NOTICE: This standard has either been superseded and replaced by a new version or withdrawn.
Contact ASTM International (www.astm.org) for the latest information

Designation: E 139 – 00$^{\epsilon 1}$

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

This standard is issued under the fixed designation E 139; 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 Department of Defense.

ε[1] NOTE—Section 9.2.3 was editorially updated in February 2003.

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 Section 9.

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 E 292.

1.4 Tests under conditions of short times are not included. These test methods are addressed in Test Methods E 21.

1.5 The values stated in inch-pound units are to be regarded as the 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 4 Practices for Force Verification of Testing Machines[2]

E 6 Terminology Relating to Methods of Mechanical Testing[2]

E 8 Test Methods for Tension Testing of Metallic Materials[2]

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

E 74 Practice for Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines[2]

E 83 Practice for Verification and Classification of Extensometers[2]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[3]

E 220 Method for Calibration of Thermocouples by Comparison Techniques[4]

E 292 Practice for Conducting Time-for-Rupture Notch Tension Tests of Materials[2]

E 633 Guide for Use of Thermocouples in Creep and Stress Rupture Testing to 1800°F (1000°C) in Air[2]

E 1012 Practice for Verification of Specimen Alignment Under Tensile Loading[2]

2.2 *Military Standard:*

MIL-STD-120 Gage Inspection[5]

2.3 *ASTM Adjuncts:*[6]

Standard unmachined specimens for calibrating creep testing machines (4 by 15⁄16 in. square bar)

3. Terminology

3.1 *Definitions*—The definitions of terms relating to creep testing, which appear in Section E of Terminology E 6 shall

[1] This practice is under the jurisdiction of the ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee 28.04 on Uniaxial Testing.

Current edition approved May 10, 2000. Published August 2000. Originally published as E 139 – 58. Last previous edition E 139 – 96.

[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[6] Available from ASTM Headquarters. Order Adjunct: ADJE0139.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

Documents
Document Sharing Hub

Full document details: ASTM E139-00e1

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 load 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 9.2.3).

3.2.8 *plastic strain during loading*—the portion of the strain during loading determined as the offset from the linear portion to the end of a stress-strain curve made during load application. The offset construction is shown in Test Methods E 8.

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 7.6.

3.2.10 *strain during loading*—the change in strain during the time interval from the start of loading to the instant of full-load 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 loading plus creep.

3.2.13 *total strain, at a specified time*—equal to the sum of the strain during loading 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 supplement 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 which best defines the service usefulness of the material.

5. Apparatus

5.1 *Testing Machine*:

5.1.1 The accuracy of the testing machine shall be within the permissible variation specified in Practices E 4.

5.1.2 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 loading 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 zero force and 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.

5.1.2.1 In testing of brittle 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.

5.1.2.2 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 specimen concentricity should be as near perfect as reasonably possible. 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.

5.1.2.3 Test Method E 1012, or an equivalent test method (**1,2**),[7] shall be used for the measurement and calculation of bending strain for round, rectangular, and thin strip specimens.

5.1.2.4 Axiality measurements should be made at room temperature on the assembled machine, 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.

5.1.3 The testing machine should incorporate means of taking up the extension of the specimen so that the load will be maintained within the limits specified in 5.1.1. The extension of the specimen should not allow the loading system to introduce eccentricity of loading in excess of the limits specified in 5.1.2. The take-up mechanism should avoid

[7] The boldface numbers refer to the References at the [illegible]

AVA Documents
Document Sharing Hub

Full document details: ASTM E139-00e1

introducing shock loads, overloading due to friction or inertia in the loading system, or apply torque to the specimen.

5.1.4 The testing machine should be erected to secure reasonable freedom from vibration and shock due to external causes. Precautions should be made to minimize the transmission of shock to neighboring test machines and specimens when a specimen fractures.

5.1.5 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 loads must be made. For instance, compensation must be made for differences in pressures inside and outside of the capsule and for any load variation due to sealing-ring friction, bellows or other features.

5.2 *Heating Apparatus*:

5.2.1 The apparatus for and method of heating the specimens should provide the temperature control necessary to satisfy the requirements specified in 9.4.4 without manual adjustments more frequent than once in each 24-h period after load application.

5.2.2 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* **(3)** *:*

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 9.4.4.

5.3.2 Temperature should be measured with thermocouples in conjunction with potentiometers or millivoltmeters.

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 should 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 should not be calibrated. Base-metal thermocouples also should not be re-used without clipping back to remove wire exposed to the hot zone and rewelding. 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*:

5.4.1 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 sensitivity and accuracy of the extensometer should be made part of the report of test results.

5.4.2 Nonaxiality of loading is usually sufficient to cause significant errors at small strains when strain is measured on only one side of the specimen **(4)**. Therefore, the extensometer should be attached to and indicate strain on opposite sides of the specimen. The reported strain should be the average of the strains on the two sides, either a mechanical or electrical average internal to the instrument or a numerical average of two separate readings.

5.4.3 Whenever possible the extensometer should be attached to the specimen, not to any load carrying parts joined to the specimen, because the intervening joints and parts introduce significant extensions which are not accurately separable from the extension in the specimen alone.

5.4.4 To avoid the inaccuracy introduced by strain in the fillets and shoulders, the extensometer should be attached to the reduced portion of the specimen, whenever this is feasible.

5.4.4.1 However, it is sometimes necessary to attach the extensometer to the specimen shoulders. For example, when materials with low ductility are tested, failure tends to occur at the extensometer attachments unless these are located on the specimen shoulders.

5.4.4.2 When making a creep-rupture test of a ductile material an extensometer attached to the reduced section of a specimen tends to loosen as the cross-sectional area decreases during the test. In this case the extensometer may be attached to the specimen shoulders or to small ribs machined at the ends of the reduced section of the specimen for that purpose **(5)**.

5.4.5 When it is necessary to use miniature specimens, the extensometer may be attached to the specimen holders. The observed values of extension should be adjusted as described in 9.6.3 and 10.2.4. Even with this adjustment the strain values are of inferior accuracy and the reported values should be

AVA Documents
Document Sharing Hub

Full document details: ASTM E139-00e1

labeled "approximate." The method of measurement should be described in the report.

5.5 *Room Temperature Control*:

5.5.1 The temperature in the room should be sufficiently constant so the specimen temperature variations do not exceed the limits stated in 9.4.4.

5.5.2 Extensometer readings should be taken only when the room temperature is within ±5°F (3°C) of the room temperature at the time of loading, unless a correction is applied to the extensometer reading. The extensometer correction equation or chart should have specimen temperature as well as room temperature as a variable. The correction may be omitted if it has been established that the extensometer reading is not changed by variations in room temperature. In evaluating the effect of such variations, the electronic instrumentation should also be calibrated at various ambient temperatures.

5.6 *Timing Apparatus*—For rupture testing machines, provide suitable means for measuring the elapsed time between complete application of the load and the time at which fracture of the specimen occurs, to within 1 % of the elapsed time.

6. Sampling

6.1 Unless otherwise specified the following sampling procedures shall be followed:

6.1.1 Samples of the material to provide test specimens shall be taken from such locations as to be representative of the lot from which it was taken.

6.1.2 Samples shall be taken from material in the final condition (temper). One test shall be made on each lot.

6.1.3 A lot shall consist of all material from the same heat, nominal size, and condition (temper).

7. Test Specimen and Sample

7.1 The size and shape of test specimens should be based primarily on the requirements necessary to obtain representative samples of the material being investigated.

7.2 Unless otherwise specified, test specimens shall be oriented such that the axis of the specimen is parallel to the direction of fabrication, and located as follows:

7.2.1 At the center for products 1½ ″ (38 mm) or less in thickness, diameter, or distance between flats, or

7.2.2 Midway from the center to the surface for products over 1½ ″ (38 mm) in thickness, diameter, or distance between flats.

7.3 Test specimens of the type, size, and shape described in Test Methods E 8 are generally suitable for tests at elevated temperature with the following modifications: (*1*) tighter dimensional tolerances are recommended in 7.6; (*2*) for creep tests, larger ratios of length to diameter (or width) of reduced section may be desirable to increase the accuracy of strain measurement; and (*3*) for coarse-threaded specimens, made from material with little ductility, the size of thread should be at least ¾ the diameter of the reduced section. According to 7.1, rectangular specimens will be used for sheet and strip. Otherwise, the specimen should have a reduced section of circular cross section. The largest diameter or greatest width specimen consistent with 7.1 should be used except that these dimensions need not be greater than 0.5 in. (12.5 mm).

NOTE 4—Specimen size in itself has little effect on creep and rupture properties provided the material is sound and is not subject to appreciable surface corrosion or orientation effects. A small number of grains in the specimen cross section, or preferred orientation of grains due to fabrication conditions, can have a pronounced effect on the test results. When corrosion oxidation occurs, the results may be a function of specimen size. Likewise, surface preparation of specimens, if affecting results, becomes more important as the specimen size is reduced.

7.4 Specimens of circular cross section should have threaded, shouldered, or other suitable ends for gripping which will meet the requirements of 5.1.2.

NOTE 5—Satisfactory axial alignment may be obtained with precisely machined threaded ends. But at temperatures where oxidation and creep are readily apparent, precisely fitted threads are difficult to maintain and to separate after test. Practical considerations require the use of relatively loose-fitting threads. Other gripping methods have been successfully used (**2**, **6**).

7.5 For rectangular specimens some modifications of the standard specimens described in Test Methods E 8 are usually necessary to permit application of the load to the specimen in the furnace with the axiality specified in 5.1.2. If the material available is sufficient, the use of elongated shoulder ends to permit gripping outside the furnace is the easiest method. When the length of the specimen is necessarily restricted, several methods of gripping may be used as follows:

7.5.1 A device that applies the load through a cylindrical pin in each of the enlarged ends of the specimen. The pin holes should be accurately centered on extensions of the centerline of the gage section. The good axiality of loading of a grip of this type has been demonstrated (**6**).

7.5.2 High-temperature sheet grips similar to those illustrated in Test Methods E 8 and described as self-adjusting grips have proved satisfactory for testing sheet materials that cannot be tested satisfactorily in the usual type of wedge grips.

7.5.3 Extension tabs may be welded or brazed to the specimen shoulders and extended to grips outside the furnace. When these are used, care must be exercised to maintain coaxiality of the centerlines of the extensions and the gage length. Any brazing or welding should be done in a jig or fixture to maintain accurate alignment of the parts. Any machining should be done after brazing or welding.

7.5.4 Grips that conform to and apply load against the fillets at the ends of the reduced section.

7.6 The diameter (or width) at the ends of the reduced section of the specimen should not be less than the diameter (or width) at the center of the reduced section. It may be desirable to have the diameter (or width) of the reduced section of the specimen slightly smaller at the center than at the ends. The diameter (or width) at the ends of the reduced section shall not be greater than 100.5 % of the diameter (or width) at the center of the reduced section. When specimens of this form are used to test brittle materials, failure may regularly occur at the fillets. In these cases, the center of the reduced section may be made smaller by a gradual taper from the ends and the exception to the requirements above noted in the report. Specimen surfaces shall be smooth and free from undercuts and scratches. Special care should be exercised to minimize disturbance of surface layers by cold work which produces high residual stresses plastic deformation produces [illegible]

AVA Documents
Document Sharing Hub

Full document details: ASTM E139-00e1