Standard Test Methods of Tension Testing of Metallic Foil[1]

This standard is issued under the fixed designation E 345; 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.

1. Scope

1.1 These test methods cover the tension testing of metallic foil at room temperature in thicknesses less than 0.006 in. (0.150 mm).

NOTE 1—Exception to these methods may be necessary in individual specifications or test methods for a particular material.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI values 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:*

B 193 Test Method for Resistivity of Electrical Conductor Materials[2]

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

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

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

E 8M Test Methods for Tension Testing of Metallic Materials (Metric)[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 252 Test Method for Thickness of Thin Foil and Film by Weighing[5]

E 796 Test Method for Ductility Testing of Metallic Foil[3]

3. Terminology

3.1 The definitions of terms relating to tension testing appearing in Terminology E 6 apply 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.

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

4.3 These test methods are considered satisfactory for acceptance testing of commercial shipments since the methods have been used extensively for these purposes.

4.4 Tension tests provide a means to determine the ductility of materials through the measurement either of elongation or reduction of area. However, as specimen thickness is reduced, tension tests may become less useful for the determination of ductility. For these purposes Test Method E 796 presents an alternative procedure for measuring ductility.

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, yield strength, and 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 specimen. To ensure axial tensile stress within the gage length, the axis of the test specimen must coincide with the center line of the heads of the testing machine. Any departure from this center line may introduce bending stresses that are not included in the usual stress computation (load divided by cross-sectional area).

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[1] These test methods are under the jurisdiction of ASTM Committee E28 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 02.03.

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

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

[5] *Annual Book of ASTM Standards*, Vol 02.02.

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 materials in the thicker foil gages. If, 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 proper gripping, it is desirable that the entire length of the serrated face of each wedge be in contact with the specimen. A buffer material such as 320-grit silicon carbide paper may be inserted between the specimen and serrated faces to minimize tearing of specimens.

5.2.3 *Smooth Face Grips*—For foils less than 0.003 in. (0.076 mm) thickness, it may be desirable that the grips have smooth faces and that the gripping pressure be about 100 psi (0.7 MPa) for each 0.001 in. (0.025 mm) of specimen thickness.

6. Test Specimen

6.1 *General*—Test specimens shall be prescribed in the product specification for the material being tested. If a Type A specimen is used, all specimen dimensions, test procedures, and calculations shall be in compliance with those shown in Test Methods E 8 or E 8M.

6.2 *Type A Specimen*—Type A specimens shall be in accordance with the ½-in. (12.5-mm) sheet-type specimen shown in Fig. 1. To avoid lateral buckling in tests of some materials, the minimum radius of the fillet should be ¾ in. (19 mm), or the width of the grip ends should be only slightly larger than the width of the reduced section, or both; and the reduced section should be at least 20 % longer than the gage length.

6.3 *Type B Specimens*—Type B specimens shall be in accordance with the ½-in. (12.5-mm) wide parallel sided specimen shown in Fig. 1.

7. Procedures

7.1 *Type A Specimen Preparation*—The specimens can be machined in packs by use of a milling-type cutter. The machined specimens shall be examined under about 20× magnification to determine that the edges are smooth and that there are no surface scratches or creases. Specimens showing discernible scratches, creases, or edge discontinuities shall be rejected. The milling cutter shall be sharpened or renewed when necessary. When machining some thicknesses and tempers of material it may be necessary to interleave the samples with hard aluminum sheet, a plastic, or other suitable material. For some materials it may be desirable to polish the edges of the specimens, either mechanically or by electropolishing.

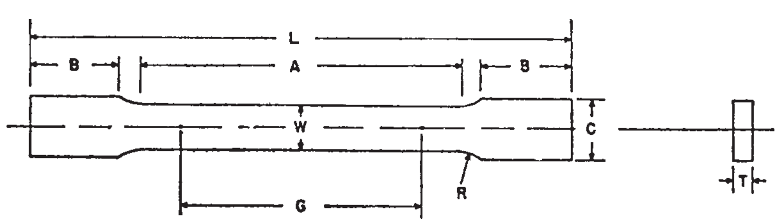
7.2 *Type B Specimen Preparation*—The specimens, particularly of soft and of thin hard metals, may be prepared by shearing, for example, by use of a double-bladed cutter (Fig. 2) or by slitting.[6] The cutting edges should be lubricated, if necessary with a material such as stearic acid in alcohol or another suitable material. The finished specimens shall be examined under about 20× magnification to determine that the edges are smooth and there are no surface scratches or creases. Specimens showing discernible surface scratches, creases, or edge discontinuities shall be rejected.

7.3 *Specimen Measurement*:

7.3.1 *Thickness*:

7.3.1.1 Thickness of specimens taken from soft foils or from foils 0.002 in. (0.05 mm) and thinner shall be determined to an accuracy of 2 % of the thickness by weighing in accordance with Test Method E 252 or by measuring devices. When using

[6] The Thwing-Albert JDC-50 precision cutter available from Thwing-Albert Instrument Co., 10960 Dutton Rd., Philadelphia, PA 19154, has been found to be acceptable.



Dimensions				
	Specimen			
	Type A		Type B	
	in.	mm	in.	mm
G—Gage length	2.000 ± 0.005	50.0 ± 0.1	5	125
W—Width	0.500 ± 0.010	12.50 ± 0.25	0.500	12.5
T—Thickness	thickness of foil		thickness of foil	
R—Radius of fillet, min	¾	19	...	...
L—Overall Length, min	8	200	9	230
A—Length of reduced section, min	2¼	60	...	...
B—Length of grip section, min	2	50	...	...
C—Width of grip section, approx.	¾	20	0.500	12.5

NOTE 1—For Type A specimens, the ends of the reduced section shall not differ in width by more than 0.002 in. (0.05 mm). Also, there may be a gradual decrease in width from the ends to the center, but the width at either end shall not be more than 0.005 in. (0.10 mm) larger than the width at the center.

NOTE 2—The dimension *T* is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 1 Foil Tension Test Specimen

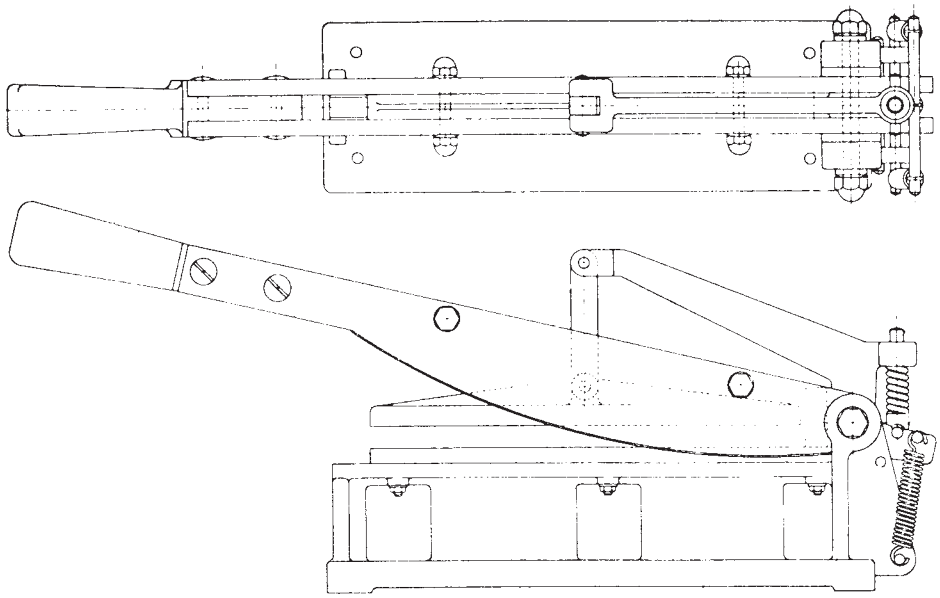


FIG. 2 Double-Bladed Cutter for Making Type B Specimens

Test Method E 252, the specimens themselves shall be weighed when it is practical. At least two specimens shall be weighed together. When Type B specimens are not used for weighing, a sample in accordance with Test Method E 252 may be used when taken from an area adjacent to that from which the test specimens were taken.

7.3.1.2 The thickness of specimens taken from hard materials or materials 0.001 in. (0.0245 mm) and greater in thickness may be determined by use of an optimeter, an electrical-type measuring device, or vernier micrometer, provided that the thickness is measured to at least the nearest 2 %.

NOTE 2—When specimens or samples are weighed, the thickness shall be computed to the nearest 0.0001 in. (0.0025 mm) and preferably to the nearest 0.00001 in. (0.00025 mm) by use of the formula:

$$T = W/AD \quad (1)$$

where:

where:
T = thickness of specimen or sample, in.,
W = weight of specimen or sample, g,
A = area of specimen or sample, in.^{2}, and
D = density of material, g/in.^{3}(see Appendix).

7.3.2 *Width*—Measure and record the specimen width dimension to the nearest 0.001 in. (0.025 mm).

7.4 *Speed of Testing*—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 in determining yield strength, yield point, tensile strength, and elongation, they should be stated in the product specification. In the absence of any specified limitations on the speed of testing the following general rules shall apply:

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

7.4.2 When yield strength or yield point is to be determined, the rate of stress application shall not exceed 100 ksi/min (12 MPa/s) but shall be greater than 1 ksi/min (1.2 MPa/s). The speed may be increased after removal of the extensometer, but it shall not exceed 0.5 in./in. (mm/mm) of reduced section (or distance between grips for specimens not having reduced section) per min.

7.4.3 The rate of strain shall be 0.06 to 0.5 in./in.·min when the yield strength is not being determined, except when the product specification requires a different speed.

7.4.4 When yield strength is to be determined, the strain rate shall be 0.002 to 0.010 in./in.·min until the stress is above the yield strength.

7.5 *Rounding*—Round all values of strength to the nearest 0.1 ksi (0.7 MPa) and each value of elongation to the nearest 0.5 %, unless specified otherwise, in accordance with the rounding method of Practice E 29.

7.6 *Yield Strength*—Determine yield strength by the offset or extension-under-load method, as follows:

7.6.1 *Offset Method*—To determine 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. 3) lay off *om* equal to the specified value of the "offset," draw *mn* parallel to *oA*, and thus locate *r*, the intersection of the *mn* with the stress-strain diagram (Note 4). 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 ksi (360 MPa).

7.6.2 *Extension-Under-Load-Method*—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams (Fig. 4) were plotted, the total strain corresponding to the stress at which the specified offset occurs will be known within satisfactory limits; therefore, in such tests a specified total strain may be used, and

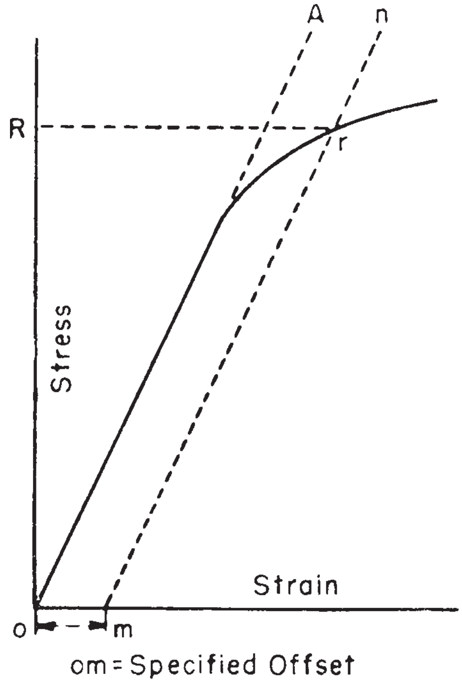


FIG. 3 Stress-Strain Diagram for Determination of Yield Strength by the Offset Method

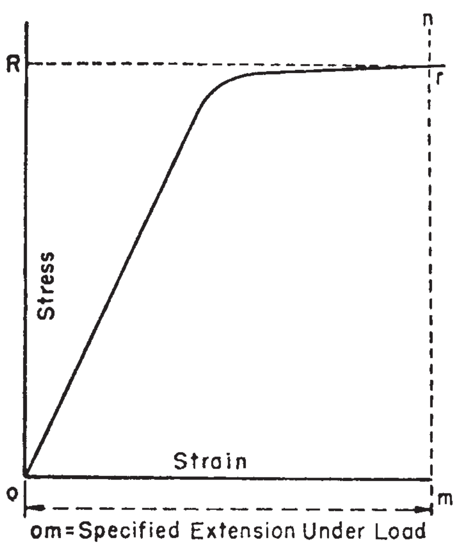


FIG. 4 Stress-Strain Diagram for Determination of Yield Strength by the Extension-Under-Load Method

the stress on the specimen, when this total strain is reached, is the value of the yield strength.

NOTE 3—Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated to be acceptable.

NOTE 4—If the load drops before the specified offset is reached, technically the material does not have a yield strength (for that offset), but the stress at maximum load before the specified offset is reached may be reported as the yield strength.

7.7 *Tensile Strength*—Calculate the tensile strength by dividing the maximum load carried by the specimen by the original cross-sectional area of the specimen.

7.8 *Elongation*:

7.8.1 When elongation is to be determined and Type A specimens are used, the 2-in. gage length may be lightly marked on the specimen by scribing fine lines of a 1-mil radius scriber and a precision ground template. The scribed lines should be about ⅛in. (3 mm) long and should not be placed near the specimen edges or in the fillet radii.

7.8.2 When elongation is to be determined and Type B specimens are used, the minimum and preferred distance between grips shall be 5 in. (125 mm), and the elongation may be determined from the differences in the distance between the grips before testing and at fracture. When a Type B specimen is tested using a positive head-speed type testing machine, the elongation may be taken from the loadelongation graph computed by the equation:

$$\text{Head speed} \times \text{inches of chart} \tag{2}$$

$$\text{Elongation, \%} = \frac{\text{head speed} \times \text{inches of chart}}{\text{chart speed} \times \text{gage length}} \times 100$$

7.8.3 When elongation is reported, the value shall be shown to the nearest 0.5 %.

8. Replacement of Specimens

8.1 A test specimen may be discarded and a replacement specimen taken from the same sample remnant, if possible, in the following cases:

8.1.1 The original specimen had surface scratches or creases.

8.1.2 The original specimen had a poorly machined surface.

8.1.3 The original specimen had the wrong dimensions.

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

8.1.5 The test procedure was incorrect.

8.1.6 The fracture was outside the gage length.

8.1.7 For elongation determinations, the fracture was outside the middle half of the gage length when using Type A specimens.

8.1.8 There was a malfunction of the testing equipment.

9. Report

9.1 The report shall include the following:

9.1.1 Metal or alloy, temper, lot or heat number,

9.1.2 Test specimen orientation and type,

9.1.3 Methods of determining yield strength and elongation, and

9.1.4 Mechanical properties.

10. Precision and Bias

10.1 *Precision*—The precision of these methods is to be established.

10.2 *Bias*—There are no available standards for determination of bias.

11. Keywords

11.1 ductility (elongation); metallic foil; specimen measurements (dimensions); specimen preparation; specimen type (A vs. B); speed of testing; strength (ultimate and yield); tension testing; uniaxial tensile stresses

APPENDIX

(Nonmandatory Information)

X1. DENSITY

X1.1 When Type B tension test specimens or samples are weighed to determine their thickness, the established value of density for the material should be used in the equation $T = W/AD$.

X1.1.1 *Aluminum Alloys:*[7]

	Density	
Material[7]	lb/in.^{3}	g/cm^3
1100	0.098	2.71
1145	0.0975	2.700
1180	0.0975	2.700
1199	0.0975	2.700
1235	0.0975	2.705
3003	0.099	2.73
5050	0.097	2.69
5052	0.097	2.68
5056	0.095	2.64

[7] Density Source: "Registration Record of Aluminum Association Designation and Chemical Composition Limits for Wrought and Wrought Aluminum Alloys," June 1, 1985.

X1.1.2 *Copper Alloys*:

	Density	
Material	g/in.^{3}	g/cm^3
EPT No. 110	146.06	8.91
OF	146.06	8.91
CDA No. 260	139.71	8.53

Density of other copper alloys may be obtained from Table 2 of Test Method B 193.

X1.1.3 *Lead Alloys*:

The densities of lead alloys may be calculated by the equation:

$$\text{Density, g/in.}^3 = \frac{1}{\frac{\%\ \text{lead}}{0.4097} + \frac{\%\ \text{tin}}{0.2637} + \frac{\%\ \text{antimony}}{0.2390}} \times 453.59 \quad \text{(X1.1)}$$