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Standard Guide for
Development and Use of a Galvanic Series for Predicting Galvanic Corrosion Performance[1]

This standard is issued under the fixed designation G82; 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 guide covers the development of a galvanic series and its subsequent use as a method of predicting the effect that one metal can have upon another metal can when they are in electrical contact while immersed in an electrolyte. Suggestions for avoiding known pitfalls are included.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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.* Specific precautionary statements are given in Section 5.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

G3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing

G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[3]

G16 Guide for Applying Statistics to Analysis of Corrosion Data

G71 Guide for Conducting and Evaluating Galvanic Corrosion Tests in Electrolytes

3. Terminology

3.1 Definitions of terms used in this guide are from Terminology G15.

3.2 *active*—the negative (decreasingly oxidizing) direction of electrode potential.

3.3 *corrosion potential*—the potential of a corroding surface in an electrolyte relative to a reference electrode measured under open-circuit conditions.

3.4 *galvanic corrosion*—accelerated corrosion of a metal because of an electrical contact with a more noble metal or nonmetallic conductor in a corrosive electrolyte.

3.5 *galvanic series*—a list of metals and alloys arranged according to their relative corrosion potentials in a given environment.

3.6 *noble*—the positive (increasingly oxidizing) direction of electrode potential.

3.7 *passive*—the state of the metal surface characterized by low corrosion rates in a potential region that is strongly oxidizing for the metal.

3.8 *polarization*—the change from the open-circuit electrode potential as the result of the passage of current.

4. Significance and Use

4.1 When two dissimilar metals in electrical contact are exposed to a common electrolyte, one of the metals can undergo increased corrosion while the other can show decreased corrosion. This type of accelerated corrosion is referred to as galvanic corrosion. Because galvanic corrosion can occur at a high rate, it is important that a means be available to alert the user of products or equipment that involve the use of dissimilar metal combinations in an electrolyte of the possible effects of galvanic corrosion.

4.2 One method that is used to predict the effects of galvanic corrosion is to develop a galvanic series by arranging a list of the materials of interest in order of observed corrosion potentials in the environment and conditions of interest. The metal that will suffer increased corrosion in a galvanic couple in that environment can then be predicted from the relative position of the two metals in the series.

4.3 *Types of Galvanic Series:*

4.3.1 One type of Galvanic Series lists the metals of interest in order of their corrosion potentials, starting with the most active (electronegative) and proceeding in order to the most

[1] This guide is under the jurisdiction of ASTM Committee G01 on Corrosion of Metalsand is the direct responsibility of Subcommittee G01.11 on Electrochemical Measurements in Corrosion Testing.

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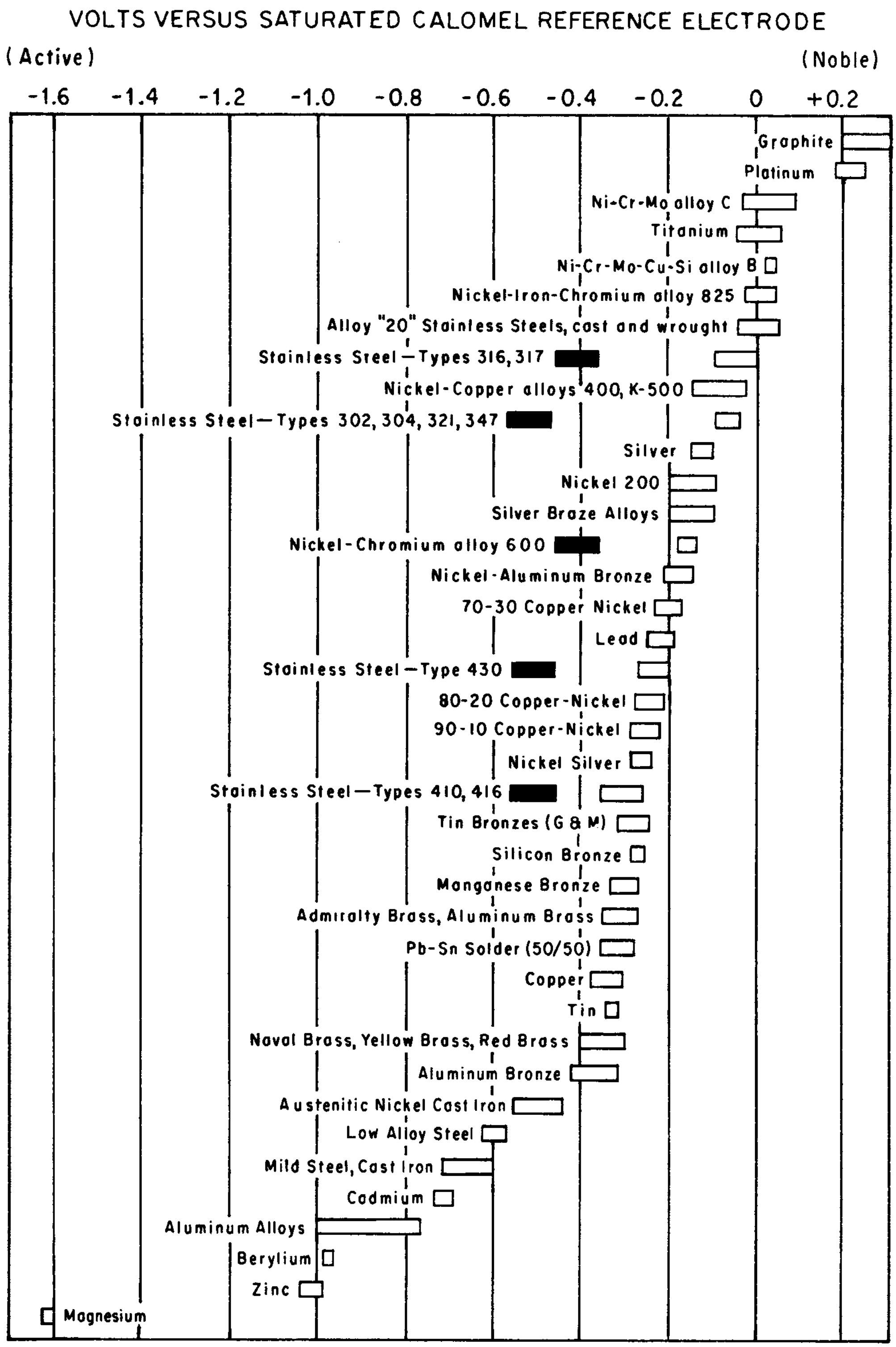
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

noble (electropositive). The potentials themselves (versus an appropriate reference half-cell) are listed so that the potential difference between metals in the series can be determined. This type of Galvanic Series has been put in graphical form as a series of bars displaying the range of potentials exhibited by the metal listed opposite each bar. Such a series is illustrated in Fig. 1.



NOTE 1—Dark boxes indicate active behavior of active-passive alloys.

FIG. 1 Galvanic Series of Various Metals in Flowing Seawater at 2.4 to 4.0 m/s for 5 to 15 Days at 5 to 30°C (Redrawn from Original) (see Footnote 5)

4.3.2 The second type of galvanic series is similar to the first in that it lists the metals of interest in order of their corrosion potentials. The actual potentials themselves are not specified, however. Thus, only the relative position of materials in the series is known and not the magnitude of their potential difference. Such a series is shown in Fig. 2.

4.4 *Use of a Galvanic Series:*

4.4.1 Generally, upon coupling two metals in the Galvanic Series, the more active (electronegative) metal will have a tendency to undergo increased corrosion while the more noble (electropositive) metal will have a tendency to undergo reduced corrosion.

4.4.2 Usually, the further apart two metals are in the series, and thus the greater the potential difference between them, the greater is the driving force for galvanic corrosion. All other factors being equal, and subject to the precautions in Section 5, this increased driving force frequently, although not always, results in a greater degree of galvanic corrosion.

ACTIVE END	Magnesium
(–)	Magnesium Alloys
↑	Zinc
|	Galvanized Steel
|	Aluminum 1100
|	Aluminum 6053
|	Alclad
|	Cadmium
|	Aluminum 2024 (4.5 Cu, 1.5 Mg, 0.6 Mn)
|	Mild Steel
|	Wrought Iron
|	Cast Iron
|	13 % Chromium Stainless Steel
|	Type 410 (Active)
|	18-8 Stainless Steel
|	Type 304 (Active)
|	18-12-3 Stainless Steel
|	Type 316 (Active)
|	Lead-Tin Solders
|	Lead
|	Tin
|	Muntz Metal
|	Manganese Bronze
|	Naval Brass
|	Nickel (Active)
|	76 Ni-16 Cr-7 Fe alloy (Active)
|	60 Ni-30 Mo-6 Fe-1 Mn
|	Yellow Brass
|	Admirality Brass
|	Aluminum Brass
|	Red Brass
|	Copper
|	Silicon Bronze
|	70:30 Cupro Nickel
|	G-Bronze
|	M-Bronze
|	Silver Solder
|	Nickel (Passive)
|	76 Ni-16 Cr-7 Fe
|	Alloy (Passive)
|	67 Ni-33 Cu Alloy (Monel)
|	13 % Chromium Stainless Steel
|	Type 410 (Passive)
|	Titanium
|	18-8 Stainless Steel
|	Type 304 (Passive)
|	18-12-3 Stainless Steel
↓	Type 316 (Passive)
(+)	Silver
NOBLE or	Graphite
PASSIVE END	Gold
	Platinum

FIG. 2 Galvanic Series of Various Metals Exposed to Seawater (see Footnote 3)

5. Precautions in the Use of a Galvanic Series

5.1 The galvanic series should not be confused with the electromotive force series, which, although of a similar appearance to the galvanic series, is based on standard electrodepotentials of elements and not on corrosion potentials of metals. The electromotive force series should not be used for galvanic corrosion prediction.

5.2 Each series is specific to the environment for which it was compiled. For example, a series developed in a flowing ambient temperature seawater should not be used to predict the performance of galvanic couples in fresh water or in heated seawater.

5.3 Corrosion potentials can change with time and the environment. These changes can affect the potential difference between the metals of interest and, in some cases, can reverse relative positions. It is thus imperative that the series used for the prediction be obtained under similar conditions of exposure duration and electrolyte composition as the situation being predicted.

5.4 Galvanic corrosion can occur between two identical materials in different environments. The galvanic series generated herein cannot be applied to this situation.

5.5 Use of a galvanic series provides qualitative prediction of galvanic corrosion. It should not be used for quantitative predictions of galvanic corrosion rate. A more precise determination of the effect of galvanic coupling can be obtained by the measurement of the corrosion currents involved as outlined in Guide G71.[4,5]

5.6 Some published Galvanic Series, such as those in Fig. 1[6] and Fig. 2, consider the possibility of there being more than one potential range for the same material, depending on whether the material is in the active or the passive state. Knowledge of conditions affecting passivity of these materials is necessary to determine which potential range to use in a particular application.

5.7 Galvanic corrosion behavior is affected by many factors besides corrosion potentials. These factors must also be considered in judging the performance of a galvanic couple. They include, but are not limited to, the following:

5.7.1 Anode-to-cathode area ratio,

5.7.2 Electrolyte conductivity,

5.7.3 Distance between coupled metals,

5.7.4 Shielding of metal surfaces by marine growth, sediments, and so forth,

5.7.5 Localized electrolyte concentration changes in shielded areas, and

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[4] Brasunas, A., Editor, *NACE Basic Corrosion Course*, Chapter 3, NACE, Houston, TX, 1970.

[5] Baboian, R., "Electrochemical Techniques for Predicting Galvanic Corrosion," *Galvanic and Pitting Corrosion-Field and Laboratory Studies*, *ASTM STP 576*, Am. Soc. Testing Mats., 1976, pp. 5–19.

[6] LaQue, F. L., *Marine Corrosion, Causes and Prevention*, John Wiley and Sons, New York, NY, 1975.