Standard Test Method for
Water Penetration into Pipeline Coatings[1]

ε¹ NOTE—Editorial corrections were made throughout in June 2013.

1. Scope

1.1 This method covers the determination of the apparent rate of depth of water penetration into insulating coatings applied to pipe.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

G12 Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel (Withdrawn 2013)[3]

3. Summary of Test Method

3.1 The method consists of an immersion-type test where pipe specimens are suspended in an aqueous electrolyte for the duration of the test period. Electrical measurements of coating capacitance and dissipation factor are used to follow the water absorption rate of the test materials.

4. Significance and Use

4.1 The deterioration of an insulating coating film is intimately related to its moisture content. The water penetration test provides a means for monitoring the passage of moisture through a coating material by means of changes in its dielectric constant. When expressed in relation to time, the test data will reflect a rate of deterioration which is a characteristic of the coating material and will bear a relation to its expected useful life as an insulating coating. The test for water penetration will also provide information that is useful in establishing the optimum coating thickness for a given material.

5. Apparatus

5.1 *Immersion Cell*—Any suitable nonmetallic vessel to contain the test specimens. Dimensions of the vessel shall permit the following requirements:

5.1.1 Test specimens shall be suspended vertically with at least 25 mm (1.0 in.) clearance from the sides and bottom.

5.1.2 Test specimens shall be separated by not less than 25 to 40 mm (1 to 1.5 in.) and a vertically suspended anode shall be placed at an equal distance from each specimen not less than the separation of distance.

5.1.3 The test vessel shall be deep enough to allow for immersion of the samples in the electrolyte to the level specified in 8.1.

NOTE 1—Commercially available, glass battery jars in 2-L (0.55-gal) and 10-L (2.7-gal) sizes can be conveniently used with 19-mm (0.75-in.) and 51-mm (2.0-in. nominal) diameter specimens, respectively.

5.1.4 A suitable sample support plate fabricated from a material having a low dielectric constant shall be used to suspend the samples and anode above the immersion cell. The support plate shall contain an access hole for the reference electrode. A typical test cell is illustrated in Fig. 1.

5.2 *Electrolyte,* consisting of tap water with the addition of 1 weight % of each of the following technical-grade anhydrous salts: sodium chloride, sodium sulfate, and sodium carbonate.

NOTE 2—Add 10 g of each for each litre (0.26 gal) of water.

5.2.1 The electrolyte in the immersion cell shall be maintained at the proper level by regular additions of tap water. The electrolyte shall not be reused after completion of the test.

5.3 *Voltage Source*—A direct current power supply, capable of supplying low ripple voltage shall be used to maintain a potential difference of 6.0 ± 0.1 V dc between each of the test specimens and a common electrode.

FIG. 1 Typical Test Cell

NOTE 3—A shield for the test cell can conveniently be fabricated from most commercially-available tin or aluminum foils of approximately 0.0382-mm (0.0015-in.) thickness and formed around the container.

5.7 *Thickness Gage*—Measurements of coating thickness will be required for this test. Any instrument suitable for use with Test Method G12 can be used.

5.8 *Anode,* fabricated from 4.76-mm (0.1875-in.) diameter AISI Type 303 stainless-steel rod, and shall be 178 mm (7.00 in.) long, with the upper 50 mm (2.00 in.) threaded to accept a locking nut.

6. Test Specimen

6.1 The test specimen shall be a representative piece of production-coated pipe and shall be free of obvious coating flaws or defects (see Fig. 3). Any suitable diameter and specimen length can be used. Physical limitations of the immersion cells suggested in 5.1.3, Note 1, make it necessary to restrict the overall sample length to approximately 300 mm (12.0 in.) for both the 19-mm (0.75-in. nominal) and 51-mm (2.0-in. nominal) diameter coated pipe specimens.

6.2 The upper and lower ends of the test specimen shall be plugged and sealed with nonconductive caps of sufficient bulk to minimize effectively capacitive end effects in the measuring circuit. For this purpose, an end-cap thickness of from 13 mm (0.5 in.) to 19 mm (0.75 in.) shall be maintained.

6.2.1 The end-cap material shall have a dielectric constant in the range from 2 to 6, bond well to the coating surface, and exhibit a low water-absorption rate. Several commercially available poly(vinyl chloride)-paraffin compounds, are well suited for this purpose. They have a melting point in the 150 to 200°C (300 to 390°F) range, can be poured into molds around the pipe sample, and appear as resilient, durable solids at room temperature.

NOTE 4—Using these materials, the end-caps can be applied to the required thickness by repeated dipping of the sample ends into a molten-wax bath, or through the use of light-weight, disposable molds of aluminum foil or paper formed around the pipe sample to allow the casting of the caps directly to the surface of the coated pipe sample.

6.3 The end of the specimen which will protrude above the immersion line shall be provided with a suitable means of support and a separate wire connection for electrical purposes. The protruding end of the sample shall be waterproofed with a thin coating of end-cap material (see Fig. 1).

7. Preliminary Test Measurements

7.1 *Coating Thickness*—Measure and record the coating thickness by referring to Test Method G12.

7.2 *Specimen Length*—Measure and record the length of exposed coating surface, between the end caps.

7.3 *End-Cap Capacitance*—Vertically suspend the test specimens and anode in the immersion cell, observing the clearances specified in 5.1.1 through 5.1.3. Fill the container with the electrolyte until it just covers the lower end cap. Energize the impedance bridge and measure the series capacitance, C_c of the lower end cap.

7.4 *Initial Coating Capacitance*—Add additional electrolyte to the immersion cell until its level reaches the lower edge of
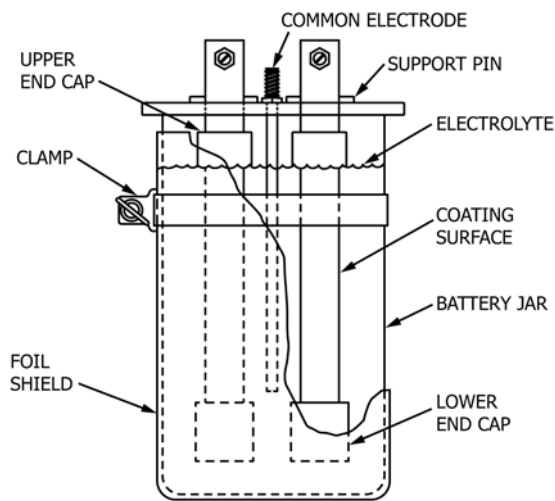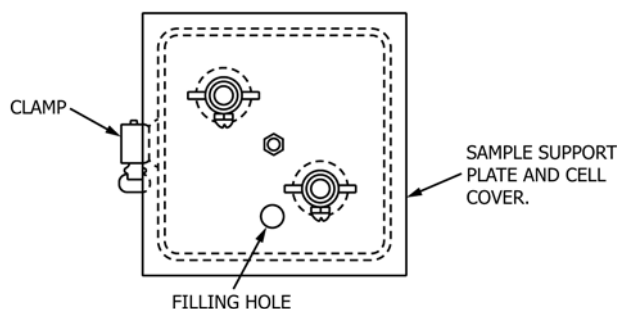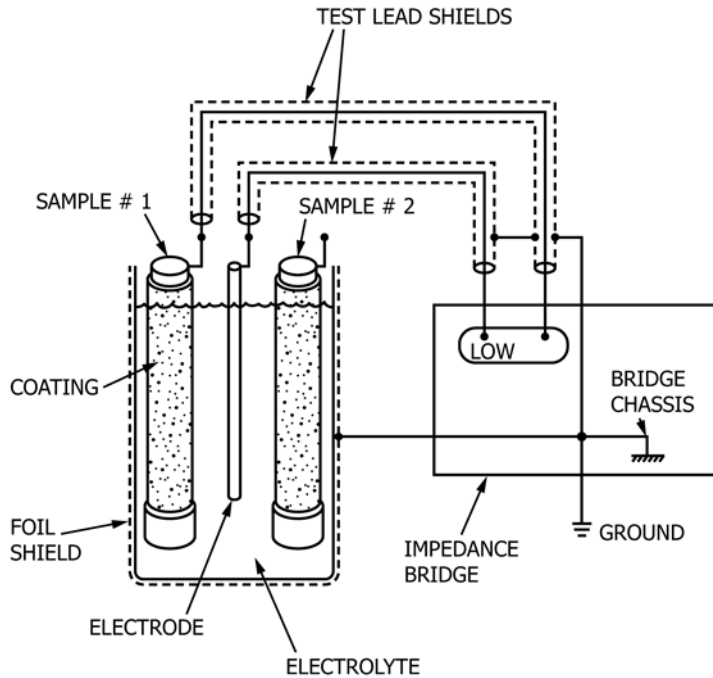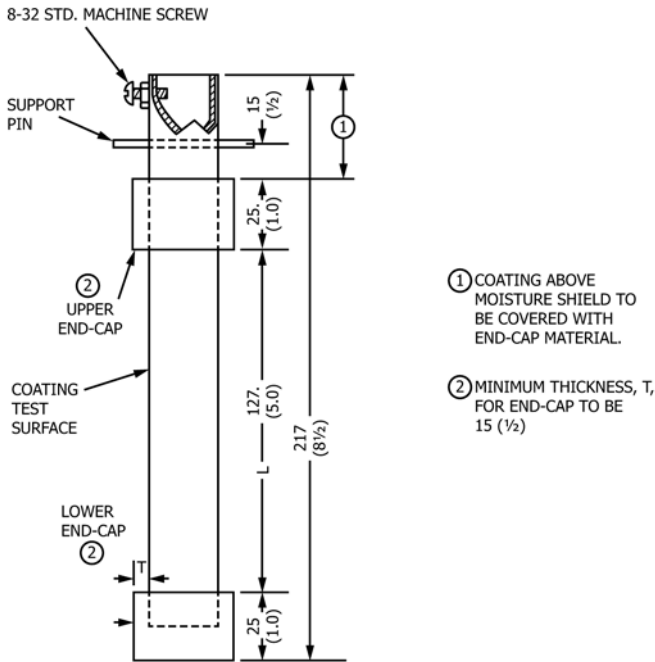
5.4 *Connectors*—Wiring connections from the anode to the specimen shall be of No. 18 AWG insulated copper. Attachment to the anode shall be sealed and kept above the level of the electrolyte. Attachment to the specimen shall be made by a method that will allow disconnection from the anode when the measuring bridge is in use. A convenient means for accomplishing this is through the use of insulated pin-type jacks.

5.5 *Capacitance Bridge*—Measurements of equivalent specimen capacitance and coating dissipation factor shall be made with a low-voltage a-c, resistive-ratio-arm type measuring bridge having the following characteristics:

5.5.1 Oscillator frequency, 1 kHz ± 2 %,

5.5.2 Series capacitance range, 1 to 1100 pF ± 1 %,

5.5.3 Series capacitance sensitivity, 0.5 pF,

5.5.4 Dissipation factor range, 0.001 to 1.0 at 1 kHz, and

5.5.5 Dissipation factor sensitivity, 0.001 at 1 kHz.

5.6 *Measuring Circuit*—Measurements of specimen capacitance and coating dissipation factor shall be made using a circuit that places the sample unknown in series with the comparison circuit of the measuring bridge. Connection of the unknown to the measuring bridge shall be made in such a manner as to eliminate the introduction of stray capacitance into the measuring circuit. A diagram for connecting the test cell to the bridge is shown in Fig. 2. In this arrangement, both the test leads are shielded and the chassis of the bridge is grounded. The immersion cell shall also be shielded to avoid capacitance effects from surrounding objects.

FIG. 2 Connecting the Test Cell to the Bridge

NOTE 1—Dimensions are in millimetres with inches in parentheses.
FIG. 3 Detail Drawing of Pipe Specimen

the upper end cap. Immediately measure and record the initial series capacitance, C_0, and dissipation factor, DF, of the specimen.

8. Procedure

8.1 Energize each specimen by connecting it to the negative side of the voltage source. Keep each sample energized and immersed to the lower edge of the upper end cap for the

duration of the test period. Maintain the specified electrolyte level through regular additions of tap water.

8.2 Throughout the test make periodic measurements of the series capacitance and dissipation factor of the immersed specimens in the following manner:

8.2.1 Temporarily disconnect the test specimen from the voltage source. Verify that the electrolyte is at the proper level within the immersion cell. Connect the measuring bridge between the test specimen and stainless-steel anode. Energize the bridge and measure the series capacitance, C, and dissipation faction, DF, of the test specimen.

8.2.2 Using the observed value of series capacitance, C_s, calculate the apparent depth of water penetration by the method described in 9.2.

8.2.3 Repeat the measurements of series capacitance and specimen dissipation factor at periodic intervals throughout the duration of the test. The frequency of measurement will depend upon the rate of deterioration of the coating sample. Where the water penetration process is relatively rapid, daily readings of sample capacitance and dissipation factor will be required. Normally, readings made at weekly intervals will adequately define the penetration rate.

NOTE 5—Some coatings exhibit an initial rise in capacitance and dissipation factor, but reach a state of equilibrium in 6 to 9 months. An increase in capacitance and dissipation factor following this period of equilibrium, (or failure to reach equilibrium) indicates impending failure. A sample can be considered to have failed when the dissipation factor reaches a value of 1.0.

9. Calculations

9.1 *Dielectric Constant*—Calculate the dielectric constant, K_0, for the coating film as follows:

$$K_0 = \frac{(C_0 - C_c)\ln[(2t_0 + d)/d]}{NL} \quad (1)$$

where:

K_0 = dielectric constant,
C_0 = initial coating capacitance, pF,
C_c = end-cap capacitance, pF,
d = outside pipe diameter, mm (in.),
t_0 = initial coating thickness, mm (in.),
L = exposed coating length, mm (in.), and
N = 0.0556 when d, t_0, L, are in mm (1.413 when d, t_0, L, are in in.).

9.2 *Apparent Depth of Penetration*—Calculate the depth of water penetration by applying the calculated value of K_0 from 9.1 and the measured value of equivalent series capacitance, C, to the following equations:

$$t_p = t_0 - t \qquad (2)$$

$$t = (d/2)\left[(e^M) - 1\right]$$

where:

M = $NK_0L/(C - C_c)$,
t = unpenetrated coating thickness, mm (in.),
C = series capacitance, pF, and
t_p = depth of penetration, mm (in.).

10. Report

10.1 The report shall include the following:

10.1.1 Complete identification of specimen, including:

10.1.1.1 Name and code number of the coating,

10.1.1.2 Size of pipe,

10.1.1.3 Source, production date, and production-run number,

10.1.1.4 Minimum, maximum, and average coating thickness,

10.1.1.5 Dates of starting and terminating test, and

10.1.1.6 Other information that may be pertinent,

10.1.2 Magnitude and polarity of d-c voltage applied to sample during the test period,

10.1.3 Length of the test period in days,

10.1.4 Apparent depth of water penetration for the test period indicated,

10.1.5 Initial value of coating dissipation factor, and

10.1.6 Value of coating dissipation factor at the end of the test period.

NOTE 6—For the purpose of monitoring coating performance, plotted graphs of apparent depth of water penetration versus time in rectangular coordinates and coating dissipation factor versus time in semilogarithmic coordinates will render useful information over the duration of the test period.

11. Precision and Bias

11.1 Due to the range of coating formulations, thicknesses, densities, etc., found among commercially available coated pipe samples, the reproducibility of the test results by these methods will tend to be poorer than those expected on insulating material of a more uniform nature.

11.2 The precision (reproducibility)[4] of the dissipation factor and depth of penetration by these methods in general is considered to be such that when two tests are performed consecutively on the same specimen under identical conditions, the difference between the two results may normally be expected not to exceed ±5 % of their mean.

12. Keywords

12.1 capacitance; coating; dielectric constant; dissipation factor; immersion; pipeline; water absorption; water penetration

---

[4] The reproducibility of this test method is being determined and will be available on or before March 2009.