Designation: D8370 – 22

Standard Test Method for Field Measurement of Electrochemical Impedance on Coatings and Linings[1]

This standard is issued under the fixed designation D8370; 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 the procedure for field measurement of electrochemical impedance spectroscopy (EIS) for polymeric coatings over conductive substrates.

1.2 This test method covers the parameters for determining an adequate sample size.

1.3 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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.*

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]

D16 Terminology for Paint, Related Coatings, Materials, and Applications

D610 Practice for Evaluating Degree of Rusting on Painted Steel Surfaces

D660 Test Method for Evaluating Degree of Checking of Exterior Paints

D661 Test Method for Evaluating Degree of Cracking of Exterior Paints

D714 Test Method for Evaluating Degree of Blistering of Paints

G3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing

G106 Practice for Verification of Algorithm and Equipment for Electrochemical Impedance Measurements

G193 Terminology and Acronyms Relating to Corrosion

G215 Guide for Electrode Potential Measurement

2.2 *ISO Standards:*[3]

ISO 16773-1 Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens—Part 1: Terms and definitions

ISO 16773-2 Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens—Part 2: Collection of data

ISO 16773-3 Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens—Part 3: Processing and analysis of data from dummy cells

ISO 16773-4 Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens—Part 4: Examples of spectra of polymer-coated and uncoated specimens

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminologies G193 and D16.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *test area, n*—total area of the coating surface within a pair of test cells.

3.2.2 *test location, n*—discrete physical location(s) selected on each structure for performing the electrochemical impedance spectroscopy (EIS) measurements.

4. Significance and Use

4.1 This test method is suitable for in-service condition assessment and quality control (QC) testing.

4.2 This technique is used to investigate a polymer barrier coating over a conductive substrate and is limited to exposed and accessible coating surfaces.

[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.48 on Durability of Pipeline Coating and Linings.

Current edition approved March 1, 2022. Published March 2022. DOI: 10.1520/D8370-22.

[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] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

4.3 This test method is applicable to polymer barrier coatings of all thicknesses provided the impedance is within equipment capabilities. Special considerations are required for evaluation of coatings exceeding 2 mm thickness or containing conductive media, such as metal pigments and conducting polymers.

4.4 This test method provides the experimental method needed to ensure proper application of field EIS testing and reporting of its results. This test method uses two test cells per measurement with no electrical connection to the substrate **(1-4)** (a deviation from the traditional three-electrode measurement) to prevent the need for electrical connection to the underlying structure.

NOTE 1—The two-test-cell method measures the impedances beneath the two cells plus the impedance of the path between them. This arrangement has additional risks of false negatives/positives that are not encountered using the traditional three-electrode measurement in which an electrical connection to the substrate is made. For this test method, a false positive is defined as a higher impedance value than is typical for the coating, and a false negative is defined as a lower impedance value than is typical for the coating. A traditional three-electrode measurement in the field is possible, but a reliable electrical connection to the substrate can be challenging and may require damage to an otherwise good coating.

4.5 This test method may be used at any time during the life of a coating system. If used for QC, allow for any manufacturer's recommended cure or drying time unless otherwise agreed upon between the participating parties.

NOTE 2—The results obtained by using this test method could be used for informed coating maintenance decisions, for example, whether to replace a coating system, and may also be applicable as QC measurement for coating contracts.

4.6 The results obtained by using this test method shall not be considered as a means for estimating the structural properties of the underlying structure.

4.7 The results obtained by using this test method do not measure the corrosion susceptibility of the underlying structure because it uses two test cells with no electrical connection to the substrate. The open circuit potential and voltage perturbation are applied to the test cell electrode, per 5.3, and not the underlying structure.

4.8 The electrochemical impedance measurements shall be interpreted by engineers or technical specialists experienced in the fields of protective coatings and corrosion testing. It is often necessary to use other data such as visual inspection, dry film thickness, and adhesion testing, in addition to electrochemical impedance, to formulate conclusions concerning corrosion activity of the underlying structure or the remaining service life of the coating system. See Test Methods D660, D661, D714, or Practice D610 for more information on coating visual inspection.

5. Apparatus

5.1 *Test Cell*—The measurement shall be performed using a surface area of 25 cm^2 or otherwise agreed upon within each test cell. The test cell should be a nonconductive material. Use adhesives or other means to ensure the surface area is unchanged during testing.

NOTE 3—To achieve measurement of high-impedance coatings that are approaching the limit of the instrument's input impedance, larger surface areas may be needed. Typical test cell materials include a 100 mL plastic beaker with the bottom removed or a short length of plastic pipe such as acrylic, polycarbonate, or PVC. A fast-setting marine or silicone adhesive to secure the test cell to the coating surface is preferred when needed. Application of adhesives, especially those using solvents, may be destructive to the field coating being tested; proper repair procedures need to be developed in advance of testing. Commercial gasket-sealed magnetic test cells (in the case of ferritic steel substrates) and similar approaches that combine the test cell and the electrodes into a single unit are also suitable, provided the conditions of 5.3 are met.

5.2 *Electrolyte Solution*—An electrolyte solution shall be added to the test cell to reduce the resistance between the electrodes and the coating surface. The electrolyte solution resistance shall be sufficiently less than the coating being measured.

NOTE 4—Tap or bottled water generally meets this requirement but may be treated with table salt to decrease the electrolyte resistance further. Other electrolytes such as conductive gels may be suitable.

5.3 *Measurement Electrodes*—Measurement electrodes are required to perform the test method. At a minimum, two electrodes are required: one electrode to apply the potentiostat voltage and current to one test cell (working electrode (WE)) and one electrode to sense the voltage and current response in the other test cell (counter electrode (CE)). See Guide G106 for more information.

NOTE 5—Consult with the potentiostat manufacturer for guidance on their specific electrode configurations and how to perform a two-electrode impedance measurement using their equipment.

5.3.1 *Working and Counter Electrodes*—The WE and CE shall be the same material, inert, and conductive with a surface area that is sufficiently high to not limit uniform current density.

NOTE 6—Ensure that the WE and CE surfaces are clean and uncorroded before each test for consistent results. Acceptable materials should have low reactivity such as platinum, stainless steel, or graphite.

5.3.2 *Reference Electrode (RE) (if Used)*—The RE can be used to sense the circuit voltage separately rather than coupling both parameters under a CE. Suitable REs include a silver/silver chloride/potassium chloride reference electrode or saturated calomel electrode (SCE). See Guide G215 for more information.

5.4 *Electrical Lead Wires*—Use potentiostat manufacturer supplied cable, which should be electrically shielded, for the potentiostat used.

NOTE 7—External sources of electrical interference should be avoided or diminished. Sources of interferences can include fluorescent lights, motors, and cellular phones in transmitting mode in close proximity. The leads should all be as far away from one another as possible (the counter lead far from the working lead far from the reference lead). Care should be taken in arranging leads by not coiling or crossing over one another so that stray current or inductance is not introduced in the experiment.

5.5 *Potentiostat*—A potentiostat should have a floating design, that is, the WE is not grounded within the instrument. The minimum parameters are a frequency range of 0.01 Hz to 10 000 Hz, an input impedance of 10^{11} Ω, a compliance voltage of 5 V, and a current range of ±100 pA to ±10 mA with a current resolution no greater than 0.015 % of the current range (see Appendix X1). The potentiostat may use any power