



Designation: C 876 – 91 (Reapproved 1999)

Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete¹

This standard is issued under the fixed designation C 876; 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 estimation of the electrical half-cell potential of uncoated reinforcing steel in field and laboratory concrete, for the purpose of determining the corrosion activity of the reinforcing steel.

1.2 This test method is limited by electrical circuitry. A concrete surface that has dried to the extent that it is a dielectric and surfaces that are coated with a dielectric material will not provide an acceptable electrical circuit. The basic configuration of the electrical circuit is shown in Fig. 1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 *This standard does not purport to address 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:*

G 3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing²

3. Significance and Use

3.1 This test method is suitable for in-service evaluation and for use in research and development work.

3.2 This test method is applicable to members regardless of their size or the depth of concrete cover over the reinforcing steel.

3.3 This test method may be used at any time during the life of a concrete member.

3.4 The results obtained by the use of this test method shall not be considered as a means for estimating the structural properties of the steel or of the reinforced concrete member.

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 March 11, 1991. Published May 1991. Originally published as C 876 – 77. Last previous edition C 876 – 87.

² *Annual Book of ASTM Standards*, Vol 03.02.

3.5 The potential measurements should be interpreted by engineers or technical specialists experienced in the fields of concrete materials and corrosion testing. It is often necessary to use other data such as chloride contents, depth of carbonation, delamination survey findings, rate of corrosion results, and environmental exposure conditions, in addition to half-cell potential measurements, to formulate conclusions concerning corrosion activity of embedded steel and its probable effect on the service life of a structure.

4. Apparatus

4.1 The testing apparatus consists of the following:

4.1.1 *Half Cell:*

4.1.1.1 A copper-copper sulfate half cell (**Note 1**) is shown in Fig. 2. It consists of a rigid tube or container composed of a dielectric material that is nonreactive with copper or copper sulfate, a porous wooden or plastic plug that remains wet by capillary action, and a copper rod that is immersed within the tube in a saturated solution of copper sulfate. The solution shall be prepared with reagent grade copper sulfate crystals dissolved in distilled or deionized water. The solution may be considered saturated when an excess of crystals (undissolved) lies at the bottom of the solution.

4.1.1.2 The rigid tube or container shall have an inside diameter of not less than 1 in. (25 mm); the diameter of the porous plug shall not be less than 1/2 in. (13 mm); the diameter of the immersed copper rod shall not be less than 1/4 in. (6 mm), and the length shall not be less than 2 in. (50 mm).

4.1.1.3 Present criteria based upon the half-cell reaction of $\text{Cu} \rightarrow \text{Cu}^{++} + 2e$ indicate that the potential of the saturated copper-copper sulfate half cell as referenced to the hydrogen electrode is -0.316 V at 72°F (22.2°C). The cell has a temperature coefficient of about 0.0005 V more negative per° F for the temperature range from 32 to 120°F (0 to 49°C).

NOTE 1—While this test method specifies only one type of half cell, that is, the copper-copper sulfate half cell, others having similar measurement range, accuracy, and precision characteristics may also be used. In addition to copper-copper sulfate cells, calomel cells have been used in laboratory studies. Potentials measured by other than copper-copper sulfate half cells should be converted to the copper-copper sulfate

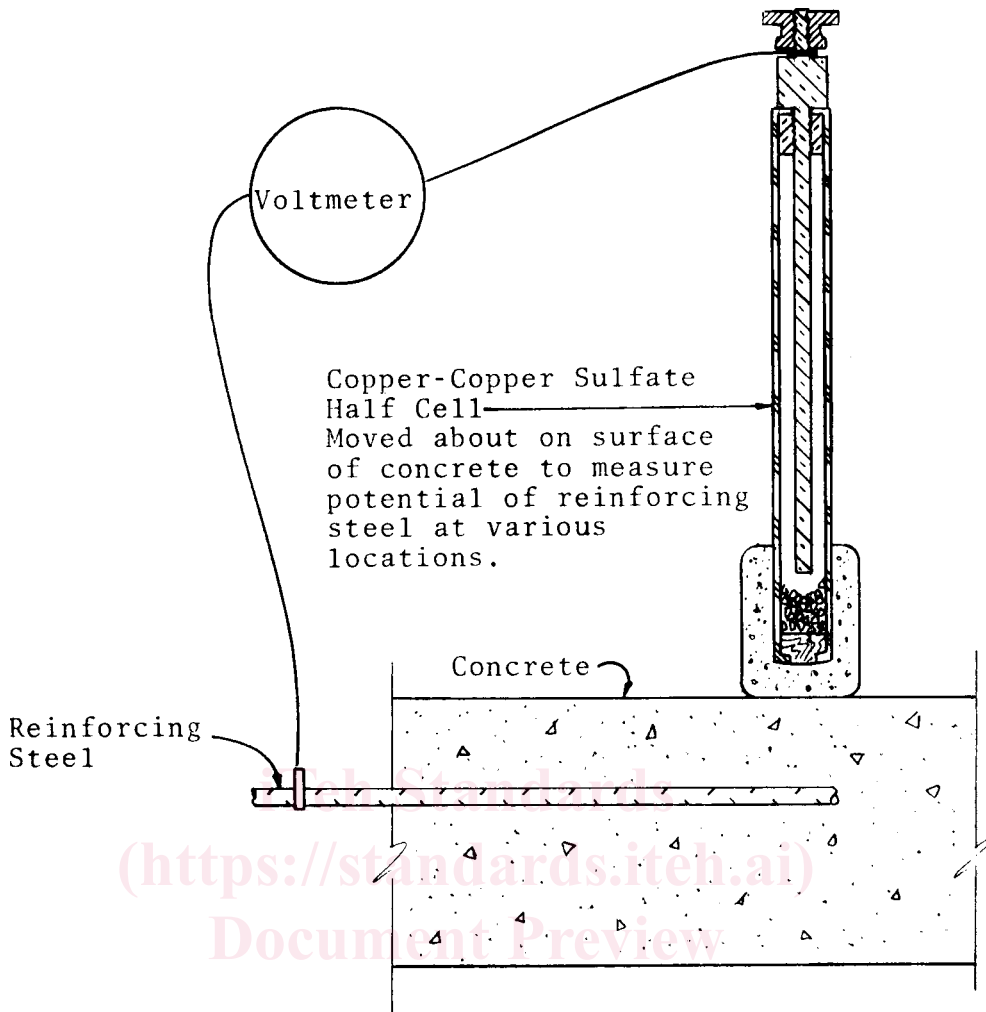


FIG. 1 Copper-Copper Sulfate Half Cell Circuitry

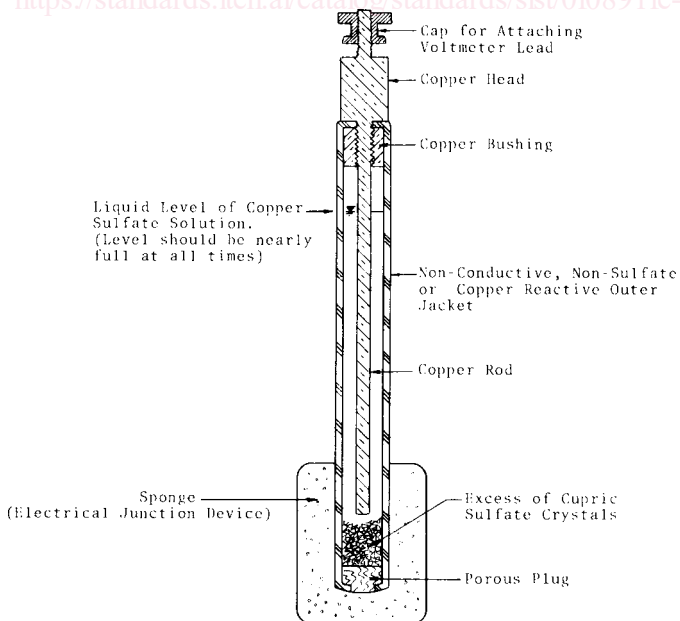


FIG. 2 Sectional View of a Copper-Copper Sulfate Half Cell

equivalent potential. The conversion technique can be found in Practice

G3 and it is also described in most physical chemistry or half-cell technology text books.

4.1.2 *Electrical Junction Device*—An electrical junction device shall be used to provide a low electrical resistance liquid bridge between the surface of the concrete and the half cell. It shall consist of a sponge or several sponges pre-wetted with a low electrical resistance contact solution. The sponge may be folded around and attached to the tip of the half cell so that it provides electrical continuity between the porous plug and the concrete member.

4.1.3 *Electrical Contact Solution*—In order to standardize the potential drop through the concrete portion of the circuit, an electrical contact solution shall be used to wet the electrical junction device. One such solution is composed of a mixture of 95 mL of wetting agent (commercially available wetting agent) or a liquid household detergent thoroughly mixed with 5 gal (19 L) of potable water. Under working temperatures of less than about 50°F (10°C), approximately 15 % by volume of either isopropyl or denatured alcohol must be added to prevent clouding of the electrical contact solution, since clouding may inhibit penetration of water into the concrete to be tested.

4.1.4 *Voltmeter*—The voltmeter shall have the capacity of being battery operated and have $\pm 3\%$ end-of-scale accuracy at

the voltage ranges in use. The input impedance shall be no less than 10 M Ω when operated at a full scale of 100 mV. The divisions on the scale used shall be such that a potential difference of 0.02 V or less can be read without interpolation.

4.1.5 *Electrical Lead Wires*—The electrical lead wire shall be of such dimension that its electrical resistance for the length used will not disturb the electrical circuit by more than 0.0001 V. This has been accomplished by using no more than a total of 500 linear ft (150 m) of at least AWG No. 24 wire. The wire shall be suitably coated with direct burial type of insulation.

5. Calibration and Standardization

5.1 *Care of the Half Cell*—The porous plug shall be covered when not in use for long periods to ensure that it does not become dried to the point that it becomes a dielectric (upon drying, pores may become occluded with crystalline copper sulfate). If cells do not produce the reproducibility or agreement between cells described in Section 11, cleaning the copper rod in the half cell may rectify the problem. The rod may be cleaned by wiping it with a dilute solution of hydrochloric acid. The copper sulfate solution shall be renewed either monthly or before each use, whichever is the longer period. At no time shall steel wool or any other contaminant be used to clean the copper rod or half-cell tube.

6. Procedure

6.1 *Spacing Between Measurements*—While there is no pre-defined minimum spacing between measurements on the surface of the concrete member, it is of little value to take two measurements from virtually the same point. Conversely, measurements taken with very wide spacing may neither detect corrosion activity that is present nor result in the appropriate accumulation of data for evaluation. The spacing shall therefore be consistent with the member being investigated and the intended end use of the measurements (Note 2).

NOTE 2—A spacing of 4 ft (1.2 m) has been found satisfactory for evaluation of bridge decks. Generally, larger spacings increase the probability that localized corrosion areas will not be detected. Measurements may be taken in either a grid or a random pattern. Spacing between measurements should generally be reduced where adjacent readings exhibit algebraic reading differences exceeding 150 mV (areas of high corrosion activity). Minimum spacing generally should provide at least a 100-mV difference between readings.

6.2 *Electrical Connection to the Steel:*

6.2.1 Make a direct electrical connection to the reinforcing steel by means of a compression-type ground clamp, or by brazing or welding a protruding rod. To ensure a low electrical resistance connection, scrape the bar or brush the wire before connecting to the reinforcing steel. In certain cases, this technique may require removal of some concrete to expose the reinforcing steel. Electrically connect the reinforcing steel to the positive terminal of the voltmeter.

6.2.2 Attachment must be made directly to the reinforcing steel except in cases where it can be documented that an exposed steel member is directly attached to the reinforcing steel. Certain members, such as expansion dams, date plates, lift works, and parapet rails may not be attached directly to the reinforcing steel and, therefore, may yield invalid readings. Electrical continuity of steel components with the reinforcing

steel can be established by measuring the resistance between widely separated steel components on the deck. Where duplicate test measurements are continued over a long period of time, identical connection points should be used each time for a given measurement.

6.3 *Electrical Connection to the Half Cell*—Electrically connect one end of the lead wire to the half cell and the other end of this same lead wire to the negative (ground) terminal of the voltmeter.

6.4 *Pre-Wetting of the Concrete Surface:*

6.4.1 Under certain conditions, the concrete surface or an overlaying material, or both, must be pre-wetted by either of the two methods described in 6.4.3 or 6.4.4 with the solution described in 4.1.3 to decrease the electrical resistance of the circuit.

6.4.2 A test to determine the need for pre-wetting may be made as follows:

6.4.2.1 Place the half cell on the concrete surface and do not move.

6.4.2.2 Observe the voltmeter for one of the following conditions:

(a) The measured value of the half-cell potential does not change or fluctuate with time.

(b) The measured value of the half-cell potential changes or fluctuates with time.

6.4.2.3 If condition (a) is observed, pre-wetting the concrete surface is not necessary. However, if condition (b) is observed, pre-wetting is required for an amount of time such that the voltage reading is stable (± 0.02 V) when observed for at least 5 min. If pre-wetting cannot obtain condition (a), either the electrical resistance of the circuit is too great to obtain valid half-cell potential measurements of the steel, or stray current from a nearby direct current traction system or other fluctuating direct-current, such as arc welding, is affecting the readings. In either case, the half-cell method should not be used.

6.4.3 *Method A for Pre-Wetting Concrete Surfaces*—Use Method A for those conditions where a minimal amount of pre-wetting is required to obtain condition (a) as described in 6.4.2.2. Accomplish this by spraying or otherwise wetting either the entire concrete surface or only the points of measurement as described in 6.1 with the solution described in 4.1.3. No free surface water should remain between grid points when potential measurements are initiated.

6.4.4 *Method B for Pre-Wetting Concrete Surfaces*—In this method, saturate sponges with the solution described in 4.1.3 and place on the concrete surface at locations described in 6.1. Leave the sponges in place for the period of time necessary to obtain condition (a) described in 6.4.2.2. Do not remove the sponges from the concrete surface until after the half-cell potential reading is made. In making the half-cell potential measurements, place the electrical junction device described in 4.1.2 firmly on top of the pre-wetting sponges for the duration of the measurement.

6.5 *Underwater, Horizontal, and Vertical Measurements:*

6.5.1 Potential measurements detect corrosion activity, but not necessarily the location of corrosion activity. The precise location of corrosion activity requires knowledge of the electrical resistance of the material between the half cell and the