Designation: E139 – 11 (Reapproved 2018)

Standard Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials[1]

This standard is issued under the fixed designation E139; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 These test methods cover the determination of the amount of deformation as a function of time (creep test) and the measurement of the time for fracture to occur when sufficient force is present (rupture test) for materials when under constant tensile forces at constant temperature. It also includes the essential requirements for testing equipment. For information of assistance in determining the desirable number and duration of tests, reference should be made to the product specification.

1.2 These test methods list the information which should be included in reports of tests. The intention is to ensure that all useful and readily available information is transmitted to interested parties. Reports receive special attention for the following reasons: *(1)* results from different, recognized procedures vary significantly; therefore, identification of methods used is important; *(2)* later studies to establish important variables are often hampered by the lack of detailed information in published reports; *(3)* the nature of prolonged tests often makes retest impractical, and at the same time makes it difficult to remain within the recommended variations of some controlled variables. A detailed report permits transmittal of test results without implying a degree of control which was not achieved.

1.3 Tests on notched specimens are not included. These tests are addressed in Practice E292.

1.4 Tests under conditions of short times are not included. These test methods are addressed in Test Methods E21.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *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.*

1.7 *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 Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E8/E8M Test Methods for Tension Testing of Metallic Materials
E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E74 Practices for Calibration and Verification for Force-Measuring Instruments
E83 Practice for Verification and Classification of Extensometer Systems
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E220 Test Method for Calibration of Thermocouples By Comparison Techniques
E292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E633 Guide for Use of Thermocouples in Creep and Stress-Rupture Testing to 1800°F (1000°C) in Air
E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

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[1] These test methods are under the jurisdiction of the ASTM Committee E28 on Mechanical Testing

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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.

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

3. Terminology

3.1 *Definitions*—The definitions of terms relating to creep testing, which appear in Section E of Terminology E6 shall apply to the terms used in this practice. For the purpose of this practice only, some of the more general terms are used with the restricted meanings given below.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *axial strain*—the average of the strain measured on opposite sides and equally distant from the specimen axis.

3.2.2 *bending strain*—the difference between the strain at the surface of the specimen and the axial strain. In general it varies from point to point around and along the reduced section of the specimen.

3.2.2.1 *maximum bending strain*—measured at a position along the length of the reduced section of a straight unnotched specimen.

3.2.3 *creep*—the time-dependent strain that occurs after the application of a force which is thereafter maintained constant.

3.2.4 *creep-rupture test*—a test in which progressive specimen deformation and the time for rupture are measured. In general, deformation is much larger than that developed during a creep test.

3.2.5 *creep test*—a test that has the objective of measuring creep and creep rates occurring at stresses usually well below those which would result in fracture during the time of testing. Since the maximum deformation is only a few percent, a sensitive extensometer is required.

3.2.6 *gage length*—the original distance between gage marks made on the specimen for determining elongation after fracture.

3.2.7 *length of the reduced section*—the distance between tangent points of the fillets which bound the reduced section.

3.2.7.1 The adjusted length of the reduced section is greater than the length of the reduced section by an amount calculated to compensate for strain in the fillet region (see 8.2.3).

3.2.8 *plastic strain during force application*—the portion of the strain during force application determined as the offset from the linear portion to the end of a stress-strain curve made during force application. The offset construction is shown in Test Methods E8/E8M.

3.2.9 *reduced section, of the specimen*—the central portion of the length having a cross section smaller than the ends which are gripped. The cross section is uniform within tolerances prescribed in 6.6.

3.2.10 *strain during force application*—the change in strain during the time interval from the start of force to the instant of full-force application.

3.2.11 *stress-rupture test*—a test in which time for rupture is measured, no deformation measurements being made during the test.

3.2.12 *total plastic strain, at a specified time*—equal to the sum of plastic strain during force application plus creep.

3.2.13 *total strain, at a specified time*—equal to the sum of the strain during force application plus creep.

4. Significance and Use

4.1 Rupture tests, properly interpreted, provide a measure of the ultimate load-carrying ability of a material as a function of time. Creep tests measure the load-carrying ability for limited deformations. The two tests complement each other in defining the load-carrying ability of a material. In selecting material and designing parts for service at elevated temperatures, the type of test data used will depend on the criterion of load-carrying ability that better defines the service usefulness of the material.

5. Apparatus

5.1 *Testing Machine:* The accuracy of the testing machine shall be within the permissible variation specified in Practices E4.

5.1.1 Exercise precaution to ensure that the force on the specimens is applied as axially as possible. Perfect axial alignment is difficult to obtain, especially when the pull rods and extensometer rods pass through packing at the ends of the furnace. However, the machine and grips should be capable of applying force to a precisely made specimen so that the maximum bending strain does not exceed 10 % of the axial strain, when the calculations are based on strain readings taken at the lowest force for which the machine is being qualified.

NOTE 1—This requirement is intended to limit the maximum contribution of the testing apparatus to the bending which occurs during a test. It is recognized that even with qualified apparatus, different tests may have quite different percent bending strains due to chance orientation of a loosely fitted specimen, lack of symmetry of that particular specimen, lateral force from furnace packing, and thermocouple wire, etc.

5.1.1.1 In testing of low ductility material, even a bending strain of 10 % may result in lower strength than would be obtained with improved axiality. In these cases, measurements of bending strain on the specimen to be tested may be specifically requested and the permissible magnitude limited to a smaller value.

5.1.1.2 The testing apparatus may be qualified by measurements of axiality made at room temperature. When one is making an evaluation of equipment, the specimen form should be the same as that used during the elevated-temperature tests. The evaluation specimen concentricity shall be at least as good as called out in the specimen drawing. Only elastic strains should occur throughout the reduced section. This requirement may necessitate use of a material different from that used during the elevated-temperature test.

5.1.1.3 Test Method E1012, or an equivalent test method (**1**),[3] shall be used for the measurement and calculation of bending strain for round, rectangular, and thin strip specimens.

5.1.1.4 Axiality measurements should be made at room temperature during the initial setup of the assembled test machine, (including the pull rods, and grips) before use for testing. Gripping devices and pull rods may oxidize, warp, and creep with repeated use at elevated temperatures. Increased bending stresses may result. Therefore, grips and pull rods should be periodically retested for axiality and reworked when necessary.

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

5.1.2 The testing machine shall incorporate means of taking up the extension of the specimen so that the applied force will be maintained within the limits specified in 5.1. The extension of the specimen shall not allow the force application system to introduce eccentricity of force application in excess of the limits specified in 5.1.1. The take-up mechanism shall avoid introducing shock forces, overloading due to friction or inertia in the force application system, or apply torque to the specimen.

5.1.3 The testing machine shall be erected to secure reasonable freedom from vibration and shock due to external causes. Precautions shall be made to minimize the transmission of shock to neighboring test machines and specimens when a specimen fractures. Vibration and shock effects may be seen as noise in the curve when plotting the creep versus time. When such effects are visible in the plotted data, vibration and shock should not introduce apparent noise to the creep data in excess of 7.5 % total creep or total plastic strain. Such external vibrations shall not result in applied force errors in excess of +1 % of the specified test force.

5.1.4 For high-temperature testing of materials which are readily attacked by their environment (such as oxidation of metal in air), the specimen may be enclosed in a capsule so that it can be tested in a vacuum or inert-gas atmosphere. When such equipment is used, the necessary corrections to obtain true specimen applied forces shall be made. For instance, compensation shall be made for differences in pressures inside and outside of the capsule and for any force application variation due to sealing-ring friction, bellows or other features.

5.2 *Heating Apparatus:* The apparatus for and method of heating the specimens shall provide the temperature control necessary to satisfy the requirements specified in 8.4.4 without manual adjustments more frequent than once in each 24-h period after force application. Automatic temperature control is preferred.

5.2.1 Heating shall be by an electric resistance or radiation furnace with the specimen in air at atmospheric pressure unless other media are specifically agreed upon in advance.

NOTE 2—The media in which the specimens are tested may have a considerable effect on the results of tests. This is particularly true when the properties are influenced by oxidation or corrosion during the test, although other effects can also influence test results.

5.3 *Temperature-Measuring Apparatus* (**2**):

5.3.1 The method of temperature measurement must be sufficiently sensitive and reliable to ensure that the temperature of the specimen is within the limits specified in 8.4.4.

5.3.2 Temperature shall be measured with calibrated thermocouples in conjunction with calibrated thermocouple measurement instrumentation. Other calibrated methods of temperature measurement may be used if they are well characterized with respect to standard thermocouple measurement methods.

NOTE 3—Such measurements are subject to two types of error. Thermocouple calibration and instrument measuring errors initially introduce uncertainty as to the exact temperature. Secondly both thermocouples and measuring instruments may be subject to variation with time. Common errors encountered in the use of thermocouples to measure temperatures include, calibration error, drift in calibration due to contamination or deterioration with use, lead-wire error, error arising from method of attachment to the specimen, direct radiation of heat to the bead, heat-conduction along thermocouple wires, etc.

5.3.3 Temperature measurements shall be made with calibrated thermocouples. Representative thermocouples should be calibrated from each lot of wires used for making base-metal thermocouples. Except for relatively low temperatures of exposure, base-metal thermocouples are subject to error upon reuse unless the depth of immersion and temperature gradients of the initial exposure are reproduced. Consequently base-metal thermocouples should be calibrated by the use of representative thermocouples and actual thermocouples used to measure specimen temperatures shall not be calibrated. Base-metal thermocouples also should not be re-used without clipping back to remove wire exposed to the hot zone . Any reuse of base-metal thermocouples after relatively low-temperature use without this precaution should be accompanied by recalibration data demonstrating that calibration was not unduly affected by the conditions of exposure.

5.3.3.1 Noble-metal thermocouples are also subject to errors due to contamination, etc., and should be annealed periodically and checked for calibration. Care should be exercised to keep the thermocouples clean prior to exposure and during use at elevated temperatures.

5.3.3.2 Measurement of the drift in calibration of thermocouples during use is difficult. When drift is a problem during tests, a method should be devised to check the readings of the thermocouples on the specimens during the test. For reliable calibration of thermocouples after use, the temperature gradient of the testing furnace must be reproduced during the recalibration.

5.3.4 Temperature-measuring, controlling and recording instruments should be calibrated periodically against a secondary standard, such as a precision potentiometer. Lead-wire error should be checked with the lead wires in place as they normally are used.

5.4 *Extensometer System:* The sensitivity and accuracy of the strain-measuring equipment should be suitable to define the creep characteristics with the precision required for the application of the data. The Practice E83 extensometer classification should be made part of the report of test results. Suitability of the sensor type and characteristics for creep measurement should be determined before implementation of the system. Suitability of individual sensors should be periodically evaluated or evaluated upon occurrence of significant noise in the creep curve. Acceptable noise levels should not exceed 5 % of the total calibrated range. Laboratories employing multiple sensors and electrical averaging should ensure that the additive effects of each sensor's noise do not result in an unacceptable average noise level. Peak to peak noise on the raw creep data should not exceed 7.5 % of the total creep or total plastic strain for the test. Noise levels exceeding these values must be documented in the test report.

5.4.1 Nonaxiality of force application is usually sufficient to cause significant errors at small strains when strain is measured on only one side of the specimen (**3**). Therefore, the extensometer shall be attached to and indicate strain on opposite sides of the specimen. The reported strain shall be the average of the