Designation: G78 – 20

Standard Guide for Crevice Corrosion Testing of Iron-Base and Nickel-Base Stainless Alloys in Seawater and Other Chloride-Containing Aqueous Environments[1]

This standard is issued under the fixed designation G78; 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.

INTRODUCTION

Crevice corrosion of iron-base and nickel-base stainless alloys can occur when an occlusion or crevice limits access of the bulk environment to a localized area of the metal surface. Localized environmental changes in this stagnant area can result in the formation of acidic/high chloride conditions that may result in initiation and propagation of crevice corrosion of susceptible alloys.

In practice, crevices can generally be classified into two categories: (*1*) naturally occurring, that is, those created by biofouling, sediment, debris, deposits, etc. and (*2*) man-made, that is, those created during manufacturing, fabrication, assembly, or service. Crevice formers utilized in laboratory and field studies can represent actual geometric conditions encountered in some service applications. Use of such crevice formers in service-type environments are not considered accelerated test methods.

The geometry of a crevice can be described by the dimensions of crevice gap and crevice depth. Crevice gap is identified as the width or space between the metal surface and the crevice former. Crevice depth is the distance from the mouth to the center or base of the crevice.

1. Scope

1.1 This guide covers information for conducting crevice-corrosion tests and identifies factors that may affect results and influence conclusions.

1.2 These procedures can be used to identify conditions most likely to result in crevice corrosion and provide a basis for assessing the relative resistance of various alloys to crevice corrosion under certain specified conditions.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

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.* For a specific warning statement, see 7.1.

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:*[2]

G1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens

G4 Guide for Conducting Corrosion Tests in Field Applications

G46 Guide for Examination and Evaluation of Pitting Corrosion

G48 Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

G52 Practice for Exposing and Evaluating Metals and Alloys in Surface Seawater

[1] This guide is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.04 on Corrosion of Metals in Natural Atmospheric and Aqueous Environments.

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[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.

G193 Terminology and Acronyms Relating to Corrosion

3. Terminology

3.1 Definitions of related terms can be found in Terminology G193.

4. Significance and Use

4.1 This guide covers procedures for crevice-corrosion testing of iron-base and nickel-base stainless alloys in seawater. The guidance provided may also be applicable to crevice corrosion testing in other chloride containing natural waters and various laboratory prepared aqueous chloride environments.

4.1.1 While this guide focuses on testing of iron-base and nickel-base stainless alloys, the procedures and evaluations methods described herein have been successfully applied to characterize the crevice corrosion performance of other alloy systems (see, for example, Aylor et al.[3]).

NOTE 1—In the case of copper alloys, the occurrence of crevice-related corrosion associated with different corrosion mechanisms takes place immediately adjacent to the crevice former rather than within the occlusion.

4.2 This guide describes the use of a variety of crevice formers including the nonmetallic, segmented washer design referred to as the multiple crevice assembly (MCA) as described in 9.2.2.

4.3 In-service performance data provide the most reliable determination of whether a material would be satisfactory for a particular end use. Translation of laboratory data from a single test program to predict service performance under a variety of conditions should be avoided. Terms, such as immunity, superior resistance, etc., provide only a general and relatively qualitative description of an alloy's corrosion performance. The limitations of such terms in describing resistance to crevice corrosion should be recognized.

[3] Aylor, D. M., Hays, R. A., Kain, R. M., and Ferrara, R. J., "Crevice Corrosion Performance of Candidate Naval Ship Seawater Valve Materials in Quiescent and Flowing Natural Seawater," CORROSION/99 Paper #329, NACE International.

4.4 While the guidance provided is generally for the purpose of evaluating sheet and plate materials, it is also applicable for crevice-corrosion testing of other product forms, such as tubing and bars.

4.5 The presence or absence of crevice corrosion under one set of conditions is no guarantee that it will or will not occur under other conditions. Because of the many interrelated metallurgical, environmental, and geometric factors known to affect crevice corrosion, results from any given test may or may not be indicative of actual performance in service applications where the conditions may be different from those of the test.

5. Apparatus

5.1 Laboratory tests utilizing filtered, natural seawater, or other chloride containing aqueous environments are frequently conducted in tanks or troughs under low velocity (for example, ~0.5 m/s (1.64 ft/s) or less) or quiescent conditions. Containers should be resistant to the test media.

5.2 Fig. 1 shows a typical test apparatus for conducting crevice-corrosion tests under controlled temperature conditions with provisions for recirculation or refreshment of the aqueous environment, or both, at a constant level.

5.3 The apparatus should be suitably sized to provide complete immersion of the test panel. Vertical positioning of the crevice-corrosion specimens facilitates visual inspection without the need to remove them from the environments.

6. Test Specimens

6.1 Because of the number of variables which may affect the test results, a minimum of three specimens are suggested for each set of environmental, metallurgical, or geometric conditions to be evaluated. If reproducibility is unsatisfactory, additional specimens should be tested.

6.2 Dimensions of both the test specimen and crevice former should be determined and recorded.

6.3 Variations in the boldly exposed (crevice-free) to shielded (crevice) area ratio of the test specimen may influence

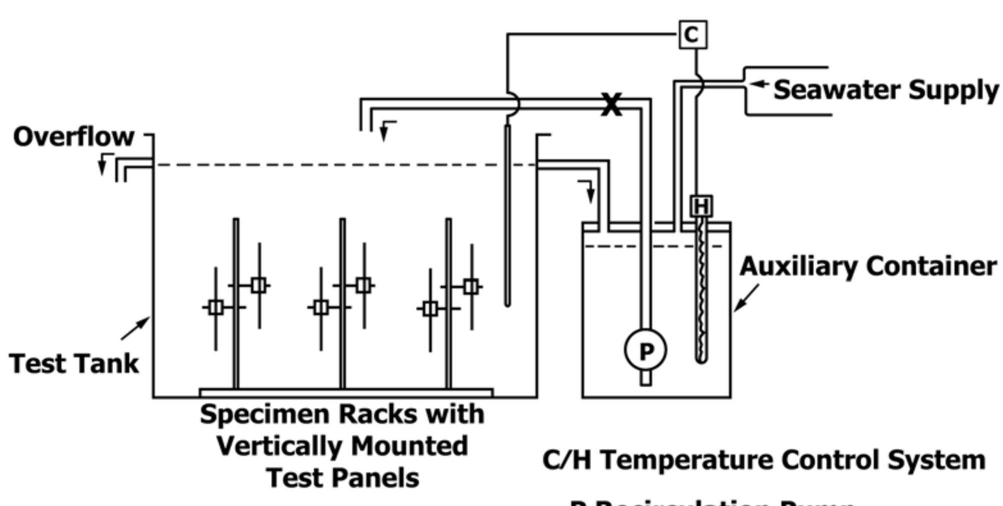


FIG. 1 Positioning of Crevice-Corrosion Test Specimens—Typical Arrangement in Controlled Environment Apparatus

crevice corrosion. All specimens in a test series should have the same nominal surface area. While no specific specimen dimensions are recommended, test panels measuring up to 300 mm by 300 mm (11.81 in. by 11.81 in.) have been used in seawater tests with both naturally occurring and man-made crevice formers. For laboratory studies, the actual size of the specimen may be limited by the dimensions of the test apparatus and this should be taken into consideration in making comparisons.

6.3.1 A test program may be expanded to assess any effect of boldly exposed to shielded area ratio.

6.3.2 If crevice geometry aspects, such as crevice depth, are to be studied, the adoption of a constant boldly exposed to shielded area ratio is recommended to minimize the number of test variables.

6.4 When specimens are cut by shearing, it is recommended that the deformed material be removed by machining or grinding. Test pieces that are warped or otherwise distorted should not be used. The need to provide parallel surfaces between the crevice former and the test specimen is an important consideration in providing maximum consistency in the application of the crevice former.

6.5 Appropriate holes should be drilled (and deburred) in the test specimen to facilitate attachment of the crevice former. Punched holes are not recommended since the punching process may contribute to specimen distortion or work hardening, or both. The diameter of the holes should be large enough to allow clearance of the fastener (and insulator) otherwise additional crevice sites may be introduced.

6.6 Specimens should be identified by alloy and replication. Mechanical stenciling or engraving are generally suitable, provided that the coding is on surfaces away from the intended crevice sites. Identification markings should be applied prior to the final specimen cleaning before test. Marking the samples may affect the test results. See the Identification of Test Specimens section of Guide G4.

6.7 Depending on the test objectives, mill-produced surfaces may be left intact or specimens may be prepared by providing a surface definable in terms of a given preparation process.

6.7.1 Because of the possible variations between "as-produced" alloy surface finishes, the adoption of a given surface finish is recommended if various alloys are to be compared. This will tend to minimize the variability of crevice geometry in contact areas.

6.7.2 While some specific alloys may have proprietary surface conditioning, some uncertainty may exist with regard to the actual end use surface finish. It is recommended that more than one surface condition be examined to assess any effect of surface finish on an individual alloy's crevice corrosion behavior.

6.7.3 Surface grinding with 120 grit SiC abrasive paper is a suitable method for preparing laboratory test specimens. Wet grinding is preferred to avoid possible superficial metallurgical changes due to overheating that may affect material performance.

NOTE 2—Depending on the surface roughness of the mill product, machining may be required prior to final grinding. If the effect of abrasion is a test parameter, then the grit size, type of abrasive, and ideally the resulting surface roughness (Ra) value should be recorded.

6.7.4 The time between last metal removal from a mechanically finished surface and immersion in the test solution can have a significant effect on crevice corrosion initiation and should be standardized for comparative tests or at least recorded.

6.8 Cut lengths of pipe and tubing can be used as specimens to test the crevice corrosion resistance of these product forms in the as-manufactured or surface treated condition. Other cylindrical products can be tested in the as-produced or finished condition.

6.8.1 The selection of cylindrical sample sizes should be made with the knowledge of the availability of appropriately sized crevice formers, as described in 9.5.

6.8.2 The type of crevice former selected may dictate the length of the cylindrical test specimens. Specimen lengths of 4 in. to 12 in. (10 cm to 30 cm) and longer have been used.

7. Pre-test Cleaning

7.1 Cleaning procedures shall be consistent with Practice G1. Typically, this may include degreasing with a suitable solvent, followed by vigorous brush scrubbing with pumice powder, followed by water rinse, clean solvent rinse, and air drying. (**Warning—**Solvent safety and compatibility with the test material should be investigated and safe practices followed).

7.2 For the most part, commercially produced stainless alloys and surface ground materials do not require a pre-exposure pickling treatment. The use of acid cleaning or pretreatments shall be considered only when the crevice-corrosion test is designed to provide guidance for a specific application.

7.3 Any use of chemical pretreatments shall be thoroughly documented and appropriate safety measures followed.

8. Mass Loss Determinations

8.1 Mass loss data calculated from specimen weighing before and after testing may provide some useful information in specific cases. However, comparisons of alloy performance based solely on mass loss may be misleading because highly localized corrosion, which is typical of crevice corrosion, can often result in relatively small mass losses.

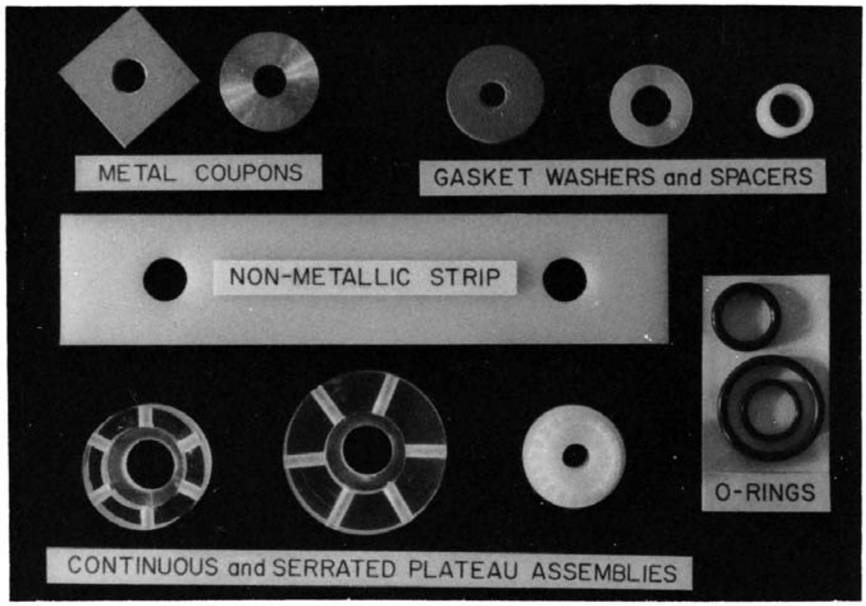
9. Crevice Formers

9.1 *General Comments:*

9.1.1 The severity of a crevice-corrosion test in a given environment can be influenced by the size and physical properties of the crevice former.

9.1.2 Both metal-to-metal and nonmetal-to-metal crevice components are frequently used in laboratory and field studies.

9.1.3 Nonmetallic crevice formers often have the capacity for greater elastic deformation and may produce tighter crevices which are generally considered to more readily promote crevice-corrosion initiation. Acrylic plastic, nylon, polyethylene, PTFE-fluorocarbons, and acetal resin are a few of the commonly used nonmetallics.



NOTE 1—Various crevice former designs utilized in laboratory and field test crevice-corrosion studies. Severity of the test may vary as a function of crevice geometry, that is, size of the crevice former and degree of tightness

FIG. 2 Crevice Former Designs

9.1.4 The properties of the nonmetallic crevice former must be compatible with the physical and environmental demands of the test.

9.1.5 Regardless of the material or type of crevice former, contacting surfaces should be kept as flat as possible to enhance reproducibility of crevice geometry.

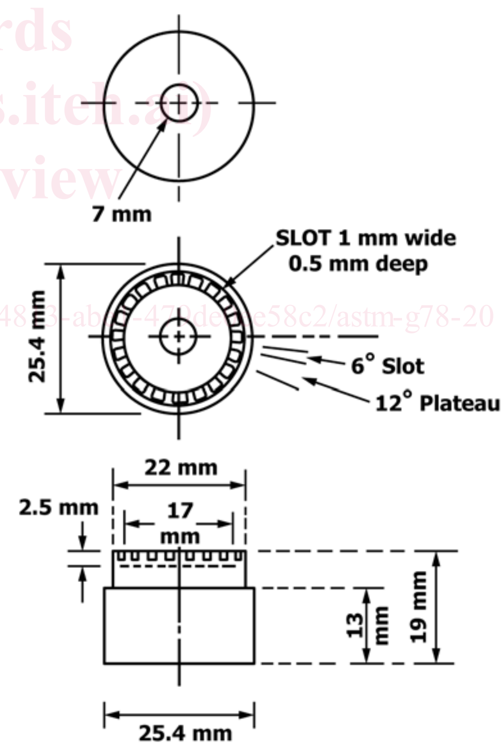
9.1.6 For rigid type crevice formers, as shown for example in Fig. 2, the prepared contact surface finish or finishes should also be documented and reported as in 6.7.3.

NOTE 3—Footnote 4 provides examples of variations in crevice former and test specimen surface finish/roughness.[4]

9.2 *Various Designs for Flat Specimens:*

9.2.1 Fig. 2 shows the shapes of a few popular crevice former designs, such as coupons, strips, O-rings, blocks, continuous and segmented washers. In many cases, two crevice formers are fastened to a flat specimen, that is, one on each side.

9.2.2 Multiple crevice assemblies (MCA) consist of two nonmetallic segmented washers, each having a number of grooves and plateaus. The design shown in Figs. 3 and 4 is only one of a number of variations of the multiple crevice assembly which are in use. Each plateau, in contact with the metal surface, provides a possible site for initiation of crevice corrosion. Multiple crevice assemblies fabricated of acetal resin have been shown to be suitable for seawater exposures. Other nonmetallics, such as PTFE-fluorocarbon and ceramic, have also been used (see 9.1.4).



NOTE 1—Inch-pound equivalents for SI units:
0.5 mm = 0.0197 in.
1 mm = 0.039 in
2.5 mm = 0.098 in.
7 mm = 0.25 in.
13 mm = 0.512 in.
17 mm = 0.669 in.
19 mm = 0.748 in.
22 mm = 0.866 in.
25.4 mm = 1 in.

FIG. 3 Details of Multiple Crevice Washer

[4] Kain, R. M., "Effects of Surface Finish on the Crevice Corrosion Resistance of Stainless Steels in Seawater and Related Environments," CORROSION/91 Paper 508, March 1991, NACE International.