



BSI Standards Publication

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

National foreword

This British Standard is the UK implementation of EN ISO 204:2018. It supersedes BS EN ISO 204:2009, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/101/1, Uniaxial testing.

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

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English Version

**Metallic materials - Uniaxial creep testing in tension -
Method of test (ISO 204:2018)**

Matériaux métalliques - Essai de fluage uniaxial en
traction - Méthode d'essai (ISO 204:2018)

Metallische Werkstoffe - Einachsiger Zeitstandversuch
unter Zugbeanspruchung - Prüfverfahren (ISO
204:2018)

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European foreword

This document (EN ISO 204:2018) has been prepared by Technical Committee ISO/TC 164 "Mechanical testing of metals" in collaboration with Technical Committee ECISS/TC 101 "Test methods for steel (other than chemical analysis)" 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of an identical text or by endorsement, at the latest by April 2019, and conflicting national standards shall be withdrawn at the latest by April 2019.

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

This document supersedes EN ISO 204:2009.

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Endorsement notice

The text of ISO 204:2018 has been approved by CEN as EN ISO 204:2018 without any modification.

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Foreword

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

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).

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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_0

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

Note 1 to entry: In general, $L_0 \geq 5D$.

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 \(2\)](#)

$$A = \frac{\Delta L_o}{L_r} \times 100 \quad (2)$$

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 \(3\)](#)

$$e_i = e_{ti} - e_e \quad (3)$$

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 \(4\)](#)

$$e_p = e_t - e_e \quad (4)$$

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 \(5\)](#)

$$e_f = e_p - e_i \quad (5)$$

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 \(6\)](#)

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

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 \(7\)](#)

$$A_u = \frac{L_u - L_o}{L_r} \times 100 \quad (7)$$

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: $e_{f50/5\,000}^{375}$: 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: $A_{per50/5\,000}^{375}$: 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_{u50}^{375} : 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_{u50}^{375} : 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_{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_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 $0,01 \Delta L_r$ 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.

If an extensometer is used, the parts of this instrument outside the furnace shall be designed and protected in such a way that the temperature variations in the air around the furnace do not significantly affect the measurements of the variations in length.

Variations in temperature of the air surrounding the test machine should not exceed ± 3 °C.

In the interrupted test, the variation of the room temperature during all measurements of the gauge length should not exceed ± 2 °C. If this range is exceeded, corrections for ambient temperature variations shall be applied.

6.3.2 Temperature measurement.

6.3.2.1 General.

The temperature indicator shall have a resolution of at least 0,5 °C. The temperature measuring equipment shall have an accuracy equal to or better than ± 1 °C.

For thermocouples, in the absence of measuring instruments with cold junction compensation, cold junction temperatures, normally at 0°C, shall be measured to within 0,5 °C.

Many laboratories maintain the cold junction above ambient temperature. Whatever its temperature, it shall remain stable and appropriate compensation shall be applied to determine the temperature measured by the thermocouple.

NOTE Information concerning drift of thermocouples is given in [Annex A](#) and methods of calibration of thermocouples are given in [Annex B](#).

For indirect methods of temperature measurement e.g. pyrometry, thermal cameras or resistivity techniques, it shall be demonstrated that traceability is provided to the SI System of temperature measurement and that the above criteria for accuracy and resolution can be achieved.

6.3.2.2 Calibration of the temperature measuring equipment.

The calibration of the temperature measuring equipment (including the cable, the connection, the cold junction, the indicator or the recorder, the data line, etc.) shall be carried out by a method traceable to the international unit (SI) of temperature.

If practicable, this calibration should be carried out annually over the range of temperatures measured by the equipment and the readings shall be given in the calibration report.

6.3.2.3 Single test piece machines.

In single test piece machines, with thermocouples used for temperature measurement, at least two thermocouples should be used for test pieces with a parallel length less than or equal to 50 mm. For test pieces with a parallel length greater than 50 mm, at least three thermocouples should be used. In all cases, a thermocouple should be placed at each end of the parallel length and, if a third thermocouple is used, it should be placed in the middle region of the parallel length.

The number of thermocouples may be reduced to one if it can be demonstrated that the conditions of the furnace and the test piece are such that the variation of temperature of the test piece does not exceed the values specified in [6.3.1](#).

6.3.2.4 Multiple test piece machines.

In multiple test piece machines, with thermocouples used for temperature measurement, at least one thermocouple should be used for each test piece. If only one thermocouple is used, it shall be positioned at the middle of the parallel length. Three thermocouples may only be used if located at appropriate positions within the furnace, and if there is supporting data to demonstrate that for all test pieces the temperature conforms to the requirements of [6.3.1](#).

In the case of indirect temperature measurement, regular control measurements are required to determine differences between the thermocouple(s) of each heating zone and a significant number of test pieces within a given zone. The non-systematic components of the temperature differences shall not exceed $\pm 2^\circ\text{C}$ up to 800°C and $\pm 3^\circ\text{C}$ above 800°C .

6.3.2.5 Notched test pieces.

Temperature measurement of notched test pieces shall be in accordance with either [6.3.2.3](#) or [6.3.2.4](#). It is recommended that one thermocouple be placed close to the notch.

NOTE Details about testing notched test pieces are given in [Annex C](#).

6.3.3 Thermocouples.

The thermocouple junctions shall make good thermal contact with the surface of the test piece and shall be screened from direct radiation from the heating source. The remaining portions of the wires within the furnace shall be thermally shielded and electrically insulated.

Precautions shall be taken to minimize contamination and physical damage of thermocouples. Insulators and/or insulation shall be maintained in a clean state to also minimise contamination and prevent conduction.

Information concerning different types of thermocouples is given in IEC 60584-1[7].

The use of rare metal thermocouples, preferentially of type S or R, is recommended for temperatures equal to or greater than 400°C [44].

Base metal thermocouples of type K should only be used either for temperatures lower than 400°C or for times less than 1 000 h at higher temperatures and should not be re-used without cutting back exposed wire and re-calibrating.

Base metal thermocouples of type N may be used either for temperatures lower than 600°C or for times less than 3 000 h at higher temperatures and should not be re-used. The use of type N base metal thermocouples is not permitted at temperatures above 760°C [44].

Where the drift exceeds the following values within the calibration period, either more frequent calibrations should be carried out or a correction be applied to the temperature indicated by the thermocouple. See [Annex A](#) and References [48] to [52].

- $\pm 1^\circ\text{C}$ for $T \leq 600^\circ\text{C}$;
- $\pm 1,5^\circ\text{C}$ for $600^\circ\text{C} < T \leq 800^\circ\text{C}$;
- $\pm 2^\circ\text{C}$ for $800^\circ\text{C} < T \leq 1\,100^\circ\text{C}$.

Records of drift shall be recorded and available on request.

NOTE 1 Thermocouple drift is dependent on the type of thermocouple used and the exposure duration at temperature; see [Annex A](#).

NOTE 2 Reference can be made to ASTM E633[8].

NOTE 3 This clause is not applicable in the case of indirect temperature measurement.

NOTE 4 Other types of thermocouples are available but their suitability will be demonstrated.

6.3.4 Calibration of the thermocouples.

NOTE 1 Further information relating to thermocouples calibration is given in [Annex B](#).

The calibration period for rare metal thermocouples in repeated use for short duration tests (typically 500 h or less) shall not exceed 13 months. Otherwise the period for calibration shall be as follows:

- 4 years for $T \leq 600\text{ }^{\circ}\text{C}$;
- 2 years for $600\text{ }^{\circ}\text{C} < T \leq 800\text{ }^{\circ}\text{C}$;
- 1 year for $T > 800\text{ }^{\circ}\text{C}$.

The re-use of base metal thermocouples is not permitted without re-calibration after each test unless experience has shown that errors due to drift do not exceed the limits in 6.3.3 for the test conditions in question, in which case they may be calibrated at intervals not exceeding 500 h use.

If the test duration exceeds the above calibration periods, the thermocouple shall be calibrated upon completion of the test.

It shall be demonstrated that the error of the thermocouple used has been established at the test temperature or is typical for a range containing the test temperature. Thermocouples showing errors in excess of $1\text{ }^{\circ}\text{C}$ may be used provided the appropriate corrections are made.

If a thermocouple is rewelded, the thermocouple shall be recalibrated before use.

NOTE 2 Base metal thermocouples can be cut back removing any exposed wire and will be re-calibrated before use.

7 Test pieces

7.1 Shape and dimensions

7.1.1 Shape and dimension of smooth test pieces

Normally test pieces with circular cross-sections shall be used; see Figure 2.

In general, the smooth (unnotched) test piece is a machined proportional cylindrical test piece ($L_T = k\sqrt{S_0}$) with a circular cross-section (see Figure 2). The value k should be equal to or greater than 5,65. The value used shall be recorded in the test report, i.e. $L_T \geq 5D$.

In special cases, the cross-section of the test piece may be square, rectangular or of some other shape. For these specific test pieces, the provisions specified for cylindrical test pieces with a circular cross section shall be applied.

In general, L_T should not exceed L_C by more than 10 % for circular test pieces, or by more than 15 % for square or rectangular test pieces.

The parallel length shall be joined by transition curves to the gripped ends, which may be of any shape to suit the grips of the testing machine. The transition radius (R) should be between $0,25D$ and $1D$ for the cylindrical test pieces, or $0,25b$ and $1b$ in the case of rectangular or square test pieces.

Unless the sample size does not permit it, the original cross-sectional area (S_0) shall be greater than or equal to 7 mm^2 .

NOTE In some cases, especially for brittle materials, the transition radius can be greater than $1D$.

When a test piece having extensometer attachment ridges (collars) in the parallel length is used, the transition radius of the collars may be less than $0,25d$; this should be selected to minimize stress concentrations and there should be no evidence of undercut when inspected. For test pieces with collars, the diameter between the collar and the grip end may be up to 10 % larger than the diameter of the original gauge length; this should ensure that fracture will occur within the gauge length.