



Designation: E1450 – 24

Standard Test Method for Tension Testing of Structural Alloys in Liquid Helium¹

This standard is issued under the fixed designation E1450; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method describes procedures for the tension testing of structural alloys in liquid helium. The format is similar to that of other ASTM tension testing standards, but the contents includes modifications for cryogenic testing that require special apparatus, smaller specimens, and concern for discontinuous yielding, adiabatic heating, and strain-rate effects.

1.2 To conduct a tension test by this standard, the specimen in a tensile cryostat is fully submerged in normal liquid helium (He I) and tested using crosshead displacement control at a nominal strain rate of 10^{-3} mm/mm/s or less. Tests using force control or high strain rates are not considered.

1.3 This test method specifies methods for the measurement of yield strength, tensile strength, elongation, and reduction of area. The determination of the Young's modulus is treated in Test Method E111.

NOTE 1—The boiling point of normal liquid helium (He I) at sea level is 4.2 K (–269 °C or –452.1 °F or 7.6 °R). It decreases with geographic elevation and is 4.0 K (–269.2 °C or –452.5 °F or 7.2 °R) at the National Institute of Standards and Technology in Colorado, 1677 m (5500 ft) above sea level. In this standard the temperature is designated 4 K.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* See Section 5.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

¹ This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

Current edition approved May 15, 2024. Published July 2024. Originally approved in 1992. Last previous edition approved in 2016 as E1450 – 16. DOI: 10.1520/E1450-24.

2. Referenced Documents

2.1 ASTM Standards:²

- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- E4 Practices for Force Calibration and Verification of Testing Machines
- E6 Terminology Relating to Methods of Mechanical Testing
- E8/E8M Test Methods for Tension Testing of Metallic Materials
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E83 Practice for Verification and Classification of Extensometer Systems
- E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
- E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages
- E328 Test Methods for Stress Relaxation for Materials and Structures
- E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
- E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
- E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

3. Terminology

3.1 Definitions:

3.1.1 Refer to Terminology E6 for the definitions of the following terms used in this standard: bending strain, calibration, elongation, elongation after fracture, elongation at fracture, extensometer, extensometer system, force, gage factor, gauge length, lead wire, proportional limit, reduced section, reduced parallel section, reduction of area, stress-strain diagram, tensile strength, verification, yield strength and Young's modulus.

3.1.2 In addition, the following common terms from Terminology E6 are defined:

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

3.1.3 *adjusted length of the reduced parallel section*—the length of the reduced parallel section plus an amount calculated to compensate for strain in the fillet region.

3.1.4 *discontinuous yielding, n* —in a uniaxial test, a hesitation or fluctuation of force observed at the onset of plastic deformation, due to localized yielding.

3.1.4.1 *Discussion*—The stress-strain curve need not appear to be discontinuous.

3.1.5 *discontinuous yielding stress, σ_i* —the peak stress at the initiation of the first measurable serration on the curve of stress-versus-strain.

3.1.5.1 *Discussion*—The parameter σ_i is a function of test variables and is not a material constant.

3.1.6 *gauge length, n* —the original length of that portion of the specimen over which strain, elongation, or change of length is determined.

3.1.6.1 *Discussion*—Typically, this length is also the distance between gauge marks, if gauge marking is used to facilitate measurement of the elongation after fracture.

3.1.6.2 *Discussion*—When sensing extension or motion with a gauge length that is predetermined by the specimen geometry or specific test method, then only resolution and strain error for the specified gauge length should determine the class of the extensometer system.

3.1.7 *length of the reduced parallel section*—the distance between the tangent points of the fillets that bound the reduced parallel section.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *adiabatic heating*—the internal heating of a specimen resulting from tension testing under conditions such that the heat generated by plastic work cannot be quickly dissipated to the surrounding cryogen.

3.2.2 *Dewar*—a vacuum-insulated container for cryogenic fluids.

3.2.3 *tensile cryostat*—a test apparatus for applying tensile forces to test specimens in cryogenic environments Fig. 1.

4. Significance and Use

4.1 Tension tests provide information on the strength and ductility of materials under uniaxial tensile stresses. This information can be useful for alloy development, comparison and selection of materials, and quality control. Under certain circumstances, the information can also be useful for design.

4.2 The force-time and force-extension records for some alloys tested in liquid helium using displacement control are often serrated (1).³ 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 reduced parallel section at higher-than-nominal rates of strain with adiabatic heating. Examples of serrated stress-strain curves for a typical austenitic stainless steel with discontinuous yielding are shown in Fig. 2.

4.3 A constant specimen temperature cannot be maintained at all times during tests in liquid helium. The specimen temperature at local regions in the reduced parallel section rises temporarily above 4 K during each discontinuous yielding event (see Fig. 2), owing to adiabatic heating. The number of events and the magnitude of the associated drops in magnitude of force are a function of the material composition and other factors such as specimen size and test speed. Typically, altering the mechanical test variables can modify but not eliminate the

³ The boldface numbers in parentheses refer to the list of references at the end of this test method.

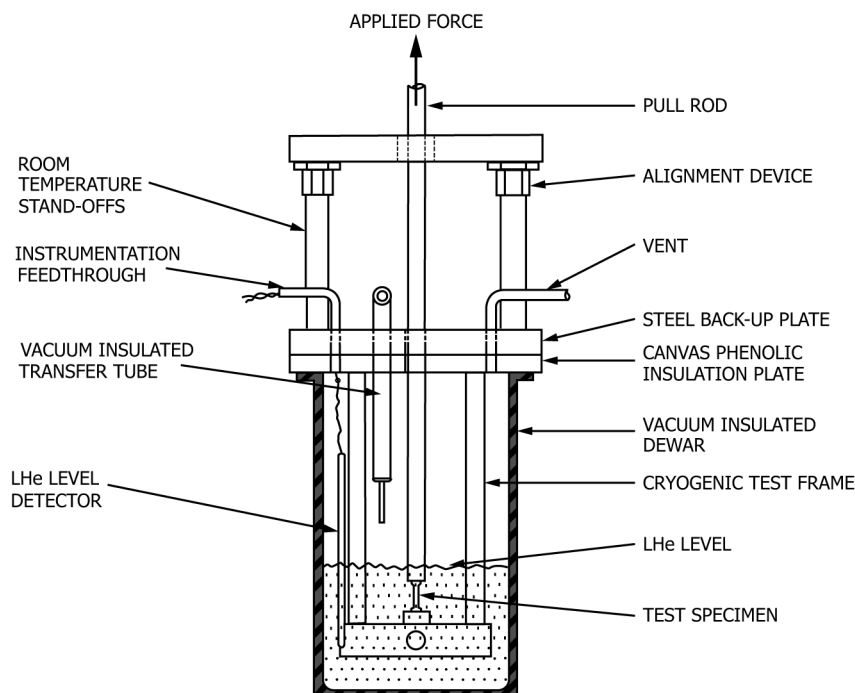


FIG. 1 Schematic Illustration of Typical Tensile Cryostat for Tension Testing at 4 K



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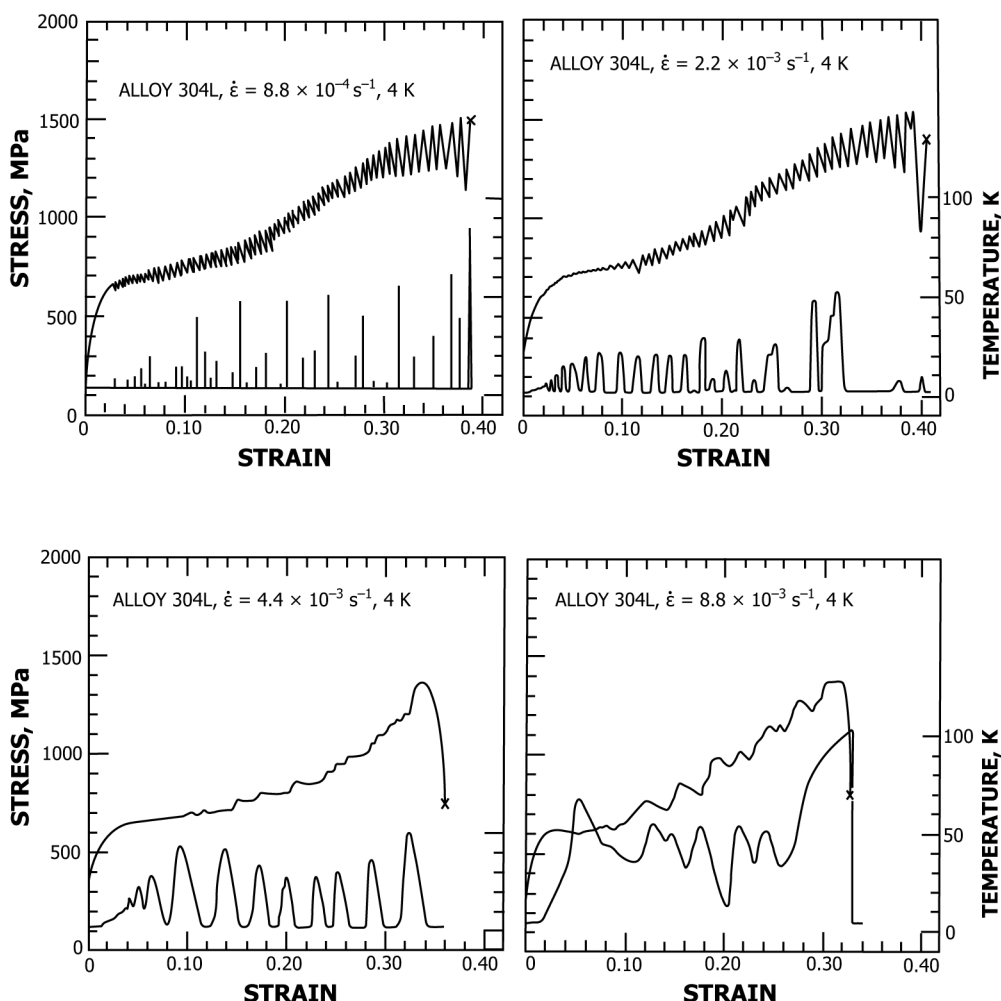


FIG. 2 Typical Engineering Stress-Strain Curves and Specimen Temperature Histories, at Four Different Nominal Strain Rates, for AISI 304L Stainless Steel Tested in Liquid Helium (4)

discontinuous yielding (2-4). Therefore, tensile property measurements of alloys in liquid helium (especially tensile strength, elongation, and reduction of area) lack the usual significance of property measurements at room temperature, where deformation is more nearly isothermal and discontinuous yielding typically does not occur.

4.4 The stress-strain response of a material tested in liquid helium depends on whether force control or displacement control is used (3). Crosshead displacement control is specified in this standard since the goal is material characterization by conventional methods. The possibility of a different and less favorable material response must be taken into account when data are used for design in actual applications subject to force-controlled conditions.

5. Hazards

5.1 Several precautions shall be observed in the use of cryogenic fluids and equipment. Skin or eye contact with cryogenics will freeze and destroy tissue. The appropriate protection may require goggles, clothing without pockets or cuffs, gloves, and tongs for handling cold specimens. Cryogenic containers that are internally pressurized or evacuated are

potentially hazardous in that damage or leaks can produce explosions or implosions. Also, when liquids evaporate to gases, there is a huge volume increase; therefore asphyxiation is a potential threat where liquid nitrogen or liquid helium evaporates in rooms that are not properly ventilated. Safety guidelines pertaining to the use of liquid helium and other cryogenic fluids are considered elsewhere in more detail (5).

6. Apparatus

6.1 Testing Machines:

6.1.1 The force-measuring system of the testing machine shall conform to the requirements of Practices E4.

6.1.2 The forces used in determining tensile strength and yield strength shall be within the verified range of forces of the force-measuring system of the testing machine.

NOTE 2—Because it is important to minimize heat loss from the dewar through the cryogenic test frame (Fig. 1), the cross-sections of these components are often smaller than they would be in a conventional testing machine. A drawback to these smaller cross sections is that the compliance of the testing machine frame, (displacement per unit of applied force), can be unacceptably large. High-compliance testing machine frames can introduce artifacts in the stress-strain curve that complicate the interpretation of discontinuous yielding. It is often desirable to minimize the compliance of the testing machine frame.