ELECTROLYSIS TESTING
ROUTINE UNDERGROUND— MEASUREMENTS AND INSPECTIONS

Contents **Page**

1. GENERAL

1.01 This section describes in detail the method of making current and potential measurements in connection with routine electrolysis tests on underground cable. It also outlines other necessary tests and inspections to be made on routine electrolysis work.

2. CURRENT MEASUREMENTS

2.01 The current on a cable sheath is determined by observing, with a millivoltmeter, the drop in potential between two points on the same sheath a known distance apart. The potential drop in millivolts per foot, multiplied by the amperes per millivolt drop per foot for the particular size of cable under test gives the number of amperes flowing on the cable sheath.

2.02 In all electrolysis work the direction of current flow on cable sheaths or other conductors is from positive to negative, that is, from points of higher potential to points of lower potential.

2.03 In making current measurements by the potential drop method, the sensitivity of the voltmeter will have an important bearing on the accuracy of data obtained. When using the lower scales of a low resistance meter such as the Weston Model 56, the error introduced in the readings due to excessive test lead resistance may be appreciable. For example a pair of No. 16 gauge test leads 30′ long will develop a 10 to 15% error in readings made on the 5-millivolt scale of such a meter. For this reason it is recommended that only leads calibrated for the meter be used. Where lead resistance is a factor, observations made on different scales of the same meter will not check, the higher scale producing the more nearly correct result. Certain Model 56 meters are equipped with a special circuit for indicating the presence of excessive lead resistance. By depressing a button on the face of the instrument the needle will deflect in proportion to the magnitude of lead resistance as compared with the resistance of the meter movement. Thus, a large deflection will indicate that lead or contact resistance is unduly high. If a Weston Model 622 millivoltmeter having 10,000 ohms per volt sensitivity or similar high resistance unit is employed, the resistance of leads will have no appreciable effect on results and, therefore, can be ignored.

2.04 Current measurements should be made on every cable in the manhole, including subsidiary leads to blocks and aerial cables. In an area where sheath currents remain reasonably constant, no problem is involved in reading individual drops, cable by cable, in a particular bank of ducts and adding the total. However, to determine accurately the total amount of current existing at a given moment on a bank of cables in an active stray current area would necessitate obtaining simultaneous readings on all cable sheaths at the same time which is impractical. It has been found that satisfactory results can usually be achieved by readings taken progressively over the sheaths, each successive reading being referred by the tester in turn to some representative current condition on a selected control cable or to a correlated potential difference between cable plant and earth or some other structure.

2.05 Potential drops on cable sheaths frequently provide a clue to the presence of unwanted contacts with other subsurface plants or structures. As it is difficult and oftentimes impracticable to drain cables that are tied to earth through metallic contacts with other grounded systems, such as water mains and building structures, any indication of current on cable sheaths entering buildings or blocks, aerial cable leads and the like, should be construed as evidence of a contact and so reported. In a like manner, unequal distribution of current on cross-bonded main underground cables in the same bank of ducts may indicate a contact.

2.06 The approximate values of amperes per millivolt drop per foot for the various sizes of toll and exchange cable are given in another section. For convenience it is usual to observe the potential drop (in millivolts) over **four** feet of cable or in any case as great a length as practicable, without including a sleeve in the test section. In some instances, to obtain a span of four feet it will be necessary to include a sleeve which introduces a certain amount of error because of the greater conductivity of the sleeve. Where a sleeve is included in the section of sheath over which the potential drop is measured, it should be noted on the field form.

2.07 Where more than one cable passes through a manhole or vault and it is necessary to determine the total amount of current on the cable system, a millivolt drop measurement must be made on each separate cable. The total current is the sum of the current indicated on each individual cable.

2.08 The following example illustrates the use of the data tables on a toll cable with a circumference of 3-1/2 inches. The potential drop over four feet was observed as 2.04 millivolts. From the tables the amperes per millivolt drop per foot for a toll cable of 3-1/2 inches circumference is 2.74. An observed potential drop of 2.04 millivolts for four feet is $2.04 \div 4 = .51$ millivolts per one foot. Therefore, the current flowing is $.51 \times 2.74 = 1.40$ amperes.

3. POTENTIAL MEASUREMENTS

3.01 Voltages between cable sheaths and earth provide a reasonably good indication of the areas in which stray current is being collected or discharged by the cable plant. Supplemental measurements of potentials to other structures are useful in determining the significance of the earth readings.

3.02 For cable to earth potential readings, it is customary to use a standard ground electrode made of cable sheath to minimize errors due to possible galvanic potentials between them.

3.03 Potential readings made with low sensitivity moving coil type voltmeters should be checked to ascertain if accuracy will be impaired by contact resistance. Errors of large magnitude may be expected where this resistance is high compared with the meter resistance on any particular scale. The efficiency of a test contact can be determined by either one of the following two methods.

(a) Shifting from one scale to another and observing the indicated potential in each case. Where contact resistance is a factor, the two readings will not agree.

(b) Depressing the special test button built into certain of the Model 56 voltmeters and noting its effect on a given reading. This operation will decrease the observed deflection of the needle where contact resistance is important.

3.04 Errors due to contact resistance will usually be insignificant where a firm electrical contact can be established between the test lead and a clean metal structure or electrode. However, in making measurements to corroded structures or electrodes buried in the earth or laid on the ground, high contact resistance may be unavoidable. Special measures may therefore be necessary to compensate for errors in observations where a low resistance meter is used as discussed in the following paragraph.

3.05 Cable to earth potential readings should preferably be taken with a high sensitivity meter having a 200,000-ohm per volt movement. With such an instrument, the magnitude of a deflection on a 5-volt scale will be one-fifth that on the one-volt scale, since the resistance of the movement in either case will be high compared with the resistance of the ground electrode to earth. If a duplex meter, such as a Weston Model 56, or other comparatively low sensitivity meter is used, the true (cable to earth) potentials will be somewhat greater than the readings indicate because of the relatively high contact resistance between the earth and ground electrode, especially under dry conditions. As previously stated, the presence of this condition will be revealed by wide variations in readings taken on different scales of the same meter. When the earth contact resistance is high compared with the meter resistance, the deflections on all scales tend to become equal in magnitude. If the contact resistance is several hundred ohms or more, the error introduced in the readings through the use of a low resistance meter usually becomes appreciable, and a "correction factor" should be developed by solving the following formula:

$$f_c = \frac{r_m + r_g}{r_m}$$

Where:

f_c = Voltage correction factor, which when multiplied by the meter reading gives the true cable to earth potential.

r_m = Meter resistance of the scale on which the cable to earth potential measurements are made.

r_g = Ground electrode contact resistance measured directly with a volt-ohmmeter, such as the Western Electric M9B, bridge method or Biddle Megger.

3.06 In addition to the indicated meter reading, the correction factor for the cable to earth potential value, obtained as above, shall be entered on the field form.

4. TIME REQUIRED AT MANHOLES

4.01 The time required for testing at a particular manhole is dependent upon local conditions. In an area where there is either a continuous or no rapid transit or d-c power load, observations over a period of a few minutes will generally suffice. However, in many cases a test may be of little value unless extended over a much longer period. Twenty-four hour recordings will be desirable where the load varies appreciably from hour to hour during the day and night. In any event, the period of test should be sufficient to cover the conditions most likely to result in positive cable to earth readings.

5. INSPECTION OF CABLE AND MANHOLES

5.01 Whenever conditions permit, the cable sheath in the manhole should be examined for traces of electrolytic corrosion, especially near the duct entrances. Corroded cable has a pitted appearance although sometimes the pits are filled with the products of corrosion. Inspection of the cable sheath is of particular value in locations where an electrolysis exposure is known to have existed at some previous time. In such inspections it is first desirable to remove the dirt, etc., from the cable sheath with a carding brush. Any evidence of corrosion, mechanical damage to the cable or other undesirable conditions such as missing or improperly soldered bonds, copper wire scrap, or cinders in manholes, should be reported on the field form.

5.02 Where water is observed at the mouth of ducts in the manhole a test of its acidity or alkalinity should be made, and the indicated pH should be recorded on the field form. As the pH paper provided for this purpose will respond to any moisture which reaches it, care must be exercised to avoid contamination due to contact with wet hands or any object other than the material being tested.

6. TESTS AND INSPECTION OF PROTECTION SYSTEMS

6.01 Routine tests and inspections as prescribed in the following paragraphs shall be made periodically on all drainage systems to determine whether they are operating properly. The frequency of such tests will be determined by supervision in accordance with local requirements. The required data can usually be obtained with the use of an indicating meter, but where readings are desired over extended periods, a recording instrument should be used.

6.02 Routine tests shall include measurements of minimum and maximum values of current flowing in the drainage wire and the direction of current flow. These measurements shall be made with a direct reading ammeter or by the potential drop method.

6.03 Where a reverse current switch is included in a bond wire circuit, the following additional tests are required:

(a) Potential across terminals of switch. Report open circuit voltage necessary to operate the switch in the forward or drainage direction.

(b) Current in drainage wire. Report magnitude of reverse current, if any, required to open the switch.

6.04 Occasionally, cable sheaths will be used for drainage conductors. It may be assumed that 200 amperes can be safely carried per square inch of cross-sectional area of cable sheath. This provides for a factor of safety of possibly as much as five with respect to actual fusing.

6.05 Cable to earth potential measurements shall be made at each drainage manhole with the (a) drainage circuit closed through and (b) with the circuit open during a period when current would normally flow from the cables into the drainage wire.

6.06 Potential readings shall also be obtained across the open terminals of the drainage circuit during or following step (b) above.

6.07 Additional tests to be made on corrosion protection systems equipped with alarm wires shall consist of potential drop measurements taken over the portion of drainage wire spanned by the alarm conductors. This should be done in the office in which these wires are terminated.

6.08 At the time tests are made on drainage systems an inspection should be made to determine (1) the condition of the drainage wire at the points of connection to the cable and bus bar, negative feeder, etc., and (2) the condition of any fuses which may be used with the system.

6.09 A record shall be kept of the results of all inspections and tests of drainage systems. In the event that considerable change in conditions is found, arrangements shall be made to eliminate any faults which may exist.

6.10 In manholes where local forced drainage (duct anodes) is used to lower cable potentials, the effective potential (voltage of cable to anode) and anode current (amperes of current lost from anode) shall be measured and compared with previous values.

6.11 Where it is necessary to replace or move duct anodes or expendable grounding electrodes due to deterioration, cable to earth potential and current loss measurements should be made in spare ducts within the influence of the system both before and after the change.

7. TESTS AND INSPECTION OF INSULATING JOINTS

7.01 Insulating joints in main U.G. cables in manholes shall be tested at intervals not exceeding six months; including those equipped with short-circuit alarms.

7.02 Measurements shall be taken to ascertain that (a) no hazardous electrolytic potentials are created across the joint, (b) the cable to earth potentials have not changed appreciably from those noted in previous tests, and (c) the joint is not shorted out by stubs, wire, defective bridging condensers, or other conducting material.

7.03 Where insulating joints are bridged with a resistance, a measurement of the current flowing through the resistance shall also be made.