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Metallic materials — Tensile testing —

Part 3:
Method of test at low temperature

Matériaux métalliques — Essai de traction —

Partie 3: Méthode d'essai à basse température

Reference number
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Foreword

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

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

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

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

The committee responsible for this document is ISO/TC 164, *Metallic materials*, Subcommittee SC 1, *Uniaxial testing*.

This first edition cancels and replaces ISO 15579:2000.

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

— *Part 1: Method of test at room temperature*

— *Part 2: Method of test at elevated temperature*

— *Part 3: Method of test at low temperature*

— *Part 4: Method of test in liquid helium*

Introduction

In this edition, there are two methods of testing speeds available. The first one, Method A, is based on strain rates (including crosshead separation rate) with narrow tolerances (±20 %) and the second, Method B, is based on conventional strain rate ranges and tolerances. Method A is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results.

Mechanical properties determined by tensile test at low temperatures have been determined at the same rates at room temperature. This revised part of ISO 6892 incorporates the new set of testing rates of ISO 6892-1 and ISO 6892-2, developed to reduce the variability of test results.

Metallic materials — Tensile testing —

Part 3:
Method of test at low temperature

WARNING — This International Standard calls for the use of substances and/or procedures that can be injurious to health if adequate safety measures are not taken. This International Standard does not address any health hazards, safety or environmental matters associated with its use. It is the responsibility of the user of this International Standard to establish appropriate health, safety and environmentally acceptable practices and take suitable actions for any national and international regulations. Compliance with this International Standard does not in itself confer immunity from legal obligations.

1 Scope

This part of ISO 6892 specifies a method of tensile testing of metallic materials at temperatures between +10 °C and -196 °C.

2 Normative references

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

ISO 6892-1:2009, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6892-1:2009 and the following apply.

In general, all test piece geometries/dimensions are based on measurements taken at room temperature. The exception can be the extensometer gauge length (see 3.3).

NOTE The following properties are generally not determined at low temperature unless required by relevant specifications or agreement:

- — permanent set strength (R_r);
- — percentage permanent elongation;
- — percentage permanent extension;
- — percentage yield point extension (A_e);
- — percentage total extension at maximum force (A_{gt});
- — percentage plastic extension at maximum force (A_g);
- — percentage total extension at fracture (A_t).

3.1
original gauge length
L_o
gauge length measured at room temperature before cooling of the test piece and before application of force

3.2
percentage elongation after fracture
A
permanent elongation of the gauge length, measured at room temperature, after fracture (L_u-L_o), expressed as a percentage of the original gauge length (L_o)

Note 1 to entry: For further details, see ISO 6892-1:2009.

3.3
extensometer gauge length
L_e
initial extensometer gauge length used for measurement of extension by means of an extensometer

3.4
extension
increase in the extensometer gauge length (L_e) at a given moment during the test

3.4.1
percentage extension
extension (3.4) expressed as a percentage of the extensometer gauge length (L_e)

3.5
percentage reduction of area
Z
maximum change in cross-sectional area which has occurred during the test (S_o-S_u), expressed as a percentage of the original cross-sectional area (S_o), where S_o and S_u are calculated from the dimensions at room temperature

3.6
stress
R
force at any moment during the test divided by the original cross-sectional area (S_o) of the test piece

Note 1 to entry: All stresses referenced in this part of ISO 6892 are engineering stresses, calculated using the cross-sectional area of the test piece derived from dimensions measured at room temperature.

3.7
soaking time
t_s
time taken to stabilize the temperature of the test piece prior to mechanical loading

4 Symbols and designations

Additional symbols to ISO 6892-1:2009, Table 1 used throughout this International Standard and their designation are given in Table 1.

Table 1 — Symbols and designations

Symbol	Unit	Designation
T	°C	Specified temperature or nominal temperature at which the test should be performed
T_i	°C	Indicated temperature or measured temperature on the surface of the parallel length of the test piece
t_s	min	Soaking time

5 Principle

The test involves straining a test piece by tensile force for the determination of one or more of the mechanical properties defined in ISO 6892-1:2009, Clause 3.

The test is carried out at a specified temperature between +10 °C and -196 °C.

6 Test piece

For requirements concerning test pieces, see ISO 6892-1:2009, Clause 6.

NOTE Additional examples of test pieces are given in Annex A.

7 Determination of original cross-sectional area (S_o)

For requirements concerning the determination of the original cross-sectional area, see ISO 6892-1:2009, Clause 7.

NOTE This parameter is calculated from measurements taken at room temperature.

8 Marking the original gauge length (L_o)

For requirements concerning marking the original gauge length, see ISO 6892-1:2009, Clause 8.

9 Apparatus

9.1 Force measuring system

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

9.2 Extensometer

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

The extensometer gauge length shall be not less than 10 mm and shall correspond to the central portion of the parallel length.

NOTE When using an extensometer to measure extension up to fracture, the extensometer gauge length, L_e, should be approximately equal to the original gauge length, L_o, otherwise, the extensometer gauge length, L_e, should be at least half as long as the marked original gauge length, L_o, but cover no more than 90 % of the parallel length, L_c. This will ensure that the extensometer detects all yielding events that occur in the test piece. Further, for measurement of parameters “at” or “after reaching” maximum force, L_e will be approximately equal to L_o.

Any part of the extensometer projecting beyond the cooling device shall be designed or protected from air currents so that fluctuations in the room temperature have only a minimal effect on the readings. It is advisable to maintain reasonable stability of the temperature and air currents surrounding the testing machine.

9.3 Cooling device

9.3.1 General

The cooling device shall be capable of cooling the test piece to the specified temperature, *T*.

The means of cooling can be, for example,

— by refrigeration unit,

— by expansion of compressed gas (e.g. CO_2 or N_2), and

— by immersion in a liquid maintained at its boiling point (e.g. N_2) or in a refrigerated liquid (e.g. alcohol).

Tensile tests at low temperatures are performed using gaseous or liquid cooling media. The type of cooling medium has a significant influence on the cooling time and on the heat transfer during the test (isothermal and/or adiabatic) and might have a significant influence on the test result.

Examples for cooling curves can be found in Annex B.

9.3.2 Permitted deviations of temperature

The cooling device for the test piece shall be such that the test piece can be cooled to the specified temperature, T.

The indicated temperatures, T_i, are the temperatures measured on the surface of the parallel length of the test piece or measured in the agitated liquid with corrections applied for any known systematic errors, but with no consideration of the uncertainty of the temperature measurement equipment.

The permitted deviation between the specified temperature, T, and the indicated temperature, T_i, is ±3 °C. The temperature gradient along the surface of the test piece shall not exceed 3 °C.

The temperature along the parallel length (L_c) shall be controlled within the permitted tolerances until the final proof strength is reached.

NOTE When the final proof strength is reached, temperature control should be attempted but experience has shown that it can be very difficult to control the temperature within the permitted range especially if a gaseous cooling medium is used.

9.3.3 Measurement of temperature

When the gauge length is less than 50 mm, one temperature sensor shall measure the temperature at each end of the parallel length directly. When the gauge length is equal to or greater than 50 mm, a third temperature sensor shall measure near the centre of the parallel length.

This number can be reduced if the general arrangement of the cooling device and the test piece is such that, from experience, it is known that the variation in temperature of the test piece does not exceed the permitted deviation specified in 9.3.2. However, at least one sensor shall be measuring the test piece temperature directly.

Temperature sensor junctions shall make good thermal contact with the surface of the test piece.

NOTE Use of the proper type and class of thermocouple is important to ensure accuracy of the measured temperature.

If the test piece is in an agitated liquid medium which can be assumed to be homogeneous, the temperature measurement can be made at any point within the cooling media.

If testing is carried out in liquid nitrogen, no temperature measurement is needed. In this case, the absence of temperature recording equipment shall be recorded in the test report.

9.3.4 Verification of the temperature-measuring system

The temperature-measuring equipment shall have a resolution equal to or better than 1 °C and an accuracy of ±2 °C for the range +10 °C to -40 °C and ±3 °C for the range -41 °C to -196 °C.

NOTE The temperature-measuring system includes all components of the measuring chain (sensor, cables, indicating device, and reference junction).

All components of the temperature-measuring system shall be verified and calibrated over the working range at intervals not exceeding 1 year. Errors shall be recorded on the verification report. The components of the temperature-measuring system shall be verified by methods traceable to the international unit (SI unit) of temperature.

10 Test conditions

10.1 Setting the force zero point

The force measuring system shall be set to zero after the testing equipment has been assembled but before the test piece is actually placed in the gripping jaws. Once the force zero point has been set, the force measuring system cannot be changed in any way during the test.

NOTE The use of this method ensures that the weight of the gripping system is compensated in the force measurement and that any force resulting from the clamping operation does not affect the force zero point.

10.2 Gripping of the test piece, fixing of the extensometer and cooling of the test piece, not necessarily in the following sequence

10.2.1 Method of gripping

For requirements concerning the method of gripping, see ISO 6892-1:2009, 10.2.

10.2.2 Fixing of the extensometer and establishing the gauge length

10.2.2.1 General

Different methods of establishing the extensometer gauge length are used in practice. This may lead to minor differences in the test results. The method used shall be documented in the test report.

NOTE Because there is only a temperature range of about 200 °C, the influence of (negative) thermal expansion on the test result is less significant than in the wider temperature range available in ISO 6892-2.

10.2.2.2 L_e based on room temperature (Method 1)

The extensometer is set on the test piece at room temperature with nominal gauge length. The extension is measured at test temperature and the percentage extension is calculated with the gauge length at room temperature. The thermal extension is not considered.

10.2.2.3 L_e based on test temperature (Method 2)

The methods below consider thermal expansion of the test piece and possibly the extensometer.

10.2.2.3.1 Nominal L_e at test temperature (Method 2a)

The extensometer is set on the test piece at the test temperature with nominal gauge length before mechanical loading.

10.2.2.3.2 Extended L_e at room temperature (Method 2b)

An extensometer with extended gauge length is set on the test piece at room temperature such that, at test temperature, the nominal gauge length is achieved.

For the calculation of percentage extension, the nominal gauge length is used.

10.2.2.3.3 Corrected L_e at test temperature (Method 2c)

The extensometer is set on the test piece at room temperature with the nominal gauge length.

For the calculation of percentage extension, the corrected nominal gauge length at test temperature (gauge length at room temperature + thermal expansion) is used.

NOTE The thermal expansion is negative in this case.

10.2.3 Cooling of the test piece

The test piece shall be cooled to the specified temperature, T, and shall be maintained at that temperature (soaking time) for at least 10 min before loading. The loading shall only be started after the output of the extensometer has stabilized.

NOTE Longer soaking times can be required to achieve the specified temperature throughout the cross section of larger test pieces (e.g. S_o > 100 mm^2).

During cooling, the temperature of the test piece shall not go below the specified temperature within its tolerances, except by agreement between the parties concerned.

10.3 Testing rate based on strain rate control (Method A)

10.3.1 General

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

For additional requirements concerning testing rate based on strain rate control (Method A), see ISO 6892-1:2009, 10.3.1.

It is not always the case that all properties of the tensile test at room temperature will be determined at low temperature. Hence, only the appropriate test rates/modes for the properties to be determined shall be used (see Figure 1).

10.3.2 Strain rate for the determination of the upper yield strength (R_{eH}) or proof strength properties (R_p and, if required, R_t)

For additional requirements concerning strain rate for the determination of the upper yield strength (R_{eH}) or proof strength properties (R_p and, if required, R_t), see ISO 6892-1:2009, 10.3.2 but observe one of the following specified ranges.

Range 1: $\dot{e}_{L_e}$ = 0,000 07 s^{-1} (equal to 0,004 2 min^{-1}), with a relative tolerance of ±20 %

Range 2: $\dot{e}_{L_e}$ = 0,000 25 s^{-1} (equal to 0,015 min^{-1}), with a relative tolerance of ±20 % (recommended unless otherwise specified; see also Figure 1)

