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Standard Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials[1]

This standard is issued under the fixed designation E 292; 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.

ε1 NOTE—Editorial changes were made throughout in November 1996.

1. Scope

1.1 These test methods cover the determination of the time for rupture of notched specimens under conditions of constant load and temperature. These test methods also includes the essential requirements for testing equipment.

1.2 The values stated in inch-pound units are to be regarded as the standard. The units in parentheses are for information only.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 453/A453M Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Steels[2]

E 4 Practices for Force Verification of Testing Machines[3]

E 6 Terminology Relating to Methods of Mechanical Testing[3]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines[3]

E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials[3]

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

E 602 Test Method for Sharp-Notch Tension Testing with Cylindrical Specimens[3]

2.2 *Military Standard:*

MIL-STD-120 Gage Inspection[5]

3. Terminology

3.1 *Definitions*—The definitions of terms relating to creep testing, which appear in Section E of Terminology E 6 shall apply to the terms used in these test methods. 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 reduced section of the specimen.

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

3.2.4 *length of the reduced section*—the distance between tangent points of the fillets that bound the reduced section.

3.2.5 The adjusted length of the reduced section is greater than the length of the reduced section by an amount calculated to compensate for the strain in the fillets adjacent to the reduced section.

3.2.6 *maximum bending strain*—the largest value of bending strain in the reduced section of the specimen. It can be calculated from measurements of strain at three circumferential positions at each of two different longitudinal positions.

3.2.7 *reduced section of the specimen*—the central portion of the length having a cross section smaller than that of the ends that are gripped. The reduced section is uniform within tolerances prescribed in Test Methods E 8.

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

4. Significance and Use

4.1 Rupture life of notched specimens is an indication of the ability of a material to deform locally without cracking under

[1] These test methods are under the jurisdiction of ASTM Committee E-28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.10 on Effect of Elevated Temperature on Properties.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

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

[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.

multi-axial stress conditions, thereby redistributing stresses around a stress concentrator.

4.2 The notch test is used principally as a qualitative tool in comparing the suitability of materials for designs that will contain deliberate or accidental stress concentrators.

5. Apparatus

5.1 *Testing Machine*:

5.1.1 The testing machine shall ensure the application of the load to an accuracy of 1 % over the working range.

5.1.2 The rupture strength of notched or smooth specimens may be reduced by bending stresses produced by eccentricity of loading (that is, lack of coincidence between the loading axis and the longitudinal specimen axis). The magnitude of the effect of a given amount of eccentricity will increase with decreasing ductility of the material and, other things being equal, will be larger for notch than for smooth specimens. Eccentricity of loading can arise from a number of sources associated with misalignments between mating components of the loading train including the specimen. The eccentricity will vary depending on how the components of the loading train are assembled with respect to each other and with respect to the attachments to the testing machine. Thus, the bending stress at a given load can vary from test to test, and this variation may result in a substantial contribution to the scatter in rupture strength **(1, 2)**.[6]

5.1.3 Zero eccentricity cannot be consistently achieved. However, acceptably low values may be consistently achieved by proper design, machining, and assembly of all components of the loading train including the specimen. Devices that will isolate the loading train from misalignments associated with the testing machine may also be used. For cylindrical specimens, precision-machined loading train components employing either buttonhead, pin, or threaded grips connected to the testing machine through precision-machined ball seat loading yokes have been shown to provide very low bending stresses when used with commercial creep testing machines **(3)**. However, it should be emphasized that threaded connections may deteriorate when used at sufficiently high temperatures and lose their original capability for providing satisfactory alignment.

5.1.4 Whatever method of gripping is employed, the testing machine and loading train components when new should be capable of loading a verification specimen at room temperature as described in 7.2 so that the maximum bending strain is 10 % or less at the lowest anticipated load in the creeprupture test. It is recognized that this measurement will not necessarily represent the performance in the elevated-temperature rupture test, but is designed to provide a practical means of evaluating a given testing machine and its associated loading train components. Generally, the eccentricity of loading at elevated temperatures will be reduced by the higher compliance, lower modulus of various mating parts as compared with the verification test at room temperature. However, it should be recognized that depending on the test conditions, the fits between mating parts may deteriorate with time and that furnace seals if not properly installed could cause lateral forces to be applied to the loading rods. In either case, misalignments may be increased relative to the values measured at room temperature for new equipment. Axiality requirements and verifications may be omitted when testing performed is for acceptance of material to minimum strength requirements. As discussed in 5.1.2, excessive bending would result in reduced strength or conservative results. In this light, should acceptance tests pass minimum requirements, there would be little benefit to improving axiality of loading. However, if excessive bending resulted in high rejection rates, economics would probably favor improving axiality.

5.1.5 This requirement is intended to limit the maximum contribution of the testing apparatus to the bending that occurs during a test. It is recognized that even with qualified apparatus different tests may have quite different percent bending strain 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.

5.1.6 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 5.1.4. The take-up mechanism should avoid introducing shock loads or torque to the specimen, and overloading due to friction, or inertia in the loading system.

5.1.7 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 when a specimen fractures.

5.1.8 For high-temperature testing of materials that are readily attacked by their environment (such as oxidation of metal in air), the sample 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 accurate specimen load 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 5.3.1 without manual adjustment 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 1—The medium 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.

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

5.3 *Temperature Control*:

5.3.1 Indicated specimen temperature variations along the reduced section and notch(es) on the specimen should not exceed the following limits initially and for the duration of the test:

Up to and including	1800 ± 3°F (980 ± 1.7°C)
Above	1800 ± 5°F (980 ± 2.8°C)

5.3.2 The temperature should be measured and recorded at least once each working day. Manual temperature readings may be omitted on non-working days provided the period between reading does not exceed 48 h. Automatic recording capable of assuring the above temperature limits at the notch(es) may be substituted for manual readings provided the record is read on the next working day.

5.3.3 A minimum of one thermocouple at or near each notch is required if a notch-only specimen is used. If a combination smooth and notched specimen is used, one or more additional thermocouples will be required. If the unnotched gage section is 1 in. (25.4 mm) or less, a minimum of one additional thermocouple placed at the center of the gage section is required. For unnotched gage sections greater than 1 in. (25.4 mm) at least two additional thermocouples, at or near the fillets, are required.

5.3.4 The terms "indicated nominal temperature" or "indicated temperature" mean the temperature that is indicated on the specimen by the temperature-measuring device using good pyrometric practice.

5.3.5 The heating characteristics of the furnace and the temperature control system should be studied to determine the power input, voltage fluctuation, temperature set point, proportioning control adjustment, reset adjustment, and control thermocouple placement necessary to limit transient temperature overshoot and overheating due to set point error. Overheating prior to attaining the limits specified in 5.3.1 should not exceed 25°F (14°C) above the indicated nominal test temperature, the duration of such overheating not to exceed 20 min.

5.3.6 In testing materials that are subjected to changes in mechanical properties due to any overheating, and all alloys where the test temperature is at or above the temperature of final heat treatment, overheating should not exceed the limits in 5.3.1.

6. Test Specimens

6.1 The size and shape of test specimens should be based primarily on the requirements necessary to obtain representative samples of the material being investigated. If at all possible, the specimens should be taken from material in the form and condition in which it will be used.

6.2 Specimen type, size, and shape have a large effect on rupture properties of notch specimens **(4, 5, 6, 7)**. In a notched specimen test, the material being tested most severely is the small volume at the base of the notch.

6.3 Selection of the exact specimen geometry and the machining practice used to achieve this geometry and the methods used to measure it should be agreed upon by all parties concerned because of the influence of these factors on rupture life.

NOTE 2—The notch rupture strength is not only a function of the theoretical stress concentration, K_t, but also of the absolute size of the specimen, even though the various specimens used are geometrically similar. Therefore, a comparison of material or different conditions of the same material on the basis of their notch rupture strength can only be made from test results on the same size specimen.

6.4 Numerous different specimen geometries have been used; some cylindrical specimens are suggested in Fig. 1. A similar specimen is described in Specification A 453/A 453M. Separate plain and notched specimens may be used instead of the combination specimen described in Fig. 1. Suggested flat specimens are shown in Fig. 2. Notch preparation methods should be chosen to minimize the surface effect and residual stresses.

NOTE 3—Dimensions of specimens are given in inch-pound units, and metric units are not always exact arithmetic equivalents (except for tolerances which are reasonable equivalents) but have been adjusted to provide practical equivalents for critical dimensions while retaining geometric proportionality.

6.5 Various methods of attachment of the specimen to the loading train may be used. Threaded attachments are shown in Fig. 1 for cylindrical specimens, but buttonhead, tapered, or pin attached may be used. The flat specimen types shown in Fig. 2 may be attached through loading yokes and pins or by wedge grips. If sufficient test material is available, the specimen head length may be increased to permit attachment to the loading train at a point outside the furnace. Removing the attachment outside the furnace has the advantage that these components are not subjected to the test temperature and should therefore have longer useful lives than similar attachments used inside the furnace.

6.6 Whatever method of gripping is used, care should be taken to minimize the eccentricity of loading, and in all cases the requirements of 5.1.4 for permissible percent bending shall be met.

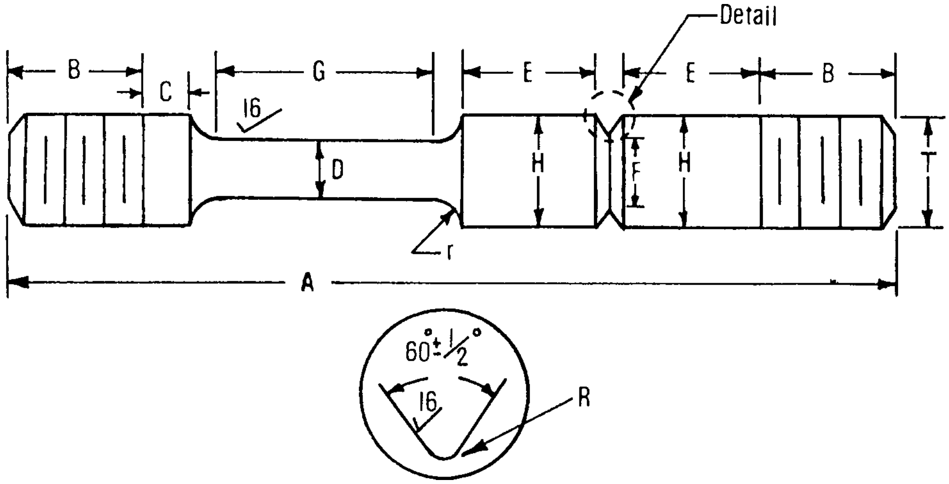
7. Verification and Standardization

7.1 The following devices should be verified against standards traced to the National Institute of Standards and Technology. Applicable ASTM standards are listed beside the device.

Loading-measuring system	Practices E 4 and E 74
Thermocouples	Method E 220. Melting point methods are also recommended for thermocouple calibration.
Potentiometers	Method E 220 and STP 470 A[7]
Micrometers	MIL-STD-120 Gage Inspection[5]

7.2 Verification of the axiality of loading in terms of conformance to the percent bending requirement of 5.1.4 is considered as part of calibration and standardization procedure. Specific features of the procedure for determining the percent bending (100 times the difference between the maximum outer-fiber stress and the axial stress, divided by the average stress) in verification specimen are given in Test Method E 602. This method should be carefully studied before attempts are made to determine the percent bending introduced by the testing machine and loading train components. The verification procedure in this recommended practice is complicated by the

[7] *Manual on the Use of Thermocouples in Temperature Measurement, ASTM STP 470 A*, ASTM, 1971.



	Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5		Specimen 6	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
D-Diameter of gage	0.125± 0.001	3.18± 0.012	0.150± 0.001	3.81± 0.012	0.160± 0.001	4.06± 0.012	0.178± 0.001	4.45± 0.012	0.252± 0.001	6.4± 0.025	0.357± 0.001	9.07± 0.025
G-Gage length	0.50± 0.05	12.7± 1.3	0.60± 0.05	15.2± 1.3	0.65± 0.05	16.5± 1.3	0.75± 0.05	19.05± 1.3	1.0± 0.05	24.5± 1.3	1.5± 0.05	38.1± 1.3
R-Radius of notch	0.0035± 0.0005	0.09± 0.01	0.004± 0.0005	0.10± 0.01	0.0045± 0.0005	0.11± 0.01	0.005± 0.0005	0.13± 0.01	0.0075± 0.0005	0.19± 0.01	0.010± 0.0005	0.25± 0.01
E-Shoulder length (approx)	1⁄4	6.4	5⁄16	8.0	5⁄16	8.0	3⁄8	9.5	1⁄2	12.7	3⁄4	19.0
H-Shoulder diameter (Major)	0.177± 0.003	4.5± 0.08	0.212± 0.003	5.4± 0.08	0.226± 0.003	5.7± 0.08	0.250± 0.003	6.4± 0.08	0.375± 0.003	9.5± 0.08	0.500± 0.003	12.7± 0.08
r-Radius of fillet	3⁄32	2.4	3⁄32	2.4	3⁄32	2.4	1⁄8	3.2	3⁄16	4.7	1⁄4	6.4
K_t-Stress concentration factor	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9

NOTE 1—Surfaces marked[16], finish to 16 µin., rms or better.

NOTE 2—The difference between dimensions *F* and *D* shall not exceed 0.001 in. (0.025 mm).

NOTE 3—Taper the gage length *G* to the center so that the diameter *D* at the end of the gage length exceeds the diameter at the center of the gage length by no less than 0.0005 in. (0.01 mm) nor more than 0.0015 in. (0.04 mm).

NOTE 4—All sections shall be concentric about the specimen axis within 0.001 in. (0.025 mm).

NOTE 5—Threads *T* may be any convenient size, but root diameter must be greater than *F*. Some brittle materials may require root diameter equal to or greater than *H*.

NOTE 6—Dimensions *A* and *B* are not specified, but *B* shall be equal to or greater than *T*.

NOTE 7—Shoulder length *C* shall be 1⁄8 in. (3.2 mm) min.

NOTE 8—K_t, stress concentration factor (see Ref (**9**)).

FIG. 1 Standard Cylindrical Specimens

wide range of specimen sizes that are accommodated. This is necessary for the following reasons: (*1*) The loading train components will be different for the various specimen sizes, and checking one set of components will not ensure satisfactory performance when another set is used; and (*2*) for a given eccentricity, the percent bending will increase with decreasing specimen diameter (or width) provided the test section length-to-diameter (or width) ratios remain constant. The verification specimens described in the following sections are proportioned to major test section dimension *H*.

7.2.1 The test section of the cylindrical verification specimen is shown in Fig. 3. If $H \geq 0.357$ in. (9.07 mm), foil resistance strain gage described in Ref. **(4)** may be used. The test section should be incorporated in a specimen with overall length and heads identical to the specimen that will be used in the rupture test.

7.2.2 In the case of the flat specimens, Fig. 2, the possibility of introducing unacceptably large bending stresses is reduced as compared with the cylindrical specimens. This is because the ratio of gage length to thickness is large enough that the flat specimens have sufficient flexibility to align themselves with very low bending stresses for load line displacements normal to the width direction. Load line displacements parallel to the width direction can, however, produce unacceptably large stress gradients across the width of the specimen. This problem will be encountered in jaw-type grips but will be minimized by the use of properly machined pin-and-yoke gripping arrangements. The test section of the flat verification specimen is shown in Fig. 4 and should be incorporated in a specimen with overall length and heads identical to the specimen that will be used in creep-rupture tests. A strain gage with overall dimensions of 0.180 by 0.050 in. (4.57 by 1.27 mm) and with a grid