computer controlled tests are given in [Figure A.2](#).

3.12

computer-controlled tensile testing machine

machine for which the control and monitoring of the test, the measurements, and the data processing are undertaken by computer

3.13

modulus of elasticity

E

quotient of change of stress ΔR and change of percentage extension Δe in the range of evaluation, multiplied by 100 %

$$E = \frac{\Delta R}{\Delta e} \cdot 100 \%$$

Note 1 to entry: It is recommended to report the value in GPa rounded to the nearest 0,1 GPa and according to ISO 80000-1.

3.14

default value

lower or upper value for stress respectively strain which is used for the description of the range where the modulus of elasticity is calculated

3.15

coefficient of correlation

R^2

additional result of the linear regression which describes the quality of the stress-strain curve in the evaluation range

Note 1 to entry: The used symbol R^2 is a mathematical representation of regression and is no expression for a squared stress value.

3.16

standard deviation of the slope

S_m

additional result of the linear regression which describes the difference of the stress values from the best fit line for the given extension values in the evaluation range

3.17**relative standard deviation of the slope** $S_{m(\text{rel})}$

quotient of the standard deviation of the slope and the slope in the evaluation range, multiplied by 100 %

$$S_{m(\text{rel})} = \frac{S_m}{E} \cdot 100 \%$$

4 SymbolsThe symbols used in this part of ISO 6892 and corresponding designations are given in [Table 1](#).**Table 1 — Symbols and designations**

Symbol	Unit	Designation
Test piece		
a_o, T^a	mm	original thickness of a flat test piece or wall thickness of a tube
b_o	mm	original width of the parallel length of a flat test piece or average width of the longitudinal strip taken from a tube or width of flat wire
d_o	mm	original diameter of the parallel length of a circular test piece, or diameter of round wire or internal diameter of a tube
D_o	mm	original external diameter of a tube
L_o	mm	original gauge length
L'_o	mm	initial gauge length for determination of A_{wn} (see Annex J)
L_c	mm	parallel length
L_e	mm	extensometer gauge length
L_t	mm	total length of test piece
L_u	mm	final gauge length after fracture
L'_u	mm	final gauge length after fracture for determination of A_{wn} (see Annex J)
S_o	mm ²	original cross-sectional area of the parallel length
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 J)
Extension		
e	%	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_f	mm	extension at fracture
Rates		
$\dot{e}_{L_e}$	s ⁻¹	strain rate
$\dot{e}_{L_c}$	s ⁻¹	estimated strain rate over the parallel length

Table 1 (continued)

Symbol	Unit	Designation
$\dot{R}$	MPa s ⁻¹	stress rate
v_c	mm s ⁻¹	crosshead separation rate
Force		
F_m	N	maximum force
Yield strength — Proof strength — Tensile strength		
R	MPa ^b	stress
R_{eH}	MPa	upper yield strength
R_{eL}	MPa	lower yield strength
R_m	MPa	tensile strength
R_p	MPa	proof strength, plastic extension
R_r	MPa	specified permanent set strength
R_t	MPa	proof strength, total extension
Modulus of Elasticity — slope of the stress-percentage extension curve		
E	GPa	modulus of elasticity ^c
m	MPa	slope of the stress-percentage extension curve at a given moment of the test
m_E	MPa	slope of the elastic part of the stress-percentage extension curve ^d
R_1	MPa	lower stress value
R_2	MPa	upper stress value
e_1	%	lower strain value
e_2	%	upper strain value
R^2	—	coefficient of correlation
S_m	MPa	standard deviation of the slope
$S_{m(rel)}$	%	relative standard deviation of the slope
^a Symbol used in steel tube product standards. ^b 1 MPa = 1 N mm ⁻² . ^c The calculation of the modulus of elasticity is described in Annex G . It is not required to use Annex G to determine the slope of the elastic part of the stress-percentage extension curve for the determination of proof strength. ^d 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 may closely agree with the value of the modulus of elasticity if optimal conditions are used (see Annex G). CAUTION — The factor 100 is necessary if percentage values are used.		

5 Principle

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

The test shall be carried out at room temperature between 10 °C and 35 °C, unless otherwise specified. For laboratory environments outside the stated requirement, it is the responsibility of the testing laboratory to assess the impact on testing and or calibration data produced with and for testing machines operated in such environments. When testing and calibration activities are performed outside the recommended temperature limits of 10 °C and 35 °C, the temperature shall be recorded and reported. If significant temperature gradients are present during testing and or calibration, measurement uncertainty may increase and out of tolerance conditions may occur.

Tests carried out under controlled conditions shall be made at a temperature of 23 °C ± 5 °C.

If the determination of the modulus of elasticity is requested in the tensile test, this shall be done in accordance with [Annex G](#).

6 Test pieces

6.1 Shape and dimensions

6.1.1 General

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

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

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

Preferred test pieces have a direct relationship between the original gauge length, L_0 , and the original cross-sectional area, S_0 , expressed by the formula $L_0 = k\sqrt{S_0}$, where k is a coefficient of proportionality, and are called proportional test pieces. The internationally adopted value for k is 5,65. The original gauge length shall be not less than 15 mm. When the cross-sectional area of the test piece is too small for this requirement to be met with, $k = 5,65$, a higher value (preferably 11,3) or a non-proportional test piece may be used.

NOTE By using an original gauge length smaller than 20 mm, the uncertainty of the result “elongation after fracture” will be increased.

For non-proportional test pieces, the original gauge length, L_0 , is independent of the original cross-sectional area, S_0 .

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

Other test pieces such as those specified in relevant product standards or national standards may be used by agreement with the customer, e.g. ISO 3183[1], (API 5L), ISO 11960[2], (API 5CT), ASTM A370[6], ASTM E8M[7], DIN 50125[10], IACS W2[13], and JIS Z 2241[14].

6.1.2 Machined test pieces

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

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

The parallel length, L_c , or, in the case where the test piece has no transition radii, the free length between the grips, shall always be greater than the original gauge length, L_0 .

6.1.3 Unmachined test pieces

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

As-cast test pieces shall incorporate a transition radius between the gripped ends and the parallel length. The dimensions of this transition radius are important and it is recommended that they be

defined in the product standard. The gripped ends may be of any shape to suit the grips of the testing machine provided that they enable the centre of the test piece to coincide with the axis of application of force. The parallel length, L_c , shall always be greater than the original gauge length, L_0 .

6.2 Types

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

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

Dimensions in millimetres

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

6.3 Preparation of test pieces

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

7 Determination of original cross-sectional area

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

A minimum of three cross-sections is recommended.

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

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

All measuring devices used for the determination of the original cross-sectional area shall be calibrated to the appropriate reference standards with traceability to a National Measurement System.

8 Original gauge length and extensometer gauge length

8.1 Choice of the original gauge length

For proportional test pieces, if the original gauge length is not equivalent to $5,65\sqrt{S_0}$ where S_0 is the original cross-sectional area of the parallel length, the symbol A should be supplemented by a subscript

indicating the coefficient of proportionality used, e.g. $A_{11,3}$ indicates a percentage elongation of the gauge length, L_0 , according to [Formula \(1\)](#):

$$A_{11,3} = 11,3 \sqrt{S_0} \quad (1)$$

NOTE $5,65 \sqrt{S_0} = 5 \sqrt{4S_0 / \pi}$.

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, e.g. $A_{80 \text{ mm}}$ indicates a percentage elongation of a gauge length, L_0 , of 80 mm.

8.2 Marking the original gauge length

For the manual determination of the elongation after fracture A , each end of the original gauge length, L_0 , shall be marked by means of fine marks, scribed lines, or punch marks, but not by marks which could result in premature fracture. The original gauge length shall be marked to an accuracy of $\pm 1 \%$.

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

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

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

8.3 Choice of the extensometer gauge length

For measurement of yield and proof strength parameters, L_e should span as much of the parallel length of the test piece as possible. Ideally, as a minimum, L_e should be greater than $0,50L_0$ but less than approximately $0,9L_c$. This should ensure that the extensometer detects all yielding events that occur in the test piece. Further, for measurement of parameters “at” or “after reaching” maximum force, L_e should be approximately equal to L_0 .

9 Accuracy of testing apparatus

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

For the determination of proof strength (plastic or total extension), the extensometer used shall be in accordance with ISO 9513, class 1 or better, in the relevant range. For other properties (with extensions greater than 5 %), an ISO 9513, class 2 extensometer in the relevant range may be used.

10 Conditions of testing

10.1 Setting the force zero point

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

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

10.2 Method of gripping

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

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

In order to ensure the alignment of the test piece and grip arrangement, a preliminary force may be applied provided it does not exceed a value corresponding to 5 % of the specified or expected yield strength. A correction of the extension should be carried out to take into account the effect of the preliminary force.

10.3 Testing rates

10.3.1 General information regarding testing rates

Unless otherwise agreed, the choice of method (A1, A2, or B) and test rates are at the discretion of the producer or the test laboratory assigned by the producer, provided that these meet the requirements of this part of ISO 6892.

NOTE 1 The difference between Method A and Method B is that the necessary testing speed of Method A is defined at the point of interest (e.g. $R_{p0,2}$), where the property has to be determined; whereas, in Method B, the necessary testing speed is set in the elastic range before the property (e.g. $R_{p0,2}$) has to be determined.

NOTE 2 Under certain conditions using Method B (e.g. for some steels a stress rate in the elastic range of approximately 30 MPa/s, using a testing rig and clamping system with high stiffness and a test piece geometry according Annex B, [Table B.1](#), Test piece type 2), a strain rate near the range 2 of Method A may be observed.

NOTE 3 Product standards and corresponding test standards (e.g. aerospace standards) may specify test rates that are different from those contained in this part of ISO 6892.

10.3.2 Testing rate based on strain rate (method A)

10.3.2.1 General

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

Two different types of strain rate control are described in this subclause.

- Method A1 closed loop involves the control of the strain rate itself, $\dot{\epsilon}_{L_e}$, that is based on the feedback obtained from an extensometer.
- Method A2 open loop involves the control of the estimated strain rate over the parallel length, $\dot{\epsilon}_{L_c}$, which is achieved by using the crosshead separation rate calculated by multiplying the required strain rate by the parallel length [see [Formula \(2\)](#)].

NOTE A more rigorous strain rate estimation procedure for Method A2 is described in Annex F.

If a material shows no discontinuous yielding and the force remains nominally constant, the strain rate, $\dot{\epsilon}_{L_e}$, and the estimated strain rate over the parallel length, $\dot{\epsilon}_{L_c}$, are approximately equal. Differences exist if the material exhibits discontinuous or serrated yielding (e.g. some steels and AlMg alloys in the yield point extension range, or materials which show serrated yielding like the Portevin-Le Chatelier effect) or if necking occurs. If the force is increasing, the strain rate [if the crosshead separation rate is

calculated using [Formula \(2\)](#) may be below the target strain rate due to the compliance of the testing machine.

The testing rate shall conform to the following requirements.

- a) Unless otherwise specified, any convenient speed of testing may be used up to a stress equivalent to half of the expected yield strength. Above this range and for the determination of R_{eH} , R_p or R_t , the specified strain rate, $\dot{\epsilon}_{L_e}$ (or for Method A2 the crosshead separation rate v_c), shall be applied.

In this range, to eliminate the influence of the compliance of the tensile testing machine, the use of an extensometer clamped on the test piece is necessary to have accurate control over the strain rate. For testing machines unable to control by strain rate method A2 may be used.

- b) During discontinuous yielding, the estimated strain rate over the parallel length, $\dot{\epsilon}_{L_c}$ (see [3.7.2](#)), should be applied. In this range, it is impossible to control the strain rate using the extensometer clamped on to the test piece because local yielding can occur outside the extensometer gauge length. The required estimated strain rate over the parallel length may be maintained in this range sufficiently accurately using a constant crosshead separation rate, v_c (see [3.7.3](#)) (open loop);

$$v_c = L_c \dot{\epsilon}_{L_c} \quad (2)$$

where

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

L_c is the parallel length.

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

The strain rates specified in [10.3.2.2](#) to [10.3.2.4](#) shall be maintained during the determination of the relevant material property (see also [Figure 9](#)).

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

The shape of the stress-strain curve in the work-hardening range can also be influenced by the strain rate. The testing rate used should be documented (see [10.3.4](#)).

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

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

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

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

If the testing machine is not able to control the strain rate directly, Method A2 shall be used.

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

Following the detection of the upper yield strength (see [A.3.2](#)), the estimated strain rate over the parallel length, $\dot{\epsilon}_{L_c}$, shall be maintained in one of the following two specified ranges (see [Figure 9](#)) until discontinuous yielding has ended.

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

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

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

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

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

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

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

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

10.3.3 Testing rate based on stress rate (method B)

10.3.3.1 General

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

NOTE It is not the intent of Method B to maintain constant stress rate or to control stress rate with closed loop force control while determining yield properties, but only to set the crosshead speed to achieve the target stress rate in the elastic region (see [Table 3](#)). When a specimen being tested begins to yield, the stressing rate decreases and may even become negative in the case of a specimen with discontinuous yielding. The attempt to maintain a constant stressing rate through the yielding process requires the testing machine to operate at extremely high speeds and, in most cases, this is neither practical nor desirable.

10.3.3.2 Yield and proof strengths

10.3.3.2.1 Upper yield strength, R_{eH}

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

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

Table 3 — Stress rate

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

10.3.3.2.2 Lower yield strength, R_{eL}

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

In no case shall the stress rate in the elastic range exceed the maximum rates given in [Table 3](#).

10.3.3.2.3 Upper and lower yield strengths, R_{eH} and R_{eL}

If both upper and lower yield strengths are determined during the same test, the conditions for determining the lower yield strength shall be complied with (see 10.3.3.1.2).

10.3.3.2.4 Proof strength (plastic extension) and proof strength (total extension), R_p and R_t

The crosshead separation rate of the machine shall be kept as constant as possible and within the limits corresponding to the stress rates in [Table 3](#) for the elastic range. This crosshead separation rate shall be maintained up to the proof strength (plastic extension or total extension). In any case, the strain rate shall not exceed 0,002 5 s⁻¹.

10.3.3.2.5 Rate of separation

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

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

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

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

10.3.4 Report of the chosen testing conditions

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

ISO 6892-1 Annn, or ISO 6892-1 Bn

where “A” defines the use of method A (strain rate based), and “B” the use of method B (stress rate based). The symbols “nnn” are a series of up to 3 characters that refer to the rates used during each phase of the test, as defined in [Figure 9](#), and ‘n’ may be added to indicate the stress rate (in MPa s⁻¹) selected during elastic loading.

EXAMPLE 1 ISO 6892-1:2016 A224 defines a test based on strain rate, using ranges 2, 2 and 4.

EXAMPLE 2 ISO 6892-1:2016 B30 defines a test based on stress rate, performed at a nominal stress rate of 30 MPa s⁻¹.

EXAMPLE 3 ISO 6892-1:2016 B defines a test based on stress rate, performed at a nominal stress rate according to [Table 3](#).

11 Determination of the upper yield strength

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

12 Determination of the lower yield strength

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

In case of materials having yield phenomena and when A_e is not to be determined: For productivity of testing, R_{eL} may be reported as the lowest stress within the first 0,25 % strain after R_{eH} , not taking into account any initial transient effect. After determining R_{eL} by this procedure, the test rate may be increased as per [10.3.2.4](#) or [10.3.2.3](#). Use of this shorter procedure should be recorded on the test report.

13 Determination of proof strength, plastic extension

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

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

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

NOTE Several methods can be used to define the corrected origin of the force-extension curve. One of these is to construct a line parallel to that determined by the hysteresis loop so that it is tangential to the force-extension curve. The point where this line crosses the abscissa is the corrected origin of the force-extension curve (see [Figure 6](#)).

Care should be taken to ensure that the hysteresis is performed after the final proof strength has passed, but at as low an extension as possible, as performing it at excessive extensions will have an adverse effect on the slope obtained.

If not specified in product standards or agreed by the customer, it is inappropriate to determine proof strength during and after discontinuous yielding.

13.2 The property may be obtained without plotting the force-extension curve by using automatic devices (microprocessor, etc.) (see Annex A).

NOTE Another available method is described in GB/T 228.[12]

14 Determination of proof strength, total extension

14.1 R_t is determined on the force-extension curve, taking 10.2 into consideration, by drawing a line parallel to the ordinate axis (force axis) and at a distance from this equivalent to the prescribed total percentage extension. The point at which this line intersects the curve gives the force corresponding to the desired proof strength. The value is calculated by dividing this force by the original cross-sectional area of the test piece, S_0 (see Figure 4).

14.2 The property may be obtained without plotting the force-extension curve by using automatic devices (see Annex A).

15 Method of verification of permanent set strength

The test piece is subjected to a force corresponding to the specified stress for 10 s to 12 s. This force is obtained by multiplying the specified stress by the original cross-sectional area of the test piece, S_0 . 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 performed 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 specification or the requester of the test. Example: Reporting " $R_{r0,5} = 750 \text{ MPa Pass}$ " indicates that a stress of 750 MPa was applied to the test piece and the resulting permanent set was less than or equal to 0,5 %.

16 Determination of the percentage yield point extension

For materials that exhibit discontinuous yielding, A_e is determined from the force-extension curve by subtracting the extension at R_{eH} from the extension at the start of uniform work-hardening. The extension at the start of uniform work-hardening is 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 work-hardening and a line corresponding to the highest slope of the curve occurring at the start of uniform work-hardening (see Figure 7). It is expressed as a percentage of the extensometer gauge length, L_e .

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

17 Determination of the percentage plastic extension at maximum force

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

Calculate the percentage plastic extension at maximum force, A_g , from Formula (3):

$$A_g = \left(\frac{\Delta L_m}{L_e} - \frac{R_m}{m_E} \right) \cdot 100 \quad (3)$$

where

L_e is the extensometer gauge length;

m_E is the slope of the elastic part of the stress-percentage extension curve;

R_m is the tensile strength;

ΔL_m is the extension at maximum force.

NOTE For materials which exhibit a plateau at maximum force, the percentage plastic extension at maximum force is the extension at the mid-point of the plateau (see [Figure 1](#)).

18 Determination of the percentage total extension at maximum force

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

Calculate the percentage total extension at maximum force, A_{gt} , from [Formula \(4\)](#):

$$A_{gt} = \frac{\Delta L_m}{L_e} \cdot 100 \quad (4)$$

where

L_e is the extensometer gauge length;

ΔL_m is the extension at maximum force.

NOTE For materials which exhibit a plateau at maximum force, the percentage total extension at maximum force is the extension at the mid-point of the plateau (see [Figure 1](#)).

19 Determination of the percentage total extension at fracture

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

Calculate the percentage total elongation at fracture, A_t , from [Formula \(5\)](#):

$$A_t = \frac{\Delta L_f}{L_e} \cdot 100 \quad (5)$$

where

L_e is the extensometer gauge length;

ΔL_f is the extension at fracture.

20 Determination of percentage elongation after fracture

20.1 Percentage elongation after fracture shall be determined in accordance with the definition given in [3.4.2](#).

For this purpose, the broken pieces 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 broken parts of the test piece when measuring the final gauge length. This is particularly important for test pieces of small cross-section and test pieces having low elongation values.

Calculate the percentage elongation after fracture, A , from [Formula \(6\)](#):

$$A = \frac{L_u - L_o}{L_o} \cdot 100 \quad (6)$$

where

L_o is the original gauge length;

L_u is the final gauge length after fracture.

Elongation after fracture, $L_u - L_o$, shall be determined 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 H). The result of this determination is valid only if the distance between the fracture and the nearest gauge mark is not less than $L_o/3$. However, the percentage elongation after fracture can be regarded as valid, irrespective of the position of the fracture, if the percentage elongation after fracture is equal to or greater than the specified value. To avoid having to reject test pieces where the distance between the fracture and the next gauge mark is less than $L_o/3$, the method described in Annex I may be used by agreement.

20.2 When extension at fracture is measured using an extensometer, it is not necessary to mark the gauge lengths. The elongation is measured as the total extension at fracture, and it is therefore necessary to deduct the elastic extension in order to obtain percentage elongation after fracture. To obtain comparable values with the manual method, additional adjustments can be applied (e.g. high enough dynamic and frequency bandwidth of the extensometer) (see [A.2.2](#)).

The result of this determination is valid only if fracture and localized extension (necking) occurs within the extensometer gauge length, L_e . The percentage elongation after fracture can be regarded as valid regardless of the position of the fracture cross-section if the percentage elongation after fracture is equal to or greater than the specified value. If the product standard specifies the determination of percentage elongation after fracture for a given gauge length, the extensometer gauge length should be equal to this length.

20.3 If elongation is measured over a given fixed length, it can be converted to proportional gauge length, using conversion formulae or tables as agreed before the commencement of testing (e.g. as in ISO 2566-1 and ISO 2566-2).

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

21 Determination of percentage reduction of area

Percentage reduction of area shall be determined in accordance with the definition given in [3.8](#).

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

For round test pieces, the measurements at the minimum reduced section should be made in 2 planes at 90° to each other and the average used for the calculation of Z .

Care should be taken to ensure that the fracture surfaces are not displaced when making the readings.

Calculate the percentage reduction of area, Z , from [Formula \(7\)](#):

$$Z = \frac{S_o - S_u}{S_o} \cdot 100 \quad (7)$$

where

S_o is the original cross-sectional area of the parallel length;

S_u is the minimum cross-sectional area after fracture.

It is recommended to measure S_u to an accuracy of $\pm 2\%$ (see [Figure 13](#)).

Measuring S_u with an accuracy of $\pm 2\%$ on small diameter round test pieces, or test pieces with other cross-sectional geometries, may not be possible.

22 Test report

The test report shall contain at least the following information, unless otherwise agreed by the parties concerned:

- a) reference to this part of ISO 6892, extended with the test condition information specified in [10.3.4](#), e.g. ISO 6892-1:2016 A224;
- b) identification of the test piece;
- c) specified material, if known;
- d) type of test piece;
- e) location and direction of sampling of test pieces, if known;
- f) testing control mode(s) and testing rate(s) or testing rate range(s) (see [10.3.1](#)) if different from the recommended methods and values given in [10.3.2](#) and [10.3.3](#);
- g) test results:
 - results should be rounded (according to ISO 80000-1) to the following precisions or better, if not otherwise specified in product standards: strength values, in megapascals, to the nearest whole number;
 - percentage yield point extension values, A_e , to the nearest 0,1 %;
 - all other percentage extension and elongation values to the nearest 0,5 %;
 - percentage reduction of area, Z , to the nearest 1 %.

23 Measurement uncertainty

23.1 General

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

Product standards and material property databases based on this part of ISO 6892 and earlier editions of ISO 6892 have an inherent contribution from measurement uncertainty. 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.