Designation: G200 – 09 (Reapproved 2014)

Standard Test Method for Measurement of Oxidation-Reduction Potential (ORP) of Soil[1]

This standard is issued under the fixed designation G200; 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 a procedure and related test equipment for measuring oxidation-reduction potential (ORP) of soil samples removed from the ground.

1.2 The procedure in Section 9 is appropriate for field and laboratory measurements.

1.3 Accurate measurement of oxidation-reduction potential aids in the analysis of soil corrosivity and its impact on buried metallic structure corrosion rates.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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]

D1498 Test Method for Oxidation-Reduction Potential of Water

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

G3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing

G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[3]

G57 Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method

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

3. Terminology

3.1 The terminology used in this test method, if not specifically defined otherwise, shall be in accordance with Terminology G15.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration solution, n*—commercially available solution with a stable ORP used for calibrating an ORP measuring system (meter and probe).

3.2.2 *ORP*—abbreviation for oxidation-reduction potential.

3.2.3 *ORP electrode (probe), n*—commercially available combination two-element electrode (probe) specifically designed for the measurement of ORP when used in conjunction with a compatible ORP meter.

3.2.3.1 *Discussion*—The combination probe consists of a platinum electrode and a reference electrode, which are generally silver/silver chloride. For soil measurements, the probe must be sufficiently robust to withstand the rigors of the measurement. Regardless, the often fragile probe should be used with caution to avoid damage and maintain measurement reliability.

3.2.4 *ORP meter, n*—commercially available electrical meter specifically designed for the measurement of ORP with internal impedance greater than 10 Ω. Often, the meter is capable of measuring ORP and pH when used in conjunction with the appropriate electrode.

3.2.4.1 *Discussion*—Standard voltmeters or multimeters with internal impedances typically less than 10 Ω are not suitable for soil ORP measurements. Pocket style meters where the electrode is an integral part of the meter housing are also not suitable.

3.2.5 *oxidation-reduction potential (soil), n*—electrical potential measurement to determine the tendency of a soil to transfer electrons between its chemical species. It is the measured potential of an inert metal electrode (generally platinum) with respect to a reference electrode such as silver/silver chloride.

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[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.

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[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] The last approved version of this historical standard is referenced on www.astm.org.

3.2.5.1 *Discussion*—A soil with a higher, more positive potential has an increased tendency to acquire electrons and be reduced (aerobic soil conditions). A soil with a lower positive or negative potential has an increased tendency to lose electrons and be oxidized (anaerobic soil conditions). Soil oxidation-reduction potential is typically reported in units of millivolts (mV) or volts (1 volt = 1000 mV). Sign convention and reference electrodes conform to Practice G3.

3.2.6 *redox potential, n*—synonym for oxidation-reduction potential.

3.2.7 *soil sample, n*—sample of soil to be tested. The minimum (typical) sample size is 1 qt.

4. Summary of Test Method

4.1 The measurement procedure, as described in Section 9 of this test method for determining the ORP of a soil sample, aids in determining the corrosivity of that sample.

4.2 Soil ORP can be measured in a field or laboratory setting.

4.3 While the primary purpose of this test method is measuring soil ORP, it may also be used as a general indicator of ORP in groundwater. Test Method D1498 was specifically developed for accurate ORP measurements of aqueous samples.

5. Significance and Use

5.1 Soil ORP, in conjunction with other soil characteristics such as electrical resistivity (see Test Methods G57 and G187), is used to predict corrosion tendencies of buried metallic structures (for example, pipelines and culverts. The ORP of the soil is one of many factors that influence structure service life. Its measurement is used in the design of new buried structures and in the evaluation of existing buried structures.

5.2 Soil ORP is a time-sensitive measurement. For an accurate indication of soil corrosivity, the measurement should be made as soon as practicable after removal of the soil sample from the ground.

5.3 The user of this test method is responsible for determining the significance of reported ORP measurements. ORP alone should typically not be used in characterizing the corrosivity of a particular soil. ORP measurements are appropriate when evaluating oxygen related reactions.

5.4 ORP measurements can sometimes be quite variable and non-reproducible. This is related, in part, to the general heterogeneity of a given soil. It is also related to the introduction of increased oxygen into the sample after extraction. The interpretation of soil ORP should be considered in terms of its general range rather than as an absolute measurement.

5.5 ORP measurements can be used to determine if a particular soil has the propensity to support microbiologically influenced corrosion (MIC) attack. These measurements can also be used to provide an indication of whether soil conditions will be aerobic or anaerobic. Appendix X1 provides reference guidelines for general interpretation of ORP data.

6. Apparatus

6.1 The equipment required for the measurement of soil ORP, either in the field or in the laboratory, consists of:

6.1.1 *ORP Meter.*

6.1.2 *Compatible Two-Electrode Combination ORP Electrode (Probe)*—A main probe and a backup probe are recommended.

NOTE 1—This test method calls for soil ORP measurements to utilize a commercially available combination electrode (inert metal and reference combined in one probe). Commercially available ORP combination electrodes are generally platinum (inert metal) with silver/silver chloride (reference) in a 3.5 to 4 M KCl electrolyte.

6.1.3 *Operating Instructions*—For ORP meter and ORP electrode.

6.1.4 *Calibration Solution(s)*—For verification of measuring system accuracy within the range of expected ORP values. Calibration solutions should remain uncontaminated. They typically have a published shelf life of no more than 1 year and should not be used once the shelf life is exceeded. Calibration solutions can be obtained commercially or may be mixed in the laboratory using standard pH buffers (4 and 7) and quinhydrone.

NOTE 2—Commercially available ORP calibration solution values should be appropriate for the combination electrode (platinum and silver/silver chloride) used. Calibration kits utilizing pH buffers and quinhydrone solutions are generally used for the platinum and silver/silver chloride combination electrode.

6.1.5 *Clear Plastic or Polyethylene Bags*—1 gal (3.785 L) size is typical, or other convenient means to collect the soil sample and to compress the sample while under test. One clean and dry bag should be used for each sample. Do not reuse.

6.1.6 *Squirt Bottle and Soft Toothbrush*—Bottle with gooseneck (or similar) filled with distilled or deionized water and soft toothbrush (or similar) for cleaning ORP electrode after each measurement. Cleaning procedures should be in accordance with the probe manufacturer's written instructions and should in no way damage the probe or otherwise compromise the ORP measurement.

7. Sampling

7.1 Generally, collected soil samples to be tested in the laboratory shall be placed in an appropriate sealable container or polyethylene type bag. This allows containers to be identified by location, date/time sample was collected, etc.

7.2 Soil samples shall 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. Soil samples to be tested in the laboratory shall be allowed to reach room temperature, approximately 68°F (20°C), prior to the ORP measurement. Field measurements shall reflect the soil's temperature during testing.

8. Calibration and Standardization

8.1 Turn on the ORP meter in accordance with the meter manufacturer's written instructions. Allow sufficient warm-up/stabilization time as specified by the manufacturer.

8.2 Check the meter "zero" by shorting the input connection in accordance with the manufacturer's instructions. For a BNC type connection and probe cable, a paper clip between the meter input center connection and outer shield (ground) typically suffices. With the input shorted, adjust the meter as necessary in accordance with the manufacturer's instructions so it is no greater than ±0.5 mV. A meter that cannot be zeroed to within ±0.5 mV may be faulty and should not be used.

8.3 Clean the ORP probe with three changes of distilled or deionized water or by means of a flowing stream of distilled or deionized water from a wash bottle or other source.

8.4 *Calibration Procedure using Commercially Available Calibration Solution*—With the cleaned ORP probe connected to the properly operating ORP meter, place the ORP probe element in one or more calibration solutions and measure the responses. For non-adjustment type meters, the ORP reading should be within 30 mV of the stated calibration solution potential for platinum and silver/silver chloride probe. For meters that can be adjusted, adjust the reading in accordance with the manufacturer's instructions to the stated potential for the calibration solution. Once an initial, stable reading is obtained, remove the probe and place in a fresh sample of the same calibration solution. The second reading should differ from the first by no more than 10 mV. Rinse the ORP probe with distilled or deionized water between readings if more than one calibration solution is used, that is, solutions with different ORP values.

8.5 *Calibration Procedure using pH Buffers and Quinhydrone Calibration Solution*—In a 4 oz (118.4 mL) beaker, pour 0.5 oz (14.8 mL) of pH 7 buffer. Using a wood applicator stick add quinhydrone until the pH 7 buffer is just oversaturated, stirring frequently. A small amount of the quinhydrone must remain undissolved. In another beaker, repeat this procedure using a pH buffer of 4. With the cleaned ORP probe connected to the properly operating ORP meter, put the probe in the beaker filled with the 7 buffer/quinhydrone mixture, stir the electrode gently and let it rest against the side of the beaker. Allow to stabilize (60 s), and note the reading. A properly performing platinum and silver/silver chloride ORP combination electrode should be within about plus or minus 15 mV from the following values:

Temperature and Reading
68°F (20°C) = +96 mV
77°F (25°C) = +90 mV
86°F (30°C) = +83 mV

Rinse the ORP electrode and pat dry with a soft tissue. Now put it in the beaker with the 4 buffer/quinhydrone mixture, stir the electrode gently and let it rest against the side of the beaker. Allow to stabilize (60 s), and note the reading. This reading should be between +170 mV and +185 mV above the reading in the 7 buffer mixture.

8.6 The buffer/quinhydrone mixtures should be freshly made each time the ORP electrodes are calibrated. Do not store the mixtures or use after 2 h as their values can change with time.

9. Procedure

9.1 Remove all stones, pebbles, gravel, roots, twigs and other deleterious material from the soil sample that could break or abrade the ORP probe sense element. Place the suitable sample in a clear plastic bag.

9.2 Adjust the ORP meter, and calibrate and clean the ORP probe, in accordance with Section 8. The probe should be rinsed in distilled or deionized water after removing from the calibration solution(s).

9.3 Carefully insert the ORP probe vertically into the center of the soil sample so a minimum of 2 in. (5.08 cm) of the probe barrel (lower portion) is covered. There should be a minimum of 2 in. (5.08 cm) of soil around the probe in all directions. Avoid exerting pressure, since the sense element is fragile and may break.

9.4 Squeeze the bagged soil around the probe barrel and sense element to assure a tight, complete contact between the sense element and the soil. For "soft" (loose) soils, the probe should be gently pushed in to the soil sample, lightly compacting the soil around the probe tip as necessary.

9.5 With the probe stationary, observe the meter reading waiting until it stabilizes or 2 min, whichever occurs first. Certain ORP meters have a stabilization/lock-hold function that can be used as appropriate to capture a stable reading based on meter-specific processing and algorithms. For this test method, readings that vary less than 30 mV over a 2 min period should be considered stable with the least positive or most negative potential recorded.

NOTE 3—In certain soils (for example, heavy mucks) there can be a considerable range in ORP within a given sample from one measurement location to the next. In such instances, it is best to "probe" with the electrode in a few locations within the sample until the least positive or most negative potential is determined.

9.6 Clean the probe with distilled or deionized water including removing any lodged material from the sensor area.

9.7 Repeat Steps 9.3 – 9.6 two times inserting the probe at different locations within the sample. For each location, once the reading has stabilized, read and record the least positive or most negative potential measured.

10. Report

10.1 Report the following information for each soil sample tested:

10.1.1 Three ORP measurements.

10.1.2 Date and time of measurements.

10.1.3 Ambient air temperature at time of measurements.

10.1.4 Soil sample description including location, depth, and other pertinent information.

10.1.5 Date and time soil sample was extracted from the ground.

10.1.6 Manufacturer, model number and serial number for ORP meter.

10.1.7 Manufacturer, model number and purchase date for ORP probe.

10.1.8 Stated ORP value(s) and purchase dates (and or expiration dates) for calibration solutions.

TABLE 1 Statistics from Interlaboratory Study (ILS) for Measurement of Soil ORP

NOTE 1—where: r = 2.8 (s_r); R = 2.8 (s_R); values in millivolts (mV).

	Average of Averages, y	Standard Deviation of Averages, s_x	Repeatability Standard Deviation, s_x	Reproducibility Standard Deviation, s_R	Repeatability Limit, r	Reproducibility Limit, R
Soil Sample #1	231.9	19.5	20.5	25.7	57.4	72.0
Soil Sample #2	106.6	18.6	29.2	30.3	81.8	84.8
Soil Sample #3	358.4	20.7	16.2	24.6	45.4	68.9

11. Precision and Bias[4]

11.1 *Precision*—The precision of this test method was determined by a statistical evaluation of an interlaboratory study in accordance with Practice E691. The data from this evaluation are available from ASTM in an interlaboratory study research report.[4] A summary of these data is given in Table 1.

11.1.1 *Repeatability*—Repeatability refers to the variation in results obtained by the same operator with the same equipment and the same operating conditions in successive tests. In the case of soil ORP measurements, the repeatability may be characterized by the variances of the repeatability standard deviations. The ILS results indicate a repeatability standard deviation of 23 mV. The 95% repeatability limits is 2.8 (s_r) or 63 mV.

11.1.2 *Reproducibility*—Reproducibility refers to the variation in results that occurs when different operators measure samples of the same soil. In the case of soil ORP measurements reproducibility may be characterized by the variances of the reproducibility standard deviations. The ILS results indicate a reproducibility standard deviation of 27 mV. The 95% reproducibility limits is 2.8 (s_R) or 75 mV.

11.1.3 *Bias*—The procedure in this test method for the measurement of soil ORP has no bias because the ORP value is defined only in terms of this test method.

12. Keywords

12.1 ORP; oxidation-reduction potential; soil

APPENDIX

(Nonmandatory Information)

X1. REFERENCE GUIDELINES FOR INTERPRETING ORP GUIDELINES

X1.1 Recognizing that ORP measurements alone should typically not be used in characterizing the corrosivity of a particular soil, reference guidelines for interpreting the corrosion significance of ORP data include the following:

X1.1.1 One use of a soil ORP measurement is to determine if a particular soil has the propensity to support microbiologically influenced corrosion (MIC) attack. The following table illustrates the general relationship for ferrous materials based on the soil test evaluation protocol included in Appendix A of ANSI/AWWA C105 A21.5-99.[5]

	Soil will support MIC
Negative potential	High probability
0 mV or positive potential less than 100 mV	Moderate probability
Positive potential equal to or greater than 100 mV	MIC attack unlikely

X1.1.2 Uhlig[6] reports that ORP measurements can provide an indication of whether soil conditions will be aerobic or anaerobic. Under aerobic conditions, oxygen content will be high and the ORP will be more positive than that measured for an anaerobic soil. The general conclusion is that aerobic soil conditions are relatively benign. More severe corrosivity is seen under anaerobic conditions. This observation is at least partly explained by the potential for anaerobic microbial activity in soils with a low ORP.

X1.1.3 Reference Electrode Potentials at 25°C

NHE (Normal Hydrogen Electrode)	0 mV
SCE (Saturated Calomel Electrode)	241 mV
SSCE (Sodium Saturated Calomel Electrode)	236 mV
Ag/AgCl (Saturated KCl)	199 mV
Hg/Hg_2SO_4 (Saturated K_2SO_4)	640 mV

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[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:G01-1023.

[5] *ANSI/AWWA C105 A21.5-99*, American National Standard for Polyethylene Encasement for Ductile Iron Pipe Systems, Appendix A, American Water Works Association, Denver, CO.

[6] *Uhlig's Corrosion Handbook*, Second Edition, Revie, R. Winston, Ed., The Electrochemical Society, Inc., Pennington, NJ, 2000, pp. 339-341.

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