Standard Test Methods of Tension Testing of Metallic Materials

This standard is issued under the fixed designation E 8; 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 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 example, 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 Turbines
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
B 557 Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
E 4 Practices for Load Verification of Testing Machines
E 6 Terminology Relating to Methods of Mechanical Testing
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

--- Footnotes ---
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.
2 Annual Book of ASTM Standards, Vol 01.02.
3 Annual Book of ASTM Standards, Vols 01.01-01.03 and 03.01.
4 Annual Book of ASTM Standards, Vols 02.02 and 03.01.
5 Annual Book of ASTM Standards, Vols 03.01.
6 Annual Book of ASTM Standards, Vols 03.01 and 14.02.

--- End Footnotes ---
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 ½-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 length 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 specimen, 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 these 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 1/32 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 1/32 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 0.035 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 1/2-in. diameter round test specimen shown in Fig. 8 is used in its general 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 1/32 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 1/32 to 1/16 in. in thickness, and one of the round specimens described in 6.4 may also be used for material 1/16 in. or more in thickness.

6.5.2 For material having a nominal thickness of 1/32 in. or over (Note 8), use the plate-type specimen described in 6.2.

6.5.3 For material having a nominal thickness of 1/16 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.

6.6.2.1 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 \( \frac{1}{4} \) 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 \( \frac{3}{4} \)-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 shown the ppc 6.11. in Fig. 6.12 iron th otherw 6.13 tes otherw 6.14 For te speci oth w mak ng trans se alow g BECAUSE tensile will has determi 6.15 6.15. mation sh for the lightly effe ct o layout sh a frac 6.15% than the 6.16
TABLE 1  Details of Test Coupon Design for Castings (See Fig. 16)

<table>
<thead>
<tr>
<th>Log Design (5 in.)</th>
<th>Riser Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( L ) (length)</td>
<td>1. ( L ) (length)</td>
</tr>
<tr>
<td>2. End taper</td>
<td></td>
</tr>
<tr>
<td>Use of and size of end taper is at the point of the foundry.</td>
<td></td>
</tr>
<tr>
<td>3. Height</td>
<td>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.</td>
</tr>
<tr>
<td>4. Width (at top)</td>
<td>The maximum height of the riser shall be 2 in. The maximum height is at the point 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.</td>
</tr>
<tr>
<td>5. Radius (at bottom)</td>
<td>The maximum height of the riser shall be 2 in. The maximum height is at the point 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.</td>
</tr>
<tr>
<td>6. Spacing between legs</td>
<td>( T ) (riser taper) Height</td>
</tr>
<tr>
<td>A ( \frac{3}{4} )-in. radius will be used between the legs.</td>
<td></td>
</tr>
<tr>
<td>7. Location of test bars</td>
<td>Use of and size is at the point of the foundry.</td>
</tr>
<tr>
<td>The tensile, bend, and impact bars will be taken from the lower portion of the leg (see Note 2).</td>
<td></td>
</tr>
<tr>
<td>8. Number of legs</td>
<td>3. ( T ) (riser taper) Height</td>
</tr>
<tr>
<td>The number of legs attached to the coupon is at the option of the foundry providing they are equispaced according to item 6.</td>
<td></td>
</tr>
</tbody>
</table>

9. \( R_s \) Radius from 0 to approximately \( \frac{3}{4} \) in.

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 \( \frac{1}{2} \) in. or less in thickness, diameter, or distance between flats.

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

In 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 coupon 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 1—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 \( \frac{3}{4} \) 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 \( D/W \leq 6 \):

\[
A = [(W/4) \times (D^2 - W^2)^{1/2} + (D^3/4) \times \arcsin(W/D)] - ((W/4) \times ((D - 2T)^2 - W^2)^{1/2}) - ((D - 2T)/2)^3 \times \arcsin(W/(D - 2T))
\]

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.
- \( T \) = 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 indicated 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 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.

Note 11—For most small differences, sections, or For these cases
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 One 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:

Yield strength (offset = 0.2 %) = 52 000 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:

Yield strength (EUL = XX) = YY 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 reference 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.
7.6 Tensile Strength—Calculate the tensile strength by dividing the maximum load carried by the specimen during a tension test by the original cross-sectional area of the specimen.

7.7 Elongation:
7.7.1 In reporting values of elongation, give both the original gage length and the percentage increase.

Example: elongation = 30% increase in gage length

7.7.2 When the specified elongation is greater than 3%, fit ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. For gage lengths of 2 in. and under, and to at least the nearest 0.5 % of the gage length for gage lengths over 2 in. A percentage scale reading to 0.5 % of the gage length may be used.

7.7.3 When the specified elongation is 3% or less, determine the elongation of standard round specimens (see Fig. 8) using the following procedure, except that the procedure given in 7.7.2 may be used instead when the measured elongation is greater than 3%.

7.7.3.1 Measure the original gage length of the specimen to the nearest 0.002 in.

7.7.3.2 Remove partly torn fragments that will interfere with fitting together the ends of the fractured specimen or with making the final measurement.

7.7.3.3 Fit the fractured ends together with matched surfaces and apply an end load along the axis of the specimen sufficient to close the fractured ends together. If desired, this end load may then be removed carefully, provided the specimen remains intact.

Note 23—The use of an end load of approximately 2000 psi has been found to give satisfactory results on test specimens of aluminum alloy.

7.7.3.4 Measure the final gage length to the nearest 0.002 in. and report the elongation to the nearest 0.2%.

7.7.4 Specimens other than the standard specimen described in Fig. 8 are exempt from the requirement of 7.7.3 except as required by the applicable product specification.

7.7.5 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. In acceptance testing, if the elongation so measured meets the minimum requirements specified, no further testing is required, but if the elongation is less than the minimum requirements, discard the test results and retest.

7.7.6 In determining extension at fracture (elastic plus plastic extension), autographic or automated methods using extensometers may be employed.

7.7.6.1 In determining percent elongation from extension at fracture data, only the plastic extension shall be used. The elastic portion can be estimated graphically or by calculation and then subtracted from the total extension at fracture.

7.8 Reduction of Area:
7.8.1 Specimens with Originally Circular Cross Sections—Fit the ends of the fractured specimen together and measure the reduced diameter to the same accuracy as the original measurement.

Note 24—Because of anisotropy, circular cross sections often do not remain circular during straining in tension. The shape is usually elliptical, thus, the area may be calculated by \( \pi \cdot d_1 \cdot d_2 / 4 \), where \( d_1 \) and \( d_2 \) are the major and minor diameters, respectively.

7.8.2 Specimens with Original Rectangular Cross Sections—Fit the ends of the fractured specimen together and measure the thickness and width at the minimum cross section to the same accuracy as the original measurements.

Note 25—Because of the constraint to deformation that occurs at the corners of rectangular specimens, the dimensions at the center of the original flat surfaces are less than those at the corners. The shape of these surfaces are often assumed to be parabolic. When this assumption is made, an effective thickness, \( t_e \), may be calculated as follows:

\[ t_e = \left( t_1 + t_2 + t_3 \right) / 6 \]

where \( t_1 \) and \( t_3 \) are the thicknesses at the corners, and \( t_2 \) is the thickness at mid-width. An effective width may be similarly calculated.

7.8.3 Calculate the reduced area based upon the dimensions determined in 7.8.1 or 7.8.2. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area, is the reduction of area.

7.8.4 If any part of the fracture takes place outside of the middle half of the reduced section or in a punched or scribed gage mark within the reduced section, the reduction of area value obtained may not be representative of the material. In acceptance testing, if the reduction of area so calculated meets the minimum requirements specified, no further testing is required, but if the reduction of area is less than the minimum requirements, discard the test results and retest.

7.8.5 Results of measurements of reduction of area shall be rounded using the procedures of Practice E 29 and any specific procedures in the product specifications. In the absence of a specified procedure, it is recommended that reduction of area test values in the range from 0 to 10 % be rounded to the nearest 0.5 % and test values of 10 % and greater, to the nearest 1 %.

7.9 Rounding Reported Test Data for Yield Strength, Yield Point, and Tensile Strength—Test data should be rounded using the procedures of Practice E 29 and the specific procedures in the product specifications. In the absence of a specified procedure for rounding the test data, one of the procedures described in the following paragraphs is recommended.

7.9.1 For test values up to 50,000 psi, round to the nearest 100 psi; for test values of 50,000 psi and up to 100,000 psi, round to the nearest 500 psi; for test values of 100,000 psi and greater, round to the nearest 1000 psi.

Note 26—For steel products, see Test Methods and Definitions A 370.

7.9.2 For all test values, round to the nearest 100 psi.

Note 27—For aluminum- and magnesium-alloy products, see Methods B 557.

7.9.3 For all test values, round to the nearest 500 psi.

7.10 Replacement of Specimens—A test specimen may be discarded and a replacement specimen selected from the same lot of material in the following cases:

7.10.1 The original specimen had a poorly machined surface.

7.10.2 The original specimen had the wrong dimensions.

7.10.3 The specimen's properties were changed because of poor machining practice.

7.10.4 The test procedure was incorrect.

7.10.5 The fracture was outside the gage length.
7.10.6 For elongation determinations, the fracture was outside the middle half of the gage length, or
7.10.7 There was a malfunction of the testing equipment.

Note 28—The tension specimen is inappropriate for assessing some types of imperfections in a material. Other methods and specimens employing ultrasonics, dye penetrants, radiography, etc., may be considered when flaws such as cracks, flakes, porosity, etc., are revealed during a test and soundness is a condition of acceptance.

8. Report

8.1 Test information on materials not covered by a product specification should be reported in accordance with 8.2 or both 8.2 and 8.3.

8.2 Test information to be reported shall include the following when applicable:

8.2.1 Material and specimen identification.

8.2.2 Specimen type (see Section 6).

8.2.3 Yield strength and the method used to determine yield strength (see 7.4).

8.2.4 Yield point and the method used to determine yield point (see 7.5).

8.2.5 Tensile strength (see 7.6).

8.2.6 Elongation (report both the original gage length and the percentage increase) (see 7.7).

8.2.7 Reduction of area (see 7.8).

8.3 Test information to be available on request shall include:

8.3.1 Specimen test section dimension(s).

8.3.2 Equation used to calculate cross-sectional area of rectangular specimens taken from large-diameter tubular products.

8.3.3 Speed and method used to determine speed of testing (see 7.3).

8.3.4 Method used for rounding of test results (see 7.9).

8.3.5 Reasons for replacement specimens (see 7.10).

9. Precision and Bias

9.1 Precision—An interlaboratory test program\(^8\) gave the following values for coefficients of variation for the most commonly measured tensile properties:

<table>
<thead>
<tr>
<th>Coefficient of Variation, %</th>
<th>Tensile Strength</th>
<th>Yield Strength</th>
<th>Parallel</th>
<th>Elongation Gage Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV ( %_p )</td>
<td>0.9</td>
<td>2.7</td>
<td>1.4</td>
<td>2.8</td>
</tr>
<tr>
<td>CV ( %_R )</td>
<td>1.3</td>
<td>4.5</td>
<td>2.3</td>
<td>5.4</td>
</tr>
</tbody>
</table>

\( CV \%_p \) = repeatability coefficient of variation in percent within a laboratory

\( CV \%_R \) = repeatability coefficient of variation in percent between laboratories

9.1.1 The values shown are the averages from tests on six frequently tested metals, selected to include most of the normal range for each property listed above. When these materials are compared, a large difference in coefficient of variation is found. Therefore, the values above should not be used to judge whether the difference between duplicate tests of a specific material is larger than expected. The values are provided to allow potential users of this test method to assess, in general terms, its usefulness for a proposed application.

9.2 Bias—The procedures in Test Methods E 8 for measuring tensile properties have no bias because these properties can be defined only in terms of a test method.

10. Keywords

10.1 accuracy; bending stress; discontinuous yielding; drop-of-the-beam; eccentric loading; elastic extension; elongation; extension-under-load; extensometer; force; free-running crosshead speed; gage length; half-of-the pointer; percent elongation; plastic extension; preload; rate of stressing; rate of straining; reduced section; reduction of area; sensitivity; strain; stress; taring; tensile strength; tension testing; yield point; yield strength

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*Supporting data can be found in Appendix I and additional data are available from ASTM Headquarters. Request RR: E28-1004.*
Dimensions

<table>
<thead>
<tr>
<th></th>
<th>Standard Specimens</th>
<th>Subsize Specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plate-Type, 1/2-in. Wide</td>
<td>Sheet-Type, 1/4-in. Wide</td>
</tr>
<tr>
<td></td>
<td>in.</td>
<td>in.</td>
</tr>
<tr>
<td>G—Gage length (Notes 1 and 2)</td>
<td>0.00 ± 0.01</td>
<td>2.000 ± 0.005</td>
</tr>
<tr>
<td>W—Width (Notes 3 and 4)</td>
<td>1 1/4 ± 1/8, –1/4</td>
<td>0.500 ± 0.010</td>
</tr>
<tr>
<td>T—Thickness (Note 5)</td>
<td>thickness of material</td>
<td></td>
</tr>
<tr>
<td>R—Radius of fillet, min (Note 6)</td>
<td>1</td>
<td>1/8</td>
</tr>
<tr>
<td>L—Over-all length, min (Notes 2 and 7)</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>A—Length of reduced section, min</td>
<td>9</td>
<td>2 1/4</td>
</tr>
<tr>
<td>B—Length of grip section, min (Note 8)</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>C—Width of grip section, approximate (Notes 4 and 9)</td>
<td>2</td>
<td>1/4</td>
</tr>
</tbody>
</table>

Note 1—For the 1/2-in. wide specimen, punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. Either a set of nine or more punch marks 1 in. apart, or one or more pairs of punch marks 8 in. apart may be used.

Note 2—When elongation measurements of 1/2-in. wide specimens are not required, a minimum length of reduced section (A) of 2 1/4 in. may be used with all other dimensions similar to those of the plate-type specimen.

Note 3—For the three sizes of specimens, the ends of the reduced section shall not differ in width by more than 0.004, 0.002 or 0.001 in., respectively. Also, there may be a gradual decrease in width from the ends to the center, but the width at each end shall not be more than 0.015, 0.005, or 0.003 in., respectively, larger than the width at the center.

Note 4—For each of the three sizes of specimens, narrower widths (W and G) may be used when necessary. In such cases the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used.

Note 5—The dimension T is the thickness of the test specimen as provided for in the applicable material specifications. Minimum thickness of 1 1/2-in. wide specimens shall be 9/16 in. Maximum thickness of 1/2-in. and 1/4-in. wide specimens shall be 3/4 in. and 1 1/4 in., respectively.

Note 6—For the 1/2-in. wide specimen, a 1 1/2-in. minimum radius at the ends of the reduced section is permitted for steel specimens under 100,000 psi in tensile strength when a profile cutter is used to machine the reduced section.

Note 7—To aid in obtaining axial loading during testing of 1/4-in. wide specimens, the over-all length should be as large as the material will permit, up to 8.00 in.

Note 8—It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of 1/2-in. wide specimens is over 9/16 in., longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.

Note 9—For the three sizes of specimens, the ends of the specimen shall be symmetrical in width with the center line of the reduced section within 0.10, 0.05 and 0.005 in., respectively. However, for referee testing and when required by product specifications, the ends of the 1/2-in. wide specimen shall be symmetrical within 0.01 in.

Note 10—Specimens with slides parallel throughout their length are permitted, except for referee testing, provided: (a) the above tolerances are used; (b) an adequate number of marks are provided for determination of elongation; and (c) when yield strength is determined, a suitable extensometer is used. If the fracture occurs at a distance of less than 2W from the edge of the gripping device, the tensile properties determined may not be representative of the material. In acceptance testing, if the properties meet the minimum requirements specified, no further testing is required, but if they are less than the minimum requirements, discard the test and retest.

FIG. 1 Rectangular Tension Test Specimens

FIG. 2 Wedge Grips with Liners for Flat Specimens
FIG. 3 Gripping Device for Threaded-End Specimens

FIG. 4 Gripping Device for Shouldered-End Specimens

FIG. 5 Gripping Devices for Sheet and Wire Specimens
**FIG. 6 Snubbing Device for Testing Wire**

**FIG. 7 Pin-Loaded Tension Test Specimen with 2-in. Gage Length**

---

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>In.</th>
</tr>
</thead>
<tbody>
<tr>
<td>G — Gage length</td>
<td>2.000 ± 0.005</td>
</tr>
<tr>
<td>W — Width (Note 1)</td>
<td>0.500 ± 0.010</td>
</tr>
<tr>
<td>T — Thickness, max (Note 2)</td>
<td>5%</td>
</tr>
<tr>
<td>R — Radius of fillet, min (Note 3)</td>
<td>½</td>
</tr>
<tr>
<td>L — Over-all length, min</td>
<td>8</td>
</tr>
<tr>
<td>A — Length of reduced section, min</td>
<td>2 ¾</td>
</tr>
<tr>
<td>B — Length of grip section, min</td>
<td>2</td>
</tr>
<tr>
<td>C — Width of grip section, approximate</td>
<td>2</td>
</tr>
<tr>
<td>D — Diameter of hole for pin, min (Note 4)</td>
<td>1 ½</td>
</tr>
<tr>
<td>E — Edge distance from pin, approximate</td>
<td>½</td>
</tr>
<tr>
<td>F — Distance from hole to fillet, min</td>
<td>½</td>
</tr>
</tbody>
</table>

**Note 1** — The ends of the reduced section shall differ in width by not more than 0.002 in. There may be a gradual taper in width from the ends to the center, but the width at each end shall be not more than 0.005 in. greater than the width at the center.

**Note 2** — The dimension T is the thickness of the test specimen as stated in the applicable product specifications.

**Note 3** — For some materials, a fillet radius R larger than ½ in. may be needed.

**Note 4** — Holes must be on center line of reduced section, within ±0.002 in.

**Note 5** — Variations of dimensions C, D, E, F, and L may be used that will permit failure within the gage length.
FIG. 8 Standard 0.500-in. Round Tension Test Specimen with 2-in. Gage Length and Examples of Small-Size Specimens Proportional to the Standard Specimen

FIG. 9 Various Types of Ends for Standard Round Tension Test Specimens
FIG. 21 Stress-Strain Diagram for Determination of Yield Strength by the Offset Method

FIG. 22 Stress-Strain Diagram for Determination of Yield Strength or Yield Point by the Extension-Under-Load Method

FIG. 23 Stress-Strain Diagram Showing Yield Point Corresponding with Top of Knee