INTERNATIONAL STANDARD

ISO 204

Third edition
2018-08

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

Matériaux métalliques — Essai de fluage uniaxial en traction — Méthode d'essai

Reference number
ISO 204:2018(E)

Contents

Page

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 voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 204:2009), which has been technically revised. The main changes compared to the previous edition are as follows:

— Some of the symbols have been changed to achieve harmonization with the ISO 6892 series.

— For the purpose of this document, the terms “fracture” and “rupture” are interchangeable.

— The term “indicated temperature”, T_i, has been replaced by “corrected measured temperature”, T_c, with errors from all sources being taken into account and any systematic errors having been corrected. The terms “elongation” and “extension” have been clarified and aligned with the terms used in the ISO 6892 series. Elongation refers to the test piece deformation measured manually either during deliberate test interruptions or after fracture, whilst extension is determined by continuous measurement using an extensometer.

— Some information relating to the calibration of thermocouples has been transferred from an informative annex into the main body of the document.

— Some changes have been made to Table 1 and formulae have been amended using reference length, L_r.

— Equation E.1 (now Formula C.1) has been corrected.

— A new informative annex relating to computer compatible representation of standards has been added.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Creep is the phenomenon exhibited by materials which slowly deform when subjected to loading at elevated temperature. This document is concerned with the method used to measure such material behaviour.

Annexes are included concerning temperature measurement using thermocouples and their calibration, creep testing test pieces with circumferential V and blunt (Bridgman) notches, estimation of measurement uncertainty, methods of extrapolation of creep rupture life and information about computer compatible representation of standards.

NOTE 1 Information is still sought relating to the influence of off-axis loading or bending on the creep properties of various materials. Based on the future availability of quantitative data, consideration might be given 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[43].

NOTE 2 Information concerning the benefit of standards being produced in a computer compatible format is given in Annex F.

This document incorporates many recommendations developed through the European Creep Collaborative Committee (ECCC).

NOTE 3 Several different gauge lengths and reference lengths are specified in this document. 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 can 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 3.3). "Extension" is used for uninterrupted creep test with continuous measurement of the increase of the length of the test piece by using an extensometer. "Elongation" is mainly used for interrupted creep test with the manual measurement of the increase of the length of the test piece.

NOTE 4 For many applications, the term "strain" is synonymous with extension.

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

1 Scope

This document specifies the methods for

a) uninterrupted creep tests with continuous monitoring of extension,

b) interrupted creep tests with periodic measurement of elongation,

c) stress rupture tests where normally only the time to fracture is measured,

d) a test to verify that a predetermined time can be exceeded under a given force, with the elongation or extension not necessarily being reported.

NOTE A creep test can be continued until fracture has occurred or it can be stopped before fracture.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 6892-2, *Metallic materials — Tensile testing — Part 2: Method of test 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 extensometer systems used in uniaxial testing*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
reference length
L_r
base length used for the calculation of either percentage elongation or percentage extension

Note 1 to entry: A method to calculate this value is given in 7.5.

3.2
original gauge length
L_o
length between gauge length marks on the test piece measured at ambient temperature before the test

Note 1 to entry: In general, $L_o \geq 5D$.

3.3
extensometer gauge length
L_e
distance between the measuring points of the extensometer

3.4
parallel length
L_c
length of the parallel reduced section of the test piece

3.5
final gauge length after fracture
L_u
length between gauge length marks on the test piece measured after fracture, at ambient temperature, with the pieces carefully fitted back together with their axes in a straight line

3.6
original cross-sectional area
S_o
cross-sectional area of the parallel length as determined at ambient temperature prior to testing

3.7
minimum cross-sectional area after fracture
S_u
minimum cross-sectional area of the parallel length as determined at ambient temperature after fracture, with the pieces carefully fitted back together with their axes in a straight line

3.8
initial stress
R_o
applied force divided by the original cross-section area, S_o, of the test piece

3.9
extension
ΔL_e
increase of extensometer gauge length, L_e, at time t and at test temperature

Note 1 to entry: For further information, see 6.2.

3.10
elongation
ΔL_o
increase of original gauge length, L_o, at time t

Note 1 to entry: For further information, see 6.2.

3.11
percentage extension
e
extension at test temperature expressed as a percentage of the reference length, L_r, as given in Formula (1)

$$e = \frac{\Delta L_e}{L_r} \times 100 \quad (1)$$

Note 1 to entry: See Figure 1.

3.12
percentage elongation
A
elongation expressed as a percentage of the reference length, L_r, as given in Formula (2)

$$A = \frac{\Delta L_o}{L_r} \times 100 \tag{2}$$

3.13
percentage elastic extension
e_e
extension at test temperature expressed as a percentage of the reference length, L_r, which is proportional to the initial stress, R_o

Note 1 to entry: This value can be calculated from the stress/percentage extension values during loading. See 8.4.2.

Note 2 to entry: See Figure 1.

3.14
percentage initial total extension
e_{ti}
extension at test temperature expressed as a percentage of the reference length, L_r, at end of loading with the initial stress, R_o

Note 1 to entry: See Figure 1.

3.15
percentage initial plastic extension
e_i
extension at end of loading and at test temperature with the initial stress, R_o, expressed as a percentage of the reference length, L_r, and determined as the difference between the percentage initial total extension, e_{ti}, and the percentage elastic extension, e_e, as given in Formula (3)

$$e_i = e_{ti} - e_e \tag{3}$$

Note 1 to entry: See Figure 1.

Note 2 to entry: This value represents the plastic extension during the loading phase.

3.16
percentage total extension
e_t
extension at the test force at time *t* and at test temperature, expressed as a percentage of the reference length, L_r

Note 1 to entry: See Figure 1.

3.17
percentage plastic extension
e_p
extension at time *t* and at test temperature determined as the difference between the percentage total extension, e_t, and the percentage elastic extension, e_e, expressed as a percentage of the reference length, L_r, as given in Formula (4)

$$e_p = e_t - e_e \tag{4}$$

Note 1 to entry: See Figure 1.

3.18
percentage total ultimate extension
e_u
total extension at rupture and at test temperature, expressed as a percentage of the reference length, L_r

3.19
percentage creep extension
e_f
extension at loading determined and at test temperature as the difference between the percentage plastic extension, e_p, and the percentage initial plastic extension, e_i, expressed as a percentage of the reference length, L_r, as given in Formula (5)

$$e_f = e_p - e_i \tag{5}$$

Note 1 to entry: See Figure 1.

Note 2 to entry: Suffix f originates from “fluage”, “creep” in French.

3.20
percentage anelastic extension
e_k
negative extension at end of unloading at test temperature, expressed as a percentage of the reference length, L_r

Note 1 to entry: See Figure 1 and 8.4.

3.21
percentage permanent extension
e_{per}
extension at end of unloading and at test temperature determined as the difference between the percentage total extension, e_t, and the sum of percentage elastic extension, e_e, plus the percentage anelastic extension, e_k, expressed as a percentage of the reference length, L_r, as given in Formula (6)

$$e_{per} = e_t - (e_e + e_k) \tag{6}$$

Note 1 to entry: In the case of $e_k \approx 0$, the following relationship may be used: $e_{per} \approx e_p$.

Note 2 to entry: See Figure 1.

3.22
percentage permanent elongation
A_{per}
elongation expressed as a percentage of the reference length, L_r, at end of unloading and at room temperature

3.23
percentage elongation after creep fracture
A_u
permanent elongation after fracture, $L_u - L_o$, expressed as a percentage of the reference length, L_r, as given in Formula (7)

$$A_u = \frac{L_u - L_o}{L_r} \times 100 \tag{7}$$

Note 1 to entry: A_u may have the specified temperature, T, in degrees Celsius as superscript and the initial stress, R_o, in megapascals as subscript; see the example in Table 1.

3.24
percentage reduction of area after creep fracture
Z_u
maximum change in cross-sectional area measured after fracture, $S_o - S_u$, expressed as a percentage of the original cross-sectional area, S_o, as given in Formula (8)

$$Z_u = \frac{S_o - S_u}{S_o} \times 100 \quad (8)$$

Note 1 to entry: Z_u may have the specified temperature, T, in degrees Celsius as superscript and the initial stress, R_o, in megapascals as subscript; see the example in Table 1.

3.25
creep extension time
t_{fx}
time required for a strained test piece to obtain a specified percentage creep extension, x, at the specified temperature, T, and the initial stress, R_o

EXAMPLE $t_{f0,2}$

3.26
plastic extension time
t_{px}
time required to obtain a specified percentage plastic extension, x, at the specified temperature, T, and the initial stress, R_o

Note 1 to entry: An example for t_{p1} is given in Figure E.2 a) (t_{p1} = 100 000 h corresponds to e_p = 1 % at R_o = 120 MPa).

3.27
creep rupture time
t_u
time to rupture for a test piece maintained at the specified temperature, T, and the initial stress, R_o

Note 1 to entry: The symbol t_u can have as superscript the specified temperature, T, in degrees Celsius and as subscript the initial stress, R_o, in megapascals; see the example in Table 1.

3.28
single test piece machine
testing machine that permits straining of a single test piece

3.29
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	Designation
D	mm	Diameter of gauge 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/unnotched test piece (see Figure C.1)
d_n	mm	Diameter across root of circumferential notch For a combined notched/unnotched 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)]
ΔL_{et}		Increase of extensometer gauge length at time t
ΔL_{ot}	mm	Increase of original gauge length at time t
L_o	mm	Original gauge length
L_n	mm	Parallel gauge length containing a notch
L_u	mm	Final gauge length after fracture
L_c	mm	Parallel length
L_e	mm	Extensometer gauge length
r_t	mm	Transition radius
r_n	mm	Notch root radius
S_o	mm^2	Original cross-sectional area of the parallel length
S_u	mm^2	Minimum cross-sectional area after fracture
R_o	MPa	Initial stress
e	%	Percentage extension
e_e	%	Percentage elastic extension
e_f	%	Percentage creep extension: $e_f = \frac{\Delta L_{ot}}{L_r} \times 100$ NOTE As an example, the symbol can be completed as follows: $e_{f\,50/5\,000}^{375}$: percentage creep extension with an initial stress of 50 MPa after 5 000 h at the specified temperature of 375 °C.
e_{fu}	%	Percentage creep extension at creep rupture time
e_i	%	Percentage initial plastic extension
e_k	%	Percentage anelastic extension

[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).

NOTE For the purposes of creep testing in this document, the terms “fracture” and “rupture” are interchangeable and are used to describe when a test piece breaks.

Table 1 *(continued)*

Symbol[a]	Unit	Designation
e_p	%	Percentage plastic extension
e_{per}	%	Percentage permanent extension
e_{pu}	%	Percentage plastic extension at creep rupture time
e_t	%	Percentage total extension
e_u	%	Percentage total extension at creep rupture time
A_{per}	%	Percentage permanent elongation NOTE As an example, the symbol can be completed as follows: $A^{375}_{per 50/5\,000}$: percentage permanent elongation with an initial stress of 50 MPa after 5 000 h at the specified temperature of 375 °C.
A_u	%	Percentage elongation after creep fracture: $A_u = \frac{L_u - L_o}{L_r} \times 100$ NOTE As an example, the symbol can be completed as follows: $A^{375}_{u\,50}$: percentage elongation after creep fracture with an initial stress of 50 MPa at the specified temperature of 375 °C.
Z_u	%	Percentage reduction of area after creep fracture: $Z_u = \frac{S_o - S_u}{S_o} \times 100$ NOTE As an example, the symbol can be completed as follows: $Z^{375}_{u\,50}$: percentage reduction of area after creep fracture with an initial stress of 50 MPa at the specified temperature of 375 °C.
t	h	Elapsed time from end of loading
t_{fx}	h	Creep extension time
t_{px}	h	Plastic extension time
t_u	h	Creep rupture time NOTE As an example, the symbol can be completed as follows: $t^{375}_{u\,50}$: 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_c	°C	Corrected measured temperature
x	%	Specified percentage creep or plastic extension
n		Norton 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).

NOTE For the purposes of creep testing in this document, the terms “fracture” and “rupture” are interchangeable and are used to describe when a test piece breaks.

5 Principle

The test consists of heating a test piece to the specified temperature and of straining it 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 extension (uninterrupted test) with continuous extension measurement;

— values of permanent elongation at suitable intervals throughout the test (interrupted test);

— the creep rupture time (uninterrupted and interrupted test).

NOTE "Constant stress" or "true 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[47].

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 shall 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 fractures.

NOTE At present, there appears to be insufficient quantitative data in the literature demonstrating the influence of bending upon creep and stress rupture life. Any organization with such information is encouraged to forward it to ISO/TC 164[43].

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

6.2 Extension and elongation measuring devices.

6.2.1 Extension measuring device.

In uninterrupted tests, the extension 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 be non-contacting (e.g. a non-contacting optical or laser extensometer).

It is recommended that the extensometer be 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 duration 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 capable of measuring extension of one side of the test piece or, preferably, on opposite sides of the test piece.

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

When the extension 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 extension has occurred completely within the reference length of the test piece. Percentage creep extension 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.

Care should be taken to avoid spurious negative creep when using nickel base alloy extensometers. See the Code of Practice[42].

For low creep strain measurements, e.g. ≤1 % strain, on test pieces with short gauge lengths, careful consideration should be given to ensure that the measuring device used has sufficient resolution and accuracy over the range of use.

NOTE 1 Information on the long-term stability of transducers used for creep testing and accreditation issues is given in References [40] and [41].

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

6.2.2 Elongation measuring device.

In interrupted tests, periodically unload the test piece, 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 ΔL_r or 0,01 mm, whichever is the greater. After this measurement, the test piece may be first reheated and then reloaded.

6.3 Heating device, temperature measuring equipment and calibration.

6.3.1 Permissible temperature deviations.

The heating device shall heat the test piece to the specified temperature, T. The permitted deviations between the corrected measured temperature, T_c, 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_c and T and maximum permissible temperature variation along the test piece

Specified temperature T °C	Permitted deviation between T_c 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, including drift, shall be defined by agreement between the parties concerned.

The corrected measured temperatures, T_c, are the temperatures measured at the surface of the parallel length of the test piece, errors from all sources, including drift (see Annex A), being taken into account and any systematic errors having been corrected.

It is permitted to carry out indirect measurement of the temperature of each heating zone of the furnace provided that it is demonstrated that the tolerance defined above is fulfilled on the test piece instead of measuring the temperature at the surface of each individual test piece.