Designation: D 6190 – 97

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428

Standard Test Method for Cathodic Disbonding of Pipeline Coatings by Laboratory Simulation of Soil Burial[1]

This standard is issued under the fixed designation D 6190; 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 an accelerated procedure for determining the relative disbonding characteristics of electrically insulating coating systems applied to steel pipe exteriors. The coating is applied for the purpose of preventing or mitigating corrosion that may occur in underground service. The pipe may be exposed to elevated temperatures while under cathodic protection. This test method is intended for use with samples of coated pipe taken from commercial production and is applicable to such samples when the coating functions as an electrical barrier.

1.2 The values stated in SI units to three significant figures are to regarded as the standard.

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:*

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[2]

G 12 Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel[3]

G 19 Test Method of Test for Disbonding Characteristics of Pipeline Coatings by Direct Soil Burial[3]

3. Summary of Test Method

3.1 An apparatus is described in which soil is brought in contact with a coated pipe sample under conditions that simulate soil burial. The specimens with intentionally damaged areas are electrically connected to a rectifier to apply an electrical stress. A highly conductive soil mixture consisting of electrolyte soaked sand is used to accelerate the test. After test, the disbonded areas of coating are removed and the exposed area is measured.

3.2 The cathodic stress may be applied under conditions of a constant level elevated temperature.

3.3 Physical examination is conducted by comparing the extent of loosened or disbonded coating at the perforations in the soil exposed area with the extent of loosened or disbonded coating at a new test hole in the coating made in an area that was not exposed to soil.

4. Significance and Use

4.1 Damage to pipe coating is almost unavoidable during transportation and construction. Breaks or holidays in pipe coatings may expose the pipe to possible corrosion, since after a pipe has been installed underground, the surrounding soil could be an effective electrolyte. These coatings are generally used under cathodic protection conditions; damaged areas in them can enlarge to an extent that would not allow the cathodic protection to be effective. Elevated temperature increases the tendency of coatings to disbond, however, there may be a considerable difference in the tendency to disbond in the ground and in the laboratory electrolyte test. It is therefore appropriate for some coatings to test cathodic disbonding in soil both at room and elevated temperatures. The test is accelerated by using sand soaked with electrolyte as the conducting medium.

4.2 When compared to field testing of samples outdoors in soil, the method described here offers better control, uses less soil, and can be performed in the laboratory. In addition, the use of highly conductive electrolyte-soaked sand results in significant acceleration of the test over Test Method G 19.

4.3 The physical examination is made easier by comparing the adhesion of the coating to that obtained at a section not exposed to the soil. This is assumed to be the maximum adhesion or bond as measured by the lifting technique used and that the same lifting technique can be used at a test hole that was exposed to the soil. This provides a means of comparing the relative resistance to lifting.

4.4 It is assumed that any relatively lesser bonded area at the exposed test holes in the coating was caused by electrical stressing.

5. Apparatus

5.1 The soil simulation test apparatus is shown schematically in Fig. 1. Drawings for the aluminum lower seal, plastic top plate, aluminum top seal, and plastic main body are shown in Fig. 2. These drawings will enable the construction of an

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[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.48 on Durability of Pipeline Coating and Linings .

Current edition approved Nov. 10, 1997. Published February 1998.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 06.02.

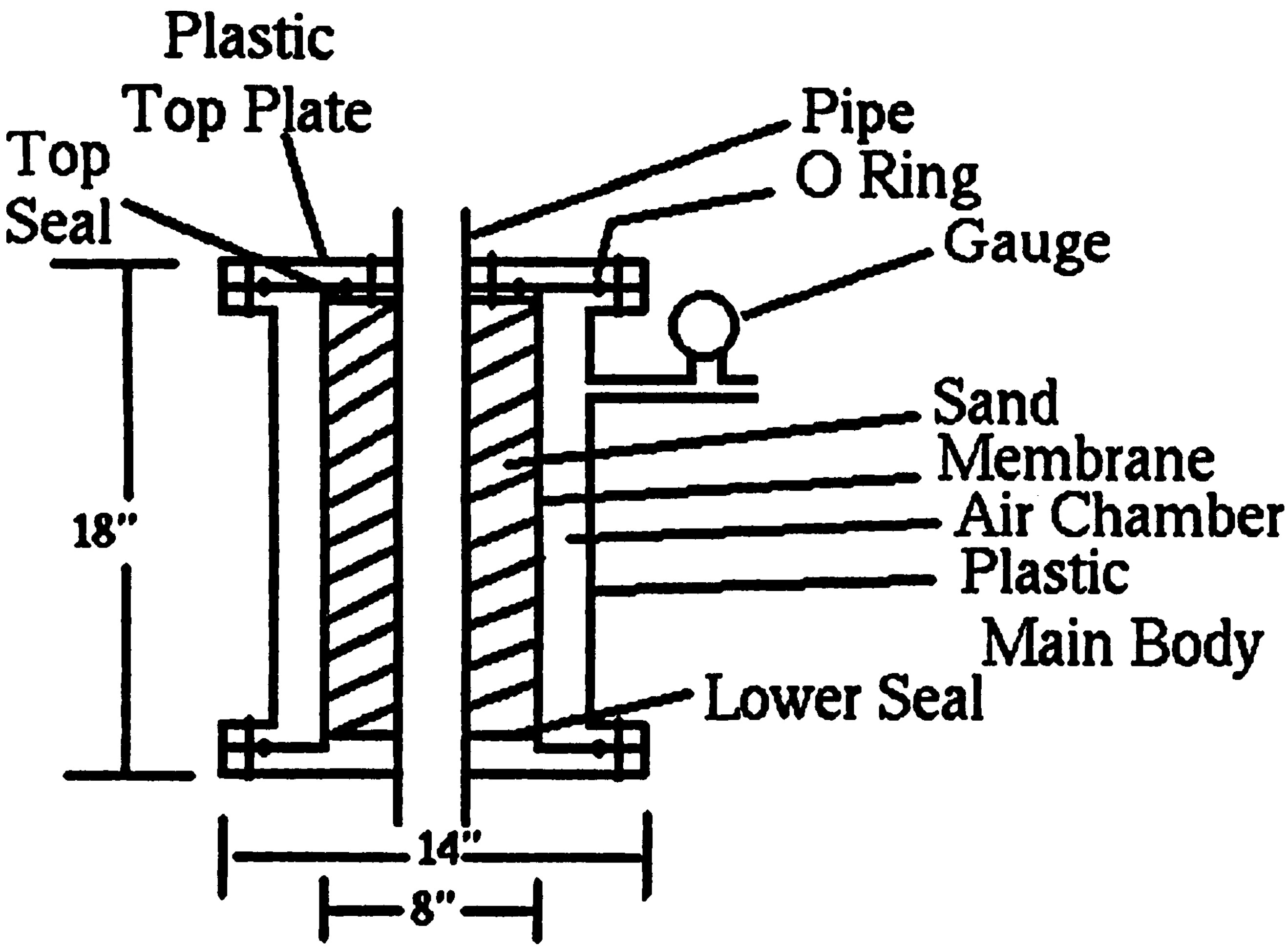

FIG. 1 Soil Simulator Apparatus

apparatus by the user. The coated pipe specimen is placed in the center of the apparatus surrounded by the sand. The sand is held in place with a rubber membrane in the shape of a cylinder that transmits the air pressure on the outside of the membrane and the outer plastic cylinder can be pressurized with air. This effectively reproduces any desired radial force on the soil/pipe interface. The "O" rings on the top and lower seal plates seal the air chamber between the plastic cylinder and the rubber membrane. Thus, there is no air seal between the sample and the soil. A pressure gage reads the air pressure in the chamber that can be controlled by a regulator. The pressure used to simulate the burial depth varies with the density of soil and is given in Fig. 3 for densities of 23.0 kN/m^3(125 lb/ft^3) to 15.7 kN/m^3 (80 lb/ft^3).

5.1.1 With noncohesive soils, such as sand, a rubber diaphragm end seal is used to prevent leakage of soil sample. The rubber seal is in the shape of a circle cut in the center to allow a tight fit for the test pipe. The rubber seal is placed on the pipe specimen before the pipe is placed in the apparatus as shown in Fig. 4.

5.1.2 The apparatus is sized for a 5-cm (2-in.) nominal pipe diameter, 61 cm (24 in.) long with a 20.3-cm (8-in.) soil diameter. However, it can easily be scaled for larger diameter pipe. In order to determine the cathodic disbondment as a function of temperature of the pipe, a cartridge heater[4] and thermocouple are inserted in the center of the specimen and surrounded by copper chips or steel shot. The copper chips or steel shot effectively maintain a uniform temperature throughout the interior of the sample. This arrangement has been found to be superior to using circulating oil as the heating medium, however, a circulating oil system is acceptable.

5.2 *Miscellaneous Apparatus*:

5.2.1 *Connectors*—Wiring from anode to test specimen shall be 4107–cmil (14–gage Awg) minimum, insulated copper. Attachment to the test specimen shall be by soldering, brazing or bolting to the unburied end, and the place of attachment shall be coated with an insulating material. A junction in the connecting wire is permitted provided that it is made by means of a bolted pair of terminal lugs soldered or mechanically crimped to clean wire ends.

5.2.2 *Holiday Tools*—Holidays shall be made with conventional drills of the required diameter. For use in preparing small

[4] The sole source of supply of the heater, Model CIR-5177, 850 W, 451 mm (17.75 in.) long, known to the committee at this time is Capp Inc., 6 Beacon Street, Boston, MA 02108. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

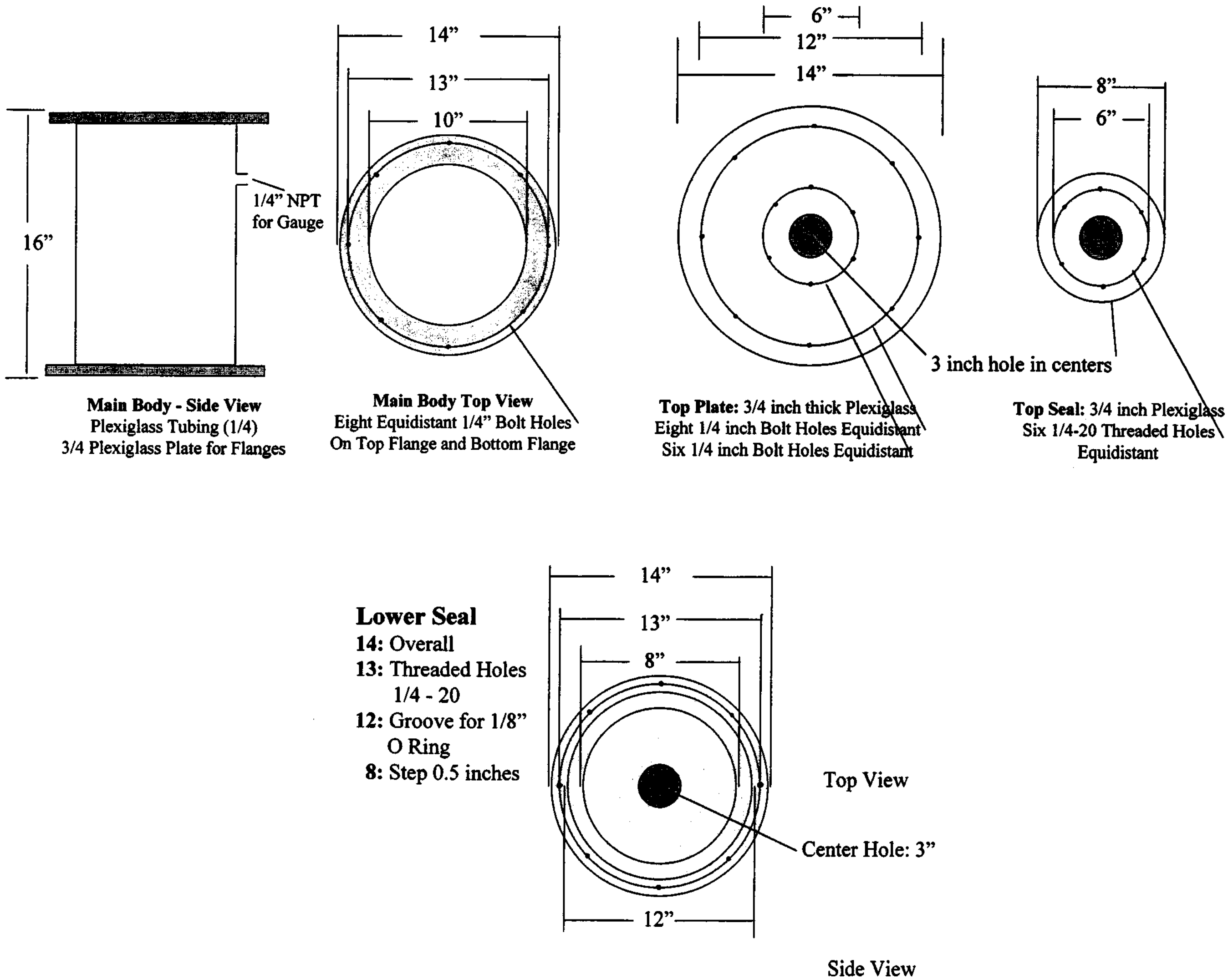

FIG. 2 Soil Simulator Parts

diameter pipe specimens such as 19.05-mm (0.75-in.) nominal diameter pipe, the use of a drill modified by substantially grinding away the sharp cone point has been found effective in preventing perforation of the metal wall of the pipe. A sharp pointed knife with a safe handle is required for use in making physical examinations.

5.2.3 *High Resistance Voltmeter*, for direct current having an internal resistance of not less than 10 megohms and having a range of 0.01 to 5 V for measuring potential to the reference electrode.

5.2.4 *Reference Electrode*, saturated $Cu/CuSO_4$, of conventional glass or plastic tube with porous plug construction, preferably not over 10.05-mm (0.75-in.) in diameter, having a potential of –0.316 V with respect to the standard hydrogen electrode. A calomel electrode may be used, but measurements made with it shall be converted to the $Cu/CuSO_4$, reference for reporting by adding –0.072 V to the observed reading.

5.2.5 *Thickness Gage*, for measuring coating thickness in accordance with Test Method G 12.

5.2.6 *Thermometer*, for measuring electrolyte temperature, general lab type, 1° subdivisions, 76.2 mm (3 in.) immersion.

5.2.7 *Precision Wire Wound Resistor*, 1 Ω ± 1 %, 1 W (minimum), to be used in the test cell circuit as a shunt for current.

5.2.8 *Volt-Ohm Meter*, for initial testing of apparent coating resistance.

5.2.9 *Additional Connecting Wires*, 4107–cmil (14–gage Awg) minimum, insulated copper.

5.2.10 *Brass Studs*, used at a terminal board, together with alligator clips or knife switches, for making and breaking circuits. However, alligator clips shall not be used to connect to electrodes or specimens at the top location of test cells.

5.2.11 *Direct Current Rectifier*, capable of supplying constant voltage at a voltage of 1.5 ± 0.01 V, as measured between the specimen and reference electrode.

5.2.12 *Impressed Current Anode*, shall be of the nonconsumable type provided with a factory sealed, insulated copper wire. Platinum clad anodes, 3.2 by 610 mm (1/8 by 24 in.) have been found useful.

6. Reagents and Materials

6.1 The electrolyte to be added to the sand shall consist of potable tap water or higher purity water (distilled or demineralized water is satisfactory) with the addition of 3 weight % of

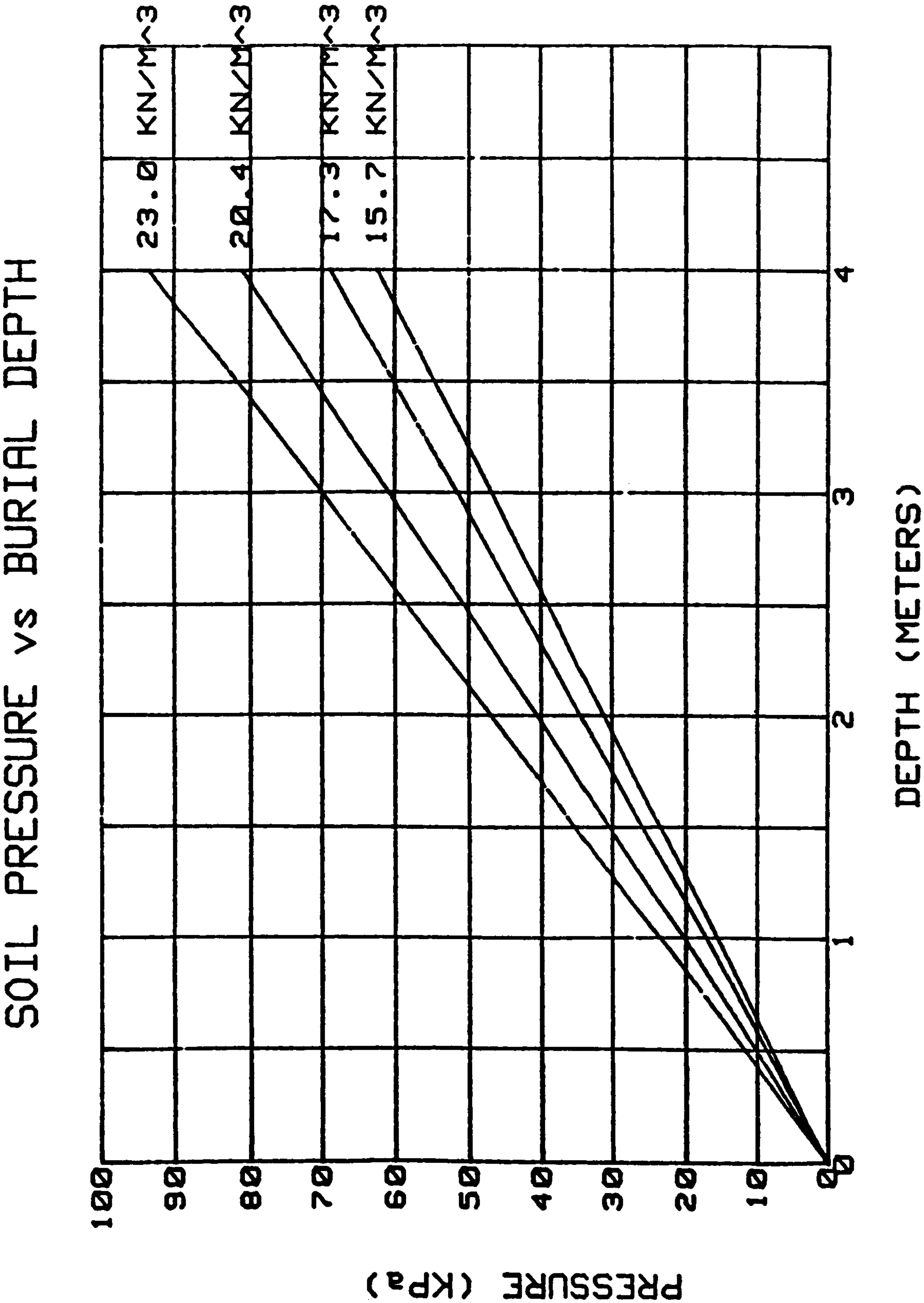

FIG. 3 Soil Pressure Versus Burial Depth

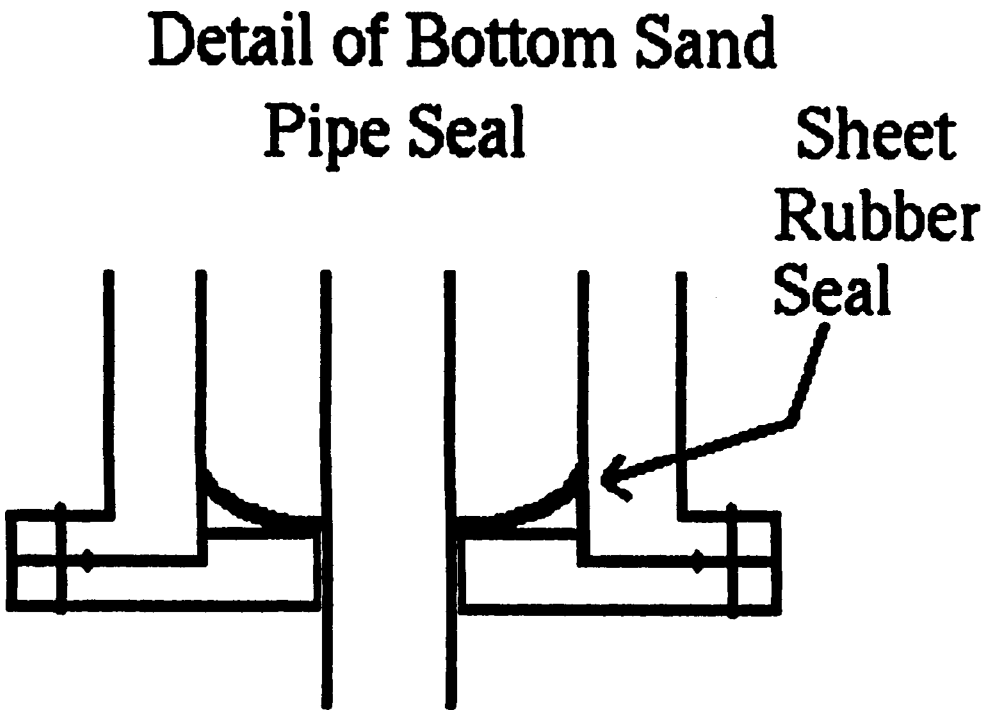

FIG. 4 Bottom Sand Seal

technical grade sodium chloride calculated on an anhydrous basis.

6.2 The bottom end of the specimens must be sealed in order to determine the integrity of the coating before testing and to contain the heat transfer material. Materials for sealing the ends of coated pipe specimens may consist of bituminous products, wax, epoxy or other materials, including molded elastomeric or plastic end caps capable of withstanding the test temperatures.

6.3 Natural silica sand from the St. Peters or Jordan sandstone deposits (located in the central United States) shall be considered standard when not more than 15 % of the grains in a sample are retained on a No. 20 (850–µm) sieve and not more than 5 % of the grains pass a No. 30 (600–µm) sieve after 5 min, of continuous sieving. The sand is characterized by its roundness of grains and its exceptionally high silicon dioxide content and may be used unwashed. Use the sieves described in Specification E 11.

7. Test Specimen

7.1 The test specimen shall be a representative piece of production coated pipe. One end shall be plugged, sealed or capped with sufficient sealing to prevent the copper chips or steel shot heat transfer material from spilling out.

7.2 One holiday shall be made in the middle of the buried length by drilling a radial hole through the coating so that the angular cone point of the drill will fully enter the steel where the cylindrical portion of the drill meets the steel surface. The drill diameter shall be 6 mm (1/4 in.) in diameter. The steel wall of the pipe shall not be perforated by the drill.

7.3 The end of the pipe that will protrude from the soil simulator shall be provided with a wire connection bolted, soldered or brazed to the pipe.

7.4 Verify the continuity of the coating before making the intentional holiday as in 8.1.

8. Specimen Preparation

8.1 Before making the intentional holiday, verify the continuity of the coating as follows:

8.1.1 Immerse the test specimen and a metallic electrode in an electrolyte bath. Connect one terminal of the ohmmeter to the test specimen and the other terminal to the metallic electrode. Measure the apparent resistance in ohms making two determinations: One with the specimen connected to the positive terminal of the ohmmeter; and one with the specimen connected to the negative terminal.

8.1.2 Disconnect the specimen from the ohmmeter but leave it immersed for 15 min. Then measure the resistance again as in 8.1.1.

8.1.3 A significant decrease in either resistance reading after 15 min will indicate a flaw in the coating or endcap seal. Reject the specimen if the flaw is identified in the coating.

8.1.4 The lowest resistance after 15 min of immersion shall be not less than 1000 megohms, but a stable reading below 1000 megohms may not indicate a flaw and the specimen may be used for test. All resistance measurements shall be reported in the results.

8.2 Record initial holiday diameter.

8.3 Measure and record the minimum and maximum coating thickness in accordance with Test Method G 12, and the thickness where the holiday is made.

9. Procedure

9.1 *Soil Simulator Setup*:

9.1.1 The lower seal plate is fitted with a flexible rubber sheet with a hole cut at least 10 mm (0.4 in.) smaller than the pipe diameter. This sheet is placed over the pipe sample and lowered until it is against the lower seal plate. The flexible rubber against the pipe sample and the lower seal plate will function adequately to keep the sand in place.

9.1.2 The coated pipe specimen is placed in the apparatus and the rubber membrane is secured in place in the lower seal plate with a hose clamp. Position the holiday to face toward the anode.

9.1.3 The sand is poured in place between the test sample and the rubber membrane.

9.1.4 The top seal plate is put in place and secured to the rubber membrane with a hose clamp.

9.1.5 The plastic cylinder is now placed over the membrane and bolted to the base plate.

9.1.6 The prepared electrolyte mixture is poured into the sand until electrolyte is visible above the sand level.

9.1.7 The plastic top plate is then bolted to the top seal plate and the plastic main body.

9.2 *Air Pressure*—The air pressure can be of any source, regulated to a pressure of 28 kPa (4 psi) with a precision of 0.7 kPa (0.1 psi).

9.3 *Electrical Connection*:

9.3.1 A potential of –3.00 volts relative to a $Cu/CuSO_4$, reference electrode is established by the rectifier by connection to an inert anode buried in the soil sample. The reference electrode must be placed as close as possible to the holiday to avoid IR drop error in the impressed voltage at the holiday site.

9.3.2 The test specimen and anode are connected to the rectifier as shown in Fig. 5. Adjust the rectifier voltage so that the potential between specimen and reference cell is –3.00 ± 0.01 V at 25°C (-3.06 at 60°C).

9.4 *Monitoring Schedule*:

9.4.1 Electrical measurements shall be made on the start-up day and on each normal working day thereafter for the duration of the test. A maximum of three consecutive non-working days shall be preceded by at least two working days: one non-working day or two consecutive non-working days shall be preceded by at least one working day, except at start-up and termination when three and two working days are required, respectively.

9.4.2 Electrical measurements characterizing the start of the test are defined as the average of measurements taken on the second and third days after immersion.

9.4.3 Electrical measurements characterizing intermediate and terminal time spans shall be taken on two successive days prior to and including the target date.

9.5 *Examination*:

9.5.1 An examination shall be performed immediately upon

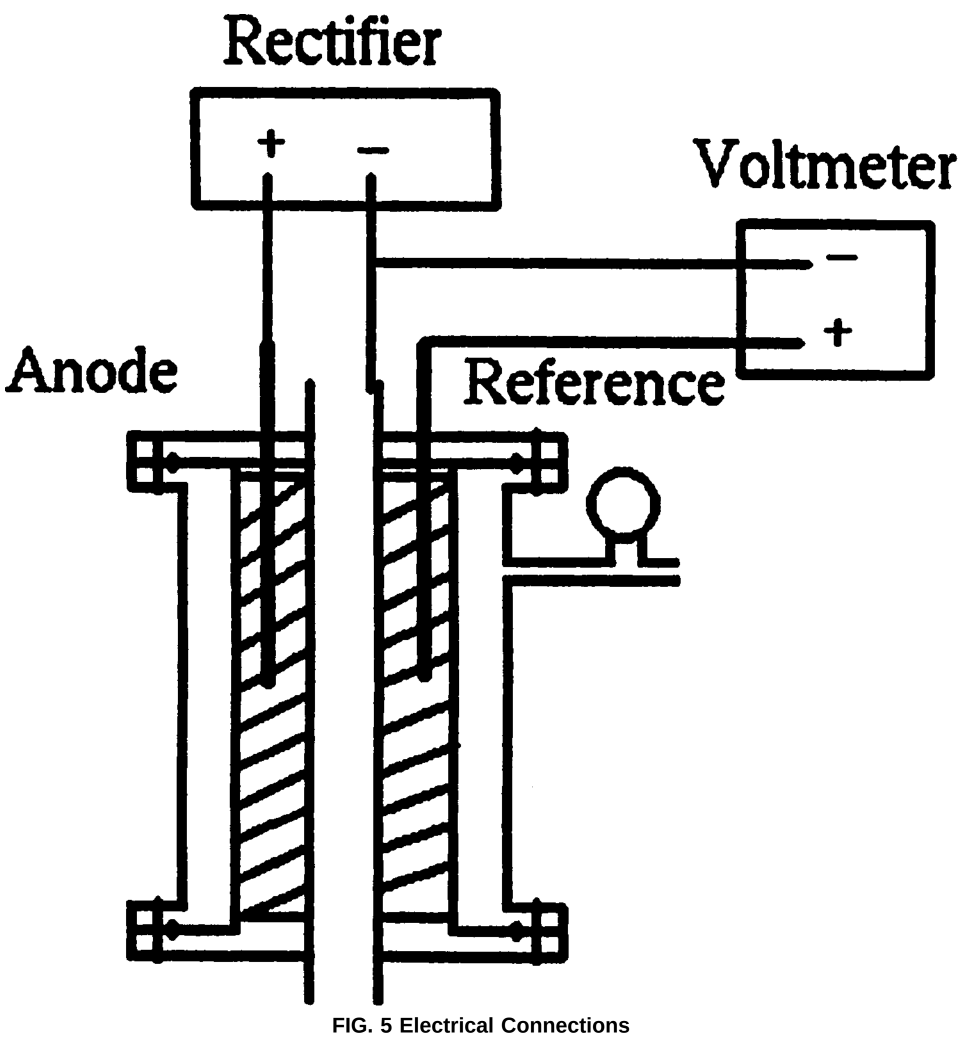

FIG. 5 Electrical Connections

termination of the test period as follows:

9.5.2 Visually examine the entire buried area for any evidence of new holidays and loosening of coating at the edge of all holidays, including the intentional holidays.

9.5.3 Drill a new test hole in the coating in an area that was not buried, above the soil level, staying away from the immersion line and the cut end. Recommended distance is midway between the cut end of the pipe specimen and the immersion line.

9.5.3.1 Follow the same drilling procedure described in 7.2.

9.5.4 In order to gage or calibrate the lifting technique, attempt to lift the coating at the new test hole with the point of a sharp knife after making cuts through the coating intersecting at the center of the hole. Inability or relative resistance to lifting or disbonding of the coating shall be considered the adhered or bonded condition of the untested coating with respect to the lifting technique used.

9.5.5 Determine if the coating has been loosened at the buried test holes by attempting to lift the coating with the point of a sharp knife after making cuts through the coating intersecting at the holiday or point of inspection using the same technique applied in 9.5.4. Identify coating that can be removed more readily than at the new test hole as disbonded area. Measure the disbonded area.

NOTE 1—The use of a transparent film having a grid laid out in small squares such as 2.54 mm (0.1 in.) on a side has been found useful. The film is placed against the disbonded area and the boundary of the disbonded area traced on the grid. The area is then obtained by counting the squares within the bonded area.

10. Report

10.1 Report the following information (see Fig. 6):

10.1.1 Complete identification of the test 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 coating thickness,

10.1.1.5 Buried area,

10.1.1.6 Size and number of initial holidays, and

10.1.1.7 Dates of starting and termination test.

10.1.2 The relative resistance of the test specimen in ohms, before the intentional holiday was made as described in 8.1.

10.1.3 Tally of areas that have been found disbonded on the terminal date. Areas may be reported in square millimetres (or square inches) or millimetres (or inches) of equivalent circle diameter of the area, or both.

10.1.4 The results of starting, intermediate, and terminal electrical measurements. Report the following measurements:

10.1.4.1 Current demand in microamperes or negative characteristic of the logarithm of the current in amperes or both,

10.1.4.2 The voltage in volts,

10.1.4.3 Change from the start to termination for values in 10.1.4.1 and 10.1.4.2,

10.1.5 Temperature of the electrolyte at approximately the same hour each working day, and

10.1.6 Other information that may be pertinent.

11. Precision and Bias

11.1 Although an interlaboratory study in accordance with Practice E 691 is underway, sufficient data is not yet available for precision, repeatability, and reproducibility calculations. However, a reasonable estimate of precision from similar tests show that precision data should be limited to two adjacent specimens taken from the same production coated pipe and assumed that the production process was uniform with respect to pipe surface condition and coating material. Specimens that were not adjacent in the as-produced condition or were taken from different lengths of pipe may represent differing process conditions.

11.2 *Repeatability*—Duplicate results obtained within a laboratory should be acceptable unless they differ by more than 25 mm (1 in.) in value D in accordance with the following equation:

$$D = (A/0.785)^{1/2} \tag{1}$$

where:

A = disbonded area developed from one intentional holiday, inches^2(or mm^2) or if they differ by more than unity in the negative characteristic of the logarithm of the current demand in amperes.

11.3 *Reproducibility*—The results reported by one laboratory should be acceptable unless they differ from those of another laboratory by more than 24 mm (1 in.) for the value D

Data Sheet and Report for Cathodic Disbonding of Pipeline Coatings in Soil

1. Specimen No. __________ *Report No.* __________ *Initials* _______ *Date* ________________

2. Pipe:

______________________mm(in.) O.D. _________________mm (in.) Wall _____________mm (in.) Length

Mfgr. ____API____________________________

3. Coating:

Name, No. ____

Mfrg. ____

Application method____

Applicator ____

Thickness, mm (in.)

Max. _______ Min._______ Av. __________ At holiday: _______

4. Test:

Date Started _______________ Date Finished ___________________

Test Area _________________ mm² (in.²)

Initial holiday diameter mm (in.)	
Final unsealed area mm² (in.²)	
Minus Initial holiday area mm² (in.²)	
Equals Net disbonded area mm² (in.²)	
Disbonded Equivalent Circle Diameter mm (in.)	

5. Preliminary Verification:

Largest disbonded Equivalent Circle Diameter (EDC) does not exceed:

Group	mm	in.	Spontaneous Holidays
A	12.7	0.50	None
B	25.4	1.00	None
C	38.1	1.50	None
D	50.8	2.00	None
E	More than 50.8	More than 2.00	Any

6. Rectifier Current:

If rectifier current was not continuous indicated interrupted time (min.,hrs.):____________________

FIG. 6 Suggested Form for Use in Presenting Data for One Specimen in the equation given in 11.2, and by more than unity in the negative characteristic of the logarithm of the current demand in amperes.