Designation: E252 – 06 (Reapproved 2013)

Standard Test Method for Thickness of Foil, Thin Sheet, and Film by Mass Measurement[1]

This standard is issued under the fixed designation E252; 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 This test method covers the determination of the thickness of metallic foil and sheet 0.015 in. (0.38 mm) and less in thickness by measuring the mass of a specimen of known area and density. The test method is applicable to other sheet, foil, and film as indicated in Annex A3.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units, which 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 The following documents of the issue in effect on the date of material purchase, unless otherwise noted, form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]

D1505 Test Method for Density of Plastics by the Density-Gradient Technique

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

3. Apparatus

3.1 *Precision Blanking Press*—to cut foil or sheet circles that are 8.000 ± 0.008 in.^{2} (51.613 ± 0.051 cm^2) in area or 3.1915 ± 0.0015 in. (81.06 ± 0.04 mm) in diameter. Other size specimens may be used with the recognition that the accuracy stated in 6.1 is no longer applicable. See Annex A1 for the selection of other specimen sizes and the resulting change in accuracy of the test method.

3.2 *Balance*—capable of measuring to the nearest 0.1 mg of thickness for the 8.000-in.^{2} (51.613-cm^2) circle.

4. Procedure

4.1 Blank an 8.000 ± 0.008-in.^{2} (51.613 ± 0.051-cm^2) circle representative of the foil or sheet, swab with acetone or other suitable solvent to ensure a surface free of soil, and determine the mass of the clean, dry specimen to the nearest 0.1 mg. Use a suitable solvent to remove any coating known to exceed 0.005 mg/ft^2 (4.645 mg/cm^2) of surface area.

5. Calculation

5.1 Determine the thickness from the relationship:

$$T = \frac{M}{A \cdot D}$$

where:

T = thickness of the foil, sheet, or film, in. (or cm),
M = mass of the circle, g,
A = area of the circle, in.^{2} (or cm^2), and
D = density of the foil, sheet, or film, g/in.^{3} (or Mg/m^3).

5.2 *Densities of Aluminum Alloys:*

5.2.1 Calculate the density of aluminum foil or sheet from chemical composition limits of the alloy by the method described in Annex A2. The densities of foil or sheet alloys determined in this manner are accurate to within ± 0.3 %.

5.2.2 Calculated densities for some of the common foil or sheet alloys can be found in Table 1. A column headed "mils/g for 8.000-in.^{2} Area" is added for convenience in determining thickness of the 8.000-in.^{2} (51.613-cm^2) specimens. The mass of the specimen in grams multiplied by this factor is equal to the thickness of the foil or sheet in mils. One mil is equal to 0.001 in. (0.0254 mm).

6. Precision and Bias

6.1 Following the procedure outlined in this test method, repeated mass measurements of the same specimen on different

[1] This test method is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.05 on 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.

***A Summary of Changes section appears at the end of this standard**

TABLE 1 Densities of Aluminum Foil or Sheet Alloys Applicable to the Determination of Thickness by the Mass Measurement Method

Alloy	Density		mils/g for 8.000-in.^{2} Area
	g/in.^{3}	Mg/m^3 [A]	
1100	44.41	2.71	2.815
1145	44.24	2.700	2.826
1188	44.24	2.700	2.826
1199	44.24	2.700	2.826
1235	44.33	2.705	2.820
3003	44.74	2.73	2.794
5052	43.92	2.68	2.846
5056	43.26	2.64	2.890
8079	44.57	2.72	2.805
8111	44.41	2.71	2.815

[A] *Registration Record of Aluminum Association Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys*, Aluminum Assoc., Washington, DC.

balances should result in agreement within 1 mg. It is outside of the scope of this test method to describe maintenance and calibration procedures for balances, but disagreement larger than 1 mg warrants attention to maintenance or recalibration of the balance.

ANNEXES

(Mandatory Information)

A1. SPECIMEN SIZE AND SHAPE AND ITS EFFECT ON ACCURACY

A1.1 General

A1.1.1 Specimens of sizes and shapes other than the 8.000-in.^{2} (51.613-cm^2) circle maybe used provided consideration is given to controllable factors affecting the accuracy of the method. Specifically, the area of the specimen shall be known and controlled to an accuracy of ±0.1 %, and the minimum mass of the specimen shall be 70 mg. Specimens ranging in size from 8 to 32 in.^{2} (52 to 206 cm^2) are convenient to handle and can be prepared to meet the aforementioned requirements.

A1.2 Source of Error

A1.2.1 Inherent errors in determining thickness by the mass measurement method result from the limits on the accuracy of the density value assigned to the alloy, the accuracy with which a specimen can be cut and its area determined, and the accuracy of the mass measurement. Much time could be devoted to a discussion of refinement of errors but it shall suffice here to draw on experience as a guide for determining the accuracy of the method.

A1.3 Error from Uncertainty of the Densities of the Specimen (E_D)

A1.3.1 The density of aluminum foil or sheet alloys shall be those listed in Table 1 or it shall be determined by the method described in Annex A2. Values so obtained are accurate to ± 0.3 % of the true density. The error imposed by uncertainty of the density then is $E_D = \pm\ 0.3\ \%$ of the thickness determined.

A1.4 Error from Control of the Area of the Specimen (E_A)

A1.4.1 A precision blanking press can cut a specimen whose area is known and reproducible to an accuracy of ±0.1 %. If d is the specific diameter required to provide the area used in the thickness computation, then the error in area resulting from a small error, Δd, in the diameter is 200 $\Delta d/d$ %. It follows then that to maintain an area accurate to ±0.1 %, the tolerance on the diameter of the blanked circle shall be ±0.0005 times the circle diameter. The fact that the tolerance on diameter decreases in direct proportion to the diameter is a factor to consider in selecting the specimen size to use in the method. Compliance with this tolerance limits the area error to $E_A = \pm\ 0.1\ \%$ of the thickness determined.

A1.5 Error from Measuring the Mass of the Specimen (E_M)

A1.5.1 The accuracy of measuring the mass of a foil or sheet specimen has been found to be 0.7 mg. This imposes a maximum error on the method of $\pm\ 0.07/(T{\cdot}A{\cdot}D)$ % of the thickness determined. Since D, density of the foil or sheet, is fixed, it is seen that the magnitude of the mass measurement error is a function of the thickness, T, of the foil or sheet and the area, A, of the specimen. The area, A, is a controllable factor in the method, and the importance of selecting a large area to minimize the overall percentage error in the method for thin foil or sheet is apparent from a few simple calculations. The product $T \cdot A \cdot D$ is the mass of the specimen in grams, so to prevent the mass measurement error from introducing errors in excess of ± 1.0 %, it is necessary that the mass of the specimen be larger than 70 mg. The maximum error in the method due to mass measurement then is $E_M = \pm\ 0.07/\ (T \cdot A \cdot D)$ % of the thickness determined.

A1.6 Maximum Error of the Method

A1.6.1 If E_D, E_A, and E_M represent the errors in percentage of thickness determined as imposed by the limits of accuracy of density, area, and mass measurement, respectively, then the maximum error of the method is $(E_D + E_A + E_M)$ percent of the thickness determined. Since these errors at a given test location are normally in the nature of a bias rather than random error, the accuracy of the method is best described in terms of this maximum error. The maximum error of the method in percent is as follows:

$$E_D + E_A + E_M = \left[0.4 + \frac{0.07}{(T \cdot A \cdot D)}\right]$$

where $T \cdot A \cdot D$ is the mass of the specimen in grams.

A2. CALCULATING THE DENSITY OF ALUMINUM ALLOYS

A2.1 Calculation

A2.1.1 The following describes the procedures used to calculate nominal densities of aluminum and aluminum alloys.

A2.1.2 The form shown in Table A2.1 is convenient for making such calculations. A sample calculation is shown for 5052 alloy.

A2.1.2.1 For each alloying element, the arithmetic mean of its registered limits is determined. The mean is rounded to the number of places indicated in Table A2.2. Rounding, except when specified otherwise, shall be in accordance with the rounding method of Practice E29.

A2.1.2.2 For each impurity element or combination of impurity elements for which a maximum limit is registered, an arithmetic mean is determined using zero as the minimum limit. The mean is rounded to the number of places indicated in Table A2.1.

A2.1.2.3 For impurity elements having a combined limit (such as Si + Fe), each of the elements is considered to have an equal concentration. The concentrations are calculated by dividing the mean determined for the combined limit in A2.1.2.2 by the number of elements in the combined limit. Each element concentration is rounded to the number of places indicated in Table A2.1.

A2.1.2.4 The element concentrations in A2.1.2.1 – A2.1.2.3 are totaled and then subtracted from 100 to obtain the concentration of aluminum to be used in the calculation. The aluminum concentration is rounded to two decimal places. For 1XXX series aluminum, calculated aluminum content may be less than the specified minimum aluminum content. Nevertheless, the calculated aluminum content should be used for purposes of this calculation procedure.

A2.1.2.5 Each element concentration determined in A2.1.2.1 – A2.1.2.4 is multiplied by the value 1/Density given in Table A2.2. Each of these results is rounded to three decimal places.

TABLE A2.1 Density Calculations of Aluminum and Aluminum Alloys at 20°C

		Example for Alloy 5052	
Element	1/Density[A,B,C] (m^3/Mg)	Mass Percent Present	1/Density × Mass Percent Present
Cu	0.1116	0.05	0.006
Fe	0.1271	0.20	0.025
Si	0.4292	0.12	0.052
Mn	0.1346	0.05	0.007
Mg	0.5522[D]	2.5	1.380
Zn	0.1401	0.05	0.007
Ni	0.1123		
Cr	0.1391	0.25	0.035
Ti	0.2219		
Pb	0.0882		
V	0.1639		
B	0.4274		
Be	0.5411		
Zr	0.1541		
Ga	0.1693		
Bi	0.1020		
Sn	0.1371		
Cd	0.1156[C]		
Co	0.1130[C]		
Li	1.4410[D]		
		3.22 (Subtotal)	1.512
Al	0.3705	96.78 (Remainder)	35.857
		100.00 (Total)	37.369
		Calculated Density 100/37.369 = 2.68 Mg/m^3 = 43.92 $g/in.^3$	

[A] Aluminum Properties and physical Metallurgy, Edited by John C. Hatch, American Society for Metals, Metals Park, OH, 1984, pp. 201 – 203.
[B] Kunkle, D. E., and Willey, L. A., "Densities of Wrought Aluminum Alloys," *Journal of Materials*, ASTM, Vol 1, No. 1, March 1966.
[C] Handbook of Chemistry and Physics, 71st Edition, CRC Press, 1991.
[D] The densities used for these elements are different than the handbook densities because of the metallurgical formations that normally occur in alloys containing these elements.

TABLE A2.2 Precision for Standard Limits for Alloy Elements and Impurities

Less than 1/1000%	0.000×
1/1000 to 1/100 %	0.00×
1/100 to 1/10 %	
Unalloyed aluminum made by a refining process	0.0××
Alloys and unalloyed aluminum not made by a	0.0×
refining process	0.0×
1/10 through 1/2 %	0.××
Over 1/2 %	0.×, × .×, and so forth.

A2.1.2.6 The values determined in A2.1.2.5 are added together and this sum is divided into the number 100. The result is the unrounded density in Mg/m^3.

A2.1.2.7 The final expression of density in metric units (Mg/m^3) is obtained by rounding the value determined in A2.1.2.6 as follows:

(1) For aluminum and aluminum alloys having a specified minimum aluminum content of 99.35 % or greater, the value obtained is rounded to the nearest multiple of .005 and expressed as X.XX0 or X.XX5.

(2) For aluminum and aluminum alloys having a specified minimum aluminum content less than 99.35 %, the value obtained is rounded to the nearest multiple of .01 and expressed as X.XX.

NOTE A2.1—Limiting the expression of density to the number of decimal places indicated above is based on the fact that composition variations are discernible from one cast to another for most alloys. The expression of density values to more decimal places than is outlined above infers a higher precision than is justified and should not be used.

A2.1.2.8 The density in $g/in.^3$ is calculated by multiplying the value obtained in A2.1.2.7 by 16.387 and rounding to two decimal places.

A2.2 Accuracy

A2.2.1 The accuracy of the density arrived at by this method is ±0.3 % of the determined value for the common foil or sheet alloys and ± 0.5 % for highly alloyed compositions such as 2024.

A3. USE OF METHOD FOR POLYETHYLENE FILM

A3.1 Scope

A3.1.1 This method is applicable to a wide range of film, foil, or sheet. As an example of the slight modifications required for adaptation to other materials, the procedure recommended for polyethylene film of 0.002 in. (0.05 mm) and less in thickness is described.

A3.2 Apparatus

A3.2.1 A hand striking die is a convenient way to cut the specimen. The precision blanking press with the polyethylene film on a piece of paper will also produce good results, but any other method capable of the desired precision may be used.

A3.3 Test Specimen

A3.3.1 Because of the lower density of polyethylene film, a minimum specimen of 16.000 ± 0.016 $in.^2$ (103.23 ± 0.10 cm^2) is recommended; other specimen sizes may be used as discussed in Annex A1. If there is evidence of surface contamination, the specimen may be wiped clean with a dry cloth or tissue, but no solvent should be used.

A3.4 Calculations

A3.4.1 The density of polyethylene film may be determined directly by Test Method D1505. In many cases the film density will be known within the accuracy needed for this method (about 0.5 %) from specifications or previous experience. Polyethylene density is usually reported in g/cm^3. To convert this to $g/in.^3$ as needed in this calculation, multiply by 16.39.

SUMMARY OF CHANGES

Committee B07 has identified the location of selected changes to this standard since the last issue (E252 – 05) that may impact its use. (Approved in May 1, 2006.)

(1) Changed the lithium inverse density factor in Table A2.1 *to 1.4410 to agree with AS&D.*
(2) Updated references in Table A2.1.
(3) Change "grams per cubic cm" and "grams per cubic inch" to abbreviations in A3.4.1
(4) Change title so "thin" modifies sheet instead of foil.
(5) Correct punctuation and spacing.
(6) Change the symbol for mass from W to M. Make equations containing "TAD" unambiguous.