4 17

Interim Report

A NON-OVERLAY CATHODIC PROTECTION SYSTEM

by

Gerardo G. Clemeña
Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways & Transportation and the University of Virginia)

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

August 1983
VHTRC 84-R5

BRIDGE RESEARCH ADVISORY COMMITTEE

ABSTRACT

This interim report describes Virginia's experience in installing its first cathodic protection system for a bridge deck. The installation was completed with practically no problems. Very minor problems have been encountered with the rectifier/control unit. However, these problems haven't prevented the system from functioning as designed.

420

Interim Report

A NON-OVERLAY CATHODIC PROTECTION SYSTEM

by

Gerardo G. Clemeña
Research Scientist

INTRODUCTION

A non-overlay, impressed-current cathodic protection (CP) system for stopping the corrosion of reinforcing bars in bridge decks was recently installed on a bridge deck on Route 15 that crosses the Willis River in Buckingham County, Virginia. This installation represents Virginia's participation in the Federal Highway Administration's Demonstration Project No. 34.

This system consists of three electrical circuits that serve the three physically and electrically isolated spans, each approximately 11.4 m (37.5 ft.) long x·8.5 m (28.0 ft.) wide, that make up the deck. The system has been designed so that direct current is brought transversely into each span with two primary anodes separated approximately 7.3 m (24.0 ft.) apart and made of platinized niobium copper core wires. The current is spread longitudinally in the span by secondary anodes made of graphite strands and located at 0.3-m (1-ft.) intervals across the width of the span. Both the primary and secondary anodes are set in slots sawed approximately 1.3 cm (0.50 in.) wide and 2.0 cm (0.75 m) deep and filled with a conductive polymer concrete.

HISTORY OF INSTALLATION

Work on the design for the system was started in February 1982 with valuable assistance from the Region 15 Demonstration Project Division of the Federal Highway Administration and the bridge office of the Lynchburg District of the Virginia Department of Highways & Transportation. The project was advertised for bidding in the latter part of June 1982 and awarded to the lowest bidder, the Lanford Brothers Construction, Inc. of Hollins, Virginia, in early September at the low bid of $52,500.

The installation was commenced on October 7, with the sawing of the slots in the northbound lane of the two-lane bridge. A total of 515 lin. m (1,688 lin. ft.) of slots were cut into the concrete in the lane in approximately 5.5 working days. This translates to a rate of 11 lin. m (35 lin. ft.) of slots per hour, a rate that must and can be improved upon so that the cost can be reduced.

While the slots were being cut, reference cells, rebar probes, and system negative connections were installed.

On October 18, the anodes were laid in the slots in slightly more than 2 hours. Immediately afterwards, the slots were filled with conductive polymer concrete under an early morning temperature of 40°F. Despite this relatively cold temperature, the only problem encountered was difficulty in ensuring a uniform rate of dispensation of the backfill material, which wasn't temperature related. The problem resulted from the use of "Zip-Loc" type plastic bags from which the still-pourable backfill material was squeezed through a small hole cut in a corner. There is a need for a dispensing device that provides better control.

All installations on the northbound lane were completed in 2 weeks. On October 21, similar installations were started in the southbound lane. This work also took approximately 2 weeks.

There was an unusual delay in the delivery of the rectifier/control (R/C) unit by the manufacturer, Good-All Electric, Inc. of Ogallala, Nebraska. The unit wasn't delivered to the general contractor until the middle of February 1983. In the latter part of that month, work was begun on connecting the primary anodes, reference cells, rebar probes, and system negatives to the lead wires and routing these wires in conduits on the underside of the deck. This system was completed and connected to a 220 VAC utility line on March 3.

On March 14, the Harco Corporation, which specializes in cathodic protection and serves as a subcontractor, energized the system. The E-log I characteristic of each span (Figures 1-3) was determined, so that the proper amount of impressed current needed on each span for adequate cathodic protection, in accordance with one of the criteria recommended by the National Association of Corrosion Engineers (NACE) for underground metallic piping systems, could be determined. Then, by March 16, the R/C unit was adjusted to supply and automatically maintain the required level of current for each span.

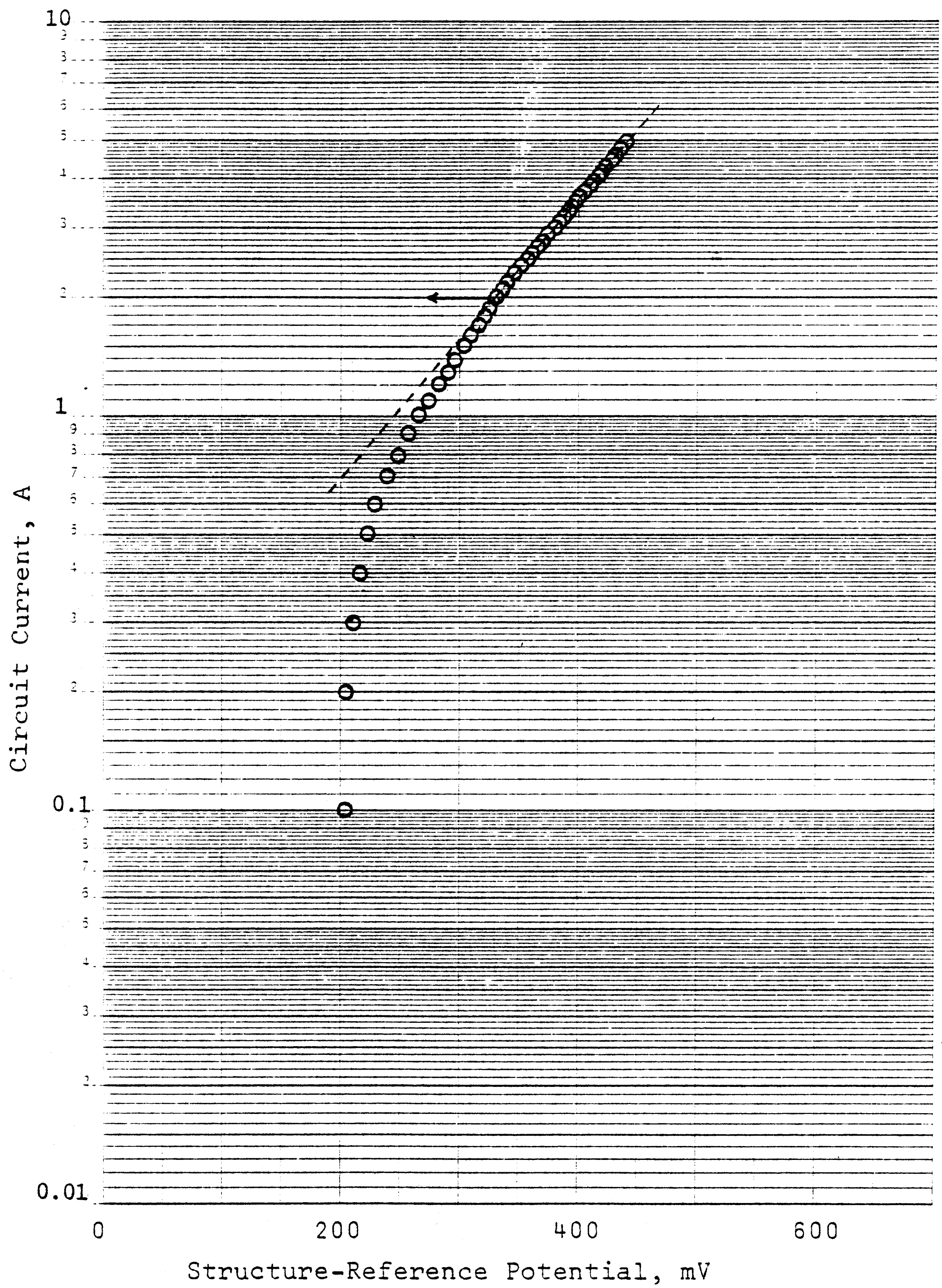

Figure 1. E-log I curve for circuit 1 serving span 3.

. 194

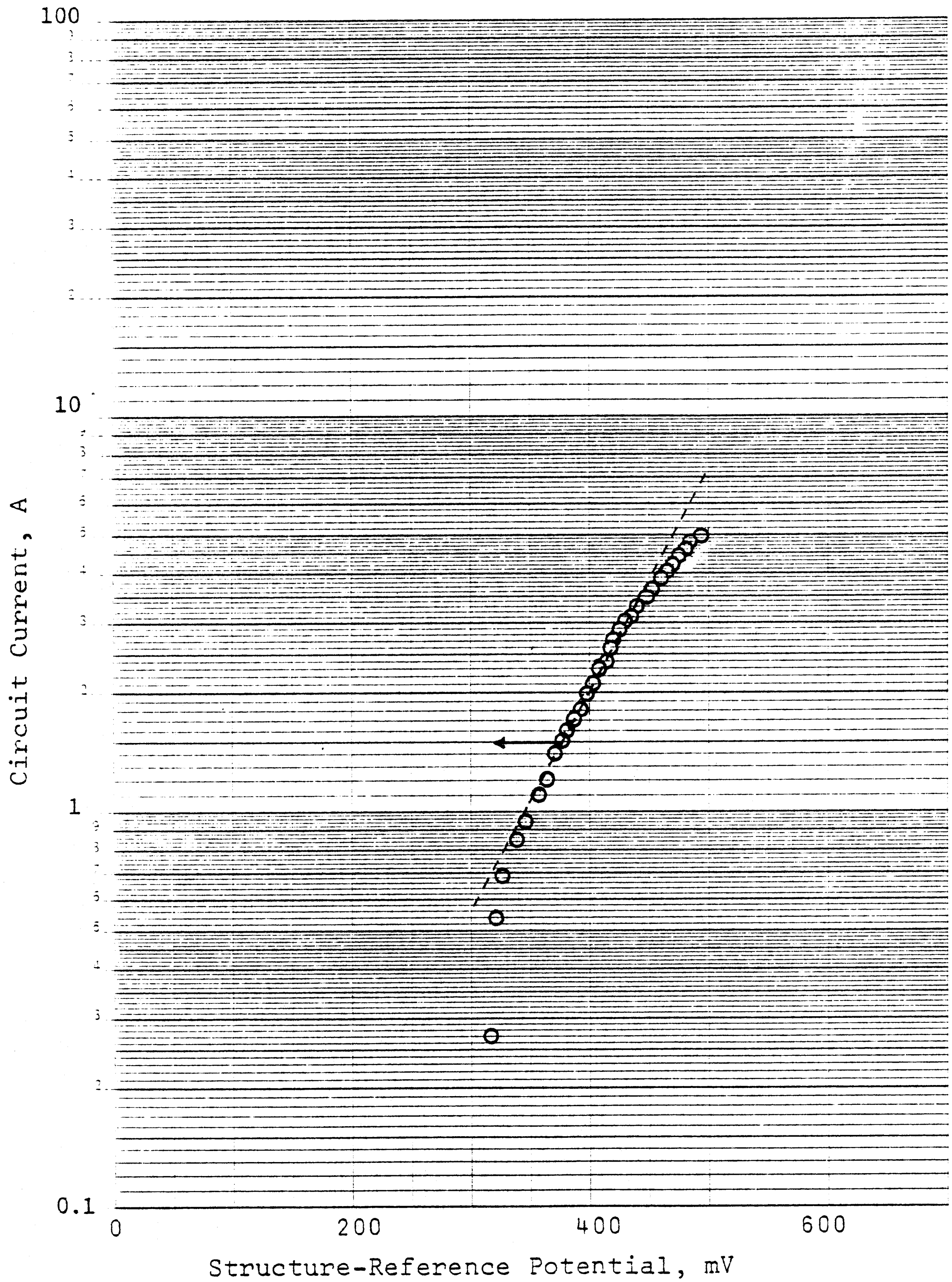

Figure 2. E-log I curve for circuit 2 serving span 2.

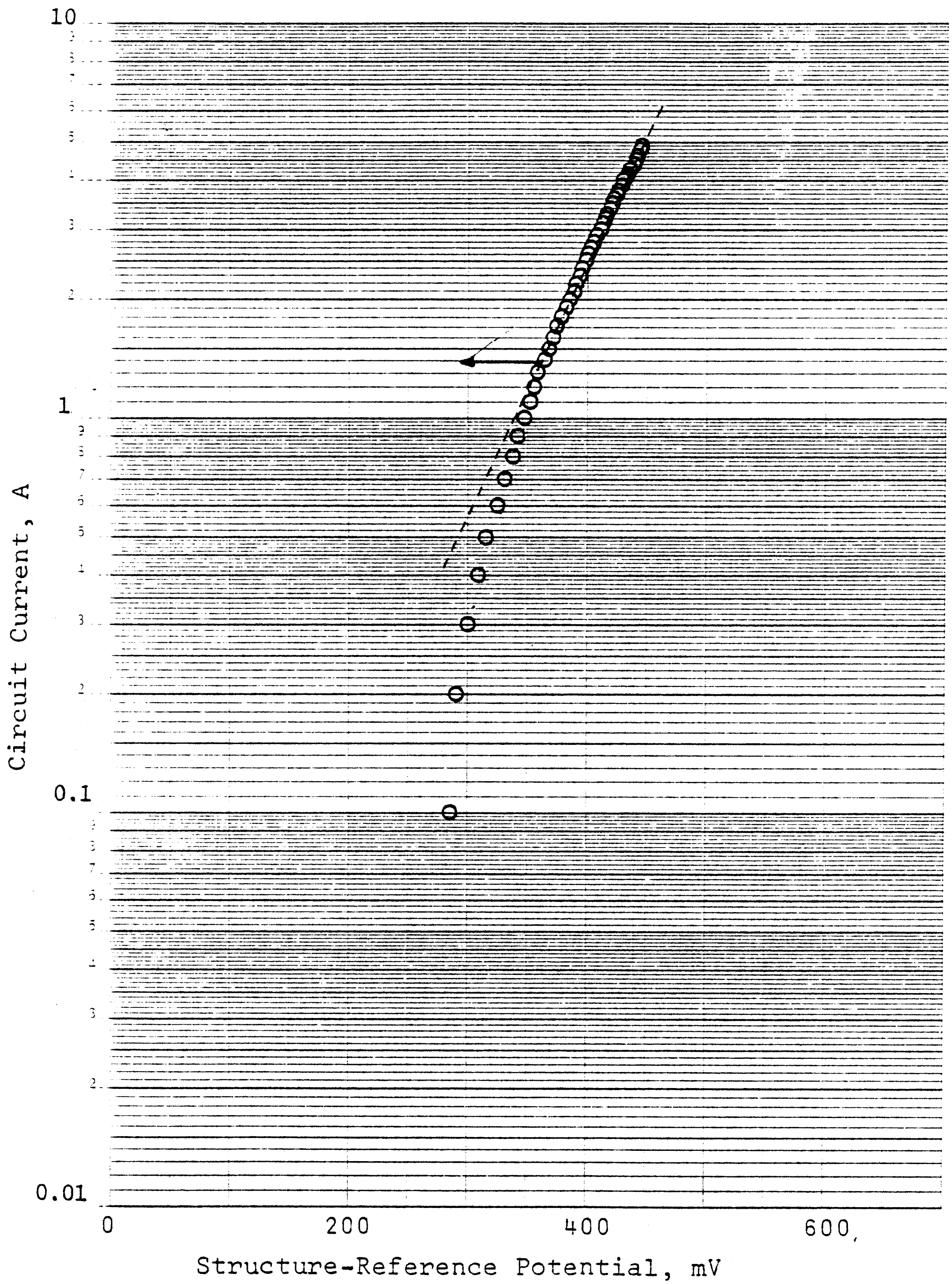

Figure 3. E-log I curve for circuit 3 serving span 1.

OBSERVATION AND DISCUSSION

One of the criteria recommended by the NACE for CP of a metallic piping system in its electrolyte requires a structure-to-electrolyte voltage at least as negative (cathodic) as that originally established at the beginning of the Tafel segment of a E-log I curve. In accordance with this criterion and the E-log I curve obtained for each of the three spans (Figures 1-3), the minimum amperages for the three DC circuits to protect their respective spans were determined and are listed in Table 1. For the entire deck, the total current applied is 4.9 amperes. This translates into 17 mA/m^2 (1.6 $mA/ft.^2$).

The application of these levels of protective current to the spans caused shifts in the structure-rebar probe potentials for all nine rebar probes installed in the deck, as shown in Table 2. The observed shifts toward positive polarity for all nine rebar probes indicate that these rebars, and, therefore, the reinforcement in the three spans, are receiving protection; although, for three probes (nos. 3, 6, and 7), the protection may not be sufficient yet. It must be noted that these rebar probes were made with the rebar encased in concrete that was spiked with chloride at a concentration of 8.9 $kg.Cl/m^3$ (15 lb. $Cl^-/yd.^3$) to simulate very extreme salt contamination in the concrete. This chloride concentration is considerably higher than even the high values encountered in most decks, which is likely from 2.4 to 4.7 $Kg./Cl^-/m^3$ (4 to 8 lb. $Cl^-/yd.^3$). Incidentally, the highest chloride concentration found in this deck was 2.6 kg. Cl^-/m^3 (4.4 lb. $Cl^-/yd.^3$). (In future installations, consideration might be given to encasing the rebar probes in concrete with 4.7 $kg.Cl^-/m^3$ [8 lb. $Cl^-/yd.^3$].) Since these rebar probes simulate extreme salt contamination, the deck areas surrounding probes 3, 6, and 7 are not necessarily insufficiently protected by the applied amperages.

For the structure-reference cell (Ag-AgCl) potentials, Table 3 shows that the application of a protective current resulted in a negative (cathodic) voltage shift in each of the three circuits.

Table 1

Required Current Outputs of the Three DC Circuits
As Determined From E-log I Curves

Span	Circuit	Amperes
1	3	1.4
2	2	1.5
3	1	2.0

Table 2

Shifts in the Rebar Probe Potentials After Application of Protective Current

Bridge Span	Rebar Probe No.	Rebar Probe Potential (mV) Before	After	ΔV (mV)
3	1	-1.4	+0.1	+1.5
	2	-0.9	+0.7	+1.6
	3	-2.3	-0.5	+1.8
2	4	-1.3	+0.2	+1.5
	5	-1.3	+0.4	+1.7
	6	-3.4	-0.3	+3.1
1	7	-2.0	-0.3	+1.7
	8	-0.7	+0.2	+0.9
	9	-1.5	+0.2	+1.7

Table 3

Shifts in the Structure-Reference Cell Potential After Application of Protective Current

Bridge Span	Structure-Reference Potential (mV) Before	After	ΔV (mV)
3	-200	-347	-147
2	-290	-437	-147
1	-281	-360	- 79

Since the final adjustments of the R/C unit on March 16, the whole cathodic protection system has been inspected almost every 2 weeks. During each inspection, the electrical output, structure-reference cell potential, and rebar probe potentials in each zone, or circuit, and temperature have been measured. These readings are presented in Tables 4-6 and Figures 4-7. It should be noted that on April 26, circuit 1 was found to be inoperative, as indicated by blown secondary fuses protecting the circuit. Replacement of these fuses restored operation of the circuit. It is speculated that a very severe thunderstorm reported to have occurred in the general area caused this temporary shutdown.

Table 4

Bridge Deck on Route 15 over Willis River, Buckingham County, Virginia

SPAN 3 ZONE (CIRCUIT) 1

DATE	AMBIENT AIR TEMP. (F)	SET MAX.POLARIZED POTENTIAL (VOLT)	ACTUAL POLARIZED STRUCTURE-REFERENCE CELL POTENTIAL (VOLT)	CIRCUIT VOLTAGE	CIRCUIT AMPERAGE	REBAR PROBE POTENTIAL (MILLIVOLT) NO.1	NO.2	NO.3
3-14-83	68	0.000	-.200	0.0	0.0	-1.4	-.9	-2.3
3-16-83	45	-.800	-.347	3.1	2.0	.1	.7	-.5
3-30-83	65	-.800	-.385	2.6	2.0	.2	.7	-.2
4-26-83	65	-.800	-.191	.1	0.0	-8.0	-4.0	-4.3
4-27-83	70	-.800	-.356	1.7	2.1	-8.2	-4.5	-4.5
5- 6-83	73	-.800				-.7	(9.8)	-2.1
5-10-83	70	-.800	-.380	2.5	2.1	-1.1	.4	-2.5
5-25-83	72	-.800	-.400	2.8	2.0	.1	.5	-1.1
6-10-83	68	-.800	-.440	2.9	2.1	.1	.6	-2.4
6-27-83	100	-.800	-.369	2.5	2.1	-.5	-.7	-4.8
6-28-83	80	-.800	-.355	2.7	2.1	-.2	-.3	-4.0
7-13-83	104	-.800	-.356	2.6	2.1	-.3	-.7	-5.0
7-29-83	94	-.800	-.387	2.8	2.1	.1	-.2	-3.5
8- 3-83	100	-.800	-.350	2.7	2.1	-.1	-.9	-4.1

Table 5

Bridge Deck on Route 15 over Willis River, Buckingham County, Virginia

SPAN 2 ZONE (CIRCUIT) 2

DATE	AMBIENT AIR TEMP. (F)	SET MAX.POLARIZED POTENTIAL (VOLT)	ACTUAL POLARIZED STRUCTURE-REFERENCE CELL POTENTIAL (VOLT)	CIRCUIT VOLTAGE	CIRCUIT AMPERAGE	REBAR PROBE POTENTIAL (MILLIVOLT) NO.4	NO.5	NO.6
3-14-83	68	0.000	-.290	0.0	0.0	-1.3	-1.3	-3.4
3-16-83	45	-.800	-.437	3.1	1.5	.2	.4	-.3
3-30-83	65	-.800	-.468	2.5	1.5	.1	.1	-.7
4-26-83	65	-.800	-.442	2.2	1.5	-.3	-.1	-2.2
4-27-83	70	-.800	-.350	1.7	1.5	-1.5	-1.2	-6.0
5- 6-83	73	-.800				.3	.4	-1.7
5-10-83	70	-.800	-.460	2.4	1.5	0.0	.2	-2.7
5-25-83	72	-.800	-.471	2.8	1.5	.3	.3	-1.4
6-10-83	68	-.800	-.476	2.7	1.5	.4	(2.4)	-1.8
6-27-83	100	-.800	-.403	2.4	1.6	.1	.1	-6.6
6-28-83	80	-.800	-.417	2.8	1.6	.2	.2	-4.7
7-13-83	104	-.800	-.400	2.5	1.6	.2	.1	-6.8
7-29-83	94	-.800	-.413	2.7	1.6	.3	.4	-4.5
8- 3-83	100	-.800	-.405	2.5	1.6	.2	.3	-5.8

230

Table 6

Bridge Deck on Route 15 over Willis River, Buckingham County, Virginia

SPAN 1 ZONE (CIRCUIT) 3

DATE	AMBIENT AIR TEMP. (F)	SET MAX. POLARIZED POTENTIAL (VOLT)	ACTUAL POLARIZED STRUCTURE-REFERENCE CELL POTENTIAL (VOLT)	CIRCUIT VOLTAGE	CIRCUIT AMPERAGE	REBAR PROBE POTENTIAL (MILLIVOLT) NO.7	NO.8	NO.9
3-14-83	68	0.000	-.281	0.0	0.0	-2.0	-.7	-1.5
3-16-83	45	-.800	-.360	3.4	1.4	-.3	.2	.2
3-30-83	65	-.800	-.398	2.7	1.4	0.0	.2	.1
4-26-83	65	-.800	-.395	2.3	1.4	-.4	.1	-.2
4-27-83	70	-.800	-.386	2.3	1.4	-.5	.1	-.2
5- 6-83	73	-.800				.2	.6	.2
5-10-83	70	-.800	-.400	2.5	1.4	-.4	.3	-.1
5-25-83	72	-.800	-.429	3.2	1.4	.3	.5	0.0
6-10-83	68	-.800	-.458	3.2	1.4	.3	.4	0.0
6-27-83	100	-.800	-.354	2.5	1.5	-1.4	.2	-.2
6-28-83	80	-.800	-.349	2.9	1.4	-.8	.2	-.1
7-13-83	104	-.800	-.333	2.6	1.5	-1.8	.2	-.3
7-29-83	94	-.800	-.375	3.0	1.5	.8	.3	0.0
8- 3-83	100	-.800	-.379	2.8	1.5	.4	.2	-.1

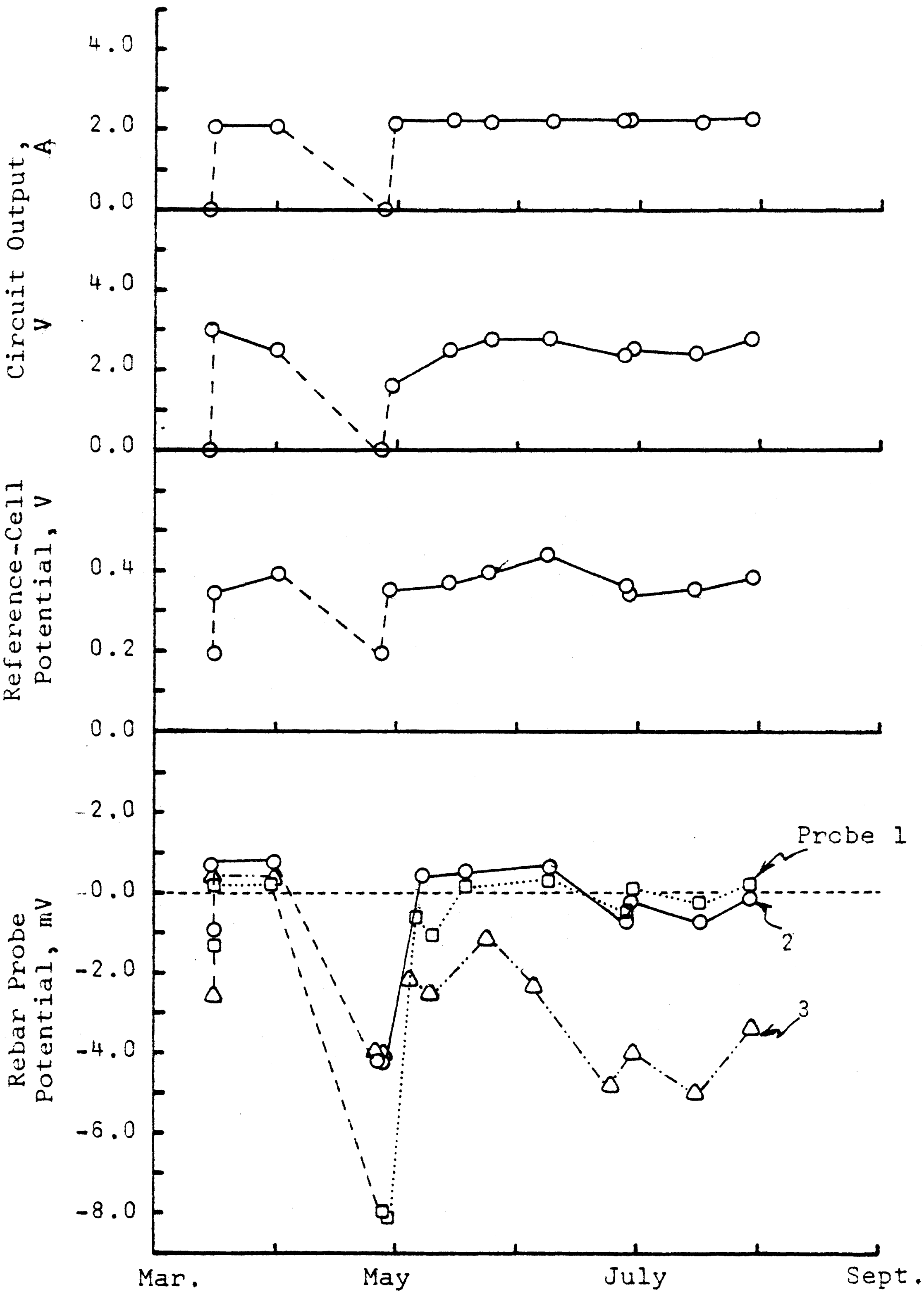

Figure 4. Performance of circuit 1.

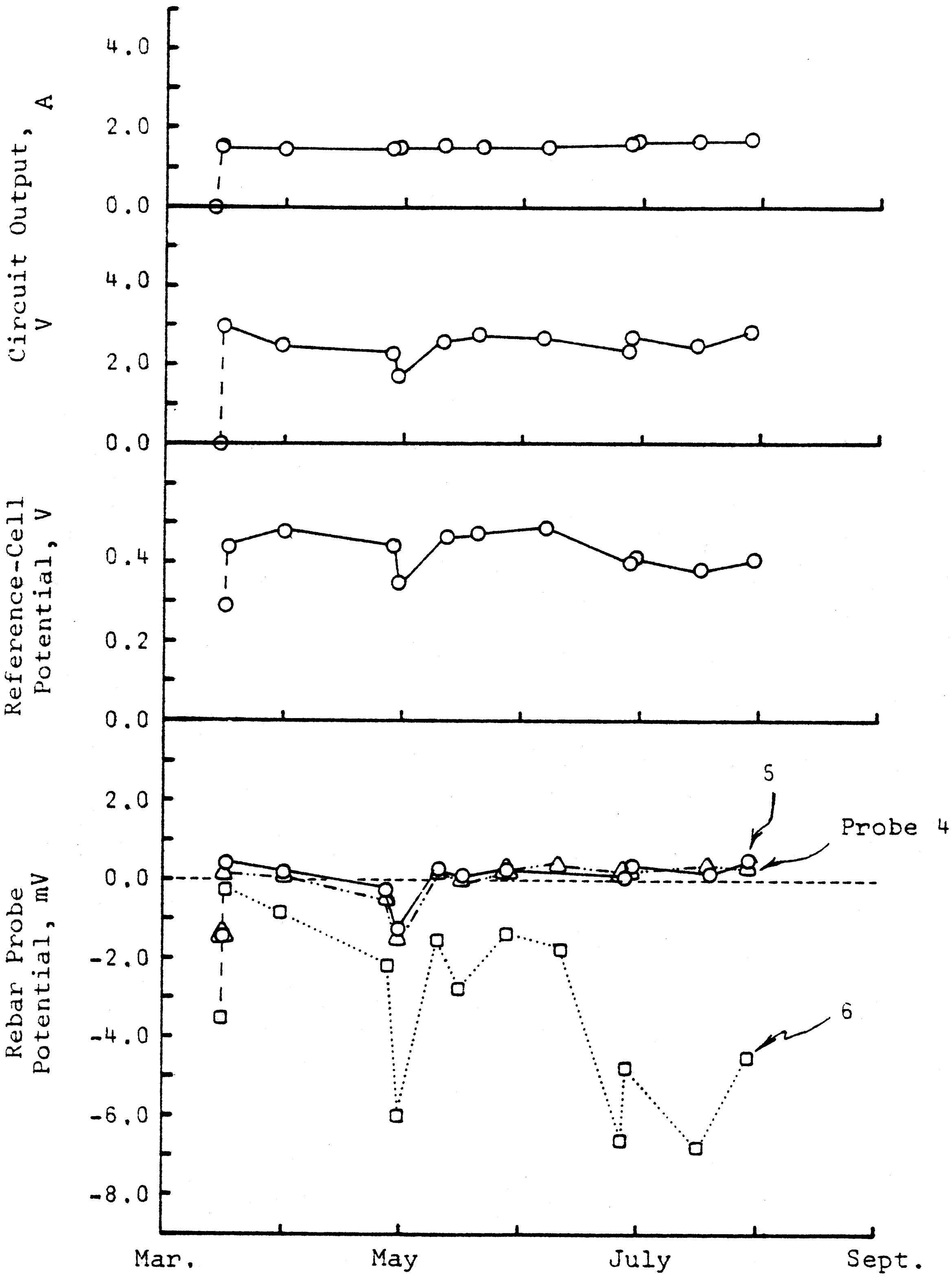

Figure 5. Performance of circuit 2.

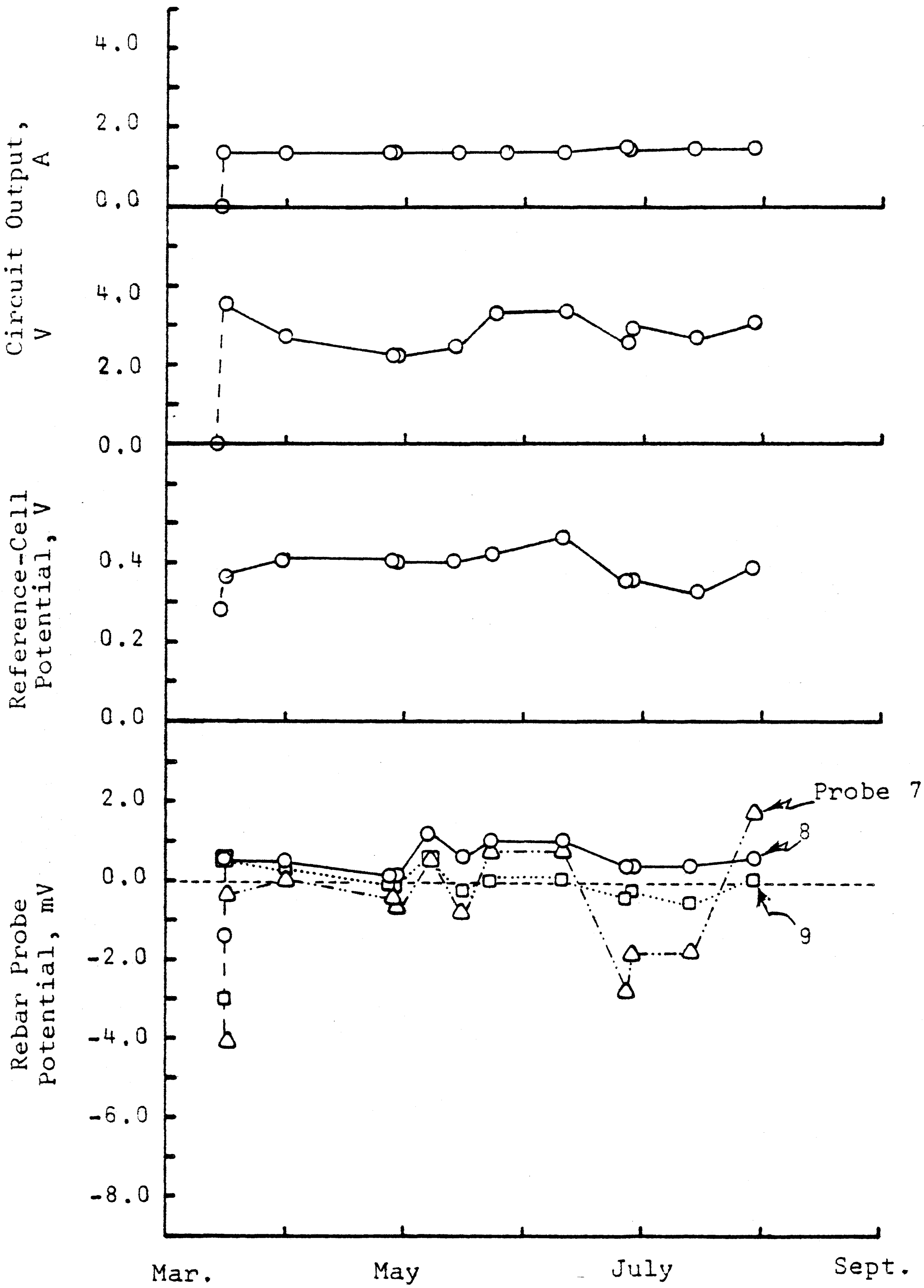

Figure 6. Performance of circuit 3.

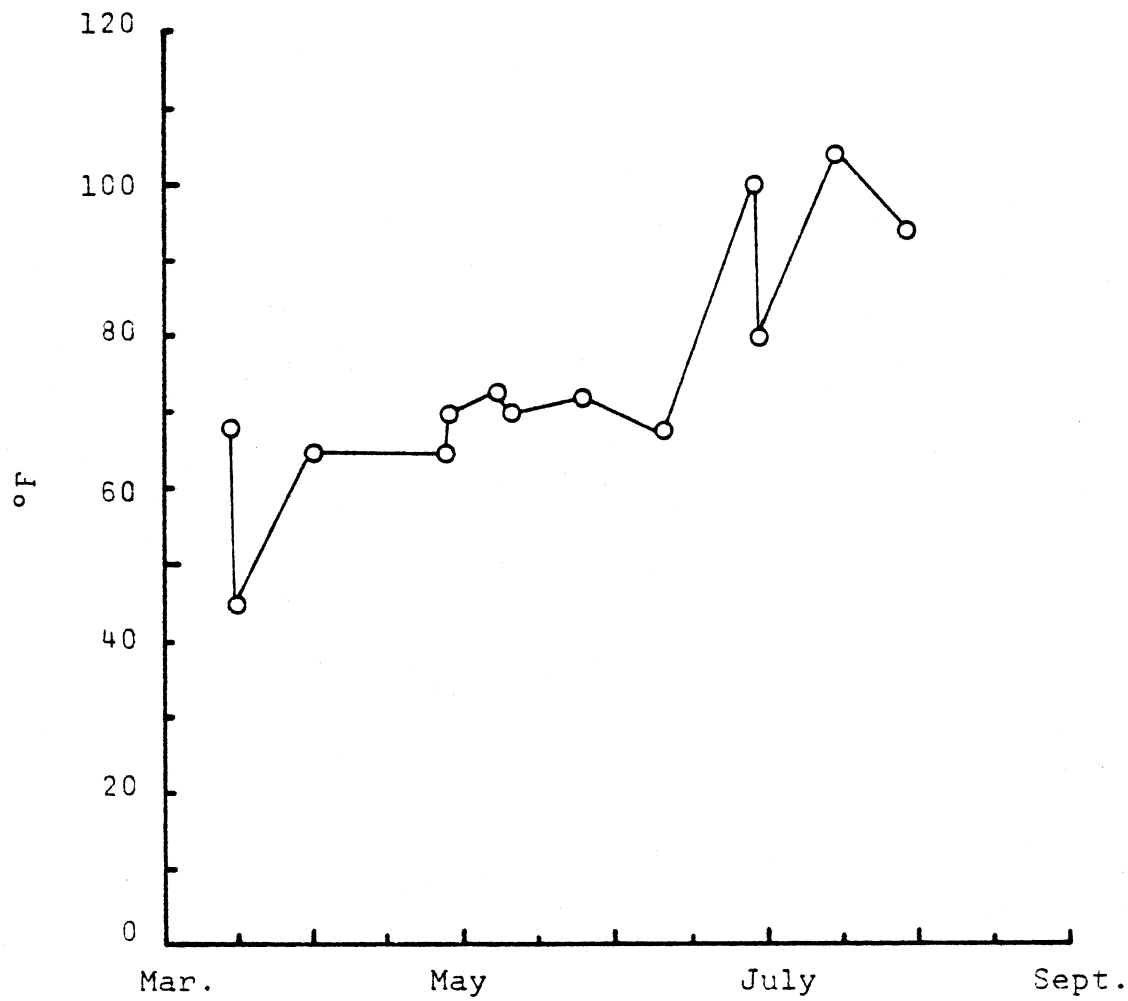

Figure 7. Ambient temperature at the installation site.

In addition, on May 6 the LCD meter in the R/C unit was found to be defective. A faulty circuit board for the meter was found to be the cause and was repaired by Good-All, under warranty. Before the repair was done, the various readings normally provided by the meter were measured with a portable digital multimeter. Nevertheless, the data collected so far have indicated that the cathodic protection system is functioning as expected. Since the chosen mode of operation of the R/C unit is constant current, the unit has been maintaining the current level it is set to provide to each span, as illustrated in Figures 4 through 6. It can be observed that the extreme high temperatures and lack of precipitation experienced this summer have led to temporary anodic shifts in the structure-rebar probe potentials. The shifts for probe 3 in span 3 and probe 6 in span 2 were particularly large. These shifts were caused by increased resistivity of the concrete brought about by the absence of moisture. Fortunately, corrosion activity typically is extremely slow, or nil, under this condition.

Lastly, the conductive polymer concrete used in the slots appears to be holding properly.

CONCLUSION

The cost of this particular CP system, which is approximately $179.3/m^2$ ($16.67/ft.^{2}), probably does not serve as a good guide for what similar installations might cost. Because this was the first such installation in the state, it is believed that the bidders built-in an appreciable cushion to protect themselves against the unexpected. In addition, there were some costs, such as that for the R/C unit and start-up of construction, that would be essentially the same regardless of the size of the deck. For a larger deck, such costs would mean relatively smaller costs per unit area.

The design and installation of such a system is very straightforward, so that installation by state force to reduce cost is an alternative that might be considered.

The data collected so far indicate that this whole CP system is functioning properly; although it may be possible that the levels of protective current applied to some areas in spans 2 and 3 aren't sufficient and need to be increased. It is believed that it is best to continue observing the behavior of the system until it is a year old before making a decision regarding this matter.