Designation: G102 – 23

Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements[1]

This standard is issued under the fixed designation G102; 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 practice covers the providing of guidance in converting the results of electrochemical measurements to rates of uniform corrosion. Calculation methods for converting corrosion current density values to either mass loss rates or average penetration rates are given for most engineering alloys. In addition, some guidelines for converting polarization resistance values to corrosion rates are provided.

1.2 The values stated in SI units are to be regarded as standard. Other units of measurement are included in this standard because of their usage.

1.3 *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]

D2776 Methods of Test for Corrosivity of Water in the Absence of Heat Transfer (Electrical Methods) (Withdrawn 1991)[3]

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

G5 Reference Test Method for Making Potentiodynamic Anodic Polarization Measurements

G59 Test Method for Conducting Potentiodynamic Polarization Resistance Measurements

3. Significance and Use

3.1 Electrochemical corrosion rate measurements often provide results in terms of electrical current. Although the conversion of these current values into mass loss rates or penetration rates is based on Faraday's Law, the calculations can be complicated for alloys and metals with elements having multiple valence values. This practice is intended to provide guidance in calculating mass loss and penetration rates for such alloys. Some typical values of equivalent weights for a variety of metals and alloys are provided.

3.2 Electrochemical corrosion rate measurements may provide results in terms of electrical resistance. The conversion of these results to either mass loss or penetration rates requires additional electrochemical information. Some approaches for estimating this information are given.

3.3 Use of this practice will aid in producing more consistent corrosion rate data from electrochemical results. This will make results from different studies more comparable and minimize calculation errors that may occur in transforming electrochemical results to corrosion rate values.

4. Corrosion Current Density

4.1 Corrosion current values may be obtained from galvanic cells and polarization measurements, including Tafel extrapolations or polarization resistance measurements. (See Reference Test Method G5 and Test Method G59 for examples.) The first step is to convert the measured or estimated current value to current density. This is accomplished by dividing the total current by the geometric area of the electrode exposed to the solution. The surface roughness is generally not taken into account when calculating the current density. It is assumed that the current distributes uniformly across the area used in this calculation. In the case of galvanic couples, the exposed area of the anodic specimen should be used. This calculation may be expressed as follows:

$$i_{cor} = \frac{I_{cor}}{A} \quad (1)$$

where:

i_{cor} = corrosion current density, μA/cm^2,
I_{cor} = total anodic current, μA, and

[1] This practice is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and 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.

A = exposed specimen area, cm^2.

Other units may be used in this calculation. In some computerized polarization equipment, this calculation is made automatically after the specimen area is programmed into the computer. A sample calculation is given in Appendix X1.

4.2 *Equivalent Weight*—Equivalent weight, EW, may be thought of as the mass of metal in grams that will be oxidized by the passage of one Faraday (96 489 ± 2 A·s) of electric charge.

NOTE 1—The value of EW is not dependent on the unit system chosen and so may be considered dimensionless.

NOTE 2—The unit of charge A·s has been named Coulomb, abbreviated C. However, the units A and s are primary SI units, and A·s will be used exclusively for unit charge below.

For pure elements, the equivalent weight is given by:

$$EW = \frac{W}{n} \tag{2}$$

where:

W = the atomic weight of the element, and
n = the number of electrons required to oxidize an atom of the element in the corrosion process, that is, the valence of the element.

4.3 For alloys, the equivalent weight is more complex. It is usually assumed that the process of oxidation is uniform and does not occur selectively to any component of the alloy. If this is not true, then the calculation approach will need to be adjusted to reflect the observed mechanism. In addition, some rationale must be adopted for assigning values of n to the elements in the alloy because many elements exhibit more than one valence value.

4.4 To calculate the alloy equivalent weight, the following approach may be used. Consider 1 g of an alloy oxidized. The electrical charge equivalent for this mass oxidized, Q, is then:

$$Q = \sum \frac{\text{nifi}}{\text{Wi}} \tag{3}$$

where:

fi = the mass fraction of the i^{th} element in the alloy,
Wi = the atomic weight of the i^{th} element in the alloy, and
ni = the valence of the i^{th} element of the alloy.

Therefore, the alloy equivalent weight, EW, is the reciprocal of this quantity:

$$EW = \frac{1}{\sum \frac{\text{nifi}}{\text{Wi}}} \tag{4}$$

Normally only elements above 1 mass percent in the alloy are included in the calculation. In cases where the actual analysis of an alloy is not available, it is conventional to use the mid-range of the composition specification for each element, unless a better basis is available. A sample calculation is given in Appendix X2 (**1**).[4]

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

4.5 Valence assignments for elements that exhibit multiple valences can create uncertainty. It is best if an independent technique can be used to establish the proper valence for each alloying element. Sometimes it is possible to analyze the corrosion products and use those results to establish the proper valence. Another approach is to measure or estimate the electrode potential of the corroding surface. Equilibrium diagrams showing regions of stability of various phases as a function of potential and pH may be created from thermodynamic data. These diagrams are known as Potential-pH (Pourbaix) diagrams and have been published by several authors (**2, 3**). The appropriate diagrams for the various alloying elements can be consulted to estimate the stable valence of each element at the temperature, potential, and pH of the contacting electrolyte that existed during the test.

NOTE 3—Some of the older publications used inaccurate thermodynamic data to construct the diagrams and consequently they are in error.

4.6 Some typical values of EW for a variety of metals and alloys are given in Table 1.

4.7 *Calculation of Corrosion Rate*—Faraday's Law can be used to calculate the corrosion rate, either in terms of penetration rate (CR) or mass loss rate (MR) (**4**):

$$CR = K_1 \frac{i_{cor}}{\rho} EW \tag{5}$$

$$MR = K_2 i_{cor} EW \tag{6}$$

where:

CR is given in mm/yr, i_{cor} in $\mu A/cm^2$,

K_1 = 3.27×10^{-3}, mm s g/μA cm yr (Note 4),
ρ = density in g/cm^3, (see Practice G1 for density values for many metals and alloys used in corrosion testing),
MR = g/m^2d, and
K_2 = 8.954×10^{-3}, g s $cm^2/\mu A$ m^2d (Note 4).

NOTE 4—EW is considered dimensionless in these calculations.

Other values for K_1 and K_2 for different unit systems are given in Table 2.

4.8 Errors that may arise from this procedure are discussed below.

4.8.1 Assignment of incorrect valence values may cause serious errors (**5**).

4.8.2 The calculation of penetration or mass loss from electrochemical measurements, as described in this standard, assumes that uniform corrosion is occurring. In cases where non-uniform corrosion processes are occurring, the use of these methods may result in a substantial underestimation of the true values.

4.8.3 Alloys that include large quantities of metalloids or oxidized materials may not be able to be treated by the above procedure.

4.8.4 Corrosion rates calculated by the method above where abrasion or erosion is a significant contributor to the metal loss process may yield significant underestimation of the metal loss rate.