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Sly Park Bridge Cathodic Protection System Operating and Instruction Manual

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The following is a manual of instructions for the performance of routine measurements of the Cathodic Protection System of the Sly Park Bridge (Bridge #25-42).

16. ABSTRACT

The purpose of this manual is to provide the instructions necessary for performing routine measurements on the Sly Park Bridge deck's Cathodic Protection System without interrupting the system.

In the case of questionable measurements, proper functioning of the instrument should be checked first, as in low battery or poor connection between the meter and terminal or the wrong polarization of the meter-probes. If the same measurement is obtained upon repetition, try to determine if the power source to the bridge C.P. System is cutoff. If this is the case, do not turn the power source on immediately. The
Corrosion Lab should be contacted to determine the cause of the problem and to prevent any hazard to the system or the public.

Beside the routine measurements there are several special measurements which can be made on this cathodic protection system. These tests, which include the; Half-cell potential drop determination, E Log I test, Resistance change, and Current leakage determination, are not covered in the "Measurement Details" section of this manual as these tests require more detailed and technical preparation to setup and record the data. If data from these tests are found necessary, the tests will be scheduled and performed by the Transportation Laboratory Corrosion Unit.

Several simple maintenance steps have been included in the last chapter. After making the routine measurements, these steps should be followed to maintain the system in operation and to help eliminate any unforeseen problems.

17. KEYWORDS

Sly Park Bridge Manual, Instant-Off Tests, Current Density, Driving Voltage, Corrosmeter Probe, Half-cells , Operating Manual

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SLY PARK BRIDGE

CATHODIC PROTECTION SYSTEM
OPERATING & INSTRUCTION
MANUAL

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

November 1980

The following is a manual of instructions for the performance of routine measurements of the Cathodic Protection System of the the Sly Park Bridge (Bridge #25-42).

Manual Study Provided by .....ECE Branch
Corrosion Unit

Under the Supervision of .....John Apostolos, P.E.

Manual Prepared by .....R. A. Carello
G. H. C. Chang, P.E.

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PREFACE

The purpose of this manual is to provide the instructions necessary for performing routine measurements on the Sly Park Bridge deck's Cathodic Protection System without interrupting the system.

In the case of questionable measurements, proper functioning of the instrument should be checked first, as in low battery or poor connection between the meter and terminal or the wrong polarization of the meter-probes. If the same measurement is obtained upon repetition, try to determine if the power source to the bridge C.P. System is cut-off. If this is the case, do not turn the power source on immediately. The Corrosion Lab should be contacted to determine the cause of the problem and to prevent any hazard to the system or the public.

Besides the routine measurements there are several special measurements which can be made on this cathodic protection system. These tests, which include the; Half-cell potential drop determination, E Log I test, Resistance change, and Current leakage determination, are not covered in the "Measurement Details" section of this manual as these tests require more detailed and technical preparation to set-up and record the data. If data from these tests are found necessary, the tests will be scheduled and performed by the Transportation Laboratory Corrosion Unit.

Several simple maintenance steps have been included in the last chapter. After making the routine measurements, these steps should be followed to maintain the system in operation and to help eliminate any unforseen problems.

BRIDGE LOCATION: Bridge Number 25-42 (Sly Park Bridge) is located approximately 60 miles east of Sacramento, on State Route 50 (03-50-ED, Post Mile 31.3) at 4000 feet of elevation.

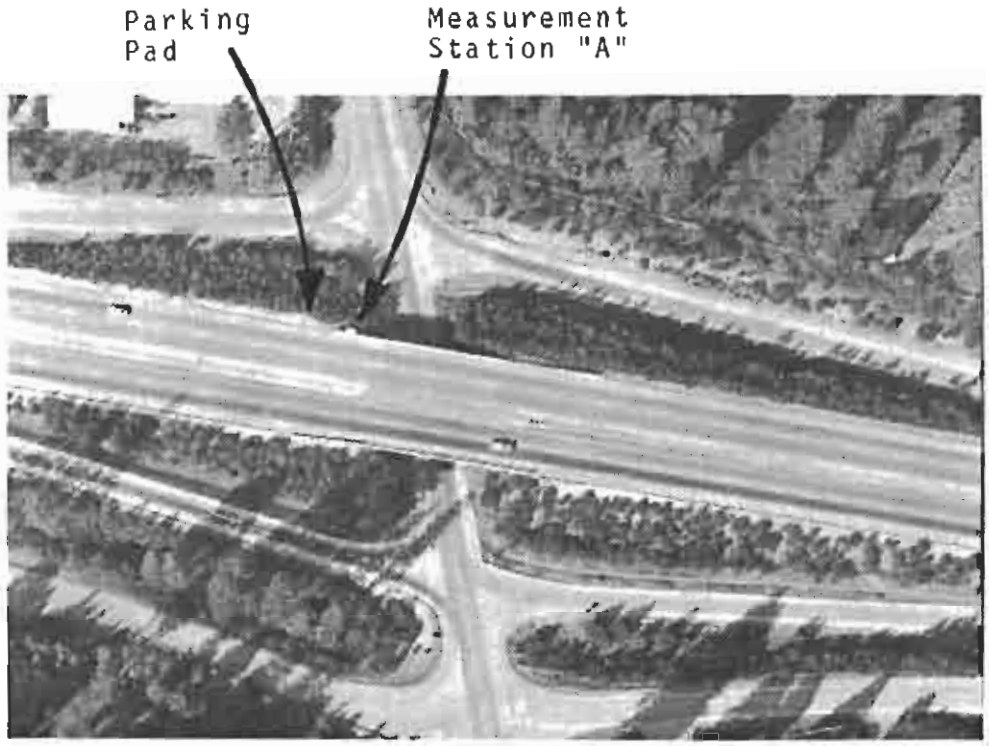


Figure 1
Sly Park Bridge

ACCESS TO BRIDGE PARKING AND INSTRUMENTS: A parking area is available on the westbound lane only. Park on the sand pad, approximately 40 feet long, immediately past the end of the bridge guardrail. Place out traffic cones along the shoulder line, full length of the bridge, to allow parking protection and working room (see following photo).

For alternate parking, during inclement weather, use the roadway shoulder under the bridge.

Figure 2

Parking pad next to measurement Station "A".

GENERAL INFORMATION

A. Measurement Stations

There are four measurement stations at the Sly Park Bridge for the purpose of collecting data from the various corrosion related instruments within the bridge structure. Descriptions of these four stations and the data to be collected are summarized in the following table and drawings.

Name of Measurement Terminal	Location of Measurement Terminal	Data to be Collected	Measuring Instrument (see code below)
Main Control Cabinet	Measurement Station "A"	Impressed Current	1
		Driving Voltage	1
		Back EMF	2
		Peak Current	2
		Current Flow Through Corrosometer Probes #7 and #9	1
		Current Flow Through Each Anode	1
		Bridge Deck Potentials (CSE)	2 and 4
Corrosometer Probe Junction Box	Measurement Station "B"	Corrosometer Probe Corrosion Rate	3
Isolated Rebars West End of Bridge	Measurement Station "C"	Resistance	5
		Current Flow	6
		Voltage	1
Isolated Rebars East End of Bridge	Measurement Station "D"	Resistance	5
		Current Flow	6
		Voltage	1

Instrument Code:

1) Hewlett-Packard Multimeter #3465-B
2) Oscilloscope "Tektronix 213 DMM"
3) Corrosometer Probe Meter, "MAGNA" Model CK3
4) Cu-$CuSO_4$ Half-cell
5) "WILSON" 430, Resistance Meter
6) "Keithley" Digital Pico-ammeter, Model 480

Table 1

Table of instrumentation and data required for C.P. measurements of the Sly Park Bridge

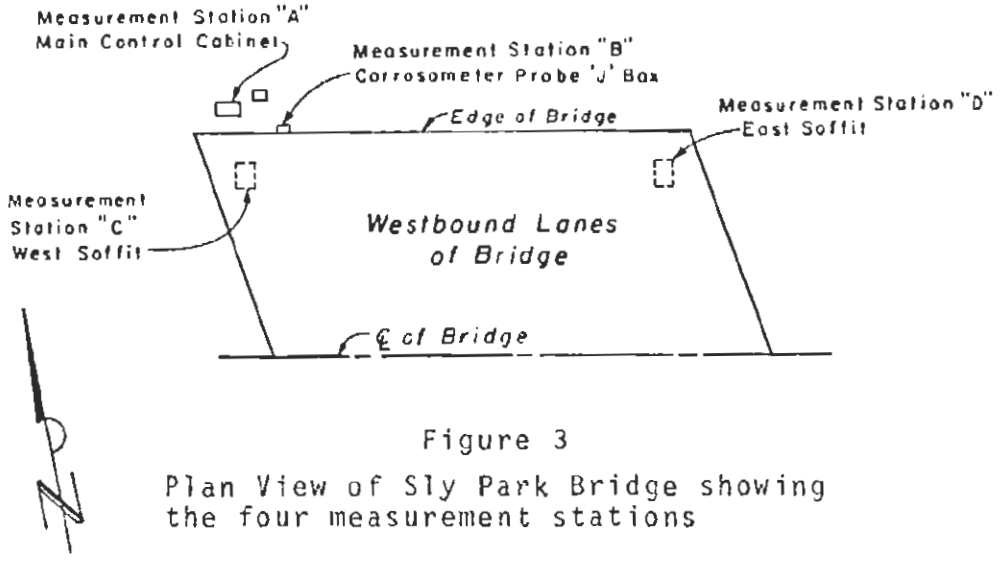


Figure 3

Plan View of Sly Park Bridge showing the four measurement stations

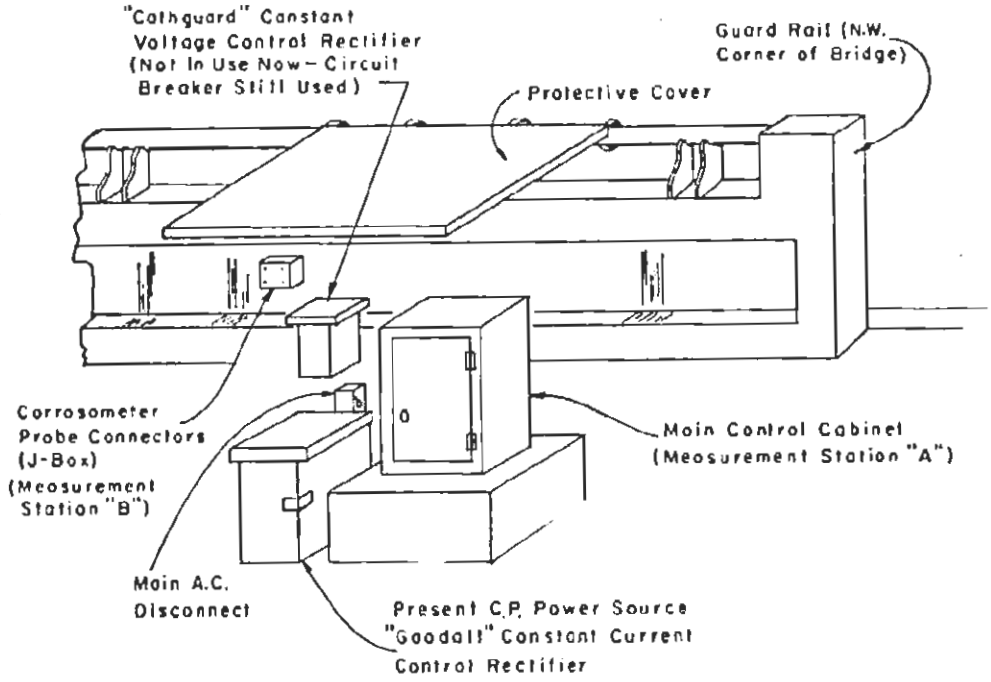


Figure 4

Details of Measurement Stations "A" and "B" at North West Corner of Sly Park Bridge

B. Limits of the Cathodic Protection System

The cathodic protection system is designed to protect only the westbound lanes of the Sly Park Bridge deck. The maximum output of the cathodic protection constant current rectifier is 8 amperes. The constant current rectifier ("Goodall" rectifier) can be operated either automatically, or manually with a range limit of 2-7 amps. At present, the system is adjusted seasonally to operate at 1.5 amps during the summer and 2.7 amps during the winter.

C. A.C. Power Source

The A.C. power source is the PG&E power pole at the Safeway Supermarket located about 250 feet north of the bridge. A meter and circuit breaker is located on the PG&E pole (see Figure 5). An underground cable provides the power transmission from the PG&E pole to the pull disconnect box located directly behind the "Goodall" rectifier at Station "A", (see Figure 4). A.C. power is transmitted through the circuit breaker in the "Cathguard" rectifier (rectifier now not used) to the present "Goodall" rectifier.

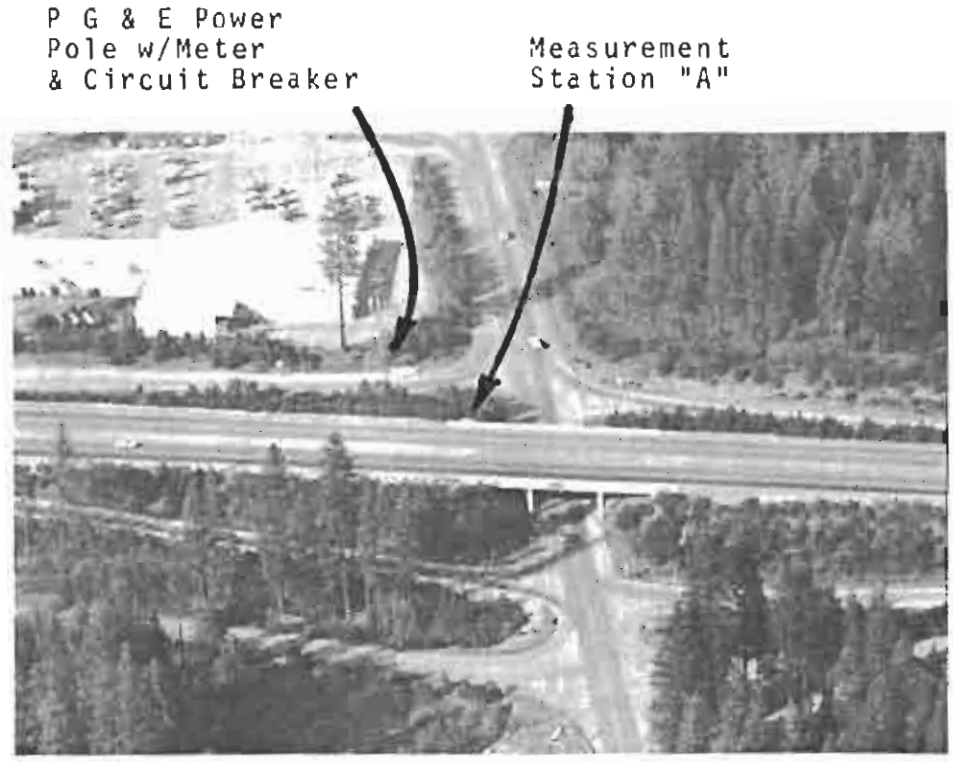


Figure 5

A.C. Power Source at Sly Park Bridge

D. Electrical Fuse Locations

1. Main circuit breaker is located, with the meter, on the PG&E power pole 250 feet north of the bridge.

2. A sub-panel circuit breaker is located within the "Cathguard" rectifier box, directly above the main A.C. disconnect, at measurement Station "A", (see Figure 4).

3. The "Goodall" rectifier is protected with a circuit breaker, accessable by opening the front cover of the rectifier.

E. Keying and Locking Information

1. The key for the Main Control Cabinet (an Electromatic Traffic Control Cabinet) is kept in the Corrosion Laboratory, 5900 Folsom Boulevard, Sacramento. A spare key, kept at the site, is hidden in the Corrosometer Probe J-Box (Measurement Station "B") attached to the side of the bridge structure approximately five feet east of the Main Control Cabinet. A screwdriver will be needed to open the J-Box.

2. A key, for access to the PG&E power pole circuit breaker box is hidden on the top shelf of the Main Control Cabinet.

3. All other locks used on panels and/or equipment at this site are combination padlocks. As of May 12, 1980, the combination to all padlocks is "9066". This combination will be changed periodically.

MEASUREMENT DETAILS, (Routine)

Use the Corrosion Unit Record Sheet (sample attached as Appendices A & B), for recording data. The instructions, as presented in this manual, for taking the readings and the recording of the data on the Record Sheet follow in consecutive order as they appear on the recording sheet.

MEASUREMENT DETAIL

A. Preliminary Information

Fill in the preliminary information (Date, Time, Temperature and Weather conditions). The "El Dorado Savings" display tower (approximately 900 feet northwest of the bridge) can be used for information of time of day and ambient temperature, if a calibrated thermometer is not available.

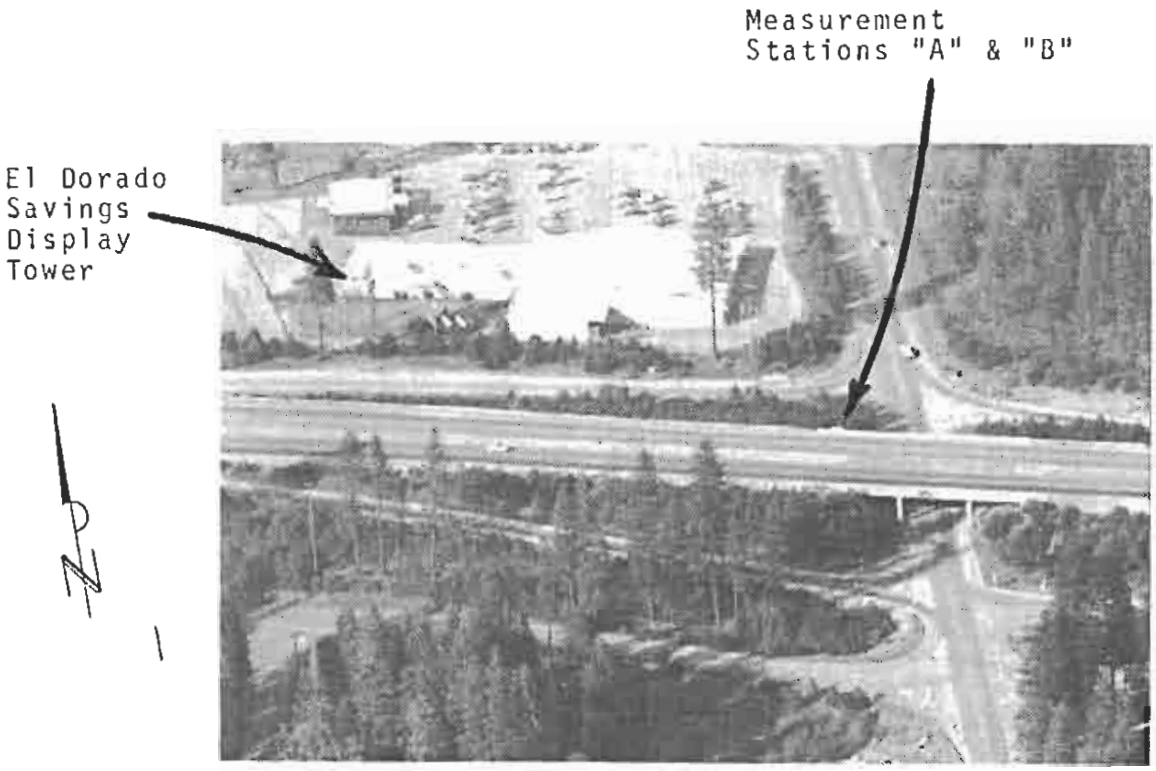


Figure 6
"El Dorado Savings" display tower at Sly Park Bridge

MEASUREMENT DETAIL

B. Current (Amps) Impressed Current

a. Instrument Used: Hewlett-Packard Multimeter Model 3465B or any voltmeter with 10 meg-ohm minimum impedance.

b. Measurement Station: "A"

c. Terminal Connections: All connections are made within the main control cabinet. The connections between the voltmeter and the control cabinet panel are: Positive lead of the voltmeter to Red Terminal on the control panel, and Negative to the White Terminal (see the photo-detail below).

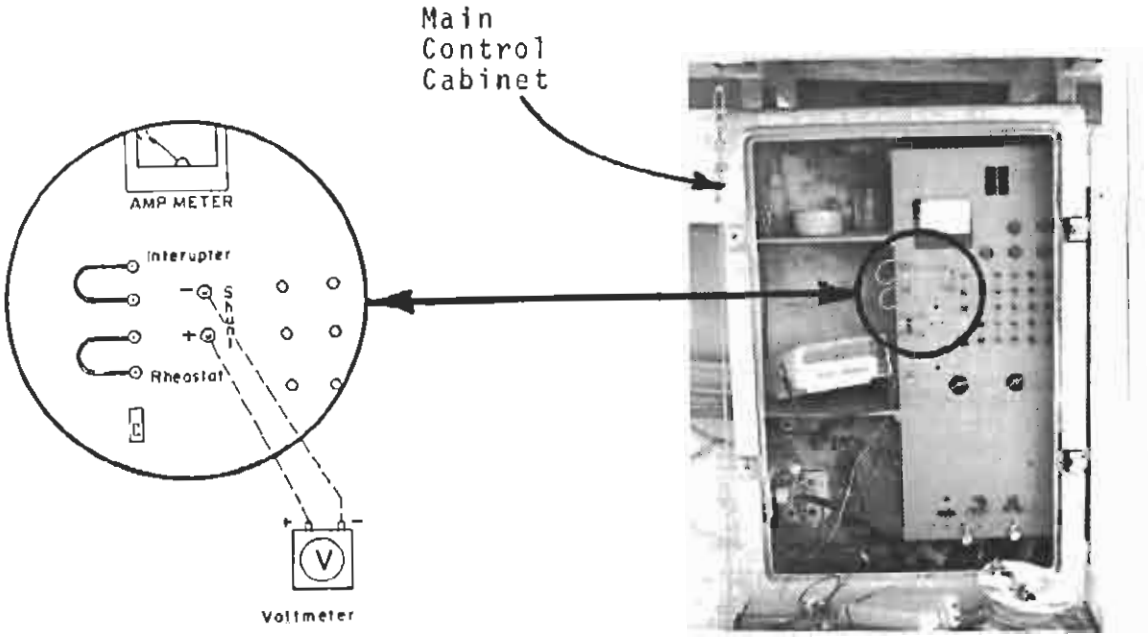


Figure 7
Connection for Impressed Current Measurement

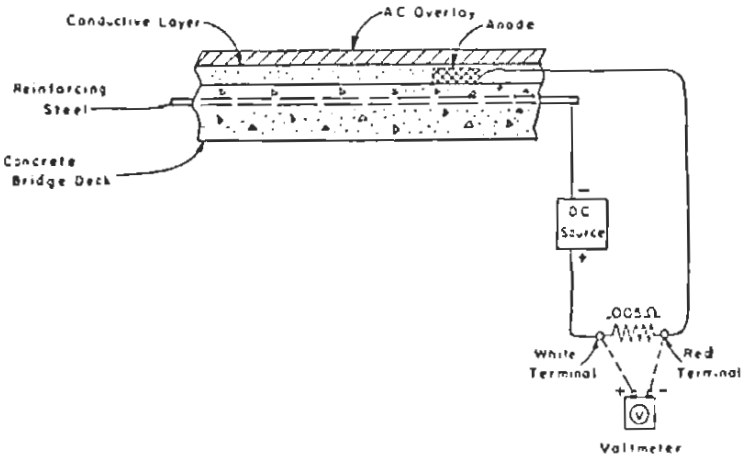


Figure 8
Schematic of Impressed Current Measurement

d. Instructions: Take voltage drop readings across the .005 (±1%) ohm shunt with the D.C. voltmeter. Measurements are read, on the D.C. voltmeter, across the two terminals shown on the previous drawings. The .005 (±1%) ohm resistance shunt, between these two terminals, is used to convert the voltage recordings into amperage, using Ohm's Law. The amperage draw is automatically controlled through the rectifier, so the resulting recordings should calculate to approximately 1.5 amps during the summer and 2.7 amps during the winter. (These suggested figures should be used only as a guide and not as a determination of accuracy.)

e. Recording Conversion Factor: 1 mv = 0.2A.

MEASUREMENT DETAIL

C. Driving Voltage (v):

a. Instrument Used: Hewlett-Packard Multimeter Model 3465B or any equivalent voltmeter with 10 meg-ohm minimum impedance.

b. Measurement Station: "A"

c. Terminal Connections: All connections are made within the main control cabinet. The connections between the voltmeter and the control cabinet panel are: The positive lead of the voltmeter to the "Rheostat" terminal (white) on the control panel, and the negative lead of the voltmeter to the terminal block which is a terminus of all leads from the reinforcing steel mat of the structure, (see the photo-detail in Figure 9).

d. Instructions: The purpose of these readings is to determine the difference in electrical potential between the anodes and the reinforcing steel mat in the bridge deck.

The driving voltage is read directly from the D.C. voltmeter, and will be in the approximate range of 1.5 to 3.0 volts D.C.

e. Recording Conversion Factor: None

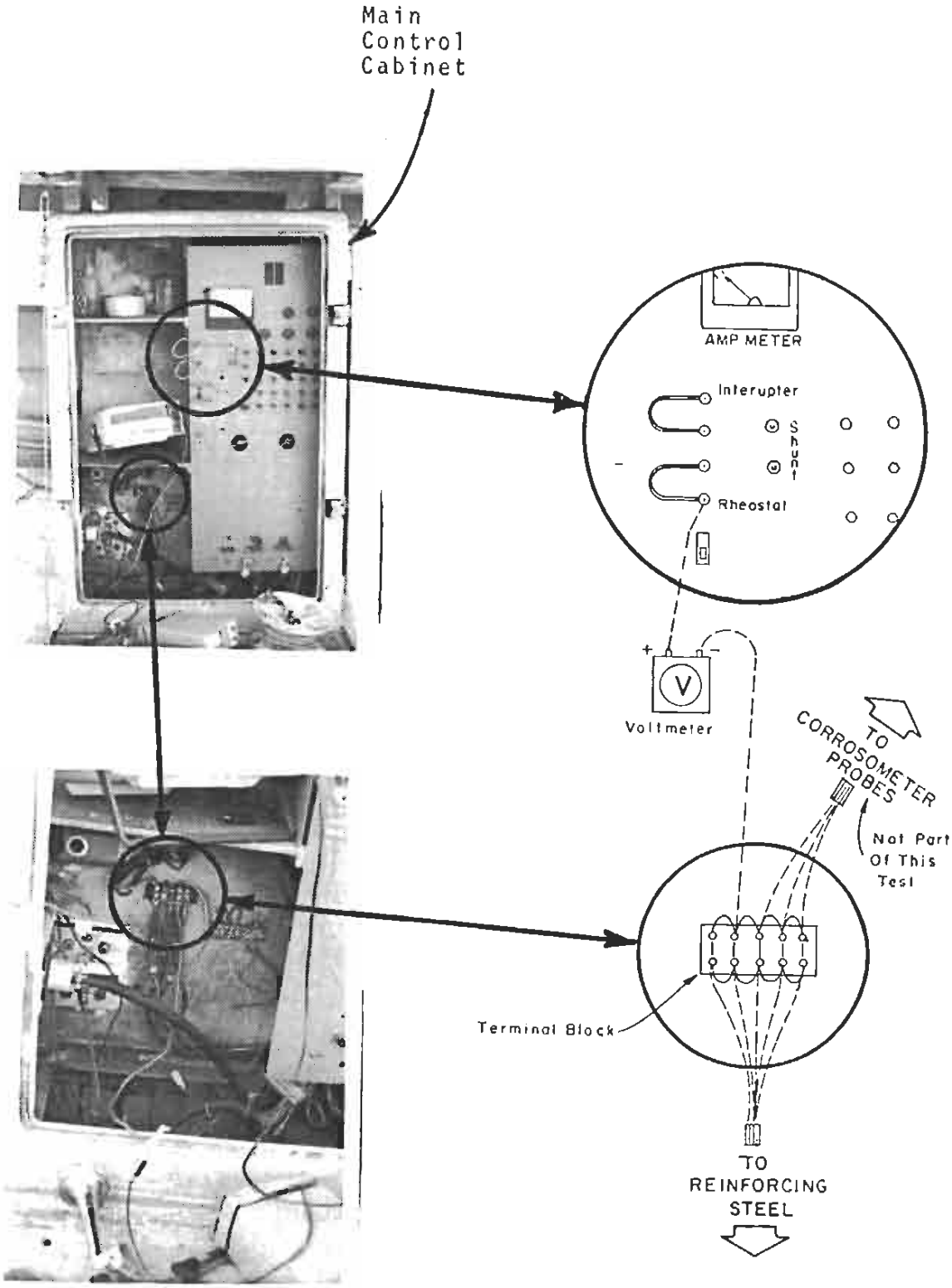


Figure 9

Connection for Driving Voltage Measurement

MEASUREMENT DETAIL

D. Back EMF (v)

a. Instrument Used: "Tektronic 213 DMM" portable Oscilloscope or any equivalent oscilloscope with a minimum of 10 meg-ohm impedance and vertical deflection capability of 0.01 volt/division.

b. Measurement Station: "A"

c. Terminal Connections: All connections are made within the main control cabinet. The oscilloscope positive lead is connected to the "Rheostat" terminal (white) on the control panel, and the negative lead of the voltmeter to the terminal block which is the terminus of all leads from the reinforcing steel mat of the structure, (see the photo-detail in Figure 11).

Due to the type of terminal clip furnished with the oscilloscope, an adapter has been fabricated to make the connection easier and more reliable, (Figure 10).

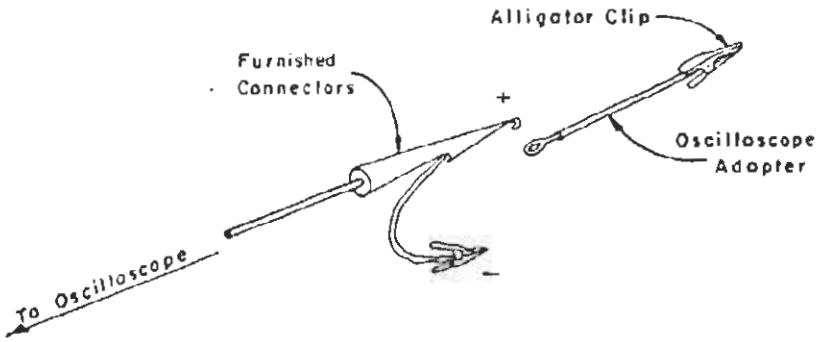


Figure 10
Oscilloscope Adapter

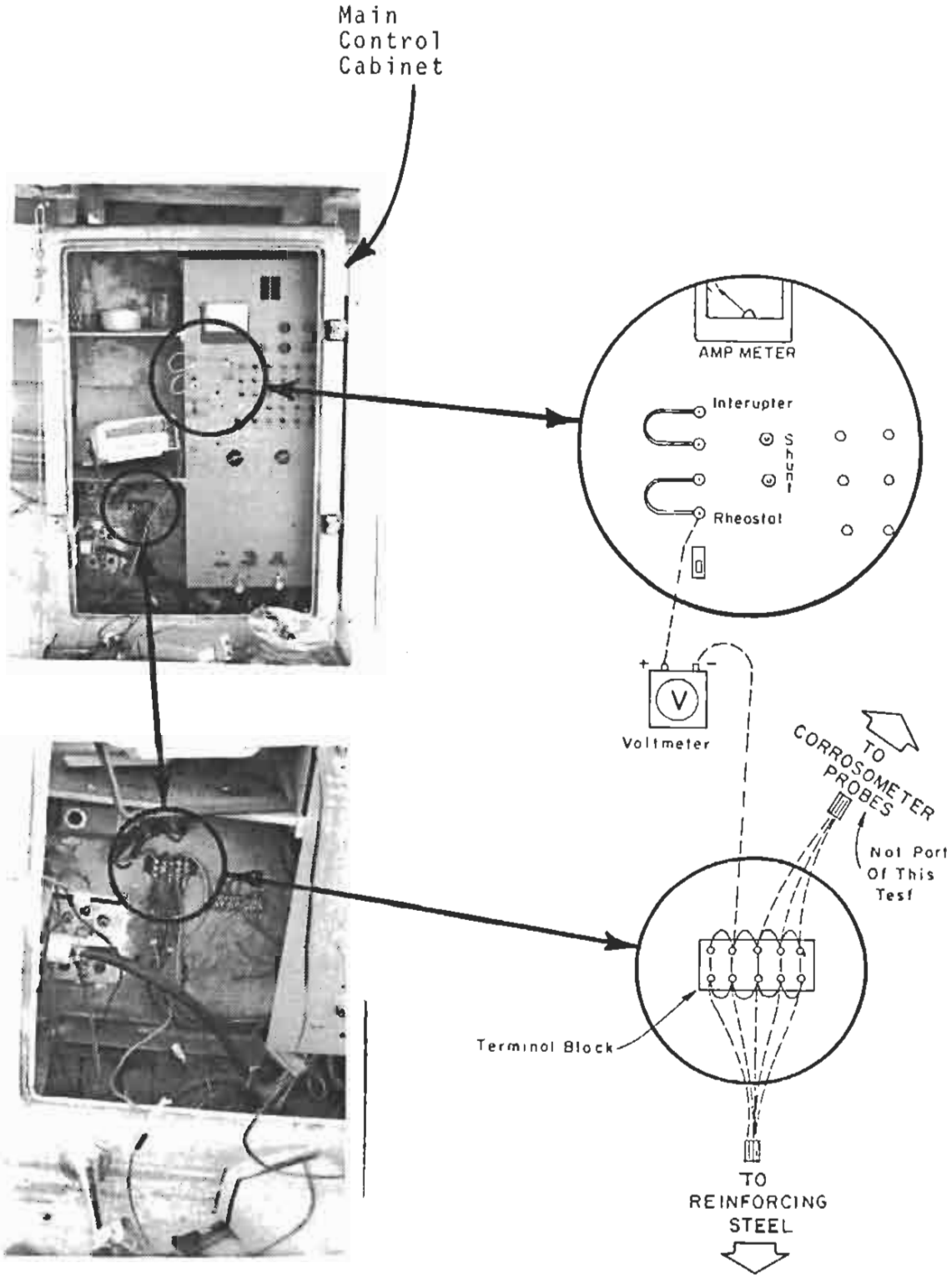


Figure 11
Connection for Back EMF Measurement

d. Instructions: Back EMF, (Back Voltage), is a measurement of the voltage that must be overcome by the impressed current power source before current can be forced to discharge from the anode system. This voltage is read off the oscilloscope screen as the difference between the "Base Line" (0 volts) and "Off Voltage" lines, and is recorded on the Corrosion Unit Record Sheet in volts, (typical display shown in Figure 12). Figure 13 shows the appropriate setting of the "Tektronic 213 DMM Portable Oscilloscope" controls for this test.

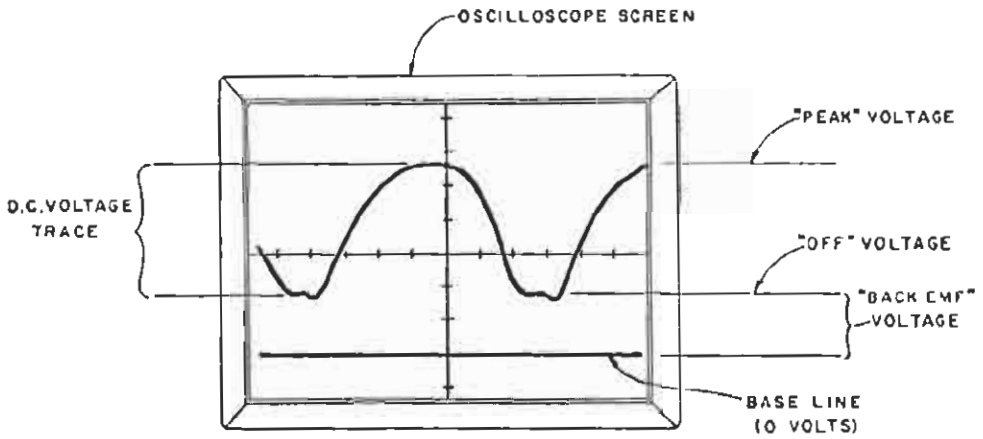


Figure 12
Typical back EMF display on Oscilloscope Screen

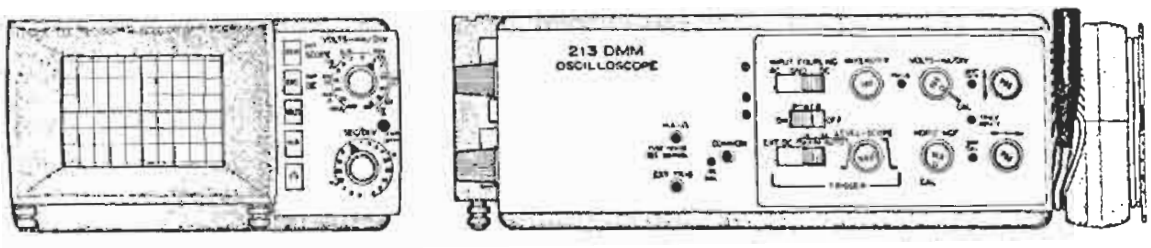


Figure 13
"Tektronic 213 DMM Portable Oscilloscope"
with controls set for the "Back EMF" Test.

e. Recording Conversion Factor: None

MEASUREMENT DETAIL

E. Peak Voltage (v)

a. Instrument Used: "Tektronic 213 DMM" portable oscilloscope or any equivalent oscilloscope with a minimum of 10 meg-ohm impedance and vertical deflection capability of 0.01 volt/division.

b. Measurement Station: "A"

c. Terminal Connections: All connections are made within the main control cabinet. The oscilloscope positive lead is connected to the "Rheostat" terminal (white) on the control panel, and the negative lead of the voltmeter to the terminal block which is the terminus of all leads from the reinforcing steel mat of the structure, (see the photo-detail in Figure 15).

Due to the type of terminal clip furnished with the oscilloscope, an adapter has been fabricated to make the connection easier and more reliable, (Figure 14).

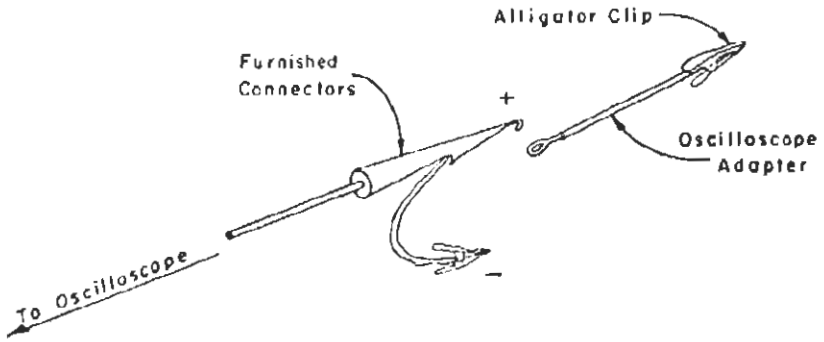


Figure 14
Oscilloscope Adapter

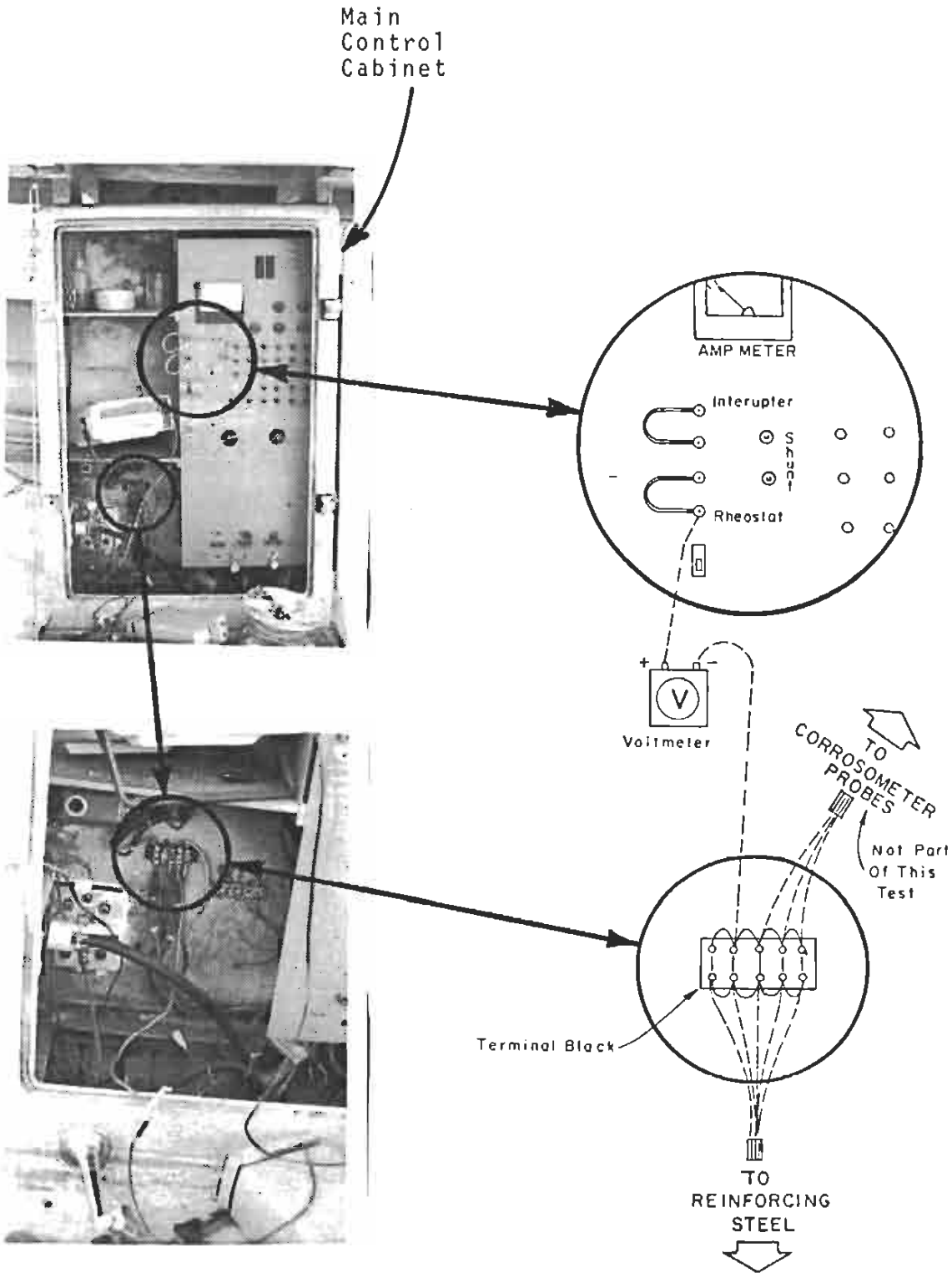


Figure 15
Connection for Peak Voltage Measurement

d. Instructions: "Peak voltage" is a measurement of the maximum voltage being supplied by the "Goodall" rectifier to the anode distribution system within the structure. This voltage is read off the oscilloscope screen at the highest point of the D.C. voltage trace, (typical display shown in Figure 16). Figure 17 shows the appropriate setting of the "Tektronic 213 DMM Portable Oscilloscope" controls for this test.

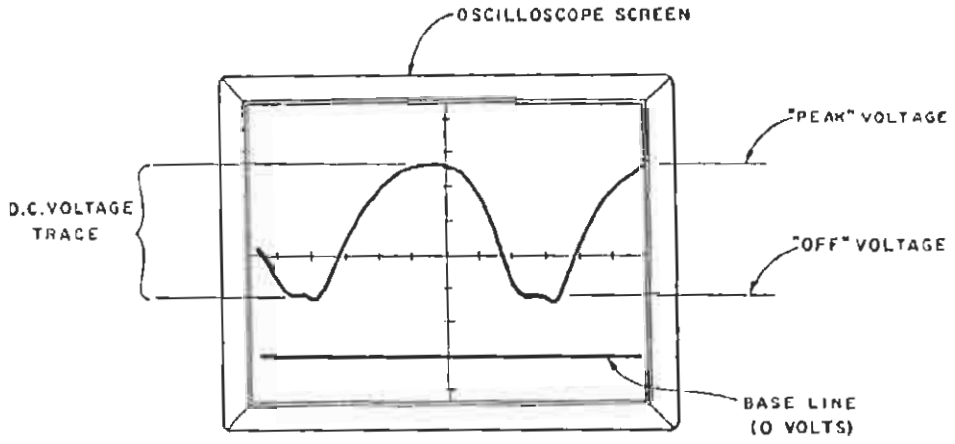


Figure 16
Typical Peak Voltage Display on Oscilloscope Screen

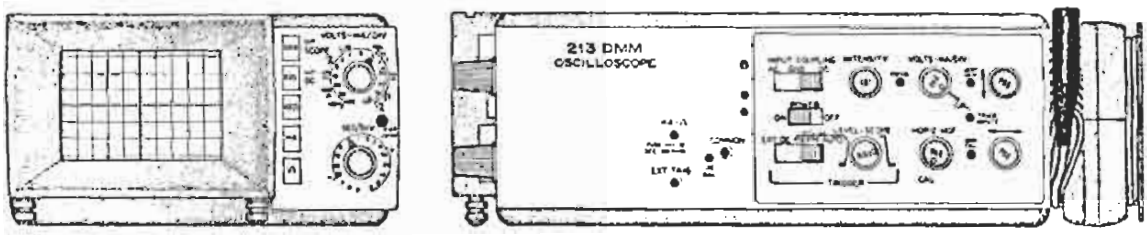


Figure 17

"Tektronic 213 DMM Portable Oscilloscope" with controls set for the "Peak Voltage" Test

e. Recording Conversion Factor: None

MEASUREMENT DETAIL

F(1). Corrosometer Probe (Impressed Current)

a. Instrument Used: Hewlett-Packard Multimeter, Model 3465B or any equivalent voltmeter with 10 meg-ohm minimum impedance.

b. Measurement Station: "A"

c. Terminal Connections: All connections are made within the main control cabinet. The terminals to be read are located at the lower edge of the control panel and are numbered as "#7" and "#9" corrosometer probe. The connections between the voltmeter and these terminals are: Positive lead of the voltmeter to the left terminal and the negative lead to the right terminal. (See the photo-detail in Figure 18).

d. Instruction: Take voltage drop readings of corrosometer probes 7 and 9, across the 100 (±1%) ohm shunts with the D.C. voltmeter (see Figures 18 and 19). The shunt, between the terminals is used to convert the voltage recordings into amperage using Ohm's Law.

Do not readjust or change the settings of the potentiometer knobs directly above the terminals being read. Changing these settings will alter the protective current being delivered to the corrosometer probes.

e. Recording Conversion Factor: 1 mv = .01 Amp.

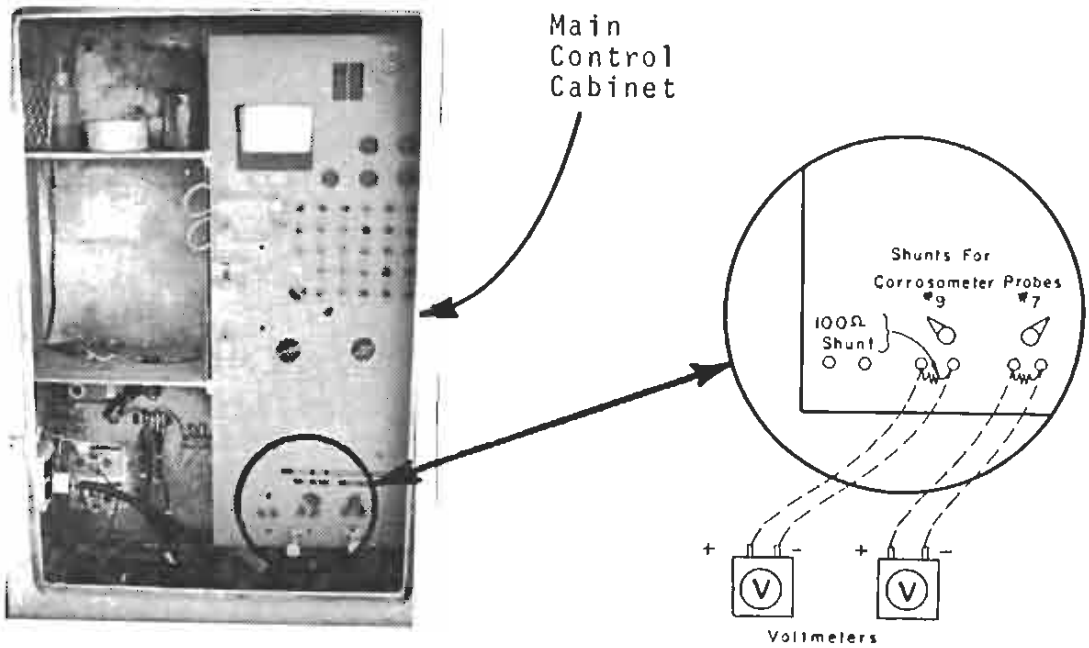


Figure 18

Connection for Corrosometer Probe Impressed Current Measurement

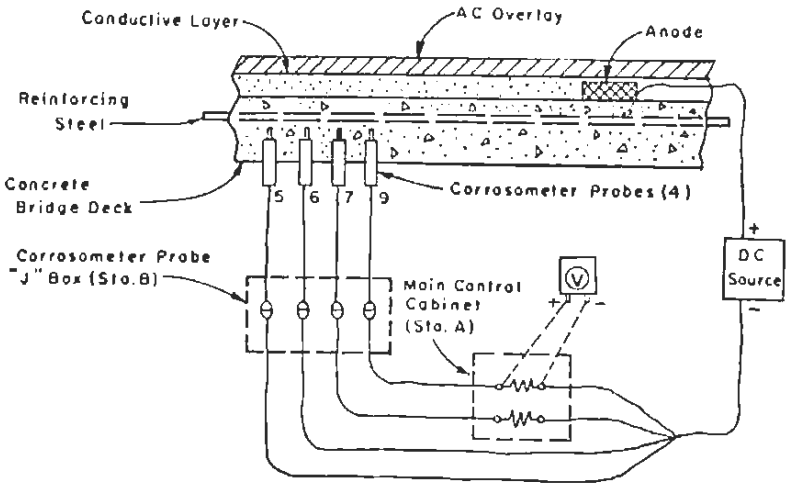


Figure 19

Schematic of Corrosometer Probe Impressed Current Measurement

MEASUREMENT DETAIL

F(2). Corrosometer Probe (Corrosometer Reading)

a. Instrument Used: "Magna Model CK-3" Corrosometer Probe Meter.

b. Measurement Station: "B"

c. Terminal Connections: The connectors for this test are located within the 8" x 8" electrical J-Box attached to the side of the concrete bridge rail (approximately 5 feet east of the main control cabinet). Each of the four connectors in this box is in series with one of the four corrosometer probes within the bridge structure, (corrosometer probe numbers 5, 6, 7 and 9).

Separate each connector (one at a time) and plug in the terminal from the "Magna CK-3". (See the photo-detail in Figure 20 and schematic, Figure 21).

d. Instructions: Separate each corrosometer probe connector plug (one at a time to minimize the chance of an error during reconnection) within the 8" x 8" J-Box and plug in the "Magna CK-3" meter. This instrument is a "null" balance type meter that, when balanced, is read directly. Take two readings of each Corrosometer Probe; one with the selector, of the Magna CK-3, on the "Tube/Strip" setting and record the results on the Corrosion Unit Recording Sheet under the "T/S" column; the second reading is taken with the selector on the "Check" setting and record these results under the "Check" column. Reconnect each plug upon completion.

e. Recording Conversion Factor: None

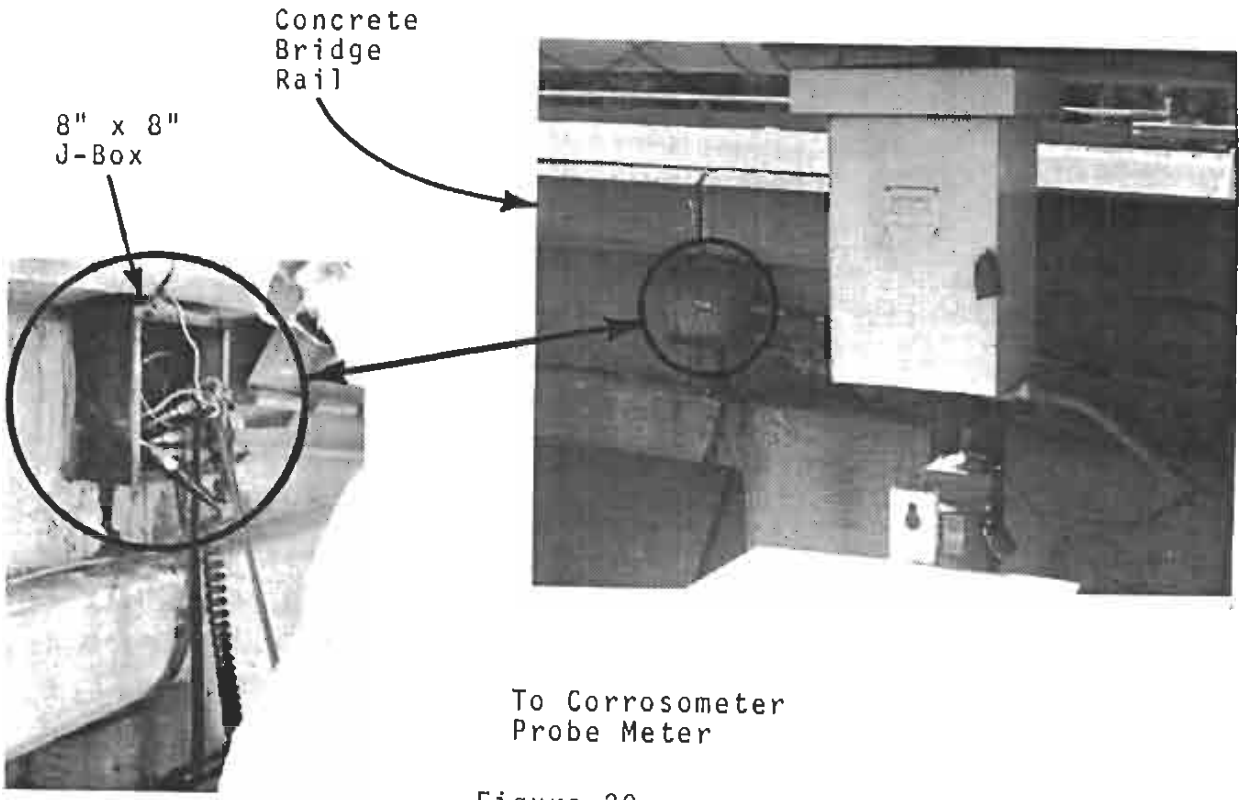


Figure 20
Connection for Corrosometer Probe Reading

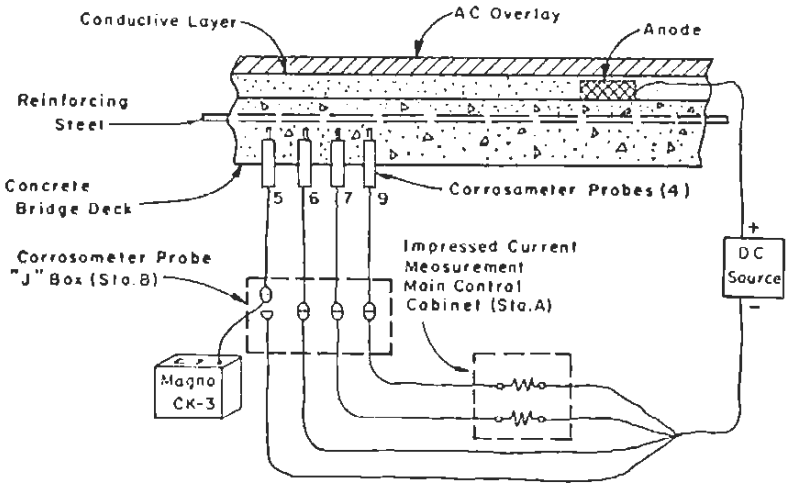


Figure 21
Schematic of Corrosometer Probe Reading

MEASUREMENT DETAIL

G. Bridge Deck CSE (mv) ("Peak" Potential and Instant "Off" Potential)

a. Instrument Used: A 1-1/4 inch maximum diameter $Cu\text{-}CuSO_4$ reference cell and the "Tektronic 213 DMM" portable Oscilloscope or any equivalent oscilloscope with a deflection capability of 0.01 volt/division. Additional equipment needed: one reel of 16 gauge stranded insulated wire, 150 feet long; eight sponges approximately one cubic inch in size; and a container of tap water.

b. Measurement Station: "A" and eight separate access holes in the surface of the roadway shoulder, (details of these access holes are described in the following paragraphs).

c. Terminal Connections: The oscilloscope negative lead is connected to the terminal block in the bottom section of the main control panel (see Figure 22), which is the terminus of all leads from the reinforcing steel mat within the structure. The positive lead is connected through the 150 foot reel of 16 gauge wire to the $Cu\text{-}CuSO_4$ reference cell.

Due to the type of terminal clip furnished with the oscilloscope, an adapter has been fabricated to make the connection easier and more reliable (see Figure 23).

Figure 29 shows the appropriate setting of the "Tektronic 213 DMM Portable Oscilloscope" controls for this test.

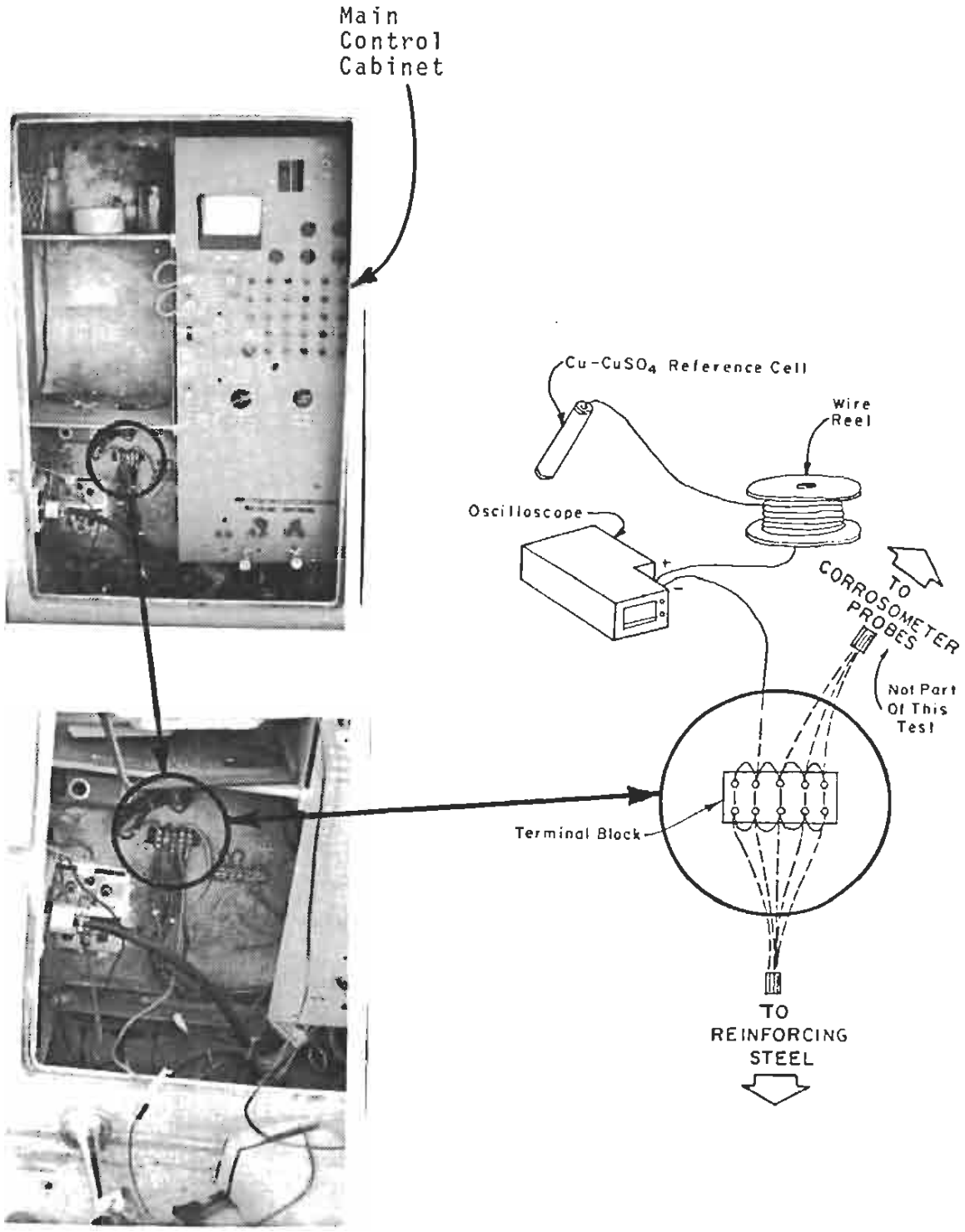


Figure 22
Connection for Bridge Deck CSE Measurement

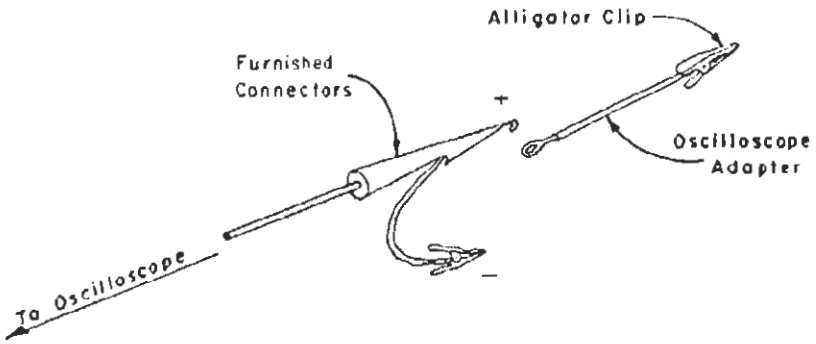


Figure 23
Oscilloscope Adapter

d. Instructions: Electrical potential readings of the reinforcing steel within the structure are taken with a Cu-$CuSO_4$ reference cell through access holes in the roadway surface. The stations, (or access holes), on the Corrosion Unit Recording Sheet correspond to the locations indicated on the following grid drawing of the bridge deck. Although there are many stations available in the roadway surface, the only stations used for these routine potential tests are represented on grids: B7-1/2, B12-1/2, B15-1/2, B19-1/2, B22-1/2 and B25-1/2.

An easy method for determining the proper access hole is by the diameter of the plastic pipe segment. Those requiring routine testing are 1-1/2 inches in diameter. All other access holes (see Figure 24) are 1-1/4 inches in diameter and are not tested under these routine tests.

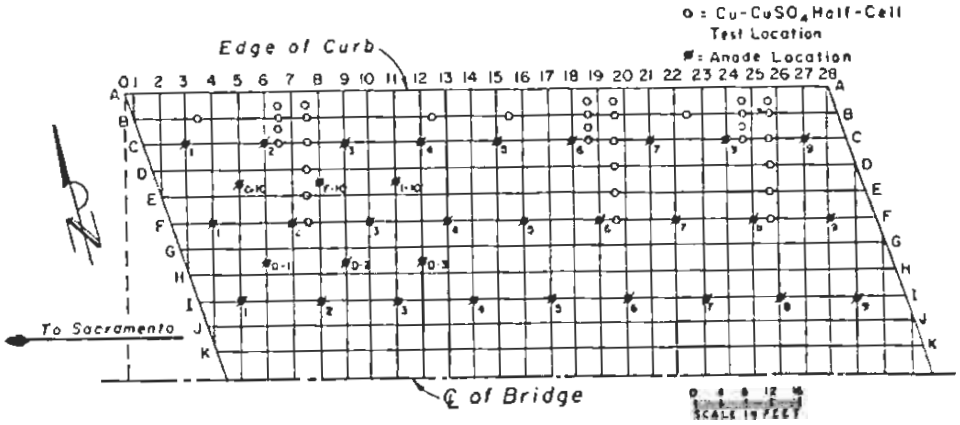


Figure 24
$Cu\text{-}CuSO_4$ Reference Cell Access Holes and Anode Locations on Bridge Deck

As the only access holes used for this test are in the shoulder area of the bridge, no lane closure is needed, but traffic cones must be placed for protection within the shoulder area.

Figure 25
Traffic Cone Placement

The access holes, (segments of 1-1/2 inch diameter PVC pipe extending from the concrete deck of the bridge to the surface of the roadway), have plastic covers inserted into them approximately 3/4 inch down from the top edge. Thoroughly clean the accumulated dirt and debris from the cover before removing it to assure that no dirt or debris drops onto the recording surface of the bridge deck. A small screwdriver is needed to pry out the plastic cover.

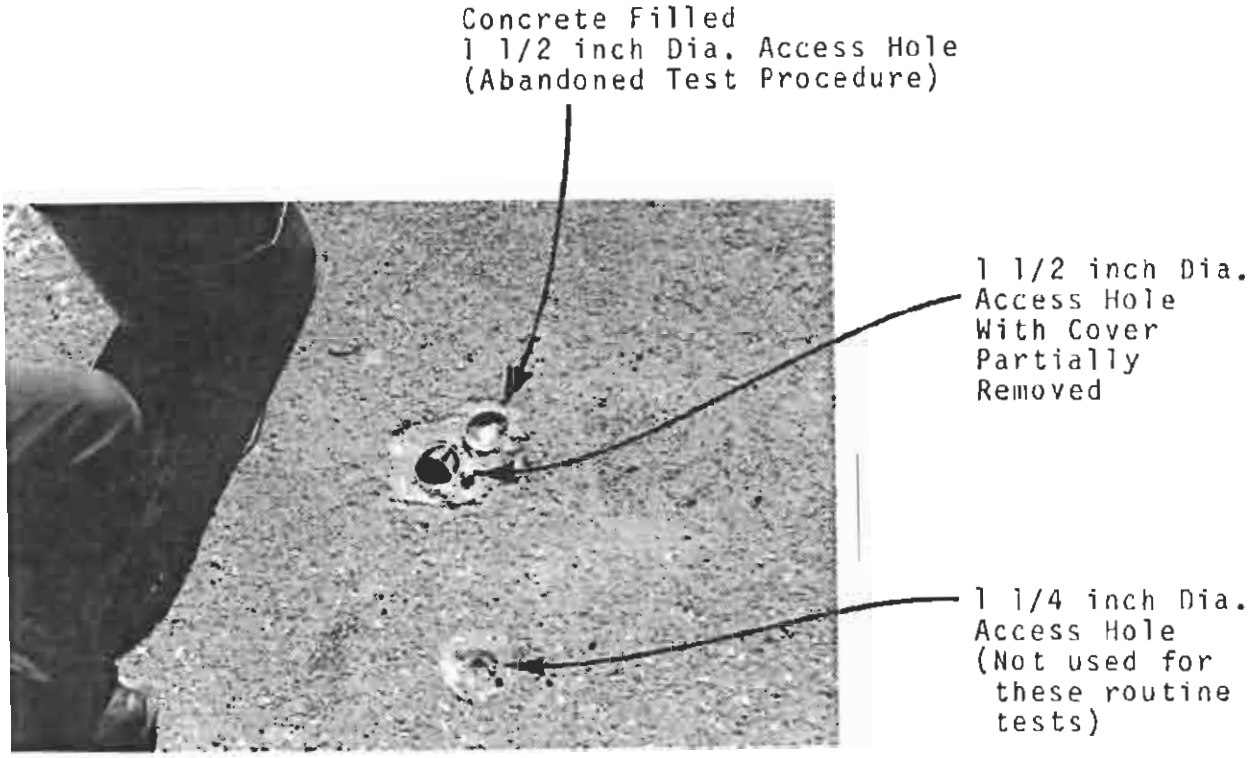


Figure 26
Reference Cell Access Hole

Insert a small sponge (approximately 1 cu. in. in size) into the access hole of the bridge deck. Make sure the sponge is in contact with the deck surface. Add sufficient water to completely saturate the sponge. Allow at least 5 minutes for the water to saturate the concrete surface. Add more water if the sponge dries. Insert the Cu-$SuSO_4$ Half-cell into access hole, making certain it rests firmly against the sponge surface in the hole.

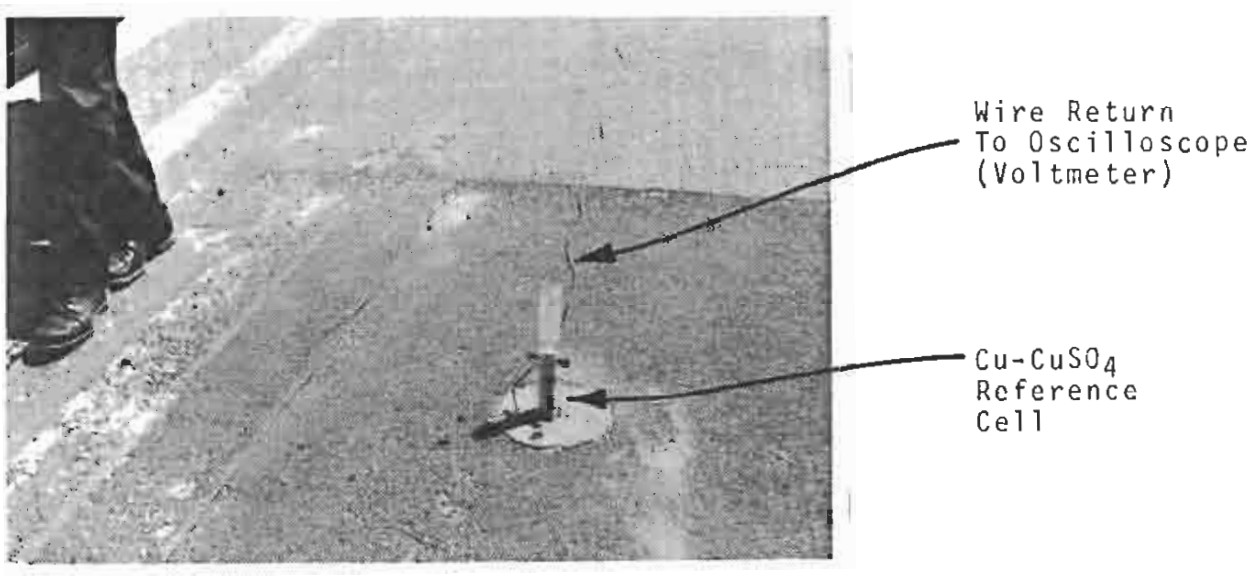


Figure 27
Cu-$CuSO_4$ Reference Cell Shown in Access Hole

Two readings can be made simultaneously with the use of the portable oscilloscope. "Peak" half-cell potential is read from the crest of the oscilloscope wave trace and the instant "off" from the bottom of the trace.

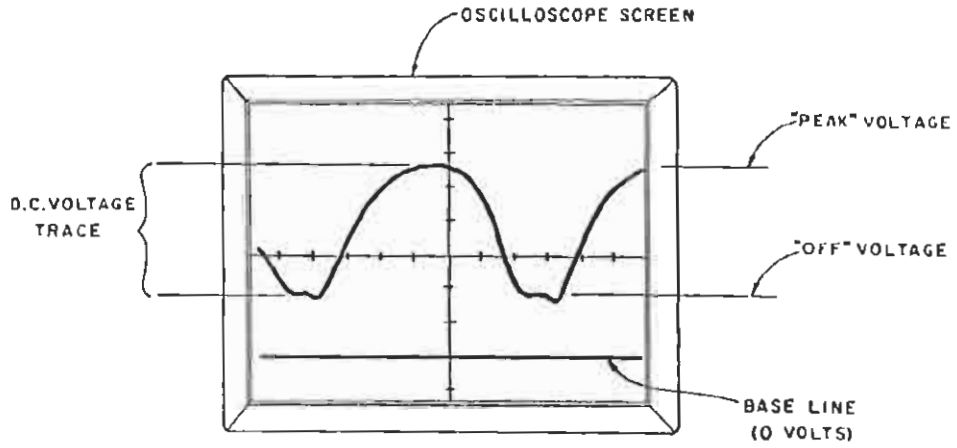


Figure 28
Typical "Bridge Deck CSE" Display on Oscilloscope Screen

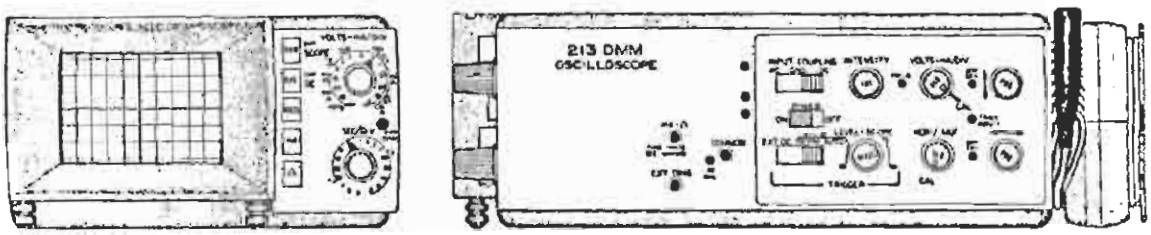


Figure 29
"Tektronic 213 DMM Portable Oscilloscope" with controls set for "Peak" and "Instant Off" test.

e. Recording Conversion Factor: None

MEASUREMENT DETAIL

H. Anode Current

a. Instrument Used: Hewlett-Packard multimeter, Model 3465B or any equivalent voltmeter with 10 meg-ohm minimum impedance.

b. Measurement Station: "A"

c. Terminal Connections: All connections are made within the main control cabinet. The main panel cover must be opened for access to the terminal boards attached to the back of the panel. There are 22 separate readings to be made during this series and the individual connections will be described in detail in the "Instructions" paragraph to follow. For the present, the general description is that the voltmeter negative lead is connected to the "common bar" and the positive lead is connected to the individual "shunt wire" terminals (see the photo-detail in Figure 30).

d. Instructions: This test is used to determine the amount of current, from the rectifier, that is delivered to each anode on the bridge deck. The physical location of each anode is shown by the following grid of the bridge deck, (Figure 31).

There are a total of 32, 8 inch diameter disc shaped, hi-silicon iron anodes installed in the bridge deck. Of them, 22 anodes have been connected to the C.P. current distribution system as active anodes.

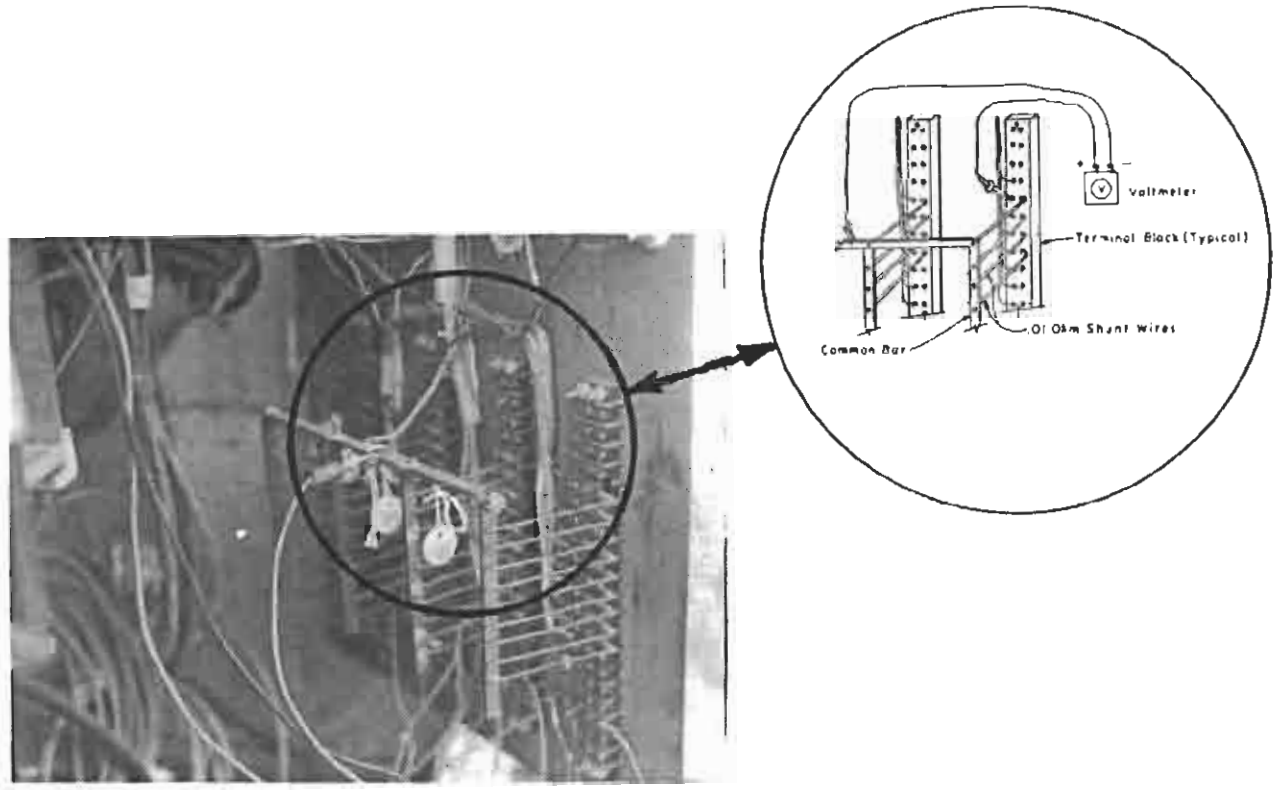


Figure 30
Connection of the Voltmeter to Anode Terminals

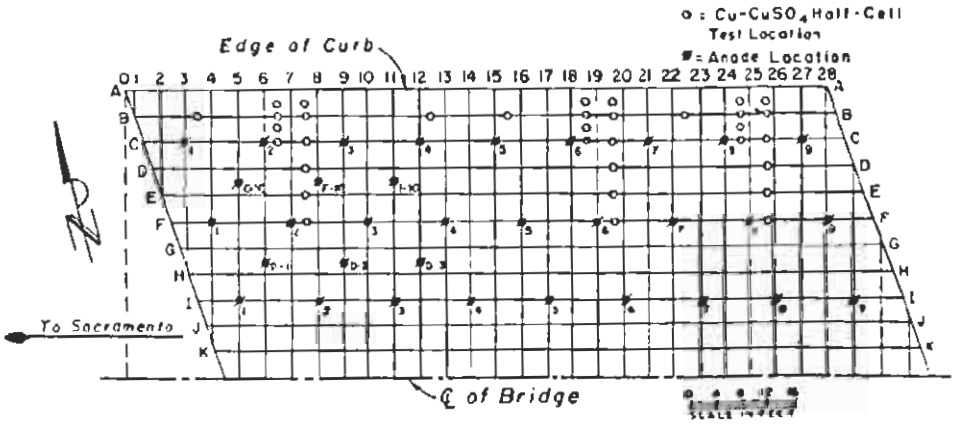


Figure 31
Anode Locations on Bridge Deck

The recording sheet for this test carries the individual anodes identified by the grid cross reference. Only the anodes on the C, F and one-half of the I grid lines are used for recording purposes (C1 through C9, F1 through F9 and F9 and I1 through I4), (see Figure 31).

The measurements are made with the voltmeter and are recorded in millivolts read across a .01 ($\pm$1%) ohm shunt. Using Ohm's Law, the millivolt readings are converted to amperes for the current draw of each anode.

To perform the tests: Open the hinged instrument panel of the main terminal cabinet. The panel door is secured by one removable screw on its left edge, (Figure 32).

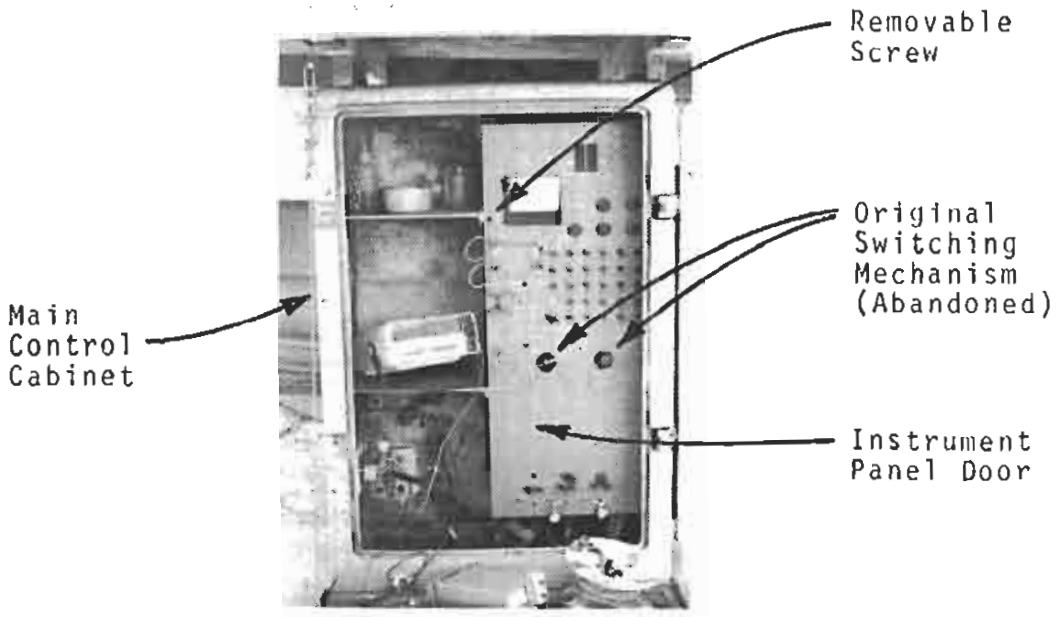


Figure 32
Access To Anode Terminals

On the back side of the panel door, at the lower edge, is a grid system of terminal blocks and shunt wires. This grid is the terminal connections and their individual .01 (±1%) ohm shunt from each anode. Each shunt wire is connected between the terminal block and the common bar, (Figure 30 and 33).

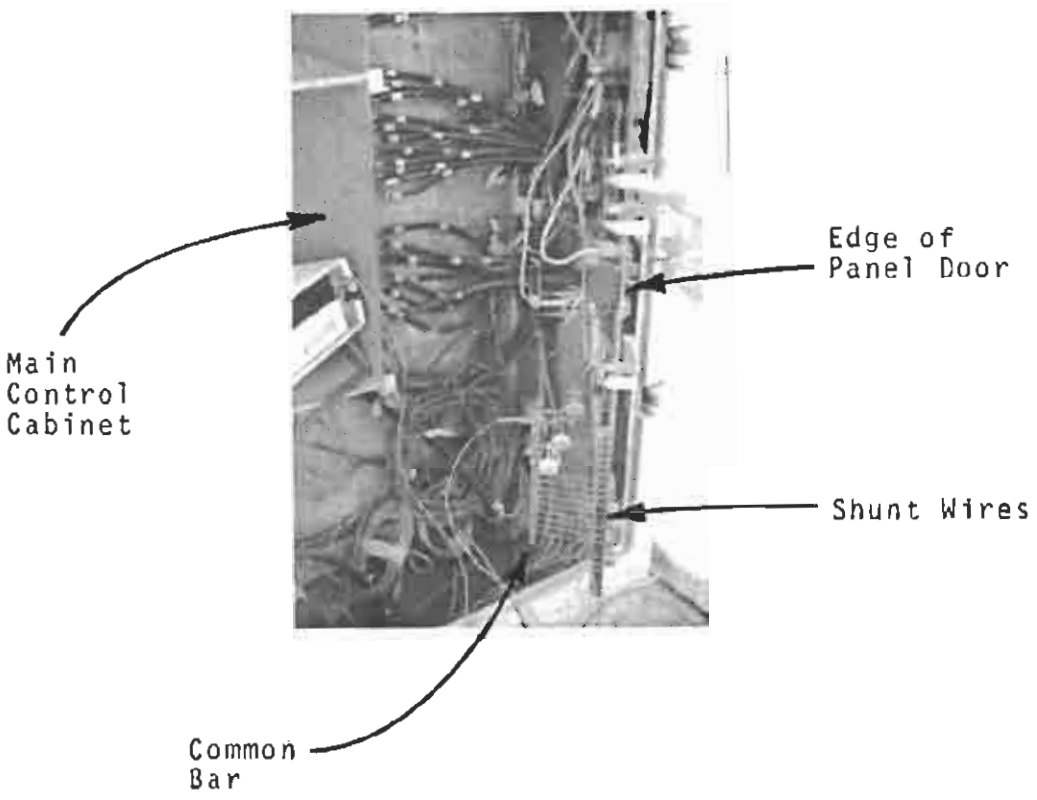


Figure 33
Location of Anode Terminals

There are 4 terminal blocks attached to the back of the panel door. The terminal block on the far left (while looking at the back of the panel door) is connected to the anodes on the "C" grid line and is numbered in increasing order from top to bottom. The next terminal block is connected to the anodes on the "F" grid line, etc., (Figure 34).

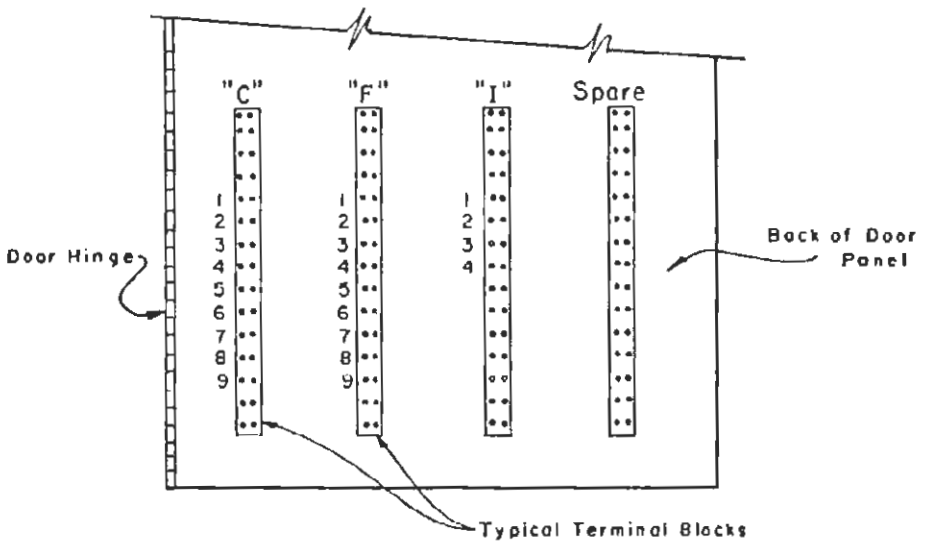


Figure 34
Anode Terminal Numbering System

Measurements are taken on the top 9 shunted terminals of the "C" and "F" blocks but only on the top 4 shunted terminals of the "I" block. The terminal block on the far right is kept as a spare and is connected only to the shunt wire common bar.

The method of measurement is to connect the negative lead of the voltmeter to the shunt common bar and using the positive probe, touch each terminal in order, reading and recording the voltage across the .01 ($\pm$1%) ohm shunt and at a later time converting these readings to milliamps (ma), (Figure 35).

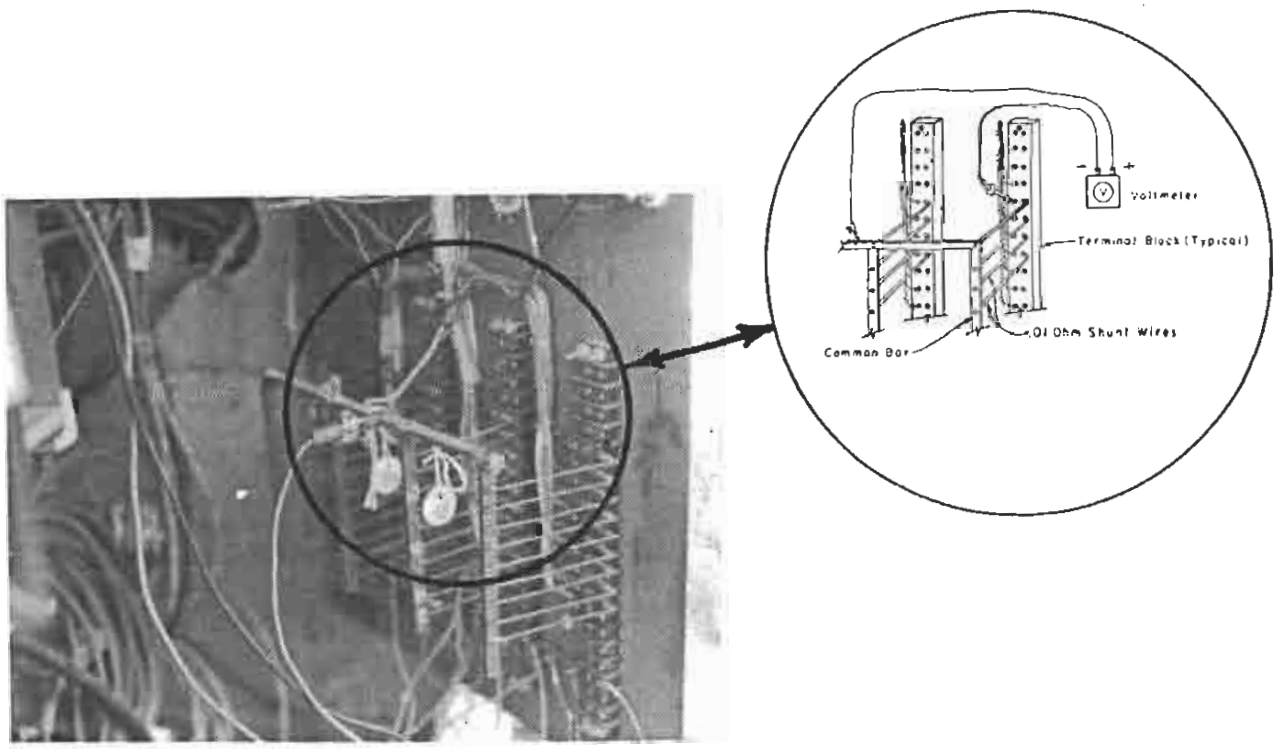


Figure 35
Typical Connection of Voltmeter to Anode Terminals

It should be noted that the readings from 6 of the 22 active anodes (C3, C4, C9, F5, F6 and I3) are noticeably lower than the rest of the anodes. We suspect that there are damaged leads or connectors at the anodes or the anodes themselves are damaged. It is not known at this time what is actually the cause.

e. Recording Conversion Factor: 1 mv = 0.1 Amp.

MEASUREMENT DETAIL

I. Isolated Reinforcing Bar Sections

Introduction: Measurements of the "Isolated Rebar" sections are measurements taken of segments of the bridge deck's lower reinforcing steel mat. These segments are short (4 inches to 7 inches long) lengths of reinforcing steel bars that have been isolated, by cutting, from the remainder of the reinforcing steel mat. The sketch below shows the location of these isolated segments and their identifying codes.

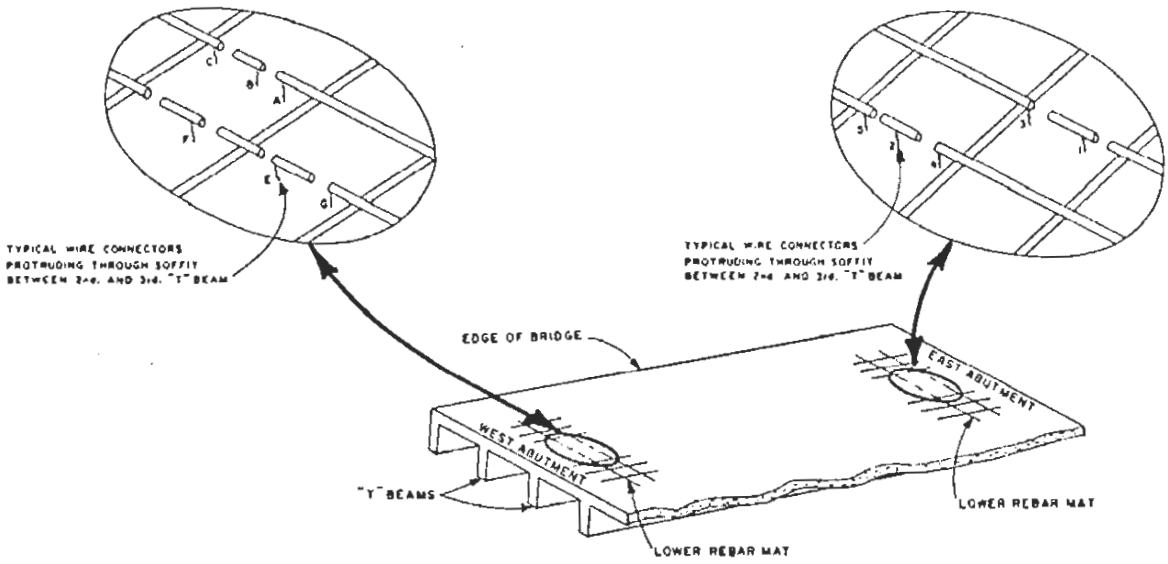


Figure 36
Isolated Rebar Segments
Plan View of Bridge Deck

Figure 37

Typical isolated rebar location and instrument connection near West Abutment. Measurement Station "C"

Figure 38

Typical isolated rebar location and instrument connection near East Abutment. Measurement Station "D"

Each isolated rebar segment and the adjacent lower mat of reinforcing steel have wire connectors attached which protrude through the concrete soffit.

Readings from the isolated rebar sections are taken by attaching the appropriate instrument, for the data desired, (refer to the following sections pertaining to each type of recorded information required), to the wire connectors protruding from the soffit of the bridge, (between the second and third "T" Beam, at both the west abutment and the east abutment).

Figure 39
Typical Connection of Instrument
to Wires Protruding From Soffit

The wire connectors are all identified by numbers and letters painted on the concrete surface that match corresponding numbers and letters on the recording form.

MEASUREMENT DETAIL

I(1). Isolated Reinforcing Bar Section
(Resistance Measurement, Ohms, West Soffit)

a. Instrument Used: Resistance Meter, "Nilsson 400"

b. Measurement Station: "C"

c. Terminal Connections: Four resistance measurements are taken from this location. Using the following sequence, attach the two leads from the Resistance Meter to wire connectors (protruding from the soffit): E and G, E and A, F and G, F and A, (see the following schematic).

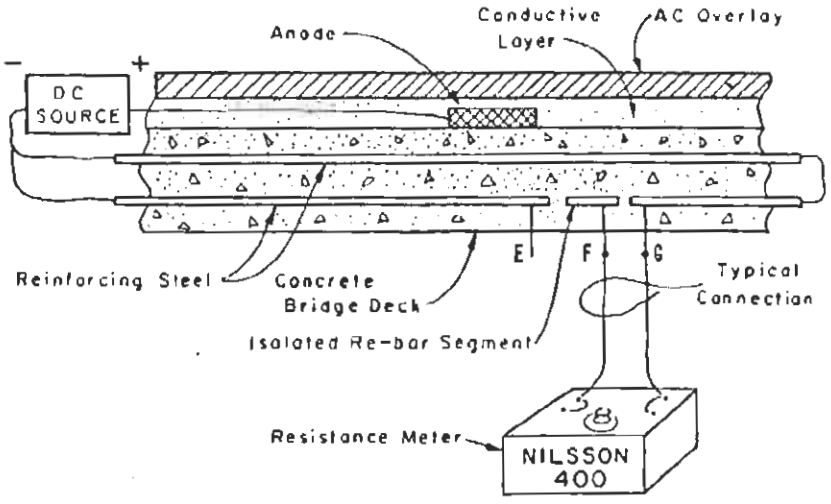


Figure 40
Resistance Measurements, West Soffit

d. Instructions: Measurements are made of the resistance between the rebar segments using a Soil Resistance Meter. The connections are made to the various identified leads, (identifying letters are painted on the bridge soffit immediately adjacent to the wire connectors), protruding from the soffit, in the order indicated on the recording form, and recorded on that form in "Ohms".

e. Recording Conversion Factor: None

MEASUREMENT DETAIL

I(2). Isolated Reinforcing Bar Section
(Current Measurements, Amps, West Soffit)

a. Instrument Used: Digital Pico-ammeter "Keithley" Model 480

b. Measurement Station: "C"

c. Terminal Connections: Four current measurements are taken from this location. Using the following sequence, attach the two leads from the Pico-ammeter to the wire connectors (protruding from the soffit): E and G, E and A, F and G, F and A, (see the following schematic).

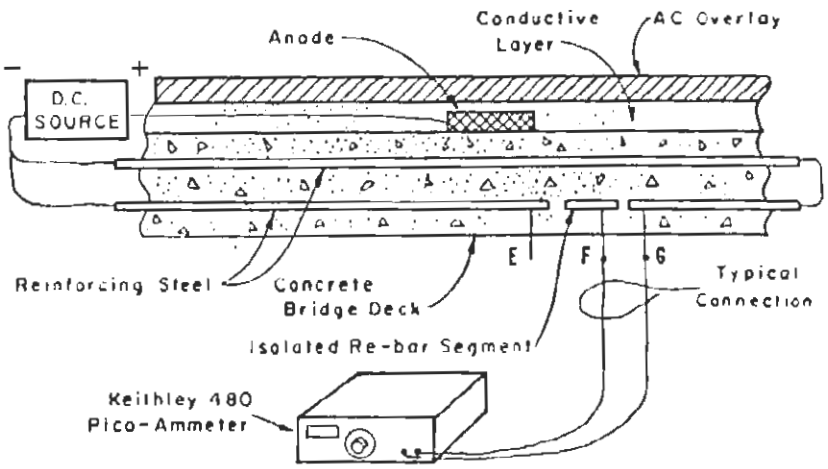


Figure 41
Current Measurements, West Soffit

d. Instructions: Measurements are made of the current flow between the rebar segments using a Pico-ammeter. The connections are made to the various identified leads, (identifying letters are painted on the bridge soffit immediately adjacent to the wire connectors), protruding from the soffit, in the order indicated on the recording form, and recorded on that form in "Amperes".

e. Recording Conversion Factor: None

MEASUREMENT DETAIL

I(3). Isolated Reinforcing Bar Section
(Voltage Measurements, Volts, West Soffit)

a. Instrument Used: Hewlett-Packard multimeter, Model 3465B or any equivalent voltmeter with 10 meg-ohm minimum impedance.

b. Measurement Station: "C"

c. Terminal Connections: Four voltage measurements are taken from this location. Using the following sequence, attach the two leads from the voltmeter to the wire connectors (protruding from the soffit): E and G, E and A, F and G, F and A, (see the following schematic).

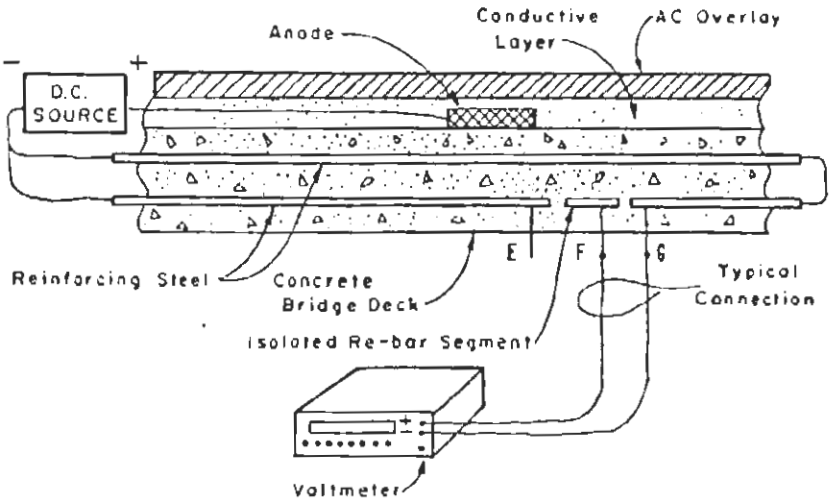


Figure 42
Voltage Measurements, West Soffit

d. Instructions: Measurements are made of the current flow between the rebar segments using a voltmeter. The connections are made to the various identified leads, (identifying letters are painted on the bridge soffit immediately adjacent to the wire connectors), protruding from the soffit, in the order indicated on the recording form, and recorded on that form in "volts".

e. Recording Conversion Factor: None

MEASUREMENT DETAIL

I(4). Isolated Reinforcing Bar Section
(Resistance Measurement, Ohms, East Soffit)

a. Instrument Used: Resistance Meter, "Nilsson 400"

b. Measurement Station: "D"

c. Terminal Connections: Four resistance measurements are taken from this location. Using the following sequence, attach the two leads from the Resistance Meter to wire connectors (protruding from the soffit): 1 and 4, 1 and 3, 2 and 4, 2 and 3, (see the following schematic).

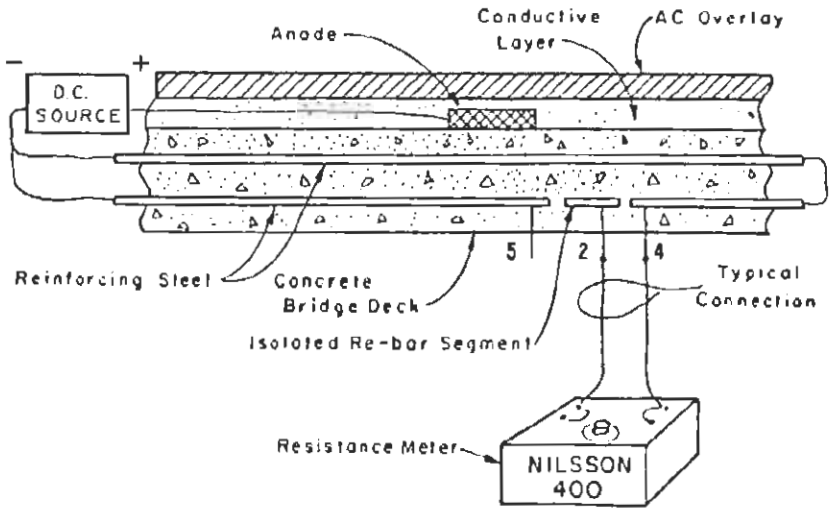


Figure 43
Resistance Measurements, East Soffit

d. Instructions: Measurements are made of the resistance between the rebar segments using a Soil Resistance Meter. The connections are made to the various identified leads, (identifying numbers are painted on the bridge soffit immediately adjacent to the wire connectors), protruding from the soffit, in the order indicated on the recording form, and recorded on that form in "Ohms".

e. Recording Conversion Factor: None

MEASUREMENT DETAIL

I(5). Isolated Reinforcing Bar Section
(Current Measurements, Amps, East Soffit)

a. Instrument Used: Digital Pico-ammeter "Keithley" Model 480

b. Measurement Station: "D"

c. Terminal Connections: Four current measurements are taken from this location. Using the following sequence, attach the two leads from the Pico-ammeter to the wire connectors (protruding from the soffit): 1 and 4, 1 and 3, 2 and 4, 2 and 3, (see the following schematic).

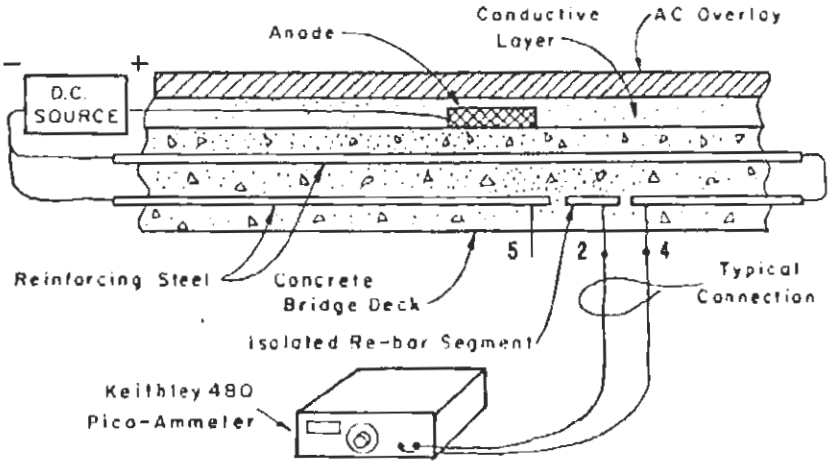


Figure 44
Current Measurements, East Soffit

d. Instructions: Measurements are made of the current flow between the rebar segments using a Pico-ammeter. The connections are made to the various identified leads, (identifying numbers are painted on the bridge soffit immediately adjacent to the wire connectors), protruding from the soffit, in the order indicated on the recording form, and recorded on that form in "Amperes".

e. Recording Conversion Factor: None

MEASUREMENT DETAIL

I(6). Isolated Reinforcing Bar Section
(Voltage Measurements, Volts, East Soffit)

a. Instrument Used: Hewlett-Packard multimeter, Model 3465B or any equivalent voltmeter with 10 meg-ohm minimum impedance.

b. Measurement Station: "D"

c. Terminal Connections: Four voltage measurements are taken from this location. Using the following sequence, attach the two leads from the voltmeter to the wire connectors (protruding from the soffit): 1 and 4, 1 and 3, 2 and 4, 2 and 3, (see the following schematic).

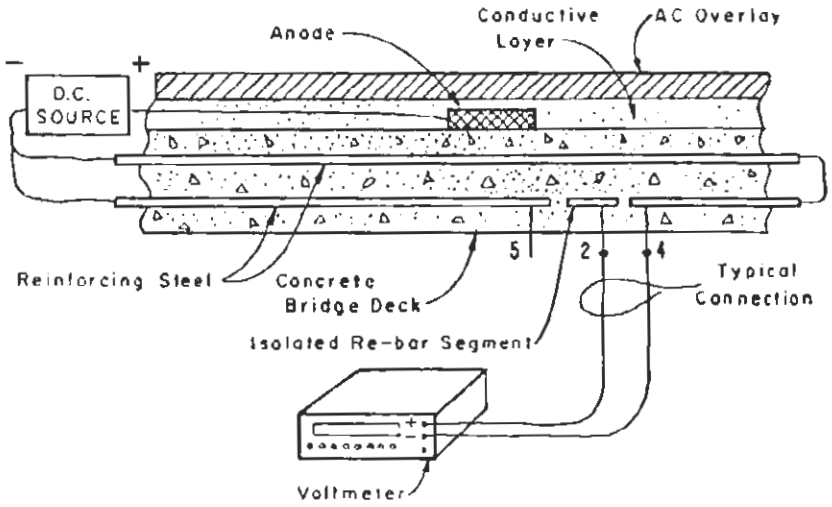


Figure 45
Voltage Measurements, East Soffit

d. Instructions: Measurements are made of the current flow between the rebar segments using a voltmeter. The connections are made to the various identified leads, (identifying numbers are painted on the bridge soffit immediately adjacent to the wire connectors), protruding from the soffit, in the order indicated on the recording form, and recorded on that form in "volts".

e. Recording Conversion Factor: None

LIST OF INSTRUMENTS AND EQUIPMENT REQUIRED

A. Instruments:

1. Hewlett-Packard Multimeter, Model 3465-B or any equivalent voltmeter with 10 meg-ohm minimum impedance.

2. Oscilloscope (portable) "Tektronic" 213 DMM or any equivalent oscilloscope with a minimum of 10 meg-ohm impedance and vertical deflection capability of 0.01 volt/division.

3. Corrosometer Probe meter, "Magna" Model CK-3.

4. Resistance Meter, "Nilsson 400".

5. Pico-Ammeter (Digital) "Keithley" Model 480.

B. Equipment (Testing):

1. Two Cu-$CuSO_4$ Reference Cells, (1-1/4 inch maximum diameter).

2. One extension handle for Cu-$CuSO_4$ Reference Cell

3. One plastic bottle (pint) of copper sulfate saturated solution.

4. Two wire reels with 150 feet (each) of 16 guage, stranded, insulated electric wire.

5. One 2 gallon plastic bottle of tap water.

LIST OF INSTRUMENTS AND EQUIPMENT REQUIRED

B. Equipment (Testing): (Continued)

6. One 5 gallon capacity plastic bucket.

7. One 1/2 gallon plastic water bottle with spray nozzle.

8. Two screwdrivers, slot type, (one medium and one small size).

9. One pair slip joint plier.

10. One clip board or binder with blank paper.

11. Blank recording data sheets.

12. Pencils.

13. Pair of leather work gloves.

14. Liquid and powdered hand soap.

15. Paper towels.

16. Small, soft paint brush (approximately 1/2" wide).

17. One can WD-40 Lubricant Spray.

18. Replacement batteries for instruments.

LIST OF INSTRUMENTS AND EQUIPMENT REQUIRED

C. Equipment (Safety):

1. Eight traffic cones.

2. Personal safety helmet and vest.

MAINTENANCE

Preliminary Inspection: Before beginning any maintenance procedures, check the main control cabinet (Station "A") for visual signs of trouble. These include burned or loose components, loose or broken connectors, and possible shorts or open shunt resisters.

Interconnections: Check all the cables that are readily accessable. A misplaced or loose cable connector is a typical cause of improper operation.

There are many insect and spider nests built-up between the components and terminals. Dust these with a soft paint brush, then clean all the measurement terminals if necessary.

Water Drainage: Water drainage from the corrosometer probe J-box (Station "B") sometimes causes shorts in the connectors during raining or snow melting seasons. Re-open the drains if necessary.

Lubrication: Lubricate all door hinges and the locking screws on the corrosometer probe J-box cover.

Painting: Paint the top surface of the plywood protective cover over the main control cabinet (Station "A"). Touch-up paint any other metal surface as needed. This should be done annually during the early fall.

APPENDIX A

1979
1980

SLY PARK BRIDGE CATHODIC PROTECTION SYSTEM

DATE		TIME		TEMPERATURE	
CURRENT (A)		WEATHER			
DRIVING (V)		BACK EMF (V)		PEAK (V)	

CORROSOMETER PROBE

N.O.	T/S	CHECK	C.P CURRENT μA	CSE (CUSO4 ½ cell Potential (mV)		
				GROUND (-) CELL (+)	PROBE (-) CELL (+)	GROUND (-) PROBE (+)
5						
6						
7						
9						

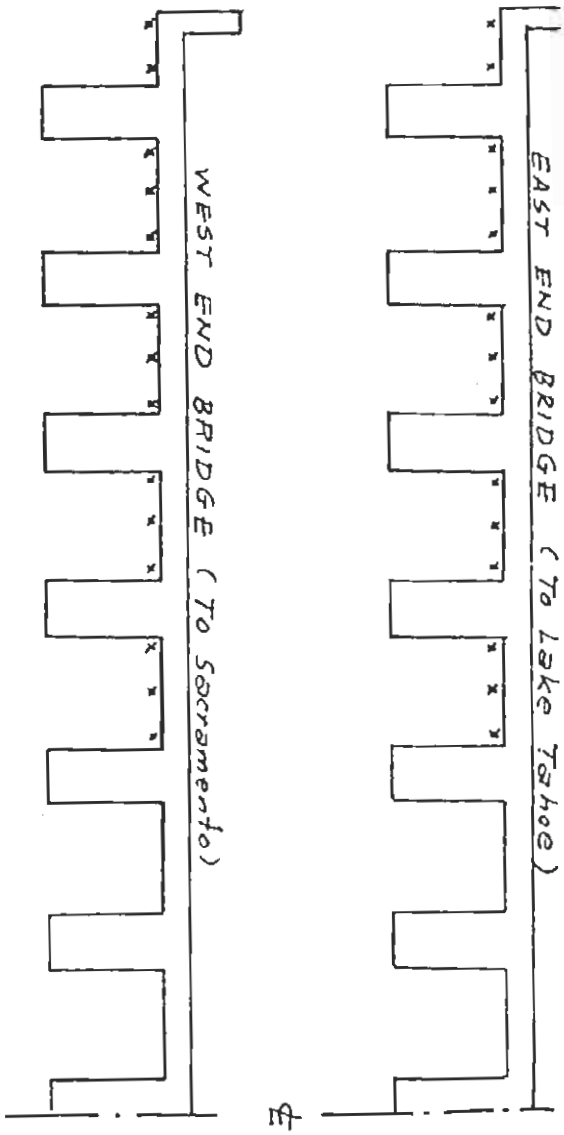
BRIDGE DECK CSE (MV)

STATION	IN HOLE		COKE	
	PEAK	OFF	PEAK	OFF
B 25½				
B 22½				
B 19½				
B 15½				
B 12½				
B 7½				
AVG				

ANODE

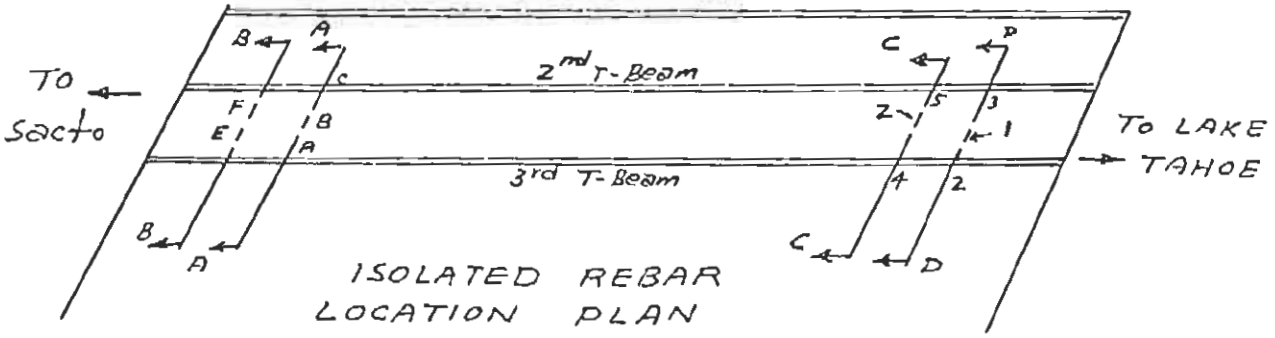
CSE (mv) HOLE	PEAK/OFF COKE		CURRENT (MA)		
C_1			C_1	F_1	I_1
C_2			C_2	F_2	I_2
C_3			C_3	F_3	I_3
C_4			C_4	F_4	I_4
C_5			C_5	F_5	
C_6			C_6	F_6	
C_7			C_7	F_7	
C_8			C_8	F_8	
C_9			C_9	F_9	
AVG					

SOFFIT CSE (MV)

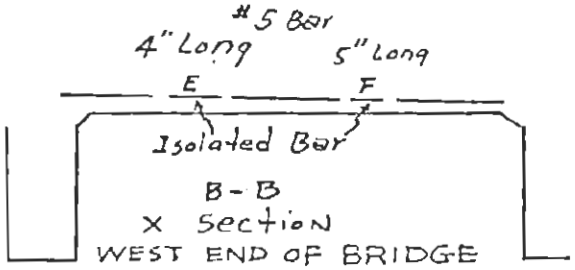


Sly Park Bridge

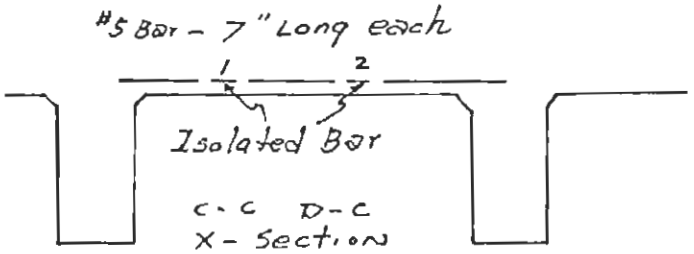
Determination of C.P. Current Flow Along the Bottom Rebar Mats of Concrete Bridge Deck.



ISOLATED REBAR LOCATION PLAN



B-B
X Section
WEST END OF BRIDGE



C-C D-C
X-Section
EAST END OF BRIDGE

Measurement Between Isolated Bar And Rebar Mats								CSE mv.
Readings / Location		Resistance		Current			Voltage	Between Soffit Surface & Rebars
		Ohm	AVG ohm	10 mv shunt mv.	uA	AVG uA/FT^2	Volt	
West End Bridge	E-G							
	E-A							
	E-C							
	F-G							
	F-A							
	F-C							
East End Bridge	1-2							
	1-3							
	1-5							
	2-4							
	2-3							
	2-5							

APPENDIX B

1979

SLY PARK BRIDGE CATHODIC PROTECTION SYSTEM

DATE	11/20	TIME	1330	TEMPERATURE	44°F (Ambient)
CURRENT (A)	2.56	WEATHER	Sunny clear (cold)		
DRIVING (V)	2.12	BACK EMF (V)	1.75	PEAK (V)	2.75

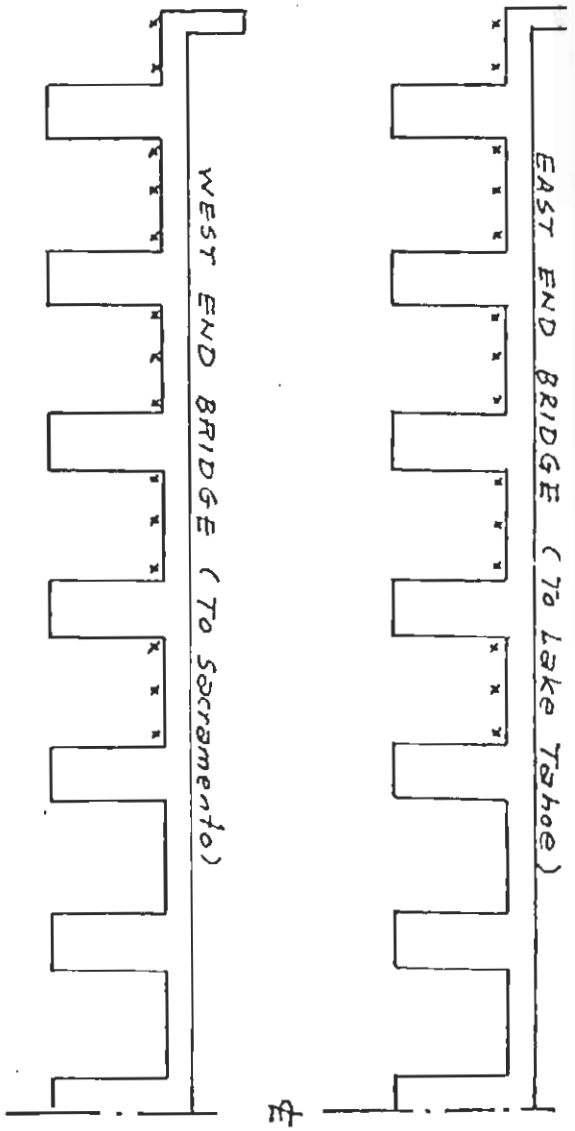
CORROSOMETER PROBE

N.O.	T/S	CHECK	C.P CURRENT μA	CSE (CUSO4 ½ cell Potential (MV) GROUND (-) CELL (+)	PROBE (-) CELL (+)	GROUND (-) PROBE (+)
5	133	819				
6	137	826				
7	176	831	0.33 μA			
9	371	829	4.4 μA			

BRIDGE DECK CSE (MV)

STATION	IN HOLE PEAK	IN HOLE OFF	COKE PEAK	COKE OFF
B 25½	820	600		
B 22½	820	600		
B 19½	1100	800		
B 15½	1050	850		
B 12½	1100	900		
B 7½	900	700		
AVG	965	741		

SOFFIT CSE (MV)



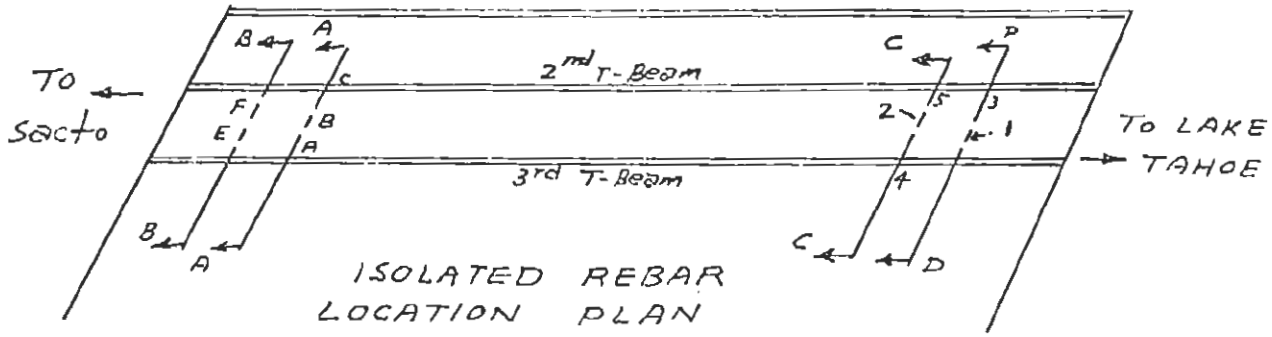
ANODE

.01 Ω shunt

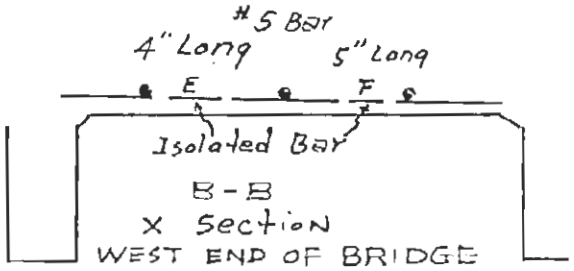
	CSE (mv) HOLE	CSE (mv) COKE	CURRENT (MV/ΔA)		
C_1			C_1 1.93	F_1 0.69	I_1 0.90
C_2	/	/	C_2 2.48	F_2 1.74	I_2 0.51
C_3			C_3 0.25	F_3 1.31	I_3 0.19
C_4			C_4 0.18	F_4 1.04	I_4 0.64
C_5			C_5 3.59	F_5 0.11	
C_6	/	/	C_6 1.69	F_6 0.17	
C_7			C_7 3.23	F_7 1.64	
C_8	/	/	C_8 3.04	F_8 1.90	
C_9			C_9 0.19	F_9 1.55	
AVG	/	/			

Sly Park Bridge 11/20/79 1330

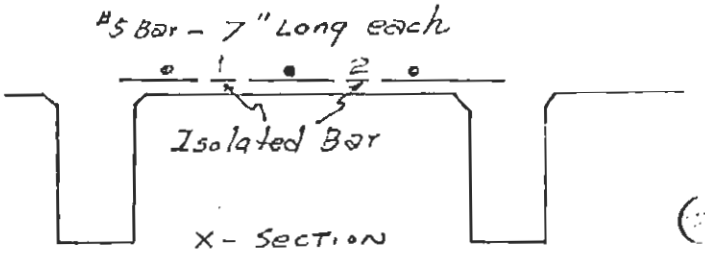
Determination of C.P. Current Flow Along the Bottom Rebar Mats of Concrete Bridge Deck.



ISOLATED REBAR LOCATION PLAN



B-B
X Section
WEST END OF BRIDGE



X-Section
EAST END OF BRIDGE

Measurement Between Isolated Bar And Rebar Mats								CSE mv.
Readings / Location		Resistance		Current			Voltage	Between Soffit Surface & Rebars
		Ohm	AVG ohm	10 mv shunt mv.	uA	AVG uA/FT²	Volt	
West End Bridge	E-G	5200			6.2		256	
	E-A	5200			6.2		270	
	E-C							
	F-G	2600			26.3		385	
	F-A	2600			21.3		385	
	F-C							
East End Bridge	1-4	650			77.9		362	
	1-3							
	1-5	650			75.4		363	
	2-4	1900			30.5		412	
	2-3							
	2-5	1900			26.4		412	