Designation: F2082/F2082M – 23

Standard Test Method for Determination of Transformation Temperature of Nickel-Titanium Shape Memory Alloys by Bend and Free Recovery[1]

This standard is issued under the fixed designation F2082/F2082M; 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 a procedure for quantitatively determining the martensite-to-austenite or the martensite to R-phase transformation temperature of annealed, aged, shape-set, or tempered nickel-titanium alloy specimens by deforming the specimen in bending and measuring the deformation recovered during heating through the thermal transformation (BFR method). See 3.1.1.

NOTE 1—For aged, shape-set, or tempered specimens the transformation may be from martensite to austenite or from martensite to R-phase. See Reference (**1**)[2] for details.

1.2 The test specimen may be wire, tube, or strip or a specimen extracted from a semifinished or finished component.

1.2.1 For specimens not in the form of a wire, tube, or strip that are extracted from semifinished or finished components, a wire, tube, or strip shaped test specimen shall be made from the component such that the deformation mode in the test specimen is pure bending.

1.2.2 Other specimen geometries or displacements resulting in a more complex strain state, such as bending with torsion or buckling, are beyond the scope of this standard.

1.3 Ruggedness tests have demonstrated that sample A_f must be limited to obtain good test results. See 5.6 for details. Ruggedness tests have demonstrated that deformation strain, deformation temperature, and equilibration time at the deformation temperature must be controlled to obtain good test results. See 9.1, 9.2, and 9.4 for details.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with this 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.*

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

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

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

F2005 Terminology for Nickel-Titanium Shape Memory Alloys

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Definitions*—Specific technical terms used in this test method are found in Terminology F2005.

3.1.2 *free recovery, n*—unconstrained motion of a shape memory alloy specimen upon heating and transformation to austenite or R-phase after deformation at a temperature below the temperature for the start of the formation of martensite, M_s.

3.1.3 $A_{f\text{-}95}$—austenite finish temperature of a finished wire, tube, or component measured by bend and free recovery using the 95 percent recoverable deformation methodology.

[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] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] 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.

3.1.4 $A_{f\text{-}tan}$—austenite finish temperature of a finished wire, tube, or component measured by bend and free recovery using the tangent methodology.

3.2 *Abbreviations:*

3.2.1 *LVDT*—linear variable differential transducer.

3.2.2 *RVDT*—rotary variable differential transducer.

4. Summary of Test Method

4.1 This test method involves cooling a test specimen to a temperature below the start temperature for the reversion to austenite, A_s, or to below the start temperature for the reversion to R-phase, R'_s, if there is an intermediate R-phase, deforming the specimen, and heating the specimen to its fully austenitic phase. During heating, the motion of the specimen is measured and plotted versus the specimen temperature. For a two-stage transformation, the R'_s, R'_f, A_s, and A_f, as defined in Terminology F2005, are determined using the tangent methodology. For a single-stage transformation, the A_s and A_f are determined using the tangent methodology. Alternatively, for either single or two-stage transformation material, the A_f may be measured using the 95 percent recoverable deformation methodology.

5. Significance and Use

5.1 This test method provides a rapid, economical method for determination of transformation temperatures.

5.2 Measurement of the specimen motion closely parallels many shape memory applications and provides a result that is applicable to the function of the material.

5.3 This test method uses a wire, tube, strip specimen, or a wire, tube, or strip specimen extracted from a component; thus, it provides an assessment of a nickel titanium product in its semifinished or finished form.

5.4 This test method may be used on annealed samples to determine the transformation temperatures and ensure the alloy formulation, since chemical analysis is not precise enough to adequately determine the nickel-to-titanium ratio of shape memory alloys.

5.5 In general, the transformation temperatures measured by this method will not be the same as those measured by the DSC method defined in Test Method F2004. Therefore, the results of DSC and BFR cannot be compared directly.

5.5.1 The BFR method measures the transformation temperatures by tracking shape recovery of stress-induced martensite deformed below the R'_s temperature or the A_s temperature. In contrast, the DSC method measures the start, peak, and finish temperatures of the thermal transformation of martensite to R-phase or to austenite. See Refs (**1-4**).

5.6 The test method is applicable to shape memory alloys with A_f temperatures in the range of approximately –25 to 90 °C.

6. Apparatus

6.1 *LVDT,* with range greater than half the mandrel diameter (see 9.2), with power supply, mounted in an appropriate fixture with counterbalanced probe (see Fig. 1); or RVDT with range greater than 45°, with power supply, mounted in an appropriate

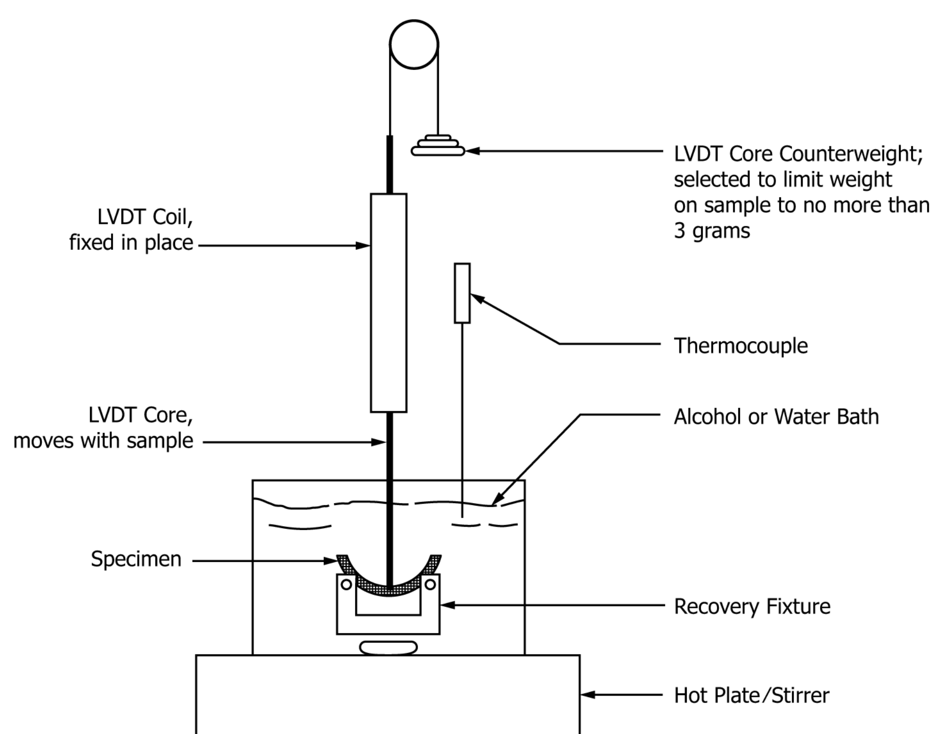

FIG. 1 Schematic Showing Side View of Test Apparatus Using a Vertically Mounted and Counterbalanced LVDT (LVDT Power Supply, Thermocouple Indicator, and Data Acquisition System are not shown)