Standard Test Method for Continuity of Porcelain Enamel Coatings[1]

This standard is issued under the fixed designation C 743; 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 Porcelain enamel coatings are applied to metals to provide protection from corrosion as well as to enhance their appearance. This test method permits the easy detection of discontinuities and areas of light coverage, not readily seen by visual inspection, which limit the protection to the substrate. Somewhat similar tests applicable to the thicker glass coatings used for chemical reaction vessels are found in Test Methods C 536 and C 537.

1.2 Values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only.

1.3 *This standard does not purport to address all of the safety problems, 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:*

C 536 Test Method for Continuity of Coatings in Glassed Steel Equipment by Electrical Testing[2]

C 537 Test Method for Reliability of Glass Coatings on Glassed Steel Reaction Equipment by High Voltage[2]

3. Terminology

3.1 *air-gap voltage*—the voltage needed to arc through a defect that is open to both the surface of the porcelain enamel and the metal substrate. The length of the air gap is estimated by measuring the enamel thickness.

3.2 *overvoltage*—the difference between an applied test voltage and the air-gap voltage for the porcelain enamel being tested.

3.3 *RMS voltage*—the root mean square voltage, or "average" voltage, shown on ac test meters.

3.4 *peak voltage*—for ac meters, the voltage that will discharge across the air gap or across a defect. The peak voltage is the RMS voltage multiplied by 1.414.

4. Apparatus

4.1 A nondestructive coating thickness gage with a range of at least 0 to 0.5 mm in 0.03-mm increments (0 to 20 mils in 1.0-mil increments).

4.2 Either an ac or a dc high-voltage discharge test instrument[3] with a continuously variable output voltage over the range of at least 0 to 4 kV as indicated on a built-in voltmeter. The instrument shall be capable of being set to 0.1 kV and shall have an insulated cable and probe and a means for indicating (light, meter, or bell) a voltage discharge. Before use in this test, the high-voltage discharge test instrument shall be calibrated in accordance with the procedure set forth in Annex A1.

4.3 A test probe constructed of 100 mesh wire gauze as illustrated in Fig. 1.[4]

5. Test Specimens

5.1 Porcelain enameled specimens of any size may be used in this test. The enamel shall be removed from an edge or the back of the specimen to provide an electrical ground for the test instrument. If the probe is wider than the specimen, the edges of the specimen shall be masked with electrical insulating tape to prevent discharges from occurring at the edges where porcelain coverage may be light.

6. Conditioning

6.1 Before testing, wash the specimens with a 1 weight %, solution of trisodium phosphate on a soft cellulose sponge, rinse with tap water, and then rinse with distilled water. Then dry the specimens thoroughly in air.

7. Procedure

7.1 *Measuring the Enamel Thickness*— Measure the enamel thickness at a minimum of three locations on the specimen. Make these measurements to the nearest 0.03 mm (1.0 mil) in accordance with the operating instructions for the thickness gage. Use the maximum value obtained as the enamel thickness.

7.2 *Selecting the Test Voltage*—The test voltage to be used

[1] This test method is under the jurisdiction of ASTM Committee B-8 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.12 on Materials for Porcelain Enamel and Ceramic-Metal Systems.

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[2] *Annual Book of ASTM Standards,* Vol 02.05.

[3] Suitable test equipment is available from Associated Research, Inc., 8221 North Kimble Ave., Skokie, IL 60076 and The Pfaudler Co., Div. of Sohio, 1000 West Ave., Rochester, NY 14603.

[4] Suitable probes are available from Associated Research, Inc., 8221 North Kimble Ave., Skokie, IL 60076 and The Pfaudler Co., Div. of Sohio, 1000 West Ave., Rochester, NY 14603.

FIG. 1 Test Probe

depends upon the purpose for conducting the test. The test can be used to determine (*1*) the presence of defects open to both the enamel surface and the base metal, (*2*) the location of areas of light coverage in addition to defects open to both the enamel surface and the base metal, or (*3*) compliance with a specification. According to the user's purpose for conducting the test, the following three instructions correspond respectively to (*1*), (*2*), or (*3*) above:

7.2.1 *Test Method A*—For Open Defects:

7.2.1.1 Determine the air-gap voltage that corresponds to the enamel thickness from the calibration curve described in the annex. This value is the test voltage.

7.2.1.2 Probe the specimen in accordance with 7.3.

7.2.2 *Test Method B—For Light Coverage and Open Defects*:

7.2.2.1 Determine the air-gap voltage that corresponds to the enamel thickness from the calibration curve described in the annex.

7.2.2.2 Arbitrarily select the overvoltage to be used. (Increasingly smaller defects are located with this test as the overvoltage is increased. Therefore, confidence that ware passing this test will have a long, corrosion-free service life is increased as the overvoltage is increased.)

7.2.2.3 Add the selected overvoltage to the air-gap voltage. This value is the test voltage.

7.2.2.4 Probe the specimen in accordance with 7.3.

7.2.3 *Test Method C—For Compliance with a Specification*—Specifications for continuity of coating will be in terms of d-c overvoltage or peak a-c overvoltage (these are identical). Determination of the test voltage depends on whether a d-c or an a-c test instrument is used.

7.2.3.1 *DC Test Instruments*—Determine the test voltage in accordance with 7.2.2, substituting the specified overvoltage for the selected overvoltage as in 7.2.2.2 and 7.2.2.3.

7.2.3.2 *AC Test Instruments*—Divide the specified overvoltage by 1.414, then determine the test voltage as in 7.2.2, substituting the specified overvoltage divided by 1.414 for the selected overvoltage as in 7.2.2.2 and 7.2.2.3.

7.2.3.3 Probe the specimen as shown in 7.3.

7.3 *Probing the Specimens*:

7.3.1 Connect the ground wire of test instrument to the base metal of the specimen.

7.3.2 Turn on the test instrument.

7.3.3 Set the output voltage (as indicated on the built-in voltmeter) to the value selected in 7.2.

7.3.4 Let the voltage stabilize for 15 s.

7.3.5 Hold the probe with a light pressure at approximately 30° to the surface of the specimen.

7.3.6 Probe the specimen at a rate of 3 to 4 in./s (75 to 100 mm/s).

7.4 *Locating Discontinuities*:

7.4.1 When the probe passes over a discontinuity, a spark will arc across the discontinuity to the ground provided by the base metal. This spark can be seen and heard. In addition, most instruments are equipped with an auxiliary light that flashes when a discontinuity is located. Some instruments also have an audible signal or digital counter to aid in the detection of discontinuities.

7.4.2 When a discontinuity is located, a failure in the coating is present.

8. Report

8.1 The report shall include the following:

8.1.1 Title of test, ASTM designation, and issue.

8.1.2 Enamel thickness,
8.1.3 Air-gap voltage,
8.1.4 Method of selecting test voltage (Test Method A, B, or C),
8.1.5 Overvoltage used,
8.1.6 Name and model of test equipment,
8.1.7 Whether or not discontinuities were present,
8.1.8 Type of specimen tested,
8.1.9 Number of specimens tested, and
8.1.10 Type of enamel tested.

9. Precision and Bias

9.1 No statement is made about either the precision or bias of this test method since the result merely states whether there is conformance to the criteria for success specified in the procedure.

ANNEX

(Mandatory Information)

A1. CALIBRATING THE TEST INSTRUMENTS

A1.1 Even though each test instrument is equipped with a built-in voltmeter, the discharge voltage across a given air gap will vary from instrument to instrument. Therefore, each instrument must be calibrated by determining its air-gap voltage curve.

A1.2 *Specimens Required*—Three specimens of each of 15 enamels are required to determine the air-gap voltage for the test instrument. These 15 enamels shall spread over the range of thicknesses from 0.1 to 0.5 mm (4 through 18 mils) as uniformly as possible. These specimens shall be prepared as outlined in 4.1 and 5.1.

A1.3 *Procedure:*

A1.3.1 *Puncturing the Enamel Coating*:

A1.3.1.1 Connect the ground wire of the test instrument to the base metal of the specimen.

A1.3.1.2 Turn on the test instrument.

A1.3.1.3 Raise the output voltage of the test instrument to its maximum and allow it to stabilize for 15 s.

A1.3.1.4 Hold the probe with a light pressure at approximately 30° to the surface of the specimen.

A1.3.1.5 Probe the specimen at a rate of 75 to 100 cm/s (3 to 4 in./s).

A1.3.1.6 Discard all specimens that are not punctured by this treatment.

A1.3.2 *Reprobing the Specimens*:

A1.3.2.1 Reprobe the specimens that were punctured by the high-voltage probe in a manner similar to that outlined in A1.3.1.1 through A1.3.1.4, except that the test voltage shall be 100 V initially and shall be increased in increments of 100 V until a discharge occurs. A15-s stabilization period shall be observed for each increase in voltage before reprobing the test specimens. This procedure may be expedited by starting the reprobing of duplicate specimens at 300 Volts lower than the breakdown voltage noted for the first reprobed specimen, then increasing the voltage by increments of 100 V. The discharge voltage determined in this manner is defined as the air-gap voltage.

A1.4 *Measuring the Enamel Thickness*—Measure the enamel thickness at three locations on the surface of the specimen. Make these measurements close to the area where the discharge occurred. Make these measurements to the nearest 0.025 mm (1.0 mil) in accordance with the operating instructions for the thickness gage. Average the three measurements to give the average enamel thickness which is assumed equivalent to the length of the air gap.

A1.5 *Calculations*—Calculate the average enamel thickness and air-gap voltage for each specimen. Plot these averages and fit the least squares line (of the form $y = a + bx$) through these averages as follows:

$$a = (\Sigma x^2 \Sigma y - \Sigma x \Sigma xy)/[N\Sigma x^2 - (\Sigma x)^2] \quad \text{(A1.1)}$$

$$b = (N\Sigma xy - \Sigma x \Sigma y)/[N\Sigma x^2 - (\Sigma x)^2]$$

where:
a = intercept,
b = slope,
N = number of specimens,
x = average thickness of an enamel, mils, and average air gap voltage of an enamel, kV.

The resulting curve is the calibration curve.

NOTE A1.1—The equations given here are for hand computation or desk calculator use only. If the least squares line is fitted by digital computer, any accurate library program may be used.