



# Standard Specification for Aluminum Foil for Capacitors<sup>1</sup>

This standard is issued under the fixed designation B 373; 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 ( $\epsilon$ ) 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 specification covers nine thicknesses (0.00017 to 0.00050 in. (0.0043 to 0.0127 mm)) of annealed aluminum foil used in the manufacture of capacitors.

1.2 Foil to be used as anodes in electrolytic capacitors is beyond the scope of this specification.

1.3 Alloy designations are in accordance with ANSI H35.1. The equivalent Unified Numbering System alloy designations are those of Table 1 preceded by A9, for example, A91145 for Aluminum 1145 in accordance with Practice E 527.

1.4 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A1.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

2.1 The following documents of the issue in effect on the date of material purchase form a part of this specification to the extent referenced herein.

### 2.2 ASTM Standards:

B 193 Test Method for Resistivity of Electrical Conductor Materials<sup>2</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>3</sup>

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys<sup>4</sup>

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition<sup>4</sup>

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique<sup>4</sup>

E 252 Test Method for Thickness of Thin Foil and Film by Weighing<sup>5</sup>

E 345 Test Methods of Tension Testing of Metallic Foil<sup>6</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 02.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>4</sup> Annual Book of ASTM Standards, Vol 03.05.

<sup>5</sup> Annual Book of ASTM Standards, Vol 02.02.

<sup>6</sup> Annual Book of ASTM Standards, Vol 03.01.

E 527 Practice for Numbering Metals and Alloys (UNS)<sup>7</sup>

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere<sup>8</sup>

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis<sup>8</sup>

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge<sup>8</sup>

### 2.3 ANSI Standard:

H35.1 Alloy and Temper Designation Systems for Aluminum<sup>5</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 *foil*—a rolled product rectangular in cross section of thickness less than 0.006 in. (0.15 mm).

3.1.2 *matte one-side foil (M1S)*—foil with a diffuse reflecting finish (matte) on one side and bright specular finish on the other (10.1).

3.1.3 *dry annealed A*—having a test dryness of 100/0, free from residual rolling oil, as determined by the water test (10.2.1).

3.1.4 *dry annealed B*—having a test dryness of 90/10, a slight film of residual rolling oil, as determined by the water-alcohol test (10.2.2).

3.1.5 *dry annealed C*—having a test dryness of 80/20, a slight film of residual rolling oil, as determined by the water-alcohol test (10.2.3).

3.1.6 *slick annealed*—having a uniform film of residual rolling oil or applied oil as determined by the water test (10.2.4).

3.1.7 *producer*—the primary manufacturer of the material.

3.1.8 *supplier*—includes only the category of jobbers and distributors as distinct from producers.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *capable of*—The term *capable of* as used in this specification means that the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these

<sup>7</sup> Annual Book of ASTM Standards, Vol 01.01.

<sup>8</sup> Annual Book of ASTM Standards, Vol 03.06.

**TABLE 1 Chemical Requirements<sup>A,B,C</sup>**

Aluminum Designation	Silicon plus Iron	Copper	Manganese	Magnesium	Zinc	Vanadium	Titanium	Other Elements <sup>D</sup>		Aluminum
								Each	Total	
1145	0.55	0.05	0.05	0.05	0.05	0.05	0.03	0.03	...	99.45 min <sup>E</sup>
1235	0.65	0.05	0.05	0.05	0.10	0.05	0.06	0.03	...	99.35 min <sup>E</sup>

<sup>A</sup> Limits are in percent maximum unless stated otherwise.

<sup>B</sup> Analysis shall be made for the elements for which limits are shown in this table.

<sup>C</sup> For purposes of determining the conformance to these limits, an observed value or a calculated value attained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with the rounding method of Practice E 29.

<sup>D</sup> *Others* includes all unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered nonconforming.

<sup>E</sup> The minimum content shall be calculated by subtracting from 100.00 %, the sum of all metallic elements present in amounts of 0.010 % or more, each rounded to the second decimal before determining the sum.

requirements, the material shall be subject to rejection.

#### 4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

- 4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),
- 4.1.2 Quantity in pounds,
- 4.1.3 Aluminum designation (Section 7),
- 4.1.4 Nominal thickness and width (Section 11),
- 4.1.5 Surface condition (Section 10),
- 4.1.6 Outside diameter of rolls (Section 13),
- 4.1.7 Inside diameter of cores (Section 13);

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

- 4.2.1 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (Section 16), and
- 4.2.2 Whether certification is required (Section 18).

#### 5. Manufacturing Process Changes

5.1 No process changes shall be made in the manufacture of this material after initially approved by the purchaser, except by prior agreement between the purchaser and the producer.

#### 6. Responsibility for Quality Assurance

6.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure that the material conforms to prescribed requirements.

6.2 *Lot Definition*—An inspection lot shall consist of an identifiable quantity of material of the same alloy, temper, and nominal dimensions subjected to inspection at one time.

#### 7. Chemical Composition

7.1 *Limits*—The foil shall conform to the chemical composition limits prescribed in Table 1. Conformance shall be determined by the producer by analyzing samples taken at the

time the ingots are poured, or samples taken from the finished or semi-finished product. If the producer of the foil or the producer of the material from which the foil is produced has determined the chemical composition of the material during the course of manufacture, sampling and analysis of the finished product shall not be required.

NOTE 1—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

7.2 *Number of Samples*—The number of samples taken to determine chemical composition shall be as follows:

7.2.1 When samples are taken at the time the ingots are poured, at least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal.

7.2.2 When samples are taken from the finished or semi-finished product, a sample shall be taken to represent each 1000 lb (454 kg), or fraction thereof, of material in the lot, except that not more than one sample shall be required per piece.

7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, clipping, etc., a representative piece or pieces to obtain a weight of prepared sample not less than 75 g. Sampling shall be in accordance with Practice E 55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E 716. Samples for other methods of analysis shall be taken by methods suitable for the form of material being analyzed and the type of analytical method used.

7.4 *Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34), or spectrochemical (Test Methods E 227, E 607, and E 1251), methods. Other methods may be used only when no published ASTM method is available. In case of dispute, the methods of analysis shall be agreed upon between the producer and the purchaser.

#### 8. Mechanical Properties

8.1 *Tensile Breaking Load*—The foil shall be capable of

conforming to the tensile breaking load requirements prescribed in Table 2. Splices shall be capable of developing 80 % of the breaking load specified for unspliced foil.

8.2 *Number of Specimens*—When tensile breaking load is determined, tests shall be made on samples from each 1000 lb (454 kg), or fraction thereof, of each thickness and width of coil in a lot. Not less than two samples shall be selected with each sample from a different roll of foil except that if the lot consists of only one roll of foil, one sample shall be selected. Each sample shall consist of either a single-thickness or multiple-thickness specimen from one roll of foil.

8.3 *Test Method*—For determination of tensile breaking load, tests shall be made in accordance with Test Methods E 345. If breaking load tests of a sample are made by both single-thickness specimens (Type B) and by multiplethickness specimens (Type A) and the results do not agree with each other, the results of the tests of the single-thickness specimens shall be the basis for acceptance or rejection of the material.

8.4 *Retests*—If any test specimen for tensile breaking load fails to conform to the requirements prescribed in Table 2, two additional specimens shall be selected from other representative rolls in the inspection lot, or from the same roll if the lot consists of only one roll, and tested. If either of these specimens fails to conform to the applicable requirements, the material may be rejected. If, however, the failure of the foil to conform to the requirements is the result of an inadequate thermal treatment, the material may be reannealed and resampled in accordance with 7.2. Only one such reworking of material shall be permitted.

NOTE 2—Experience of testing of foil has demonstrated that failures are more likely due to faulty test specimens, or to misalignment of the specimen in the testing machine, than is the case with material having a greater section thickness. Care must be exercised to discard test results where the evidence indicates that the specimen failure may be related to testing conditions.

9. Electrical Properties

9.1 *Electrical Resistance*—The foil shall be capable of conforming to the direct current electrical resistance requirements prescribed in Table 3 when measured at a temperature between 60 and 80°F (15 and 25°C).

NOTE 3—Direct-current electrical resistance values listed in Table 3 are based on a minimum electrical conductivity of 58.5 % IACS and the minimum permissible foil thickness corresponding with each nominal thickness.

TABLE 2 Tensile Breaking Load

NOTE—SI values in parentheses are for information only.

Nominal Thickness in. (mm)	Breaking Load, min, lbf/in. of Width (N/m of Width)
0.00017 (0.0043)	1.1 (192)
0.00020 (0.0051)	1.3 (228)
0.00023 (0.0058)	1.5 (262)
0.00025 (0.0064)	1.6 (280)
0.00030 (0.0076)	1.9 (332)
0.00035 (0.0089)	2.3 (402)
0.00040 (0.0102)	2.6 (455)
0.00045 (0.0114)	2.9 (508)
0.00050 (0.0127)	3.2 (560)

TABLE 3 Direct Current Electrical Resistance

NOTE—SI values in parentheses are for information only.

Nominal Thickness in. (mm)	Ohms per Foot of Length for 1-in. Width max	(Ohms per Metre of Length for 10 - mm Width, max)
0.00017 (0.0043)	0.090	(0.75)
0.00020 (0.0051)	0.077	(0.64)
0.00023 (0.0058)	0.066	(0.55)
0.00025 (0.0064)	0.061	(0.51)
0.00030 (0.0076)	0.051	(0.43)
0.00035 (0.0089)	0.044	(0.36)
0.00040 (0.0102)	0.038	(0.32)
0.00045 (0.0114)	0.034	(0.28)
0.00050 (0.0127)	0.031	(0.25)

9.2 *Number of Specimens*—When electrical resistance is determined, tests shall be made on samples from each 1000 lb (454 kg), or fraction thereof, of each thickness and width of coil in a lot. Not less than two samples shall be selected with each sample from a different roll of foil except that if the lot consists of only one roll of foil, one sample shall be selected.

9.3 *Method of Test*—When electrical resistance is determined, this determination shall be made by any method having an accuracy of ±0.001 Ω, provided that in the case of dispute, the results obtained by Test Method B 193 shall be the basis for acceptance.

10. Surface Condition

10.1 The foil shall be supplied with the finish bright on one side and matte on the other.

10.2 The foil shall be supplied in the dry or slick condition, as specified on the purchase order. The foil shall be tested for surface condition by spraying, as from a squeeze bottle, a continuous line of distilled water or distilled water-alcohol mixture across the web of foil inclined 30° from horizontal. To ensure an acceptable water-alcohol mixture, the alcohol denaturant shall be methanol (Formula 30—ten parts ethyl alcohol and one part methanol by volume) or equivalent. Foil dryness is categorized by the water or water-alcohol test in which the foil will support a continuous unbroken line across the web for 2 s. (The unbroken line is the top of the band of water or mixture across the web.)

10.2.1 *Dry Annealed A (test dryness 100/0)*—Foil shall support a continuous unbroken line using 100 % distilled water. Alternatively, the foil may be tested by a distilled water drop test, in which case the drops shall spread evenly into a thin film.

10.2.2 *Dry Annealed B (test dryness 90/10)*—Foil shall support a continuous unbroken line using a mixture of 90 % distilled water and 10 % alcohol.

10.2.3 *Dry Annealed C (tested dryness 80/20)*—Foil shall support a continuous unbroken line using a mixture of 80 % distilled water and 20 % alcohol.

10.2.4 *Slick Annealed*—Foil shall exhibit no areas wettable by a distilled water drop test, that is, the water shall remain in spherical drops on the surface of foil. Slick foil shall not have lubricant sufficient to be visible on the foil surface as the foil is unwound.

## 11. Dimensional Tolerances

11.1 *Width*—The foil width shall not vary from that specified on the purchase order by more than  $\pm 1/64$  in. (0.4 mm) for widths under 12 in. (305 mm),  $\pm 1/32$  in. (0.8 mm) for width 12 in. and over.

## 12. Area per Unit Weight

12.1 The foil shall conform to the requirements for area per unit weight prescribed in Table 4.

12.2 *Number of Tests*—Two samples of unspliced foil, each consisting of at least 16 in.<sup>2</sup> (103 cm<sup>2</sup>), shall be taken to represent each 1000 lb (454 kg) or fraction thereof of each thickness and width of foil in a lot. When the lot includes more than one roll of a specified thickness and width, the two samples shall be taken from different rolls. When the roll width is insufficient to permit blanking the standard circular specimen, each sample will consist of a length of unspliced foil sufficient to provide at least 100 in.<sup>2</sup> of area. At least one specimen from each sample shall be tested.

12.3 *Method of Test*—The area per unit weight shall be determined in accordance with Test Method E 252 or by means of a direct-reading basis-weight scale. When the sample width is insufficient to permit blanking the standard circular specimen, a length of unspliced foil sufficient to provide at least 100 in.<sup>2</sup> (650 cm<sup>2</sup>) of area shall be taken as the specimen. The covering area shall be determined by measuring the area of the specimen with an accuracy of  $\pm 0.5\%$ , weighing the specimen to the nearest 1 mg, and calculating the area per pound by use of the covering equation:

$$\text{Covering area, in.}^2/\text{lb} = \frac{453.6 \times \text{area of specimen, in.}^2}{\text{weight of specimen, g}} \quad (1)$$

## 13. Spooling

13.1 *Roll Dimensions*—The foil shall be wound on metal or plastic cores having an inside diameter of  $1.312 \pm 0.012$  in. ( $33.32 \pm 0.30$  mm). When specified on the order, foil may be wound on metal or plastic cores having an inside diameter of  $3.000 \pm 0.015$  in. ( $76.20 \pm 0.38$  mm). The maximum outside diameter of rolls shall be as specified on the order.

13.2 *Roll Winding*—The foil shall be wound firmly on metal or plastic cores in such a manner as to prevent slipping or

telescoping, and also to permit the foil to be unwound freely without sticking or tearing. The ends of metal cores shall be as nearly flush as practicable with the edges of the wound foil to prevent damage to the foil edges adjacent to the core.

13.3 *Roll Covering*—Each roll shall be protected with a layer of paper that is free of contaminants harmful to the foil.

## 14. Splices

14.1 Foil splices shall be either welded or knurled.

## 15. General Quality

15.1 The foil shall be free of splits, slivers, wrinkles, ragged edges, or excessive pinholes.

## 16. Source Inspection

16.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the material prior to shipment, such agreement shall be made by the purchaser and producer as part of the purchase contract.

16.2 When such inspection or witness of inspection and testing is agreed upon, the producer shall afford the purchaser's representative all reasonable facilities to satisfy him that the material meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

## 17. Rejection

17.1 Material failing to conform to the requirements of this specification, or in which defects are discovered during subsequent manufacturing operations, may be rejected. If rejected, the producer or supplier shall be responsible only for replacement of material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier.

## 18. Certification

18.1 The producer or supplier shall, on request, furnish to the purchaser a certificate stating that the material has been sampled, tested, and inspected in accordance with this specification, and has met the requirements.

## 19. Packaging and Package Marking

19.1 *Marking Rolls for Identification*—Unless otherwise specified, each roll shall be marked on at least one end with the

**TABLE 4 Area per Unit Weight Requirements**

NOTE—SI values in parentheses are for information only.

Nominal Thickness		Nominal Covering Area <sup>A</sup>		Permissible Range of Covering Area <sup>B</sup>			
				min		max	
in.	(mm)	in. <sup>2</sup> /lb (10 <sup>3</sup> )	(m <sup>2</sup> /kg)	in. <sup>2</sup> /lb (10 <sup>3</sup> )	(m <sup>2</sup> /kg)	in. <sup>2</sup> /lb (10 <sup>3</sup> )	(m <sup>2</sup> /kg)
0.00017	(0.0043)	60.3	(85.7)	54.8	(77.9)	67.0	(95.3)
0.00020	(0.0051)	51.3	(72.9)	46.6	(66.3)	57.0	(81.1)
0.00023	(0.0058)	44.6	(63.4)	40.5	(57.6)	49.5	(70.4)
0.00025	(0.0064)	41.0	(58.3)	37.3	(53.0)	45.6	(64.8)
0.00030	(0.0076)	34.2	(48.6)	31.1	(44.2)	38.0	(54.0)
0.00035	(0.0089)	29.3	(41.7)	26.6	(37.8)	32.6	(46.4)
0.00040	(0.0102)	25.6	(36.4)	23.3	(33.1)	28.5	(40.5)
0.00045	(0.0114)	22.8	(32.4)	20.7	(29.4)	25.3	(36.0)
0.00050	(0.0127)	20.5	(29.1)	18.6	(26.4)	22.8	(32.4)

<sup>A</sup> Covering area is based on a density of 0.0975 lb/cu in. for 1145 and 1235 aluminum.

<sup>B</sup> Range of covering area based on the standard thickness tolerance of plus and minus 10% per roll or shipment.

nominal thickness and producer's name or trademark. The marking material shall be such as to resist obliteration during normal handling and shipping.

19.2 *Packaging, Marking, and Shipping:*

19.2.1 The material shall be packaged to provide adequate protection during normal handling and transportation. The type of packaging and gross weight of containers shall, unless otherwise agreed upon, be at the producer's or supplier's discretion. Packaging methods and containers shall be so selected as to permit maximum utility of mechanical equipment in unloading and subsequent handling. Each package or container shall contain only one nominal composition, thick-

ness, width, or surface condition of material when packaged for shipment, unless otherwise agreed upon.

19.2.2 Each container shall be marked with the purchase order number, aluminum designation, size, quantity, specification number, gross and net weights, and the producer's name or trademark.

19.2.3 Containers shall be such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery.

20. **Keywords**

20.1 aluminum foil

ANNEX

(Mandatory Information)

**A1. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION**

A1.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1. The Aluminum Association<sup>9</sup> holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A1.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A1.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1. A designation not in conflict with other designation systems or a trade name is acceptable.

A1.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A1.2.3 The complete chemical composition limits are submitted.

A1.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A1.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A1.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	
Over 0.55 %	0.X, X.X, etc.
(except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A1.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A1.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A1.2).

NOTE A1.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A1.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

<sup>9</sup> The Aluminum Association, 900 19th Street, NW, Washington, DC 20006.

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