SR 24 Yakima River Bridge

Cathodic Protection Check-Out

WA-RD 87.2.1
November 1986

Washington State Department of Transportation
Planning, Research and Public Transportation Division
Research Office
in cooperation with the
United States Department of Transportation
Federal Highway Administration

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15. SUPPLEMENTARY NOTES

The system check-out and report were completed using the services of Intermountain Corrosion Services Inc., and ETCO Engineering Services Inc., Redondo, WA.

16. ABSTRACT

The cathodic protection system on the Yakima River Bridge on SR-24 near Yakima was evaluated for proper operation. Three out of six reference electrodes and rebar probes were found to be non-functioning. One temperature sensing thermistor was also found to be non-functional. All three deck zones were found to be receiving the proper cathodic protection current. Recommendations were made to continue the monitoring at regular intervals and maintain the present rectifier settings.

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CATHODIC PROTECTION
CHECK-OUT
SR 24
Yakima River Bridge

By

ETCO Engineering Services, Inc.
Redondo, WA

Prepared for

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

November 1986

DISCLAIMER

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YAKIMA RIVER BRIDGE
SR 24
CATHODIC PROTECTION SYSTEM
YAKIMA, WASHINGTON

OCTOBER 1986

INTRODUCTION

The cathodic protection system on the subject bridge deck was installed in August, 1985. Initial system start-up and activation was completed on January 30, 1986. This annual check-out was completed by Intermountain Corrosion Service, Inc., on October 9, 1986. Monthly monitoring has been performed by WSDOT forces.

TEST PROCEDURES

Potential values were obtained with a solid state high impedance voltmeter, Model LC-4 or 372-ML as manufactured by M.C. Miller Co. Potential values were referenced to permanently installed silver silver-chloride reference electrode or a portable copper copper-sulfate reference electrode.

Thermistor values were measured with an Omega Model 865 thermometer.

Resistance values were measured with a Nilsson Model 400 Soil Resistivity Meter.

TEST RESULTS AND ANALYSIS

I. Permanent reference electrode potential values are reported in Table I, which also contains thermistor temperature and thermistor resistance measurements. Based on the values obtained at reference terminals R1 it is apparent an electrical discontinuity exists in the positive (+) lead wire, for the reference cell, because all the negative terminals are commonly bonded. The R1 thermistor cables appear to be discontinuous also due to the unstable values and the high resistance between the thermistor terminals.

Based on a review of the data obtained by HARCO in August, 1986, and submitted with their letter dated September 25, 1986, copy attached, the above conditions appear to have existed since the original system start-up.

Reference cell R4 is experiencing the same conditions as R1, which existed since the system was first activated. Potential values obtained during this survey as well as initial values are inconsistent with other values that would normally be in a similar range. Also, the depolarization potential values, Table VII obtained during this survey as well as the original values indicate a circuit discontinuity at cells 1 and 4.

The terminal board in the CRB enclosure was removed and inspected for loose or broken connections. All connections appeared to be in good condition.

II. The rebar probe potential values are reported in Table II. The analysis in section I leads to the conclusion that reference cell cable R1 and R4 are ineffective. Probe P-5 connecting cable appears to be discontinuous. The only test stations with functional reference cells and probes are 2, 3, and 6. Comparing the potential values obtained during this investigation with the original values in the HARCO report, page 5, gives the following results;

	Potential - mV		
PROBE NO.	January 1986	October 1986	Change
P-2	104	365	(-) 261
P-3	380	160	(+) 220
P-6	263	56.5	(+) 207.5

A positive potential shift would indicate possible current pick-up while a negative shift would be indicative of current discharge at an anodic area which would sacrifice the metal structure. However, the significance of these values cannot be accurately analyzed until more test data is collected over a longer period.

III. The high probe to rebar resistance values shown in Table III is more confirmation that probes P-1, P-4, and P-5 are ineffective.

IV. Table IV contains the potential values between the rebar and the rebar probes. Here again, only values for probes P-2, P-3, and P-6 can be utilized. These potential values would be comparable to the algebraic difference between the values in Tables I and II, with the exception of a few millivolts.

The original contract specifications required that " . . . . resistance type corrosion rate probes . . . ." be installed as a component to the deck instrumentation. This type of probe is basically a length of metal with similar composition as the reinforcing steel with a calibrated resistance. Corrosion rates of the reinforcing steel can be determined by measuring the change in resistance of the resistance probe. Changes in resistance would be caused by reduction in cross section of the resistance wire caused by corrosion cell activity.

The rebar probes installed on this project will not function as a resistance type probe. The rebar probes can be used to determine the corrosion rate of steel rebar not being cathodically protected. However, potential values will not indicate magnitude or presence of corrosion cells. The probes will normally exist in an anodic condition due to their chloride laden environment. Corrosion rates of the probes can be calculated by measuring the current flow from the probe with the rectifier off. No current flow was detected during this check-out, therefore, we must assume corrosion cell activity has not been initiated. This method of corrosion rate measurement must be used with caution because the bridge deck rebar may be in a different environment than the rebar probe in the fabricated corrosion cell.

V. Table V indicates the cathodic protection current output for the three zones on the bridge deck.

VI. Table VI is a measure of the ability of the rebar probe to receive or discharge current when connected to the cathodic protection circuit. See discussion in section IV.

VII. The four hour depolarization potential values are presented in Table VII. The depolarization potential values indicate reference electrodes R2, R5, and R6 are performing satisfactorily. To confirm that Zone 2 (R3 & R4) was receiving cathodic protection, a portable reference electrode (Ref 4A) was placed on the deck in the area near R4. The portable reference electrode indicates Zone 2 is receiving adequate cathodic protection current.

CONCLUSIONS

1. Reference electrodes R1, R3, and R4 are not functioning properly.

2. Rebar probes P-1, P-4 and P-5 are not functioning properly.

3. Thermistor R1, is not functioning properly.

4. All deck zones, 1, 2, and 3 are receiving cathodic protection current.

5. Using the 100-mV polarization decay or the 300-mV shift from native potential values as the criterion for acceptable levels of cathodic protection, all zones appear to be cathodically protected. The instant off potential value of a mortar coated steel structure is extremely difficult to measure with common field test instruments. Past experience has shown that accurate instant off potential values can only be measured with a laboratory oscilloscope that will time instant off as the alternating current reversal between the 60 cps frequency. Testing for instant off on a mortar coated structure with an oscilloscope has shown decreases in potential values from the "on" position to the rectifier "off" to be less than 15-mV, and in some cases no detectable change. Portable test equipment is being developed that will accurately measure the instant off potential values to facilitate field testing.

Conclusions Continued.

6. The thermistor data being collected will provide a historical record on the operation of the system. The system will be susceptible to seasonal changes which will be related to changes in temperature. There values should be recorded at each periodic monitoring.

7. Rebar probe corrosion has not been initiated at this time but will most likely occur in the future.

RECOMMENDATIONS

1. For accurate testing and monitoring, ineffective reference electrodes should be replaced.

2. Continue monitoring by WSDOT forces with present established procedures. Measurement of temperature values have been interrupted and should be resumed.

3. At the locations with ineffective reference electrodes, portable reference electrodes should be used for monitoring.

4. Maintain present rectifier settings until such time it is determined by an experienced Corrosion Engineer that changes are necessary.

5. This system should be monitored by an experienced Corrosion Engineer at three month intervals for one year to properly analyze the effects of seasonal changes on the operation of the system.

APPENDIX A

TABLES

TABLE I
YAKIMA RIVER BRIDGE
SR 24
CATHODIC PROTECTION SYSTEM
YAKIMA, WASHINGTON

October 1986

PERMANENT REFERENCE ELECTRODE POTENTIALS AND THERMISTOR DATA

	RECTIFIER "ON" POTENTIAL-mv	THERMISTOR Degree - F	THERMISTOR RESISTANCE ohms
R 1.	46 mv Fluctuating	UNSTABLE	28,000
R 2.	345	57	3,500
R 3.	338	57	3,500
R 4.	204	58	3,600
R 5.	325	58.5	3,600
R 6.	358	59.3	3,550

AIR TEMP - 63F

TIME 10:50 A.M.

TABLE II
YAKIMA RIVER BRIDGE
SR 24
CATHODIC PROTECTION SYSTEM
YAKIMA, WASHINGTON

October 1986

PROBE POTENTIAL vs. REFERENCE CELL - mV
PROBE (-)

P 1.	54	P 4.	(-) 67
P 2.	365	P 5.	NO READING
P 3.	160	P 6.	56.5

AIR TEMP - 63F

TIME 11:00 A.M.

TABLE III
YAKIMA RIVER BRIDGE
SR 24
CATHODIC PROTECTION SYSTEM
YAKIMA, WASHINGTON

October 1986

RESISTANCE - ohms

REBAR PROBE	TO REBAR
PROBE	
P-1.	26,000
P-2.	900
P-3.	1,200
P-4.	13,000
P-5	2,500
P-6.	1,200

AIR TEMP - 63F

TIME 11:40 A.M.

TABLE IV
YAKIMA RIVER BRIDGE
SR 24
CATHODIC PROTECTION SYSTEM
YAKIMA, WASHINGTON

October 1986

REBAR PROBE vs. INST. NEGATIVE

POTENTIAL BETWEEN REBAR PROBE AND REBAR - mV

REBAR (+)

P 1.	(-) 47	P 4.	139
P 2.	(-) 21	P 5.	330
P 3.	450	P 6.	300

AIR TEMP - 63F

TIME 11:45 A.M.

TABLE V
YAKIMA RIVER BRIDGE
SR 24
CATHODIC PROTECTION SYSTEM
YAKIMA, WASHINGTON

October 1986

INDIVIDUAL CIRCUIT OUTPUTS

	PORTABLE METER		RECTIFIER METER	
	VOLTS	AMPS	VOLTS	AMPS
ZONE 1	6.13	4.56	5.7	4.2
ZONE 2	5.3	11.28	5.0	11
ZONE 3	4.04	4.52	4.2	4.5

AIR TEMP - 63F

TIME 10:55 A.M.

TABLE VI
YAKIMA RIVER BRIDGE
SR 24
CATHODIC PROTECTION SYSTEM
YAKIMA, WASHINGTON

October 1986

REBAR PROBLE CURRENT - ma

MEASURED BETWEEN THE REBAR PROBE AND THE REBAR, REBAR (+)

PROBE		
P-1.	(-)	.042
P-2.	(-)	.133
P-3		.043
P-4.		.056
P-5.		.032
P-6.		.050

AIR TEMP - 63F

TIME 11:15 A.M.

TABLE VII
YAKIMA RIVER BRIDGE
SR 24
CATHODIC PROTECTION SYSTEM
YAKIMA, WASHINGTON

October 1986

DEPOLARIZATION TESTING

POTENTIAL - mV

	ZONE 1		ZONE 2		ZONE 3		PORTABLE REF. CELL
TIME	REF 1	REF 2	REF 3	REF 4	REF 5	REF 6	REF 4A
ON	UNSTABLE	345	338	204	325	358	280
FIRST OFF(12:10)	READINGS	313	338	198	275	324	200
12:20		282	335	199	236	306	144
12:30		270	334	199	222	298	135
12:40		261	333	199	212	293	126
12:50		254	333	199	206	289	119
1:00	UNSTABLE READINGS	248	332	199	200	286	108
1:10		243	332	199	196	284	106
1:40		234	331	199	188	279	98
2:10		227	331	199	183	276	100
2:40		222	331	202	178	274	92
3:10	UNSTABLE READINGS	216	330	201	176	273	89
3:40		214	331	203	173	272	91
4:10		212	331	204	171	271	85

AIR TEMP - 63F

TIME 10:50 A.M.

APPENDIX B

PREVIOUS REPORTS & TEST DATA

ENGINEERING DATA SHEET

WASHINGTON D.O.T--BRIDGE SR 24 YAKIMA -- 85FX01 | DATE. | 11-5/6/85

45 DEG. F

TEMPERATURE

PANEL END TO END RESISTANCE --BEFORE POUR

BRIDGE	PANEL NO.	RESISTANCE		BRIDGE	PANEL NO.	RESISTANCE
WEST BOUND	1			EAST BOUND	4	13.2
WEST BOUND	2			EAST BOUND	5	13.6
WEST BOUND	3			EAST BOUND	6	CL
WEST BOUND	7			EAST BOUND	11	12.9
WEST BOUND	8			EAST BOUND	12	13.1
WEST BOUND	9			EAST BOUND	13	12.2
WEST BOUND	10			EAST BOUND	14	12.4
WEST BOUND	15			EAST BOUND	18	13.7
WEST BOUND	16			EAST BOUND	19	13.6
WEST BOUND	17			EAST BOUND	20	13.3

INDIVIDUAL CIRCUIT OUTPUTS

DATE	11-5-85			Current mA/s f	SYST NEG TO SYST NEG	
ZONE NO.	VOLTAGE	CURRENT	CIR. RES.	of concrete surface	RESISTANCE BEFORE POUR	
1	4.6	4.4	1.05	0.76		
2	3.3	5.5	0.6	0.75	PANEL #	OHMS
3	3.2	4.4	0.73	0.76	1--3	0.41
DATE	11-6-85				7--10	0.85
1	5.9	4.2	1.4	0.72	15--17	0.52
2	2.96	5.4	0.55	0.74	4--6	0.63
3	4.85	4.65	1	0.84	11--14	0.79
DATE	11-6-85				18--20	0.44
1	6.22	6.44	0.97	1.11		
2	5.33	11.64	0.46	1.6		
3	3.55	4.68	0.76	0.81		

	A	B	C	D	E	F	G
39	++						
40	SYS NEG TO PANEL RESIST -- BEFORE POUR				SYSTEM NEGATIVE TO PANEL +---A.C. RESIST. A		
41	WEST BOUND		EAST BOUND				OHMS
42		OHMS		OHMS			
43	1 - 1	INFINITY	4 - 4	INFINITY	SN1 - P1,2,3 +		1.1
44	3 - 3	INFINITY	6 - 6	INFINITY	SN1-P4,5,6 +		1.2
45	7 - 7	INFINITY	11 - 11	INFINITY	SN2-P7,8,9,10 +		2
46	10 - 10	INFINITY	14 - 14	INFINITY	SN2-P11,12,13,14 +		1.8
47	15 - 15	INFINITY	18 - 18	INFINITY	SN3-P15,16,17 +		1.3
48	17 - 17	INFINITY	20 - 20	INFINITY	SN3-P18,19,20 +		1.4
49	++						
50	AgCL REF. TO $CuSO_4$ REF BEFORE POUR			Ag Cl REF. TO $CuSO_4$ REF. AFTER POUR			
51	CELL	VOLTAGE	LANE	CELL	VOLTAGE	LANE	
52	AGCL 1	N/A	EB	AGCL 1	-.492	EB	
53	AGCL 2	N/A	WB	AGCL 2	-.131	WB	
54	AGCL 3	N/A	EB	AGCL 3	-.163	EB	
55	AGCL 4	N/A	WB	AGCL 4	-.126	WB	
56	AGCL 5	N/A	WB	AGCL 5	-.241	WB	
57	AGCL 6	N/A	EB	AGCL 6	-.208	EB	
58	++						
59	REBAR POTENTIALS VS. AgCl REF-AFTER POUR			$CuSO_4$ over	INITIAL POTENTIALS AFTER ENERGIZING		
60	INS. NEG.	REF CELL	STATIC POT.	AgCl Ref	ON" POTENTIAL	OFF" POTENTIAL	
61	ALL ZONE	REF 1	-0.239	-0.151	-0.415	-0.378	
62	INSTRUMENT	REF 2	-0.282	-0.143	-0.415	-0.393	
63	NEGATIVES	REF 3	-0.382	-0.214	-0.376	-0.379	
64	ARE TIED	REF 4	-0.275	-0.109	-0.276	-0.269	
65	TOGETHER	REF 5	-0.357	-0.113	-0.426	-0.422	
66		REF 6	-0.352	-0.142	-0.439	-0.418	
67	++						
68	REBAR POTENTIALS AND CURRENTS - BEFORE ENERGIZE				AFTER ENERGIZING		A C RESIST
69	PROBE NO.	VOLTAGE	CURRENT		VOLTAGE	CURRENT	IN OHMS
70		BETW. REBAR	BETW. REBAR		BETW. REBAR	BETW. REBAR	
71	P1	0.068	-48uA			-38uA	370
72	P2	-0.073	48uA			-39uA	280
73	P3	0.167	-107uA			-185uA	340
74	P4	0.038	-38uA			-18uA	300
75	P5	0.158	-158uA			-158uA	390
76	P6	0.262	-262uA			-168uA	360

A	B	C	D	E	F	G
	DEPOLARIZATION TEST AFTER 16 HOURS ON					
TIME		POTENTIALS IN MILLIVOLTS		AND ALL ARE NEGATIVE VS. REFERENCE		
MINUTES	CELL R1	CELL R2	CELL R3	CELL R4	CELL R5	CELL R6
0	736	388	380	273	413	394
15	745	325	380	273	374	366
30	758	314	380	273	366	360
45	763	308	380	273	362	356
60	766	303	380	273	359	354
75	765	298	380	273	357	352
90	775	296	380	273	357	352
105	779	292	380	273	355	350
120	778	290	380	273	355	349
135	779	289	380	272	355	349
150	780	287	380	272	354	349
165	794	286	380	271	354	349
RECTIFIER OUTPUT PRIOR TO DEPOLARIZATION TEST						
CIRCUIT 1	4.2 AMPS	5.9 VOLTS				
CIRCUIT 2	5.4 AMPS	3.0 VOLTS				
CIRCUIT 3	4.4 AMPS	4.9 VOLTS				

A	B	C	D	E	F	G
	POTENTIALS VS. A SURFACE COPPER SULPHATE REFERENCE CELL OVER PANEL NO. 6					
	TAKEN TO VERIFY THE BREAK IN THE ANODE HAS NO					
	DETRIMENTAL EFFECT ON THE C. P. SYSTEM'S PERFORMANCE					
			POTENTIALS EXPRESSED IN MILLIVOLTS			
		CENTER LINE	OUT 10.5 FT	OUT 5.25 FT.	AT CURB	
EXP JT =0+00	ON POTENTIAL	-222	-174	-194	-225	
	OFF POTENTIAL	-215	-170	-188	-212	
	DELTA V	-7	-4	-6	-13	
0+08	ON POTENTIAL	-746	-686	-659	-878	
	OFF POTENTIAL	-389	-326	-330	-349	
	DELTA V	-357	-360	-329	-529	
0+16	ON POTENTIAL	-443	-548	-734	-628	
	OFF POTENTIAL	-262	-315	-369	-397	
	DELTA V	-181	-233	-365	-231	
0+24	ON POTENTIAL	-550	-608	-458	-453	
	OFF POTENTIAL	-324	-330	-293	-279	
	DELTA V	-226	-278	-165	-174	
0+32	ON POTENTIAL	-412	-442	-418	-253	
	OFF POTENTIAL	-296	-300	-254	-208	
	DELTA V	-116	-142	-164	-45	
0+40	ON POTENTIAL	-308	-459	-438	-308	
	OFF POTENTIAL	-229	-292	-270	-235	
	DELTA V	-79	-167	-168	-73	
0+48	ON POTENTIAL	-352	-506	-569	-580	
	OFF POTENTIAL	-240	-285	-320	-339	
	DELTA V	-112	-221	-249	-241	
0+56	ON POTENTIAL	-435	-723	-869	-583	
	OFF POTENTIAL	-282	-320	-368	-285	
	DELTA V	-153	-403	-501	-298	
0+64	ON POTENTIAL	-541	-792	-696	-720	
	OFF POTENTIAL	-309	-425	-358	-346	
		-232	-367	-338	-374	

	A	B	C	D	E	F	G
1			ENGINEERING WORKSHEET				
2							
3	WASHINGTON	D O T--BRIDGE SR 24 YAKIMA-85FX01			DATE:		
4	++++++++++	++++++++++	++++++++++	++++++++	++++++++	++++++++	++++++++
5							
6	INDIVIDUAL CIRCUIT OUTPUTS						
7							
8		--PORTABLE METER--		--RECTI...		TEMPERATURE	
9	ZONE NUMB...	VOLTS D.C.	AMPS D.C.	VOLTS D.C	AMPS D.C.		
10	----------	----------	----------	--------	--------	--------	--------
11	1						
12	2						
13	3						
14	++++++++++	++++++++++	++++++++++	++++++++	++++++++	++++++++	++++++++
15							
16	Ag/AgCL REFERENCE ELECTRODE POTENTIALS VS. THE INSTRUMENT NEGATIVE						
17		The Reference Electrode should be connected to the D.C.					
18		voltmeter's "Common" terminal and the Instrument					
19		Negative should be connected to the positive voltmeter					
20		terminal. This configuration results in "negative					
21		Potentials displayed on the meter.					
22							
23	REFERENCE ...	ON POTENTIAL"	OFF POTENTIAL"			TEMPERATURE	
24	----------	----------	----------	--------	--------	--------	--------
25	R1						
26	R2						
27	R3						
28	R4						
29	R5						
30	R6						
31	++++++++++	++++++++++	++++++++++	++++++++	++++++++	++++++++	++++++++
32		REBAR PROBE POTENTIALS AND CURRENTS					
33							
34	Probe Potentials VS. Ref. Cell(Connect probe to "positive" and Ref. cell to "common".)						
35		VOLTAGE		VOLTAGE			
36	P1		P4				
37	P2		P5				
38	P3		P6				
39							
40	Rebar Probe Currents VS. Ins. Neg.(Connect probe to"common" and Ins. Neg. to "positive")						
41		CURRENT(uA)		CURRENT(uA)			
42	P1		P4				
43	P2		P5				
44	P3		P6				
45							
46							

FOUR HOUR DEPOLARIZATION TEST

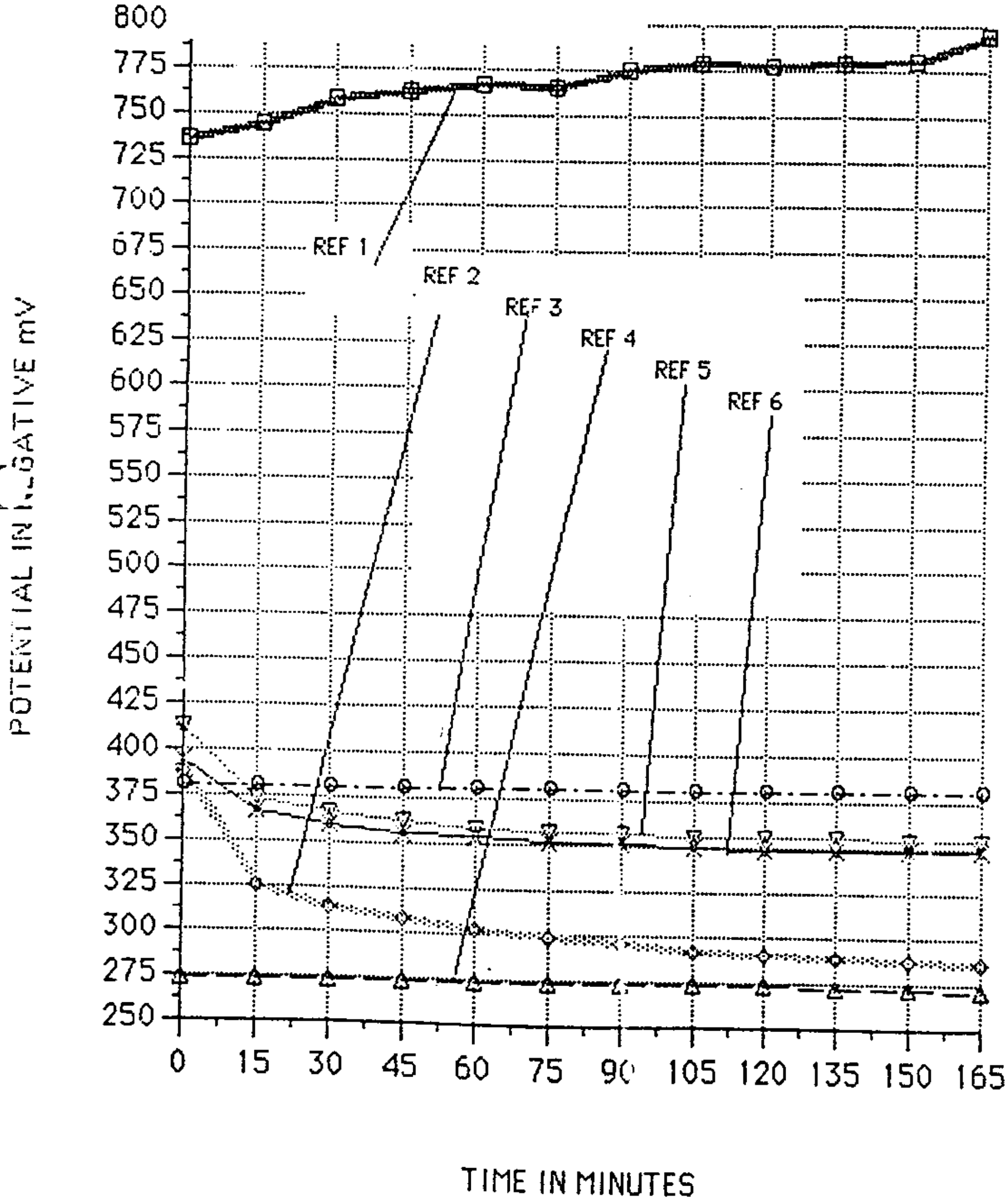
Connect the Reference Electrode to the common" and the Instrument Negative to the voltmeter "pos;tive" terminals

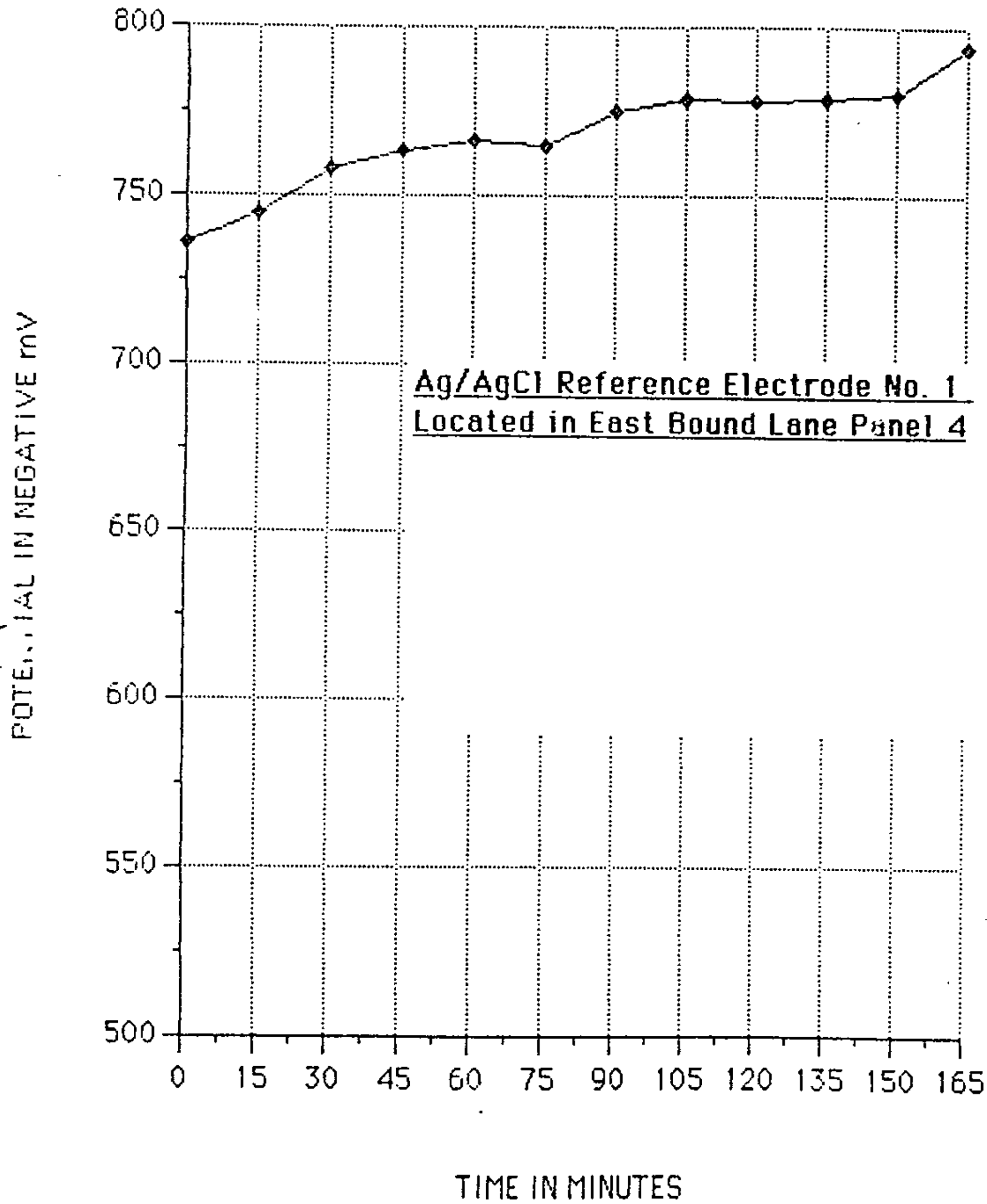
A	B	C	D	E	F	G
TIME(MINUT...	REF.1	REF.2	REF.3	REF.4	REF.5	REF.6
0-RECT ON						
0- RECT OFF						
10						
20						
30						
40						
50						
60						
90						
120						
150						
180						
210						
240						

PROCEDURE:

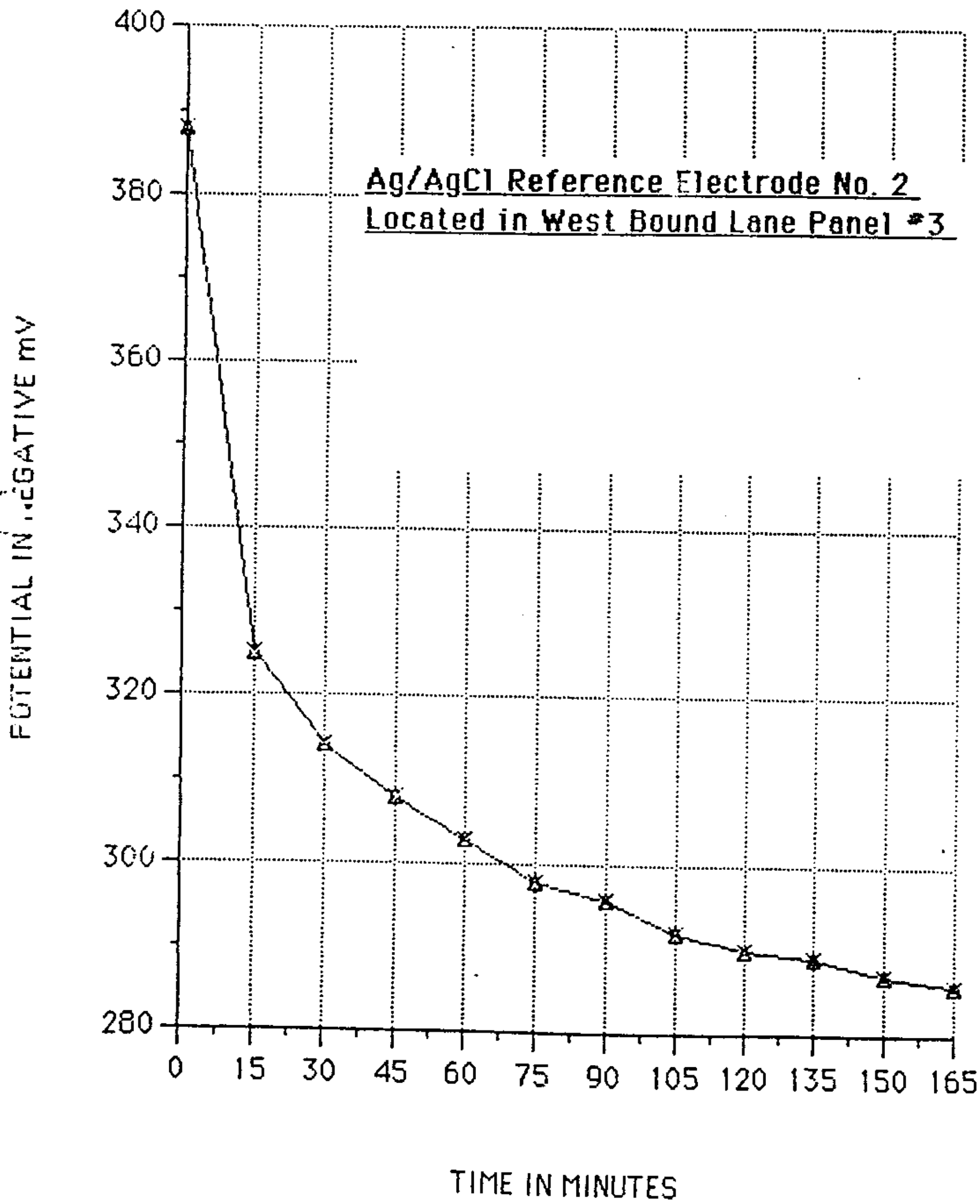
Connect reference electrodes to meter ans instrument negatives. Snap the rectifier off for 1-2 seconds and individually measure each cell's Instant Off Potential. These potentials are the "0" minute values. Then shut the rectifier off and leave it off. Measure potentials on the reference cells every 10 minutes for the first hour and every 30 minutes for the next 3 hours. The depolarization value for each cell is calculated by subtracting the cell potential after 4 hours from the starting instant off potential recorded at "0" minutes. This depolarization value should range between 100 and 250 millivolts. The circuit outputs should be adjusted accordingly.

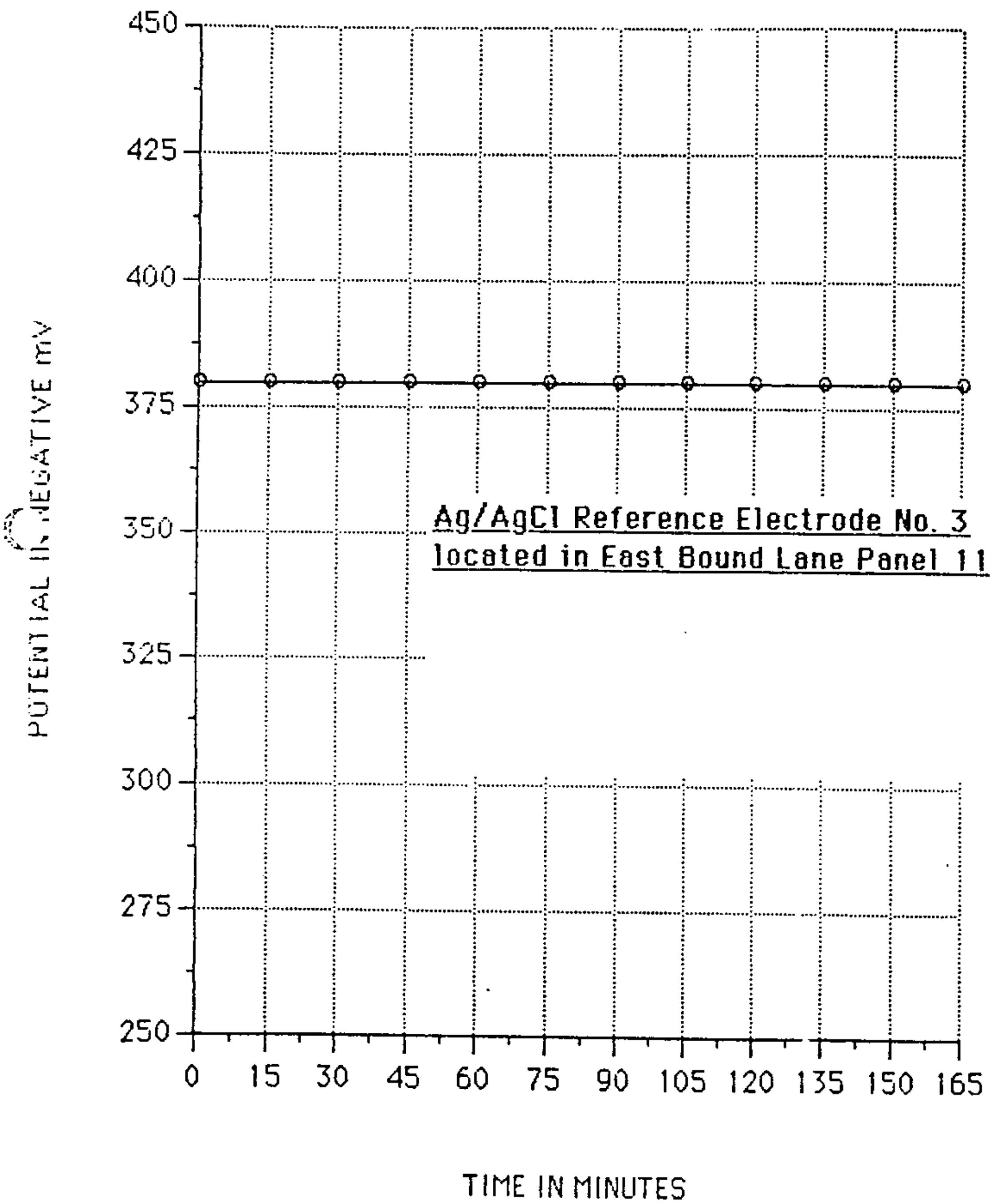
DEPOLARIZATION PLOTS OF ALL
REFERENCE CELLS ON BRIDGE
SR 24 YAKIMA TO MOXEE

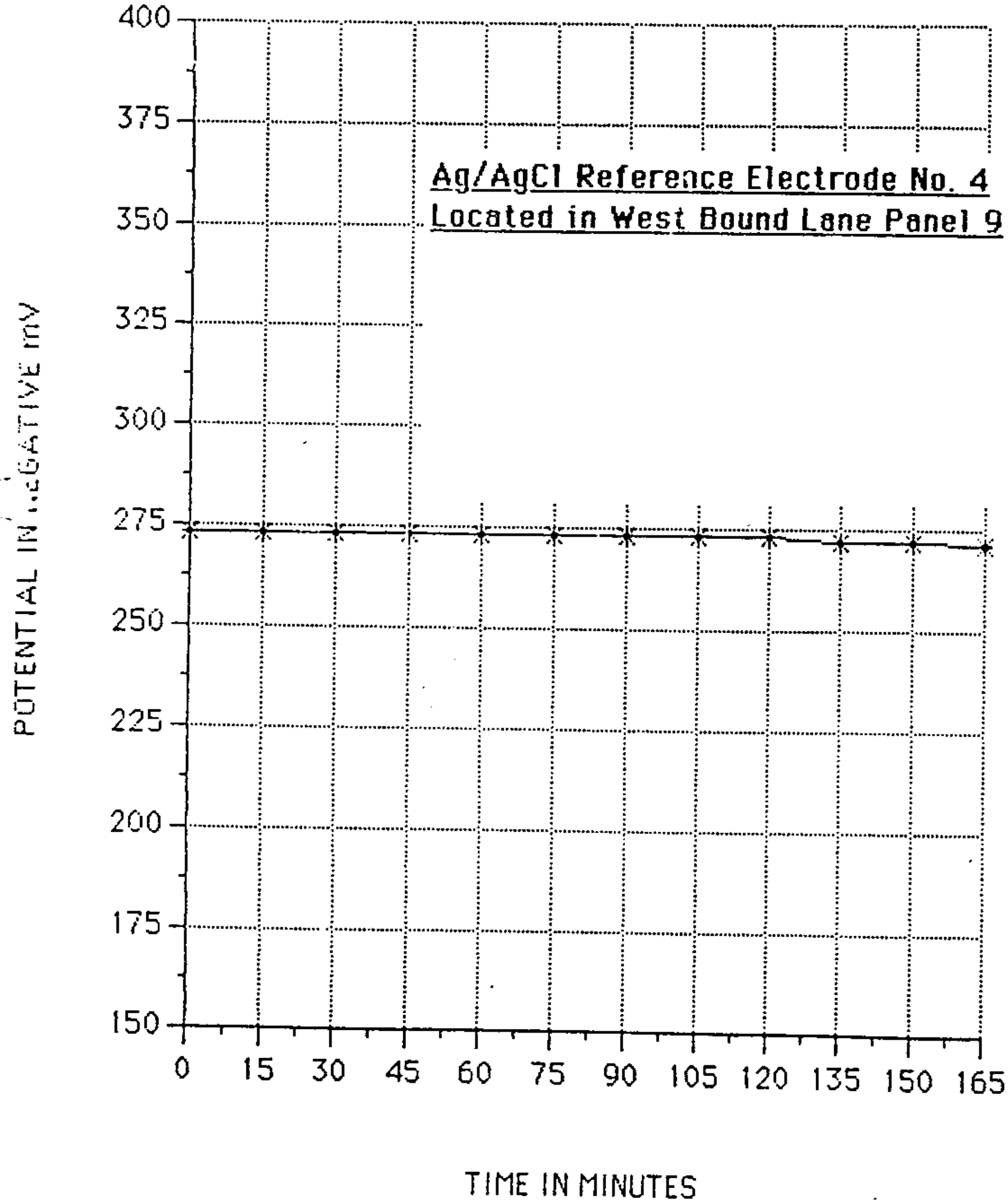


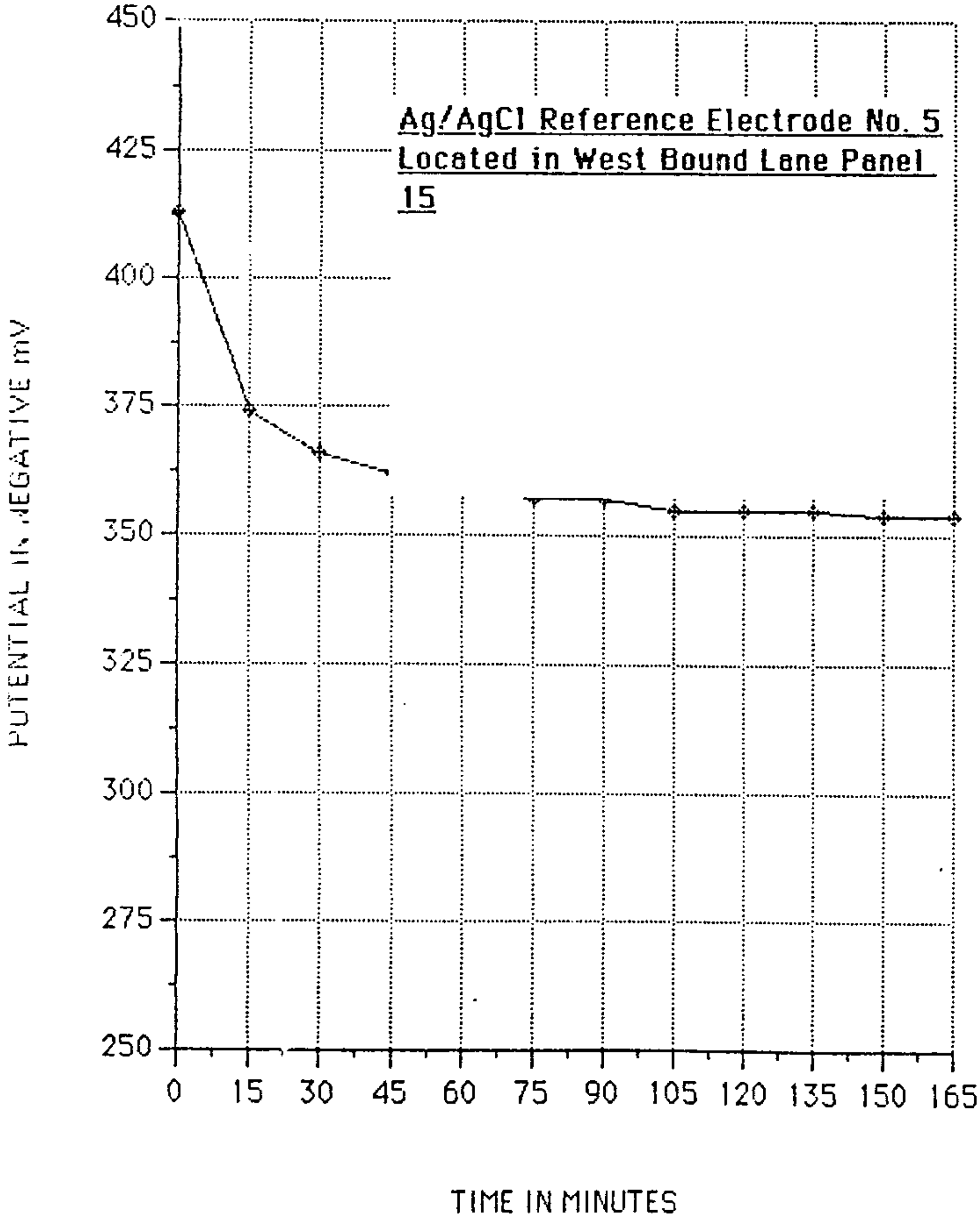


800
750
700
650
600
550
500
POTE...IAL IN NEGATIVE mV
Ag/AgCl Reference Electrode No. 1
Located in East Bound Lane Panel 4
0 15 30 45 60 75 90 105 120 135 150 165
TIME IN MINUTES

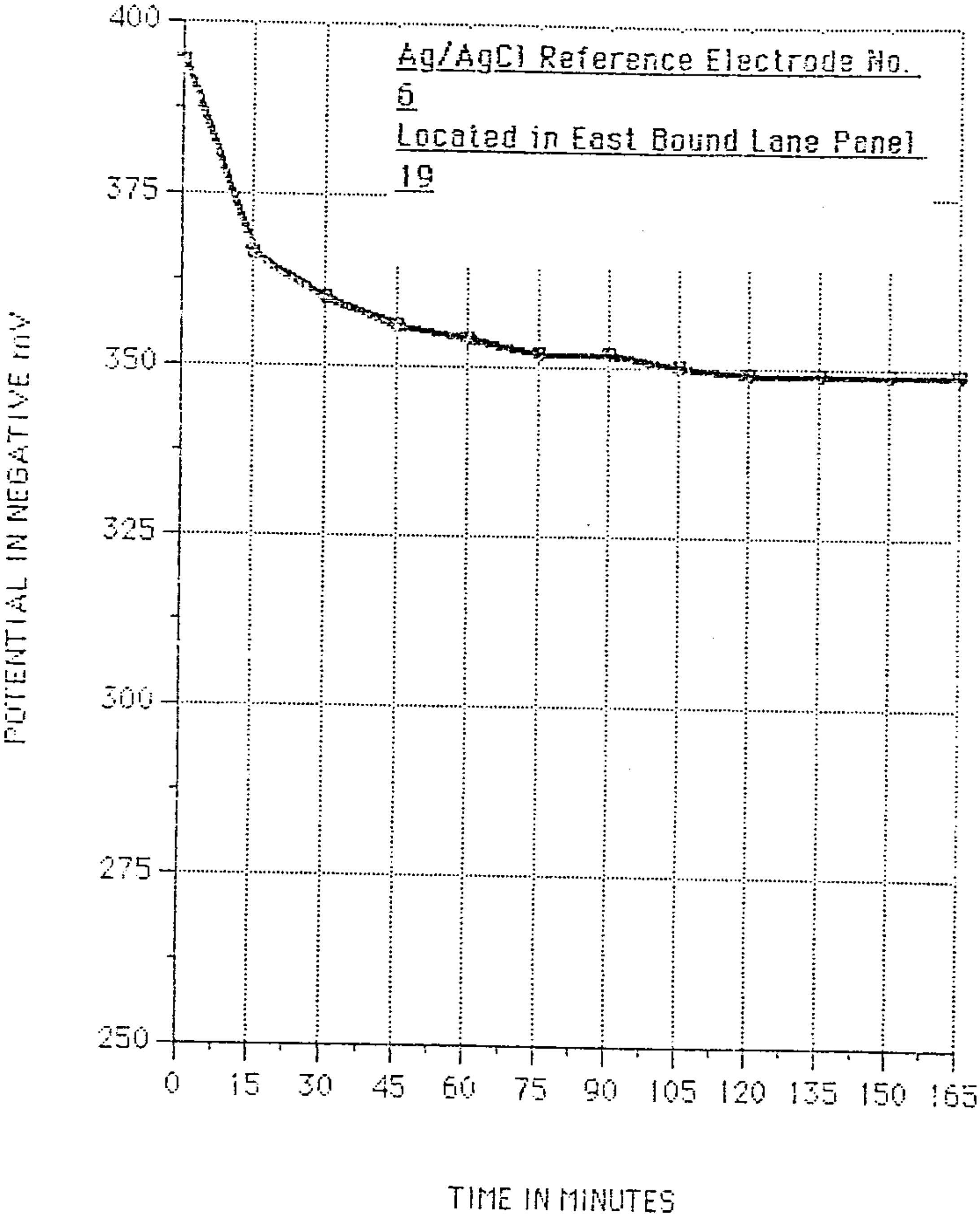

Ag/AgCl Reference Electrode No. 2
Located in West Bound Lane Panel #3
400
380
360
340
320
300
280
0
15
30
45
60
75
90
105
120
135
150
165
TIME IN MINUTES


450
425
400
375
350
325
300
275
250
POTENTIAL IN NEGATIVE mV
Ag/AgCl Reference Electrode No. 3
located in East Bound Lane Panel 11
0
15
30
45
60
75
90
105
120
135
150
165
TIME IN MINUTES


Ag/AgCl Reference Electrode No. 4
Located in West Bound Lane Panel 9
400
375
350
325
300
275
250
225
200
175
150
POTENTIAL IN NEGATIVE mV
0
15
30
45
60
75
90
105
120
135
150
165
TIME IN MINUTES



Ag/AgCl Reference Electrode No. 5
Located in West Bound Lane Panel
15
450
425
400
375
350
325
300
275
250
0
15
30
45
60
75
90
105
120
135
150
165
TIME IN MINUTES
POTENTIAL IN NEGATIVE mV


Ag/AgCl Reference Electrode No. 6
Located in East Bound Lane Panel 19
POTENTIAL IN NEGATIVE mV
400
375
350
325
300
275
250
0
15
30
45
60
75
90
105
120
135
150
165
TIME IN MINUTES

HARCO CORPORATION

Cathodic Protection Division

3411 ARDEN ROAD · HAYWARD, CALIFORNIA 94545 · (415) 783-0924

September 25, 1986
KMH-086-068a

Mr. Leonard Pittman
Washington State Department of Transportation
115 E. Ahtanum Road
Union Gap, WA 98903

Dear Mr. Pittman,

The enclosed report which pertains to the cathodic protection system on State Route 24, Yakima to Moxee Canal, includes the data collected during the system energization as well as the evaluation survey performed in January. A copy of this report has been sent to Tom Roper at the D.O.T. in Olympia.

If there are any questions regarding the cathodic protection system or the report, please direct them to our Hayward, California office at (415) 783-0924.

Yours truly,

HARCO CORPORATION

Kerri M. Howell

Kerri M. Howell, P.E.

KMH/v

cc: Tom Roper/State of Washington
Office of Bridge & Structures
Highway Administration Bldg.
Olympia, WA 98504

encl./6 copies of report

CATHODIC PROTECTION SYSTEM
STATE ROUTE 24
YAKIMA TO MOXEE CANAL
F.A. PROJECT NO. F-024 (13)

HARCO CORPORATION
Corrosion Engineering Division

CATHODIC PROTECTION SYSTEM
STATE ROUTE 24
YAKIMA TO MOXEE CANAL
F.A. PROJECT NO. F-024 (13)

PREPARED FOR:

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION
115 E. AHTANUM ROAD
UNION GAP, WASHINGTON 98903
ATTN: LEONARD PITTMAN

PREPARED BY:

HARCO CORPORATION
3411 ARDEN ROAD
HAYWARD, CALIFORNIA 94545

KMH-086-068

KMH-086-068

TABLE OF CONTENTS

INTRODUCTION

During August of 1985 an impressed current cathodic protection system was installed on SR 24 Yakima to Moxee Canal. The major components of the system are "Anode Flex" as manufactured by Raychem, a cathodic protection rectifier manufactured by Goodall, 6 rebar probes and 6 silver-silver chloride reference electrodes supplied by Harco Corporation. The materials and installation for this project are as shown in the specifications and as-built drawings.

OBJECTIVE:

Harco Corporation performed two corrosion engineering surveys of the structure after installation of the cathodic protection system. The first took place on November 5 and 6. At this time, the system was energized and electrical measurements were made to determine that the system was functioning properly and to establish the operating level of the rectifier.

The second survey was performed on January 30, 1986. The purpose of which was to check the system operation and make any necessary adjustments to the rectifier output. The data from these surveys is contained in this report.

CONCLUSIONS:

The cathodic protection system on the Yakima to Moxee Canal bridge deck was surveyed after approximately 90 days of operation. The results of the reference cell polarization decay indicate that the reinforcing steel in the deck has polarized and is cathodically protected.

One of the accepted criterion for determining whether a reinforced concrete structure is cathodically protected is a polarization decay of 100 millivolts in a four hour period. Projecting the decay from three hours to four hours would provide a 100 millivolt decay in all zones.

The rectifier output of zone 1 was decreased because the decay in zone 1 after three hours was 138 millivolts. This would indicate that more current was being delivered than is necessary to protect the structure.

RECOMMENDATIONS:

We recommend that the system be monitored on a monthly basis. This should include checking the rectifier outputs of all zones, verifying those readings with a portable multi-meter and recording all measurements taken at the monitoring station junction box. We would also suggest that a corrosion survey be performed by a qualified engineer on an annual basis to make any necessary adjustments. Harco Corporation will gladly review the monthly inspection sheets if you will send them to our Hayward, California office.

CATHODIC PROTECTION SYSTEM SURVEY (JAN. 1986):

The testing performed during the January survey consisted of electrical measurements taken at the monitoring station junction box using a high impedance Beckman multi-meter and a Nilsson 400 soil resistance meter.

Initial readings were taken when we arrived at the site. The rectifier was then turned off and the system was allowed to depolarize. The polarization decay was recorded and the system was energized once again to make any necessary adjustments to the rectifier outputs. The weather on the day of the survey was sunny and cold and the temperature of the bridge deck was 32 F.

READINGS TAKEN PRIOR TO DEPOLARIZATION

RECTIFIER OUTPUTS

	VOLTS	AMPS
ZONE 1	6.0	6.0
ZONE 2	4.9	11.8
ZONE 3	3.5	4.5

RESISTANCE (OHMS) BETWEEN REFERENCE ELECTRODE AND REINFORCING STEEL:

CELL 1	32,000 ohm
CELL 2	370 ohm
CELL 3	420 ohm
CELL 4	10,900 ohm
CELL 5	3,400 ohm
CELL 6	580 ohm

REFERENCE CELL POTENTIALS * (Millivolts)

CELL 1	839
CELL 2	467
CELL 3	397
CELL 4	258
CELL 5	414
CELL 6	418

* These readings were obtained while the rectifier was operating. The positive connection was made to the reference cell and the negative connection to the reinforcing steel.

REBAR PROBE POTENTIALS (Millivolts)

Probe	1	91
Probe	2	104
Probe	3	380
Probe	4	145
Probe	5	265
Probe	6	263

REBAR PROBE CURRENT (Milliamps)

Probe	1	0.040
Probe	2	0.120
Probe	3	0.290
Probe	4	0.019
Probe	5	0.230
Probe	6	0.280

POLARIZATION DECAY

(January 1986)

REFERENCE CELL	1	2	3	4	5	6
Rectifier ON	825	397	467	258	412	417
Instant OFF	815	378	433	245	412	390
1 Min	810	394	368	253	392	357
2 Min	815	378	367	254	383	349
3 Min	814	372	366	254	379	344
4 Min	819	368	365	254	375	340
5 Min	816	361	364	254	371	336
10 Min	815	344	360	254	361	326
20 Min	817	323	356	254	349	314
30 Min	818	309	354	254	343	307
40 Min	818	298	352	254	340	303
50 Min	818	289	351	254	337	299
60 Min	818	282	350	254	336	296
70 Min	818	276	348	253	334	293
80 Min	819	271	348	253	332	291
90 Min	820	267	347	253	331	289
100 Min	830	261	348	253	330	288
110 Min	820	258	346	253	329	287
120 Min	830	254	345	253	329	286
135 Min	818	250	345	253	328	284
150 Min	818	246	344	252	326	282
165 Min	820	243	344	252	327	282
180 Min	834	240	343	252	326	280

ALL READINGS ARE IN MILLIVOLTS

When power was restored, the following readings were recorded:

RECTIFIER OUTPUTS

	VOLTS	AMPS
ZONE 1	4.8	4.5
ZONE 2	5.0	10.8
ZONE 3	3.5	4.5

* REFERENCE CELL POTENTIALS (Millivolts)

CELL 1	840
CELL 2	325
CELL 3	390
CELL 4	259
CELL 5	376
CELL 6	369

Rectifier had been operating for 5 minutes

CATHODIC PROTECTION SYSTEM ENERGIZATION (NOVEMBER 1985):

The following data was obtained when the system was energized in November, 1985:

RECTIFIER OUTPUTS

	VOLTS	AMPS
ZONE 1	5.9	4.2
ZONE 2	3.0	5.4
ZONE 3	4.9	4.9

REFERENCE CELL POTENTIALS * (Millivolts)

CELL 1	415
CELL 2	415
CELL 3	376
CELL 4	276
CELL 5	426
CELL 6	439

* These readings were obtained while the rectifier was operating. The positive connection was made to the reference cell and the negative connection to the reinforcing steel.

REBAR PROBE POTENTIALS (Millivolts)

Probe 1	68
Probe 2	73
Probe 3	167
Probe 4	38
Probe 5	158
Probe 6	262

REBAR PROBE CURRENT (Milliamps)

Probe 1	0.048
Probe 2	0.048
Probe 3	0.107
Probe 4	0.038
Probe 5	0.158
Probe 6	0.262

After the polarization decay, the rectifier was adjusted to the following outputs:

RECTIFIER OUTPUTS

	VOLTS	AMPS
ZONE 1	6.2	6.4
ZONE 2	5.3	11.6
ZONE 3	3.6	4.7

REBAR PROBE CURRENT (Milliamps)

Probe 1	0.038
Probe 2	0.039
Probe 3	0.185
Probe 4	0.018
Probe 5	0.158
Probe 6	0.168

POLARIZATION DECAY

(November 1985)

REFERENCE CELL	1	2	3	4	5	6
Instant OFF	736	388	380	273	413	394
15 Min	745	325	380	273	374	366
30 Min	758	314	380	273	366	360
45 Min	763	308	380	273	362	356
60 Min	766	303	380	273	359	354
75 Min	765	298	380	273	357	352
90 Min	775	296	380	273	357	352
105 Min	779	292	380	273	355	350
120 Min	778	290	380	273	355	349
135 Min	779	289	380	272	355	349
150 Min	780	287	380	272	354	349
165 Min	794	286	380	272	354	349

ALL READINGS ARE IN MILLIVOLTS

2 month report

ENGINEERING WORKSHEET

WASHINGTON D O T--BRIDGE SR 24 YAKIMA-85FX01 DATE: 1-30-86 Ron Teglar, Kan Flatt

++

INDIVIDUAL CIRCUIT OUTPUTS — Weather - ovc, FOG, 40° wet pavement

ZONE NUMB...	--PORTABLE METER-- VOLTS D.C.	AMPS D.C.	--RECTI... VOLTS D.C	AMPS D.C.	TEMPERATURE
1	5.12	4.8	4.8	4.5	37°
2	5.25	11.6	5.0	10.8	38°
3	3.56	4.7	3.5	4.5	37°

++

Ag/AgCL REFERENCE ELECTRODE POTENTIALS VS. THE INSTRUMENT NEGATIVE

The Reference Electrode should be connected to the D.C. voltmeter's "Common" terminal and the Instrument Negative should be connected to the positive voltmeter terminal. This configuration results in "negative Potentials displayed on the meter.

REFERENCE ...	ON POTENTIAL"	OFF POTENTIAL"	TEMPERATURE
R1	0.78	—	—
R2	0.36	—	—
R3	0.39	—	—
R4	0.26	—	—
R5	0.40	—	—
R6	0.39	—	—

++

REBAR PROBE POTENTIALS AND CURRENTS

Probe Potentials VS. Ref. Cell(Connect probe to "positive" and Ref. cell to "common".)

	VOLTAGE		VOLTAGE
P1	-0.70	P4	-0.24
P2	-0.36	P5	-0.10
P3	-0.01	P6	-0.07

Rebar Probe Currents VS. Ins. Neg.(Connect probe to "common" and Ins. Neg. to "positive")

	~~CURRENT(uA)~~		~~CURRENT(uA)~~
P1	83.6	P4	13.3
P2	5.8	P5	301
P3	385	P6	329
	VOLTS mV		VOLTS mV

MARCH-86 1 MONTH REPORT RON TEGELER

	A	B	C	D	E	F	G
1			ENGINEERING WORKSHEET				
2							
3	WASHINGTON	D O T--BRIDGE SR 24 YAKIMA-85FX01			DATE:	3-3-86	9:00 AM
4	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++
5		WEATHER PARTLY CLOUDY, DRY PAVEMENT 44°F					
6	INDIVIDUAL CIRCUIT OUTPUTS						
7							
8		--PORTABLE METER--		--RECTI...		TEMPERATURE	
9	ZONE NUMB...	VOLTS D.C.	AMPS D.C.	VOLTS D.C	AMPS D.C.		
10	-----------	-----------	-----------	-----------	-----------	-----------	-----------
11	1	5.13	4.72	4.80	4.5	48°	
12	2	5.26	11.48	5.00	11.0	48°	
13	3	3.57	4.68	3.50	4.50	48°	
14	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++
15							
16	Ag/AgCL REFERENCE ELECTRODE POTENTIALS VS. THE INSTRUMENT NEGATIVE						
17		The Reference Electrode should be connected to the D.C.					
18		voltmeter's "Common" terminal and the Instrument					
19		Negative should be connected to the positive voltmeter					
20		terminal. This configuration results in "negative					
21		Potentials displayed on the meter.					
22							
23	REFLRENCE ...	ON POTENTIAL"	OFF POTENTIAL"			TEMPERATURE	
24	-----------	-----------	-----------	-----------	-----------	-----------	-----------
25	R1	0.772	—			—	
26	R2	0.364	—			—	
27	R3	0.376	—			—	
28	R4	0.288	—			—	
29	R5	0.377	—			—	
30	R6	0.385	—			—	
31	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++	+++++++++++
32		REBAR PROBE POTENTIALS AND CURRENTS					
33							
34	Probe Potentials VS. Ref. Cell(Connect probe to "positive" and Ref. cell to "common".)						
35		VOLTAGE		VOLTAGE			
36	P1	−0.690	P4	−0.190			
37	P2	−0.348	P5	−0.095			
38	P3	+0.030	P6	−0.050			
39							
40	Rebar Probe Currents VS. Ins. Neg.(Connect probe to "common" and Ins. Neg. to "positive")						
41		~~CURRENT(uA)~~		~~CURRENT(uA)~~			
42	P1	87.8	P4	97.2			
43	P2	16.0	P5	294			
44	P3	406	P6	335			
45							
46		VOLTS (MV)		VOLTS (MV)			

April - 86   1 Month Report   Ron Teeter

	A	B	C	D	E	F	G
1			ENGINEERING WORKSHEET				
2							
3	WASHINGTON D O T--BRIDGE SR 24 YAKIMA-85FX01				DATE:	4-1-86	2:00PM
4	++						
5	Weather - Pretty Cloudy Dry Pavement -					60° F	
6	INDIVIDUAL CIRCUIT OUTPUTS						
7							
8		--PORTABLE METER--		--RECTI...		TEMPERATURE	
9	ZONE NUMB...	VOLTS D.C.	AMPS D.C.	VOLTS D.C	AMPS D.C.		
10	--						
11	1	4.72	4.76	4.50	4.50	57.5°	
12	2	5.28	11.56	5.00	11.0	58°	
13	3	3.04	4.64	3.10	4.50	56.5°	
14	++						
15							
16	Ag/AgCL REFERENCE ELECTRODE POTENTIALS VS. THE INSTRUMENT NEGATIVE						
17		The Reference Electrode should be connected to the D.C.					
18		voltmeter's "Common" terminal and the Instrument					
19		Negative should be connected to the positive voltmeter					
20		terminal. This configuration results in "negative					
21		Potentials displayed on the meter.					
22							
23	REFLRENCE ...	ON POTENTIAL"	OFF POTENTIAL"			TEMPERATURE	
24	--						
25	R1	.282	—			—	
26	R2	.327	—			—	
27	R3	.377	—			—	
28	R4	.320	—			—	
29	R5	.360	—			—	
30	R6	.370	—			—	
31	++						
32		REBAR PROBE POTENTIALS AND CURRENTS					
33							
34	Probe Potentials VS. Ref. Cell(Connect probe to "positive" and Ref. cell to "~~common~~ positive".)						
35		VOLTAGE		VOLTAGE			
36	P1	-0.710	P4	-0.186			
37	P2	-0.338	P5	-0.116			
38	P3	+0.016	P6	-0.054			
39							
40	Rebar Probe Currents VS. Ins. Neg.(Connect probe to "common" and Ins. Neg. to "positive")						
41		~~CURRENT( )~~		~~CURRENT (m)~~			
42	P1	88.6	P4	134.4			
43	P2	-10.6	P5	244			
44	P3	391	P6	314			
45							
46		Volts (mV)		Volts (mV)			

MAY - 86 Ron TEGELER

	A	B	C	D	E	F	G
1			ENGINEERING WORKSHEET				
2							
3	WASHINGTON D O T--BRIDGE SR 24 YAKIMA-85FX01				DATE:	5-5-86	10:49AM
4	++						
5	WEATHER OVERCAST, DRY PAVEMENT					57°F	
6	INDIVIDUAL CIRCUIT OUTPUTS						
7							
8		--PORTABLE METER--		--RECTI...		TEMPERATURE	
9	ZONE NUMB...	VOLTS D.C.	AMPS D.C.	VOLTS D.C	AMPS D.C.		
10	--						
11	1	4.82	4.68	4.5	4.5	58°	
12	2	5.34	11.6	5.0	11.0	57°	
13	3	3.23	4.64	3.5	4.5	58°	
14	++						
15							
16	Ag/AgCL REFERENCE ELECTRODE POTENTIALS VS. THE INSTRUMENT NEGATIVE						
17		The Reference Electrode should be connected to the D.C.					
18		voltmeter's "Common" terminal and the Instrument					
19		Negative should be connected to the positive voltmeter					
20		terminal. This configuration results in "negative					
21		Potentials displayed on the meter.					
22							
23	REFERENCE ...	ON POTENTIAL"	OFF POTENTIAL"			TEMPERATURE	
24	--						
25	R1	.760	—				
26	R2	.345	—				
27	R3	.367	—				
28	R4	.316	—				
29	R5	.359	—				
30	R6	.383	—				
31	++						
32		REBAR PROBE POTENTIALS AND CURRENTS					
33							
34	Probe Potentials VS. Ref. Cell(Connect probe to "positive" and Ref. cell to "common".)						
35		VOLTAGE		VOLTAGE			
36	P1	-.711	P4	-.153			
37	P2	-.365	P5	-.097			
38	P3	+.018	P6	-.040			
39							
40	Rebar Probe Currents VS. Ins. Neg.(Connect probe to "common" and Ins. Neg. to "positive")						
41		CURRENT([illegible])		CURRENT([illegible])			
42	P1	55.7	P4	162.5			
43	P2	-20.0	P5	262			
44	P3	385	P6	343			
45							
46	VOLTS →	M.V.		M.V.			

June - 86 6-2-86 Ron Treeler

ENGINEERING WORKSHEET

WASHINGTON D O T--BRIDGE SR 24 YAKIMA-85FX01 DATE: 6-2-86 9:50 AM

WEATHER: HIGH OVERCAST BROKEN, DRY PAVEMENT 84° F

INDIVIDUAL CIRCUIT OUTPUTS

	--PORTABLE METER--		--RECTI...		TEMPERATURE
ZONE NUMB...	VOLTS D.C.	AMPS D.C.	VOLTS D.C	AMPS D.C.	
1	4.5	4.5	4.3	4.3	86°
2	5.4	11.2	5.0	11.0	86°
3	2.8	4.5	2.8	4.5	86°

Ag/AgCL REFERENCE ELECTRODE POTENTIALS VS. THE INSTRUMENT NEGATIVE

The Reference Electrode should be connected to the D.C. voltmeter's "Common" terminal and the Instrument Negative should be connected to the positive voltmeter terminal. This configuration results in "negative Potentials displayed on the meter.

REFERENCE ...	ON POTENTIAL"	OFF POTENTIAL"	TEMPERATURE
R1	.748		
R2	.319		
R3	.403		
R4	.303		
R5	.343		
R6	.365		

REBAR PROBE POTENTIALS AND CURRENTS

Probe Potentials VS. Ref. Cell(Connect probe to "positive" and Ref. cell to "common".)

	VOLTAGE		VOLTAGE
P1	-.692	P4	-.162
P2	-.366	P5	-.129
P3	-.110	P6	-.079

Rebar Probe Currents VS. Ins. Neg.(Connect probe to "common" and Ins. Neg. to "positive")

	CURRENT(uA)		CURRENT(uA)
P1	64.0	P4	141
P2	-48.0	P5	213
P3	292	P6	285
VOLTS	MV		MV

8-11-86 August [illegible]

ENGINEERING WORKSHEET

WASHINGTON D O T--BRIDGE SR 24 YAKIMA-85FX01 DATE:

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Weather: High overcast, Broken Dry Pavement 84° F

INDIVIDUAL CIRCUIT OUTPUTS

A	B	C	D	E	F	G
	--PORTABLE METER--		--RECTI...		TEMPERATURE	
ZONE NUMB...	VOLTS D.C.	AMPS D.C.	VOLTS D.C	AMPS D.C.		
1	4.65	4.4	4.5	4.5	91.5°	
2	5.41	11.2	5.0	11.0	91.4°	
3	2.84	4.4	3.0	4.5	90.1°	

++

Ag/AgCL REFERENCE ELECTRODE POTENTIALS VS. THE INSTRUMENT NEGATIVE

The Reference Electrode should be connected to the D.C. voltmeter's "Common" terminal and the Instrument Negative should be connected to the positive voltmeter terminal. This configuration results in "negative Potentials displayed on the meter.

REFLRENCE ...	ON POTENTIAL"	OFF POTENTIAL"			TEMPERATURE
R1	100 mV				
R2	332 mV				
R3	364 mV				
R4	263 mV				
R5	311 mV				
R6	389 mV				

++

REBAR PROBE POTENTIALS AND CURRENTS

Probe Potentials VS. Ref. Cell(Connect probe to "positive" and Ref. cell to "common".)

	VOLTAGE		VOLTAGE
P1	-104 mV	P4	-105 mV
P2	-348 mV	P5	-89 mV
P3	-65 mV	P6	-79 mV

Rebar Probe Currents VS. Ins. Neg.(Connect probe to "common" and Ins. Neg. to "positive")

	CURRENT([illegible])		CURRENT([illegible])
P1	25 mV	P4	-157 mV
P2	17 mV	P5	-221 mV
P3	-298 mV	P6	-310 mV
Volts	MV		MV

2 MONTH REPORT NOV. - DEC. TAKEN 12-29-86 RON TEGELER

	A	B	C	D	E	F	G
1			ENGINEERING WORKSHEET				
2							
3	WASHINGTON	D O T--BRIDGE SR 24 YAKIMA-85FX01			DATE:	12-29-86	
4	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++
5	WEATHER	OVERCAST BROKEN	WET PAVEMENT			—	35° F
6	INDIVIDUAL CIRCUIT OUTPUTS						
7							
8		--PORTABLE METER--		--RECTI...		TEMPERATURE	
9	ZONE NUMB...	VOLTS D.C.	AMPS D.C.	VOLTS D.C	AMPS D.C.		
10	----------	----------	----------	----------	----------	----------	----------
11	1	6.86	4.8	6.5	4.5	31.5° F	
12	2	5.22	11.5	5.0	10.7	31.5°F	
13	3	4.81	4.1	4.5	4.5	32.0°F	
14	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++
15							
16	Ag/AgCL REFERENCE ELECTRODE POTENTIALS VS. THE INSTRUMENT NEGATIVE						
17		The Reference Electrode should be connected to the D.C.					
18		voltmeter's "Common" terminal and the Instrument					
19		Negative should be connected to the positive voltmeter					
20		terminal. This configuration results in "negative					
21		Potentials displayed on the meter.					
22							
23	REFLRENCE ...	ON POTENTIAL"	OFF POTENTIAL"			TEMPERATURE	
24	----------	----------	----------	----------	----------	----------	----------
25	R1	4.8 MV					
26	R2	.417 V					
27	R3	.354 V					
28	R4	.173 V					
29	R5	.400 V					
30	R6	.438 V					
31	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++
32		REBAR PROBE POTENTIALS AND CURRENTS					
33							
34	Probe Potentials VS. Ref. Cell(Connect probe to "positive" and Ref. cell to "common".)						
35		VOLTAGE		VOLTAGE			
36	P1	- 4.3 MV	P4	-67.5 MV			
37	P2	-.284 V	P5	+90.1 MV			
38	P3	+.213 V	P6	+7.2 MV			
39							
40	Rebar Probe Currents VS. Ins. Neg.(Connect probe to "common" and Ins. Neg. to "positive")						
41		~~CURRENT(ON)~~ MV		~~CURRENT(ON)~~ MV			
42	P1	+52.1 MV	P4	+107.1 MV			
43	P2	+133.3 MV	P5	+.490 V			
44	P3	+.567 V	P6	+.446			
45							
46							

GOODALL

A subsidiary of Valmont Industries, Inc

INSTRUCTION

MANUAL

YAKIMA

SERIAL NO. 85A1093 VIP

INSPECTED OK

DATE 9-6-85

BY DH

A 219

Instruction Manual
for
Single Phase Tapless
Rectifiers

BY
GOOD-ALL ELECTRIC, INC.
201 South Spruce St.
Ogallala, Nebraska 69153
308-284-4081

TM-22

Purpose

The purpose of the Good-All single phase tapless rectifier is to supply controlled DC power for Cathodic protection of metalic structures in contact with an electrolyte, although its use is not limited to this application. The tapless arrangement provides output power which is adjustable electronically instead of by an arrangement of taps thereby making the unit useful for other applications such as battery charging. In addition to making the output adjustment extremely easy, a short circuit proof output is incorporated as a standard feature.

Description

The power circuit of the Good-All tapless single phase rectifier consists of a center tap, full wave type circuit. This circuit provides the most efficient type of rectification with respect to power consumption and minimum number of parts while providing some very important operating features. The rectification is accomplished via silicon controlled rectifiers (SCR's) of adequate rating to supply the design current of the unit. Proper phase angle firing control of the SCR's is accomplished by an electronic printed circuit control card. This control card is unplugable for easy field replacement.

Specification

Single phase tapless rectifiers are available in voltage ratings up to 50 volts DC and current ratings up to 160 amperes. For output voltages greater than 50 volts DC, special additional circuitry is necessary. Refer to schematics and unit drawings attached for specific rectifier configurations. The test data sheet can be referred to for specific output voltage and current ratings of the rectifier(s) supplied.

The AC input current required by a single phase tapless rectifier can be determined by the following formula:

$$I_{AC} = \frac{(E_{DC} + 3) \text{ or } 1.03 \times I_{DC}\ 1.03}{V_{AC} \text{ (low line)} \times .75}$$

Installation

Air cooled rectifiers should be installed in their intended location and fastened securely to the wall or pole to prevent sway or movement due to wind or other sources of mechanical movement. On pedistal mounted units they should be fastened to the mounting pad via the holes in the base channels. Oil immersed units are also to be mounted via the holes in the base channels. A secure mechanical installation can eliminate future electrical problems caused by continual mechanical movement of the unit.

The correct AC input voltage must be routed to the rectifier and connected to the input wires or terminals provided. In the case of dual input units the input voltage must correspond to the setting of the input change over device. Manual tapped rectifiers can be operated at lower than specified input voltages if the corresponding lower output voltage is adequate to provide sufficient output current for cathodic protection but tapless rectifiers must have the correct input AC voltage because the control cards will not operate properly at lower than the normal supply voltage.

Installation (Con't)

On units with input change-over link bars or cover plates for the AC input be sure to replace the safety cover over the terminals.

The structure and anode leads should be properly connected to the output terminals. The structure lead should be connected to the negative (-) output terminal and the anode lead to the positive (+) output terminal. Be certain of the connection of these leads! Reversal can cause severe damage to the structure!

On oil immersed and explosion proof units, fill the tank with a NEMA Grade 10C transformer oil. Several types of oil are available for this purpose. The rectifier is now ready to be set into operation.

Operation

After the rectifier has been properly installed, connected and filled, it is ready to be set into operation. Before the circuit breaker is turned on, the voltage and current control potentiometers on the control circuit card should be set to their full counter-clockwise positions. These controls should be clearly marked. The unit can now be energized.

When the power is turned on, the output voltage and current should be zero. To achieve some output both the voltage and current controls must be advanced somewhat. If the output is controlled by the voltage control the small light emitting diode (LED) labled "Voltage Mode" will be lit. If the output is controlled by the current control the LED labled current control will be lit. The output voltage and output current can be set by the voltage and current controls to any value up to the rectifier rating.

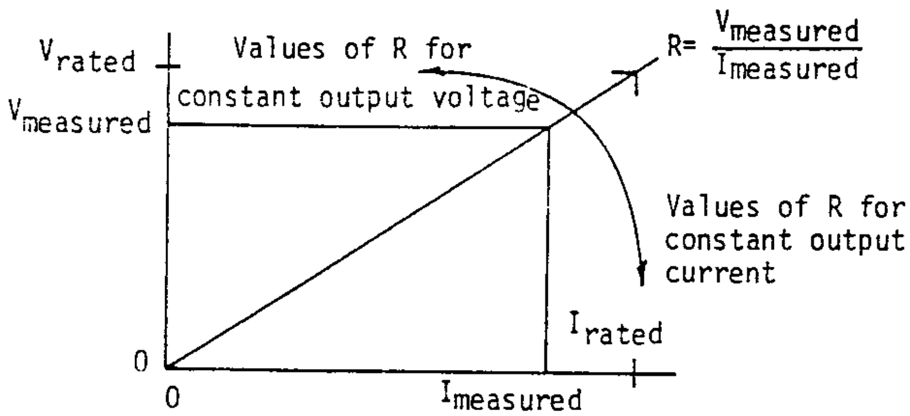
The tapless rectifier is an electronically controlled device designed to maintain a specific output voltage or a specific load current depending upon the load resistance. Thus it can be easily used as a standard cathodic protection rectifier, setting the output voltage via the voltage potentiometer. In this mode, the output voltage is maintained, providing the output current does not exceed the value established by the setting of the current control potentiometer.

The rectifier can also be used as a constant output current device (Amp-O-Matic). In this mode the output current is set by the current control potentiometer and this value of current is maintained, providing the output voltage does not exceed the value established by the voltage control potentiometer.

The value of voltage established by the voltage control potentiometer can be determined by measuring the output voltage when the voltage LED is on. If the voltage LED is not on, temporarily disconnect one output lead. The voltage LED should now be lit and the output voltage can be read. The value of current established by the current control potentiometer can be determined in the same fashion except the current LED must be lit. If it is not, the output can be shorted to light the current LED and make the reading.

Operation (Con't)

The rectifier will maintain the established output voltage for load resistances of R = Vmeasured/Imeasured or greater, and it will maintain the established output current for load resistances of R = Vmeasured/Imeasured or less. Graphically this is shown in Figure 1.



Principles of Operation

The power circuit consists of a single phase power transformer with the secondary connected in a center tap configuration. The input is protected from lightning surges by the input lightning arrester. The input circuit breaker provides overload protection for the circuit and can be used as an on-off switch. The power transformer is constructed with a shield between the primary and secondary windings which provides additional lightning protection for the secondary circuit. The secondary has an auxiliary tap to power the small control transformer that supplies power and timing signals to the control circuit card.

The power stack consists of two Silicon Controlled Rectifiers (SCR's) that are phase controlled to achieve the correct output. An output filter choke is necessary in the circuit to smooth the output current and make the unit short circuit proof.

The SCR's are protected from surge voltages via the metal oxide varistors (MOV's) installed in parallel with each SCR. The choke also provides excellent additional protection for the SCR's.

Troubleshooting

The basic components of a single phase tapless rectifier are so few in number that it is very easy to indentify the source of the problem when incorrect operation is experienced. The basic components consist of 1) the transformer, 2) the choke, 3) the stack assembly, and 4) the control card. The transformer is a magnetic component and historically is not apt to fail unless severe overloads are imposed on it. If this should happen in the secondary side of the transformer the circuit breaker will usually open to prevent damage. If the transformer is damaged it can usually be found by a visual inspection. An electrical verification that the transformer is operating properly is to measure the output AC voltage.

Troubleshooting (Con't)

The AC voltage from the center tap to each side of the secondary should be 20 to 30 percent greater than the DC rating of the rectifier. Any discrepancy in the AC readings should be cause for further investigation, however it is not anticipated that extensive testing on the transformer would be necessary to determine proper operation.

The choke is another magnetic component that is also very reliable. Severe overloading could cause damage to the choke. This can usually be detected visually. The only electrical check that can easily be made is to verify the electrical continunity of the winding. Mechanical failures such as loss of the gap material can be found visually. The choke and transformer of a tapless rectifier are the least likely components of the power train to fail so quick checks can be made and further testing is unnecessary.

The SCR's are considered a part of the power train and are the component of the power circuit most likely to fail. This is not because of the design factors but because these devices are semiconductors and are more susceptible to surge and transient voltages generated by lightning. Even though the SCR's are protected by transient voltage suppressors called metal oxide varistors (MOV's) there are occasions when the SCR's will have to be checked to verify correct operation. An initial test can be made on SCR's with an ohmmeter. This test will not prove conclusively that the SCR is good but any good SCR will pass this test. Measure the anode to cathode and cathode to anode resistance with the ohmmeter. Both of these readings should indicate a very high (essentiality infinite) resistance. This test shows that the SCR is an open circuit in both directions which must be the case but it does not conclusively prove that the SCR is okay. A further test can be performed on the SCR to verify the gate-cathode circuit. A good SCR will show some conduction from gate to cathode but not a short circuit. There may also be some conduction from cathode to gate although this is not necessary for the SCR to be good. When testing SCR's it is important that enough leads be disconnected to be sure that other paths are not being measured. The above tests are enough to reasonably determine that the stack will operate normally.

The last major item necessary for proper operation of a tapless rectifier is the control circuit card. The best way to determine if the circuit card is bad is to replace it with a card known to be good. There is very little that can be done to repair a defective circuit card in the field except to replace it. There is a test that can be made to verify that the circuit is receiving the proper voltage to operate. The circuit card must receive an AC voltage from the small isolation transformer. This voltage enters the card at pins 1,2, and 6. The AC voltage from pins 6 to 1 and 6 to 2 should be about 15 VAC. The AC voltage from pins 1 to 2 should be about 30 VAC. If this voltage is not received the control card cannot operate properly. If the AC voltage is present at the control card but proper operation is still not achieved there can be little doubt that the circuit card is defective if the other major components are okay.

Troubleshooting (Con't)

There is always the possibility that other components of the rectifier can indicate improper operation. The components might be meters, switches connectors, shunts, monitors, circuit breakers, etc. and troubleshooting of these parts should be handled in the normal manner. Wiring should always be checked along with the connection terminals of the circuit card connectors. These connectors have been known to bend preventing connection to the circuit card which results in improper operation.

Thus, troubleshooting of the single phase tapless rectifier breaks down to four major components, transformer, choke, stack and circuit card. The other components of the system should also be checked along with the wiring of the system.

GOOD-ALL ELECTRIC, INC.

QUALITY CONTROL FINAL INSPECTION RECORD

RECTIFIER PERFORMANCE

MODEL TIAYCE 25-45 EGNZ SERIAL NO. 85A1093

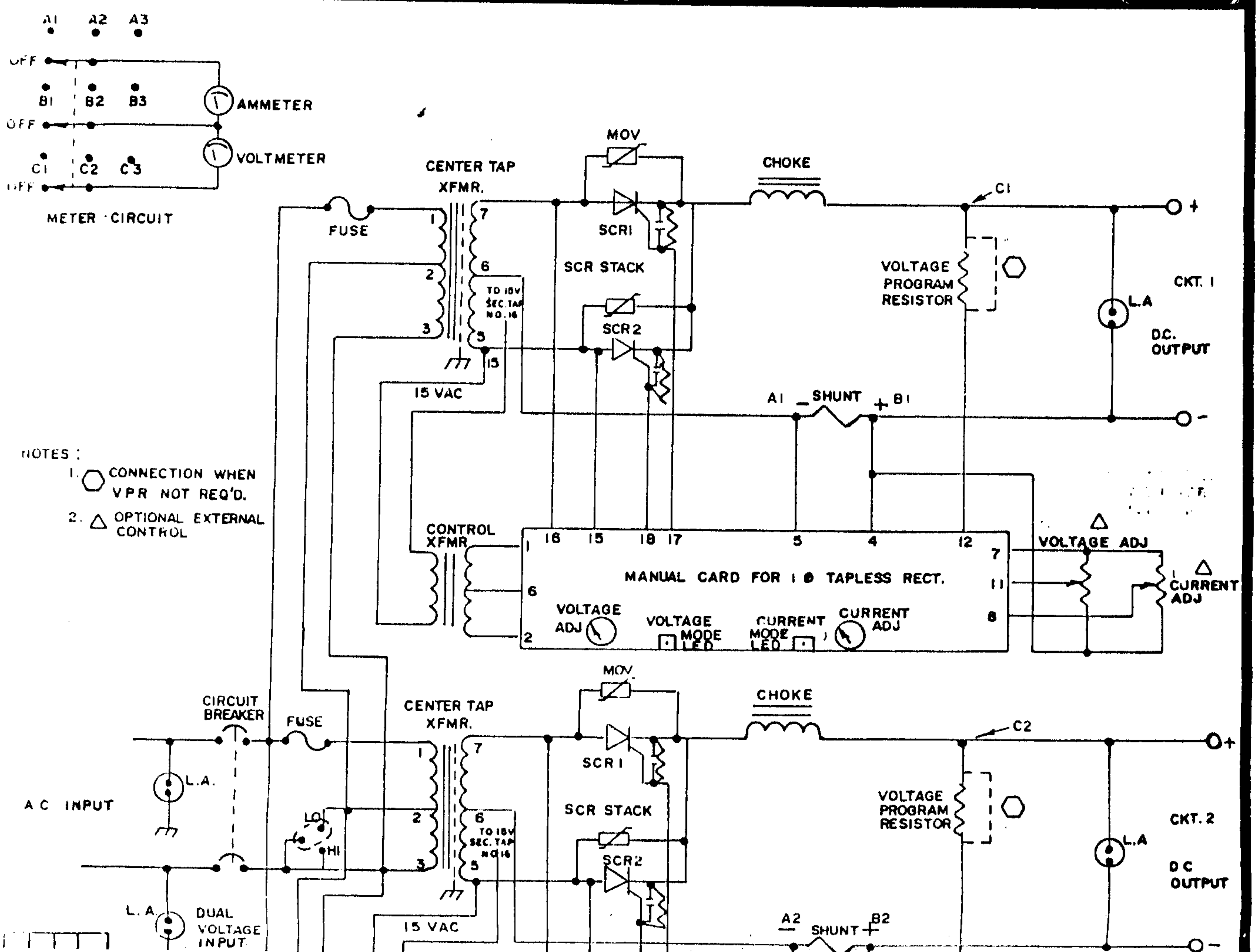
	#1		#2		#3		TOTAL	
ELECTRICAL DATE	9-6-85							
AC VOLTS INPUT	115	230	115	230	115	230	115	230
AC AMPS INPUT	5.2	2.59	5.21	2.6	5.28	2.67	13.5	6.7
APPARENT WATTS INPUT	598	596	599	598	607	605	1559	1541
TRUE WATTS INPUT	490	485	495	495	500	500	1360	1350
POWER FACTOR	82	81	83	83	82	83	88	88
DC VOLTS OUTPUT	25	25	25	25	25	25	25	25
DC AMPS OUTPUT	15	15	15	15	15	15	45	45
EFFICIENCY	77	77	76	76	75	75	83	83
AC VOLTS TO STACK (RATED CURRENT AT SHORT CIRCUIT) AMP-O-MATIC ONLY	—	—	—	—	—	—	—	—
DIELECTRIC STRENGTH	2KV							

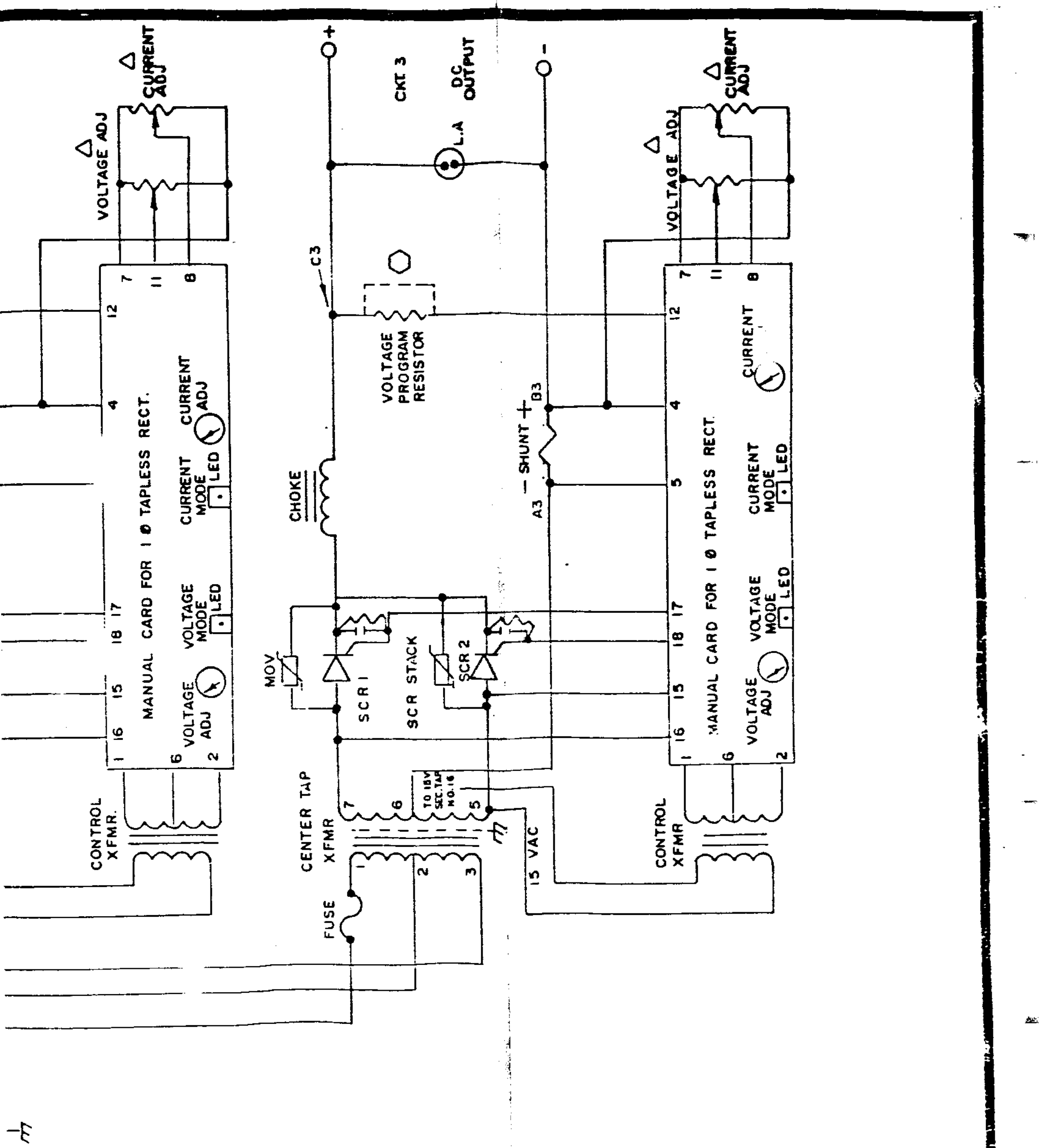
INSPECTOR DH

MECHANICAL DATE	9-6-85							
WIRING CONNECTIONS	✓							
PANEL COMPONENTS	✓							
DOORS	✓							
LATCHES	✓							
HINGES	✓							
PAINT	✓							

INSPECTOR DH

GA 251A


A1 A2 A3
OFF
B1 B2 B3
AMMETER
OFF
VOLTMETER
C1 C2 C3
OFF
METER CIRCUIT
NOTES :
1. CONNECTION WHEN VPR NOT REQ'D.
2. OPTIONAL EXTERNAL CONTROL
FUSE
CENTER TAP XFMR.
MOV
SCR1
SCR STACK
SCR2
TO 18V SEC.TAP NO.16
15 VAC
CHOKE
C1
VOLTAGE PROGRAM RESISTOR
CKT. 1
L.A
D.C. OUTPUT
A1 SHUNT B1
CONTROL XFMR
MANUAL CARD FOR 1 Ø TAPLESS RECT.
VOLTAGE ADJ
VOLTAGE MODE LED
CURRENT MODE LED
CURRENT ADJ
VOLTAGE ADJ
CURRENT ADJ
CIRCUIT BREAKER
FUSE
CENTER TAP XFMR.
MOV
CHOKE
C2
SCR1
SCR STACK
SCR2
VOLTAGE PROGRAM RESISTOR
CKT. 2
L.A
DC OUTPUT
A C INPUT
L.A.
LO
HI
L.A
DUAL VOLTAGE INPUT
15 VAC
A2 SHUNT B2



TOLERANCE ± .005 ± 1/32 ± .0? UNLESS SPECIFIED   BREAK ALL CORNERS

MAT'L	ENGR. DATE	ENGR. DATE	GOOD-ALL ELECTRIC INC. OGALLALA NEBRASKA
SURFACE FINISH	DRAWN DATE S.B 7-24-95	CHECKED DATE	
PAINT	TITLE THREE ... IN ONE ...		