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Standard Test Methods of Tension Testing of Metallic Materials¹

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This standard has been approved for use by agencies of the Department of Defense to replace method 211.1 of Federal Test Method Standard No. 151b. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 These test methods cover the tension testing of metallic materials in any form at room temperature, specifically, the methods of determination of yield strength, yield point, tensile strength, elongation, and reduction of area.

NOTE 1—A complete metric companion to Test Methods E 8 has been developed—E 8M; therefore, no metric equivalents are shown in these test methods.

NOTE 2—Gage lengths in these test methods are required to be 4D for most round specimens. Test specimens made from powder metallurgy (P/M) materials are exempt from this requirement by industry-wide agreement to keep the pressing of the material to a specific projected area and density.

NOTE 3—Exceptions to the provisions of these test methods may need to be made in individual specifications or test methods for a particular material. For examples, see Test Methods and Definitions A 370 and Methods B 557.

NOTE 4—Room temperature shall be considered to be 50 to 100°F unless otherwise specified.

1.2 *This standard does not purport to address all of the safety problems, 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 356/A 356M Specification for Heavy-Walled, Carbon, Low Alloy, and Stainless Steel Castings for Steam Turbines²
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products³
- B 557 Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products⁴
- E 4 Practices for Load Verification of Testing Machines⁵
- E 6 Terminology Relating to Methods of Mechanical Testing⁵
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications⁶

¹ These test methods are under the jurisdiction of ASTM Committee E-28 on Mechanical Testing and are the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

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² Annual Book of ASTM Standards, Vol 01.02.

³ Annual Book of ASTM Standards, Vols 01.01–01.05 and 03.01.

⁴ Annual Book of ASTM Standards, Vols 02.02 and 03.01.

⁵ Annual Book of ASTM Standards, Vol 03.01.

⁶ Annual Book of ASTM Standards, Vols 03.01 and 14.02.

E 83 Practice for Verification and Classification of Extensometers⁵

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁷

E 345 Test Methods of Tension Testing of Metallic Foil⁵

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method⁷

E 1012 Practice for Verification of Specimen Alignment Under Tensile Loading⁵

3. Terminology

3.1 *Definitions*—The definitions of terms relating to tension testing appearing in Terminology E 6 shall be considered as applying to the terms used in these methods of tension testing.

4. Significance and Use

4.1 Tension tests provide information on the strength and ductility of materials under uniaxial tensile stresses. This information may be useful in comparisons of materials, alloy development, quality control, and design under certain circumstances.

4.2 The results of tension tests of specimens machined to standardized dimensions from selected portions of a part or material may not totally represent the strength and ductility properties of the entire end product or its in-service behavior in different environments.

4.3 These test methods are considered satisfactory for acceptance testing of commercial shipments. The test methods have been used extensively in the trade for this purpose.

5. Apparatus

5.1 *Testing Machines*—Machines used for tension testing shall conform to the requirements of Practices E 4. The loads used in determining tensile strength and yield strength or yield point shall be within the verified loading range of the testing machine as defined in Practices E 4.

5.2 Gripping Devices:

5.2.1 *General*—Various types of gripping devices may be used to transmit the measured load applied by the testing machine to the test specimens. To ensure axial tensile stress within the gage length, the axis of the test specimen should coincide with the center line of the heads of the testing machine. Any departure from this requirement may intro-

⁷ Annual Book of ASTM Standards, Vol 14.02

duce bending stresses that are not included in the usual stress computation (load divided by cross-sectional area).

NOTE 5—The effect of this eccentric loading may be illustrated by calculating the bending moment and stress thus added. For a standard $\frac{1}{2}$ -in. diameter specimen, the stress increase is 1.5 percentage points for each 0.001 in. of eccentricity. This error increases to 2.24 percentage points/0.001 in. for a 0.350-in. diameter specimen and to 3.17 percentage points/0.001 in. for a 0.250-in. diameter specimen.

NOTE 6—Alignment methods are given in Practice E 1012.

5.2.2 Wedge Grips—Testing machines usually are equipped with wedge grips. These wedge grips generally furnish a satisfactory means of gripping long specimens of ductile metal and flat plate test specimens such as those shown in Fig. 1. If, however, for any reason, one grip of a pair advances farther than the other as the grips tighten, an undesirable bending stress may be introduced. When liners are used behind the wedges, they must be of the same thickness and their faces must be flat and parallel. For best results, the wedges should be supported over their entire lengths by the heads of the testing machine. This requires that liners of several thicknesses be available to cover the range of specimen thickness. For proper gripping, it is desirable that the entire length of the serrated face of each wedge be in contact with the specimen. Proper alignment of wedge grips and liners is illustrated in Fig. 2. For short specimens and for specimens of many materials it is generally necessary to use machined test specimens and to use a special means of gripping to ensure that the specimens, when under load, shall be as nearly as possible in uniformly distributed pure axial tension (see 5.2.3, 5.2.4, and 5.2.5).

5.2.3 Grips for Threaded and Shouldered Specimens and Brittle Materials—A schematic diagram of a gripping device for threaded-end specimens is shown in Fig. 3, while Fig. 4 shows a device for gripping specimens with shouldered ends. Both of these gripping devices should be attached to the heads of the testing machine through properly lubricated spherical-seated bearings. The distance between spherical bearings should be as great as feasible.

5.2.4 Grips for Sheet Materials—The self-adjusting grips shown in Fig. 5 have proven satisfactory for testing sheet materials that cannot be tested satisfactorily in the usual type of wedge grips.

5.2.5 Grips for Wire—Grips of either the wedge or snubbing types as shown in Figs. 5 and 6 or flat wedge grips may be used.

5.3 Dimension-Measuring Devices—Micrometers and other devices used for measuring linear dimensions shall be accurate and precise to at least one half the smallest unit to which the individual dimension is required to be measured.

6. Test Specimens

6.1 General:

6.1.1 Test specimens shall be either substantially full size or machined, as prescribed in the product specifications for the material being tested.

6.1.2 Improperly prepared test specimens often are the reason for unsatisfactory and incorrect test results. It is important, therefore, that care be exercised in the preparation of specimens, particularly in the machining, to assure the desired precision and bias in test results.

6.1.3 It is desirable to have the cross-sectional area of the

specimen smallest at the center of the reduced section to ensure fracture within the gage length. For this reason, a small taper is permitted in the reduced section of each of the specimens described in the following sections.

6.1.4 For brittle materials it is desirable to have fillets of large radius at the ends of the gage length.

6.2 Plate-Type Specimens—The standard plate-type test specimen is shown in Fig. 1. This specimen is used for testing metallic materials in the form of plate, shapes, and flat material having a nominal thickness of $\frac{3}{16}$ in. or over. When product specifications so permit, other types of specimens may be used, as provided in 6.3, 6.4, and 6.5.

6.3 Sheet-Type Specimens:

6.3.1 The standard sheet-type test specimen is shown in Fig. 1. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, hoop, rectangles, and shapes ranging in nominal thickness from 0.005 to $\frac{5}{8}$ in. When product specifications so permit, other types of specimens may be used, as provided in 6.2, 6.4, and 6.5.

NOTE 7—Test Methods E 345 may be used for tension testing of materials in thicknesses up to 0.0059 in.

6.3.2 Pin ends as shown in Fig. 7 may be used. In order to avoid buckling in tests of thin and high-strength materials, it may be necessary to use stiffening plates at the grip ends.

6.4 Round Specimens:

6.4.1 The standard 0.500-in. diameter round test specimen shown in Fig. 8 is used quite generally for testing metallic materials, both cast and wrought.

6.4.2 Figure 8 also shows small-size specimens proportional to the standard specimen. These may be used when it is necessary to test material from which the standard specimen or specimens shown in Fig. 1 cannot be prepared. Other sizes of small round specimens may be used. In any such small-size specimen it is important that the gage length for measurement of elongation be four times the diameter of the specimen.

6.4.3 The shape of the ends of the specimen outside of the gage length shall be suitable to the material and of a shape to fit the holders or grips of the testing machine so that the loads may be applied axially. Figure 9 shows specimens with various types of ends that have given satisfactory results.

6.5 Specimens for Sheet, Strip, Flat Wire, and Plate—In testing sheet, plate, flat wire, and strip one of the following types of specimens shall be used:

6.5.1 For material ranging in nominal thickness from 0.005 to $\frac{5}{8}$ in., the sheet-type specimen described in 6.3.

NOTE 8—Attention is called to the fact that either of the flat specimens described in 6.2 and 6.3 may be used for material from $\frac{3}{16}$ to $\frac{5}{8}$ in. in thickness, and one of the round specimens described in 6.4 may also be used for material $\frac{1}{2}$ in. or more in thickness.

6.5.2 For material having a nominal thickness of $\frac{3}{16}$ in. or over (Note 8), use the plate-type specimen described in 6.2.

6.5.3 For material having a nominal thickness of $\frac{1}{2}$ in. or over (Note 8), use the largest practical size of specimen described in 6.4.

6.6 Specimens for Wire, Rod, and Bar:

6.6.1 For round wire, rod, and bar, test specimens having the full cross-sectional area of the wire, rod, or bar shall be used wherever practicable. The gage length for the measure-

ment of elongation of wire less than $\frac{1}{8}$ in. in diameter shall be as prescribed in product specifications. In testing wire, rod, or bar that has a $\frac{1}{8}$ -in. or larger diameter, unless otherwise specified, a gage length equal to four times the diameter shall be used. The total length of the specimens shall be at least equal to the gage length plus the length of material required for the full use of the grips employed.

6.6.2 For wire of octagonal, hexagonal, or square cross section, for rod or bar of round cross section where the specimen required in 6.6.1 is not practicable, and for rod or bar of octagonal, hexagonal, or square cross section, one of the following types of specimens shall be used:

6.6.2.1 *Full Cross Section* (Note 9)—It is permissible to reduce the test section slightly with abrasive cloth or paper, or machine it sufficiently to ensure fracture within the gage marks. For material not exceeding 0.188 in. in diameter or distance between flats, the cross-sectional area may be reduced to not less than 90 % of the original area without changing the shape of the cross section. For material over 0.188 in. in diameter or distance between flats, the diameter or distance between flats may be reduced by not more than 0.010 in. without changing the shape of the cross section. Square, hexagonal, or octagonal wire or rod not exceeding 0.188 in. between flats may be turned to a round having a cross-sectional area not smaller than 90 % of the area of the maximum inscribed circle. Fillets, preferably with a radius of $\frac{3}{8}$ in., but not less than $\frac{1}{8}$ in., shall be used at the ends of the reduced sections. Square, hexagonal, or octagonal rod over 0.188 in. between flats may be turned to a round having a diameter no smaller than 0.010 in. less than the original distance between flats.

NOTE 9—The ends of copper or copper alloy specimens may be flattened 10 to 50 % from the original dimension in a jig similar to that shown in Fig. 10, to facilitate fracture within the gage marks. In flattening the opposite ends of the test specimen, care shall be taken to ensure that the four flattened surfaces are parallel and that the two parallel surfaces on the same side of the axis of the test specimen lie in the same plane.

6.6.2.2 For rod and bar, the largest practical size of round specimen as described in 6.4 may be used in place of a test specimen of full cross section. Unless otherwise specified in the product specification, specimens shall be parallel to the direction of rolling or extrusion.

6.7 *Specimens for Rectangular Bar*—In testing rectangular bar one of the following types of specimens shall be used:

6.7.1 *Full Cross Section*—It is permissible to reduce the width of the specimen throughout the test section with abrasive cloth or paper, or by machining sufficiently to facilitate fracture within the gage marks, but in no case shall the reduced width be less than 90 % of the original. The edges of the midlength of the reduced section not less than $\frac{3}{4}$ in. in length shall be parallel to each other and to the longitudinal axis of the specimen within 0.002 in. Fillets, preferably with a radius of $\frac{3}{8}$ in. but not less than $\frac{1}{8}$ in. shall be used at the ends of the reduced sections.

6.7.2 Rectangular bar of thickness small enough to fit the grips of the testing machine but of too great width may be reduced in width by cutting to fit the grips, after which the cut surfaces shall be machined or cut and smoothed to ensure failure within the desired section. The reduced width

shall be not less than the original bar thickness. Also, one of the types of specimens described in 6.2, 6.3, and 6.4 may be used.

6.8 *Shapes, Structural and Other*—In testing shapes other than those covered by the preceding sections, one of the types of specimens described in 6.2, 6.3, and 6.4 shall be used.

6.9 *Specimens for Pipe and Tube* (Note 10):

6.9.1 For all small tube (Note 10), particularly sizes 1 in. and under in nominal outside diameter, and frequently for larger sizes, except as limited by the testing equipment, it is standard practice to use tension test specimens of full-size tubular sections. Snug-fitting metal plugs shall be inserted far enough into the ends of such tubular specimens to permit the testing machine jaws to grip the specimens properly. The plugs shall not extend into that part of the specimen on which the elongation is measured. Elongation is measured over a length of 4D unless otherwise stated in the product specification. Figure 11 shows a suitable form of plug, the location of the plugs in the specimen, and the location of the specimen in the grips of the testing machine.

NOTE 10—The term "tube" is used to indicate tubular products in general, and includes pipe, tube, and tubing.

6.9.2 For large-diameter tube that cannot be tested in full section, longitudinal tension test specimens shall be cut as indicated in Fig. 12. Specimens from welded tube shall be located approximately 90° from the weld. If the tube-wall thickness is under $\frac{3}{4}$ in., either a specimen of the form and dimensions shown in Fig. 13 or one of the small-size specimens proportional to the standard $\frac{1}{2}$ -in. specimen, as mentioned in 6.4.2 and shown in Fig. 8, shall be used. Specimens of the type shown in Fig. 13 may be tested with grips having a surface contour corresponding to the curvature of the tube. When grips with curved faces are not available, the ends of the specimens may be flattened without heating. If the tube-wall thickness is $\frac{3}{4}$ in. or over, the standard specimen shown in Fig. 8 shall be used.

6.9.3 Transverse tension test specimens for tube may be taken from rings cut from the ends of the tube as shown in Fig. 14. Flattening of the specimen may be either after separating as in A, or before separating as in B. Transverse tension test specimens for large tube under $\frac{3}{4}$ in. in wall thickness shall be either of the small-size specimens shown in Fig. 8 or of the form and dimensions shown for Specimen 2 in Fig. 13. When using the latter specimen, either or both surfaces of the specimen may be machined to secure a uniform thickness, provided not more than 15 % of the normal wall thickness is removed from each surface. For large tube $\frac{3}{4}$ in. and over in wall thickness, the standard specimen shown in Fig. 8 shall be used for transverse tension tests. Specimens for transverse tension tests on large welded tube to determine the strength of welds shall be located perpendicular to the welded seams, with the welds at about the middle of their lengths.

6.10 *Specimens for Forgings*—For testing forgings, the largest round specimen described in 6.4 shall be used. If round specimens are not feasible, then the largest specimen described in 6.5 shall be used.

6.11 *Specimens for Castings*—In testing castings either the standard specimen shown in Fig. 8 or the specimen

TABLE 1 Details of Test Coupon Design for Castings (See Fig. 16)

NOTE 1—*Test Coupons for Large and Heavy Steel Castings*: The test coupons in Fig. 16 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired. This provision does not apply to Specification A 356/A 356M.

NOTE 2—*Bend Bar*: If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 16) is indicated.

Log Design (5 in.)		Riser Design	
1. L (length)	A 5-in. minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test bars (see Note 1).	1. L (length)	The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2. End taper	Use of and size of end taper is at the option of the foundry.	2. Width	The width of the riser at the base of a multiple-leg coupon shall be $n(2\frac{1}{4} \text{ in.}) - \frac{1}{8} \text{ in.}$ where n equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3. Height	1 $\frac{1}{4}$ in.	3. T (riser taper) Height	Use of and size is at the option of the foundry. The minimum height of the riser shall be 2 in. The maximum height is at the option of the foundry for the following reasons: (a) many risers are cast open, (b) different compositions may require variation in risering for soundness, or (c) different pouring temperatures may require variation in risering for soundness.
4. Width (at top)	1 $\frac{1}{4}$ in. (see Note 1)		
5. Radius (at bottom)	$\frac{1}{2}$ in. max	3. T (riser taper) Height	Use of and size is at the option of the foundry. The minimum height of the riser shall be 2 in. The maximum height is at the option of the foundry for the following reasons: (a) many risers are cast open, (b) different compositions may require variation in risering for soundness, or (c) different pouring temperatures may require variation in risering for soundness.
6. Spacing between legs	A $\frac{1}{2}$ -in. radius will be used between the legs.		
7. Location of test bars	The tensile, bend, and impact bars will be taken from the lower portion of the leg (see Note 2)	3. T (riser taper) Height	Use of and size is at the option of the foundry. The minimum height of the riser shall be 2 in. The maximum height is at the option of the foundry for the following reasons: (a) many risers are cast open, (b) different compositions may require variation in risering for soundness, or (c) different pouring temperatures may require variation in risering for soundness.
8. Number of legs	The number of legs attached to the coupon is at the option of the foundry providing they are equispaced according to Item 6.		
9. R_g	Radius from 0 to approximately $\frac{1}{16}$ in.		

shown in Fig. 15 shall be used unless otherwise provided in the product specifications.

6.11.1 Test coupons for castings shall be made as shown in Fig. 16 and Table 1.

6.12 *Specimen for Malleable Iron*—For testing malleable iron the test specimen shown in Fig. 17 shall be used, unless otherwise provided in the product specifications.

6.13 *Specimen for Die Castings*—For testing die castings the test specimen shown in Fig. 18 shall be used unless otherwise provided in the product specifications.

6.14 *Specimens for Powder Metallurgy (P/M) Materials*—For testing powder metallurgy (P/M) materials the test specimens shown in Figs. 19 and 20 shall be used, unless otherwise provided in the product specifications. When making test specimens in accordance with Fig. 19, shallow transverse grooves, or ridges, may be pressed in the ends to allow gripping by jaws machined to fit the grooves or ridges. Because of shape and other factors, the flat unmachined tensile test specimen (Fig. 19) in the heat treated condition will have an ultimate tensile strength of 50 % to 85 % of that determined in a machined round tensile test specimen (Fig. 20) of like composition and processing.

6.15 Gage Length of Test Specimens:

6.15.1 The gage length for the determination of elongation shall be in accordance with the product specifications for the material being tested. Gage marks shall be stamped lightly with a punch, scribed lightly with dividers or drawn with ink as preferred. For material that is sensitive to the effect of slight notches and for small specimens, the use of layout ink will aid in locating the original gage marks after fracture.

6.15.2 Extensometers with gage lengths equal to or shorter than the nominal gage length (dimension shown as “G-Gage Length” in the accompanying figures) of the specimen may be used to determine the yield phenomenon.

6.16 Location of Test Specimens:

6.16.1 Unless otherwise specified, the axis of the test specimen shall be located as follows:

6.16.1.1 At the center for products 1 $\frac{1}{2}$ in. or less in thickness, diameter, or distance between flats.

6.16.1.2 Midway from the center to the surface for products over 1 $\frac{1}{2}$ in. in thickness, diameter, or distance between flats.

6.16.2 For forgings, specimens shall be taken as provided in the applicable product specifications, either from the predominant or thickest part of the forging from which a coupon can be obtained, or from a prolongation of the forging, or from separately forged coupons representative of the forging. When not otherwise specified, the axis of the specimen shall be parallel to the direction of grain flow.

6.17 *Surface Finish of Specimens*—When materials are tested with surface conditions other than as manufactured, the surface finish of the test specimens shall be as provided in the applicable product specifications.

NOTE 11—Particular attention should be given to the uniformity and quality of surface finishes of specimens for high strength and very low ductility materials since this has been shown to be a factor in the variability of test results.

7. Procedures

7.1 Measurement of Dimensions of Test Specimens:

7.1.1 To determine the cross-sectional area of a test specimen, measure the dimensions of the cross section at the center of the reduced section. For referee testing of specimens under $\frac{3}{16}$ in. in their least dimension, measure the dimensions where the least cross-sectional area is found. Measure and record the cross-sectional dimensions of tension test specimens 0.200 in. and over to the nearest 0.001 in.; the cross-sectional dimensions from 0.100 in. but less than 0.200 in., to the nearest 0.0005 in.; the cross-sectional dimensions from 0.020 in. but less than 0.100 in., to the nearest 0.0001 in.; and when practical, the cross-sectional

dimensions less than 0.020 in., to at least the nearest 1 % but in all cases to at least the nearest 0.0001 in.

NOTE 12—Rough surfaces due to the manufacturing process such as hot rolling, metallic coating, etc., may lead to inaccuracy of the computed areas greater than the measured dimensions would indicate. Therefore, cross-sectional dimensions of test specimens with rough surfaces due to processing may be measured and recorded to the nearest 0.001 in.

7.1.2 Determine cross-sectional areas of full-size test specimens of nonsymmetrical cross sections by weighing a length not less than 20 times the largest cross-sectional dimension and using the value of density of the material. Determine the weight to the nearest 0.5 % or less.

7.1.3 When using specimens of the type shown in Fig. 13 taken from tubes, the cross-sectional area shall be determined as follows:

If $D/W \leq 6$:

$$A = [(W/4) \times (D^2 - W^2)^{1/2}] + [(D^2/4) \times \arcsin(W/D)] - [(W/4) \times ((D - 2T)^2 - W^2)^{1/2}] - [(D - 2T)^2/4 \times \arcsin(W/(D - 2T))]$$

where:

A = exact cross-sectional area, in.²,

W = width of the specimen in the reduced section, in.,

D = measured outside diameter of the tube, in., and

T = measured wall thickness of the specimen, in.

arcsin values to be in radians

If $D/W > 6$, the exact equation or the following equation may be used:

$$A = W \times T$$

where:

A = approximate cross-sectional area, in.²,

W = width of the specimen in the reduced section, in., and

T = measured wall thickness of the specimen, in.

7.2 Zeroing of the Testing Machine:

7.2.1 The testing machine shall be set up in such a manner that zero force indication signifies a state of zero force on the specimen. Any force (or preload) imparted by the gripping of the specimen (see Note 13) must be indicated by the force measuring system unless the preload is physically removed prior to testing. Artificial methods of removing the preload on the specimen, such as taring it out by a zero adjust pot or removing it mathematically by software, are prohibited because these would affect the accuracy of the test results.

NOTE 13—Preloads generally by gripping of specimens may be either tensile or compressive in nature and may be the result of such things as:

- = grip design
- = malfunction of gripping apparatus (sticking, binding, etc.)
- = excessive gripping force
- = sensitivity of the control loop

7.3 Speed of Testing:

7.3.1 Speed of testing may be defined (a) in terms of free-running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), (b) in terms of rate of separation of the two heads of the testing machine during a test, (c) in terms of the elapsed time for completing part or all of the test (d) in terms of rate of stressing the specimen, or (e) in terms of rate of straining the specimen.

NOTE 14—For some materials, the free-running crosshead speed, which is the least accurate, may be adequate, while for other materials one of the remaining methods, listed in decreasing order of precision, may be necessary in order to obtain test values within acceptable limits.

7.3.1.1 Specifying suitable numerical limits for speed and selection of the method are the responsibilities of the product committees. Suitable limits for speed of testing should be specified for materials for which the differences resulting from the use of different speeds are of such magnitude that the test results are unsatisfactory for determining the acceptability of the material. In such instances, depending upon the material and the use for which the test results are intended, one or more of the methods described in the following paragraphs is recommended for specifying speed of testing.

NOTE 15—Speed of testing can affect test values because of the rate sensitivity of materials and the temperature-time effects.

7.3.2 *Rate of Straining*—The allowable limits for rate of straining shall be specified in inches per inch per minute. Some testing machines are equipped with pacing or indicating devices for the measurement and control of rate of straining, but in the absence of such a device the average rate of straining can be determined with a timing device by observing the time required to effect a known increment of strain.

7.3.3 *Rate of Stressing*—The allowable limits for rate of stressing shall be specified in pounds per square inch per minute. Many testing machines are equipped with pacing or indicating devices for the measurement and control of the rate of stressing, but in the absence of such a device the average rate of stressing can be determined with a timing device by observing the time required to apply a known increment of stress.

7.3.4 *Elapsed Time*—The allowable limits for the elapsed time from the beginning of loading (or from some specified stress) to the instant of fracture, to the maximum load, or to some other stated stress, shall be specified in minutes or seconds. The elapsed time can be determined with a timing device.

7.3.5 *Free-Running Crosshead Speed*—The allowable limits for the rate of movement of the crosshead of the testing machine, when not under load, shall be specified in inches per inch of length of reduced section (or distance between grips for specimens not having reduced sections) per minute. The limits for the crosshead speed may be further qualified by specifying different limits for various types and sizes of specimens. The average crosshead speed can be experimentally determined by using suitable length measuring and timing devices.

7.3.6 *Rate of Separation of Heads During Tests*—The allowable limits for rate of separation of the heads of the testing machine during a test shall be specified in inches per inch of length of reduced section (or distance between grips for specimens not having reduced sections) per minute. The limits for the rate of separation may be further qualified by specifying different limits for various types and sizes of specimens. Many testing machines are equipped with pacing or indicating devices for the measurement and control of the rate of separation of the heads of the machine during a test, but in the absence of such a device the average rate of separation of the heads can be experimentally determined by using suitable length-measuring and timing devices.

7.3.7 Unless otherwise specified, any convenient speed of testing may be used up to one half the specified yield strength or yield point, or up to one quarter the specified tensile strength, whichever is smaller. The speed above this point shall be within the limits specified. If different speed limitations are required for use in determining yield strength, yield point, tensile strength, elongation, and reduction of area, they should be stated in the product specifications. In the absence of any specified limitations on speed of testing the following general rules shall apply:

7.3.7.1 The speed of testing shall be such that the loads and strains used in obtaining the test results are accurately indicated.

7.3.7.2 During the conduct of the test to determine yield strength or yield point the rate of stress application shall not exceed 100 000 psi/min.

7.3.7.3 After the yield strength or yield point has been determined, the speed may be increased to correspond to a maximum strain rate of 0.5 in./in./min. The extensometer and strain rate indicator may be used to set the strain rate prior to its removal. If the extensometer and strain rate indicator are not used to set this strain rate, the speed should be set not to exceed 0.5 in./in. of the length of the reduced section (or distance between the grips for specimens not having reduced sections) per minute.

7.4 *Determination of Yield Strength*—Determine yield strength by either of the methods described in 7.4.1 or 7.4.2.

7.4.1 *Offset Method*—To determine the yield strength by the “offset method,” it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then on the stress-strain diagram (Fig. 21) lay off Om equal to the specified value of the “offset,” draw mn parallel to OA , and thus locate r , the intersection of mn with the stress-strain diagram (Note 17). In reporting values of yield strength obtained by this method, the specified value of offset used should be stated in parentheses after the term yield strength. Thus:

$$\text{Yield strength (offset} = 0.2\% \text{)} = 52\ 000 \text{ psi}$$

In using this method a Class B2 extensometer (see Practice E 83) would be sufficiently sensitive for most materials.

NOTE 16—There are two general types of extensometers, averaging and non-averaging, the use of which is dependent on the product tested. For most machined or reduced section specimens, there are minimal differences. However, for some materials such as some forgings and tube sections, significant differences in measured yield strength can occur. For these cases it is recommended that the averaging type be used.

7.4.2 *Extension-Under-Load Method*—To determine the yield strength by the extension-under-load (EUL) method, it is necessary to secure data as follows: (1) by autographic or numerical devices so that a stress-strain (or load elongation) diagram may be drawn from which the value of the stress occurring at the specified value of extension may be ascertained; or (2) by a device attached to or part of an extensometer that indicates when the specified extension occurs so that the stress then occurring may be ascertained; either or both the devices attached to the extensometer or the load-indicating device may be automatic. This method is illustrated in Fig. 22. The extension can be satisfactorily determined by the use of a Class B2 extensometer (see Practice E 83). The stress that occurs at the specified

extension shall be reported thus:

$$\text{Yield strength (EUL} = XX \text{)} = YY \text{ psi}$$

where XX is the specified value of extension.

NOTE 17—If the load drops before the specified offset or extension-under-load is reached, technically the material does not have a yield strength (for that offset or extension-under-load), but the stress at the maximum load attained before the specified offset or extension-under-load is reached may be reported instead of the yield strength.

NOTE 18—When there is disagreement over the results of this test, the offset method for determining yield strength is recommended as the referee method.

7.5 *Determination of Yield Point:*

7.5.1 For materials that exhibit discontinuous yielding, determine the yield point by either of the methods described in 7.5.1.1 or 7.5.1.2.

7.5.1.1 *Halt-of-the-Load Method*—Apply an increasing load to the specimen at a uniform deformation rate. When the yield point of the material is reached, the increase of the load stops. At that time, there is a halt or hesitation of the load-indicating mechanism. When the increase in load stops or hesitates, record the corresponding stress as the yield point.

NOTE 19—This method was formerly known as the halt-of-the-pointer method and also as the drop-of-the-beam method.

7.5.1.2 *Autographic Diagram Method*—Obtain a stress-strain (or load-elongation) diagram by an autographic device. Record the stress (or load) corresponding to the maximum point at the onset of discontinuous yielding, as the yield point. This method is illustrated in Fig. 23.

7.5.2 When test specimens do not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the drop-of-the-beam, halt-of-the-pointer, or autographic diagram methods described above, a value equivalent to the yield point in its practical significance may be determined by the following methods and may be substituted for the yield point:

7.5.2.1 *Strain Rate Method*—Attach a Class B2 extensometer to the specimen at the gage marks. When the specimen is in place and the extensometer attached, increase the load at a reasonably uniform rate. Watch the elongation of the specimen as shown by the extensometer and note for this determination the load at which the rate of elongation shows a sudden increase.

7.5.2.2 *Extension-Under-Load Method*—Attach a Class C extensometer to the specimen. When the load producing a specified extension is reached, record the stress corresponding to this load as the yield point, and remove the extensometer. This same value may be obtained from an autographic stress-strain diagram (Fig. 22).

NOTE 20—The appropriate value of the total extension should be specified. For steel with yield point specified not over 80 000 psi, an appropriate value is 0.005 in./in. of gage length. For higher strength steels, yield strength should be specified in preference to yield point.

NOTE 21—A suitable device that automatically determines the load at the specified extension without plotting a stress-strain curve may be used if its accuracy has been demonstrated to be satisfactory.

NOTE 22—When no other means of measuring elongation are available, a pair of dividers or similar device can be used to determine a point of detectable elongation between two gage marks on the specimen. The gage length shall be 2 in. The stress corresponding to the load at the instant of detectable elongation can be recorded as “approximate” yield point.