

Metallic materials — Uniaxial creep testing in tension — Method of test (ISO 204:2009)

ICS 77.040.10

National foreword

This British Standard is the UK implementation of EN ISO 204:2009. It supersedes BS EN 10291:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/NFE/4/1, Uniaxial testing of metals.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2009
© BSI 2009

ISBN 978 0 580 53648 9

Amendments/corrigenda issued since publication

Date	Comments

English Version

Metallic materials - Uniaxial creep testing in tension - Method of test (ISO 204:2009)

Matériaux métalliques - Essai de fluage uniaxial en traction
- Méthode d'essai (ISO 204:2009)

Metallische Werkstoffe - Einachsiger Zeitstandversuch
unter Zugbeanspruchung - Prüfverfahren (ISO 204:2009)

This European Standard was approved by CEN on 27 May 2009.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Foreword

This document (EN ISO 204:2009) has been prepared by Technical Committee ISO/TC 164 "Mechanical testing of metals" in collaboration with Technical Committee ECISS/TC 1 "Steel - Mechanical testing" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2009, and conflicting national standards shall be withdrawn at the latest by December 2009.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 10291:2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of ISO 204:2009 has been approved by CEN as a EN ISO 204:2009 without any modification.

Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Symbols and designations	5
5 Principle	7
6 Apparatus	7
7 Test pieces	10
8 Test procedure	13
9 Determination of results	14
10 Test validity	14
11 Accuracy of the results	15
12 Test report	15
Annex A (informative) Information concerning different types of thermocouples	21
Annex B (informative) Information concerning methods of calibration of thermocouples	22
Annex C (normative) Creep testing using test pieces with V or blunt circumferential notches	23
Annex D (informative) Method of estimating the uncertainty of the measurement in accordance with the Guide to the expression of uncertainty in measurement (GUM)	26
Annex E (informative) Representation of results and graphical extrapolation	32
Bibliography	40

Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 204 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This second edition cancels and replaces the first edition (ISO 204:1997), which has been technically revised.

Introduction

This International Standard is an extensive revision of the first edition of ISO 204:1997 and incorporates many recommendations developed through the European Creep Collaborative Committee (ECCC).

New annexes have been added concerning temperature measurement using thermocouples and their calibration, creep testing test pieces with circumferential Vee and blunt (Bridgman) notches, estimation of measurement uncertainty and methods of extrapolation of creep rupture life.

NOTE Information is sought relating to the influence of off-axis loading or bending on the creep properties of various materials. Consideration will be given at the next revision of this International Standard as to whether the maximum amount of bending should be specified and an appropriate calibration procedure be recommended. The decision will need to be based on the availability of quantitative data ^[39].

Metallic materials — Uniaxial creep testing in tension — Method of test

1 Scope

This International Standard specifies the method for the uninterrupted and interrupted creep tests and defines the properties of metallic materials which can be determined from these tests, in particular the creep elongation and the time of creep rupture, at a specified temperature.

The stress rupture test is also covered by this International Standard, as is the testing of notched test pieces.

NOTE In stress rupture testing, elongation is not generally recorded during the test, only the time to failure under a given load, or to note that a predetermined time was exceeded under a given force.

2 Normative references

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

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

ISO 783 ¹⁾, *Metallic materials — Tensile testing at elevated temperature*

ISO 7500-2, *Metallic materials — Verification of static uniaxial testing machines — Part 2: Tension creep testing machines — Verification of the applied force*

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

3 Terms and definitions

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

NOTE Several different gauge lengths and reference lengths are specified in this International Standard. These lengths reflect custom and practice used in different laboratories throughout the world. In some cases, the lengths are physically marked on the test piece as lines or ridges; in other cases, the length may be a virtual length based upon calculations to determine an appropriate length to be used for the determination of creep elongation. For some test pieces, L_r , L_o and L_e are the same length (see 3.1, 3.2 and 3.5).

1) To be revised by ISO 6892-2, *Metallic materials — Tensile testing — Part 2: Method of test at elevated temperature*.

3.1 reference length

L_r

base length used for the calculation of elongation

NOTE A method to calculate this value is given in 7.5 for test pieces where the extensometer is attached to either ridges on the parallel length or to the shoulders of the test piece.

3.1.1 original reference length

L_{r0}

reference length determined at ambient temperature before the test

NOTE In general, $L_{r0} \geq 5D$.

3.1.2 final reference length

L_{ru}

reference length determined at ambient temperature after rupture, with the pieces carefully fitted back together with their axes in a straight line

3.2 original gauge length

L_0

length between gauge length marks on the test piece measured at ambient temperature before the test

NOTE 1 In general, $L_0 \geq 5D$.

NOTE 2 L_0 may also be used for the calculation of elongation.

3.3 final gauge length after rupture

L_u

length between gauge length marks on the test piece measured after rupture, at ambient temperature, with the pieces carefully fitted back together with their axes in a straight line

3.4 parallel length

L_c

length of the parallel reduced section of the test piece

3.5 extensometer gauge length

L_e

distance between the measuring points of the extensometer

NOTE In some cases, $L_e = L_0$ and may also be used for the calculation of elongation.

3.6 original cross-sectional area

S_0

cross-sectional area of the parallel length as determined at ambient temperature prior to testing

3.7

minimum cross-sectional area after rupture

S_u

minimum cross-sectional area of the parallel length as determined at ambient temperature after rupture, with the pieces carefully fitted back together with their axes in a straight line

3.8

initial stress

σ_0

applied force divided by the original cross-sectional area (S_0) of the test piece

3.9

elongation

ΔL_r

increase of the reference length (L_r)

NOTE See 6.2.

3.10

percentage elongation

A

elongation expressed as a percentage of the original reference length (L_{r0})

NOTE 1 See Figure 1.

NOTE 2 In the terms for elongation in 3.10 to 3.16, the symbol “ ε ” may replace “ A ”.

However, when “ ε ” is used, the following conventions should apply:

ε % is the percentage strain or elongation;

ε is the absolute strain.

3.11

percentage initial plastic elongation

A_i

non-proportional increase of the original reference length (L_{r0}) due to the application of the test force

3.12

percentage creep elongation

A_f

increase in reference length at time t (ΔL_{rt}) at a specified temperature expressed as a percentage of the original reference length (L_{r0}):

$$A_f = \frac{\Delta L_{rt}}{L_{r0}} \times 100 \quad (1)$$

NOTE 1 A_f may have the specified temperature (T) in degrees Celsius ($^{\circ}\text{C}$) as superscript and the initial stress (σ_0) in megapascals²⁾ and time t (in hours) as subscript.

NOTE 2 By convention, the beginning of creep elongation measurement is the time at which the initial stress (σ_0) is applied to the test piece (see Figure 1).

NOTE 3 Suffix f originates from “fluage”, “creep” in French.

2) 1 MPa = 1 N/mm².

3.13
percentage plastic elongation

A_p
non-proportional increase of the original reference length (L_{r0}) at time t :

$$A_p = A_i + A_f \quad (2)$$

3.14
percentage anelastic elongation

A_k
non-proportional decrease of the original reference length (L_{r0}) at time t due to unloading

3.15
percentage permanent elongation

A_{per}
total increase of the original reference length (L_{r0}) at time t determined after unloading:

$$A_{per} = A_p - A_k \quad (3)$$

3.16
percentage elongation after creep rupture

A_u
permanent increase of the original reference length (L_{r0}) after rupture ($L_{ru} - L_{r0}$) expressed as a percentage of the original reference length (L_{r0}):

$$A_u = \frac{L_{ru} - L_{r0}}{L_{r0}} \times 100 \quad (4)$$

NOTE A_u may have the specified temperature (T) in degrees Celsius as superscript and the initial stress (σ_0) in megapascals as subscript.

3.17
percentage reduction of area after creep rupture

Z_u
maximum change in cross-sectional area measured after rupture ($S_0 - S_u$) expressed as a percentage of the original cross-sectional area (S_0):

$$Z_u = \frac{S_0 - S_u}{S_0} \times 100 \quad (5)$$

NOTE Z_u may have the specified temperature (T) in degrees Celsius as superscript and the initial stress (σ_0) in megapascals as subscript.

3.18
creep elongation time

t_{fx}
time required for a strained test piece to obtain a specified percentage creep elongation (x) at the specified temperature (T) and the initial stress (σ_0)

EXAMPLE $t_{f0,2}$.

3.19
plastic elongation time

t_{px}
time required to obtain a specified percentage plastic elongation (x) at the specified temperature (T) and the initial stress (σ_0)

3.20
creep rupture time t_u time to rupture for a test piece maintained at the specified temperature (T) and the initial stress (σ_0)

NOTE The symbol t_u may have as superscript the specified temperature (T) in degrees Celsius and as subscript the initial stress (σ_0) in megapascals.

3.21
single test piece machine

testing machine that permits straining of a single test piece

3.22
multiple test piece machine

testing machine that permits straining of more than one test piece simultaneously at the same temperature

4 Symbols and designations

The symbols and corresponding designations are given in Table 1.

Table 1 — Symbols and designations

Symbol ^a	Unit	
D	mm	Diameter of the cross-section of the parallel length of a cylindrical test piece
D_n	mm	Diameter of gauge length containing a notch
d	mm	Diameter of gauge length without a notch in a combined notched/un-notched test piece (see Figure C.1)
d_n	mm	Diameter across root of circumferential notch For a combined notched/un-notched test piece $d = d_n$
b	mm	Width of the cross-section of the parallel length of a test piece of square or rectangular cross-section
L_r	mm	Reference length
a	mm	Thickness of a test piece of square or rectangular cross-section [see Figure 2 b)]
L_{r0}	mm	Original reference length
L_{ru}	mm	Final reference length
ΔL_r	mm	Elongation
ΔL_{rt}	mm	Increase in reference length at time t
L_0	mm	Original gauge length
L_n	mm	Parallel gauge length containing a notch
L_u	mm	Final gauge length after rupture
L_c	mm	Parallel length
L_e	mm	Extensometer gauge length
R	mm	Transition radius
r_n	mm	Notch root radius
S_0	mm ²	Original cross-sectional area of the parallel length
S_u	mm ²	Minimum cross-sectional area after rupture

Table 1 (continued)

Symbol ^a	Unit	Designation
σ_o	MPa	Initial stress
A_e^b	%	Percentage elastic elongation
A_i^b	%	Percentage initial plastic elongation
A_k^b	%	Percentage anelastic elongation
A_p^b	%	Percentage plastic elongation
A_{per}^b	%	Percentage permanent elongation
A_f^b	%	Percentage creep elongation: $A_f = \frac{\Delta L_{rt}}{L_{ro}} \times 100$ NOTE As an example, the symbol may be completed as follows: $A_{f50/5000}^{375}$: percentage creep elongation with an initial stress of 50 MPa after 5 000 h at the specified temperature of 375 °C.
A_u^b	%	Percentage elongation after creep rupture: $A_u = \frac{L_{ru} - L_{ro}}{L_{ro}} \times 100$ NOTE As an example, the symbol may be completed as follows: A_{u50}^{375} : percentage elongation after creep rupture with an initial stress of 50 MPa at the specified temperature of 375 °C.
Z_u	%	Percentage reduction of area after creep rupture: $Z_u = \frac{S_o - S_u}{S_o} \times 100$ NOTE As an example, the symbol may be completed as follows: Z_{u50}^{375} : percentage reduction of area after creep rupture with an initial stress of 50 MPa at the specified temperature of 375 °C.
t_{fx}	h	Creep elongation time
t_{px}	h	Plastic elongation time
t_u	h	Creep rupture time NOTE As an example, the symbol may be completed as follows: t_{u50}^{375} : creep rupture time with an initial stress of 50 MPa at the specified temperature of 375 °C.
t_{un}	h	Creep rupture time of a notched test piece
T	°C	Specified temperature
T_i	°C	Indicated temperature
x	%	Specified percentage creep or plastic elongation
n		Creep exponent
^a The main subscripts (r, o and u) of the symbols are used as follows: r corresponds to reference; o corresponds to original; u corresponds to ultimate (after rupture). ^b See Note 2 in 3.10.		

5 Principle

The test consists of heating a test piece to the specified temperature and of straining the test piece by means of a constant tensile force or constant tensile stress (see note) applied along its longitudinal axis for a period of time to obtain any of the following:

- a specified creep elongation (uninterrupted test);
- values of permanent elongation at suitable intervals throughout the test (interrupted test);
- the creep rupture time (uninterrupted and interrupted test).

NOTE “Constant stress” means that the ratio of the force to the instantaneous cross-section remains constant throughout the test. The results obtained with constant stress are generally different from those obtained with constant force.

6 Apparatus

6.1 Testing machine

The testing machine shall apply a force along the axis of the test piece while keeping inadvertent bending or torsion of the test piece to a minimum. Prior to test the machine should be visually examined to ensure that loading bars, grips, universal joints and associated equipment are in a good state of repair.

The force should be applied to the test piece without shock.

The machine should be isolated from external vibration and shock. The machine should be equipped with a device which minimizes shock when the test piece ruptures.

NOTE At present, there appears to be insufficient quantitative data in the literature demonstrating the influence of bending upon creep and stress rupture life. It is requested that any organization with such information forwards it to ISO/TC164 for consideration at the next revision of this International Standard.

The machine shall be verified and shall meet the requirements of at least class 1 in ISO 7500-2.

6.2 Elongation measuring device

In uninterrupted tests, the elongation shall be measured using an extensometer, which meets the performance requirements of class 1 or better of ISO 9513 or by other means which ensure the same accuracy without interruption of the test. The extensometer can either be directly attached to the test piece, or can be non-contacting (e.g. a non-contacting optical or laser extensometer).

It is recommended that the extensometer is calibrated over an appropriate range based upon the expected creep strain.

The extensometer shall be calibrated at intervals not exceeding 3 years, unless the test duration is longer than 3 years. If the predicted test exceeds the date of the expiry of the calibration certificate then the extensometer shall be recalibrated prior to commencement of the creep test.

The extensometer gauge length shall not be less than 10 mm.

The extensometer shall be able to measure the elongation either on one side or on the opposite sides of the test piece; the latter is the preferred option.

The type of extensometer used (e.g. single-sided, double-sided, axial, diametral) should be reported. When the elongation is measured on the opposite sides, the average elongation should be reported.

NOTE 1 For uninterrupted creep tests, i.e. with an extensometer attached directly to the parallel section of a test piece, the percentage creep elongation is measured over L_e .

When the elongation is measured with an extensometer attached to the grip ends of the test piece, the ends shall be of such shape and size that it can be assumed that the observed elongation has occurred completely within the reference length of the test piece. Percentage creep elongation is measured over L_r .

The extensometer gauge length should normally be as near as possible to the reference length. In the case of accurate creep measurements, a gauge length as long as possible should be used to improve the accuracy of measurements.

NOTE 2 If only the percentage elongation after creep rupture or the percentage creep elongation for a specified test duration is determined, the use of an extensometer is not necessary.

In interrupted tests, periodically unload the test piece and cool it to ambient temperature and measure the permanent elongation on the gauge length with an appropriate device. The precision of this device shall be $0,01 \Delta L_r$ or $0,01$ mm, whichever is the greater. After this measurement the test piece may be first reheated and then reloaded.

NOTE 3 For low creep strain measurements, e.g. $\leq 1\%$ strain, on test pieces with short gauge lengths, careful consideration needs to be given to ensure that the measuring device used has sufficient resolution.

NOTE 4 Information on the long-term stability of transducers used for creep testing and accreditation issues are given in References [35] and [36] in the Bibliography.

Care should be taken to avoid spurious negative creep when using nickel base alloy extensometers. See the Code of Practice by Loveday and Gibbons (2007) [38].

6.3 Heating device

6.3.1 Permissible temperature deviations

The heating device shall heat the test piece to the specified temperature (T). The permitted deviations between the indicated temperature, (T_i) and the specified temperature, (T), and the permitted maximum temperature variation along the test piece shall be as given in Table 2.

**Table 2 — Permitted deviations between T_i and T
and maximum permissible temperature variation along the test piece**

Specified temperature, T °C	Permitted deviation between T_i and T °C	Maximum permissible temperature variation along the test piece °C
$T \leq 600$	± 3	3
$600 < T \leq 800$	± 4	4
$800 < T \leq 1\,000$	± 5	5
$1\,000 < T \leq 1\,100$	± 6	6

For specified temperatures greater than $1\,100$ °C, the permitted values shall be defined by agreement between the parties concerned.

The indicated temperatures (T_i) are the temperatures measured at the surface of the parallel length of the test piece, errors from all sources being taken into account and any systematic errors having been corrected.