CATHODIC PROTECTION FOR REINFORCED CONCRETE BRIDGE DECKS

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SECOND ANNUAL REPORT

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16. ABSTRACT

The Oklahoma Department of Transportation contracted the installation of two cathodic protection systems as part of the Federal Highway Administration's Demonstration Project No. 34, "Cathodic Protection for Reinforced Concrete Bridge Decks". Two different types of cathodic protection systems were installed under this contract. The first system known as a "slotted" or non-overlay system consists of anodes which are installed in slots that have been sawed in the bridge deck. The second system is an overlay system in which the anodes are installed on top of the deck and then a 2 inch high density concrete overlay is placed. Both systems were of the impressed current type using the local utility company for power.

This is the second year evaluation of the project.

17. KEY WORDS	anodes, E-Log I, polymer concrete, potential, rebar probes, reference cells
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Introduction

The Oklahoma Department of Transportation contracted the installation of two cathodic protection (CP) systems as part of the Federal Highway Administration's Demonstration Project No. 34 - "Cathodic Protection for Reinforced Concrete Bridge Decks". Both systems were of the impressed current type using A.C. from the local utility company. The first system known as a "slotted" or non-overlay system consists of anodes which are installed in slots that have been sawed in the bridge deck; this system was installed on the Bird Creek bridge located on SH 266 in Tulsa County, Oklahoma. The second system is an "overlay" system in which the anodes are installed on top of the deck and then a 2 inch high density concrete overlay is placed; this system was installed on the Bird Creek Overflow bridge located on SH 266 in Rogers County, Oklahoma.

In June, 1985, the installation of the cathodic protection systems was completed. A video tape and supplemental report was submitted detailing the construction phase of the project.

In August, 1986, the first annual report was submitted. This report included the results of the annual half-cell, chain drag, and visual surveys. The monthly operating data collected up through July 1986 were included.

This is the second annual report of these systems.

Update

Monthly operating data for each cathodic protection system has been collected since July, 1985. Data through December 16, 1985 were submitted in the construction report. Data from January, 1986 through July, 1986 were submitted in the first annual report. Data obtained since July, 1986, are included in Appendix A.

At the end of the first year evaluation, both systems were inoperable, and the manufacturer was notified of the problems. The following is a summation of the events that occurred since that time.

On September 8, 1986, representatives from the Harco Corporation and Good-All Electric, Inc. visited the site to investigate the problems with the controlling units. Prior to any work, static reference cell potentials were obtained.

The investigation of the Bird Creek bridge cathodic protection system yielded no immediate explanation for the cause of the malfunction. The silicon control rectifiers (SCR) for each zone were tested for shorts. No shorts were found. Repairs were made to the cards that were previously removed, and they were installed along with a new meter. When the unit was turned on, everything operated normally.

The investigation of the Bird Creek Overflow bridge cathodic protection system found additional components damaged. The SCR for Zone 12 had a short, nine of the control cards were determined to need repair, and a potentiometer located near the meter was burned out. The SCR and the control cards were removed to be repaired. The malfunction of the system was attributed to a power surge. It was speculated that the cause was a lightning strike. However, the point of entry was not determined, and the damage was confined to the internal components of the controller.

On October 13, 1986, the cathodic protection system on the Bird Creek bridge was found to be inoperable. Investigation into the problem revealed that someone tripped the circuit breaker at the pole (the cover was partially opened). The power was restored and the system activated.

On March 3, 1987, operating data was obtained and yearly testing was performed. The cathodic protection system on the Bird Creek bridge was turned off and allowed to depolarize.

On March 19, 1987, yearly testing continued on the Bird Creek Bridge and the static readings of the reference cells and rebar probes were obtained prior to re-energizing. Immediately after re-energizing, the operating data were collected again.

On April 27, 1987, personnel from the Harco Corporation installed added lightning protection for both systems (see Appendix C.).

On May 21, 1987, personnel from the Harco Corporation repaired the components on the Overflow CP system. A new potentiometer, the repaired meter and the repaired control cards were installed. Four control cards were in need of more repairs.

On June 30, 1987, personnel from the Harco Corporation installed the four control cards that had been repaired. The repaired cards operated correctly. However, four of the cards that were previously repaired were inoperable. They were removed and sent for repairs.

On August 10, 1987, the four repaired control cards were installed. All control cards for the Overflow system were operating properly. However, Zone 9 was not discharging current.

On September 18, 1987, the control card for Zone 6 on the Overflow system was inoperable.

On September 29, 1987, representatives from Goodall and the Harco Corporation investigated the problem with Zone 9 of the Overflow CP system. The lightning protection fuse for the anode was blown. The control card for Zone 6 had a blown capacitor. The problems were corrected.

On November 25, 1987, the Overflow CP system was found to be inoperable. No damage could be detected. It appears that the system was not receiving A.C. power.

Monthly Data

The systems have been inspected on a monthly basis since June 19, 1985. The amperage and voltage discharging to each zone were recorded along with the set potential, the potential of each reference cell and the voltage across each rebar probe. In cases where a system was found to be inoperable, recording of the data may have been omitted.

All potential readings are reported as they were obtained. Hence, the potential readings having a positive value were actually negative and the potential readings with a negative value were actually positive. This is the manner in which both the LCD meter and the Beckman hand held meter displays the values.

Analysis

For a given cathodic protection system, the current discharged to each zone is regulated by a controller. There are three modes of operation that a cathodic protection controller may assume - constant current, constant voltage, or constant potential.

A controller operating under "constant current" discharges power at a given amperage level, and allows the voltage level and the potentials of the steel to flucuate with changes in the environment. As shown in the first annual report, this can cause "over protection" of the steel.

A controller operating under "constant voltage" discharges power at a given voltage level, and allows the amperage level and the potentials of the steel to flucuate with changes in the environment.

A controller operating under "constant potential" discharges power by adjusting the amperage to maintain a given potential at one location, with respect to changes in the voltage level and changes in the environment.

Both of the CP systems being evaluated operate in the constant potential mode, also known as potential control. This mode of operation was chosen, since it is the only mode that facilitates changes in the environment. As the conditions of the deck, such as temperature and moisture content, change with time, the required amount of power to maintain a given potential also changes. Potential control reduces the chance of over protecting the steel when the deck is wet and requires little power. It also ensures that enough power is supplied when the deck is very dry and requires a large amount of power to protect the steel.

In order to have a potential control system, there must be a method of monitoring the potential of the steel in the deck. In each zone two reference cells were installed, a Silver/Silver-Chloride (Ag/AgCl) reference cell and a Molybdenum/Molybdenum-Oxide (Mo/MoO3) reference cell. The Ag/AgCl reference cells have been the controlling reference cells for the systems. The potentials of the steel throughout the deck for the various current levels were obtained through E-logI testing, and were correlated to the potentials of the reference cells, i.e. the reference cells were calibrated to determine the needed potential or "set potential" at the location of the reference cell to adequately protect the entire zone.

Once the set potentials are entered into the controller, the controller measures the potential of the steel at the location of the reference cell and adjusts the amperage accordingly.

If the reference cell reading is higher than the set potential, no power is supplied, i.e. the amperage level is zero.

If the reference cell reading is less than the set potential, power is supplied by increasing the amperage. A maximum amperage level is set to prevent over protection in case of a malfunction of the system.

When the reference cell reading approaches the set potential from a lesser value the controller reduces the amperage to maintain the same level as the set potential.

In reviewing the monthly data, the first step is to compare the set potential, the reference potential, and the amperage level to determine the status of each zone. The status is classified as one of the following:

Under Polarization	If the reference potential is 20 millivolts less than the set potential and the current is on.
Over Polarization	If the reference potential is 20 millivolts more than the set potential and the current is off.
OK	If the reference potential is within 20 millivolts of the set potential regardless of current output.
Malfunctioning	If the reference potential is 20 millivolts less than the set potential and the current is off.
Malfunctioning	If the reference potential is 20 millivolts more than the set potential and the current is on.

The analysis for this report will focus upon the operating status, as determined by the monthly operating data, of the two cathodic protection systems. Since the two systems have been inoperable at different periods of time, each system will be addressed separately.

Bird Creek Bridge

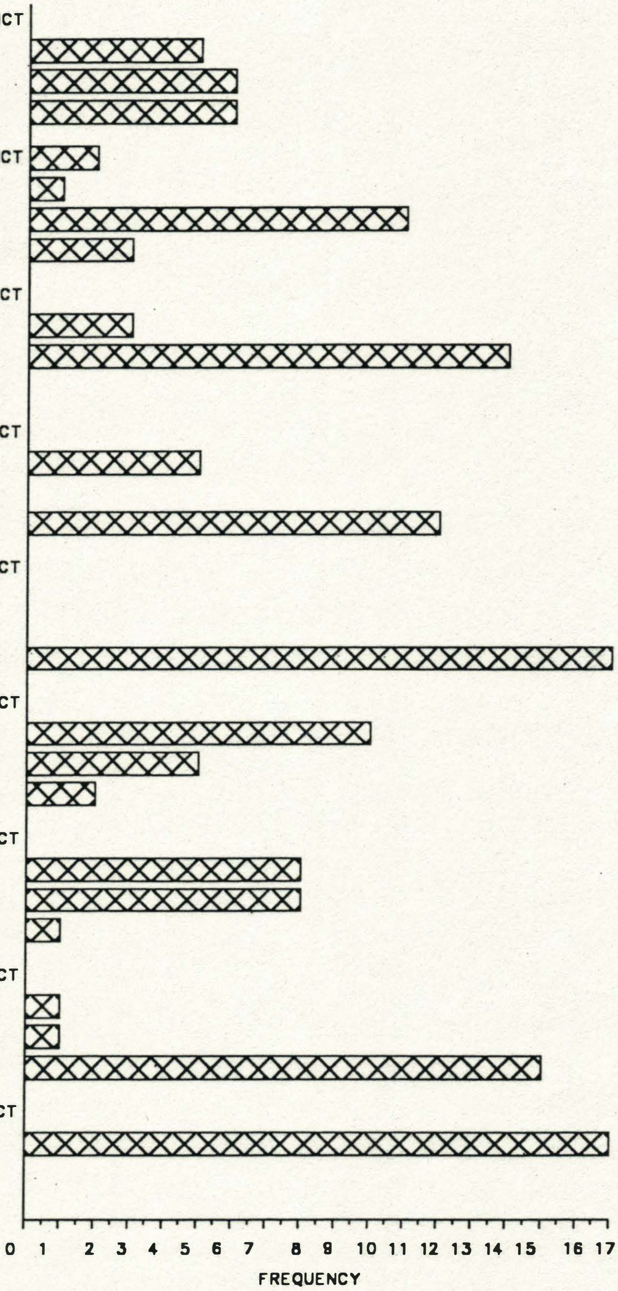
The Bird Creek cathodic protection system was set into operation in June of 1985. During the first six months of operation, the Ag/Agcl reference cells in Zones 1, 2, 3, & 7 were registering abnormally high readings, thereby, causing no current to be discharged and resulting in a status of operation as being "OVER" protected. The cause of the abnormal readings was attributed to the circuitry of the control cards and the problem was corrected in January of 1986.

The Bird Creek cathodic protection system was found to be inoperable in April of 1986. The cause of the malfunction was attributed to a power surge. The system was repaired in September of 1986, and has since, been in continuous operation.

It has been two and one half years (30 months) since the system was installed and put into operation. Six of those months the system was inoperable, and monthly data was not obtained. Figure 1. shows a summary of the status of operation for each zone while the system was in operation. The data represented in figure 1. is included in Appendix B.

STATUS OF OPERATION

BRIDGE=BIRD CREEK



ZONE	STATUS	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
1	MALFUNCT	0	0	0	0
	OK	5	5	29	29
	OVER	6	11	35	65
	UNDER	6	17	35	100
2	MALFUNCT	2	2	12	12
	OK	1	3	6	18
	OVER	11	14	65	82
	UNDER	3	17	18	100
3	MALFUNCT	0	0	0	0
	OK	3	3	18	18
	OVER	14	17	82	100
	UNDER	0	17	0	100
4	MALFUNCT	0	0	0	0
	OK	5	5	29	29
	OVER	0	5	0	29
	UNDER	12	17	71	100
5	MALFUNCT	0	0	0	0
	OK	0	0	0	0
	OVER	0	0	0	0
	UNDER	17	17	100	100
6	MALFUNCT	0	0	0	0
	OK	10	10	59	59
	OVER	5	15	29	88
	UNDER	2	17	12	100
7	MALFUNCT	0	0	0	0
	OK	8	8	47	47
	OVER	8	16	47	94
	UNDER	1	17	6	100
8	MALFUNCT	0	0	0	0
	OK	1	1	6	6
	OVER	1	2	6	12
	UNDER	15	17	88	100
9	MALFUNCT	0	0	0	0
	OK	17	17	100	100
	OVER	0	17	0	100
	UNDER	0	17	0	100

Figure 1. Bird Creek Status of Operation

Zone 1 has been classified as being "OVER" protected, "UNDER" protected, and "OK". The "OVER" protection was due to the problems with the reference cell. Since that was fixed it has been classified as either "OK" or "UNDER" protected and the current has been continuously discharging.

Zone 2 had the same as Zone 1 except it has two readings that were classified as "MALFUNCTIONING", which were a result of the reference cell's reading being higher than the meter could register. Therefore, no reading could be obtained. However, since the problem of the reference cells was fixed, Zone 2 has still been "OVER" protected. This is a result of Zone 1 constantly discharging current and the fact that these two zones interact on the same span, i.e. Zone 2 is receiving extra current from Zone 1.

Zone 3 has had a mixed status of either "OK" or "OVER" protected. This implies that sufficient current has been applied. Most of the zones that exhibit "OVER" protection are receiving current from an adjacent zone within the span. In this case Zone 3 is receiving extra current from Zone 4 which has been classified as being mostly "UNDER" protected, and like Zone 1, has continuously discharged current.

Zone 4, as previously mentioned, has consistently discharged current and has always been either "OK" or "UNDER" protected. The amount of "UNDER" protection, has not been significant.

Zone 5 has had a continuous status of "UNDER" protection throughout its entire operation. Although this is not inherently bad, it does mean that the system is not raising the reference cell reading to the desired level.

Zone 6 has had a mixed status of "OK", "OVER" protection, and "UNDER" protection. However, the potential of the reference cell has never deviated more than 78 millivolts from the set potential, and the current output has flucuated on and off accordingly. Therefore, this zone has been performing satisfactorily.

Zone 7, like Zone 1 & 2, had a problem with the reference cell. Since the problem was corrected Zone 7 has been operating satisfactorily; one exception existed where the current from Zone 8 seemed to have influenced Zone 7.

Zone 8 has mainly been classified as being "UNDER" protected. However, the last reading that was obtained showed it to be "OVER" protected. Again, the location of Zone 7 & 8 on the same span allows these zones to interact with each other.

Zone 9 is the only zone that has had a continuous status of "OK" throughout its entire operation. Incidently, this is the only zone that is not directly adjacent to another operating zone, i.e. it is in a span by itself.

In summary, all zones in the Bird Creek cathodic protection system have been operating satisfactorily since the power surge damage was repaired. The zones exhibiting "OVER" protection have potentials higher than the desired potential, but the potentials are well below that which would create hydrogen evolution. In the same manner, the zones exhibiting "UNDER" protection have potentials below the desired potential, but the potentials are significantly higher (at least 100 millivolts) than the static potentials, thereby protecting the steel cathodically. Finally, the ability of the controller to maintain the set potential within a zone has been hampered by the interaction of adjacent zones on a given span.

Overflow Bridge

The Overflow cathodic protection system was set into operation in June of 1985. In April of 1986, this system was also found to be inoperable, due to a power surge. As of December 1987, steps to repair the system to full operation are in progress.

The system was in operation for over 38 weeks. Figure 2. shows a summary of the status of operation for each zone while the system was in operation. The data represented in figure 2. is included in Appendix B.

Zone 1, 2, 3, 5, 6, 10, 11, & 12 all performed ideally up to the time of the power surge.

Zone 4 has performed satisfactorily except in one instance in which there was a blown fuse resulting in a "MALFUNCTION".

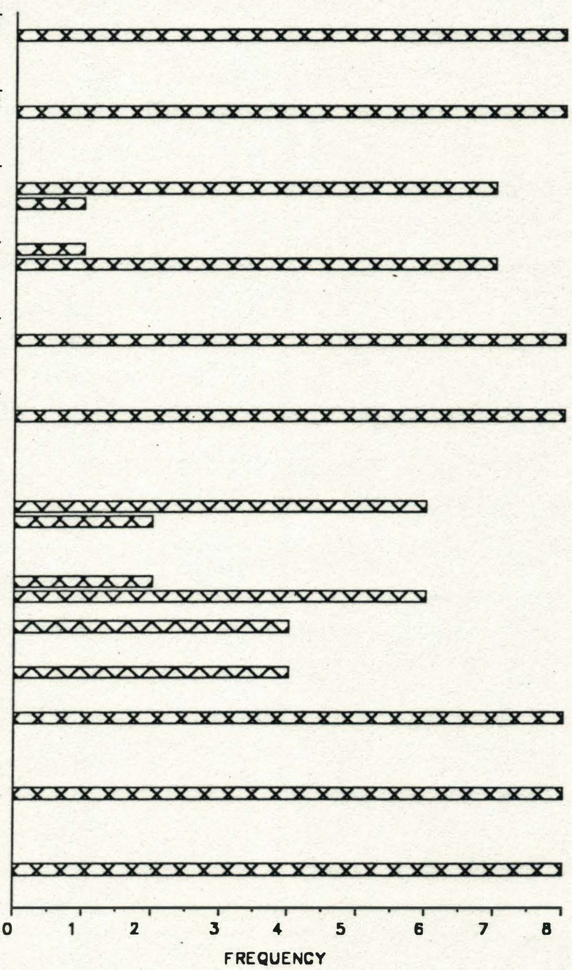
Zone 7 & 8 were either "UNDER" protected or "OVER" protected. This was due to the reference cells being crossed wired in these two zones. This problem has been corrected.

Zone 9 has malfunctioned several times due to a reccurring blown fuse.

In summary, the Overflow cathodic protection system has operated ideally with the exception of Zone 9 repeatedly blowing fuses. Zones 7 & 8 have not yielded enough information to determine the results since rewiring, and Zone 4 has not blown another fuse. The stability of the zones on the Overflow cathodic protection system can be attributed to the fact that there was one zone per span.

STATUS OF OPERATION

BRIDGE=OVERFLOW



ZONE	STATUS	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
1	MALFUNCT	0	0	0	0
	OK	8	8	100	100
	OVER	0	8	0	100
	UNDER	0	8	0	100
2	MALFUNCT	0	0	0	0
	OK	8	8	100	100
	OVER	0	8	0	100
	UNDER	0	8	0	100
3	MALFUNCT	0	0	0	0
	OK	7	7	88	88
	OVER	1	8	13	100
	UNDER	0	8	0	100
4	MALFUNCT	1	1	13	13
	OK	7	8	88	100
	OVER	0	8	0	100
	UNDER	0	8	0	100
5	MALFUNCT	0	0	0	0
	OK	8	8	100	100
	OVER	0	8	0	100
	UNDER	0	8	0	100
6	MALFUNCT	0	0	0	0
	OK	8	8	100	100
	OVER	0	8	0	100
	UNDER	0	8	0	100
7	MALFUNCT	0	0	0	0
	OK	0	0	0	0
	OVER	6	6	75	75
	UNDER	2	8	25	100
8	MALFUNCT	0	0	0	0
	OK	0	0	0	0
	OVER	2	2	25	25
	UNDER	6	8	75	100
9	MALFUNCT	4	4	50	50
	OK	0	4	0	50
	OVER	0	4	0	50
	UNDER	4	8	50	100
10	MALFUNCT	0	0	0	0
	OK	8	8	100	100
	OVER	0	8	0	100
	UNDER	0	8	0	100
11	MALFUNCT	0	0	0	0
	OK	8	8	100	100
	OVER	0	8	0	100
	UNDER	0	8	0	100
12	MALFUNCT	0	0	0	0
	OK	8	8	100	100
	OVER	0	8	0	100
	UNDER	0	8	0	100

Figure 2. Overflow Status of Operation

Testing

In March 1987, testing was done to evaluate the performance of the cathodic protection systems. The testing included half-cell and chain drag surveys. The decks were visually inspected and operating data during testing was collected. The evaluation is based on results from current surveys, past surveys, and data collected.

Half-cell Surveys

Half-cell surveys for these decks have been performed on a yearly basis since 1983. Between 1983 and 1984 the surveys showed a small increase in potential throughout the deck. This can be expected, since no corrective action was taken during this time. Therefore, for analysis purposes, the data from the survey performed in 1984 will be considered as the pre-construction data. In May 1985, after all repairs were made and the cathodic protection system hardware was installed, a half-cell survey was performed prior to energizing the cathodic protection system. The data from this survey will be considered as the post-construction data.

In March 1986, two half-cell surveys were performed on each deck. The first survey was taken with the cathodic protection systems operating ("power on"). The systems were then turned off and allowed to depolarize for ten days. The second survey was then taken with the cathodic protection systems not operating ("power off").

In March 1987, half-cell surveys were performed on each deck. A "power on" survey was obtained on the Bird Creek bridge, but was not possible for the Overflow CP system since this system had been inoperable for several months. Therefore, a "power off" survey was performed on the Overflow bridge. The

Bird Creek system was then turned off and allowed to depolarize for 15 days, and a "power off" survey was performed on the Bird Creek bridge.

The results from the pre-construction, post-construction, power on, and power off surveys for the Bird Creek bridge (slotted system) and the Bird Creek Overflow bridge (overlay system) are listed in Figures 3 & 4, respectively. There is a considerable reduction in the potential readings due to construction alone. This illustrates the reduction of corrosion activity associated with the sand blasting and repair of distressed areas. As the cathodic protection current is applied, the potentials increase dramatically throughout the deck. After depolarization, the half-cell data indicates that virtually no corrosion is occurring.

In each case, the potentials after construction are lower than the potentials before construction, and the potentials after 9 months of protection (86 power off) are lower yet.

In 1986, less than 0.01 percent of either deck had a potential greater than 350 millivolts. However, the 1987 "power off" surveys show a minute increase in the deck area that has a potential reading of higher than 350 millivolts. The Bird Creek bridge had 0.1 percent, and the Overflow bridge had 3.0 percent of the deck with potentials higher than 350 millivolts. Although there was an increase in potentials, the amount of increase is virtually insignificant, and was expected due to the time that the systems were inoperable.

BIRD CREEK BRIDGE		AREA FOR EACH MILLIVOLT LEVEL									
		UNDER 200	200- 300	300- 350	350- 400	400- 500	500- 600	600- 700	700- 800	800- 900	900 OVER
		SQFT	SQFT	SQFT	SQFT	SQFT	SQFT	SQFT	SQFT	SQFT	SQFT
TEST											
84 PRE- CONST	AREA	17538	2774	316	204	159	8	1	0	0	0
85 POST- CONST	AREA	16919	4041	29	11	0	0	0	0	0	0
86 POWER ON	AREA	187	382	408	415	2455	6689	4594	2588	1419	1863
86 POWER OFF	AREA	20446	546	8	0	0	0	0	0	0	0
87 POWER ON	AREA	168	37	23	98	2422	7437	4351	2542	1688	2234
87 POWER OFF	AREA	12534	8366	81	17	2	0	0	0	0	0

Figure 3. Bird Creek Half-Cell Data (1984-1987)

OVERFLOW BRIDGE		AREA FOR EACH MILLIVOLT LEVEL									
		UNDER 200	200- 300	300- 350	350- 400	400- 500	500- 600	600- 700	700- 800	800- 900	900 OVER
		SQFT	SQFT	SQFT	SQFT	SQFT	SQFT	SQFT	SQFT	SQFT	SQFT
TEST											
84 PRE- CONST	AREA	839	8844	5763	4743	7023	786	2	0	0	0
85 POST- CONST	AREA	2370	12272	9017	3855	486	0	0	0	0	0
86 POWER ON	AREA	1124	3519	258	257	2011	4226	4421	4664	2749	4771
86 POWER OFF	AREA	8199	19148	649	4	0	0	0	0	0	0
87 POWER OFF	AREA	3633	20869	2640	755	103	0	0	0	0	0

Figure 4. Overflow Half-Cell Data (1984-1987)

Chain Drag Survey

The results of the chain drag survey found that the areas of delamination on the Bird Creek bridge had little change from 1986 to 1987. The areas of delamination along the gutter, as reported in 1986, were not delaminations in the deck. They were a result of a thin veneer of plaster on the deck. The plaster was used to refinish the parapet walls and was extended onto the deck.

A total of 34.5 sq. ft. was determine to be delaminated. The areas of delamination were basically small and most were contained between secondary anodes. Only 0.16 percent of the deck was delaminated.

The Bird Creek Overflow bridge exhibited only one area of delamination. It's area was 1 sq. ft.

Visual Survey

The polymer backfilled slots on the Bird Creek bridge are performing well. The surface crack reported in 1986, which translated transversely through the polymer is still tight and the bonds along the sides are still intact.

The deck of the Bird Creek Overflow bridge has developed some localized scaling in Zone 6. There are several small areas for a total of 30 sq. ft. of scaling.

Discussion

As reported in the first year evaluation, both systems were inoperable. The cause of the malfunction was attributed to a power surge. It was speculated that the power surge was a result of a lightning strike. Since a maintenance budget has not been established for the upkeep of the systems, securing funds caused a considerable delay in making the repairs. The components that were damaged have been replaced and additional lightning protection components were installed. A report outlining these activities is included in Appendix C.

The Bird Creek cathodic protection system is in full operation and is performing satisfactorily. The installation of the "slotted" system required that the secondary anodes be placed across two adjacent zones in a single span. This has caused an interaction of zones which hampers the stability of potential control. The system will be modified in 1988 to operate each span as one zone rather than two. The Overflow cathodic protection system is still inoperable. The components have been repaired and were in operation. However, at this time, the system is not receiving a.c. power for operation. This is a small problem and should be corrected shortly. Since the system was inoperable for 11 months prior to annual testing, there has been a slight increase in corrosion activity as measured by the half-cell survey.

The cost of the electricity to operate the systems has been $ 20.00 - $ 30.00 per month for the Bird Creek system and $ 25.00 - $ 40.00 per month for the Overflow system when they are in operation. These amounts include a $ 15.00 per month basic charge.

The polymer backfill in the "slotted" system has performed well, and the "overlay" system has no signs of distress.

APPENDIXES

Appendix A. Monthly Data

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 90886
Meter: BECKMAN   Status: OFF   Week: 59   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	307	85	-5.00	Ag/AgCl
2	.	.	.	259	46	-3.00	Ag/AgCl
3	.	.	.	127	-69	-0.01	Ag/AgCl
4	.	.	.	176	-134	-0.01	Ag/AgCl
5	.	.	.	205	-95	-0.01	Ag/Agcl
6	.	.	.	140	-6	-3.00	Ag/AgCl
7	.	.	.	149	-8	-5.00	Ag/AgCl
8	.	.	.	225	-69	-0.01	Ag/AgCl
9	.	.	.	100	-17	-4.00	Ag/AgCl
Total	.	.					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	229	-301	-3.00	Ag/AgCl
2	.	.	.	152	-64	-0.10	Ag/AgCl
3	.	.	.	273	-323	-3.00	Ag/AgCl
4	.	.	.	156	-377	-4.00	Ag/AgCl
5	.	.	.	131	40	-2.00	Ag/AgCl
6	.	.	.	267	18	-0.10	Ag/AgCl
7	.	.	.	-98	-332	-0.10	Ag/AgCl
8	.	.	.	179	-7	-0.10	Ag/AgCl
9	.	.	.	95	-93	-2.00	Ag/AgCl
10	.	.	.	75	-442	-2.00	Ag/AgCl
11	.	.	.	104	-39	-2.00	Ag/AgCl
12	.	.	.	111	15	-5.00	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK Recorder: Senkowski Date: 91086
Meter: LCD Status: ON Week: 59 Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	2.8	3.0	449	386	163	-2.70	Ag/AgCl
2	3.0	3.3	460	308	56	-2.40	Ag/AgCl
3	1.2	2.4	353	358	272	0.50	Ag/AgCl
4	1.2	2.1	460	402	72	-0.01	Ag/AgCl
5	1.2	2.4	526	345	112	0.00	Ag/Agcl
6	1.0	2.3	353	458	208	-0.80	Ag/AgCl
7	2.0	3.8	444	444	216	-1.40	Ag/AgCl
8	2.0	3.7	522	380	151	0.10	Ag/AgCl
9	0.5	1.9	347	348	240	-0.80	Ag/AgCl
Total	14.9	24.9					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	0.0	0.2	476	242	-205	.	Ag/AgCl
2	0.0	0.1	422	150	-77	.	Ag/AgCl
3	.	.	.	.	.	.	Ag/AgCl
4	.	.	.	.	.	.	Ag/AgCl
5	.	.	.	.	.	.	Ag/AgCl
6	.	.	.	.	.	.	Ag/AgCl
7	.	.	.	.	.	.	Ag/AgCl
8	.	.	.	.	.	.	Ag/AgCl
9	1.3	3.0	499	502	219	.	Ag/AgCl
10	.	.	.	.	.	.	Ag/AgCl
11	.	.	.	.	.	.	Ag/AgCl
12	.	.	.	.	.	.	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 101786
Meter: LCD   Status: ON   Week: 64   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	2.9	4.0	450	418	205	-0.50	Ag/AgCl
2	3.1	4.4	503	416	97	-1.70	Ag/AgCl
3	0.0	2.0	352	407	263	0.40	Ag/AgCl
4	1.2	2.4	459	400	95	0.00	Ag/AgCl
5	1.2	2.4	526	325	130	0.20	Ag/Agcl
6	0.2	2.0	353	356	242	-0.80	Ag/AgCl
7	1.5	4.0	445	445	222	-1.00	Ag/AgCl
8	2.0	4.2	525	383	224	0.10	Ag/AgCl
9	0.4	2.0	347	349	253	-0.70	Ag/AgCl
Total	12.5	27.4					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	.	.	.	Ag/AgCl
2	.	.	.	.	.	.	Ag/AgCl
3	.	.	.	.	.	.	Ag/AgCl
4	.	.	.	.	.	.	Ag/AgCl
5	.	.	.	.	.	.	Ag/AgCl
6	.	.	.	.	.	.	Ag/AgCl
7	.	.	.	.	.	.	Ag/AgCl
8	.	.	.	.	.	.	Ag/AgCl
9	.	.	.	.	.	.	Ag/AgCl
10	.	.	.	.	.	.	Ag/AgCl
11	.	.	.	.	.	.	Ag/AgCl
12	.	.	.	.	.	.	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 112486
Meter: LCD   Status: ON   Week: 70   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	3.0	4.0	450	434	244	-0.20	Ag/AgCl
2	0.0	3.2	500	980	212	-0.80	Ag/AgCl
3	0.0	2.6	354	460	370	0.60	Ag/AgCl
4	1.1	3.0	451	452	192	0.00	Ag/AgCl
5	1.3	2.9	525	328	174	0.30	Ag/Agcl
6	0.0	2.3	350	420	278	0.00	Ag/AgCl
7	0.5	4.4	450	451	242	-0.60	Ag/AgCl
8	2.0	4.9	528	366	295	0.20	Ag/AgCl
9	0.2	1.8	347	349	281	-0.50	Ag/AgCl
Total	8.1	29.1					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	.	.	.	Ag/AgCl
2	.	.	.	.	.	.	Ag/AgCl
3	.	.	.	.	.	.	Ag/AgCl
4	.	.	.	.	.	.	Ag/AgCl
5	.	.	.	.	.	.	Ag/AgCl
6	.	.	.	.	.	.	Ag/AgCl
7	.	.	.	.	.	.	Ag/AgCl
8	.	.	.	.	.	.	Ag/AgCl
9	.	.	.	.	.	.	Ag/AgCl
10	.	.	.	.	.	.	Ag/AgCl
11	.	.	.	.	.	.	Ag/AgCl
12	.	.	.	.	.	.	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 10587
Meter: LCD   Status: ON   Week: 76   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	1.6	2.2	450	451	277	2.60	Ag/AgCl
2	0.0	1.8	500	871	242	1.20	Ag/AgCl
3	0.0	1.6	354	436	270	0.30	Ag/AgCl
4	0.4	1.6	450	451	350	0.10	Ag/AgCl
5	1.3	2.4	524	448	312	0.30	Ag/Agcl
6	0.0	1.9	350	423	280	0.00	Ag/AgCl
7	0.0	2.5	450	636	405	0.70	Ag/AgCl
8	2.0	3.3	528	440	340	0.50	Ag/AgCl
9	0.2	1.6	347	348	238	-0.10	Ag/AgCl
Total	5.5	18.9					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	162	-272	-0.40	Ag/AgCl
2	.	.	.	99	-62	0.00	Ag/AgCl
3	.	.	.	185	-304	-0.70	Ag/AgCl
4	.	.	.	169	-280	-1.00	Ag/AgCl
5	.	.	.	114	-40	-0.20	Ag/AgCl
6	.	.	.	199	-6	0.00	Ag/AgCl
7	.	.	.	89	-266	0.00	Ag/AgCl
8	.	.	.	129	-22	0.00	Ag/AgCl
9	0.0	1.8	525	530	288	1.40	Ag/AgCl
10	.	.	.	74	-336	-0.30	Ag/AgCl
11	.	.	.	114	-22	-0.60	Ag/AgCl
12	.	.	.	101	10	-4.20	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 22387
Meter: LCD   Status: ON   Week: 83   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	2.9	3.1	448	441	251	-1.00	Ag/AgCl
2	0.0	2.4	503	513	72	-2.30	Ag/AgCl
3	0.0	2.1	353	424	300	0.40	Ag/AgCl
4	1.1	2.5	454	455	192	3.90	Ag/AgCl
5	1.3	2.4	525	362	188	0.60	Ag/Agcl
6	0.0	1.9	350	378	219	-1.00	Ag/AgCl
7	0.0	2.7	447	535	263	-2.20	Ag/AgCl
8	2.0	3.6	526	443	320	0.80	Ag/AgCl
9	0.3	1.8	347	348	260	-1.40	Ag/AgCl
Total	7.6	22.5					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	157	-238	-1.00	Ag/AgCl
2	.	.	.	137	-81	0.00	Ag/AgCl
3	.	.	.	219	-306	-1.40	Ag/AgCl
4	.	.	.	181	-282	-1.90	Ag/AgCl
5	.	.	.	118	-37	-0.50	Ag/AgCl
6	.	.	.	177	-41	0.00	Ag/AgCl
7	.	.	.	121	-257	0.00	Ag/AgCl
8	.	.	.	148	-33	0.00	Ag/AgCl
9	0.0	.	.	520	258	2.10	Ag/AgCl
10	.	.	.	77	-440	-0.80	Ag/AgCl
11	.	.	.	108	-36	-1.00	Ag/AgCl
12	.	.	.	123	26	-1.90	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK Recorder: Senkowski Date: 30387
Meter: LCD Status: ON Week: 84 Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	2.9	4.7	448	449	237	-0.50	Ag/AgCl
2	3.0	4.9	505	471	-22	-1.30	Ag/AgCl
3	0.0	2.2	353	450	327	0.50	Ag/AgCl
4	1.2	2.7	456	441	160	6.30	Ag/AgCl
5	1.2	2.5	525	317	130	0.50	Ag/Agcl
6	0.0	2.0	350	384	240	-0.80	Ag/AgCl
7	0.0	2.9	447	447	218	-2.20	Ag/AgCl
8	2.0	3.8	525	375	236	0.40	Ag/AgCl
9	0.3	1.5	347	349	258	-1.10	Ag/AgCl
Total	10.6	27.2					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	.	.	.	Ag/AgCl
2	.	.	.	.	.	.	Ag/AgCl
3	.	.	.	.	.	.	Ag/AgCl
4	.	.	.	.	.	.	Ag/AgCl
5	.	.	.	.	.	.	Ag/AgCl
6	.	.	.	.	.	.	Ag/AgCl
7	.	.	.	.	.	.	Ag/AgCl
8	.	.	.	.	.	.	Ag/AgCl
9	.	.	.	.	.	.	Ag/AgCl
10	.	.	.	.	.	.	Ag/AgCl
11	.	.	.	.	.	.	Ag/AgCl
12	.	.	.	.	.	.	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 31987
Meter: LCD   Status: OFF   Week: 86   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	248	80	-4.30	Ag/AgCl
2	.	.	.	259	-23	-2.10	Ag/AgCl
3	.	.	.	305	20	0.00	Ag/AgCl
4	.	.	.	132	-138	0.40	Ag/AgCl
5	.	.	.	145	-107	0.00	Ag/Agcl
6	.	.	.	130	3	-1.90	Ag/AgCl
7	.	.	.	155	-26	-3.60	Ag/AgCl
8	.	.	.	85	-134	0.00	Ag/AgCl
9	.	.	.	106	-12	-2.70	Ag/AgCl
Total	.	.					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	.	.	.	Ag/AgCl
2	.	.	.	.	.	.	Ag/AgCl
3	.	.	.	.	.	.	Ag/AgCl
4	.	.	.	.	.	.	Ag/AgCl
5	.	.	.	.	.	.	Ag/AgCl
6	.	.	.	.	.	.	Ag/AgCl
7	.	.	.	.	.	.	Ag/AgCl
8	.	.	.	.	.	.	Ag/AgCl
9	.	.	.	.	.	.	Ag/AgCl
10	.	.	.	.	.	.	Ag/AgCl
11	.	.	.	.	.	.	Ag/AgCl
12	.	.	.	.	.	.	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK　　Recorder: Senkowski　　Date: 31987
Meter: LCD　　Status: ON　　Week: 86　　Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	3.1	2.5	448	311	139	1.10	Ag/AgCl
2	3.1	2.8	504	314	19	1.40	Ag/AgCl
3	1.3	1.1	353	364	238	0.90	Ag/AgCl
4	1.2	1.5	448	375	108	2.40	Ag/AgCl
5	1.2	1.7	524	240	115	0.20	Ag/Agcl
6	1.2	1.5	349	351	258	1.60	Ag/AgCl
7	2.0	3.0	449	467	225	2.70	Ag/AgCl
8	2.0	3.3	527	289	217	0.30	Ag/AgCl
9	1.1	1.3	347	348	245	1.30	Ag/AgCl
Total	16.2	18.7					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	.	.	.	Ag/AgCl
2	.	.	.	.	.	.	Ag/AgCl
3	.	.	.	.	.	.	Ag/AgCl
4	.	.	.	.	.	.	Ag/AgCl
5	.	.	.	.	.	.	Ag/AgCl
6	.	.	.	.	.	.	Ag/AgCl
7	.	.	.	.	.	.	Ag/AgCl
8	.	.	.	.	.	.	Ag/AgCl
9	.	.	.	.	.	.	Ag/AgCl
10	.	.	.	.	.	.	Ag/AgCl
11	.	.	.	.	.	.	Ag/AgCl
12	.	.	.	.	.	.	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 42787
Meter: LCD   Status-: ON   Week: 92   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	2.8	3.0	445	349	144	-4.90	Ag/AgCl
2	2.9	3.2	506	364	75	-5.10	Ag/AgCl
3	0.5	1.8	350	355	212	0.50	Ag/AgCl
4	1.2	2.1	462	373	79	0.50	Ag/AgCl
5	1.2	2.3	526	317	74	1.00	Ag/Agcl
6	1.2	2.4	350	345	178	-2.50	Ag/AgCl
7	2.0	3.5	441	441	206	-3.50	Ag/AgCl
8	2.0	3.5	521	352	104	0.30	Ag/AgCl
9	1.0	2.4	346	347	226	-2.70	Ag/AgCl
Total	14.8	24.2					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	268	-306	-3.50	Ag/AgCl
2	.	.	.	158	-117	0.00	Ag/AgCl
3	.	.	.	305	-351	-5.00	Ag/AgCl
4	.	.	.	195	-335	-5.00	Ag/AgCl
5	.	.	.	128	-50	-4.00	Ag/AgCl
6	.	.	.	217	-37	0.00	Ag/AgCl
7	.	.	.	69	-259	0.00	Ag/AgCl
8	.	.	.	223	-21	0.00	Ag/AgCl
9	0.0	.	.	505	-116	4.20	Ag/AgCl
10	.	.	.	91	-487	-2.50	Ag/AgCl
11	.	.	.	94	-271	-2.60	Ag/AgCl
12	.	.	.	116	28	-4.60	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 63087
Meter: LCD   Status: ON   Week: 101   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	2.8	3.2	445	307	129	-1.60	Ag/AgCl
2	0.0	2.4	504	772	90	-2.00	Ag/AgCl
3	0.0	2.0	348	352	275	0.30	Ag/AgCl
4	1.2	2.4	459	371	97	0.10	Ag/AgCl
5	1.2	2.4	525	313	95	0.50	Ag/Agcl
6	0.6	2.2	349	352	236	-0.30	Ag/AgCl
7	1.6	4.6	441	441	240	-1.30	Ag/AgCl
8	1.9	4.7	522	375	181	0.40	Ag/AgCl
9	0.6	2.2	344	346	255	-0.90	Ag/AgCl
Total	9.9	26.1					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Potentials (mV) Ag/AgCl	Potentials (mV) Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	.	.	.	Ag/AgCl
2	.	.	.	.	.	.	Ag/AgCl
3	.	.	.	.	.	.	Ag/AgCl
4	.	.	.	.	.	.	Ag/AgCl
5	.	.	.	.	.	.	Ag/AgCl
6	.	.	.	.	.	.	Ag/AgCl
7	.	.	.	.	.	.	Ag/AgCl
8	.	.	.	.	.	.	Ag/AgCl
9	.	.	.	.	.	.	Ag/AgCl
10	.	.	.	.	.	.	Ag/AgCl
11	.	.	.	.	.	.	Ag/AgCl
12	.	.	.	.	.	.	Ag/AgCl
Total	.	.					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK Recorder: Senkowski Date: 81087
Meter: LCD Status: ON Week: 107 Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	2.8	2.5	443	272	77	-3.20	Ag/AgCl
2	0.0	1.8	508	1049	-37	-3.80	Ag/AgCl
3	1.2	2.3	347	350	185	1.00	Ag/AgCl
4	1.2	2.4	463	358	9	0.00	Ag/AgCl
5	1.2	2.3	526	301	308	0.60	Ag/Agcl
6	1.2	2.3	350	335	155	-0.80	Ag/AgCl
7	2.0	3.8	440	374	150	-2.10	Ag/AgCl
8	2.0	3.8	520	340	82	0.10	Ag/AgCl
9	1.1	2.4	344	346	220	0.20	Ag/AgCl
Total	12.7	23.6					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	4.0	3.0	473	471	-21	0.00	Ag/AgCl
2	1.0	1.3	427	428	130	1.80	Ag/AgCl
3	0.0	0.1	294	304	-176	-4.50	Ag/AgCl
4	1.0	0.8	349	350	-125	2.60	Ag/AgCl
5	0.6	1.1	345	349	170	0.50	Ag/AgCl
6	4.8	2.8	451	436	285	1.90	Ag/AgCl
7	3.0	2.7	298	-75	-165	0.50	Ag/AgCl
8	1.1	1.8	323	322	125	0.60	Ag/AgCl
9	0.0	0.2	778	97	-271	-1.90	Ag/AgCl
10	3.5	3.5	378	379	-144	3.00	Ag/AgCl
11	2.0	2.8	400	377	41	2.10	Ag/AgCl
12	4.3	3.6	375	232	54	5.60	Ag/AgCl
Total	25.3	23.7					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Ooten   Date: 91887
Meter: LCD   Status: ON   Week: 112   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	2.8	4.1	445	359	140	0.70	Ag/AgCl
2	0.0	3.3	504	942	62	-0.70	Ag/AgCl
3	0.0	2.3	352	387	256	0.40	Ag/AgCl
4	1.2	2.8	456	400	39	0.10	Ag/AgCl
5	1.2	2.6	525	308	105	0.30	Ag/Agcl
6	0.2	2.2	348	352	235	-0.60	Ag/AgCl
7	0.6	4.3	444	444	208	-0.60	Ag/AgCl
8	2.0	4.9	524	394	190	0.20	Ag/AgCl
9	0.5	2.1	344	345	218	0.00	Ag/AgCl
Total	8.5	28.6					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	1.5	3.6	455	455	203	-2.00	Ag/AgCl
2	0.0	0.0	427	1000	-42	1.20	Ag/AgCl
3	0.0	0.5	301	304	-37	-1.30	Ag/AgCl
4	0.3	1.2	353	354	-57	1.00	Ag/AgCl
5	0.4	1.2	347	350	235	0.90	Ag/AgCl
6	0.0	0.2	448	160	86	0.00	Ag/AgCl
7	2.9	3.8	301	89	-131	0.20	Ag/AgCl
8	0.7	1.9	326	325	143	0.10	Ag/AgCl
9	0.0	0.2	780	75	-294	-0.60	Ag/AgCl
10	1.2	3.0	381	382	5	1.00	Ag/AgCl
11	1.4	2.9	400	401	211	2.40	Ag/AgCl
12	3.8	7.0	376	375	244	0.80	Ag/AgCl
Total	12.2	25.5					

CATHODIC PROTECTION PERFORMANCE UPDATE

Bridge: BIRD CREEK   Recorder: Senkowski   Date: 112587
Meter: LCD   Status: ON   Week: 122   Time: .

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	3.0	7.0	446	405	170	1.40	Ag/AgCl
2	0.0	6.2	503	919	207	2.40	Ag/AgCl
3	0.0	2.7	353	483	308	0.30	Ag/AgCl
4	0.8	3.0	449	450	180	0.10	Ag/AgCl
5	1.3	3.3	523	370	204	0.20	Ag/Agcl
6	0.0	2.8	347	425	264	0.10	Ag/AgCl
7	3.5	10	452	451	145	1.10	Ag/AgCl
8	0.0	8.5	526	724	400	0.30	Ag/AgCl
9	0.2	1.8	345	347	222	-0.10	Ag/AgCl
Total	8.8	45.7					

Bridge: OVERFLOW

Zone	Current Amps	Voltage Volts	Potentials (mV) set	Ag/AgCl	Mo/MoO3	Rebar Probes	Mode of Protection
1	.	.	.	.	.	.	Ag/AgCl
2	.	.	.	.	.	.	Ag/AgCl
3	.	.	.	.	.	.	Ag/AgCl
4	.	.	.	.	.	.	Ag/AgCl
5	.	.	.	.	.	.	Ag/AgCl
6	.	.	.	.	.	.	Ag/AgCl
7	.	.	.	.	.	.	Ag/AgCl
8	.	.	.	.	.	.	Ag/AgCl
9	.	.	.	.	.	.	Ag/AgCl
10	.	.	.	.	.	.	Ag/AgCl
11	.	.	.	.	.	.	Ag/AgCl
12	.	.	.	.	.	.	Ag/AgCl
Total	.	.					

Appendix B. Analysis Data

---------------------- BRIDGE=BIRD CREEK ZONE=1 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	445	770	OFF	325	OVER
81485	8	446	1257	OFF	811	OVER
91385	12	447	1660	OFF	1213	OVER
102185	18	445	1299	OFF	854	OVER
111585	21	445	1527	OFF	1082	OVER
121685	26	447	1113	OFF	666	OVER
20686	33	450	454	ON	4	OK
31286	38	449	453	ON	4	OK
101786	64	450	418	ON	-32	UNDER
112486	70	450	434	ON	-16	OK
10587	76	450	451	ON	1	OK
30387	84	448	449	ON	1	OK
42787	92	445	349	ON	-96	UNDER
63087	101	445	307	ON	-138	UNDER
81087	107	443	272	ON	-171	UNDER
91887	112	445	359	ON	-86	UNDER
112587	122	446	405	ON	-41	UNDER

---------------------- BRIDGE=BIRD CREEK ZONE=2 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	460	1365	OFF	905	OVER
81485	8	465	2950	OFF	2485	OVER
91385	12	527	4750	OFF	4223	OVER
102185	18	500	.	OFF	.	MALFUNCT
111585	21	502	.	OFF	.	MALFUNCT
121685	26	497	1040	OFF	543	OVER
20686	33	517	573	OFF	56	OVER
31286	38	521	521	ON	0	OK
101786	64	503	416	ON	-87	UNDER
112486	70	500	980	OFF	480	OVER
10587	76	500	871	OFF	371	OVER
30387	84	505	471	ON	-34	UNDER
42787	92	506	364	ON	-142	UNDER
63087	101	504	772	OFF	268	OVER
81087	107	508	1049	OFF	541	OVER
91887	112	504	942	OFF	438	OVER
112587	122	503	919	OFF	416	OVER

BRIDGE=BIRD CREEK ZONE=3

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	346	573	OFF	227	OVER
81485	8	347	1142	OFF	795	OVER
91385	12	348	876	OFF	528	OVER
102185	18	346	889	OFF	543	OVER
111585	21	346	934	OFF	588	OVER
121685	26	349	986	OFF	637	OVER
20686	33	349	581	OFF	232	OVER
31286	38	348	444	OFF	96	OVER
101786	64	352	407	OFF	55	OVER
112486	70	354	460	OFF	106	OVER
10587	76	354	436	OFF	82	OVER
30387	84	353	450	OFF	97	OVER
42787	92	350	355	ON	5	OK
63087	101	348	352	OFF	4	OK
81087	107	347	350	ON	3	OK
91887	112	352	387	OFF	35	OVER
112587	122	353	483	OFF	130	OVER

BRIDGE=BIRD CREEK ZONE=4

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	454	341	ON	-113	UNDER
81485	8	452	343	ON	-109	UNDER
91385	12	450	359	ON	-91	UNDER
102185	18	450	367	ON	-83	UNDER
111585	21	446	418	ON	-28	UNDER
121685	26	442	443	ON	1	OK
20686	33	449	408	ON	-41	UNDER
31286	38	452	396	ON	-56	UNDER
101786	64	459	400	ON	-59	UNDER
112486	70	451	452	ON	1	OK
10587	76	450	451	ON	1	OK
30387	84	456	441	ON	-15	OK
42787	92	462	373	ON	-89	UNDER
63087	101	459	371	ON	-88	UNDER
81087	107	463	358	ON	-105	UNDER
91887	112	456	400	ON	-56	UNDER
112587	122	449	450	ON	1	OK

---------------------- BRIDGE=BIRD CREEK ZONE=5 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	526	398	ON	-128	UNDER
81485	8	526	419	ON	-107	UNDER
91385	12	526	429	ON	-97	UNDER
102185	18	526	416	ON	-110	UNDER
111585	21	525	420	ON	-105	UNDER
121685	26	526	463	ON	-63	UNDER
20686	33	525	437	ON	-88	UNDER
31286	38	525	437	ON	-88	UNDER
101786	64	526	325	ON	-201	UNDER
112486	70	525	328	ON	-197	UNDER
10587	76	524	448	ON	-76	UNDER
30387	84	525	317	ON	-208	UNDER
42787	92	526	317	ON	-209	UNDER
63087	101	525	313	ON	-212	UNDER
81087	107	526	301	ON	-225	UNDER
91887	112	525	308	ON	-217	UNDER
112587	122	523	370	ON	-153	UNDER

---------------------- BRIDGE=BIRD CREEK ZONE=6 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	350	309	ON	-41	UNDER
81485	8	349	326	ON	-23	UNDER
91385	12	349	352	ON	3	OK
102185	18	351	354	ON	3	OK
111585	21	349	353	OFF	4	OK
121685	26	350	412	OFF	62	OVER
20686	33	349	352	ON	3	OK
31286	38	350	353	ON	3	OK
101786	64	353	356	ON	3	OK
112486	70	350	420	OFF	70	OVER
10587	76	350	423	OFF	73	OVER
30387	84	350	384	OFF	34	OVER
42787	92	350	345	ON	-5	OK
63087	101	349	352	ON	3	OK
81087	107	350	335	ON	-15	OK
91887	112	348	352	ON	4	OK
112587	122	347	425	OFF	78	OVER

---------------------- BRIDGE=BIRD CREEK ZONE=7 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	447	457	ON	10	OK
81485	8	448	523	OFF	75	OVER
91385	12	450	849	OFF	399	OVER
102185	18	450	1444	OFF	994	OVER
111585	21	451	1829	OFF	1378	OVER
121685	26	455	1569	OFF	1114	OVER
20686	33	448	536	OFF	88	OVER
31286	38	446	491	OFF	45	OVER
101786	64	445	445	ON	0	OK
112486	70	450	451	ON	1	OK
10587	76	450	636	OFF	186	OVER
30387	84	447	447	OFF	0	OK
42787	92	441	441	ON	0	OK
63087	101	441	441	ON	0	OK
81087	107	440	374	ON	-66	UNDER
91887	112	444	444	ON	0	OK
112587	122	452	451	ON	-1	OK

---------------------- BRIDGE=BIRD CREEK ZONE=8 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	522	420	ON	-102	UNDER
81485	8	524	425	ON	-99	UNDER
91385	12	526	439	ON	-87	UNDER
102185	18	520	431	ON	-89	UNDER
111585	21	521	458	ON	-63	UNDER
121685	26	525	526	ON	1	OK
20686	33	524	479	ON	-45	UNDER
31286	38	523	490	ON	-33	UNDER
101786	64	525	383	ON	-142	UNDER
112486	70	528	366	ON	-162	UNDER
10587	76	528	440	ON	-88	UNDER
30387	84	525	375	ON	-150	UNDER
42787	92	521	352	ON	-169	UNDER
63087	101	522	375	ON	-147	UNDER
81087	107	520	340	ON	-180	UNDER
91887	112	524	394	ON	-130	UNDER
112587	122	526	724	OFF	198	OVER

---------------------- BRIDGE=BIRD CREEK ZONE=9 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	348	338	ON	-10	OK
81485	8	348	352	ON	4	OK
91385	12	350	354	ON	4	OK
102185	18	350	353	ON	3	OK
111585	21	350	354	ON	4	OK
121685	26	354	357	ON	3	OK
20686	33	349	353	ON	4	OK
31286	38	348	351	ON	3	OK
101786	64	347	349	ON	2	OK
112486	70	347	349	ON	2	OK
10587	76	347	348	ON	1	OK
30387	84	347	349	ON	2	OK
42787	92	346	347	ON	1	OK
63087	101	344	346	ON	2	OK
81087	107	344	346	ON	2	OK
91887	112	344	345	ON	1	OK
112587	122	345	347	ON	2	OK

---------------------- BRIDGE=OVERFLOW ZONE=1 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	473	474	ON	1	OK
81485	8	474	475	ON	1	OK
91385	12	474	477	ON	3	OK
102185	18	475	476	ON	1	OK
111585	21	476	478	ON	2	OK
121685	26	479	480	ON	1	OK
20686	33	478	480	ON	2	OK
31286	38	476	478	ON	2	OK

---------------------- BRIDGE=OVERFLOW ZONE=2 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	424	426	ON	2	OK
81485	8	423	424	ON	1	OK
91385	12	422	423	ON	1	OK
102185	18	426	427	ON	1	OK
111585	21	425	427	ON	2	OK
121685	26	426	427	ON	1	OK
20686	33	426	428	ON	2	OK
31286	38	426	428	ON	2	OK

---------------------- BRIDGE=OVERFLOW ZONE=3 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	117	120	ON	3	OK
81485	8	116	119	ON	3	OK
91385	12	116	119	ON	3	OK
102185	18	126	129	ON	3	OK
111585	21	127	130	ON	3	OK
121685	26	130	134	ON	4	OK
20686	33	128	132	ON	4	OK
31286	38	126	148	OFF	22	OVER

---------------------- BRIDGE=OVERFLOW ZONE=4 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	348	348	ON	0	OK
81485	8	347	348	ON	1	OK
91385	12	347	348	ON	1	OK
102185	18	351	179	OFF	-172	MALFUNCT
111585	21	350	350	ON	0	OK
121685	26	352	352	ON	0	OK
20686	33	350	350	ON	0	OK
31286	38	349	350	ON	1	OK

---------------------- BRIDGE=OVERFLOW ZONE=5 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	355	355	ON	0	OK
81485	8	353	353	ON	0	OK
91385	12	351	351	ON	0	OK
102185	18	352	352	ON	0	OK
111585	21	348	348	ON	0	OK
121685	26	345	345	ON	0	OK
20686	33	350	349	ON	-1	OK
31286	38	353	352	ON	-1	OK

---------------------- BRIDGE=OVERFLOW ZONE=6 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	450	452	ON	2	OK
81485	8	450	452	ON	2	OK
91385	12	449	451	ON	2	OK
102185	18	451	453	ON	2	OK
111585	21	450	451	ON	1	OK
121685	26	450	452	ON	2	OK
20686	33	451	452	ON	1	OK
31286	38	451	452	ON	1	OK

---------------------- BRIDGE=OVERFLOW ZONE=7 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	298	444	OFF	146	OVER
81485	8	297	472	OFF	175	OVER
91385	12	297	494	OFF	197	OVER
102185	18	300	518	OFF	218	OVER
111585	21	300	550	OFF	250	OVER
121685	26	302	611	OFF	309	OVER
20686	33	699	210	ON	-489	UNDER
31286	38	698	179	ON	-519	UNDER

---------------------- BRIDGE=OVERFLOW ZONE=8 ----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	322	235	ON	-87	UNDER
81485	8	322	221	ON	-101	UNDER
91385	12	322	88	ON	-234	UNDER
102185	18	326	167	ON	-159	UNDER
111585	21	326	160	ON	-166	UNDER
121685	26	328	165	ON	-163	UNDER
20686	33	326	363	OFF	37	OVER
31286	38	325	365	OFF	40	OVER

------------------------ BRIDGE=OVERFLOW ZONE=9 ------------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	501	206	OFF	-295	MALFUNCT
81485	8	500	173	OFF	-327	MALFUNCT
91385	12	499	145	OFF	-354	MALFUNCT
102185	18	502	475	ON	-27	UNDER
111585	21	500	304	ON	-196	UNDER
121685	26	499	103	OFF	-396	MALFUNCT
20686	33	500	433	ON	-67	UNDER
31286	38	502	216	ON	-286	UNDER

----------------------- BRIDGE=OVERFLOW ZONE=10 -----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	371	371	ON	0	OK
81485	8	372	372	ON	0	OK
91385	12	374	375	ON	1	OK
102185	18	371	372	ON	1	OK
111585	21	375	380	ON	5	OK
121685	26	379	362	ON	-17	OK
20686	33	375	375	ON	0	OK
31286	38	371	372	ON	1	OK

----------------------- BRIDGE=OVERFLOW ZONE=11 -----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	398	401	ON	3	OK
81485	8	398	401	ON	3	OK
91385	12	397	400	ON	3	OK
102185	18	400	404	ON	4	OK
111585	21	400	402	ON	2	OK
121685	26	401	404	ON	3	OK
20686	33	400	402	ON	2	OK
31286	38	398	401	ON	3	OK

----------------------- BRIDGE=OVERFLOW ZONE=12 -----------------------

DATE	WEEK	SET	AGCL	CURRENT	DIF	STATUS
71985	4	371	373	ON	2	OK
81485	8	371	374	ON	3	OK
91385	12	372	375	ON	3	OK
102185	18	374	377	ON	3	OK
111585	21	376	378	ON	2	OK
121685	26	379	381	ON	2	OK
20686	33	377	379	ON	2	OK
31286	38	375	378	ON	3	OK

Appendix C. Lightning Protection

Demonstration Project No. 34
"Cathodic Protection for Concrete Bridge Decks"
State Study No. 83-08-1, Item 2417

The Oklahoma Department of Transportation contracted the installation of two cathodic protection (CP) systems as part of the Federal Highway Administration's Demonstration Project No. 34 - "Cathodic Protection for Reinforced Concrete Bridge Decks". Both systems were of the impressed current type using AC power from the local utility company. The first system known as a "slotted" or non-overlay system was installed on the Bird Creek bridge located on SH 266 in Tulsa County, Oklahoma. The second system known as an overlay system was installed on the Bird Creek Overflow bridge located on SH 266 in Rogers County, Oklahoma. Installation was completed on June 19, 1985.

On April 25, 1986 the CP system on the Bird Creek bridge was found to be inoperable. The isolation transformer fuse had blown. When the fuse was replaced the circuitry was malfunctioning which caused the potential readings from the reference cells to be greater than 10 volts. The system was turned off.

On July 1, 1986 representatives from the Harco Corporation investigated the problem. At that time the LCD meter was inoperable. The cards that were malfunctioning and the meter were removed to be repaired. When investigating the CP system on the Bird Creek Overflow structure, it was found to be inoperable. The main transformer fuse and the current output fuse for Zone 12 were fried (metalized on the inside). The lightning protection fuse for the anode in Zone 12 had disintegrated into powder, and the card for Zone 12 had burn marks and a burned out resistor. The LCD was totally inoperable and when removed had burn marks on the connection tabs.

On September 8, 1986 representatives from the Harco Corporation and Good-All Electric investigated the CP systems. The investigation of the Bird Creek CP system yielded no immediate explanation for the cause of the malfunction. The repaired cards were replaced along with a new meter. When the unit was turned on, everything operated normally.

The investigation on the Bird Creek Overflow CP system found additional components damaged. The silicon control rectifier for Zone 12 had a short, nine of the control cards were determined to need repair, and a potentiometer located near the meter was burned out. The components were removed to be repaired.

An analysis of the damage by Good-All Electric revealed that the damage was caused by an electrical surge. The cause of the electrical surge was attributed to a lightning strike. Good-All Electric suggested that the following measures for added lightning protection be taken:

1. Establish a solid earth ground to subsoil moisture as close as possible to the rectifier with a resistance to remote ground of 1 ohm or less. Connect the rectifier cabinet to this ground by a N0. 6 AWG copper cable.

2. Place an arc-gap lightning arrester with rating of no more than 125 volts between the negative output lug and case ground. (McGraw Edison AS1B2).

The Harco Corporation was contracted to install the above lightning protection to both systems, and to do the following for the Overflow CP system:

- repair 10 rectifier control cards
- repair 1 rectifier stack
- replace rectifier meter (0000303)
- replace 100 ohm potentiometer, Bourns 3299, W(7744280)
- install repaired components and make final adjustments.

The design of the cathodic protection systems already included measures for lightning protection. The A.C. lightning protection consisted of grounding rods located near the utility meter, and a lightning arrester immediately before the main circuit breaker in the controller. The D.C. lightning protection consisted of a lightning arrester for the anodes of each zone. The rectifier cabinet and the steel were tied to the grounding rods for protection.

Since none of the lightning arresters were activated, it was assumed that the path of the lightning surge came from the steel and into the system through the negative lead wire. Therefore, to protect this path a lightning arrester was placed between the negative lead and a new ground that was established. Any surge flowing through the negative lead will trigger the arrester and will be channeled directly to the new ground.

On April 27, 1987, personnel from the Harco Corporation installed an additional ground and the lightning arrester for each system. The additional grounding system for the Bird Creek CP system consisted of driving 4 - 10 foot copper grounding rods into the ground along the southwest abutment wall. A bare No. 6 AWG solid copper grounding wire was attached to all 4 rods with clamps. The wire was buried 4″ deep along the wall. At the corner, the wire was brought above the ground and attached to existing conduit back to the rectifier cabinet with plastic straps. A lightning arrester was installed on the panel. One side of the lightning arrester was connected to the system's negative output lug and the other side was connected to the new ground wire and the cabinet ground.

The additional grounding system for the Overflow CP system consisted of a No. 6 AWG stranded copper wire that was cadwelded to the steel H-pile of the first pier. The wire was layed along the inside of the outermost I-beam back to the rectifier cabinet and was secured with metal brackets. A lightning arrester was installed on the panel. One side of the lightning arrester was connected to the system's negative output lug and the other side was connected to the new ground wire and the cabinet ground.

The resistance to earth of the rectifier grounding systems were measured using the three pin method and a Nilsson Model 400 resistance meter. The new grounding systems measured 3.2 Ohms and 2.4 Ohms for the Bird Creek and the Overflow CP systems, respectively. Although this did not achieve the specified 1 Ohm, it should provide additional protection against damage caused by lightning.

On May 21, 1987, personnel from the Harco Corporation repaired the components on the Overflow system. A new potentiometer, the repaired meter and the repaired control cards were installed. Four control cards were in need of more repairs.

On June 30, 1987, Personnel from the Harco Corporation installed the four control cards that had been repaired. The repaired cards operated correctly. However, four of the cards that were previously repaired were inoperable. They were removed and sent for repairs.

On August 10, 1987, the four repaired control cards were installed. All control cards for the Overflow system were operating properly. However, Zone 9 was not discharging current.

On September 18, 1987, the control card for Zone 6 on the Overflow system was inoperable.

On September 29, 1987, representatives from Goodall and the Harco Corporation investigated the problem with Zone 9 of the Overflow system. The lightning protection fuse was blown. The control card for Zone 6 had a bad capacitor. The problems were corrected, and the system was in full operation.

On November 25, 1987, the Overflow system was found to be inoperable. No damage could be detected. It appears that the system is not receiving A.C. power.

In summary, added lightning protection was installed on both systems, and the repairs were made to the Overflow CP system. No further complications have resulted on the Bird Creek CP system. The Overflow CP system was in full operation, but is currently inoperable. It appears that the A.C. is not getting into the system.