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

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by The Japan Iron and Steel Federation (JISF) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS Z 2271:1999** is replaced with this Standard.

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Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

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

Introduction

This Japanese Industrial Standard has been prepared based on the second edition of **ISO 204** published in 2009 with some modifications of the technical contents. In the text of this Standard, the content on the interrupted creep test specified in the corresponding International Standard is described by NOTE for reference and that on the uninterrupted creep test is simply expressed as the “creep test”.

The portions given dotted underlines are the matters in which the contents of the original International Standard have been modified. A list of modifications with the explanations is given in Annex JB.

1 Scope

This Standard specifies the creep test method and the measuring method for the properties of metallic materials, in particular the creep elongation and the creep rupture time at a specified temperature, obtained by the test.

The stress rupture test using the notched test piece is also covered by this Standard.

NOTE 1 In the stress rupture test, elongation is not generally recorded during the test, but only the time to rupture under a given load is recorded or the observation over the predetermined time under the given test force is carried out.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

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

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

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

2 Normative references

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

JIS B 7741 *Verification of extensometers used in uniaxial testing*

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

JIS G 0202 *Glossary of terms used in iron and steel (testing)*

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 *Metallic materials—Tensile testing at elevated temperature*

NOTE : Corresponding Japanese Industrial Standard: JIS G 0567 *Method of elevated temperature tensile test for steels and heat-resisting alloys* (MOD)

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

3 Terms and definitions

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

NOTE : Several different gauge lengths and reference lengths are specified in this 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 collars; in other cases, the length may be a virtual length based upon calculations to determine an appropriate length to be used for the measurement of creep elongation. For some test pieces, L_r , L_o and/or L_e are the same length (see **3.1**, **3.2** and **3.5**).

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 the test piece where the extensometer is attached to either the collars on the parallel portion or 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, $L_{r0} \geq 5D$ (D is the diameter of test piece).

3.1.2 final reference length L_{r1}

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_o

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

NOTE 1 In general, $L_o \geq 5D$ (D is the diameter of test piece).

NOTE 2 L_o 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 determined at ambient temperature after rupture with the pieces carefully fitted back together with their axes in a straight line

3.4 parallel length L_c

length of the parallel portion of the test piece

3.5 extensometer gauge length L_e

length between the measuring points of the extensometer

NOTE : In some cases, $L_e = L_o$.

3.6 original cross-sectional area S_o

cross-sectional area of the parallel portion determined at ambient temperature before the test

3.7 minimum cross-sectional area after rupture S_u

minimum cross-sectional area of the parallel portion 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_o

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

3.9 elongation ΔL_r

increase of the reference length (L_r) (see 6.2)

3.10 percentage elongation A

elongation expressed as a percentage of the original gauge length (L_o)

NOTE 1 See figure 1.

NOTE 2 In the definitions for the elongation in 3.10 to 3.16, the symbol A may be replaced by ε , provided that the following definitions should apply when ε is used.

ε %: strain or elongation expressed as a percentage

ε : absolute strain

3.11 percentage initial plastic elongation A_i

initial non-proportional increase due to the application of test force to the original reference length (L_{r0}) expressed as a percentage (see figure 1)

3.12 percentage creep elongation A_f

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

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

NOTE 1 A_f may have the specified temperature (T °C) as superscript and the stress in megapascals and time t (in hours) as subscript.

NOTE 2 By convention, the beginning of test 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” that is “creep” in French.

3.13 percentage plastic elongation A_p

non-proportional plastic increase at time t due to the application of the test force to the original reference length (L_{r0}) expressed as a percentage (see figure 1)

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

3.14 percentage anelastic elongation A_k

non-proportional anelastic decrease at time t due to the unloading to the original reference length (L_{r0}) expressed as a percentage (see figure 1)

3.15 percentage permanent elongation A_{per}

total increase at the specified time t due to the unloading to the original reference length (L_{r0}) expressed as a percentage

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

3.16 percentage elongation after creep rupture A_u

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

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

NOTE : A_u may have the specified temperature (T °C) 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 ($S_0 - S_u$) to the original cross-sectional area (S_0) expressed as a percentage

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

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

3.18 creep elongation time t_{fx}

time required to obtain a specified percentage creep elongation (x %) at the specified temperature (T °C) 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 °C) and the initial stress (σ_0)

3.20 creep rupture time t_u

time required for the rupture of the test piece maintained at the specified temperature (T °C) and the initial stress (σ_0)

NOTE : t_u may have the specified temperature (T °C) as superscript and the initial stress (σ_0) in megapascals as subscript.

3.21 single test piece machine

testing machine that permits straining of only 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 shall be as given in table 1.

Table 1 Symbols and designations

Symbol ^{a)}	Unit	Designation
D	mm	Diameter of cross-section of parallel portion of cylindrical test piece
D_n	mm	Diameter of gauge length containing notch
d	mm	Diameter of gauge length not containing notch in combined notched/un-notched test piece (see figure C.1)
d_n	mm	Diameter of root of circumferential notch For combined notched/un-notched test piece, $d = d_n$
b	mm	Width of cross-section of parallel portion of test piece of square or rectangular test piece
L_r	mm	Reference length
a	mm	Thickness of cross-section of parallel portion of test piece of square or rectangular test piece [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 (in hour)
L_0	mm	Original gauge length
L_n	mm	Parallel length of test piece containing 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
S_u	mm ²	Minimum cross-sectional area after rupture

Table 1 (concluded)

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 $A_f = \frac{\Delta L_r}{L_{ro}} \times 100$ NOTE: The symbol may be completed as follows. $A_{f50/5000}^{375}$: percentage creep elongation with initial stress of 50 MPa after 5 000 h at 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: The symbol may be completed as follows. A_{u50}^{375} : percentage elongation after creep rupture with initial stress of 50 MPa at 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: 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 specified temperature of 375 °C
t_{fx}	h	Creep elongation time
t_{px}	h	Plastic elongation time
t_u	h	Creep rupture time NOTE: The symbol may be completed as follows. t_{u50}^{375} : creep rupture time with initial stress of 50 MPa at specified temperature of 375 °C
t_{un}	h	Creep rupture time of notched test piece
T	°C	Specified temperature
T_i	°C	Indicated temperature
x	%	Specified percentage creep elongation or percentage plastic elongation
n		Creep exponent
Notes ^{a)} The main subscripts (r, o and u) of the symbols are used as follows. r: corresponds to reference o: corresponds to initial or original u: corresponds to ultimate (after rupture) ^{b)} See NOTE 2 in 3.10.		

5 Principle

The test consists of heating the test piece to the specified temperature and of straining the test piece by means of a constant test force or constant tensile stress (see NOTE 1) applied along its longitudinal axis for a period of time to obtain the following.

- Time required for specified creep elongation
- Creep rupture time

NOTE 1 “Constant stress” means that the ratio of the test 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 test force.

NOTE 2 In **ISO 204**, there is an item “values of permanent elongation and creep rupture time at suitable intervals throughout the test as the interrupted creep test”.

6 Apparatus

6.1 Testing machine

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

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

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

NOTE : In **ISO 204**, there is a description “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 testing machine shall be verified so that it shall meet the requirements of at least Class 1 of **ISO 7500-2**.

6.2 Elongation measuring device

The elongation of test piece shall be measured using an apparatus which meets the performance requirements of Class 1 or better of **JIS B 7741** 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., an 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, the extensometer shall be recalibrated prior to the commencement of the creep test.

The gauge length of extensometer shall be 10 mm or more.

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

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 The percentage creep elongation over L_c shall be measured with an extensometer attached directly to the parallel portion of the test piece.

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. The 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, the 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 the specified test duration is determined, the use of an extensometer is not necessary.

NOTE 3 For low creep strain measurements, (e.g., $\leq 1\%$ strain) on the test piece with short gauge length, 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 the creep test and accreditation issues are given in References [35] and [36] in Bibliography.

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

NOTE 5 In **ISO 204**, there is a description “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.”

6.3 Heating device

6.3.1 Permissible temperature deviations

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

Table 2 Permissible temperature deviations between indicated temperature (T_i) and specified temperature (T) and maximum permissible temperature variation along test piece

Specified temperature (T) °C	Permissible temperature deviations between indicated temperature (T_i) and specified temperature (T) °C	Maximum temperature variation along 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 the specified temperature over 1 100 °C, the permissible temperature deviations shall be upon the agreement between the parties concerned with delivery.

The indicated temperature (T_i) shall be the temperature measured at the surface of the parallel portion of the test piece whose errors from all sources are taken into account and any systematic errors are corrected.

NOTE : Instead of measuring the temperature at the surface of the test piece, the indirect measurement of the temperature of each heating zone of the furnace may be carried out, provided that it is demonstrated that the permissible deviations in table 2 are fulfilled.

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 testing machine should not exceed ± 3 °C.

NOTE : In **ISO 204**, there is a description “In the interrupted test, the variation of the ambient 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 measuring equipment

6.3.2.1 General

The temperature indicator shall have a resolution of at least 0.5 °C and the temperature measuring equipment shall have an accuracy within ± 1 °C.

6.3.2.2 Single test piece machine

In the single test piece machine, for test pieces with a parallel length of 50 mm or under, at least two thermocouples should be used. For test pieces with a parallel length of over 50 mm, at least three thermocouples should be used. In all cases, a thermocouple should be placed at each end of the parallel portion of the test piece and, if a third thermocouple is used, it should be placed in the middle of the parallel portion of the test piece.

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 temperature variation of the test piece does not exceed the permissible deviations specified in **6.3.1**.

6.3.2.3 Multiple test piece machine

In the multiple test piece machine, it is recommended that at least one thermocouple be used for each test piece. If only one thermocouple is used, it shall be placed in the middle of the parallel portion of test piece. Three thermocouples may only be used, if there is supporting data to demonstrate that the temperature conforms to the permissible deviations specified in **6.3.1** for all test pieces when located at appropriate positions within the furnace.

In the case of the 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. This permissible temperature deviations (not containing drift) shall not exceed $\pm 2\text{ }^{\circ}\text{C}$ at $800\text{ }^{\circ}\text{C}$ or under and $\pm 3\text{ }^{\circ}\text{C}$ at over $800\text{ }^{\circ}\text{C}$.

6.3.2.4 Notched test piece

The temperature measurement of notched test pieces shall be carried out in accordance with **6.3.2.2** or **6.3.2.3**. It is recommended that one thermocouple is placed close to the notch.

6.3.2.5 Thermocouple

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

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

6.3.3 Calibration of thermocouple and temperature measuring equipment

NOTE : Information concerning different types of thermocouples is given in Annex A.

6.3.3.1 Calibration of thermocouple

Rare metal thermocouples in use for short duration tests (typically 500 h or under) should be calibrated at least every 12 months. Thermocouples in use for test durations over 12 months should be calibrated as follows.

- $T \leq 600\text{ }^{\circ}\text{C}$: every 4 years
- $600\text{ }^{\circ}\text{C} < T \leq 800\text{ }^{\circ}\text{C}$: every 2 years
- $800\text{ }^{\circ}\text{C} < T$: every 1 year

If the test duration exceeds the above calibration period, the thermocouple shall be calibrated upon the completion of the test. If a thermocouple is rewelded, the thermocouple shall be recalibrated before use.

It shall be demonstrated that the error of the thermocouple used has been established either at the test temperature or is typical for a range containing the test temperature.

If it is demonstrated that the drift of the thermocouple does not affect the permissible temperature deviations specified in **6.3.1**, the period between two calibrations may be longer.

Changes in the output of a thermocouple can be due not only to chemical changes from contamination leading to drift, but also as a consequence of handling physical damage. Information on such changes should be recorded and should be available on request.

NOTE 1 The thermocouple drift is dependent on the type of thermocouple used and the exposure duration.

If the drift affects the permissible temperature deviations, either more frequent calibrations should be carried out or a correction should be made to the temperature indicated by the thermocouple.

NOTE 2 Information concerning methods of calibration of thermocouples is given in Annex B.

6.3.3.2 Calibration of 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.

7 Test pieces

7.1 Shape and dimensions

In general, the test piece shall be a machined proportional cylindrical test piece ($L_{r0} = k/\sqrt{S_0}$) with a circular cross-section (see figure 2). The value k should be 5.65 or more, and the value used shall be recorded in the test report (e.g., $L_{r0} \geq 5D$).

In special cases, the cross-section of the test piece may be square or rectangular or other shapes. The provisions concerning the cylindrical test pieces do not apply to these specific test pieces.

In general, L_{r0} 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 portion shall be joined by transition curves to the grip ends of the testing machine. The transition radius (R) shall be between $0.25D$ and $1D$ for cylindrical test pieces, or between $0.25b$ and $1b$ for rectangular or square test pieces.

As long as the sample size permit, the original cross-sectional area (S_0) shall be 7 mm² or more.

For especially brittle materials, the transition radius may be greater than $1D$.

When the test piece having collars in the parallel portion is used, the transition radius of the collars may be under $0.25d$; this should be selected to minimize stress concentrations and there should be no evidence of undercut when inspected. For test pieces with collars, the difference of 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 rupture will occur within the gauge length.

The grip ends of test pieces shall have the same axis as the parallel portion with the following coaxiality tolerance.

- a) Cylindrical test pieces: $0.005 D$ or 0.03 mm whichever is greater
- b) Rectangular or square test pieces: $0.005 b$ or 0.03 mm whichever is greater

When oxidation is a significant factor, test pieces with larger original cross-sectional area (S_0) should be used.

The original reference length shall be determined to a measurement uncertainty of ± 1 %. The final reference length should be determined to a measurement uncertainty of ± 1 %.

When a notched test piece is used, the geometry and the position of this notch should be determined upon the agreement between the parties concerned with delivery.

7.2 Preparation of test piece

The test piece shall be machined in such a way as to minimize any residual deformation or surface defects.

The shape tolerances shall conform to table 3 for test pieces with circular cross-section and to table 4 for test pieces with square or rectangular cross-sections.

Table 3 Shape tolerances on test piece with circular cross-section

Unit: mm

Nominal diameter D	Shape tolerances ^{a)}
$3 < D \leq 6$	0.02
$6 < D \leq 10$	0.03
$10 < D \leq 18$	0.04
$18 < D \leq 30$	0.05
Note ^{a)} Maximum deviation between the measurements of dimension in cross-sectional direction determined along the entire parallel portion of the test piece (see ISO 286-2).	