This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: G34 – 23

Standard Test Method for Exfoliation Corrosion Susceptibility in 2XXX and 7XXX Series Aluminum Alloys (EXCO Test)[1]

This standard is issued under the fixed designation G34; 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 a procedure for constant immersion exfoliation corrosion (EXCO) testing of high-strength 2XXX (see Note 2) and 7XXX series aluminum alloys.

NOTE 1—This test method was originally developed for research and development purposes; however, it is referenced, in specific material specifications, as applicable for evaluating production material (refer to Section 14 on Precision and Bias).

NOTE 2—Some Al-Cu-Li alloys are registered in the 2xxx family. This test method has been reported as non representative of performance in outdoor atmospheres for various Al-Cu-Li alloys in both as-quenched and artificially aged tempers.[2]

1.2 This test method applies to all wrought products such as sheet, plate, extrusions, and forgings produced from conventional ingot metallurgy process.

1.3 This test method can be used with any form of specimen or part that can be immersed in the test solution.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D1193 Specification for Reagent Water

E3 Guide for Preparation of Metallographic Specimens

G112 Guide for Conducting Exfoliation Corrosion Tests in Aluminum Alloys

G193 Terminology and Acronyms Relating to Corrosion

2.2 *ASTM Adjunct:*

Adjunct to G34 Test Method for Exfoliation Corrosion Susceptibility in 2XXX and 7XXX Series Aluminum Alloys (EXCO Test) (Digital PDF illustrations of appearance classifications – 6 glossy photos (B&W))[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *exfoliation corrosion, n*—subsurface corrosion that proceeds laterally from the sites of initiation along planes parallel to the surface forming corrosion products that force metal away from the body of the material, giving rise to a layered appearance resembling the pages of a book (Terminology G193).

4. Summary of Test Method

4.1 This test method provides an accelerated exfoliation corrosion test for 2XXX and 7XXX series aluminum alloys that involves the continuous immersion of test materials in a solution containing 4 *M* sodium chloride, 0.5 *M* potassium nitrate, and 0.1 *M* nitric acid at 25 °C ± 3 °C (77 °F ± 5 °F). The susceptibility to exfoliation is determined by visual examination, with performance ratings established by reference to standard photographs.

[1] This test method is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.05 on Laboratory Corrosion Tests.

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[2] Colvin, E. L., and Murtha, S. J., "Exfoliation Corrosion Testing of Al-Li Alloys 2090 and 2091," Proceedings of the Fifth International Aluminum-Lithium Conference, Williamsburg, VA, Materials and Component Engineering Publications Ltd, U.K., March 24–31, 1989, p. 1251.

[3] 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.

[4] Available from ASTM International Headquarters. Order Adjunct No. ADJG003402-E-PDF. Original adjunct produced in 1980.

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5. Significance and Use

5.1 This test method was originally developed for research and development purposes; however, it is referenced, in specific material specifications, as applicable for evaluating production material (refer to Section 14 on Precision and Bias).

5.2 Use of this test method provides a useful prediction of the exfoliation corrosion behavior of these alloys in various types of outdoor service, especially in marine and industrial environments.[5] The test solution is very corrosive and represents the more severe types of environmental service, excluding, of course, unusual chemicals not likely to be encountered in natural environments.

5.3 The exfoliation ratings were arbitrarily chosen to illustrate a wide range in resistance to exfoliation in this test. However, it remains to be determined whether correlations can be established between EXCO test ratings and realistic service conditions for a given alloy. For example, it has been reported[6] that samples of Al-Zn-Mg-Cu alloys rated EA or P in a 48 h EXCO test did not develop more than a slight amount of incipient exfoliation (EA) during six- to nine-year exposures to seacoast atmospheres, whereas, ED rated materials in most cases developed severe exfoliation within a year in the seacoast atmosphere.

6. Apparatus

6.1 Any suitable glass, plastic, or similarly inert container can be used to contain the solution and specimens during the period of test. Depending upon the shape and size of the specimens, rods or racks of glass, plastic, or any inert substance shall be used to support the specimen above the bottom of the container. The container should be fitted with a loose-fitting cover to reduce evaporation.

7. Reagents

7.1 *Purity of Reagents*—The test solution shall be prepared with reagent grade sodium chloride (NaCl), potassium nitrate (KNO_3), and nitric acid (HNO_3).

7.2 *Purity of Water*—Distilled or deionized water shall be used to prepare test solution. The water purity must conform to Specification D1193, Type IV reagent water, except that for this method, the values of chloride and sodium can be disregarded.

7.3 A test solution of the following composition shall be used:

NaCl	(4.0 *M*)
KNO_3	(0.5 *M*)
HNO_3	(0.1 *M*)

Dissolve 234 g of NaCl, 50 g of KNO_3 in water, and add 6.3 mL of concentrated HNO_3 (70 weight %). Dilute to 1 L. This solution has an apparent pH of 0.4.

7.4 The solution shall be maintained at a temperature of 25 °C ± 3 °C (77 °F ± 5 °F).

8. Sampling

8.1 Sampling procedures are not considered applicable to this test method, as they are often covered by product specifications. It is assumed that the test specimens are removed from representative samples of materials.

9. Test Specimens

9.1 Specimens may be of any practical size or shape. Nevertheless, for the results to be of most significance a specimen size of at least 50 mm by 100 mm (2 in. by 4 in.), or the equivalent, is recommended.

9.2 The edges of sawed specimens need not be machined, but specimens obtained by blanking or shearing shall have edges dressed by machining or filling to a depth equal to the thickness of the specimen to remove cold-worked metal.

9.3 Remove the cladding of alclad sheet by machining the test surface; remove or mask the cladding on the back side (non-test surface) also.

9.4 When removing test specimens from extrusions and forgings, take care to avoid specimen locations underneath flanges, ribs, etc., where the grain structure is usually variable.

10. Standardization

10.1 To provide an indication when some inadvertent deviation from the correct test conditions occurs, it is necessary to expose to the test at regular intervals a control specimen of a material with known resistance. This control should exhibit the same degree of exfoliation each time it is included in the test.

10.2 The control may be any material of the alloy type included in the scope of this test method, preferably one with an intermediate degree of susceptibility (Fig. 1 and Fig. 2).

11. Procedure

11.1 Degrease the specimens with a suitable solvent.

11.2 Mask the back surfaces of the specimens to minimize corrosion of non-test areas. Protective coatings must have good adherence to avoid crevice corrosion beneath the coating; also, they should not contain leachable ions or protective oils that will influence the corrosion of the test surface. (See Figs. 1-6.)[4]

11.3 Use the solution in sufficient quantity to provide a volume-to-metal surface area ratio of 10 mL/cm^2 to 30 mL/cm^2 (65 mL/in.^{2} to 200 mL/in.^{2}). Include all exposed metal area in the determination of total surface area.

11.4 Use fresh solution at the start of each test. Do not change the solution even though the pH increases during the test. It is normal for the pH to increase from the initial apparent

[5] Ketcham, S. J., and Jeffrey, P. W., "Exfoliation Corrosion Testing of 7178 and 7075 Aluminum Alloys" (Report of ASTM G01.05 Interlaboratory Testing Program in Cooperation with the Aluminum Association); and Sprowls, D. O., Walsh, J. D., and Shumaker, M. B., "Simplified Exfoliation Testing of Aluminum Alloys," *Localized Corrosion—Cause of Metal Failure, ASTM STP 516*, ASTM, 1972.

[6] Sprowls, D. O., Summerson, T. J., and Loftin, F. E., "Exfoliation Corrosion Testing of 7075 and 7178 Aluminum Alloys—Interim Report on Atmospheric Exposure Tests" (Report of ASTM G01.05.02 Interlaboratory Testing Program in Cooperation with the Aluminum Association); and Lifka, B. W. and Sprowls, D. O., "Relationship of Accelerated Test Methods for Exfoliation Resistance in 7XXX Series Aluminum Alloys With Exposure to a Seacoast Atmosphere," *Corrosion in Natural Environments, ASTM STP 558*, ASTM, 1974.

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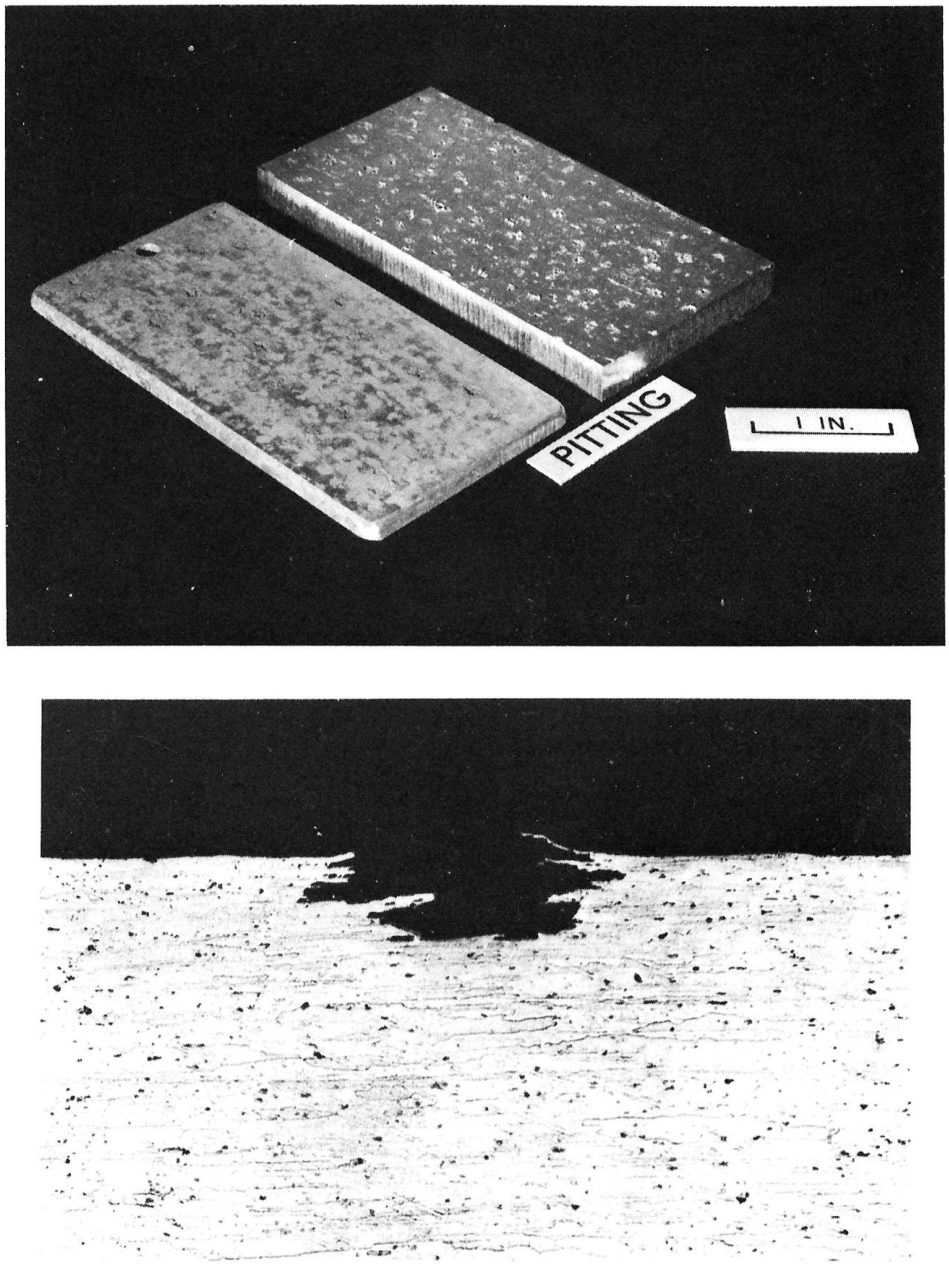

Undermining pitting that may form the surface give the appearance of incipient exfoliation (Keller's Etch; 100×).

FIG. 1 Examples of Pitting Corrosion

value of 0.4 to about 3 during the first several hours depending upon the amount of corrosion that occurs.

11.5 Immerse the specimens in the solution using rods or racks of inert material to support the specimens above the bottom of the container. Place the test surface upward in a horizontal position to prevent loss of exfoliated metal from the surface of the specimen. Do not concurrently immerse in the same container alloys containing less than 0.25 % copper with those containing greater amounts of copper.

11.6 The following maximum periods of exposure are recommended for testing the alloy types indicated:

2XXX Series	96 h
7XXX Series	48 h

The length of time to develop exfoliation in material of a given alloy and temper may vary with the mill product form, with some materials developing severe exfoliation in much shorter periods than those listed. Therefore, unless specified

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