Designation: G57 – 06 (Reapproved 2012)

Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method[1]

This standard is issued under the fixed designation G57; 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 equipment and procedures for the field measurement of soil resistivity, both in situ and for samples removed from the ground, for use in the control of corrosion of buried structures.

1.2 To convert cm (metric unit) to metre (SI unit), divide by 100.

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. Terminology

2.1 *Definitions:*

2.1.1 *resistivity*—the electrical resistance between opposite faces of a unit cube of material; the reciprocal of conductivity. Resistivity is used in preference to conductivity as an expression of the electrical character of soils (and waters) since it is expressed in whole numbers.

2.1.1.1 *Discussion*—Resistivity measurements indicate the relative ability of a medium to carry electrical currents. When a metallic structure is immersed in a conductive medium, the ability of the medium to carry current will influence the magnitude of galvanic currents and cathodic protection currents. The degree of electrode polarization will also affect the size of such currents.

3. Summary of Test Method

3.1 The Wenner four-electrode method requires that four metal electrodes be placed with equal separation in a straight line in the surface of the soil to a depth not exceeding 5 % of the minimum separation of the electrodes. The electrode separation should be selected with consideration of the soil strata of interest. The resulting resistivity measurement represents the average resistivity of a hemisphere of soil of a radius equal to the electrode separation.

3.2 A voltage is impressed between the outer electrodes, causing current to flow, and the voltage drop between the inner electrodes is measured using a sensitive voltmeter. Alternatively, the resistance can be measured directly. The resistivity, ρ, is then:

$$\rho,\ \Omega\cdot\text{cm} = 2\pi\, aR\ (a \text{ in cm}) \tag{1}$$

$$= 191.5\, aR\ (a \text{ in ft})$$

where:

a = electrode separation, and
R = resistance, Ω.

Using dimensional analysis, the correct unit for resistivity is ohm-centimetre.

3.3 If the current-carrying (outside) electrodes are not spaced at the same interval as the potential-measuring (inside) electrodes, the resistivity, ρ, is:

$$\rho,\ \Omega\cdot\text{cm} = 95.76\, b\, R/\left(1 - \frac{b}{b+a}\right) \tag{2}$$

where:

b = outer electrode spacing, ft,
a = inner electrode spacing, ft, and
R = resistance, Ω.

or:

$$\rho,\ \Omega\cdot\text{cm} = \pi b\, R/\left(1 - \frac{b}{b+a}\right) \tag{3}$$

where:

b = outer electrode spacing, cm,
a = inner electrode spacing, cm, and
R = resistance, Ω.

3.4 For soil contained in a soil box similar to the one shown in Fig. 1, the resistivity, ρ, is:

$$\rho,\ \Omega\cdot\text{cm} = R\, A/a \tag{4}$$

where:

R = resistance, Ω,

[1] This test method is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.10 on Corrosion in Soils.

Current edition approved May 1, 2012. Published June 2012. Originally approved in 1978. Last previous edition approved in 2006 as G57–06. DOI: 10.1520/G0057-06R12.

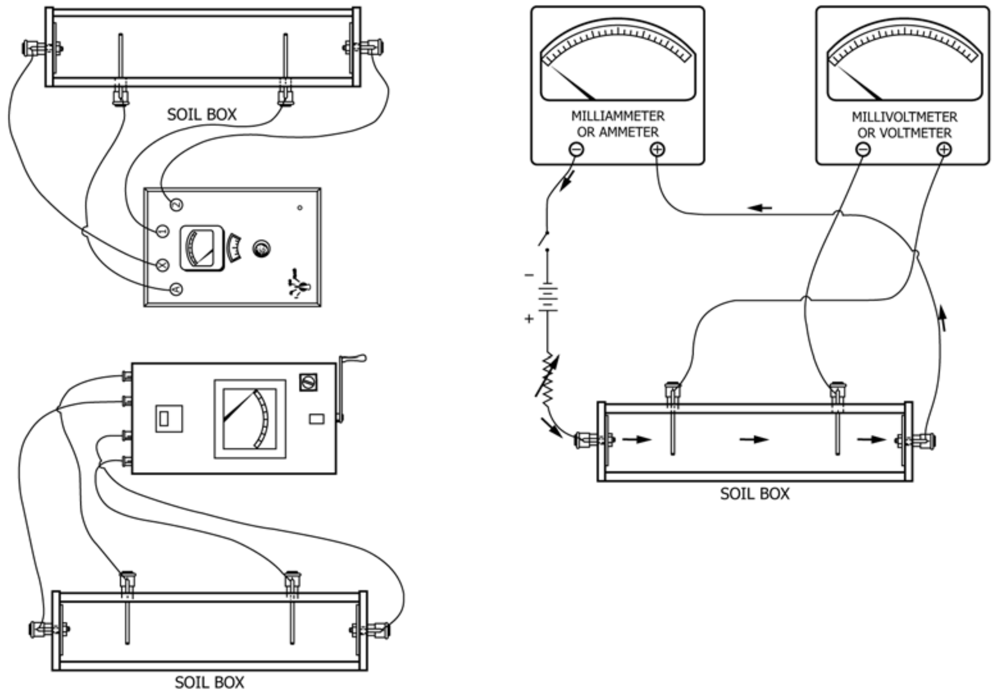

FIG. 1 Typical Connections for Use of Soil Box with Various Types of Instruments

A = cross sectional area of the container perpendicular to the current flow, cm^2, and
a = inner electrode spacing, cm.

NOTE 1—The spacing between the inner electrodes should be measured from the inner edges of the electrode pins, and not from the center of the electrodes.

4. Significance and Use

4.1 Measurement of soil resistivity is used for the control of corrosion of buried structures. Soil resistivity is used both for the estimation of expected corrosion rates and for the design of cathodic protection systems. As an essential design parameter for cathodic protection systems, it is important to take as many measurements as necessary so as to get a sufficiently representative characterization of the soil environment that the entire buried structure will experience.

5. Apparatus

5.1 *At-Grade Measurements in situ:*

5.1.1 The equipment required for field resistivity measurements to be taken at grade consists of a current source, a suitable voltmeter, ammeter, or galvanometer, four metal electrodes, and the necessary wiring to make the connections shown in Fig. 2.

5.1.2 *Current Source*—An ac source, usually 97 Hz, is preferred since the use of dc will cause polarization of most metal electrodes, resulting in error. The current can be provided by either a cranked ac generator or a vibrator-equipped dc source. An unaltered dc source can be used if the electrodes are abraded to bright metal before immersion, polarity is regularly reversed during measurement, and measurements are averaged for each polarity.

5.1.3 *Voltmeter*—The voltmeter shall not draw appreciable current from the circuit to avoid polarization effects. A galvanometer type of movement is preferred but an electronic type instrument will yield satisfactory results if the meter input impedance is at least 10 megaohm.

5.1.4 *Electrodes* fabricated from mild steel or martensitic stainless steel 0.475 to 0.635 cm (3⁄16 to 1⁄4 in.) in diameter and 30 to 60 cm (1 to 2 ft) in length are satisfactory for most field measurements. Both materials may require heat treatment so that they are sufficiently rigid to be inserted in dry or gravel soils. The electrodes should be formed with a handle and a terminal for wire attachment.

5.1.5 *Wiring,* 18 to 22-gage insulated stranded copper wire. Terminals should be of good quality to ensure that low-resistance contact is made at the electrodes and at the meter. Where regular surveys are to be made at fixed electrode spacing, a shielded multiconductor cable can be fabricated with terminals permanently located at the required intervals.

5.2 *Soil Sample Measurement:*

5.2.1 The equipment required for the measurement of the resistivity of soil samples, either in the field or in the laboratory, is identical to that needed for at-grade measurements except that the electrodes are replaced with an inert container containing four permanently mounted electrodes (see Fig. 1).

5.2.2 If the current-carrying (outside) electrodes are not spaced at the same interval as the potential-measuring (inside) electrodes, the resistivity, ρ, is:

$$\rho,\ \Omega\cdot\text{cm} = 95.76\, b\, R / \left(1 - \frac{b}{b+a}\right) \quad (5)$$

where:

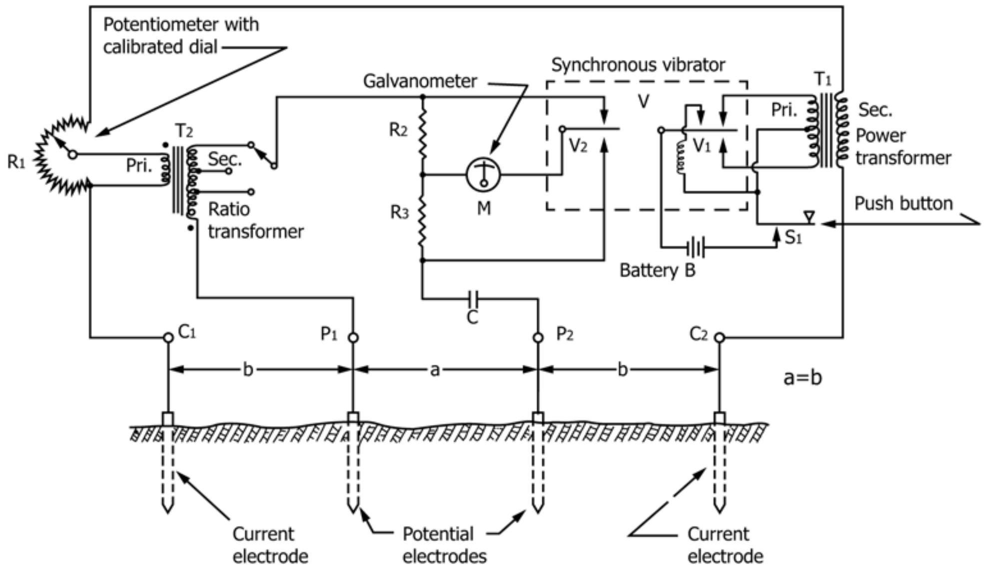

FIG. 2 Wiring Diagram for Typical dc Vibrator-Current Source

b = outer electrode spacing, ft,
a = inner electrode spacing, ft, and
R = resistance, Ω.

or:

$$\rho,\ \Omega\cdot\text{cm} = \pi b\ R / \left(1 - \frac{b}{b+a}\right) \qquad (6)$$

where:

b = outer electrode spacing, cm
a = inner electrode spacing, cm, and
R = resistance, Ω.

5.2.3 The dimensions of the box can be established so that resistivity is read directly from the voltmeter without further calculation. The box should be readily cleanable to avoid contamination by previous samples.

6. Standardization

6.1 Periodically check the accuracy of resistance meters using a commercial resistance decade box. Meter error should not exceed 5 % over the range of the instrument. If error exceeds this limit, prepare a calibration curve and correct all measurements accordingly. A soil box can be calibrated using solutions of known resistivity. Solutions of sodium chloride and distilled water with resistivities of 1000, 5000, and 10 000 Ω·cm are recommended for this purpose. These solutions should be prepared under laboratory conditions using a commercial conductivity meter, itself calibrated to standard solutions at 20°C (68°F).[2]

7. Field Procedures

7.1 *At-Grade Measurements:*

7.1.1 Select the alignment of the measurement to include uniform topography over the limits of the electrode span. Do not include large nonconductive bodies such as frozen soil, boulders, concrete foundations, and so forth, which are not representative of the soil of interest, in the electrode span. Conductive structures such as pipes and cables should not be within ½ *a* of the electrode span unless they are at right angles to the span.

7.1.2 Select electrode spacings with regard to the structure of interest. Since most pipelines are installed at depths of from 1.5 to 4.5 m (5 to 15 ft), electrode spacings of 1.5, 3.0, and 4.5 m (5, 10, and 15 ft) are commonly used. The *a* spacing should equal the maximum depth of interest. To facilitate field calculation of resistivities, spacings of 1.58, 3.16, and 4.75 m (5.2, 10.4, and 15.6 ft), which result in multiplication factors of 1000, 2000, and 3000, can be used when a d-c vibrator-galvanometer instrument is used.

7.1.3 Impress a voltage across the outer electrodes. Measure the voltage drop across the inner electrodes and record both the current and voltage drop if a separate ammeter and voltmeter are used. Where a resistivity meter is used, read the resistance directly and record.

7.1.4 Make a record of electrode spacing, resistance or amperes and volts, date, time, air temperature, topography, drainage, and indications of contamination to facilitate subsequent interpretation.

7.2 *Soil Sample Measurement:*

7.2.1 Soil samples should be representative of the area of interest where the stratum of interest contains a variety of soil types. It is desirable to sample each type separately. It will also be necessary to prepare a mixed sample. The sample should be reasonably large and thoroughly mixed so that it will be representative. The soil should be well-compacted in layers in the soil box, with air spaces eliminated as far as practicable. Fill the box flush to the top and take measurements as previously detailed (7.1.3). The meter used may limit the upper range of resistivity, which can be measured. In such cases, the resistivity should be recorded as <10 000 Ω·cm, and so forth.

7.2.2 The measured resistivity will be dependent on the degree of compaction, moisture content, constituent solubility,

[2] *Handbook of Chemistry and Physics*, 41st ed., The Chemical Rubber Co., p. 2606.