Designation: G 69 – 97 (Reapproved 2003)

Standard Test Method for
Measurement of Corrosion Potentials of Aluminum Alloys[1]

This standard is issued under the fixed designation G 69; 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.

1. Scope

1.1 This test method is a procedure for measurement of the corrosion potential (see Note 1) of an aluminum alloy in an aqueous solution of sodium chloride with enough hydrogen peroxide added to provide an ample supply of cathodic reactant.

NOTE 1—The corrosion potential is sometimes referred to as the open-circuit solution or rest potential.

1.2 *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:*
D 1193 Specification for Reagent Water[2]

3. Significance and Use

3.1 The corrosion potential of an aluminum alloy depends upon the amounts of certain alloying elements that the alloy contains in solid solution. Copper and zinc, which are two of the major alloying elements for aluminum, have the greatest effect with copper shifting the potential in the noble or positive direction, and zinc in the active or negative direction. For example, commercially unalloyed aluminum (1100 alloy)[3] has a potential of −750 mV when measured in accordance with this practice, 2024–T3 alloy with nearly all of its nominal 4.3 % copper in solid solution, a potential of −600 to −620 mV (Note 2), and 7072 alloy with nearly all of its nominal 1.0 % zinc in solid solution, a potential of − 885 mV (SCE) **(1-3)**.[4]

NOTE 2—The potential depends upon the rate of quenching.

3.2 Because it reflects the amount of certain alloying elements in solid solution, the corrosion potential is a useful tool for characterizing the metallurgical condition of aluminum alloys, especially those of the 2XXX and 7XXX types, which contain copper and zinc as major alloying elements. Its uses include the determination of the effectiveness of solution heat treatment and annealing **(1)**, of the extent of precipitation during artificial aging **(4)** and welding **(5)**, and of the extent of diffusion of alloying elements from the core into the cladding of alclad products **(2)**.

4. Apparatus

4.1 The apparatus consists of an inert container for the test solution, a mechanical support for the test specimens that insulates them electrically from each other and from ground, saturated calomel electrode (SCE) (see Note 3), wires and accessories for electrical connections, and equipment for the measurement of potential.

NOTE 3—Saturated calomel electrodes are available from several manufacturers. It is a good practice to ensure the proper functioning of the reference electrode by measuring its potential against one or more reference electrodes. The potential difference should not exceed 2 or 3 mV.[5]

4.2 A high-impedence ($>10^{12}\Omega$) voltmeter is suitable for measurement of the potential. Measurement of this potential should be carried out to within ± 1 mV. Automatic data recording systems may be used to permit the simultaneous measurement of many specimens and the continuous recording of corrosion potentials.

5. Reagents

5.1 *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.[6] 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.

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[1] This practice is under the jurisdiction of Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.11 on Electrochemical Measurements in Corrosion Testing.

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[2] *Annual Book of ASTM Standards,* Vol 11.01.

[3] All alloy designations are those of the Aluminum Association.

[4] The boldface numbers in parentheses refer to the references at the end of this standard.

[5] Round-robin test conducted by G01.11 (unpublished results).

[6] *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.

5.2 *Purity of Water*—The water shall be distilled or deionized conforming to the purity requirements of Specification D 1193, Type IV reagent water.

5.3 *Sodium Chloride* (NaCl).

5.4 *Hydrogen Peroxide* (H_2O_2) (30 %)—In case of uncertainty (for example, whenever freshly opened reagent is not used), the concentration of hydrogen peroxide in the reagent shall be confirmed by chemical analysis as described in Annex A1. In no case shall reagent containing less than 20 % hydrogen peroxide be used.

6. Solution Conditions

6.1 The test solution shall consist of 58.5 ± 0.1 g of NaCl and 9 ± 1 mL of 30 % hydrogen peroxide reagent per 1 L of aqueous solution. (This solution is 1 *M* with respect to concentration of sodium chloride.)

6.2 The hydrogen peroxide reagent shall be added just before measurements are made because it decomposes upon standing.

6.3 Freshly prepared solution shall be used for each set of measurements.

6.4 Not less than 500 mL of solution shall be used for each set of measurements.

6.5 The total exposed area of all the specimens of the same composition in each set of measurements shall not exceed 100 mm^2 per 100 mL of solution.

6.6 The temperature of the test solution shall be maintained at 25 ± 2°C.

7. Test Specimen

7.1 For measurement alone, specimen size is unimportant provided that the area for measurement is at least 25 mm^2, but for convenience the specimen, wherever possible, should be large enough to permit ease of handling during preparation and an electrical connection outside the test solution. A specimen a few millimetres thick by about 15 mm wide and 100 mm long is a convenient size.

8. Specimen Preparation

8.1 Any convenient means such as sawing or stamping may be used to prepare a specimen to size provided that it does not heat the specimen enough to change its metallurgical structure.

8.2 Irregular-shaped specimens shall be machined or prepared with a coarse file to provide a reasonably flat surface and to remove nonrepresentative metal (for example, affected by sawing or stamping, or in case of clad product where core is to be measured). Further preparation consists of filing with a long lathe file. Original flat surface specimens are also filed with long lathe file to remove the original mill scale oxide layer.

8.3 No filing or machining is needed to prepare specimens that have original flat surface, representative of its metallurgical structure, or to prepare specimens that are too thin to permit more than minimal removal of metal; these include clad products with thin claddings which are to be measured.

8.4 The surfaces of all products selected for measurement, including those with no previous preparation, are abraded dry with No. 320 grade aluminum oxide or silicon carbide cloth and then with No. 00 steel wool.

NOTE 4—**Caution:** Clad products with thin claddings should only be abraded lightly except to remove the cladding for measurement of the core.

8.5 Following mechanical preparation, the specimen is cleaned, or degreased, in an inert solvent (for example, acetone or perchloroethylene).

8.6 All parts of a specimen and its electrical connection to be exposed in the test solution, except for the area of the specimen prepared for measurement, are masked off. Any material that masks a surface physically and electrically and that is inert in the test solution may be used (see Annex A2).

9. Procedure

9.1 For corrosion potential measurements, the test specimens and the reference electrode are immersed in the appropriate quantity of test solution; the test specimens are connected to the positive terminal of the equipment for measuring potential, and the reference electrode to the negative terminal.

9.2 Care should be taken to ensure that all the unmasked area of each test specimen prepared for measurement is exposed to the test solution and that any other unmasked area is not exposed. Care should also be taken to ensure that any unmasked portion of the electrical connection is outside the test solution.

9.3 The potential of each specimen shall be measured at 5-min intervals for a period of 1 h or recorded continuously using the output of a high-impedance voltmeter.

9.4 The potential of each specimen shall be reported as the average of the values for the last 30 min of measurement (that is, for the last 7 measurements).

9.5 Duplicate specimens shall be measured.

9.6 The average of the values for duplicate specimens shall be used if the values agree within 5 mV. If they do not agree within 5 mV at least one additional specimen shall be measured. The values for the three or more specimens shall be averaged if they agree within 10 mV but they shall be reported individually if they do not agree.

10. Standardization of Test Procedure

10.1 The test procedure shall be standardized by measurement of the free corrosion potential of a sample of commercially produced 3003 alloy sheet. Sheet of any temper is suitable because the potential of this product is not affected significantly by temper.

10.2 The procedure shall be considered acceptable if the value obtained is −748 ± 11 mV (SCE).

11. Report

11.1 The following information shall be recorded:

11.1.1 Identification of product, alloy, and temper including reference to applicable specifications.

11.1.2 The results of all measurements with an indication of whether they represent individual values or averages; and if averages, also the number of values averaged.

12. Precision and Bias

12.1 *Precision*—The precision of this test method was determined by the statistical examination of the interlaboratory test results.[7]

12.1.1 *Repeatability*—The repeatability (within laboratory variability) standard deviation (S_r and the 95 % limit (r = 2.8 S_r) was determined for two alloys as follows:

Alloy	Average	S_r	r(95 %)
1100-H18	−758 mV	0.0018	±5.1 mV
3003-H18	−748 mV	0.0017	±4.7 mV

12.1.2 *Reproducibility*—The reproducibility (between laboratory variability) standard deviation (S_R) and the 95 % limit (R = 2.8 S_R) was determined for two alloys as follows:

Alloy	Average	S_R	R(95 %)
1100-H18	−758 mV	0.0018	±12 mV
3003-H18	−748 mV	0.0017	±11 mV

12.2 *Bias*—No information can be presented on the bias of the procedure in this test method because no accepted external reference value is available. The values for corrosion potential of aluminum alloys as measured by this test method are defined only in terms of this method.

13. Keywords

13.1 aluminum alloy; aqueous; copper; corrosion potential; sodium chloride; solid solution; zinc

ANNEXES

(Mandatory Information)

A1. ANALYSIS OF HYDROGEN PEROXIDE REAGENT

A1.1 Dilute a sample of the hydrogen peroxide reagent to contain approximately 6 g H_2O_2/L. Then pipet a 10-mL aliquot of this solution into a beaker to which has already been added 400 mL of water and 15 mL of 50 % sulfuric acid. Titrate this solution with standard 0.1 *N* potassium permanganate solution.

A1.2 To obtain the grams of hydrogen peroxide per litre of reagent, multiply the millilitres of potassium permanganate solution used by 0.1 times 0.017 times the aliquot factor. Tables in chemical handbooks provide the data required to convert grams per litre of hydrogen peroxide to percent.

A1.3 Some stabilizers used with hydrogen peroxide react with permanganate, but this interference can be ignored whenever the analysis given by the manufacturer was also determined by permanganate analysis.

A2. MASKING MATERIALS

A2.1 Materials suitable for masking are made by several manufacturers.

A2.2 A satisfactory masking material can be prepared by adding powdered rosin gradually to melted beeswax until saturation is obtained. Several hours may be required because of the slow rate of dissolution of the rosin.

APPENDIX

(Nonmandatory Information)

X1. CONVERSION FACTORS FOR POTENTIALS

X1.1 Many corrosion potentials of aluminum alloys in the literature were measured in an aqueous solution at 25°C containing 53 g of NaCl and 9 mL of 30 % H_2O_2/L. The potentials were measured with a 0.1 *N* calomel electrode with its tip immersed directly into the solution without bridging.

X1.2 To a good approximation, values measured under X1.1 may be converted to those measured by this practice bythe addition of 92 mV (for example, −830 mV converts to −738 mV).

X1.3 Alternatively, values measured by this practice may be converted to those measured under X1.1 by the subtraction of 92 mV (for example, −738 mV converts to −830 mV).

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[7] Supporting data are available from ASTM Headquarters. Request Research Report RR:G01.1015.

REFERENCES

(**1**) Brown, R. H., Fink, W. L., and Hunter, M. S., "Measurement of Irreversible Potentials as a Metallurgical Research Tool," *Transactions of the American Institute of Mining and Metallurgical Engineers*, Institute of Metals Division, Vol 143, 1941, pp. 115–123.

(**2**) Brown, R. H., "Aluminum Alloy Laminates: Alclad and Clad Aluminum Alloy Products," Chapter 11 in *Composite Engineering Laminates*, G. H. Dietz (editor), MIT Press, Cambridge, Mass., 1969.

(**3**) Anderson, W. A., and Stupf, H. C., *Corrosion Magazine*, Vol 6, 1980, p. 212.

(**4**) Lifka, B. W., and Sprowls, D. O., "Significance of Intergranular Corrosion in High Strength Aluminum Alloys," *Symposium on Localized Corrosion—Cause of Metal Failure, ASTM STP 516*, Am. Soc. Testing Mats., 1972, pp. 120–44.

(**5**) Shumaker, M. B., Kelsey, R. A., Sprowls, D. O., and Williamson, J. G., "Evaluation of Various Techniques for Stress Corrosion Testing Welded Aluminum Alloys," *Symposium on Stress Corrosion Testing, ASTM STP 425*, Am. Soc. Testing Mats., 1967, pp. 317–41.

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