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Metallic materials — Tensile testing —

Part 4:
Method of test in liquid helium

Matériaux métalliques — Essai de traction —

Partie 4: Méthode d'essai dans l'hélium liquide

Reference number
ISO 6892-4:2015(E)

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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).

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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, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This first edition of ISO 6892-4 cancels and replaces ISO 19819:2004, which has been technical revised.

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

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

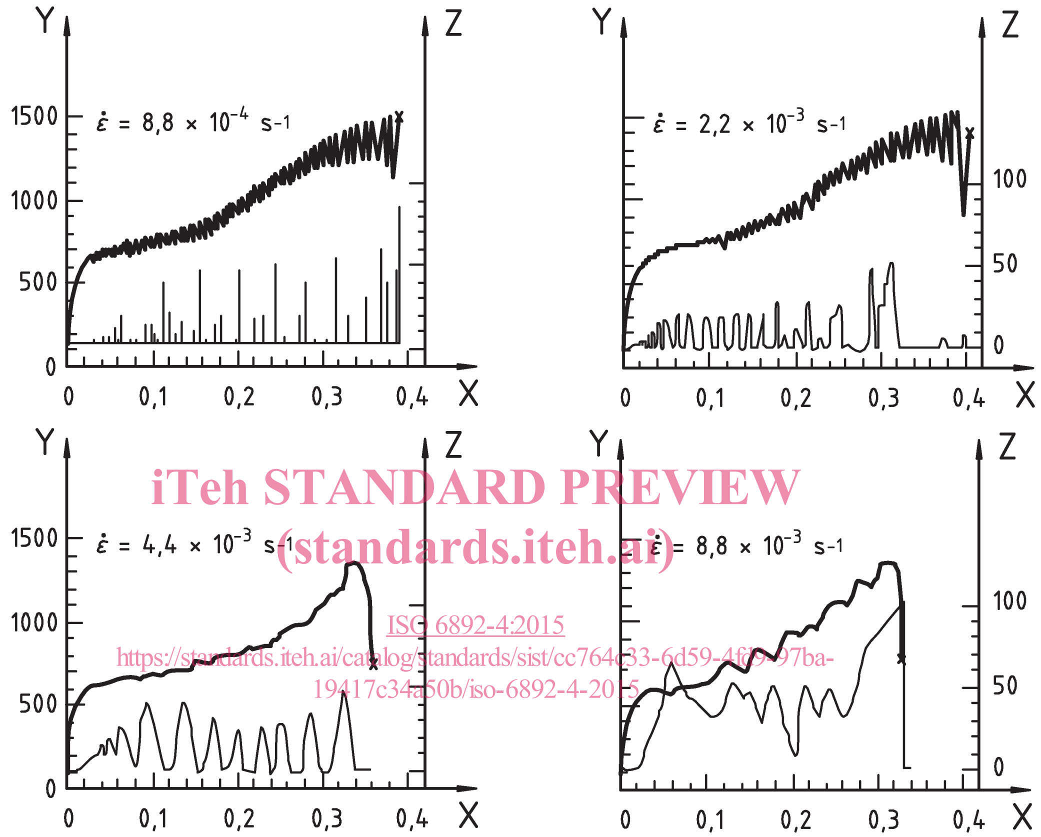
— *Part 2: Method of test at elevated temperature*

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

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

Introduction

The force-time and force-extension records for alloys tested in liquid helium using displacement control are serrated. Serrations are formed by repeated bursts of unstable plastic flow and arrests. The unstable plastic flow (discontinuous yielding) is a free-running process occurring in localized regions of the parallel length at higher rates than nominal strain rates with internal test piece heating. Examples of serrated stress-strain curves for a typical austenitic stainless steel with discontinuous yielding are shown in Figure 1.



Key

1 stress, N/mm2

2 strain

3 temperature, K

Figure 1 — Example of typical stress-strain curves and test piece temperature histories at four different nominal strain rates, for AISI 304L stainless steel tested in liquid helium

A constant test piece temperature cannot be maintained at all times during testing in liquid helium. Due to adiabatic heating, the test piece temperature at local regions in the parallel length rises temporarily above 4 K during each discontinuous yielding event (see Figure 1). The number of events and the magnitude of the associated force drops are a function of the material composition and other factors such as test piece size and test speed. Typically, altering the mechanical test variables can change the type of serration but not eliminate the discontinuous yielding. Therefore, tensile property measurements of alloys in liquid helium (especially tensile strength, elongation, and reduction of area) may lack the usual significance of property measurements at room temperature where deformation is more nearly isothermal and discontinuous yielding typically does not occur.

Strain control is the preferred control mode (Method A, 6892-1) and displacement control is the secondary method, according to Method B 6892-1.

Metallic materials — Tensile testing —

Part 4:
Method of test in liquid helium

1 Scope

This part of ISO 6892 specifies the method of tensile testing of metallic materials in liquid helium (the boiling point is –269 °C or 4,2 K, designated as 4 K) and defines the mechanical properties that can be determined.

This part of ISO 6892 may apply also to tensile testing at cryogenic temperatures (less than –196 °C or 77 K), which requires special apparatus, smaller test pieces, and concern for serrated yielding, adiabatic heating, and strain-rate effects.

To conduct a tensile test according to this part of ISO 6892 at 4 K, the test piece installed in a cryostat is fully submerged in liquid helium (He) and tested using displacement control at a nominal strain rate of 10^{-3} s^{-1} or less.

NOTE The boiling point of the rare ^{3}He isotope is 3,2 K. Usually, the tests are performed in ^{4}He or a mixture of ^{3}He and ^{4}He with a high concentration of ^{4}He. Therefore, the temperature is, as designated before, 4 K.

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:—[1)], *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 6892-3, *Metallic materials — Tensile testing — Part 3: Method of test at low temperature*

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

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

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 6892-1 and in ISO 6892-3 apply.

3.1
adiabatic heating
internal heating of a test piece resulting from deformation under conditions such that the heat generated by plastic work cannot be quickly dissipated to the surrounding cryogen

1) To be published.

3.2
axial strain
longitudinal strains measured at opposite or equally spaced surface locations on the sides of the longitudinal axis of symmetry of the test piece

Note 1 to entry: The longitudinal strains are measured using two or more strain-sensing transducers located at the mid-length of the parallel length.

3.3
bending strain
difference between the strain at the surface of the test piece and the axial strain

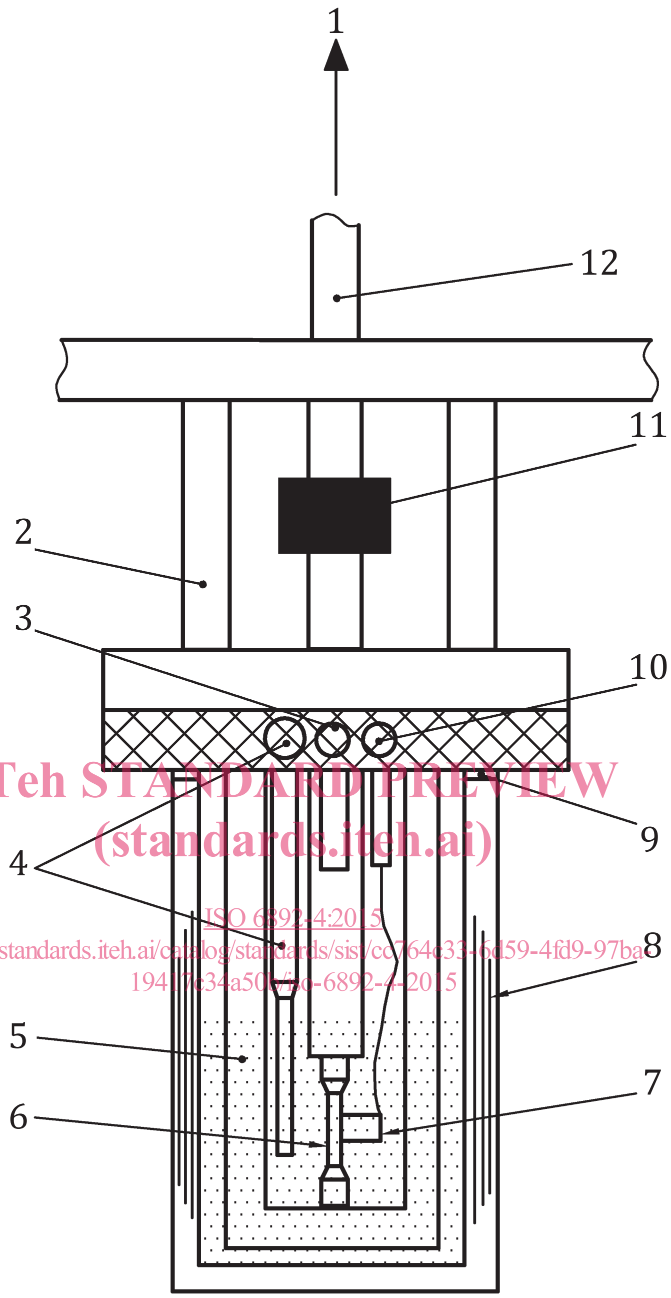
Note 1 to entry: The bending strain varies around the circumference and along the parallel length of the test piece.

3.4
dewar
vacuum-insulated container for cryogenic fluids

3.5
discontinuous yielding strength
R_i
peak stress at the initiation of the first measurable serration on the stress-strain curves

3.6
tensile cryostat
test apparatus for applying tensile forces to test pieces in cryogenic environments

Note 1 to entry: See Figure 2.



Key

1	force	7	extensometer
2	room temperature load frame	8	vacuum-insulated dewar
3	vent	9	dewar seal
4	vacuum-insulated transfer tube	10	electrical feed-through
5	cryogenic load frame	11	load cell
6	test piece	12	pull rod

Figure 2 — Schematic illustration of typical cryostat for tensile testing at 4 K

4 Symbols and designations

Symbols and corresponding designations are given in Table 1.

Table 1 — Symbols and designations

Symbol	Unit	Designation
d_o	mm	diameter of the parallel length of a cylindrical test piece or diameter of a circular wire
L_o	mm	original gauge length
L_u	mm	final gauge length after fracture
L_c	mm	parallel length
L_e	mm	extensometer gauge length
S_o	mm^2	original cross-sectional area of the parallel length
S_u	mm^2	minimum cross-sectional area after fracture (final cross-sectional area)
Z	%	percentage reduction of area: $Z = \frac{S_o - S_u}{S_o} \times 100$
A	%	percentage elongation after fracture: $A = \frac{L_u - L_o}{L_o} \times 100$
F_m	N	maximum force
R_m	N/mm^2	tensile strength
$R_{p0,2}$	N/mm^2	0,2 % proof strength, plastic extension
R_i	N/mm^2	discontinuous yielding strength

5 Principle

The test consists of straining a test piece in liquid helium by a tensile force, generally to fracture, for the purpose of determining one or more of the mechanical properties defined in Clause 4.

6 Apparatus

6.1 Testing machine

The testing machine shall be verified and calibrated in accordance with ISO 7500-1 and shall be of at least class 1, unless otherwise specified in the product standard.

6.1.1 Testing machine compliance

Compliance (displacement per unit of applied force of the apparatus itself) of the test facility (tensile machine and the cryogenic load frame) should be known. Measure the compliance by coupling the load train with a rigid test piece or by using a special calibration test piece. Then, measure the compliance at a low force and at the highest force used to qualify the machine, as indicated in 6.1.4. A practical procedure for the determination of the compliance respective of the stiffness is described in ISO 6892-1:—, Annex F.

NOTE Different system compliances may result in different stress-extension curves and material properties (e.g. elongation after fracture, tensile strength) of the material because a larger discontinuous deformation occurs in a lower compliance test facility.

6.1.2 System design

Typically, alloys in liquid helium exhibit double or triple their ambient strengths at ambient temperature. For the same test piece geometry, higher forces shall be applied to the cryostat, test piece, load train members, and grips at cryogenic temperatures. Since many conventional test machines have a maximum force of 100 kN or less, it is recommended that the apparatus be designed to accommodate one of the small test pieces cited in 7.2.

6.1.3 Construction materials

Many construction materials, including the vast majority of ferritic steels, are brittle at 4 K. To prevent service failures, fabricate the grips and other load train members using strong, tough, cryogenic alloys. Materials that have low thermal conductivity are desirable to reduce heat flow. Austenitic stainless steels (AISI 304LN), maraging steels (200, 250, or 300 grades, with nickel plating to prevent rust), wrought nickel-base superalloys, and titanium alloys (Ti-6Al-4V and Ti-5Al-2,5Sn) have been used with proper design, for grips, pull rods, and cryostat frames. Non-metallic materials (for example, glass-epoxy composites) are excellent insulators and are sometimes used for compression members.

6.1.4 Alignment

Proper system alignment is essential to minimize bending strains in the tensile tests. The machine and grips should be capable of applying force to a precisely machined calibration test piece so that the maximum bending strain should be according to ISO 23788 class 10. Reduce bending strain to an acceptable level by making proportional adjustments to a cryostat with alignment capability, or by using spacing shims to compensate an unadjustable fixture. Calculate the strain based on readings taken while the calibration test piece is subjected to a low force, as well as at the highest force for which the machine and load train are being qualified.

Qualify the apparatus by making axiality measurements at room temperature and at 4 K. To perform axiality tests of the apparatus, the test piece form and cryostat should be the same as that used during cryogenic tests, and the test piece concentricity should be as nearly perfect as possible. No plastic strain should occur in the parallel length of the alignment test piece during loading. In some cases this may necessitate the use of a relatively stiff, high-strength calibration test piece.

For cylindrical test pieces, calculate the maximum bending strain defined in 4.3 from the strains measured with three electrical-resistance strain gauges, extensometers, or clip gauges at circumferential positions, equally spaced around and at the centre of the parallel length of the test piece.

For test pieces of square or rectangular cross-section, measure the strain at the centre of two parallel (opposite) faces, or in the case of thin cross-sections, at the centre of the two broad faces.

For conventional threaded or pinned grips, evaluate the effect of test piece bias as follows. Repeat the axiality measurements with the test piece rotated 180°, but with the grips and pull rods retained in their original positions. Then calculate the maximum bending strain and the strain at the test piece axis. If other grips or methods are used to evaluate the effect of test piece bias it should be described in the report.

Strain-Averaging Technique - Nonaxiality of loading (which may be introduced due to the machining of the test pieces) is usually sufficient to introduce errors in tensile tests at small strains when strain is measured at only one position on the test piece. Therefore, measure strains at three equally spaced (or, if good alignment has been achieved, at least two opposing) positions within the parallel section. Report the average of the strains from the two or three positions centred on the parallel length.

6.1.5 Gripping mechanisms

Choose the gripping mechanism according to test piece type. Cryogenic materials shall be used in the construction of components to avoid failure in service.