By: Dr. Shamshad Ahmad

CORROSION POTENTIAL MAPPING

Introduction

- Corrosion potential mapping is carried out on concrete structures non-destructively for identifying the spots of rebars undergoing corrosion
- The corrosion status is related to the measured corrosion potential value
- The contours obtained by plotting the corrosion potential values are useful in delineating corroding portions of the structure from non-corroding portions
- Potential mapping does not give information regarding corrosion rate
- Following are the methods used for corrosion potential mapping:
  - Half-cell or open-circuit potential test method (frequently used)
  - Double-probe corrosion potential test method (rarely used)

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Significance and Uses

- This test method is suitable for in-situ evaluation and for use in research and development work.
- This test method is applicable to members regardless of their size or the depth of concrete cover over the reinforcing steel.
- This test method may be used at any time during the life of a concrete member.
- The results obtained by the use of this test method shall not be considered as a means for estimating the structural properties of the steel or of the reinforced concrete member.
- The potential measurements should be interpreted by engineers or technical specialists experienced in the fields of concrete materials and corrosion testing.

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Advantages and Limitations

- Advantages:
  - Inexpensive
  - Simple to perform
  - Whole structure quickly surveyed
  - Data analysis simple

- Limitations:
  - Limited information for potentials between –200 and –350 mV CSE
  - No information on corrosion rate
  - Difficult to perform when contaminants present on or in concrete

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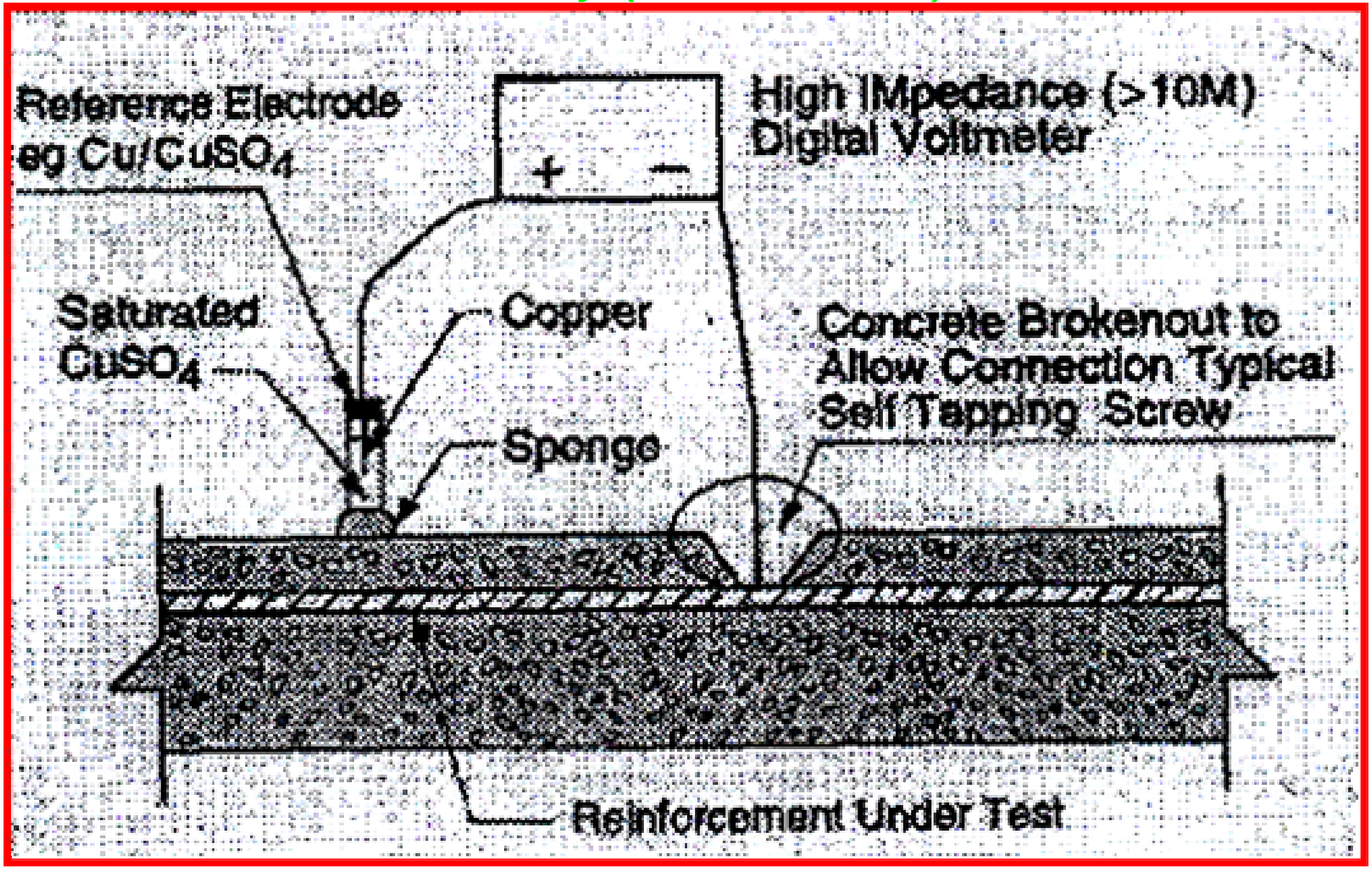
CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Equipment

Circuitry (ASTM C 876)



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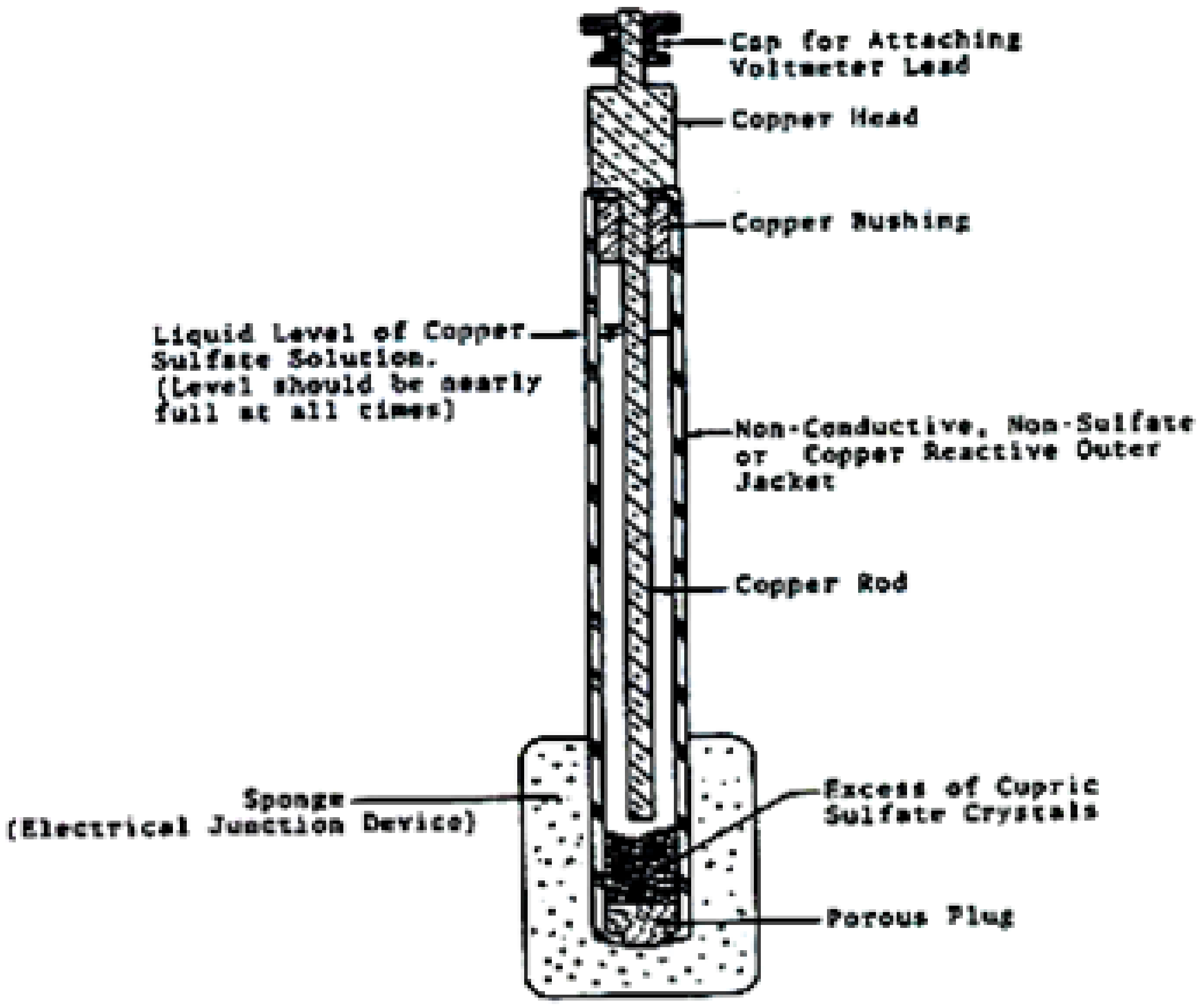
CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Equipment

Reference electrode



- **The rigid tube or container shall have an inside diameter of not less than 1 in**
- **The diameter of the porous plug shall not be less than 1/2 in.**
- **The diameter of the immersed copper rod shall not be less than 1/4 in.**
- **The length of the immersed copper rod shall not be less than 2 in.**

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Equipment

Electrical junction device

- An electrical junction device shall be used to provide a low electrical resistance liquid bridge between the surface of the concrete and the half-cell.
- It shall consist of a sponge or several sponges pre-wetted with a low electrical resistance contact solution.
- The sponge may be folded around and attached to the tip of the half-cell so that it provides electrical continuity between the porous plug and the concrete member.

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CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Equipment

Electrical contact solution

- In order to standardize the potential drop through the concrete portion of the circuit, an electrical contact solution shall be used to wet the electrical junction device
- One such solution is composed of a mixture of 95 mL of wetting agent (commercially available wetting agent) or a liquid household detergent thoroughly mixed with 5 gal (19 L) of potable water
- Under working temperatures of less than about 50°F (10°C), approximately 15 % by volume of either isopropyl or denatured alcohol must be added to prevent clouding of the electrical contact solution, since clouding may inhibit penetration of water into the concrete to be tested.

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CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Equipment

Voltmeter and electric lead wire

- The voltmeter shall have the capacity of being battery operated and have ±3 % end-of-scale accuracy at the voltage ranges in use
- The input impedance shall be no less than 10 MΩ when operated at a full scale of 100 mV
- The divisions on the scale used shall be such that a potential difference of 20 mV or less can be read without interpolation
- The electrical lead wire shall be of such dimension that its electrical resistance for the length used will not disturb the electrical circuit by more than 0.1 mV
- This has been accomplished by using no more than a total of 150 m. The wire shall be suitably coated with.

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Half-Cell Potential Test Method: Equipment

Commercially available equipment

Single half-cell equipment (Colebrand)

By: Dr. Shamshad Ahmad

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Equipment

Commercially available equipment-----continued

Single half-cell equipment (James Instruments Inc)

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Equipment

Commercially available equipment-----continued

Multi half-cell equipment (Colebrand)

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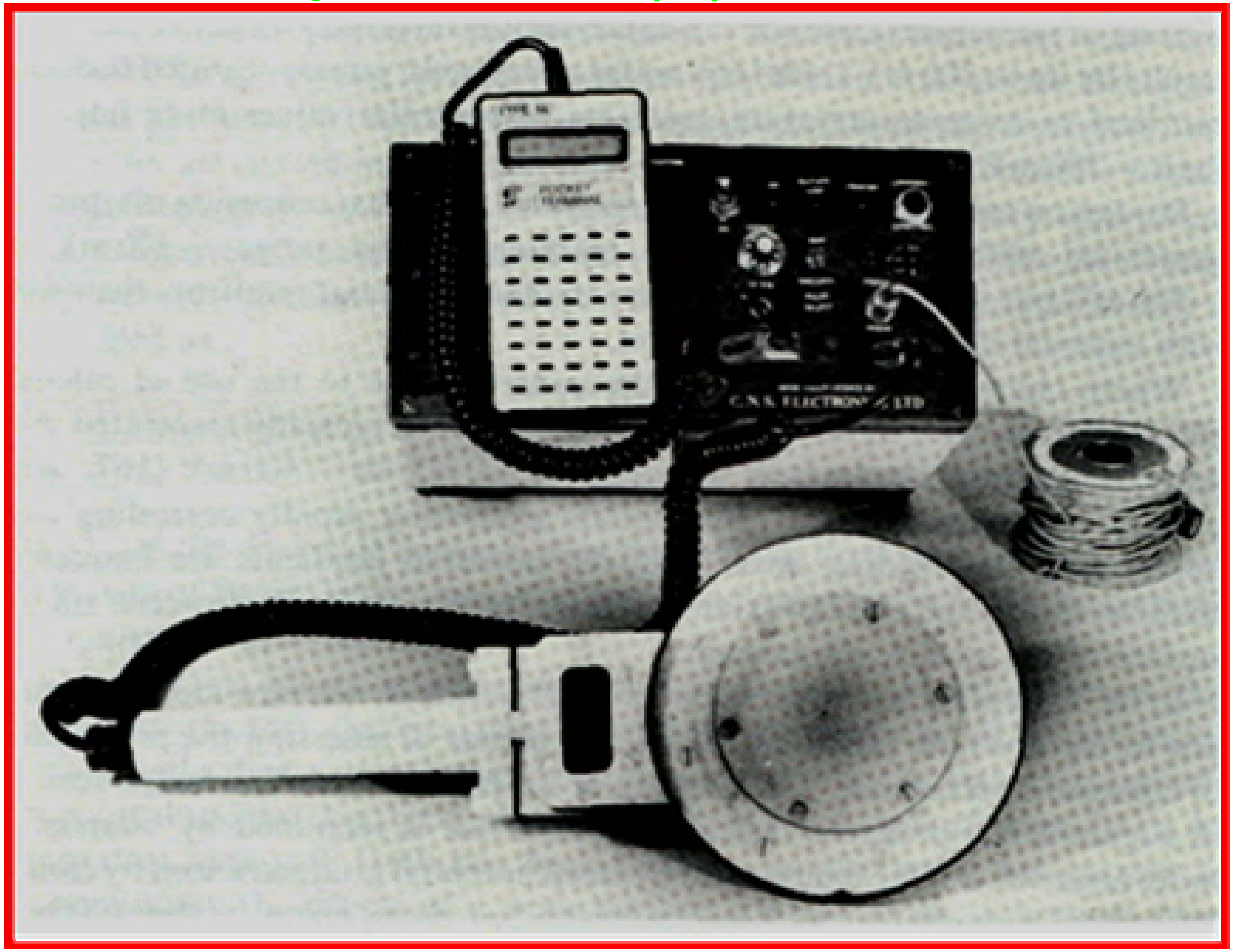
CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Equipment

Commercially available equipment-----continued



Wheel half-cell equipment (C.N.S. Electronics Ltd.)

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Testing Procedure

Spacing between measurements

- The spacing between the test points should be properly selected depending on the type of member being investigated and the intended end use of the measurements.
- On very large structures, e.g. bridge decks, the test should start with initial spacing of about 1 m and then sections should be resurveyed with 300 mm spacing where the potential difference between adjacent readings exceeded 100 mV.
- A spacing of about 300 mm is gradually becoming a more universally accepted initial spacing, reducing to 100 mm over the high-gradient sections.
- With present techniques it appears that spacings of less than 100 mm are unlikely to greatly influence the effectiveness of the survey.

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Testing Procedure

Electrical connection to the steel

- Make a direct electrical connection to the rein-forcing steel by means of a compression-type ground clamp, or by brazing or welding a protruding rod.
- To ensure a low electrical resistance connection, scrape the bar or brush the wire before connecting to the reinforcing steel.
- Electrically connect the reinforcing steel to the positive terminal of the voltmeter.
- Electrical continuity of steel components with the reinforcing steel can be established by measuring the resistance between widely separated steel components on the deck.
- Where duplicate test measurements are continued over a long period of time, identical connection points should be used each time for a given measurement.

Electrical connection to the half-cell

- Electrically connect one end of the lead wire to the half cell and the other end of this same lead wire to the negative (ground) terminal of the voltmeter.

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Testing Procedure

Pre-wetting of the concrete surface

- **Under certain conditions, the concrete surface or an overlaying material, or both, must be pre-wetted by either of the two methods (A and B), using the same solution used for making contact of reference electrode with concrete surface, to decrease the electrical resistance of the circuit.**
- **A test to determine the need for pre-wetting may be made as follows:**
  - **Place the half cell on the concrete surface and de not move.**
  - **Observe the voltmeter for one of the following conditions:**

    (a) The measured value of the half-cell potential does not change or fluctuate with time.

    (b) The measured value of the half-cell potential changes or fluctuates with time.
- **If condition *(a)* is observed, pre-wetting the concrete surface is not necessary.**
- **However, if condition *(b)* is observed, pre-wetting is required for an amount of time such that the voltage reading is stable (± 20 mV) when observed for at least 5 min.**
- **If pre-wetting cannot obtain condition *(a),* either the electrical resistance of the circuit is too great to obtain valid half-cell potential measurements of the steel, or stray current from a nearby direct current traction system or other fluctuating direct-current, such as arc welding, is affecting the readings. In either case, the half-cell method should not be used.**

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Testing Procedure

Pre-wetting of the concrete surface----continued

Method A for Pre-Wetting Concrete Surfaces

- This method is used for those conditions where a minimal amount of pre-wetting is required to obtain condition *(a)* as described above.
- Pre-wetting by this method consists of spraying or otherwise wetting either the entire concrete surface or only the points of measurement.
- No free surface water should remain between grid points when potential measurements are initiated.

Method B for Pre-Wetting Concrete Surfaces

- In this method, sponges saturated with the solution are placed on the concrete surface at locations marked for measurements.
- Leave the sponges in place for the period of time necessary to obtain condition *(a)* described above.
- Do not remove the sponges from the concrete surface until after the half-cell potential readings are taken.

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Testing Procedure

Recording of half-cell potential values

- Record the electrical half-cell potentials to the nearest 10 mV.
- Report all half-cell potential values in volts or mV and correct for temperature if the half-cell temperature is outside the range of 72 ± 10°F (22.2 ± 5.5°C).
- The temperature coefficient for the correction is 0.5 mV more negative/°F for the temperature range from 32 to 120°F (0 to 49°C).

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Data Presentation

Test measurements may be presented by one or both of the following two ways:

- **an equipotential contour map, provides a graphical delineation of areas in the member where corrosion activity may be occurring**
- **a cumulative frequency diagram**

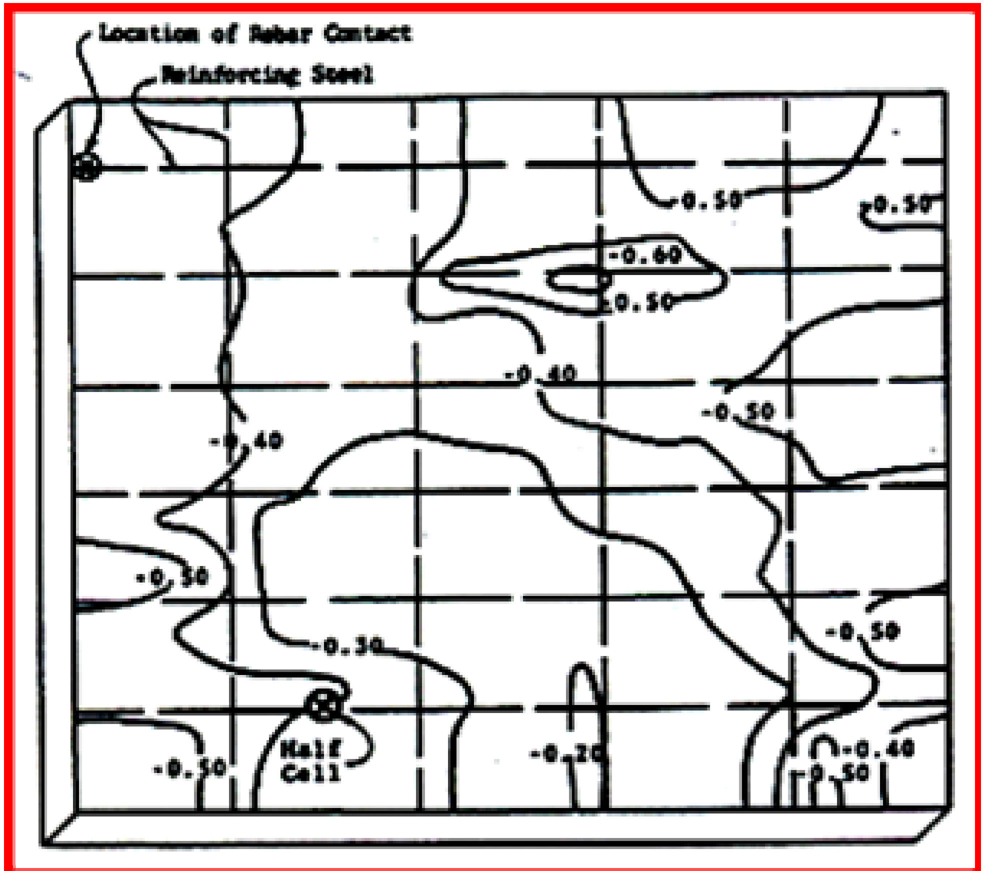
By: Dr. Shamshad Ahmad

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Data Presentation

Equipotential contour map

- On a suitably scaled plan view of the concrete member, equipotential contours with a maximum interval of 100 mV may be plotted as shown in the figure below:



CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Data Presentation

Cumulative frequency distribution

- **To determine the distribution of the measured half-cell potentials for the concrete member, make a plot of the data on normal probability paper in the following manner:**
  - **Arrange and consecutively number all half-cell potentials by ranking from least negative potential to greatest negative potential.**
  - **Determine the plotting position of each numbered half-cell potential in accordance with the following equation:**

$$f_x = \frac{r}{\sum n + 1} \times 100$$

Where:

f_x = plotting position of total observations for the ob-served value, %

r = rank of individual half-cell potential, and

Σn = total number of observations.

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Data Presentation

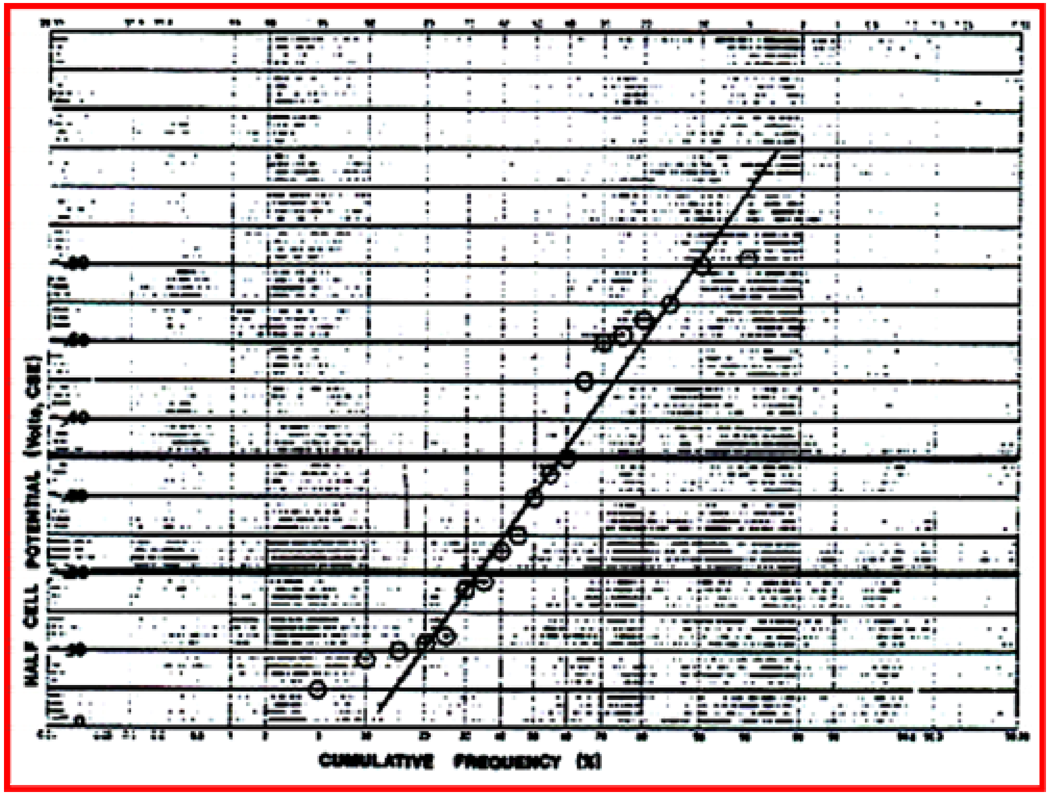
Cumulative frequency distribution---continued

- **Label the ordinate of the probability paper "Half-Cell Potential (Volts, CSE)," where CSE is the designation for copper-copper sulfate electrode.**
- **Label the abscissa of the probability paper "Cumulative Frequency (%)."**
- **Draw two horizontal parallel lines intersecting the -0.20 and -0.35 V values on the ordinate, respectively, across the chart.**
- **After plotting the half-cell potentials, draw a line of best fit through the value.**
- **An example of a completed plot is shown, as follows:**

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Data Presentation

Cumulative frequency distribution---continued



Note:

If a break in the straight line is observed, the line of best fit shall be two straight lines that intersect at an angle.

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CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Interpretation of Test Results

The half-cell potential values may be used to determine the probability of reinforcement corrosion using the criteria given in Table below:

HCP in mV ($Cu/CuSO_4$ electrode)	HCP in mV (Calomel electrode)	Probability of corrosion
> –200	> –126	Low (< 10%)
–200 to –350	–126 to –276	Intermediate/ unknown
< –350	< –276	High (> 90%)
< –500	< –426	Severe

CORROSION POTENTIAL MAPPING

Half-Cell Potential Test Method: Reporting

Report the following information:

- **Type of cell used if other than copper-copper sulfate**
- **The estimated average temperature of the half cell during the test**
- **The method for pre-wetting the concrete member and the method of attaching the voltmeter lead to the reinforcing steel**
- **An equipotential contour map, showing the location of reinforcing steel contact, or a plot of the cumulative frequency distribution of the half-cell potentials, or both**
- **The percentage of the total half-cell potentials that are more negative than -0.35 V, and**
- **The percentage of the total half-cell potentials that are less negative than -0.20 V**