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ENGINEERING SERVICE CENTER
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METHOD FOR ESTIMATING THE SERVICE LIFE OF STEEL CULVERTS

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read **"SAFETY AND HEALTH"** in Part 6 of this method. It is the responsibility of the user of this method to consult and use departmental safety and health practices and determine the applicability of regulatory limitations before any testing is performed.

A. OVERVIEW

Two environmental factors are combined for estimating the service life (years to perforation) of steel culverts. These factors are the hydrogen-ion concentration (pH) and the minimum electrical resistivity of the site and backfill materials. The pH of soil or water indicates the degree of acidity or alkalinity, while the minimum resistivity indicates the relative quantity of soluble salts in the soil or water. Using these parameters, the probable maintenance-free service life of a galvanized steel culvert in a given location can be estimated by using the chart shown in Figure 1. This information, combined with a condition survey of existing culverts, if any, provides a basis for: (1) estimating the maintenance-free service life of galvanized steel culverts and (2) estimating the additional life that would be obtained by coating the culverts with a dielectric material to reduce their corrosion rate.

The years to perforation is not the total useful service life of culverts. It is a common point at which it is likely that maintenance funds could be spent to repair corrosion damage.

This test method is divided into the following parts:

1. Method of Field Resistivity Survey and Sampling for Laboratory Tests.
2. Method of Determining pH of Water.
3. Method of Determining pH of Soil.
4. Laboratory Method of Determining Minimum Resistivity.
5. Estimating The Maintenance-Free Service Life of Steel Culverts from Test Data.
6. Safety and Health.

This test method refers to the following other California Test Methods: California Test 201 (Method of Soil and Aggregate Sample Preparation), California Test 202 (Method of Tests For Sieve Analysis of Fine and Coarse Aggregates), California Test 417 (Method of Testing Soils and Waters For Sulfate Content), and California Test 422 (Method of Testing Soils and Waters For Chloride Content).

PART 1. METHOD OF FIELD RESISTIVITY SURVEY AND SAMPLING FOR LABORATORY TESTS

SCOPE

The field resistivity test gives an indication of the quantity of soluble salts in the soil or water, and is used primarily as a guide for selecting samples that will be tested in the laboratory to obtain data for estimating the service life of culverts. The natural soil in each channel or culvert location and the structural backfill material are tested using a portable resistivity meter, and samples are selected on the basis of these test results.

A. APPARATUS AND MATERIALS

1. The resistivity meter shall be a 12-V direct current (DC) system, using a Wien Bridge (AC bridge) with a phase sensitive detector and a square wave inverter that produces a nominal alternating signal at 97 Hz. See Note 7.

2. The field probe shall be suitable for making direct measurements of the in-place soil resistivity. It is a hollow stainless steel rod, approximately 1.2 m in length with a 13-mm diameter, having a stainless steel tip that is separated from the main rod by a plastic spacer approximately 10 mm thick. One conductor is connected to the tip through the hollow rod. A second conductor is connected to the main part of the rod. Each of the two conductors are wired so they can be attached to each pair of terminals on either side of the resistivity meter.

3. The steel starting rod shall have a diameter slightly larger than the field probe. It will be used for making holes (in hard ground) prior to inserting the probe.

4. The sledge hammer is required and it shall weigh at least 1.8 kg.

5. Distilled, deionized or other clean water shall have a resistivity of 20 000 ohm-cm or greater.

6. A graduated cylinder shall have a capacity of 100 mL.

7. Various resistors are required: The sizes include: 100, 200, 300, 500, 700, 900, 2000, 3000, 5000, 10000 and 20000 (nominal value, 1 % precision).

B. RECORDING DATA

Use a field notebook or appropriate form to record field resistivity measurements when selecting laboratory samples.

C. CALIBRATION OF RESISTIVITY METER

1. Calibrate the resistivity meter according to the manufacturer's instructions and these procedures.

2. Connect each pair of test leads on the resistivity meter to the lowest value resistor and read the meter. Repeat this process with the other resistors.

3. If the meter readings are within 10 % of all the resistors, the meter is functioning satisfactorily.

D. TEST PROCEDURE

1. In the channel of a proposed culvert site, insert the field probe into the soil to a depth of between 150 mm and 300 mm, measure the resistivity, and record the reading. Follow the manufacturer's instructions for correct use of the meter. Remove the field probe and pour about 60 mL of distilled, de-ionized or other clean water into the hole.

2. Re-insert the probe, twist the probe to mix the water and soil, measure the resistivity, and record the reading.

3. Withdraw the probe and add an additional 60 mL of distilled, de-ionized or other clean water.

4. Re-insert the probe, again twist the probe to mix the water and soil, measure the resistivity of the soil and record the reading.

5. Use the lowest of the three recorded readings as the field resistivity of the soil.

E. SELECTION OF SOIL SAMPLES FOR LABORATORY TESTS

1. Take sufficient field resistivity measurements at various locations in the channel or culvert sites to adequately represent the soils of these areas.

2. If the field resistivity measurements are reasonably uniform within the limits of the site, soil samples from three different locations should be selected for the laboratory tests. If, however, some locations have field resistivities that differ significantly from the average of the field resistivities for the areas being surveyed, additional soil samples should be taken to represent these locations, particularly those with field resistivities significantly below the average.

   a. For example, if the field resistivities throughout the surveyed area are all at or near an average value of 2000 ohm-cm, three samples will be sufficient. If any of the locations tested have field resistivities markedly below this average, for example 800 ohm-cm, then additional samples should be taken to represent these "hot spots". Scattered locations of higher resistivity, for example, 3000 ohm-cm or more, do not require additional samples.

   b. Judgment must be exercised during field testing and sampling to secure representative samples.

   c. In all cases, do not take less than three laboratory samples. See NOTE 1.

F. PRECAUTIONS

In field testing and sampling, carefully follow these instructions and also the manufacturer's instructions for use of the resistivity meter.

NOTE 1:

When selecting a sample for the minimum resistivity and pH tests using the large soil box, take a sample that will yield 1.6 kg of material passing the 2.36-mm sieve. When selecting a sample for the minimum resistivity and pH tests, using the small soil box, take a sample that will yield 500g of material passing the 2.36-mm sieve. If field resistivity measurements approach 1000 ohm-cm, take a sample that will yield 2.3 kg of material passing the 2.36-mm sieve. This amount of soil will provide sufficient material for the minimum resistivity (for either the large or the small box), pH, sulfate ($SO_4^{=}$) and chloride (Cl^-) tests. The measurement of the sulfate content (California Test 417) and the chloride content (California Test 422) are required when the laboratory minimum resistivity is less than 1000 ohm-cm. These data are used for evaluating the chemical effect of the environment on reinforced concrete.

NOTE 2:

Field resistivity test data can not be used for estimating service life of steel culverts.

PART 2. METHOD OF DETERMINING pH OF WATER

SCOPE

This method is suitable for laboratory or field determination of the pH of water samples.

A. APPARATUS AND MATERIALS

1. A pH meter shall be suitable for either field or laboratory analysis.

2. A 50-mL wide mouth beaker or other suitable glass container is required.

3. Various pH standard buffer solutions of known pH values are required. They include: pH values of 4.0, 7.0 and 10.0.

B. RECORDING DATA

Record test data in a field notebook or use an appropriate form.

C. METHOD OF SAMPLING

1. Dip a clean, wide-mouth beaker into the water to be tested. Swirl to rinse and pour

out the contents to avoid contamination from the container. For laboratory testing, pour a portion of the sample from its shipping container into a wide-mouth beaker. Swirl to rinse and pour out the contents to avoid contamination from the container.

2. Fill the rinsed wide-mouth beaker a second time and retain the sample for testing.

3. Pour off any film which is on the surface of the sample before testing.

D. STANDARDIZING pH METER

Follow the instructions provided by the manufacturer with the pH meter.

E. USE OF pH METER TO DETERMINE pH OF WATER

Follow the instructions provided by the manufacturer with the pH meter.

F. PRECAUTIONS

Follow the manufacturer's instructions for use of the meter and use appropriate safety and health practices when performing chemical tests.

NOTE 3:

Field pH readings may be taken at any period other than during flood flow. For water which has a pH of less than 6, take a one liter sample in a clean glass or plastic container for laboratory analysis. Seal the container before transporting.

PART 3. METHOD OF DETERMINING pH OF SOIL

SCOPE

This method is suitable for laboratory or field determination of the pH of soil samples.

A. APPARATUS AND MATERIALS

1. The pH meter shall be suitable for laboratory or field analysis.

2. A 50-mL wide mouth beaker or other suitable container is required. When lightweight material is to be tested, it may be necessary to increase the beaker size up to 250 mL.

3. A 2.36-mm sieve shall be used (Note: refer to California Test 202 for specifications).

4. A small metal scoop is required.

5 A glass stirring rod is required.

6. A scale or balance shall have a minimum capacity of 100 g and an accuracy of 1 g.

7. A wash bottle shall contain distilled or deionized water.

8. Various standard pH buffer solutions of known pH values are required. They include pH values of 4.0, 7.0 and 10.0.

9. The thermometer shall be capable of reading from 15 to 30°C with an accuracy of 0.1°C.

10. A graduated cylinder is required with a capacity graduations from 50 to 100 mL.

B. RECORDING DATA

Record data in a field notebook or use an appropriate form.

C. PREPARATION OF TEST SPECIMENS

1. Weigh 30 g of the soil passing the 2.36-mm sieve into the glass beaker or other suitable container.

2. Add 30 mL of distilled or de-ionized water to the soil sample.

3. Stir the contents to obtain a soil slurry.

4. Allow the sample to stand for a minimum of one hour to stabilize. The sample is now ready for testing.

D. STANDARDIZATION OF pH METER

Follow the instructions provided by the manufacturer.

E. USE OF pH METER TO DETERMINE pH OF THE SOIL

Follow the instructions provided by the manufacturer. Measure and record the pH to the nearest tenth (0.1) of a unit.

F. PRECAUTIONS

NOTE 4:

Thoroughly stir soil sample with the glass rod immediately before immersing the electrode(s) into the soil slurry solution. Place the electrode(s) into the soil slurry solution (**NOT THE SOIL**) and gently move the beaker or container to make good contact between the solution and the electrode(s).

NOTE 5:

If the pH reading is unstable when the electrode is immersed in the soil slurry solution, leave the electrode immersed until the pH reading has stabilized. In some cases, it may take as long as 5 min to stabilize the pH reading.

NOTE 6:

If the pH meter being used does not have a temperature compensation feature, or the temperature of the environment is not controlled, temperature corrections must be made. The simplest method to achieving this is to standardize the pH meter with the meter and the standard buffer solutions at the same temperature as the test sample.

PART 4. LABORATORY METHOD OF DETERMINING MINIMUM RESISTIVITY

SCOPE

This method describes the procedure for determining the minimum resistivity of a soil or water sample selected as indicated in PART 1. These minimum resistivity values are used to estimate the life of a culvert, as described in PART 5.

A. APPARATUS AND MATERIALS

1. The resistivity meter shall be an alternating current (AC) system or a 12-V direct current (DC) system with a Wien Bridge (AC bridge), a phase sensitive detector and a square wave inverter to produce a nominal alternating signal at 97 Hz. See Note 7.

2. The soil box (large or small) shall be calibrated for use with the resistivity meter. See Figure 2 for details of the large soil box and Figure 3 for details of the small soil box. See Note 10 for the method for calculating the large soil box constant. See Note 14 for the method for calculating the small soil box constant.

3. Various resistors are required. They include: 100, 200, 300, 500, 700, 900, 2000, 3000, 5000, 10000, and 20000 (nominal value, 1 % precision).

4. A 2.36-mm sieve shall be used (Note: refer to California Test 202 for specifications).

5. Round mixing pans are required. They shall be non-corroding, such as plastic or stainless steel. They should be approximately 300 mm in diameter with a depth of 50 mm.

6. A spatula is required for mixing materials.

7. An oven is required: however, at no time may the temperature exceed 60°C. As a practical operating range, the oven should be maintained at 45 ± 15°C.

8. A scale or balance shall have a capacity of 5 kg with an accuracy of 1 g.

9. Distilled, deionized or other clean water shall have a resistivity of 20 000 ohm-cm or greater.

10. A graduated cylinder is required with capacity of 100 mL, or larger.

11. A 300-mm straight edge is required.

12. A sample splitter is required with splitting pans. Refer to California Test 201.

B. RECORDING DATA

Record data in a notebook or use an appropriate form.

C. CALIBRATION OF RESISTIVITY METER

1. Calibrate the resistivity meter according to the manufacturer's instructions and these procedures.

2. Connect each pair of test leads of the resistivity meter to the lowest value resistor and read the meter. Repeat this process with the other resistors.

3. If the meter readings are within 10 % of all the resistor values, the meter is functioning satisfactorily.

D. PREPARATION OF SOIL SAMPLES

After thoroughly mixing the sample, screen it through a 2.36-mm sieve. If the sample is too moist to be sieved, air dry the sample or dry the sample in the oven (not to exceed 60°C) and then crumble it for sieving. Do not crush rocks. Only the soil passing the 2.36-mm sieve is to be used for the test.

E. MEASURING THE MINIMUM RESISTIVITY OF A SOIL SAMPLE USING THE LARGE SOIL BOX

1. Thoroughly clean the mixing pan, spatula and large soil box with distilled, deionized or other clean water for each new sample.

2. Quarter or split out about 1300 g of the material passing 2.36-mm sieve. Refer to California Test 201, "Method of Soil and Aggregate Sample Preparation", for details.

3. If the sample has been dried, add about 150 mL of distilled, deionized or other clean water to the 1300 g of soil and thoroughly mix. If the sample has not been dried, skip to Step 10.

4. When the soil sample is thoroughly mixed, place the sample in the large soil box in layers and compact each layer by hand. Compact the material as densely as possible into the soil box using moderate effort with the fingers. For sticky, clayey soils, the use of a spatula is permitted for initial compaction. Continue this procedure for succeeding layers to maintain a uniform density with minimal voids. Trim the excess material flush with the top surface of the soil box using a straight edge.

5. Measure the resistance of the soil in accordance with the instructions furnished by the manufacturer with the resistivity meter. Calculate the resistivity of the soil using the large soil box constant and record the test value. (See Note 10)

6. Remove and retain the soil from the soil box, add an additional 100 mL of distilled, deionized or other clean water to the sample and mix thoroughly.

7. Following the procedures in Steps 4 and 5, place and compact the soil in the large soil box, measure its resistance, calculate the resistivity of the soil and record the test value.

8. Repeat Steps 6 and 7 again.

9. If the resistivity of the soil sample has not followed a trend of high resistivity, low resistivity and then an increase in resistivity for the preceding additions of water, continue to add water to the soil in about 50-mL increments; mixing, placing in layers, compacting, measuring resistance for each increment, and calculating the resistivity until the minimum resistivity is reached.

10. If the sample has not been dried, begin the test procedure by adding 50 mL of distilled,

deionized or other clean water in lieu of the 150 mL specified in Step 3. Continue to add water in 50-mL increments followed by mixing, placing in layers, compacting, measuring the resistance and calculating the resistivity until the minimum resistivity has been reached. Once the minimum value has been reached, additional increments of water will cause the resistivity to increase.

11. Record the amount of water added, resistance measurements and the calculated resistivity values for each of the above steps. The minimum resistivity determined in this test is the lowest electrical resistivity for this soil at any moisture content and is therefore the worse case condition. The minimum soil resistivity value should be reported in standard units of ohm-cm.

12. The Minimum Soil Resistivity, using standard units and the typical large soil box, is calculated as follows:

    Minimum Soil Resistivity, ohm-cm = [minimum resistance reading (ohm)] x [6.76 cm, typical large soil box constant]

NOTE 7:

Most resistance meters or volt-ohm meters without an inverting circuit allow the sample under test to polarize during measurement causing the reading to vary (i.e., drift).

NOTE 8:

The meter should have four connections. One pair is located on either side of the meter. Each pair of connections must be wired in parallel with two wires attached to the stainless steel machine screws on either side of the large soil box.

NOTE 9:

In some soils, the minimum soil resistivity occurs when the specimen is in a slurry condition. When this occurs it is necessary to thoroughly mix the soil slurry and then pour the soil slurry into the large soil box until it is full. If the soil box is not full using this procedure, add enough of the mixed soil to the soil box until it is filled and take the reading.

NOTE 10:

The multiplying constant for each Large Soil Box is derived as follows:

$$\frac{\text{Surface Area of One Electrode } (cm^2)}{\text{Measured Average Distance Between Electrodes (cm)}} = \frac{(cm^2)}{cm} = cm$$

Constant for Typical Large Soil Box (See Figure 2)

$$\frac{(155 \text{ mm x } 0.1 \text{ cm/mm})(45 \text{ mm x } 0.1 \text{ cm/mm})}{(103.2 \text{ mm x } 0.1 \text{ cm/mm})} = 6.76 \text{ cm}$$

F. MEASURING THE MINIMUM RESISTIVITY OF A SOIL SAMPLE USING THE SMALL SOIL BOX

1. Thoroughly clean the mixing pan, spatula and small soil box with distilled, deionized or other clean water for each new sample.

2. Quarter or split out about 130 g of the material passing 2.36-mm sieve. Refer to California Test 201, "Method of Soil and Aggregate Sample Preparation", for details.

3. If the sample has been dried, add about 15 mL of distilled, deionized or other clean water to the 130 g of soil and thoroughly mix. If the sample has not been dried, skip to Step 10.

4. When the soil sample is thoroughly mixed, place the sample in the small soil box in layers and compact each layer by hand. Compact the material as densely as possible into the soil box using moderate effort with the fingers. For sticky, clayey soils, the use of a spatula is permitted for initial compaction. Continue this procedure for succeeding layers to maintain a uniform density with minimal voids. Trim the excess material flush with the top surface of the soil box using a straight edge.

5. Measure the resistance of the soil in accordance with the instructions furnished by the manufacturer with the resistivity meter. Calculate the resistivity of the soil using the small

soil box constant and record the test value. (See Note 14)

6. Remove and retain the soil from the soil box, add an additional 10mL of distilled, deionized or other clean water to the sample and mix thoroughly.

7. Following the procedures in Steps 4 and 5, place and compact the soil in the small soil box, measure its resistance, calculate the resistivity of the soil and record the test value.

8. Repeat Steps 6 and 7 again.

9. If the resistivity of the soil sample has not followed a trend of high resistivity, low resistivity and then an increase in resistivity for the preceding additions of water, continue to add water to the soil in about 5-mL increments; mixing, placing in layers, compacting, measuring resistance for each increment, and calculating the resistivity until the minimum resistivity is reached.

10. If the sample has not been dried, begin the test procedure by adding 5 mL of distilled, deionized or other clean water in lieu of the 15 mL specified in Step 3. Continue to add water in 5-mL increments followed by mixing, placing in layers, compacting, measuring the resistance and calculating the resistivity until the minimum resistivity has been reached. Once the minimum value has been reached, additional increments of water will cause the resistivity to increase.

11. Record the amount of water added, resistance measurements and the calculated resistivity values for each of the above steps. The minimum resistivity determined in this test is the lowest electrical resistivity for this soil at any moisture content and is therefore the worse case condition. The minimum soil resistivity value should be reported in standard units of ohm-cm.

12. The Minimum Soil Resistivity, using standard units and the typical small soil box, is calculated as follows:

    Minimum Soil Resistivity, ohm-cm = [minimum resistance reading (ohm)] x [1 cm, small soil box constant]

NOTE 11:

Most resistance meters or volt-ohm meters without an inverting circuit allow the sample under test to polarize during measurement causing the reading to vary (i.e., drift).

NOTE 12:

The meter should have four connections. One pair is located on either side of the meter. Each pair of connections must be wired in parallel with two wires attached to the stainless steel machine screws on either side of the small soil box.

NOTE 13:

In some soils, the minimum soil resistivity occurs when the specimen is in a slurry condition. When this occurs it is necessary to thoroughly mix the soil slurry and then pour the soil slurry into the small soil box until it is full. If the small soil box is not full using this procedure, add enough of the mixed soil to the small soil box until it is filled and take the reading.

NOTE 14:

The multiplying constant for each Small Soil Box is derived as follows:

$$\frac{\text{Surface Area of One Electrode (cm2)}}{\text{Measured Average Distance}} = \frac{\text{(cm2)}}{\text{cm}} = \text{cm}$$

Constant for Typical Small Soil Box (See Figure 3)

$$\frac{(25.4 \text{ mm x } 0.1 \text{ cm / mm})(25.4 \text{ mm x } 0.1 \text{ cm / mm})}{(64.5 \text{ mm x } 0.1 \text{ cm / mm})} = 1.00 \text{ cm}$$

G. MEASURING THE RESISTIVITY OF A TEST WATER SAMPLE

1. Thoroughly clean the soil box of all soil particles and rinse the soil box a minimum of three times with distilled, deionized or other clean water.

2. Fill the soil box with distilled, deionized or other clean water and measure its resistance.

3. If the distilled, deionized or other clean water in the soil box measures infinite resistance (resistivity greater than 20 000 ohm-cm if other clean water is used), empty the soil box of water, fill with the test water, measure its resistance in accordance with instructions furnished by the manufacturer with the resistivity meter, calculate its resistivity using the soil box constant and record the resistivity.

4. If the distilled, deionized or other clean water in the soil box measures less than infinite resistance (or resistivity less than 20 000 ohm-cm for other clean water), continue to rinse with distilled, deionized or other clean water until the soil box is absolutely clean. This condition is indicated by an infinite resistance measurement (or resistivity greater than 20 000 ohm-cm for other clean water), when the box is filled with distilled, deionized or other clean water respectively.

H. RECORDING DATA

Record data in a notebook or use an appropriate form.

I. PRECAUTIONS

The soil box must be completely filled (level to the top).

PART 5. ESTIMATING THE MAINTENANCE-FREE SERVICE LIFE OF STEEL CULVERTS FROM TEST DATA

A. CALCULATIONS

Using the minimum resistivity and the pH values of the soil or water obtained as described in Parts 2, 3, and 4, determine the estimated Maintenance-Free Service Life (years to perforation) from the chart shown in Figure 1. This value is the estimated years to perforation for an 18 gage steel culvert having a galvanic coating of 605 g/m^2 of zinc, in the environment represented by the test samples. A factor for each steel thickness is listed in the table in Figure 1. To determine the years to perforation for a greater steel thickness, multiply the factor for that gage by the years to perforation obtained for an 18 gage steel culvert.

B. REPORTING

District reports which include an evaluation of the data obtained from tests and condition surveys of existing culverts, and test data, shall be made and the results noted in the District Materials Report or Geotechnical Design Report. The Materials Report or Geotechnical Design Report should also include recommendations for available alternative culvert materials.

NOTE 15:

The actual performance records of existing culverts in similar environments provide the most valuable information concerning culvert life for a specific site. Where such data are available, they should take precedence over the test method data for estimating the years to corrosion perforation.

NOTE 16:

A computer program is available to aid in the selection of culvert materials. For information contact the Transportation Laboratory (Corrosion Technology Branch).

REFERENCES

1. Field Test for Estimating Service Life of Corrugated Metal Culverts, by J. L. Beaton and R. F. Stratfull. Proc. Highway Research Board Vol. 41, p. 255, 1962

2. Field Method of Detecting Corrosive Soil Conditions, by R. F. Stratfull. Proc. 15th Calif. Street and Highway Conference, held at UCLA, Jan. 24-26, 1963 ITTE p. 158.

3. Comparison of Caltrans' Standard Soil Box Minimum Resistivity to the Small Soil Box Minimum Resistivity. by T. B. Kennelly, State of California, Department of Transportation, Engineering Service Center, Division of Materials Engineering and Testing Services, November 1999.

PART 6. SAFETY AND HEALTH

This method may involve bacterial, organic, and / or chemical contaminants within soils and water to be tested. Be sure to clearly identify those soils and waters which may contain contaminants. Samples which have been sampled by others also must be clearly marked when contaminants are present.

Personnel are required to wear eye protection when handling the buffer solutions for the pH test.

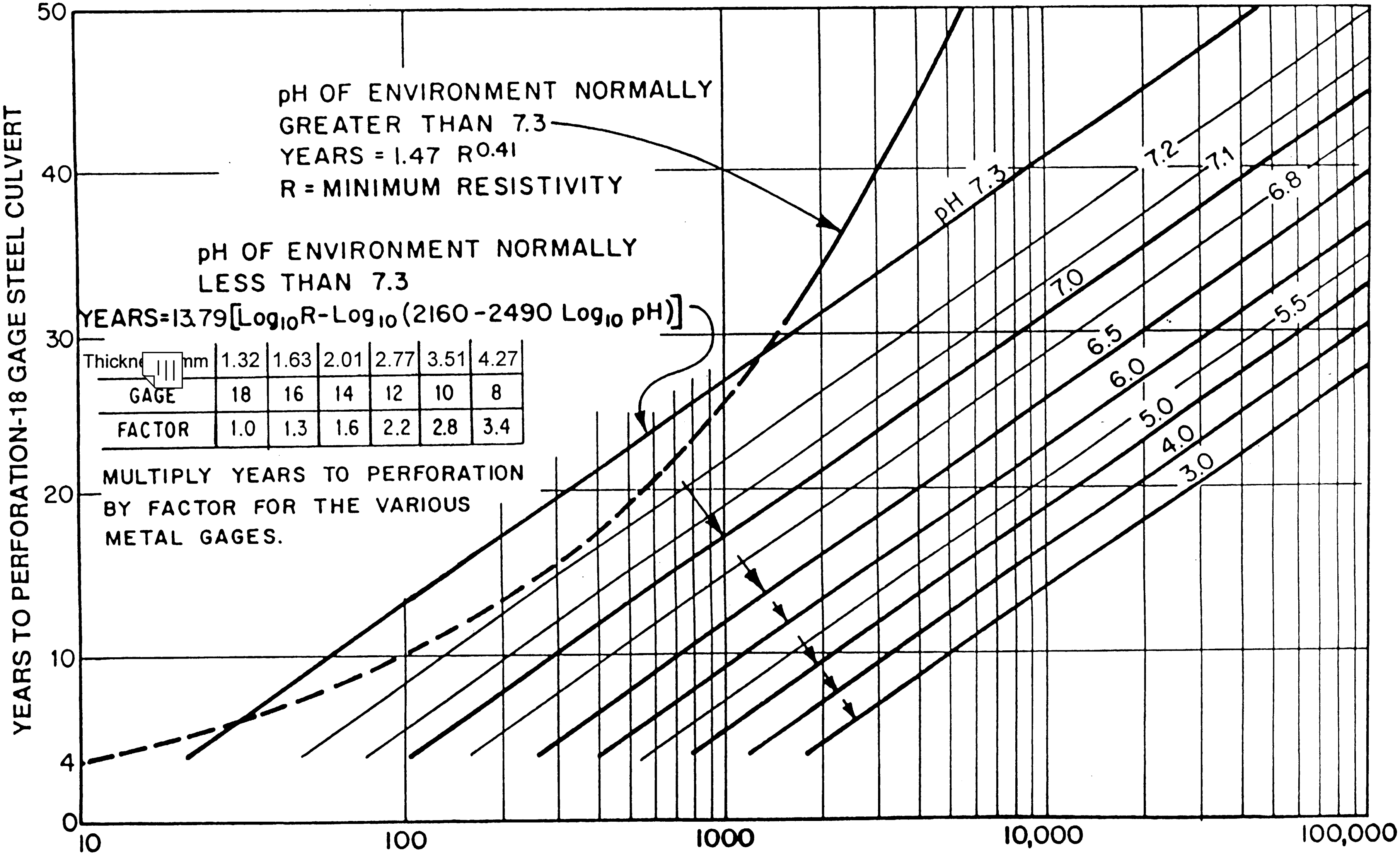
Observe good hygiene practices. Wash hands after handling samples and before eating, drinking or smoking.

Prior to handling, testing or disposing of any waste materials, testers are required to read: Part A (Section 5.0), Part B (Sections: 5.0, 6.0, 10.0 and 12.0) and Part C (Section 1.0) of Caltrans' Laboratory Safety Manual. These sections pertain to requirements for general safety principles, standard operating procedures, protective apparel and how to handle spills, accidents and emergencies, etc.

Users of this method do so at their own risk.

End of Test (California Test 643 contains 13 pages)

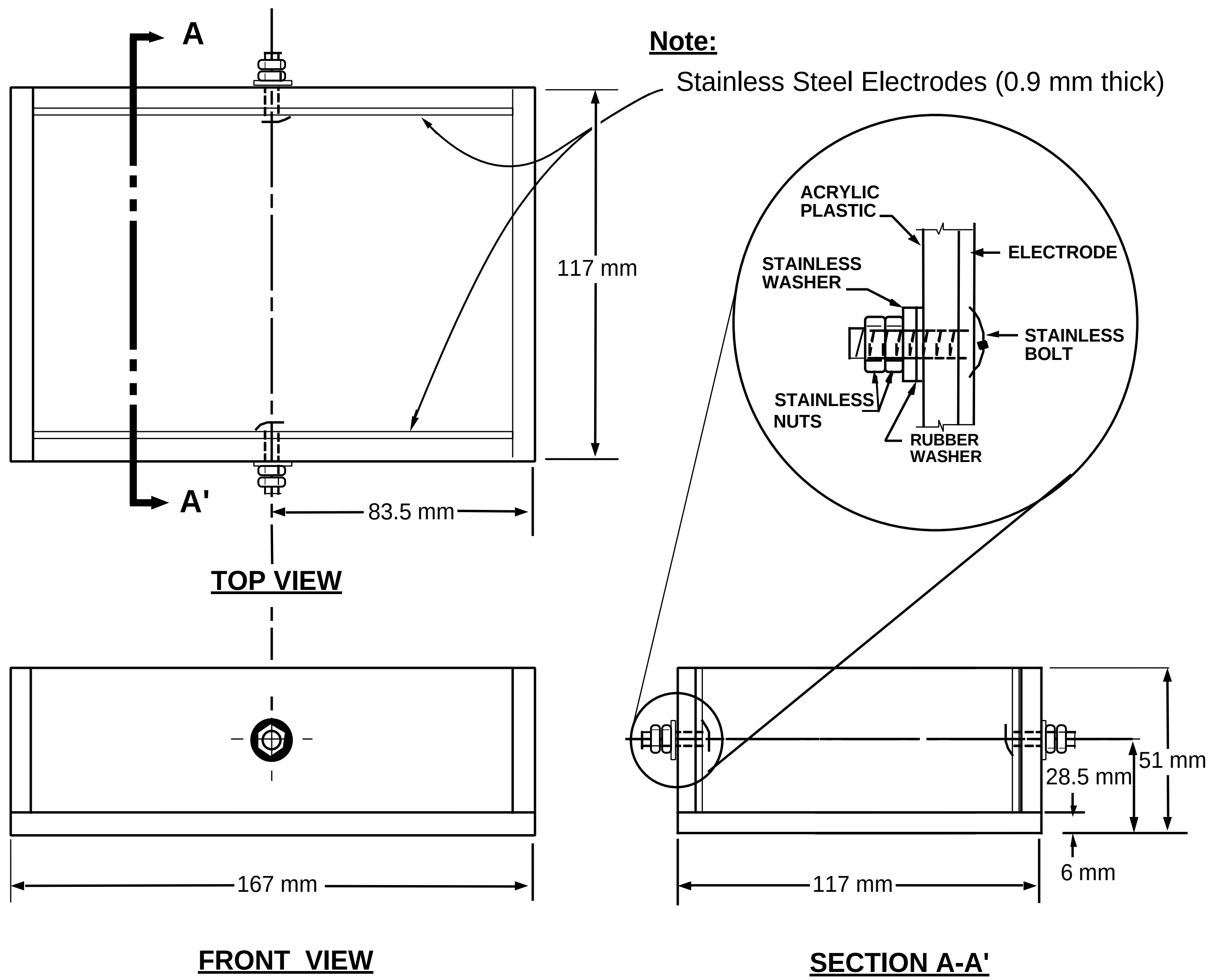
CHART FOR ESTIMATING YEARS TO PERFORATION OF STEEL CULVERTS



Thickness mm	1.32	1.63	2.01	2.77	3.51	4.27
GAGE	18	16	14	12	10	8
FACTOR	1.0	1.3	1.6	2.2	2.8	3.4

MINIMUM RESISTIVITY (R) -ohm cm

FIGURE 1



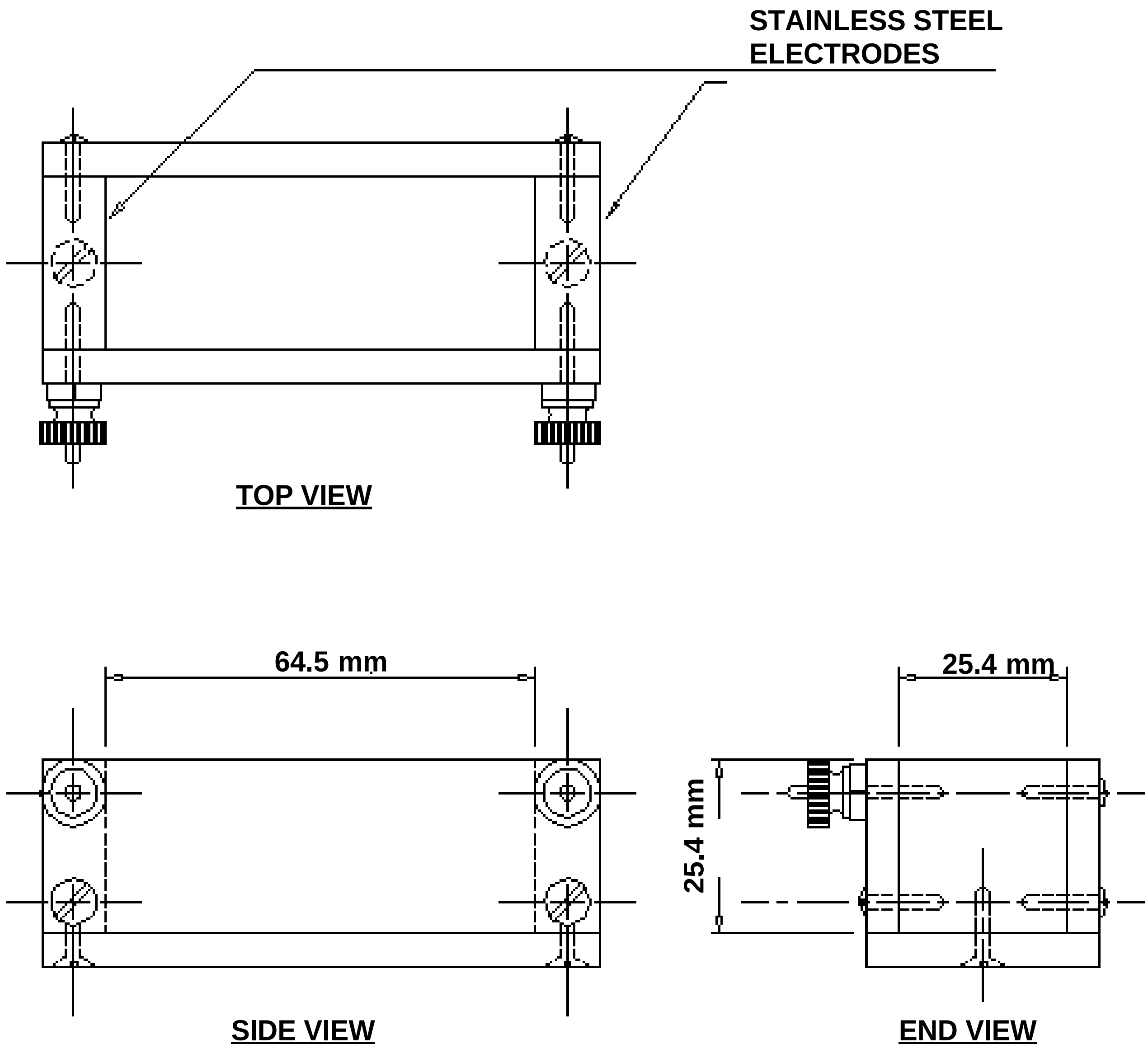
Plastic Material - 6 mm thick

Bottom - 1 piece (167 mm long by 117 mm wide by 6 mm thick)
Ends - 2 pieces (117 mm long by 45 mm wide by 6 mm thick)
Sides - 2 pieces (155 mm long by 45 mm wide by 6 mm thick)

Other Material

Electrodes - 2 pieces of stainless steel (155 mm long by 45 mm wide by 0.9 mm thick)
Two stainless steel machine screws (M 4 by 0.7 by 20 mm) with rubber washers, stainless steel washers and nuts.

FIGURE 2 - SOIL BOX FOR LABORATORY MINIMUM RESISTIVITY DETERMINATION



Plastic Material - 4 mm thick

Bottom - 1 piece (83.7 mm long by 33.4 mm wide by 4 mm thick)
Sides - 2 pieces (83.7 mm long by 25.4 mm wide by 4 mm thick)

Other Material

Electrodes - 2 pieces of stainless steel (25.4 mm long by 25.4 mm wide by 9.6 mm thick)
All screws and fasteners - stainless steel

FIGURE 3 - SMALL SOIL BOX FOR LABORATORY MINIMUM RESISTIVITY DETERMINATION