Designation: A428/A428M – 10 (Reapproved 2014)

Standard Test Method for Weight [Mass] of Coating on Aluminum-Coated Iron or Steel Articles[1]

This standard is issued under the fixed designation A428/A428M; 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 This test method covers procedures for determining the weight [mass] of coating on aluminum-coated iron or steel sheets and wire, and on other aluminum-coated iron and steel articles.

1.2 The final results determined by this test method shall be expressed in inch-pound units or SI units, depending on the units used in the material specification to which the results are to be compared. Certain portions of the procedure involving determination of specimen weight [mass] have traditionally been performed in SI units, and corresponding inch-pound units are not included.

1.3 For sheet products, the final results are expressed as either coating weight [mass] total both sides, or coating weight [mass] separately on each side, depending on the specified requirements.

1.4 *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.* For a specific precautionary statement, see Note 1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1193 Specification for Reagent Water

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

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Significance and Use

3.1 This test method provides a standard method of determining the weight [mass] of coating for comparison with specification requirements. A coating of aluminum on iron or steel articles provides protection against corrosion by forming a relatively inert barrier. Specifications for aluminum-coated articles occasionally provide for different classes (weights) [masses] of coating so that the purchaser can select the coating weight [mass] most suited to his needs. The heavier coating will provide greater protection against mechanical damage which may break the coating.

4. Reagents

4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[3] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

4.2 *Purity of Water*—Water used in preparation of reagent solutions shall conform to Specification D1193, Type IV or better.

4.3 *Antimony Trichloride Solution*—Dissolve 200 g of antimony trichloride ($SbCl_3$) in 1000 mL of concentrated hydrochloric acid (HCl, sp gr 1.18 to 1.19) without heating.

4.4 *Hydrochloric Acid (sp gr 1.18 to 1.19)*—Concentrated hydrochloric acid (HCl).

[1] This test method is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.07 on Methods of Testing.

Current edition approved Aug. 1, 2014. Published September 2014. Originally approved in 1958. Last previous edition approved in 2010 as A428/A428M – 10. DOI: 10.1520/A0428_A0428M-10R14.

[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] *Reagent Chemicals, American Chemical Society Specifications* , American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

4.5 *Sodium Hydroxide Solution (20 %)* —Dissolve 20 parts by weight [mass] of sodium hydroxide (NaOH) in 80 parts of water.

4.6 *Stannous Chloride Solution*—Dissolve 100 g of stannous chloride ($SnCl_2 \cdot 2H_2O$ in 1000 mL of concentrated hydrochloric acid (HCl, sp gr 1.18 to 1.19) without heating. Add a few granules of reagent grade tin.

4.7 *Hydrochloric Acid (1 +1)*—Mix 500 mL of HCl (sp. gr. 1.18 to 1.19) with 500 mL of reagent water and cool to room temperature.

NOTE 1—**Warning:** Small amounts of the poisonous gas stibine (SbH_3) may be evolved during the stripping process using the hydrochloric acid-antimony trichloride-stannous chloride method. Hydrochloric acid fumes are present, and hydrogen gas is evolved in the stripping process. Therefore, the test should be performed under conditions of adequate ventilation. A fume hood is recommended for large numbers of samples or where the test is to be carried out frequently over extended periods of time.

5. Sampling

5.1 *Aluminum-Coated Sheets*—Samples for weight-of-coating [mass-of-coating] determination shall be secured as designated in the appropriate specification. Test specimens shall have a minimum area of 3 in.^{2} [2000 mm^2] of sheet, but preferably approximately 5 in.^{2} [3300 mm^2] of sheet.

NOTE 2—For convenience in calculating test results in inch-pound units, the specimen should have an area of 5.08 in.^{2} of sheet (2.25 ± 0.01 in. square or 2.54 ± 0.01 in. in diameter). The weight [mass] of coating in grams on a specimen of that area is numerically equal to the weight [mass] of coating in ounces per square foot of sheet. For results to be reported in SI units, the specimen should have an area of 3330 mm^2 of sheet (57.7 ± 0.1 mm square or 65.1 ± 0.1 mm in diameter).

5.2 *Aluminum-Coated Wire*—Samples shall be secured as designated in the appropriate specification. The specimen of aluminum-coated wire may be of any length over 12 in. (approximately 300 mm), but preferably about 24 in. (approximately 600 mm). Where a continuous length is not available, shorter lengths totaling over 12 in., but preferably about 24 in., shall be used. Since the density of the steel is known (0.283 lb/in.^{3} or 7830 kg/m^3), it is not necessary to use a specific length of specimen.

5.3 *Aluminum-Coated Articles Other Than Sheet or Wire*—Samples for weight [mass] of coating determination shall be secured as designated in the appropriate specification. Except as otherwise provided, the specimens should have a minimum area of 3 in.^{2} [1935 mm^2] of aluminum-coated surface. For very small items, several pieces may have to be stripped to obtain the minimum area.

5.3.1 In the case of threaded articles, such as bolts and screws, the determination shall be made on a portion of the article that does not include any thread.

6. Procedure

6.1 Strip the aluminum coating from the specimens by using one of the following methods— the sodium hydroxide-hydrochloric acid method (method A), the hydrochloric acid-antimony trichloride-stannous chloride method (method B) or dilute hydrochloric acid method (method C).

NOTE 3—Methods A and B are the most common methods used for sheets.

6.2 Clean the specimens immediately before determining the weight [mass] by washing in petroleum ether or other suitable solvent, and dry thoroughly.

6.3 Determine the weight [mass] of the specimens individually to the nearest 0.01 g.

6.4 *Sodium Hydroxide-Hydrochloric Acid Method (method A)*—Heat the NaOH solution to approximately 195°F [90°C] (Note 4) and immerse each specimen in the hot solution until the strong reaction ceases. With silicon-free coatings, evolution of gas for considerable time is likely, but do not leave the specimens in the solution for more than a few minutes. Longer immersion inhibits the removal of coating during subsequent dips. Immersion of several specimens simultaneously is permitted provided all surfaces are freely exposed to the solution. Remove specimens from solution and scrub all surfaces under running tap water with a clean cellulose sponge to remove the loose deposit formed in the NaOH solution. Use vigorous scrubbing as necessary for some types of coating, but do not use abrasive materials to remove the deposit. Blot with a towel to remove most of the water (Note 5) and immerse each specimen singly for not more than 3 s in HCl (sp gr 1.18 to 1.19) at room temperature. Remove, scrub again under running tap water with a sponge, and re-immerse in the hot NaOH solution for not more than a few minutes or until action again ceases. Repeat this cycle until immersion in HCl shows no visible reaction (Note 6). Use one to three or more cycles as required, depending on the type and weight of coating. After the final immersion in the NaOH and HCl solutions, scrub as before, dry thoroughly, and determine the weight [mass] of each specimen to the nearest 0.01 g.

NOTE 4—This temperature is not critical, but the solution should be held several degrees below the boiling point (approximately 105°C) to prevent excessive foaming during the first immersion. The beaker used for heating the solution and immersing the specimens should be less than half full of solution to avoid the danger of foaming over when the specimens are immersed.

NOTE 5—Most of the water should be removed to prevent dilution of the HCl, as dilute HCl will attack the base metal to a greater extent than concentrated HCl.

NOTE 6—It is sometimes difficult to determine the point at which all of the alloy layer has been removed, when stripping silicon-free coatings. If in doubt, determine the weight [mass] of the specimen (after scrubbing and drying) and then put it through one additional stripping cycle. Loss in weight [mass] due to the additional cycle will be of the order of 0.005 g on a 2.25-in. [57.2-mm] square sheet specimen, if all the coating had been removed before the extra cycle.

6.5 *Hydrochloric Acid-Antimony Trichloride-Stannous Chloride Method (method B)*—After determining the weight [mass], immerse each specimen singly in a solution made by mixing 100 mL of antimony trichloride solution and 100 mL of stannous chloride solution (Note 7). Allow the specimen to remain immersed until the evolution of hydrogen has ceased. Action will stop after 1 to 4 min, or somewhat longer, depending on the thickness and silicon content of the coating. Use fresh solution for each test (Note 8). The temperature of the stripping solution shall not exceed 100°F [38°C]. After stripping, wash the specimen and scrub it with a soft cloth,

using a small amount of abrasive cleansing powder if necessary. Rinse the specimens and dry thoroughly with an absorbent cloth or paper, and determine the weight [mass] of each specimen to the nearest 0.01 g.

NOTE 7—Mix the antimony trichloride and stannous chloride solutions together as needed.

NOTE 8—Very heavy coatings may show residual coating after all action has stopped. If on examination after stripping, any coating still remains, repeat the immersion step using fresh solution.

6.6 *Dilute Hydrochloric Acid Method (1 + 1) (method C)*—After determining the weight (mass), immerse each specimen singly in the stripping solution and allow to remain until the violent evolution of hydrogen has ceased and only a few bubbles are being evolved. Action will stop after 1 to 4 min or somewhat longer depending on the thickness and silicon content of the coating. Use of the same solution is permitted until the time for stripping becomes inconveniently long. The temperature of the stripping solution shall at no time exceed 100°F [38°C]. After stripping, wash the specimens by scrubbing them under running water, dip in hot water and wipe or blow dry. Determine the weight [mass] of each specimen to the nearest 0.01 g.

6.7 *Sheet Specimens*—When measuring the total coating weight [mass] on both sides, or the single side coating weight [mass] on each side, determine the area of sheet (one surface) to the nearest 0.01 in.^{2} [5 mm^2]. If specimens were prepared to the dimensions as provided in Note 2, they shall be presumed to have an area of 5.08 in.^{2} [3330 mm^2]. When it is not possible to determine the area accurately, as in specimens from corrugated sheets, determine the average thickness of the stripped sheets to the nearest 0.001 in. [0.01 mm].

6.7.1 When determining the single side coating weight [mass] of sheet material, use the procedures described in 6.4, 6.5, or 6.6, except use a "stop-off" to protect the second side from the stripping medium. Acid-resistant paints or lacquers, acid-resistant tape, or mechanical devices fastened to the test specimen are examples of commonly used "stop-off" materials. Apply the "stop-off" to the specimen after the first determination of weight [mass] and remove before the second determination of weight [mass]. Because of the possibility of moisture absorption during the stripping process, the "stop-off" must not be on the specimen during either weight [mass] determinations. Determine the coating weight [mass] on the second side subsequently without a "stop-off" on the first side.

6.8 *Wire Specimens*—Determine the diameter of the stripped wire to the nearest 0.001 in. [0.01 mm] by taking the average of two measurements at right angles to each other.

6.9 *Specimens Other Than Sheet or Wire*—Determine the total coated area of the original specimen to the nearest 0.01 in.^{2} [5 mm^2]. Alternatively, for specimens of uniform thickness of base metal, such as a piece of plate or pipe, determine the average thickness of the stripped specimen to the nearest 0.001 in. [0.01 mm].

7. Calculation

7.1 *Aluminum-Coated Sheet:*

7.1.1 *Results in Inch-Pound Units:*

7.1.1.1 When the area of one surface of the sheet is determined, calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/A] \times K \quad (1)$$

where:

C = weight [mass] of coating, oz/ft^2 of sheet,
W_1 = original weight [mass] of specimen, g,
W_2 = weight [mass] of stripped specimen, g,
A = area of one surface of the sheet, in.^{2} or mm^2, and
K = a constant = 5.08 when A is in in.^{2}, or = 3.28 × 10^3 when A is in mm^2.

NOTE 9—If the specimen was prepared to the dimensions as provided in Note 2, having an area of 5.08 in.^{2}, the loss of weight [mass] in grams is numerically equal to the weight [mass] of coating in ounces per square foot of sheet.

7.1.1.2 When it is not possible to secure a specimen of measurable area, calculate the weight [mass] of coating as follows:

$$C = [(W_1 - W_2)/W_2] \times T \times K \quad (2)$$

where:

C = weight [mass] of coating, oz/ft^2 of sheet,
W_1 = original weight [mass] of specimen, g,
W_2 = weight [mass] of stripped specimen, g,
T = thickness of stripped sheet, in. or mm, and
K = a constant = 652 when T is in in., or = 25.7 when T is in mm.

7.1.2 *Results in Metric Units:*

7.1.2.1 When the area of one surface of the sheet is determined, calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/A] \times K \quad (3)$$

where:

C = weight [mass] of coating, g/m^2 of sheet,
W_1 = original weight [mass] of specimen, g
W_2 = weight [mass] of stripped specimen, g,
A = area of one surface of the sheet in in.^{2} or mm^2, and
K = a constant = 1.55 × 10^3 when A is in in.^{2}, or = 1 × 10^6 when A is in mm^2.

NOTE 10—If the specimen was prepared to the dimensions as provided in Note 2, having an area of 3330 mm^2 of sheet, the factor K/A is approximately 300, which may be used in the calculation.

7.1.2.2 When it is not possible to obtain a specimen of measurable area, calculate the weight [mass] of the coating as follows:

$$C = [(W_1 - W_2)/W_2] \times T \times K \quad (4)$$

where:

C = weight [mass] of coating, g/m^2 of sheet,
W_1 = original weight [mass] of the specimen, g,
W_2 = weight [mass] of the stripped specimen, g,
T = thickness of stripped sheet, in. or mm, and
K = a constant = 1.99 × 10^5 when T is in in., or = 7.83 × 10^3 when T is in mm.

7.2 *Aluminum-Coated Wire:*

7.2.1 *Results in Inch-Pound Units:*

7.2.1.1 Calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/W_2] \times D \times M \quad (5)$$

where:

C = weight [mass] of coating, oz/ft^2 of stripped wire surface,
W_1 = original weight [mass] of specimen, g,
W_2 = weight [mass] of stripped specimen, g,
D = diameter of stripped wire, in. or mm, and
M = a constant = 163 when D is in in., or = 6.42 when D is in mm

7.2.2 *Results in Metric Units:*

7.2.2.1 Calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/W_2] \times D \times M \quad (6)$$

where:

C = weight [mass] of coating, g/m^2 of stripped wire surface,
W_1 = original weight [mass] of specimen, g,
W_2 = weight [mass] of stripped specimen, g,
D = diameter of stripped wire, in. or mm, and
M = a constant = 4.97 × 10^4 when D is in in., or = 1.96 × 10^3 when D is in mm.

7.3 *Aluminum-Coated Articles Other Than Sheet or Wire:*

7.3.1 *Results in Inch-Pound Units:*

7.3.1.1 Calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/A] \times N \quad (7)$$

where:

C = weight [mass] of coating, oz/ft^2 of surface,
W_1 = original weight [mass] of specimen, g,
W_2 = weight [mass] of stripped specimen, g,
A = coated area of original specimen, in.^{2} or mm^2, and
N = a constant = 5.08 when A is in in.^{2}, or = 3.28 × 10^3 when A is in mm^2.

7.3.1.2 If the specimen has a uniform thickness of base metal, as an option to the procedure in 7.3.1.1, calculate the weight [mass] of the aluminum coating as follows:

$$C = [(W_1 - W_2)/W_2] \times G \times Z \quad (8)$$

where:

C = weight [mass] of coating, oz/ft^2 of surface,
W_1 = original weight [mass] of specimen, g,
W_2 = weight [mass] of stripped specimen, g,
G = thickness of stripped specimen, in. or mm, and
Z = a constant = 326 when G is in in., or = 12.8 when G is in mm.

7.3.2 *Results in Metric Units:*

7.3.2.1 Calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/A] \times N \quad (9)$$

where:

C = weight [mass] of coating, g/m^2 of surface,
W_1 = original weight [mass] of specimen, g,
W_2 = weight [mass] of stripped specimen, g,
A = coated area of original specimen, in.^{2} or mm^2, and
N = a constant = 1.55 × 10^3 when A is in in.^{2}, or = 1 × 10^6 when A is in mm^2.

7.3.2.2 If the specimen has a uniform thickness of base metal, as an option to the procedure in 7.3.2.1, calculate the weight [mass] of the aluminum coating as follows:

$$C = [(W_1 - W_2)/W_2] \times G \times Z \quad (10)$$

where:

C = weight [mass] of coating, g/m^2, of surface,
W_1 = original weight [mass] of specimen, g,
W_2 = weight [mass] of stripped specimen, g,
G = thickness of stripped specimen, in. or mm, and
Z = a constant = 9.95 × 10^4 when G is in in., or = 3.92 × 10^3 when$G$is in mm.

8. Report

8.1 Weight [mass] of coating on aluminum-coated sheet is expressed in weight [mass] per unit area of sheet, and is either the sum of the weights [masses] of coating on both sides of the sheet, or single side weight [mass] on each of the two sides. Weights [masses] of coating on each side of the sheet are not necessarily equal, even when both sides are exposed to the molten metal simultaneously. Coating weights [masses] on all aluminum-coated articles other than sheets are expressed in weight [mass] per unit area of surface.

8.2 Report the weight [mass] of aluminum coating to the nearest 0.01 oz/ft^2 when reporting in inch-pound units.

8.3 Report the weight [mass] of aluminum coating to the nearest 1 g/m^2 when reporting in metric (SI) units.

8.4 When the weight [mass] of coating of a number of specimens is to be averaged to determine conformance with a specification limit, the average value shall be reported to the precision of 8.2 and 8.3 in accordance with the rounding method of Practice E29.

9. Precision and Bias[4]

9.1 The precision of this test method is based on an interlaboratory study of A428 - 06, conducted in 2008. Fourteen laboratories tested a total of five different materials. Every "test result" represents an individual determination. The participating laboratories reported just a single test result for each material. Except for the exclusion of replicate results, Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:A05-1000.[5]

9.1.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

9.1.1.1 Repeatability limits cannot be determined from the results of this study, as no replicate data were reported.

[4] Research report available from ASTM Headquarters. Request RR:A05-1000.
[5] Research report available from ASTM Headquarters. Request RR:A05-1004.

9.1.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

9.1.2.1 Reproducibility limits are listed in Tables 1-3.

9.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

9.1.4 Any judgment in accordance with statements 9.1.1 and 9.1.2 would have an approximate 95 % probability of being correct.

9.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

9.3 The precision statement was determined through statistical examination of 210 results, from fourteen laboratories, on five materials. These five materials were described as the following:

Material A: T1-40
Material B: T1-40
Material C: T1-40
Material D: T1-40
Material E: T1-40

To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material.

10. Keywords

10.1 aluminum coating; coating weight [mass]; steel sheets; steel wire

TABLE 1 Top coating weight (oz/ft^2)

Material	Average[A]	Reproducibility Standard Deviation	Reproducibility Limit
	$\bar{X}$	s_R	R
A	0.224	0.0192	0.054
B	0.279	0.0292	0.082
C	0.292	0.0349	0.098
D	0.233	0.0183	0.051
E	0.219	0.0226	0.063

[A]The average of the laboratories' calculated averages.

TABLE 2 Bottom coating weight (oz/ft^2)

Material	Average[A]	Reproducibility Standard Deviation	Reproducibility Limit
	$\bar{X}$	s_R	R
A	0.205	0.0228	0.064
B	0.216	0.0260	0.073
C	0.203	0.0283	0.079
D	0.183	0.0191	0.053
E	0.188	0.0283	0.079

[A]The average of the laboratories' calculated averages.

TABLE 3 Total both sides coating weight (oz/ft^2)

Material	Average[A]	Reproducibility Standard Deviation	Reproducibility Limit
	$\bar{X}$	s_R	R
A	0.429	0.0230	0.064
B	0.494	0.0170	0.048
C	0.494	0.0134	0.037
D	0.417	0.0154	0.043
E	0.407	0.0138	0.039

[A]The average of the laboratories' calculated averages.