Standard Guide for
Conducting and Evaluating Galvanic Corrosion Tests in Electrolytes[1]

1. Scope

1.1 This guide covers conducting and evaluating galvanic corrosion tests to characterize the behavior of two dissimilar metals in electrical contact in an electrolyte under low-flow conditions. It can be adapted to wrought or cast metals and alloys.

1.2 This guide covers the selection of materials, specimen preparation, test environment, method of exposure, and method for evaluating the results to characterize the behavior of galvanic couples in an electrolyte.

NOTE 1—Additional information on galvanic corrosion testing and examples of the conduct and evaluation of galvanic corrosion tests in electrolytes are given in Refs (**1**)[2] through (**7**).

1.3 *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:*

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

G 3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing[3]

G 4 Guide for Conducting Corrosion Coupon Tests in Field Applications[3]

G 16 Guide for Applying Statistics to Analysis of Corrosion Data[3]

G 31 Practice for Laboratory Immersion Corrosion Testing of Metals[3]

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

3. Significance and Use

3.1 Use of this guide is intended to provide information on the galvanic corrosion of metals in electrical contact in an electrolyte that does not have a flow velocity sufficient to cause erosion-corrosion or cavitation.

3.2 This standard is presented as a guide for conducting galvanic corrosion tests in liquid electrolyte solutions, both in the laboratory and in service environments. Adherence to this guide will aid in avoiding some of the inherent difficulties in such testing.

4. Test Specimens

4.1 *Material*—Test specimens should be manufactured from the same material as those used in the service application being modeled. Minor compositional or processing differences between materials or between different heats can greatly affect the results in some cases.

4.2 *Size and Shape*:

4.2.1 The size and shape of the test specimens are dependent on restrictions imposed by the test location. When determining material behavior in the laboratory, it is advisable to use the largest specimens permissible within the constraints of the test equipment. In general, the ratio of surface area to metal volume should be large in order to favor maximum corrosion loss per weight. Sufficient thickness should be employed, however, to minimize the possibility of perforation of the specimens during the test exposure. When modeling large components, the size of the specimens should be as large as practical. When modeling smaller components, specimen size should be as close as possible to that of the application being modeled. Surface area ratio in the test should be identical to the application being modeled. This ratio is defined as the surface area of one member of the couple divided by the surface area of the other member of the couple. Only the area in contact with the electrolyte (wetted area) is used in this calculation. In low-resistivity electrolytes, maintaining proximity between the materials being coupled may be more important than maintaining the exact area ratio. Also, with some couples, such as copper coupled to aluminum, there may be effects of corrosion products washing from one electrode to another which may have to be considered in determining specimen placement.

4.2.2 Laboratory tests are normally performed on rectangular plates or on cylinders. When modeling service applications, the shapes of the couple members should approximate the shapes in the application. Frequently complex shapes are simplified for testing purposes. The shape of the specimen is more important in electrolytes of low conductivity, where voltage drop in the electrolyte is significant. In highly conductive electrolytes, the shapes of the couple members may therefore deviate somewhat from the shapes in the application.

4.3 *Specimen Preparation*:

4.3.1 The edges of the test specimens should be prepared so as to eliminate all sheared or cold-worked metal except that cold-working introduced by stamping for identification. Shearing will, in some cases, cause considerable attack. Therefore, specimens having sheared edges should not be used. The edges should be finished by machining or polishing. The slight amount of cold working resulting from machining will not introduce any serious error.

4.3.2 Specimens should be cleaned in accordance with Practice G 1, or else the specimen surface condition should be similar to the application being modeled. The metallurgical condition of the specimens should be similar to the application being modeled. In all cases surface contamination, such as dirt, grease, oil, and thick oxides, should be removed prior to weighing and exposure to the test environment.

4.3.3 The specimen identification system must be one that will endure throughout the test period. Edge notches, drilled holes, stamped numbers, and tags are some of the methods used for identification. The identification system must not induce corrosion attack in any way.

4.4 *Number of Specimens*:

4.4.1 The number of galvanic couples to be tested will be determined by whether or not one or more periodic specimen removals are scheduled during the course of the test. As a minimum, duplicate and preferably triplicate specimens should be tested for any given test period to determine the variability in the galvanic corrosion behavior. The effect of the number of replications on the application of the results is set forth in Guide G 16.

4.4.2 Control specimens should also be tested to provide corrosion rates of the individual metals and alloys without coupling for comparisons. These specimens should be of the same alloys, shapes, sizes, and metallurgical conditions as the materials in the couple.

5. Test Environment

5.1 *Laboratory Tests*:

5.1.1 In the laboratory, the test solution should closely approximate the service environment. The amount of test solution used depends on the size of the test specimens. A good rule of thumb is to use 40 cm^3 of test solution for every 1 cm^2 of exposed surface area of both members of the couple. The volume of test solution may be varied to closely approximate the service application.

5.1.2 Galvanic corrosion tests conducted for an extensive period of time may exhaust important constituents of the original solution. Some accumulated corrosion products may act as corrosion accelerators or inhibitors. These variables may greatly change the end results, and replenishment of the

solution should be chosen to be representative of the service application. A test system using continuously replenished test electrolytes is often the only solution to this problem.

5.1.3 Periodic measurements of the test environment should be made when the test duration in a fixed volume solution is for periods of several days or longer. These observations may include temperature, pH, O_2, H_2S, CO_2, NH_3, conductivity, and pertinent metal ion content.

5.2 *Field Tests*—Field testing should be performed in an environment similar to the service environment. Periodic measurements of those environmental variables which could vary with time, such as temperature, dissolved O_2, and so forth, should be made.

6. Procedure

6.1 *Laboratory Versus Field Testing*:

6.1.1 Galvanic corrosion tests are conducted in the laboratory for several purposes: (*1*) inexpensive screening to reduce expensive field testing, (*2*) study of the effects of environmental variables, and (*3*) study of the corrosion accelerating or protective effects of various anode/cathode surface area ratios.

6.1.2 The materials proven in the laboratory to be the most promising should also be tested in the field, since it is frequently impossible to duplicate the actual service environment in the laboratory.

6.2 *Test Procedure*:

6.2.1 Specimens should be electrically joined before exposure. There are a number of methods for joining the specimens. Laboratory testing generally employs external electrical connection through wires such as to allow current measurement (see Fig. 1). Field tests frequently employ direct contact physical bonding by threaded rods as in Fig. 2, soldering, brazing, and so forth. Prime considerations are that the electrical bond to the specimen will not corrode, which could result in decoupling, that the method of joining will not in itself be a galvanic couple or introduce other corrosion mechanisms (crevice, and so forth), and that the resistance of the electrical path be small compared to the polarization resistance of the couple materials. Soldering or brazing will prevent the use of mass measurements for calculating corrosion rates. A coating may be applied to the electrical connections to prevent electrolyte access as in Fig. 2, provided the coating does not result in other corrosion phenomena, such as crevice attack, and is sufficiently resistant to the environment.

6.2.2 The physical relationship between the members of each couple should approximate that of the service situation being modeled. This is particularly important in electrolytes with low conductivity, since the effect of *IR* drops will be more noticeable. The specimens may be positioned by the use of nonconductive holders, provided that these do not result in other corrosion phenomena (crevice, and so forth). A discussion of the mounting of specimens is included in Method G 4. The supporting device should not be affected by or cause contamination of the test solution.

6.2.3 The coupled assembly is next immersed in the test electrolyte for the period of exposure. Exposure duration should be sufficient to allow prediction of the behavior for the entire service duration. If the service duration is long, corrosion data can be taken as a function of time until a curve can be
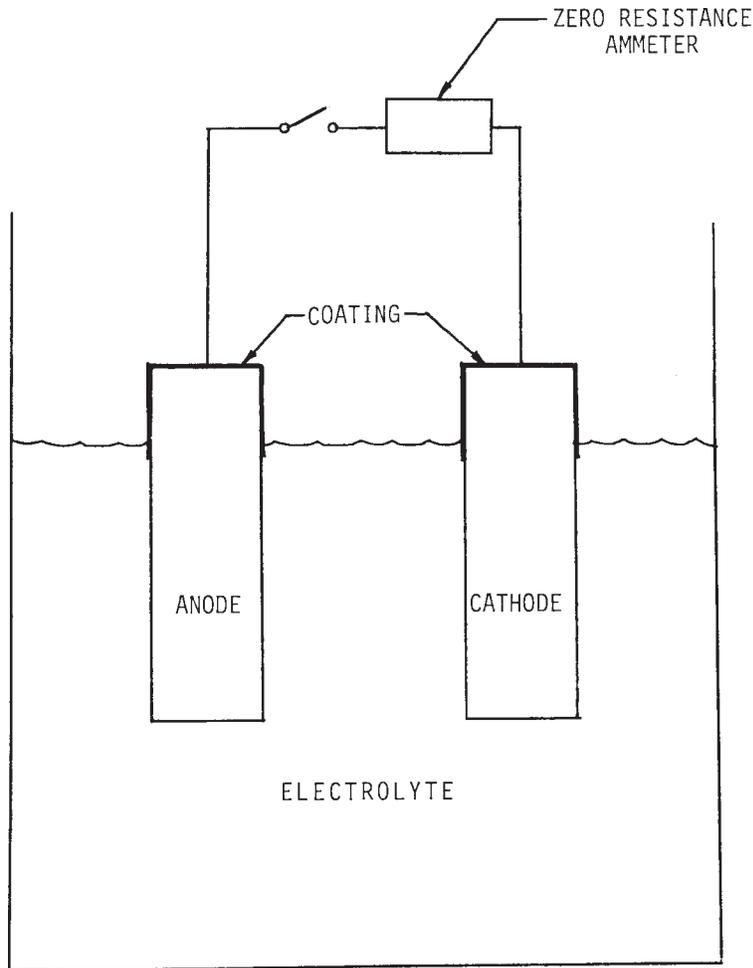
FIG. 1 Laboratory Galvanic Corrosion Test Setup With Facility for Measuring Galvanic Current
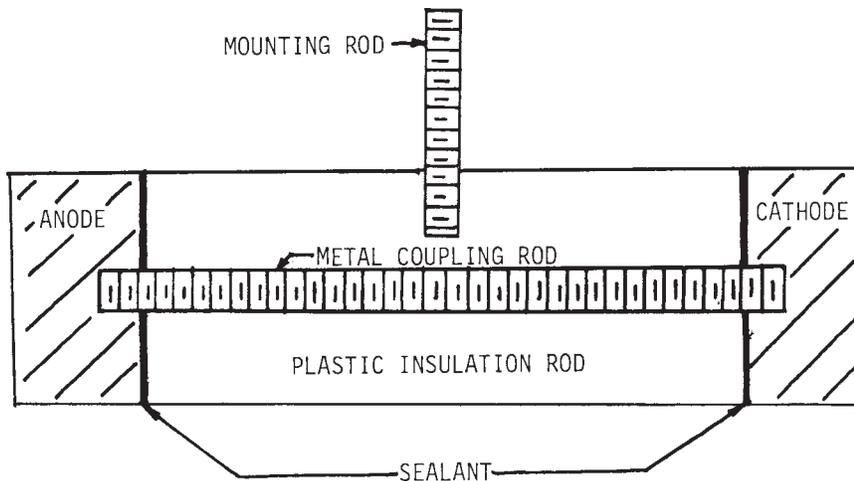
NOTE—The length of the plastic insulation rod should approximate the distance between the anode and the cathode of the final product.
FIG. 2 Specimen Configuration for Galvanic Corrosion Tests of Bar Stock Material

developed that can be extrapolated to the service duration, provided that steady-state conditions have been reached and that no transient environmental conditions are expected in service to affect this steady state.

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6.2.4 Specimen removal should be based on a preplanned removal schedule.

7. Evaluation of Test Specimens

7.1 *Measurements During Exposure*—Data recorded during exposures may include galvanic current measurements and couple and control specimen potentials measured relative to a suitable reference half-cell as recommended in Practice G 3. Current data can then be converted into a theoretical corrosion rate based on Faraday's law.

7.2 *Measurements After Removal*:

7.2.1 After removal, samples of corrosion products may be obtained for chemical and physical analysis. The specimens should then be cleaned of deposits (such as biofouling from fresh or seawater) by scraping or brushing with a wooden scraper or soft bristle brush. Visual observations should be recorded before and after this initial cleaning operation. Color photographs may be taken of each specimen before and after cleaning. Final cleaning of specimens should be in accordance with Practice G 1 after which the specimens should be weighed to determine galvanic corrosion mass loss which can be converted to corrosion rate as set forth in Practice G 31. Additional recommendations for specimen cleaning may be found in Guide G 4 and Practice G 31.

7.2.2 In some cases, mass loss measurements will not be possible or meaningful. For example, soldered assemblies cannot be separated into their components without introducing extra mass due to the remaining solder. In this case, corrosion evaluation of the end product configuration must be based on visual assessments, thickness loss measurements, or on other techniques. Materials suffering localized corrosion such as pitting may be analyzed using Practice G 46, and those suffering crevice corrosion should have the depth of attack measured and described in detail, with attention to changes at the edges as well as the surfaces. In addition, changes in physical properties such as breaking strength can also be measured. Metallographic examination of specimen cross sections may be necessary to determine parting corrosion depth.

7.2.3 Regardless of the method of assessment, the behavior of the coupled materials should be compared to that of the uncoupled controls. Subtracting control values from values of coupled specimens yields the increase in corrosion rate due to coupling. A ratio of couple data to the uncoupled data has been used to determine a percentage change in corrosion due to the couple (acceleration factor).

7.2.4 Where replicate couples are exposed, statistical analysis of the data, as set forth in Guide G 16, may be applied to generate confidence intervals for predictive purposes.

8. Report

8.1 The report should include detailed descriptions of the exposed specimens including wetted areas, pertinent data on exposure conditions including the geometry used, the deposits formed, and results of the corrosion evaluation.

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

8.3 Details of exposure conditions should include location, dates, and periods of exposure and description of the environmental conditions prevailing during the exposure period, including electrolyte conductivity.

8.4 The results of the tests may be expressed as corrosion rate in penetration per unit time (for example, millimetres per year) or loss in thickness or mass during the exposure period. Rates for both control (uncoupled) and coupled samples should be reported, with the change in rate due to the coupling reported as either the difference between control and coupled samples or as the coupled rate divided by the control rate (acceleration factor).

8.5 In cases where corrosion is in the form of pitting or crevice corrosion, a pitting factor should be reported in accordance with Practice G 46. Depths of pitting should be recorded. Pitting factors or depths can then be used to determine the change in corrosion due to coupling.

8.6 If any physical property of the specimens is measured after exposure, the change in that property should be reported and these values can be compared between control and coupled samples in the same manner as corrosion rates or pitting factors.

8.7 Changes in the physical appearance of the specimens during the exposure period should be reported.

9. Keywords

9.1 corosion; dissimilar metals; galvanic corrosion; galvanic couple; zero resistance ammeter

REFERENCES

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