Designation: ~~G57 – 06 (Reapproved 2012)~~ G57 – 20

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~~ assessment and control of corrosion of buried structures.

1.2 ~~To convert cm (metric unit) to metre (SI unit), divide by 100.~~The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard. Soil resistivity values are reported in ohm-centimeter.

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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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]

D1193 Specification for Reagent Water

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

G187 Test Method for Measurement of Soil Resistivity Using the Two-Electrode Soil Box Method

G193 Terminology and Acronyms Relating to Corrosion

2.2 *UNS Standards:*[3]

UNS Designation S30400 and S30403

UNS Designation S31600 and S31603

3. Terminology

3.1 *Definitions:*

[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~~Nov. 1, 2020. Published ~~June 2012~~December 2020. Originally approved in 1978. Last previous edition approved in ~~2006~~2012 as G57~~–06.~~ –06 (2012). DOI: ~~10.1520/G0057-06R12.~~ 10.1520/G0057-20.

[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] *Metals and Alloys in the Unified Numbering System (UNS)*, 13th Edition, developed jointly by ASTM International, West Conshohocken, PA, and SAE International, Warrendale, PA, 2017.

3.1.1 *four-electrode soil box, n*—a non-conductive container of known internal dimensions with four electrodes for measuring a substance's resistivity.

3.1.2 *saturated soil, n*—soil whose entire soil porosity is filled with water.

3.1.3 *soil resistance meter, n*—an instrument capable of measuring soil resistance.

3.1.4 *resistivity—soil resistivity, n*—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.material, typically expressed in ohm-meter, ohm-cm, or similar units; the reciprocal of conductivity

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.

3.2 The terminology used herein, if not specifically defined otherwise, shall be in accordance with Terminology G193. Definitions provided herein and not given in Terminology G193 are limited only to this test method.

3.3 *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.

4. Summary of Test Method

4.1 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.

4.2 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. directly using a soil resistance meter. 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:
where:

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

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

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

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

$$\rho, \Omega{\cdot}\text{cm} = 95.76\ \text{bR}(1 + b/a) \tag{2}$$

where:
where:

b = outer electrode spacing, ft,
a = inner electrode spacing, ft, and

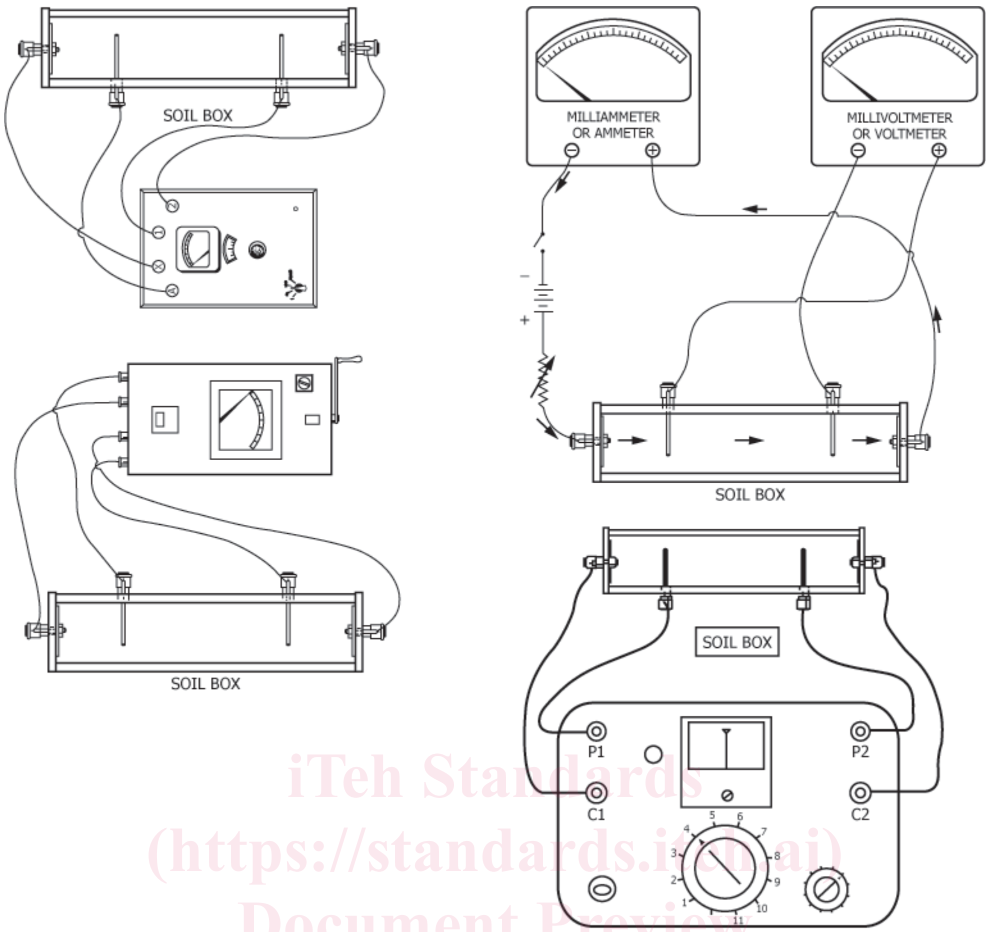

FIG. 1 Typical Connections for Use of Soil Box with Various Types of Instruments

R = resistance, Ω.

or:

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

$$\rho, \Omega\cdot\text{cm} = \pi b R(1+b/a) \quad (3)$$

~~where:~~

where:

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

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

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

~~where:~~

where:

R = resistance, Ω,
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.

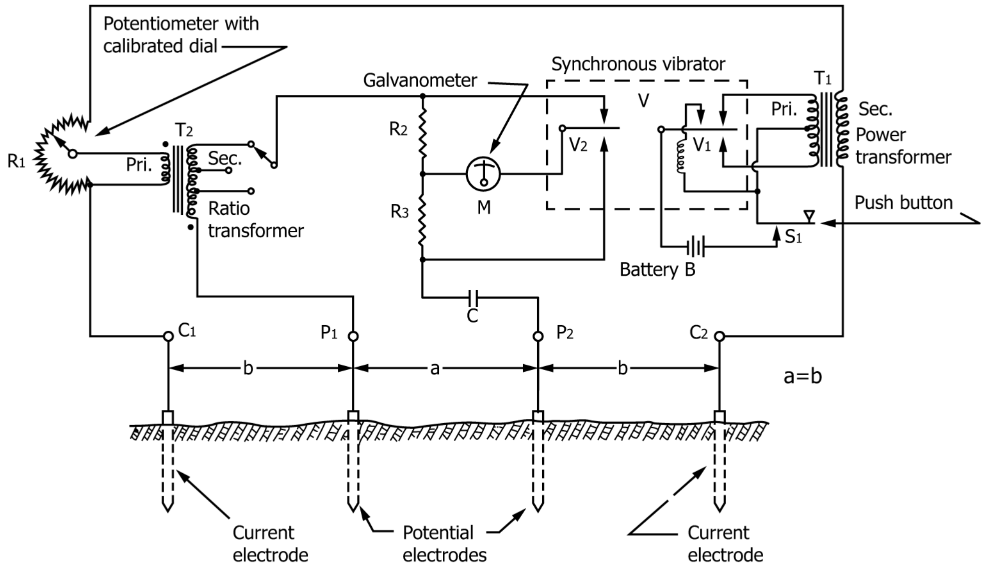

FIG. 2 Wiring Diagram for Typical dc Vibrator-Current Source

5. Significance and Use

5.1 Measurement of soil resistivity is used for ~~the~~ assessment and 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~~ to which the entire buried structure will ~~experience.~~be exposed.

6. Apparatus

6.1 *At-Grade Measurements in situ:*

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

6.1.2 *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.~~ source, which is internal to many soil resistance meters. 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.

6.1.3 *Four Terminal Soil Resistance Meter*—Commercially available, four terminal soil resistance meters are commonly used for measuring soil resistivity. They offer convenience, ease of use, and repeatability. Soil resistance meters yield direct readings in ohms. Some meters allow readings to be taken at multiple depths using electrodes spaced at pre-determined intervals. These meters allow switching between electrode sets without having to rearrange electrodes and can calculate resistivity from the entered geometry and measured current and voltages. Other models have the capability of providing one or two dimensional analysis of soil resistivity at different depths. The meter utilized may limit the upper range of resistivity, which can be measured. In such cases, the resistivity should be reported as greater than the meter's upper limit.

6.1.4 *Voltmeter*—The voltmeter shall not draw appreciable current from the circuit to avoid ~~polarization effects.~~ influencing the results. 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.

6.1.5 *Electrodes* fabricated from mild steel or martensitic stainless steel ~~0.475~~0.475 cm to 0.635 cm (3⁄16 in. to 1⁄4 in.) in diameter and ~~30~~30 cm to 60 cm ~~(1~~(1 ft 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.~~ soils, or soils containing rocks or gravel. The electrodes should be formed with a handle and a terminal for wire attachment.

6.1.6 *Wiring,* 1818 gauge to 22-gage22 gauge 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.

6.2 *Soil Sample Measurement:Measurement* (that is, soil box)*:*

6.2.1 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).

6.2.2 Four-electrode soil boxes can be constructed in various sizes provided the inside dimensions are known. Design and construction shall incorporate materials that are durable and machinable. The two end plate electrodes shall be constructed of a clean, polished, corrosion-resistant metal or alloy (that is, UNS Designation type S30400/S30403 or UNS S31600/S31603 stainless steel) that will not form a heavy oxide film or otherwise add significant resistance. The body of the box shall be constructed of a material that is non-conductive and able to maintain its desired dimensions (polycarbonate plastics). The box shall be readily cleanable to avoid contamination by previous samples. Some soil box designs incorporate removable pins (that is, electrodes) to facilitate cleaning. Other soil box designs incorporate two electrodes in lieu of four electrodes (see Test Method G187).

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

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

determined

where:

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

using Eq 2, where the spacing is given in feet, and Eq 3, where the electrode spacing is given in centimeters.

or:

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

where:

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

6.2.4 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.

7. Reagents and Materials

7.1 Distilled or deionized water (Type IV grade as referenced in Specification D1193) to saturate samples.

7.2 Commercially available solutions in the range of 1000 ohm-cm, 5000 ohm-cm, and 10 000 ohm-cm are recommended for the purpose of calibration.

8. Standardization

8.1 Periodically check the accuracy of resistance meters using a commercial resistance decade box. manufacturer's recommendations. 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 1000 Ω·cm, 5000 Ω·cm, and 10 000 Ω·cm are