Designation:E292–01 Designation: E 292 – 09

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.

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:*[2]

A 453/A 453M Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels

E 4 Practices for Force Verification of Testing Machines

E 6 Terminology Relating to Methods of Mechanical Testing

E 8/E 8M Test Methods for Tension Testing of Metallic Materials

E 74 Practice of Calibration of Force-Measuring Instruments for Verifying the LoadForce Indication of Testing Machines

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

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

E 220 Test Method for Calibration of Thermocouples byBy Comparison Techniques

E633Guide for Use of Thermocouples in Creep and Stress Rupture Testing to 1000°C (1800°F) in Air[3] 663 Practice for Flame Atomic Absorption Analysis[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E 1012 Practice for Verification of Specimen Alignment Under Tensile Loading[3] Practice for Verification of Test Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

2.2 *Military Standard:*

MIL-STD-120 Gage Inspection[4]

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

[1] These test methods are under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

Current edition approved Oct. 10, 2001. Published December 2001. Originally published as E292 – 66 T. Last previous edition E292–83 (Reapproved 1996) $^{\varepsilon 1}$.
Current edition approved April 1, 2009. Published April 2009. Originally approved in 1966. Last previous edition E 292 – 01.

[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*, Vol 01.01.volume information, refer to the standard's Document Summary page on the ASTM website.

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

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

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

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

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/E 8M.

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 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)** .[5]

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 applied force in the creep-rupture 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.

5.1.4.1 Test Method E 1012 or equivalent shall be used for the measurement and calculation of bending strain for cylindrical or flat specimens.

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

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

5.1.6 The testing machine should incorporate means of taking up the extension of the specimen so that the applied force will be maintained within the limits specified in 5.1.1. 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 or torque forces 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 and maintain accurate specimen applied forces must be made. For instance, compensation must be made for differences in pressures inside and outside of the capsule and for any applied force variation due to sealing ring friction, bellows, or other load train 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 application of force.

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.

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)

5.3.1.1 Guide E 633 or equivalent shall be used for the thermocouple preparation and use.

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 For a notch-only specimen, a minimum of one thermocouple at or near the notch (either notch for a flat specimen) is required. For a combination of smooth and notched specimens, in addition to the one thermocouple required at or near the notch, one or more thermocouples will be required in the unnotched gage section. 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 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. If thermal gradients are suspected to be greater than the limits given in 5.3.1, additional thermocouples should be added. For specimens with unnotched gage sections of 1 in. or less, position the additional thermocouples at or near the fillets. For specimens with unnotched gage sections greater than 1 in., position the additional thermocouples uniformly along the gage section.

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

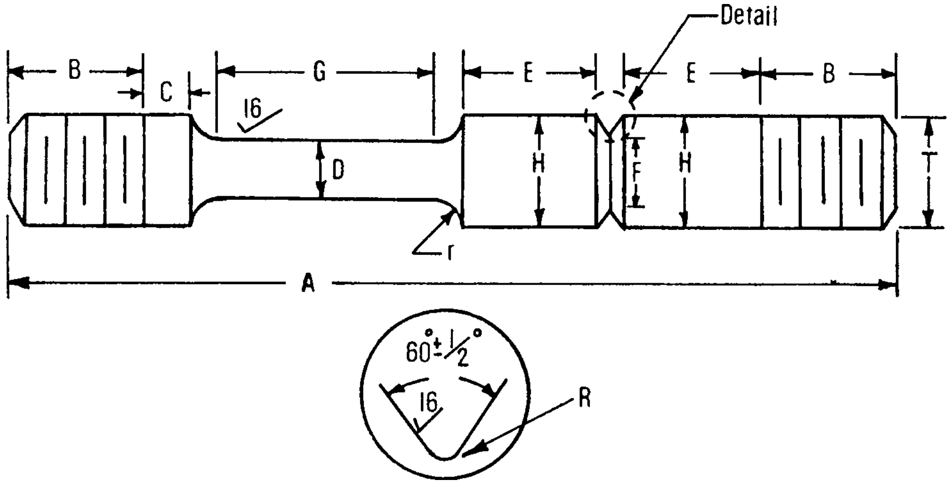
6.1 The size and shape of test specimens should be based primarily on the requirements necessary to obtain representative samples of the material being investigated. If at all possible, the specimens should be taken from material in the form and condition in which it will be used.

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 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	4.52± 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)	¼	6.4	5⁄16	8.0	5⁄16	8.0	⅜	9.5	½	12.7	¾	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	⅛	3.2	3⁄16	4.7	¼	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 ⅛ in. (3.2 mm) min.

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

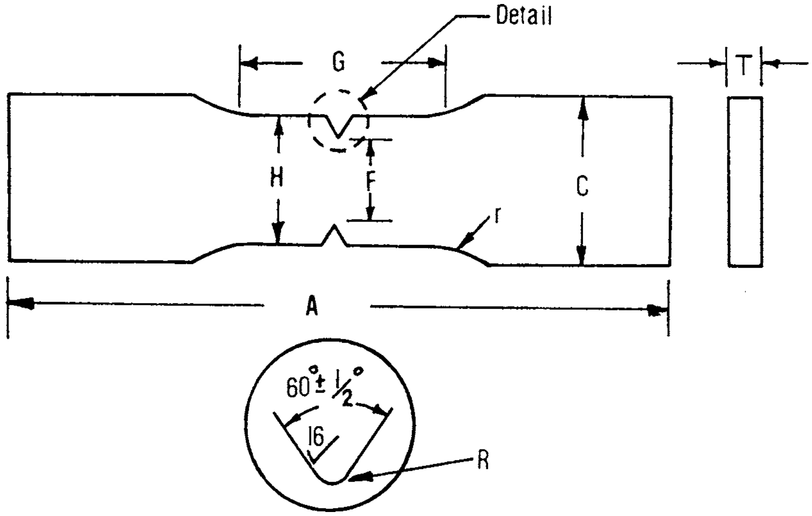
FIG. 1 Standard Cylindrical Specimens

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.



	Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5		Specimen 6	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
F-Notch width	0.125 ± 0.001	3.18 ± 0.025	0.150 ± 0.001	3.81 ± 0.025	0.160 ± 0.001	4.06 ± 0.025	0.175 ± 0.001	4.45 ± 0.025	0.250 ± 0.001	6.35 ± 0.025	0.350 ± 0.001	8.89 ± 0.025
H-Major width	0.225 ± 0.003	5.71 ± 0.08	0.230 ± 0.003	5.84 ± 0.08	0.230 ± 0.003	5.84 ± 0.08	0.250 ± 0.003	6.35 ± 0.08	0.375 ± 0.003	9.53 ± 0.08	0.500 ± 0.003	12.70 ± 0.08
R-Radius of notch	0.005 ± 0.0005	0.13 ± 0.01	0.0055 ± 0.0005	0.14 ± 0.01	0.0055 ± 0.0005	0.14 ± 0.01	0.006 ± 0.0005	0.15 ± 0.01	0.009 ± 0.0005	0.23 ± 0.01	0.012 ± 0.0005	0.30 ± 0.01
G-Gage length (approx)	¾	19.0	¾	19.0	¾	19.0	¾	19.0	1	25.4	1½	38.1
C-Shoulder width (min)	⅜	9.53	⅜	9.53	⅜	9.53	⅜	9.53	9⁄16	14.29	¾	19.0
K_t-Stress concentration factor	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5

NOTE 1—Surfaces marked[16], finish to 16 μin. rms or better.
NOTE 2—Dimension *A* is not specified, but shall be of such length to accommodate gripping ends.
NOTE 3—Dimension *T*, is thickness of material, but greater than 5 and less than 10 times the notch root radius.
NOTE 4—Radius *r* shall be ½ + 1⁄32-0 in. (12.7 + 0.8 mm).
NOTE 5—K_t, stress concentration factor (see Ref (**9**)).

FIG. 2 Standard Flat Specimens

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]~~
Potentiometers	Method E 220 and STP 470 A[6]
~~Micrometers~~	~~MIL-STD-120 Gage Inspection[5]~~
Micrometers	MIL-STD-120 Gage Inspection[4]

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. Use a specimen as shown in Fig. 3. Apply strain gages to the specimen in a configuration outlined in Practice E 1012.

7.3 Verifications of the force-measuring system and temperature-measuring and control system should be made as frequently as necessary to assure that the errors for each test are less than the permissible variations listed in this recommended practice. The maximum period between these types of calibrations should be one year, or after each test when the tests last longer than one year. Verification of the axiality of loading should be repeated whenever loading rods are replaced and at some regular intervals, which are best determined by experience and will depend on the severity of the testing conditions.

8. Procedure

8.1 *Measurement of Cylindrical Specimens*:

~~[6] The numbers in boldface type refer to the list of references at the end of this standard.~~
[6] *Manual on the Use of Thermocouples in Temperature Measurement, ASTM STP 470 A,* ASTM, 1971.

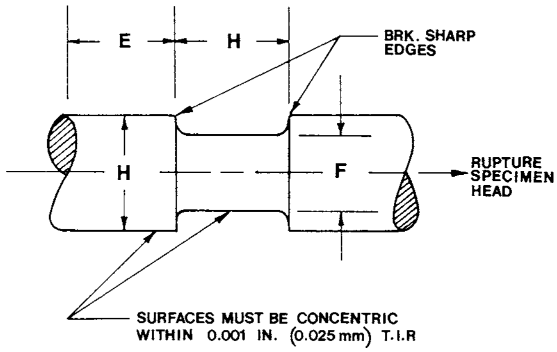


FIG. 3 Cylindrical Verification Specimen Test Section

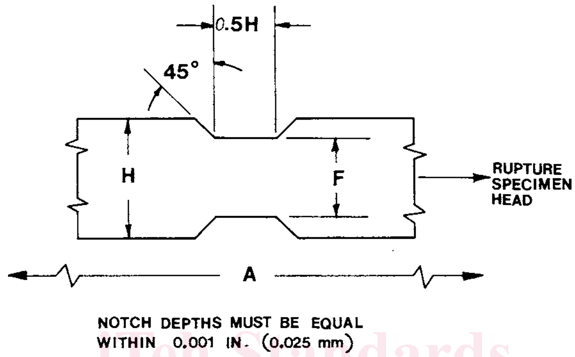


FIG. 4 Test Section of Flat Verification Specimen

8.1.1 Determine the minimum diameter at the root of the notch and the diameter at 90 deg to the minimum to the nearest 0.0005 in. (0.01 mm). Use the average of these two diameters to calculate the area.

8.1.2 Measure the major diameters in a corresponding manner.

8.1.3 Measure the distance between punched or scribed marks on the shoulders of the gage section or, if ductility permits, between the punch or scribe marks spaced four diameters apart on the unnotched reduced section, but with a longer gage length permitted by mutual agreement.

8.1.4 Scribe an axial line on major-diameter sections to assist fitting of fractured ends after testing.

8.1.5 Measure the root radius of the notch to the nearest 0.0005 in. (0.01 mm). Useful information can be obtained by tracing the notch profile on an optical comparator.

8.2 *Measurement of Flat Specimens* :

8.2.1 Measure minimum width at the root of the notch to within 0.0005 in. (0.01 mm).

8.2.2 Measure the major width on each side of the notch in a corresponding manner.

8.2.3 Measure the thickness at each edge and at the middle of the width. Use the average thickness and width to calculate area.

8.2.4 Measure the root radii of the notch to the nearest 0.0005 in. (0.01 mm). Useful information can be obtained by tracing the notch profile on an optical comparator.

8.3 *Cleaning Specimen*—Carefully wash the notch and the reduced section and those parts of the specimen which contact the grips in clean solvent that will not affect the metal being tested. Acetone with an alcohol rinse is commonly used for those metals which are not affected thereby.

8.4 *Temperature-Measuring Apparatus (*8*)*—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 5.3.1.

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

NOTE 4—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-conducting along thermocouple wire, etc.

8.4.2 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