Designation: E345 − 16

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

This standard is issued under the fixed designation E345; 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 U.S. Department of Defense.

1. Scope

1.1 These test methods cover the tension testing of metallic foil at room temperature. Exception to these methods may be necessary in individual specifications or test methods for a particular material.

1.2 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B193 Test Method for Resistivity of Electrical Conductor Materials
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E8/E8M Test Methods for Tension Testing of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E252 Test Method for Thickness of Foil, Thin Sheet, and Film by Mass Measurement
E796 Test Method for Ductility Testing of Metallic Foil (Withdrawn 2009)[3]
E2309 Practices for Verification of Displacement Measuring Systems and Devices Used in Material Testing Machines

3. Terminology

3.1 The definitions of terms relating to tension testing appearing in Terminology E6 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 of elongation or reduction of area. However, as specimen thickness is reduced, tension tests may become less useful for determining ductility. For these purposes Test Method E796 is an alternative procedure for measuring ductility.

4.5 Different industries differentiate between foil and sheet at different thicknesses.

NOTE 1—In 2013, to harmonize with international standards, the Aluminum Association revised its definition of foil to include thicknesses less than or equal to 0.2 mm (0.0079 in.).

4.6 This standard differs from Test Methods E8/E8M in that it permits determining the specimen thickness by weighing (7.3) and determining the elongation from crosshead displacement for some specimens (7.8).

4.7 It is impossible for this standard to define the thickness range for every possible alloy where this standard should be used instead of Test Methods E8/E8M or other tensile test standards. Superior results for a specific alloy and thickness could be obtained by measuring the specimen thickness by weighing (7.3) to avoid damaging the material and to obtain sufficient accuracy. In addition, it may be acceptable for a given alloy and thickness to determine the elongation from

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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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

crosshead displacement in cases where conventional extensometers that contact the specimen or scribed fiducial marks could damage the specimen or affect the test results.

5. Apparatus

5.1 *Testing Machines*—Machines used for tension testing shall conform to the requirements of Practices E4. The forces 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 E4.

5.2 *Gripping Devices:*

5.2.1 *General*—Various types of gripping devices may be used to transmit the measured force applied by the testing machine to the test specimen. To ensure axial tensile stress within the gauge length, the axis of the test specimen shall coincide with the center line of the heads of the testing machine. Any departure from this center line could introduce bending stresses that are not included in the usual stress computation (force divided by cross-sectional area).

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 gauges. If, for any reason, one grip of a pair advances farther than the other as the grips tighten, an undesirable bending stress could be introduced. When liners are used behind the wedges, they shall be of the same thickness and their faces shall 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 0.076 mm (0.003 in.) thickness, it may be desirable that the grips have smooth faces and that the gripping pressure be about 0.7 MPa (100 psi) for each 0.025 mm (0.001 in.) of specimen thickness.

6. Test Specimen

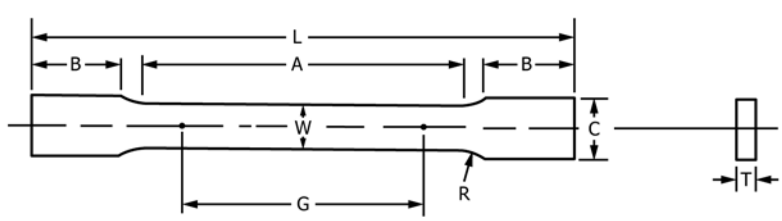
6.1 *General*—Test specimens shall be prescribed in the product specification for the material being tested. If a Type A specimen is used, all specimen dimensions, test procedures, and calculations shall comply with those shown in Test Methods E8/E8M.

6.2 *Type A Specimen*—Type A specimens shall be in accordance with the 12.5-mm (0.500 in.) sheet-type specimen shown in Fig. 1. To avoid lateral buckling in tests of some materials, the minimum radius of the fillet should be 19 mm (0.75 in.), or the width of the grip ends should be only slightly larger than the width of the reduced section, or both.

6.3 *Type B Specimens*—Type B specimens shall be in accordance with the 12.5-mm (0.500 in.) wide parallel sided specimen shown in Fig. 1.

7. Procedures

7.1 *Type A Specimen Preparation*—The specimens may be machined in packs by use of a milling-type cutter. Examine the machined specimens under about 20× magnification to determine that the edges are smooth and that there are no surface scratches or creases. Reject specimens that show discernible scratches, creases, or edge discontinuities. Sharpened or renew the milling-type cutter when necessary. When machining some thicknesses and tempers of material the samples may be interleaved with hard aluminum sheet, a plastic, or other suitable material. For some materials the edges of the specimens may be polished, either mechanically or by electropolishing.



Dimensions				
	Specimen			
	Type A		Type B	
	mm	in.	mm	in.
G—Gauge length	50.0 ± 0.1	2.000 ± 0.005	125	5
W—Width	12.50 ± 0.25	0.500 ± 0.010	12.5	0.500
T—Thickness		thickness of foil		thickness of foil
R—Radius of fillet, min	19	0.75	...	...
L—Overall Length, min	200	8	230	9
A—Length of reduced section, min	60	2.25	...	...
B—Length of grip section, min	50	2	...	...
C—Width of grip section, approx.	20	0.75	12.5	0.500

NOTE 1—For Type A specimens, the ends of the reduced section shall not differ in width by more than 0.05 mm (0.002 in.). 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 0.10 mm (0.005 in.) 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.

NOTE 3—For Type B specimens, measure the gauge length, *G*, to an accuracy of 0.25 mm (0.01in).

FIG. 1 Foil Tension Test Specimen

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[4] (Fig. 2) or by slitting. The cutting edges should be lubricated, if necessary, with a material such as stearic acid in alcohol or another suitable material. Examine the finished specimens under about 20× magnification to determine that the edges are smooth and there are no surface scratches or creases. Reject specimens that show discernible surface scratches, creases, or edge discontinuities.

7.3 *Specimen Measurement:*

7.3.1 *Thickness:*

7.3.1.1 The thickness of hard or soft foils may be determined by weighing using Test Method E252 or by the use of other measuring devices such as an optimeter, an electrical-type measuring device, or a micrometer.

7.3.1.2 When determining the thickness by weighing using Test Method E252, weigh at least two specimens together when it is practical. When Type B specimens are not used, a sample in accordance with Test Method E252 may be used if it is taken from an area adjacent to the area from which the test specimens were taken.

7.3.1.3 Regardless of the measurement method, measure the thickness of the specimen to either 2 % of the thickness or 0.0025 mm (0.0001 in.), whichever is more accurate.

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

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 forces 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 12 MPa/s (100 ksi/min) but shall be greater than 0.12 MPa/s (1 ksi/min). The speed may be increased after removal of the extensometer, but it shall not exceed 0.5 mm/mm (in./in.) of reduced section (or distance between grips for specimens not having reduced section) per min.

7.4.3 The rate of straining shall be 0.06 to 0.5 mm/mm/min. (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 rate of straining shall be 0.002 to 0.010 mm/mm/min. (in./in./min) until the stress is above the yield strength.

7.5 *Rounding*—Round all values of strength to the nearest 1 MPa (0.1 ksi) and each value of elongation to the nearest 0.5 %, unless specified otherwise, in accordance with the rounding method of Practice E29.

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

7.6.1 *Offset Method*—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 curve (see also, 7.6.2.2). In reporting values of

[4] The sole source of supply of the Thwing-Albert JDC-50 precision cutter known to the committee at this time is Thwing-Albert Instrument Co., 14 W. Collings Ave. West Berlin, NJ 08091. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

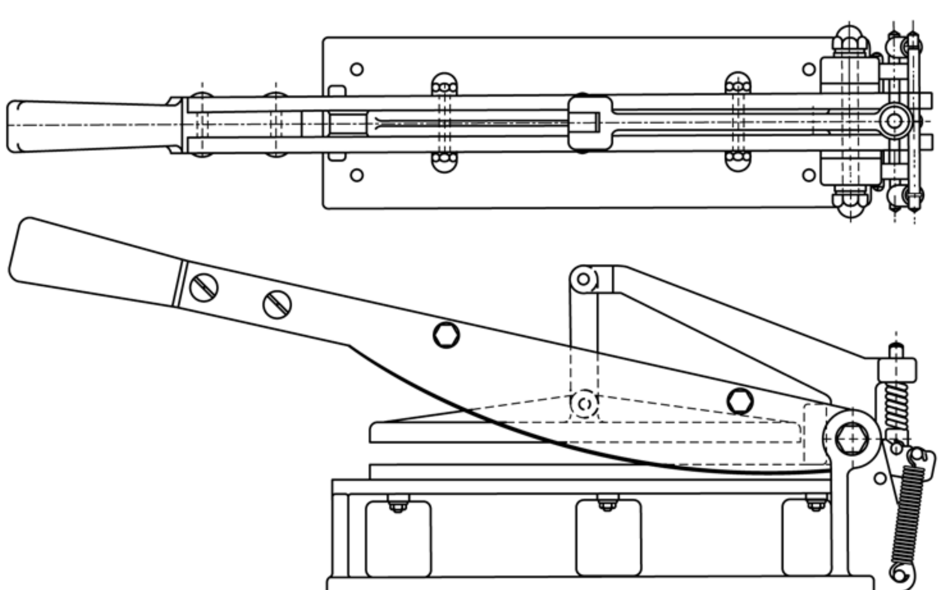


FIG. 2 Double-Bladed Cutter for Making Type B Specimens

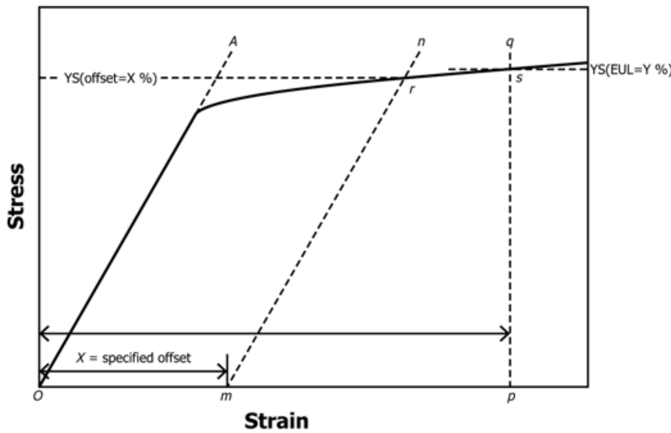


FIG. 3 Stress-Strain Diagram for Determination of Yield Strength by the Offset Method

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 %) = 359 MPa (52.1 ksi).

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. 3) were plotted, the total strain corresponding to the stress at which the specified offset occurs will be known within satisfactory limits. In such tests a specified total strain may be used, and the stress on the specimen, when this total strain is reached, is the value of the yield strength.

7.6.2.1 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.

7.6.2.2 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 force 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 50-mm (2-in.) gauge length may be lightly marked on the specimen by scribing fine lines using a scriber with 0.025mm (0.001 in.) radius and a precision ground template. The scribed lines should be about 3 mm (⅛ in.) 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 125 mm (5.00 in.), and the elongation may be determined from the differences in the distance between the grips before testing and at fracture. Measure the initial separation of the grips and their separation at failure to an accuracy of 0.25 mm (0.01 in). Meeting this accuracy requires that the displacement measuring system conform to Practices E2309 Class D.

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 gauge length.

8.1.7 For elongation determinations, the fracture was outside the middle half of the gauge 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 $T = W/AD$.

where:

T = thickness of specimen or sample,
W = mass of specimen or sample,
A = area of specimen or sample, and
D = density of material.

X1.1.1 *Aluminum Alloys:*[5]

Material[5]	Density, *D* 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

X1.1.2 *Copper Alloys:*

Material	Density, *D* 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 B193.

X1.1.3 *Lead Alloys:* The densities of lead-tin-antimony alloys may be calculated by the equation:

$$D = \frac{K}{\frac{x_{Pb}}{0.4097} + \frac{x_{Sn}}{0.2637} + \frac{x_{Sb}}{0.2390}} \quad (X1.1)$$

where:

D = density of the alloy,
x_{Pb} = mass fraction of lead in the alloy,
x_{Sn} = mass fraction of tin in the alloy,
x_{Sb} = mass fraction of antimony in the alloy,
K = 453.59 g/in.^{3} for densities expressed in g/in.^{3} ,
K = 27.680 g/cm^3 for densities expressed in g/cm^3, and
$x_{Pb} + x_{Sn} + x_{Sb}$ = 1

[5] Density Source: "International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys, Registration Record Series Teal Sheets," The Aluminum Association 1525 Wilson Boulevard, Arlington, VA 22209 2009. http://www.aluminum.org