Designation: G59 – 23

Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements[1]

This standard is issued under the fixed designation G59; 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 test method covers an experimental procedure for polarization resistance measurements which can be used for the calibration of equipment and verification of experimental technique. The test method can provide reproducible corrosion potentials and potentiodynamic polarization resistance measurements.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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]

G3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing

G5 Reference Test Method for Making Potentiodynamic Anodic Polarization Measurements

G102 Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements

3. Significance and Use

3.1 This test method can be utilized to verify the performance of polarization resistance measurement equipment including reference electrodes, electrochemical cells, potentiostats, scan generators, and measuring and recording devices. The test method is also useful for training operators in sample preparation and experimental techniques for polarization resistance measurements.

3.2 Polarization resistance can be related to the rate of general corrosion for metals at or near their corrosion potential, E_{corr}. Polarization resistance measurements are an accurate and rapid way to measure the general corrosion rate. Real-time corrosion monitoring is a common application. The technique can also be used as a way to rank alloys, inhibitors, and so forth in order of resistance to general corrosion.

3.3 In this test method, a small potential scan, $\Delta E(t)$, defined with respect to the corrosion potential ($\Delta E = E - E_{corr}$), is applied to a metal sample. The resultant currents are recorded. The polarization resistance, R_P, of a corroding electrode is defined from Eq 1 as the slope of a potential versus current density plot at $i = 0$ **(1-4)**:[3]

$$R_p = \left(\frac{\partial\, \Delta E}{\partial\, i} \right)_{i=0,\ dE/dt \to 0} \tag{1}$$

The current density is given by i. The corrosion current density, i_{corr}, is related to the polarization resistance by the Stern-Geary coefficient, B. **(3)**,

$$i_{corr} = 10^6\, \frac{B}{R_p} \tag{2}$$

The dimension of R_p is ohm-cm^2, i_{corr} is muA/cm^2, and B is in V. The Stern-Geary coefficient is related to the anodic, b_a, and cathodic, b_c, Tafel slopes in accordance with Eq 3.

$$B = \frac{b_a\, b_c}{2.303(b_a + b_c)} \tag{3}$$

The units of the Tafel slopes are V. The corrosion rate, CR, in mm per year can be determined from Eq 4 in which EW is

[1] This test method 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.

Current edition approved June 1, 2023. Published June 2023. Originally approved in 1978. Last previous edition approved in 2020 as G59 – 97 (2020). DOI: 10.1520/G0059-23.

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

the equivalent weight of the corroding species in grams and ρ is the density of the corroding material in g/cm^3.

$$CR = 3.27 \times 10^{-3} \frac{i_{corr} EW}{\rho} \quad (4)$$

Refer to Practice G102 for derivations of the above equations and methods for estimating Tafel slopes.

3.4 The test method may not be appropriate to measure polarization resistance on all materials or in all environments. See 8.2 for a discussion of method biases arising from solution resistance and electrode capacitance.

4. Apparatus

4.1 The apparatus is described in Test Method G5. It includes a 1 L round bottom flask modified to permit the addition of inert gas, thermometer, and electrodes. This standard cell or an equivalent cell can be used. An equivalent cell must be constructed of inert materials and be able to reproduce the standard curve in Test Method G5.

4.2 A potentiostat capable of varying potential at a constant scan rate and measuring the current is needed.

4.3 A method of recording the varying potential and resulting current is needed.

5. Test of Electrical Equipment

5.1 Before the polarization resistance measurement is made, the instrument system (potentiostat, *X-Y* recorder or data acquisition system) must be tested to ensure proper functioning. For this purpose, connect the potentiostat to a test electrical circuit (**5**). While more complex dummy cells are sometimes needed in electrochemical studies, the simple resistor shown in Fig. 1 is adequate for the present application.

5.2 Use R = 10.0 Ω. Set the applied potential on the potentiostat to E = –30.0 mV and apply the potential. The current should be 3.0 mA by Ohm's Law, $I = E/R$.

NOTE 1—When polarization resistance values are measured for systems with different corrosion currents, the value of R should be chosen to cover the current range of the actual polarization resistance measurement. Expected corrosion currents in the microampere range require R = 1 kΩ to 10 kΩ.

5.3 Record the potentiodynamic polarization curve at a scan rate of 0.6 V/h from ΔE = –30 mV to ΔE = +30 mV and back to ΔE = –30 mV. The plot should be linear, go through the origin, and have a slope 10 Ω. The curves recorded for the forward and reverse scans should be identical.

5.4 If the observed results are different than expected, the electrochemical equipment may require calibration or servicing in accordance with the manufacturer's guidelines.

6. Experimental Procedure

6.1 The 1.0 N H_2SO_4 test solution should be prepared from American Chemical Society reagent grade acid and distilled water as described in Test Method G5. The standard test cell requires 900 mL of test solution. The temperature must be maintained at 30 °C within 1°.

6.2 The test cell is purged at 150 cm^3/min with an oxygen-free gas such as hydrogen, nitrogen, or argon. The purge is started at least 30 min before specimen immersion. The purge continues throughout the test.

6.3 The working electrode should be prepared as detailed in Test Method G5. The experiment must commence within 1 h of preparing the electrode. Preparation includes sequential wet polishing with 240 grit and 600 grit SiC paper. Determine the surface area of the specimen to the nearest 0.01 cm^2 and subtract for the area under the gasket (typically 0.20 cm to 0.25 cm^2).

6.4 Immediately prior to immersion the specimen is degreased with a solvent such as acetone and rinsed with distilled water. The time delay between rinsing and immersion should be minimal.

NOTE 2—Samples of the standard AISI Type 430 stainless steel (UNS S45000) used in this test method are available to those wishing to evaluate their equipment and test procedure from Metal Samples, P.O. Box 8, Mumford, AL 36268.

6.5 Transfer the test specimen to the test cell and position the Luggin probe tip 2 mm to 3 mm from the test electrode surface. The tip diameter must be no greater than 1 mm.

6.6 Record the corrosion potential E_{corr} after 5 min and 55 min immersion.

6.7 Apply a potential 30 mV more negative that the recorded 55 min corrosion potential (See Note 3).

NOTE 3—Practice G3 provides a definition of sign convention for potential and current.

6.8 One minute after application of the –30 mV potential, begin the anodic potential scan at a sweep rate of 0.6 V/h (within 5 %). Record the potential and current continuously. Terminate the sweep at a potential 30 mV more positive than the 55 min corrosion potential.

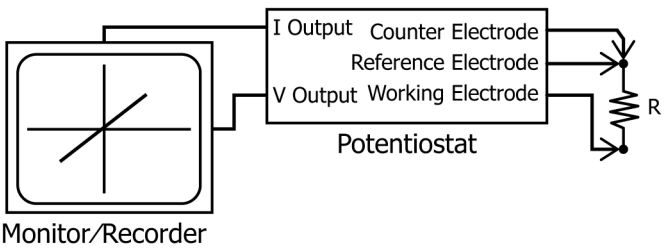

FIG. 1 Arrangement for Testing of Electrical Equipment (Potentiostat, X-Y Recorder)