Designation: G 52 – 00

Standard Practice for Exposing and Evaluating Metals and Alloys in Surface Seawater[1]

This standard is issued under the fixed designation G 52; 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 As contrasted with deep ocean testing **(1)**, this practice covers conditions for the exposure of metals, alloys, and other materials in natural surface seawater such as those typically found in bays, harbors, channels, and so forth **(2, 3)**. This practice covers full immersion, tidal zone and related splash, and spray zone exposures.

1.2 It sets forth general procedures that should be followed in conducting seawater exposure tests so that meaningful comparisons may be made from one location to another, as described, for example, in **(2, 3)**.

1.3 This practice identifies recommended procedures for evaluating the effects of natural surface seawater on the materials exposed.

NOTE 1—Terms relative to this subject matter can be found in Terminology G 15.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 3623 Test Method for Testing Anti-fouling Panels in Shallow Submergence[2]

G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens[3]

G 15 Terminology Relating to Corrosion and Corrosion Testing[3]

G 30 Practice for Making and Using U-Bend Stress-Corrosion Test Specimens[3]

G 38 Practice for Making and Using C-Ring Stress-Corrosion Test Specimens[3]

G 39 Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens[3]

G 46 Guide for Examination and Evaluation of Pitting Corrosion[3]

G 58 Practice for Preparation of Stress-Corrosion Test Specimens for Weldments[3]

G 78 Guide for Crevice Corrosion Testing of Iron Base and Nickel Base Stainless Alloys in Seawater and Other Chloride-Containing Aqueous Environments

3. Significance and Use

3.1 The procedures described herein are recommended for evaluating the corrosion or marine fouling behavior, or both, of materials exposed to quiescent or local tidal flow conditions, or both.

3.1.1 This practice is not intended to cover the influence of high seawater velocity or the behavior of materials in seawater which has been transported from its source.

3.1.2 Some aspects of this practice may be applicable to testing in tanks and troughs which are continuously provided with fresh surface seawater. Additionally, some aspects may also be applicable to deep ocean testing.

NOTE 2—Guide G 78 provides guidance for conducting crevice corrosion tests under controlled seawater test conditions.

3.2 While the duration of testing may be dictated by the test objectives, exposures of more than six months or one year are commonly used to minimize the effects of environmental variables associated with seasonal changes or geographic location, or both.

3.3 The procedures described are applicable for the exposure of simple test panels, welded test panels, or those configured to assess the effects of crevices, or both, such as those described in Guide G 78. In addition, they are useful for testing of actual components and fabricated assemblies.

3.4 It is prudent to include control materials with known resistance to seawater corrosion or fouling, or both, as described in Test Method D 3623.

NOTE 3—Materials which have been included in ASTM Worldwide Seawater Corrosivity Studies include UNS K01501 (carbon steel), UNS C70600 (90/10 CuNi) and UNS A95086 (5086-H116 Al) **(2, 3)**.

NOTE 4—In the case of evaluations of aluminum alloys, care should be exercised in the location of specimens near copper or high copper-containing alloys. In some instances, it is not sufficient to simply electrically isolate specimens to prevent bi-metallic (galvanic) corrosion; copper ions from nearby corroding copper or copper-base alloys can

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[1] This practice is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals, and is the direct responsibility of Subcommittee G01.09on Corrosion in Natural Waters.

Current edition approved May 10, 2000. Published June 2000. Originally published as G 52 – 76. Last previous edition G 52 – 88 (1993).

[2] *Annual Book of ASTM Standards*, Vol 06.02.

[3] *Annual Book of ASTM Standards*, Vol 03.02.

deposit on aluminum and accelerate its corrosion.

4. Test Sites

4.1 Test sites should be chosen at locations representative of natural seawater environments where the metals or alloys to be tested may be used. Ideally, a natural seawater test site should have clean, uncontaminated seawater, be in a protected location, and have facilities for such tests as splash, tidal, and full immersion. Reference should be made to tropical versus other conditions, and seasonal variations in temperature and in deposition of marine growth on the test panels with a defined "fouling season."

4.2 Periodic observations of critical water parameters should be made and reported; depending on the experiment, these might include water temperature, salinity, conductivity, pH, oxygen content, and tidal flow (velocity). If there is concern about the quality of water at the test site, it is suggested that ammonia, hydrogen sulfide, and carbon dioxide be determined periodically using analytical chemistry procedures.[4]

5. Exposure Racks

5.1 Test racks should be constructed of a material that will remain intact for the entire proposed period of exposure. Nickel-copper alloy 400 (UNS No. N04400) has been found to be an excellent material, but is not recommended for holding aluminum specimens. Coated aluminum racks (6061-T6 or 5086-H32) also have given satisfactory service. Nonmetallic racks made from reinforced plastic or treated wood might also be used.

5.2 Specimens must be insulated from the test racks. Mounting devices made of porcelain and other non-metallic materials are commonly used. It should be recognized that the specimen contact areas with mounting devices may produce crevice corrosion of some susceptible materials, for example, some stainless steel and aluminum alloys.

NOTE 5—Bolts used to secure the insulators must be galvanically compatible with the test rack.

5.3 Spacing of the mounted specimens can be important. It is desirable to have sufficient space between surfaces of test specimens to ensure that adequate water flows between them and that with long exposures the accumulated fouling will not block off the surface to the presence of the seawater environment.

5.4 Specimen location maps or charts should be prepared and maintained to ensure positive identification at the conclusion of testing. Pre-exposure photographs of assembled test racks are useful.

5.5 Racks may be suspended by such materials as nylon, polyester, or polypropylene rope depending on prevailing conditions. Steel wire rope should be avoided.

5.5.1 For multiple year exposures, it is recommended that the rack support rope be resistant to degradation by seawater as well as ultraviolet light.

5.6 Exposure racks should be suspended so that attached specimens will be oriented vertically and subjected to the full effects of the seawater but free of galvanic contact with other specimens and with minimal sedimentation of silt and debris on the specimen.

5.6.1 It should be recognized that in time some support ropes may stretch due to the added mass of marine fouling. In shallow waters, this should be taken into account to avoid unwanted contact with the sea bed or bottom. In some cases, the added mass will also make test rack removal more difficult.

NOTE 6—It should be recognized that barnacles attached to rack support ropes will create potential hazards if manual lifting is required.

5.7 If periodic removals are envisioned, it is recommended that different racks be utilized to support specimens for each test period. Otherwise, marine fouling and corrosion products on other specimens may be disturbed and possibly affect subsequent behavior of the test material.

5.7.1 It is prudent to check the security of support ropes and the presence of the test racks from time-to-time.

6. Specimens

6.1 When the material to be tested is in sheet form, a nominal specimen size of 100 by 300 mm (approximately 4 by 12 in.) is recommended. Specimens may be larger or smaller to suit a particular test.

6.2 Odd shaped samples and assemblies comprising like or dissimilar metals can also be tested. If testing materials in odd shapes (bolts, nuts, pipes, etc.) is desired, a means of supporting them in the test racks must be devised. It is important that the specimens be electrically insulated from their respective supports and from each other to prevent formation of galvanic corrosion cells. In some instances it is not sufficient to isolate specimens electrically to prevent corrosion of one material. For example, great care must be exercised with aluminum specimens or racks so that they will not be contaminated by copper, which will cause accelerated corrosion of the aluminum. A galvanic couple is not necessary to accelerate the corrosion of aluminum by copper. Copper or alloys containing copper physically located in the vicinity of aluminum may corrode sufficiently so that accelerated corrosion of the aluminum may be caused by copper deposition on the aluminum. (See Note 4.) Again, appropriate insulating supports are required.

6.2.1 Some specimen configurations for evaluating resistance to crevice corrosion or stress corrosion cracking may be tested under this practice. Examples are provided in Guide G 78, Practices G 30, G 38, G 39, and G 58.

6.3 The total number of test specimens required should be determined from a knowledge of the duration of the test and the planned removals of the specimens for intermediate evaluations. For reliable results, a sufficient number of replicate specimens should be used for removal at each exposure period. Triplicate specimens for each exposure period will usually satisfy this requirement. A suitable removal schedule might be 0.5, 1, 2, 5, 10, and 20 years. In case of uncertainty as to an alloy's corrosion resistance, shorter intervals might be appropriate, and corrosion rate data may be used to establish more appropriate exposure periods.

7. Preparation of Specimens

7.1 *Identification*—Specimens should be marked in a manner that will ensure identification for the life of the test. One

[4] *Annual Book of ASTM Standards*, Vols 11.01 and 11.02.

proven method is to use a series of notches or drilled holes arranged according to some desired code. Numbers stamped on relatively corrosion-resistant materials may be suitable for some tests. Another method is to attach a corrosion-resistant metal tag (for example, alloy 625 (UNS No. N06625), alloy C276 (UNS No. N10276), titanium, or alloy 400 (UNS No. N04400), (except for aluminum alloys), or PTFE) by means of an insulating cord and a suitably located hole.

NOTE 7—In long term tests, unless fabricated from antifouling materials, identification tags may also become encrusted with marine fouling.

7.2 *Cleaning*—Oil, grease, and dirt should be removed by degreasing with a solvent cleaner and scrubbing to remove insoluble soils. Mill scale should be removed from all test specimens unless it is specifically desired to perform the test with the mill scale intact. Pickling with an appropriate acid (see Practice G 1) grit blasting or machining are acceptable descaling methods. If acid pickling is used, care must be taken to stop the pickling action as soon as the mill scale has been removed. It is recommended that the finish be as close as possible to the condition in which the material will be used. To facilitate examination of exposed specimens, it is important that a uniform finish be applied to the surface; that is, there should be no pits or other depressions which might look like corrosion attack. To facilitate meaningful examination of exposed specimens it is important that any irregularities on the specimen surfaces be noted initially so that these areas will not be confused with pits or other corrosion at the completion of the experiments.

7.2.1 When a specific surface finish, such as pickled, scaled, as welded, sandblasted, or ground, is to be evaluated, the finish on the test specimens should be in accordance with test requirements. Thus, two types of tests are involved here: (*1*) an alloy evaluation test with the surface finish as close as possible to the condition in which the material will be used, and (*2*) a surface finish test.

7.2.2 To facilitate examination of exposed specimens, it is important that the pre-test surface condition be as defect-free as possible. Pre-existing pits and other depressions should be noted (or photographed) to avoid possible confusion during final inspection.

7.3 *Weighing*—Specimens should be weighed to the precision preferred by the investigator, usually ± 1 mg. Records should be kept of the mass, physical dimensions, and appearance of each specimen, including surfaces and edges, at the beginning of the test. Changes in the physical appearance and any corrosion losses of the specimen due to exposure can then be determined.

8. Evaluation of Test Specimens

8.1 Remove specimens from exposure at the scheduled times or other appropriate times.

8.2 Without scratching the specimens, scrape off marine growth and barnacles (Note). Clean the panels in accordance with Practice G 1, and then reweigh to precisions established by the investigator. For certain tests, it may be of interest to preserve corrosion products for laboratory evaluation. Photographs before and after cleaning are usually valuable documentation.

NOTE 8—Plastic or wooden scrapers should be used to remove barnacles.

8.3 Determine the mass loss of each specimen from the pre- and post-exposure weighings and convert the results to a corrosion rate (Practice G 1) or plot as mass loss per unit area versus exposure time. Where the corrosion is highly localized (as in pitting or specimens with crevice attack) the calculation of corrosion rates from mass loss data can be misleading. In these cases, the tensile properties of the exposed specimens can be determined and compared with the tensile properties of unexposed replicate specimens.

8.4 Measure the depth of attack and describe in detail with attention to changes at the edges as well as the surface of the specimen. Take care during the evaluation of specimens to recognize any other specific forms of attack, such as stress corrosion cracking and dealloying.

8.5 Mechanical properties of exposed specimens, or specimens cut from exposed panels, can be compared with the corresponding properties of unexposed material.

8.6 When testing of materials (including coated test panels) for resistance to fouling, the as-removed mass (specimen plus fouling) can be compared with the original mass of the specimen. It is recommended that a consistent period of time between removal and weighing be established.

8.6.1 When possible, identification of the attached fouling species may be beneficial. It should be recognized that different species may dominate at different times of the year in some surface seawater locations.

8.6.2 Concurrent exposure of highly susceptible (for example, plexiglass, PVC, slate) controls and highly resistant (for example, UNS C12200, C70600, C71500) controls should be considered for relative fouling-resistance rating of the test materials (see Test Method D 3623).

9. Report

9.1 The report should include detailed descriptions of the exposed specimens, pertinent data on exposure conditions, any deposits formed, and results of the corrosion evaluation.

9.2 Data for the exposed specimens should include physical dimensions, chemical composition, metallurgical history, surface preparation, and after-exposure cleaning methods.

9.3 Details of exposure conditions should include location, depth, dates and periods of exposure, and a description of the seawater conditions prevailing during the exposure period. A general description of the seawater conditions on a monthly basis is normally sufficient.

9.3.1 A more detailed compilation might be justified for certain tests. For example, in the case of pitting, assessment of the results should follow the reporting outlined in Practice G 46.

9.4 The results of the tests should be expressed as corrosion rate, such as penetration per unit time (for example, mm/year or µm/year), or loss in thickness over the exposure period, or plotted as mass loss per unit area versus exposure time. The corrosion rates will be the average of both surfaces and edges of a panel.

In the case of crevice corrosion, Guide G 78 may be useful.

9.5 Any changes in the physical appearance of the specimens during the exposure period should be noted. If the corrosive attack is nonuniform (that is, if pitting or crevice attack is predominant), the corrosion rate data can be misleading.

9.6 If the tensile properties of the specimens are measured after exposure, any tensile strength loss should be reported as a percentage loss compared to both the original and control tensile properties of unexposed material.

9.7 A comparison of the corrosion data from the test specimens with corrosion data from the control specimens will determine the relative merit of the material in question.

10. Keywords

10.1 evaluation and reporting; exposure conditions; fouling tests; specimen preparation; surface seawater corrosion tests; test racks

REFERENCES

(**1**) Reinhart, F.M., "Corrosion of Materials in Hydrospace," Technical Report R-304, U.S. Naval Civil Engineering Laboratory, Port Hueneme, CA, December 1966.

(**2**) Kirk, W.W. and Pikul, S.J., "Seawater Corrosivity Around the World: Results from Three Years of Testing,"*ASTM STP 1086 Corrosion in Natural Waters*, 1990, pp. 3-36.

(**3**) Phull, B.S., Pikul, S.J., and Kain, R.M., "Seawater Corrosivity Around the World: Results from Five Years of Testing,"*ASTM STP 1300 Corrosion in Natural Waters*, Vol 2, 1997, pp. 34-73.