



Designation: E3414 – 23

Standard Test Method for Constant Torque Thermal Cycling of Cylindrical Shape Memory Alloy Specimens¹

This standard is issued under the fixed designation E3414; 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 will define procedures for thermomechanical cycling of shape memory alloys (SMA) material and components with circular cross-sections under constant torque. This test method will measure the transformation properties such as transformation temperatures, actuation shear strain and residual shear strain, when a shape memory alloy is thermally cycled through the phase transformation under a constant applied torque. This test is done to provide data for the characterization selection of shape memory alloy materials, quality control, design allowables and actuator design.

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

- E4 Practices for Force Calibration and Verification of Testing Machines
- E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E83 Practice for Verification and Classification of Extensometer Systems

E209 Practice for Compression Tests of Metallic Materials at Elevated Temperatures with Conventional or Rapid Heating Rates and Strain Rates

E606/E606M Test Method for Strain-Controlled Fatigue Testing

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

E1169 Practice for Conducting Ruggedness Tests

E2207 Practice for Strain-Controlled Axial-Torsional Fatigue Testing with Thin-Walled Tubular Specimens

E2368 Practice for Strain Controlled Thermomechanical Fatigue Testing

E3097 Test Method for Uniaxial Constant Force Thermal Cycling of Shape Memory Alloys

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

2.2 Other Standards:

IEEE/ASTM SI 10 American National Standard for Metric Practice²

ASQ C1 General Requirements for a Quality Program³

ISO 9001 Quality Management Systems—Requirements⁴

3. Terminology

3.1 *Definitions*—The terms specific to this test method are defined in this section. All other terms used in this test method are in accordance with Terminologies in Terminology F2005, Practice E2207, Test Method E3097 and Test Method E3098. All shear stress and shear strain defined in this test method are determined on the outer diameter in accordance with Practice E2207, unless otherwise stated.

¹ This test method is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.05 on Cyclic Deformation and Fatigue Crack Formation.

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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.

³ Available from American Society for Quality (ASQ), 600 N. Plankinton Ave., Milwaukee, WI 53203, <http://www.asq.org>.

⁴ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

3.1.1 *Discussion*—During thermomechanical cycling of shape memory alloys (SMA) material shear strain typically varies non-linearly through the wall of the specimen, with the smallest and largest values occurring at the inner and outer diameters of the specimen, respectively. Furthermore, this test method allows for testing of specimens that do not meet the thin-walled condition as described in Practice E2207. Therefore, shear strain and shear stress results determined on the outer diameter should be considered representative of specimens of the NiTi based material and outer to inner diameter ratio being tested.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *actuation shear strain* (γ_{act}), n —the shear strain recovery obtained when heating from LCT to UCT at a specified shear stress.

$$\gamma_{act} = \gamma_{LCT} - \gamma_{UCT}$$

3.2.2 *austenite finish shear strain* (γ_{Af}), n —shear strain determined at the austenite finish temperature during final heating as described in 10.3. (See Fig. 1.)

3.2.3 *austenite start shear strain* (γ_{As}), n —shear strain determined at the austenite start temperature during final heating as described in 10.3. (See Fig. 1.)

3.2.4 *cooling transformation shear strain* (γ_{ct}), n —the shear strain recovery due to the martensitic transformation obtained when cooling at a specified shear stress.

$$\gamma_{ct} = \gamma_{Ms} - \gamma_{Mf}$$

3.2.5 *heating transformation shear strain* (γ_{ht}), n —the shear strain recovery due to the austenitic transformation obtained when heating at a specified shear stress.

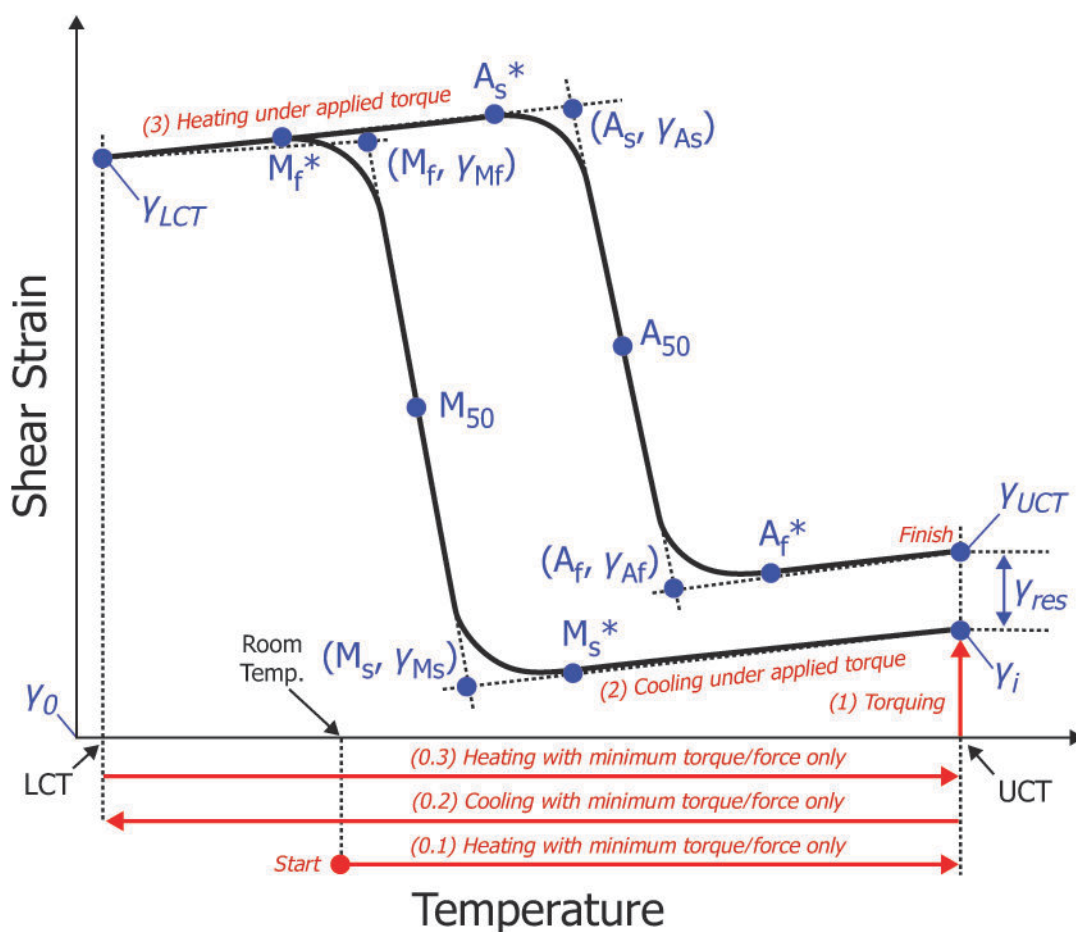
$$\gamma_{ht} = \gamma_{As} - \gamma_{Af}$$

3.2.6 *initial loading shear strain* (γ_i), n —initial specimen strain after normalization and before cooling when loaded at the UCT. (See Fig. 1.)

3.2.7 *initial shear strain* (γ_0), n —specimen shear strain at UCT after normalizing (see 10.1) and prior to loading the specimen. (See Fig. 1.)

3.2.8 *martensite finish shear strain* (γ_{Mf}), n —shear strain determined at the martensite finish temperature during cooling as described in 10.3. (See Fig. 1.)

3.2.9 *martensite start shear strain* (γ_{Ms}), n —shear strain determined at the martensite start temperature during cooling as described in 10.3. (See Fig. 1.)



NOTE 1—In cases where the starting point labeled “Start” coincides with the UCT, such as for the case of low temperature SMAs that are austenitic at room temperature, the same procedure applies with the exception that the normalization step labeled (0.1) is no longer needed.

FIG. 1 Typical Constant Torque Thermal Cycle and Test Methods Terms