M.C. MILLER Co.

MCM# 15620

Concrete Corrosion Mapping System

Reference Guide

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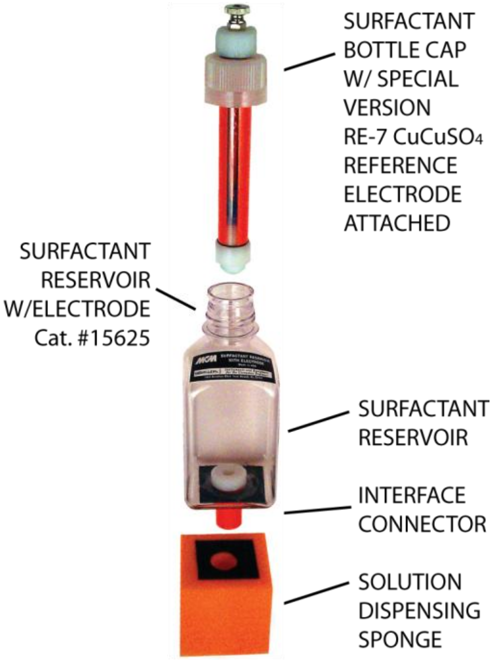
Introduction

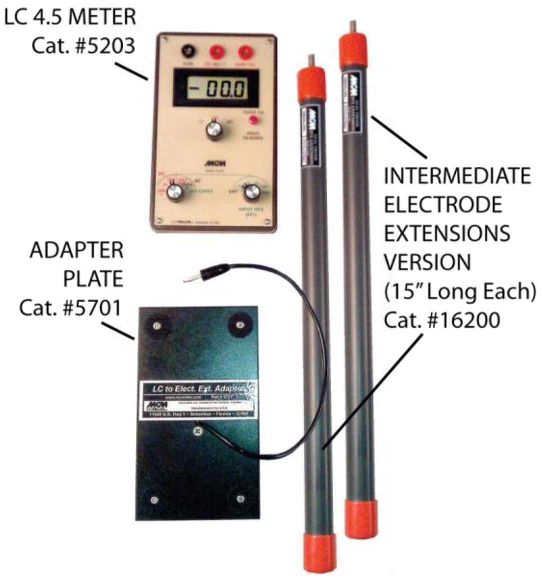
Did you know that there is a quick non-destructive method of pinpointing areas where active corrosion of rebar is taking place on reinforced concrete structures such as bridge decks or parking garages? Active corrosion will cause spalling or cracking sooner or later, if left unchecked. Why not locate active corrosion before it is too late to apply preventive measures such as sealers or cathodic protection?

The M.C. Miller Concrete Corrosion Mapping System can be used to satisfy the ASTM C-876 standard test method which has been proven effective and has been adopted by the Federal Highway Administration. With the Model LC-4.5 Meter and electrode test apparatus, you can test at a rate of better than 1,000 feet per hour. Results are immediate. No waiting for laboratory reports.

This light weight, easy to use test set is designed for field use under nearly any weather condition. Large scale digital meter read out at waist height means that there is no scale reading problems. Test set comes with complete operation manual and reference guide for making the test and interpreting the results.

Don’t wait for unpleasant surprises. Test your concrete structures now so that corrosion prevention measures can be applied at the right time and at the right place.





Corrosion of Steel in Concrete

An explanation of the corrosion of steel in concrete begins with an understanding of why steel does not corrode in concrete. The combination of steel and concrete is a viable construction material of proven durability. In the normally alkaline concrete environment, a thin oxide layer is formed on the surface of the reinforced steel. This oxide film isolates the steel from the environment and prevents corrosion for as long as the oxide layer remains intact. Protected within the concrete, the oxide layer is seldom disturbed and the structural integrity of the concrete-steel combination is unaffected by corrosion. The oxide is known as (Gamma-Fe_2O_3) (1)

Concrete deterioration corrosion of bridge decks was investigated by the FHWA. The primary cause was determined to be corrosion of the reinforcing steel. The rust product formed during the corrosion process occupies a much greater volume than the original steel member. The tensile stress exerted by the corrosion products can exceed the tensile fracture limits of the concrete and cause cracking or delamination which eventually becomes spalls.

The identification of corrosion as a cause of concrete spalling prompted the need to determine the reasons for the corrosion of normally passive steel. The mechanism for the disruption of the passive oxide layer was found to be a complex reaction between the oxide and chloride layer in the concrete. The oxide layer in the presence of chlorides is transformed into $Fe\ (OH)_2$, rust. The chloride ions remain in solution to continue their degradation of the Gamma-Fe_2O_3.

Once the passive films are removed, the reinforcing steel is subject to galvanic corrosion.

(1) See source reference No.1 (Page 15)

Rebar Potential Mapping

A means of determining the corrosion of steel in concrete is possible through the use of half cell measurements, using the M.C. Miller Concrete Corrosion Mapping System. The nature of corrosion is an exchange of energy within different sections of steel reinforcing. This energy exchange can be measured by potential. Although this is an electrical process of ion transfer, it also involves chemical changes. At the anode, corrosion occurs and ions are released into the electrolyte. The relative energy levels can be determined in relation to a reference electrode with a stable electromechanical potential (MCM RE Series Cu/$CuSO_4$ Half Cells). A high impedance voltmeter (LC-4.5) is connected between the reinforcing steel and the reference electrode placed on the surface of the concrete. The resulting potential measurement (reading) on the LC-4.5 meter is an indication of the electrical energy levels – corrosion activity – of the steel in the vicinity of the reference half cell. The methodology for this measurement and guides for interpreting are described in the ASTM C 876 test method standard.

Some precautions must be observed when obtaining half cell potential measurements. A direct electrical connection to the reinforcing steel is required. If exposed steel is not available for this purpose, excavation/destruction of the concrete in a select area, to expose the steel may be necessary. Because of the methods used to interconnect reinforcing steel, the reinforcing grid may not be electrically interconnected throughout the deck or structure. Standard test procedures are available for determining the electrical continuity and will be discussed in the next section.

Testing of any kind should not be conducted or attempted when electrical welding is in progress, as might be the case where repair or renovation work is being done concurrently with the scheduling of this testing.

Because of the high resistance inherent in the measurement circuit, the voltmeter must have sufficient input impedance to accurately measure the potentials. For that reason, the LC-4.5 voltmeter has a selectable input resistance range (from 10 MΩ to 200 MΩ)

To reduce the contact resistance between the concrete surface and the reference electrode, a special sponge bottle was designed and manufactured to contain the reference cell and electrical contact solution with an integrated dispensing sponge. Using this procedure and the M.C. Miller apparatus, with the wet sponge, may cause the potential measurement to initially appear unstable on the voltmeter display because of the slow wetting action of the concrete surface by the sponge. A means of reducing this problem is a uniform pre-wetting of the entire surface. Pre-wetting may, however, have the disadvantage of interconnecting the anode and cathodic areas which may tend to level the measured potentials and produce less pronounced contours when plotted on a graph.

Rebar potential measurements allow a comprehensive survey of the bridge deck/structure to be performed in a short period of time. When plotted on a plan view of the structure, equal potentials can be interconnected to form a contour map of the potential levels of the concrete encased steel. These contours can be used to locate probable corrosion areas and present the total area of the deck/structure surface subject to corrosion.

Continuity Testing

The electrical interconnections of the metallic components within a bridge deck/structure can be verified by electrical test methods. Re-enforcing steel is usually interconnected by wire ties and chair supports and are usually electrically continuous. Sometimes however, there are isolated segments within the structure. Metallic components other than reinforcing steel are sometimes present in the bridge deck/structure. These components can include drains, railings, expansion joints, electrical conduit, etc..

Field testing for continuity utilizes knowledge of the possible electrical circuits within the reinforcing steel mats.

3.1 Half-cell measurements for continuity

The equipment needed to conduct a continuity test based upon potential consists of a high impedance voltmeter (LC-4.5), a portable reference electrode, a reel of insulated test lead wire, and test wires for interconnection of apparatus. Direct connection to the reinforced steel and other metal components are required. Connections may be made at exposed metal, rehabilitated areas or excavations made for test purpose. Connections must be free of debris, corrosion products and coatings or films.

3.2 The test procedure consists of the following steps

1. Using the M.C. Miller concrete reference electrode assembly, place the Sponge Bottle apparatus onto the concrete surface in an area protected from foot and road traffic. Make sure the sponge is wet and sufficient electrical contact solution is in the container to keep the concrete damp for the term of the test.

2. Connect the reference cell to the reel of test wire.

3. Connect a test wire onto exposed reinforced steel or metal component.

4. Using the LC-4.5 voltmeter, measure and record the potential difference between the reference cell and the reinforced steel or metal component.

5. With the reference cell assembly location unchanged, repeat steps 3 and 4 above for another reinforcing steel site or other metallic component.

6. Repeat as necessary to obtain sufficient data.

3.3 The analysis of the data can be simplified into three categories

1. Metal potential measurements within ± 0.001v (1 millivolt) of each other = Electrical continuity probable.

2. Metal potential measurements greater than ± 0.001v (1 millivolt) but less than ± 0.003v (3 millivolts): = Electrical continuity uncertain.

3. Metal potential measurements greater than ± 0.003v (3 millivolts): = Electrical discontinuity probable.

Potential Mapping Technique

4.1 Preparation of the concrete surface for actual testing

1. Use a measuring tape to lay out a grid of the test location (typically) on four (4) foot centers covering the entire area which is to be tested. (Tests do not have to be made directly over the rebars).

2. Mark each test location with the spray paint.

3. Remove all asphalt, waterproofed surface or insulating films from each test location. This requires only a spot about two (2) inches square. The surface scarifying which is usually done to many bridge decks during repair and/or renovating will usually suffice.

4. All test points should be wetted with electrical contact solution prior to testing, and the location must still be damp at the time of actual testing.

5. Completely expose one rebar in each bridge deck panel or structure section for a few inches. Use a chisel or a file to clean the rebar down to bright metal; this will be used as a connection point for tests to be made on the panel. If a rebar is already exposed because of spalling, it may be used as a connection point after appropriate preparation.

4.2 Preparation of the RE-5U and RE-7 electrode (sponge bottle electrode)

Unscrew the top of the new electrode and fill it to the top with distilled water or MCM Antifreeze Solution. Screw the top on tightly (hand tight only). Shake the electrode for a couple of minutes and then make sure that there are still some undissolved copper sulphate crystals in the tube. If not, remove the electrode top and add more crystals. It is not possible to have too many crystals. Do not remove the plastic protective cap from the porous plug assembly on the bottom of the electrode until ready for use. It is suggested that the Cu/$CuSO_4$ electrode be prepared a day ahead of scheduled testing. This will allow time for the porous plug to become fully saturated with the copper sulphate solution.

4.3 Preparation of the sponge bottle.

Remove the surfactant reservoir cap with the RE-7 Electrode attached. Fill the container, approximately ¾ full with the prepared electrical contact solution. Mix ½ teaspoon of concentrate with 500ml of water for one (1) Sponge Bottle. Under working temperatures of less than about 50^{o}F (10^{o}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 the water into the concrete to be tested.
Upon filling, install the surfactant reservoir cap w/RE-7 electrode on the bottle as quickly as possible and hand tighten snugly. Initially there may be some excess solution dispensed through the sponge until a vacuum is created inside the surfactant reservoir container.

Note: While handling and using the electrode assembly always keep in an upright position. See precautions on MSDS in handling $CuCuSO_4$ crystals and MCM antifreeze solution.

4.4 Connecting the meter to the sponge bottle electrode

Press adapter plate onto bottom of the LC-4.5 (the Velcro pads will hold them together). Screw one 15” intermediate electrode extension into the threaded receptacle on the adapter plate. Add the second 15” intermediate electrode extension to the first one already attached. Screw the surfactant reservoir w/electrode assembly into the other end of the second extension. Plug the adapter plate pigtail into the negative (black) terminal of the meter.

4.5 Making connection to the rebar

Clamp vice-grip pliers onto previously exposed rebar and clip one end of the 250 foot test lead to the pliers and plug the other end into the positive (center red) terminal of the LC-4 meter. This procedure is repeated for each panel of the structure. This connection must be to a rebar in the panel being tested.

4.6 Placing the meter into operation

Place the function switch of the LC-4.5 meter to the DC position. Place the range selector switch to the 2V scale. Finally, place the input resistance selector switch to the 200 meg-ohm position.

Use of the selectable input resistance switch allows the operator to compensate for the error caused by a high electrode contact resistance, most prominently found when taking potential measurements in dry soils or dry concrete and would not be unusual when using the M.C. Miller concrete corrosion mapping system apparatus. See the LC-4.5 owner’s manual for further detailed information.

4.7 Making the potential measurements

Note: The reference electrode connects to the negative side of the voltmeter, and the rebar is connected to the positive side of the voltmeter. Place the reference electrode assembly against the prepared location on the concrete surface adjacent to the marked spot. If the electrical connection to the rebar is good, and the concrete and interface sponge are wet enough, a steady reading (measurement) between -0.010V and -0.600V should be obtained on the meter within 3-5 seconds. A slight variation in the last digit (thousandth place) can be considered to be normal. If the test setup is working satisfactorily, it should be possible to go back to a location and obtain an identical reading within ± 0.020V of the original reading.

4.8 Recording the potential readings

All potentials should be rounded off to the nearest 0.01V and entered (for convenience) on a data sheet laid out in a grid pattern to approximate scale similar to the bridge structure/panel being tested (see typical drawing page 12).

Interpreting the readings

1. Potentials less negative than -0.20V generally indicate a 90% or higher probability of no corrosion taking place at the time of measurement.

2. Potentials in the range of -0.20V to -0.35V are inconclusive.

3. Potentials greater than -0.35V generally indicate a 90% or higher probability of active corrosion in the area at the time of testing.

4. Positive potentials (negative sign not displayed), if obtained, generally indicate insufficient moisture in the concrete and should not be considered valid. However, stray DC currents may also cause potential measurements and therefore careful review analysis of the obtained data is required.

5.1 Suggested format of the completion report.

Following the completion of the field work, a report should be prepared and at a minimum include the following;

1. Equipotential contour map to approximate scale with all potentials plotted and contours drawn through points of equal or interpolated equal values. Maximum contours intervals should be 0.10V.

2. Estimate temperature of copper reference electrode during testing.

3. Method of pre-wetting the concrete.

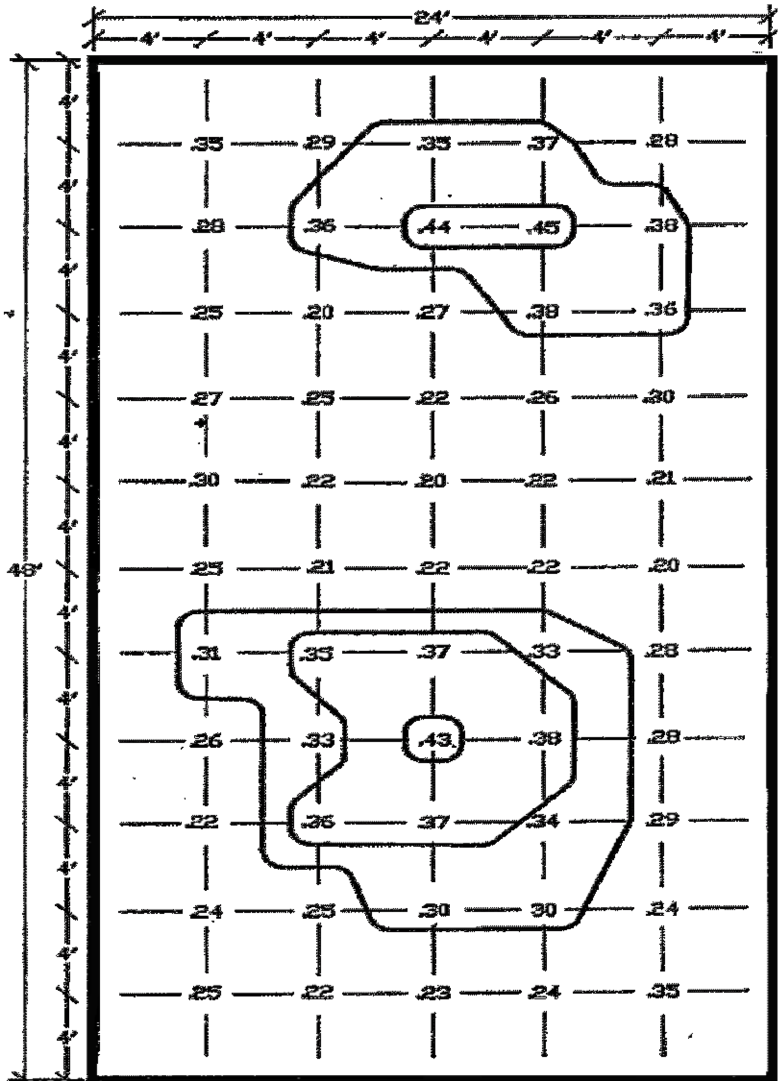
4. Method of attaching test leads to rebar.

5. Percentage of reading in each panel or section that are more negative (-) than -0.35V

6. Percentage of reading in each panel or section that are less negative (-) than -0.20V

7. All positive readings (if any obtained) and their exact location, as plotted on the contour map

Typical concrete slab with reinforcement (rebar)



Other uses for the LC-4.5 meter

The model LC-4.5 meter is designed specifically for corrosion and cathodic protection testing on all types of structures. If cathodic protection is installed on a bridge deck for corrosion control, the meter can be used to trouble-shoot the rectifier unit, check wiring for continuity, and check the performance of the cathodic protection installation.

With the use of an accessory shunt, DC currents of up to 20 Amperes can be measured accurately. See the LC-4.5 operating manual for specific as to how to perform these tests.

6.1 Disclaimer

The M.C. Miller Co. Inc. issues this reference guide in conformance with the best current technology regarding this specific subject. This reference guide represents a consensus of all those individuals involved in reviewing this document. It is intended as a guide only to those with some experience with corrosion control/cathodic protection test techniques. The M.C. Miller Co., Inc. assumes no responsibility for the interpretation or use of this reference guide. Users of this guide are responsible for reviewing appropriate health, safety and regulatory documents and for determining their applicability in relation to this reference guide to its use.

Items Include in Kit

Cat#	Description
5203	LC-4.5 meter w/carrying case and manual with test leads
5701	Electrode extension meter adapter plate
16200	Intermediate electrode extension (15”) - 2 included
15625	Sponge bottle electrode
30501	Agra hand reel (aluminum) with: 30807 No.16 AWG test lead wire (red wire insulation) 250’ included on reel
16906	Copper-sulphate crystals, 12 oz bottle
17105	Electrode anti-freeze solution, 8 oz bottle.
15109	RE-5U electrode (overhead testing)
15628	Concentrate, 4 oz surfactant solution (Liquid household detergent)
MAN060	C.C.M.S. Reference guide
CAS015	Orange carrying case C.C.M.S.

The following items will also be required and can usually be obtained locally.

A. Watering can or equivalent for wetting down test location.
B. Spray cans of brightly colored paint to mark test locations.
C. 100 foot measuring tape.
D. Vice grip pliers and /or grounding clamp.
E. Electrical contact solution to be used in dispensing decanter and/or pre-wetting concrete. Solution can be made up by thoroughly mixing approximately 3 fluid ounces of a household liquid detergent in 5 gallons of water. Add 15% by volume of denatured alcohol if working temperature is lower than 50^{o} F.

Note: The M.C. Miller Co. includes an RE 5U (15109) reference electrode for use in the inverted position for testing the underside of concrete structures such as bridge decks, ceilings of tunnels, underside of parking garages etc.

References

1) Corrosion and Cathodic Protection of Steel
Steel Reinforced Bridge Decks.
D. Burke and J. Bushman, Corrpro Co. Inc.

2) Proceedings of the Corrosion/87 Symposium on
Corrosion Metals in Concrete
NACE Publication No. 52169

3) SP 0187-2008 NACE Standards
Design Considerations for Corrosion Control
of Reinforced Steel in Concrete
NACE Publication NO.53063

4) Suggestions for Corrosion Testing of Reinforced
Concrete Structures such as Bridge Decks
MCM – information guide

5) Standard Test Method for Half Cell
Potential of Uncoated Reinforcing Steel in Concrete
ASTM Designation C 876

Revised: October 26, 2011

Notes:

WARRANTY

MCM provides a 12 month parts and labor warranty on its products, commencing on the date of shipment. Defects occurring during the warranty period will be repaired or products will be replaced at MCM's option and expense, if MCM received notice during the warranty period. **The express warranty will not apply to defects or damage due to the accidents, neglect, misuse, alterations or failure to properly use AND maintain the products.**

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