Designation: E3097 – 23

Standard Test Method for Uniaxial Constant Force Thermal Cycling of Shape Memory Alloys[1]

This standard is issued under the fixed designation E3097; 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 defines procedures for thermomechanical cycling of shape memory alloy (SMA) material and components under constant force. This method characterizes the transformation properties such as transformation temperatures, actuation strain and residual strain, when a SMA is thermally cycled through the phase transformation under a constant applied force. This test is done to provide data for the selection of SMA materials, quality control, design allowables and actuator design.

1.2 *Units*—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

E6 Terminology Relating to Methods of Mechanical Testing

E8/E8M Test Methods for Tension Testing of Metallic Materials

E9 Test Methods of Compression Testing of Metallic Materials at Room Temperature

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

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

E1169 Practice for Conducting Ruggedness Tests

E2368 Practice for Strain Controlled Thermomechanical Fatigue Testing

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

F2005 Terminology for Nickel-Titanium Shape Memory Alloys

F2516 Test Method for Tension Testing of Nickel-Titanium Superelastic Materials

2.2 *Other Standards:*

IEEE/ASTM SI 10 American National Standard for Metric Practice[2]

ASQ C1 general Requirements for a Quality program[3]

ISO 9001 Quality Management Systems—Requirements[4]

3. Terminology

3.1 Specific technical terms used in this test method are found in Terminology F2005.

3.2 *Definitions:*

3.2.1 *actuation strain (e_{act})*—The full strain recovery obtained when heating from LCT to UCT at a specified stress. It includes the thermal expansions of martensite and austenite as well the phase transformation strain. $e_{act} = e_{LCT} - e_{UCT}$

3.2.2 *austenite 50 % (A_{50})*—Temperature at which the transformation from martensite to austenite is 50 % completed.

[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.

Current edition approved June 15, 2023. Published July 2023. Originally approved in 2017. Last previous edition approved in 2017 as E3097–17. DOI: 10.1520/E3097–17

[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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

$A_{50}=(A_s + A_f)/2$.

3.2.3 *austenite finish strain (e_{Af})*—Strain calculated at the austenite finish temperature during final heating.

3.2.4 *austenite start strain (e_{As})*—Strain calculated at the austenite start temperature during final heating.

3.2.5 *cooling transformation strain (e_{ct})*—The strain recovery due to the martensitic transformation obtained when cooling at a specified stress. $e_{ct}=e_{Ms}-e_{Mf}$

3.2.6 *heating transformation strain (e_t)*—The strain recovery due to the austenitic transformation obtained when heating at a specified stress. $e_t=e_{As}-e_{Af}$

3.2.7 *hysteresis width (HWIDTH)*—Width of the thermal hysteresis curve in degrees centigrade. Distance on the temperature axis between a vertical line drawn through the A_{50} point and a vertical line drawn through the M_{50} point.

3.2.8 *initial loading strain (e_i)*—Initial specimen strain after normalization and before cooling when loaded at the UCT.

3.2.9 *initial strain (e_0)*—Specimen strain at UCT after normalizing (see 11.1) and prior to loading the specimen.

3.2.10 *lower cycle temperature (LCT)*—Minimum temperature of the thermal cycle.

3.2.11 *martensite 50 % (M_{50})*—Temperature at which the transformation from austenite to martensite is 50 % completed. $M_{50}=(M_s + M_f)/2$.

3.2.12 *martensite finish strain (e_{Mf})*—Strain calculated at the martensite finish temperature during cooling. (See Figure 1)

3.2.13 *martensite start strain (e_{Ms})*—Strain calculated at the martensite start temperature during cooling.

3.2.14 *residual strain (e_{res})*—The final strain at the upper cycle temperature minus the initial strain at the upper cycle temperature. $e_{res}=e_{UCT}-e_i$

3.2.15 *strain at the lower cycle temperature (e_{LCT})*—Specimen strain at the LCT after cooling from the UCT to the LCT under the specified stress. (See Fig. 1.)

3.2.16 *strain at the upper cycle temperature (e_{UCT})*—Specimen strain at the UCT after cooling to the LCT and heating to the UCT at the specified stress. (See Fig. 1.)

3.2.17 *thermal transformation span (TSPAN)*—Thermal transformation span in degrees centigrade at a specified stress. Distance on the temperature axis between a vertical line drawn through the A_f point and a vertical line drawn through the M_f point. $TSPAN=A_f-M_f$.

3.2.18 *upper cycle temperature (UCT)*—The maximum temperature of the thermal cycle.

3.3 *Abbreviations:*

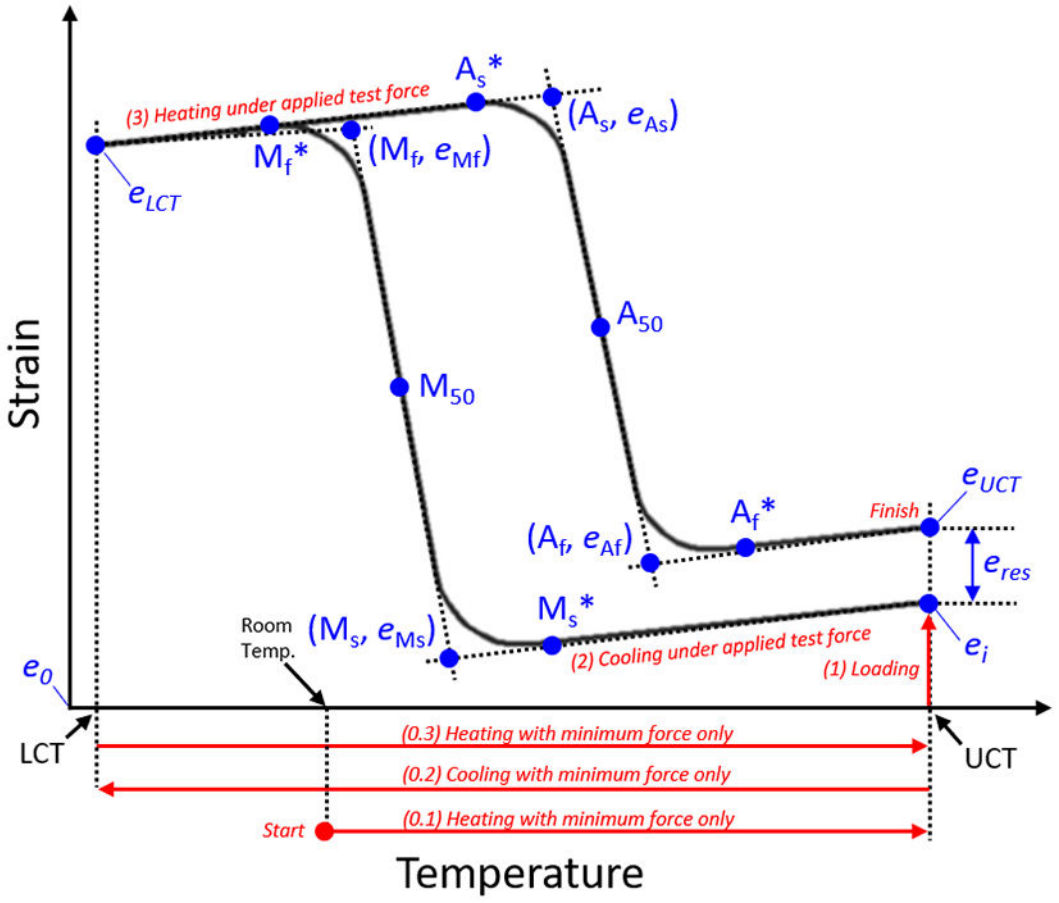

FIG. 1 Typical Constant Force Thermal Cycle and Test Methods Terms