Designation: F2516 – 22

Standard Test Method for Tension Testing of Nickel-Titanium Superelastic Materials[1]

This standard is issued under the fixed designation F2516; 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 covers the tension testing of superelastic nickel-titanium (nitinol) materials, specifically the methods for determination of upper plateau strength, lower plateau strength, residual elongation, tensile strength, and elongation.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *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.*

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E6 Terminology Relating to Methods of Mechanical Testing

E8/E8M Test Methods for Tension Testing of Metallic Materials

E83 Practice for Verification and Classification of Extensometer Systems

E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E1876 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Impulse Excitation of Vibration

E3098 Test Method for Mechanical Uniaxial Pre-strain and Thermal Free Recovery of Shape Memory Alloys

F2004 Test Method for Transformation Temperature of Nickel-Titanium Alloys by Thermal Analysis

F2005 Terminology for Nickel-Titanium Shape Memory Alloys

F2082/F2082M Test Method for Determination of Transformation Temperature of Nickel-Titanium Shape Memory Alloys by Bend and Free Recovery

3. Terminology

3.1 The definitions of terms relating to tension testing appearing in Terminology E6 and the terms relating to nickel-titanium shape memory alloys appearing in Terminology F2005 shall be considered as applying to the terms used in this test method. Engineering stress and strain are assumed unless otherwise noted. Additional terms being defined are as follows (see Fig. 1):

3.2 *Definitions:*

3.2.1 *alignment stress, n*—stress (not to exceed 7 MPa) applied to the specimen after it is installed in the grips to ensure that the specimen is straight and aligned to the grips.

3.2.2 *elongation at fracture (El_{fr}), n*—elongation measured just prior to the sudden decrease in force associated with fracture. See Fig. 1 and X1.2. **E6**

3.2.2.1 *Discussion*—Elongation at fracture results may be very sensitive to test variables such as test speed, specimen geometry, heat dissipation, surface finish, and alignment. See Test Methods E8/E8M.

3.2.2.2 *Discussion*—Corrections for nonuniform strains between the extensometer attachments, including in the necked region, are beyond the scope of this standard. See Test Methods E8/E8M.

3.2.3 *fracture ductility (ε_{fr}), n*—true plastic strain at fracture. See X1.2. **E6**

3.2.3.1 *Discussion*—For prismatic specimens, the fracture ductility is calculated as follows:

$$\varepsilon_{fr} = \ln\left(\frac{A_o}{A_{fr}}\right) = \ln\left(\frac{1}{1 - RA\%/100}\right) \quad (1)$$

[1] This test method is under the jurisdiction of ASTM Committee F04 on Medical and Surgical Materials and Devices and is the direct responsibility of Subcommittee F04.15 on Material Test Methods.

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

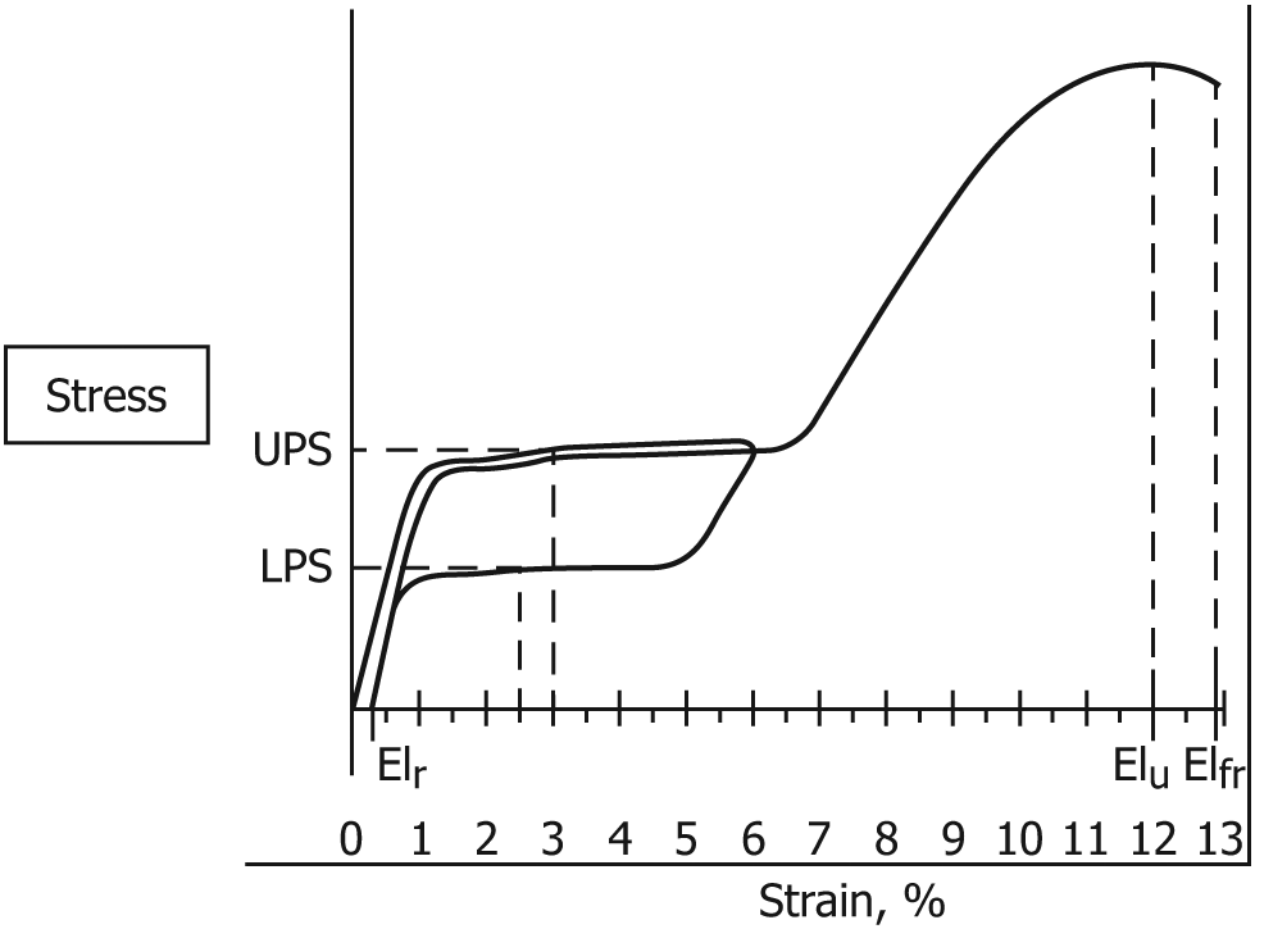

FIG. 1 Terms Illustrated on Typical Stress-Strain Diagram of Superelastic Nitinol

where:

A_O = original cross-sectional area,
A_{fr} = area at fracture of its smallest cross section after testing, and
$RA\%$ = reduction of area, %. See Terminology E6.

3.2.4 *lower plateau strength (LPS), n*—stress at 2.5 % strain during unloading of the sample, after loading to 6 % strain. See Fig. 1. **E6**

3.2.5 *reduction of area percent (RA%), n*—percent difference between the original cross-sectional area of a tension test specimen and the area of its smallest cross section after fracture.

3.2.5.1 *Discussion*—When the specimen necks prior to fracture, reduction in area provides a measure of the material ductility. The reduction of area of a prismatic specimen is calculated using the difference in the original cross-sectional area, A_O, of a specimen and the area at fracture of its smallest cross section, A_{fr}, after testing as follows:

$$RA\% = 100\% \frac{A_O - A_{fr}}{A_O} \quad (2)$$

3.2.5.2 *Discussion*—For measuring a specimen's A_{fr} with an original circular or rectangular cross sections, see Test Methods E8/E8M, subection 7.12.

3.2.6 *residual elongation, El_f, %*—difference between the strain at a set stress at or between the alignment stress and a maximum of 7 MPa during unloading and the strain at that same set stress during the initial loading. See Fig. 1 and X1.4.

3.2.7 *uniform elongation, El_u, %*—elongation determined at the maximum force sustained by the test piece just prior to necking, or fracture, or both. See Fig. 1.

3.2.7.1 *Discussion*—Uniform elongation is not an accurate measure of ductility. See X1.2.

3.2.8 *upper plateau strength (UPS)*—stress at 3 % strain during loading of the sample. See Fig. 1. **E6**

4. Summary of Test Method

4.1 Using conventional tensile testing apparatus, the material is pulled to 6 % strain, then unloaded to less than 7 MPa, then pulled to failure.