CATHODIC PROTECTION FOR A CONTINUOUS BOX GIRDER BRIDGE DECK

CONSTRUCTION AND OPERATING REPORT
PROJECT NO. IR-235-2(213)80--12-77
PROJECT HR-553

APRIL 1993

Highway Division

Iowa Department
of Transportation

Construction and Operating Report

Project No. IR-235-2(213)80--12-77
Iowa DOT Project HR-553

CATHODIC PROTECTION FOR A CONTINUOUS BOX GIRDER BRIDGE DECK

by

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Special Investigations
515-239-1357

Iowa Department of Transportation
Highway Division
Office of Materials
Ames, Iowa 50010

April 1993

TECHNICAL REPORT TITLE PAGE

1.	**REPORT NO.** HR-553	2.	**REPORT DATE** April 1993
3.	**TITLE AND SUBTITLE** Cathodic Protection for a Continuous Box Girder Bridge Box	4.	**TYPE OF REPORT & PERIOD COVERED** Construction & Operating Report June 1992 to April 1993
5.	**AUTHOR(S)** Champak Narotam Cement & Concrete Engineer Todd Hanson Special Investigations	6.	**PERFORMING ORGANIZATION ADDRESS** Iowa Department of Transportation Materials Department 800 Lincoln Way Ames, Iowa 50010

7. **ACKNOWLEDGEMENT OF COOPERATING ORGANIZATIONS**

8. **ABSTRACT**

Bridge deck deterioration due to corrosive effect of deicers on reinforcing steel is a major problem facing many agencies. Cathodic protection is one method used to prevent reinforcing steel corrosion. The application of a direct current to the embedded reinforcing steel and a sacrificial anode protects the steel from corrosion.

This 1992 project involved placing an Elgard Titanium Anode Mesh Cathodic Protection System on a bridge deck. The anode was fastened to the deck after the Class A repair work and the overlay was placed using the Iowa Low Slump Dense Concrete System. The system was set up initially at 1 mA/sq ft.

9.	**KEY WORDS** Cathodic protection Bridge	10.	**NO. OF PAGES** 42

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DISCLAIMER

BACKGROUND

Bridge deck deterioration due to corrosive effects of deicers on reinforcing steel is a problem facing many transportation agencies, particularly on aging bridge decks containing black steel. Deterioration of the deck is of utmost concern on continuous box girder bridges, where the decks are integral parts of the load supporting structure.

Many different rehabilitation techniques have been tried over the past years to repair bridge decks. The Iowa Low Slump Dense Concrete System has been a very effective method.

Cathodic protection is another rehabilitation method that has emerged. The application of an external source of direct current to the embedded reinforcing steel and a sacrificial anode protects the steel from corrosion.

The technology involved in cathodic protection as applied to bridge decks has improved in recent years. New and better anode materials have significantly increased the life expectancy of the anode, which is the integral part of the cathodic protection system.

The Elgard Corporation Titanium Anode Mesh impressed current system was selected for several reasons. The Elgard system, manufactured by Elgard Corporation of Chardon, Ohio, is readily adaptable to the Iowa System of bridge deck rehabilitation. The mesh also provides uniform current density with thousands of current paths to prevent system failures from cracks, core samples, or saw cuts.

PROJECT LOCATION AND CONDITION

The Elgard Corporation cathodic protection system was installed on the northbound Pennsylvania Avenue bridge over I-235 in Des Moines (Station 502+78.92, I-235, Polk County). The bridge was built in 1962 and is a continuous concrete box girder with 7 3/4 inches of reinforced concrete deck. The structure has approximately 9560 square feet (265.5′ x 36′) of deck surface.

The Iowa Department of Transportation performed a bridge deck survey prior to the installation of the cathodic protection system. The survey included the following: 1) visual survey of the deck; 2) delamination map of the deck; 3) chloride content at the top mat of reinforcing steel; and 4) corrosion potential map of the deck.

The visual survey (Appendix A) showed a few asphalt patches and spalled areas, especially at the south abutment. The delamination map (Appendix B) showed 210 square feet of delaminated area. Cores of the deck and the chloride contents (Appendix C) were taken at several depths. Corrosion potentials were determined with a copper-copper sulfate half-cell (Appendix D) and the core locations were noted on these plots.

CONTRACTS AND CONTRACTORS

On January 22, 1992 the Iowa Department of Transportation let a contract (Appendix E) for the bridge deck rehabilitation and cathodic protection system installation. Cramer and Associates, Inc. of Des Moines, Iowa was the successful bidder for the project.

BRIDGE DECK PREPARATION

The bridge deck was rehabilitated under traffic so the east one-third was done first and then the west two-thirds. The deck was prepared in accordance with 1984 Iowa Standard Specifications for Highway and Bridge Construction, Section 2413.05 (Appendix F). The deck required only Class A bridge floor repair. Approximately 754 square feet or 8% of the deck surface was removed down to the level of the top mat of reinforcing steel (Appendix G). On this project, instead of monolithically placing the overlay, all Class A repairs were made prior to placement of the surface course. This construction procedure facilitated installation of the anode, and also, prevented the potential for shorting due to the direct contact of the anode to the reinforcing steel.

INSTALLATION OF CATHODIC PROTECTION SYSTEM

The design of the cathodic protection system was accomplished by Elgard Corporation. A key factor in the design was that the installation had to be done in two phases so that one side of the bridge could remain open. Elgard furnished complete plans for the installation to the contractors and also provided trained personnel to supervise the installation.

The rehabilitation on the east one-third of the bridge was completed and the steel continuity testing began. Any discontinuous steel was thermit welded to achieve electrical continuity. Next, the areas of exposed rebar were covered with a mat to prevent a short between the anode and the rebar (Figure 1). The anode mesh (Appendix H) was rolled out and fastened down with pushpin fasteners (Figure 2).

Since the zones were split due to staging, the current density strips were attached with extra length (Figure 3) to attach to the west two-thirds of the anode mesh in each zone.

On July 10, 1992, the 2-inch overlay was placed on the east one-third of the bridge while bonding grout was sprayed ahead of the paver (Figure 4).

After the overlay was allowed to cure, the traffic was routed on the east one-third of the bridge and work began on the west two-thirds of the deck.

The deck was removed and the Class A repair work was completed. The areas of exposed rebar were also covered with a mat.

Next, three holes, one for each zone, were drilled through the deck (Figure 5) to allow access to the wiring under the bridge. With the system negative and the graphite reference electrodes in place (Figure 6), the electrical connections were placed in trenches and ran through the access holes (Figure 7). The locations of the access holes, reference electrodes, and wiring for each zone may be found in Appendix I.

The anode mat was rolled on the deck and fastened with the pushpin fasteners (Figure 8) and then the current density strips from the east one-third of the bridge were tied to the current density strips on the west two-thirds of the deck.

On July 27, 1992 the 2-inch overlay was placed on the west two-thirds of the deck with a sprayed on bonding grout (Figure 9).

Figure 1
Anode Mat to Prevent Short Between
Anode and Exposed Rebar

Figure 2
Drilling Holes for Placing Pushpin Fasteners

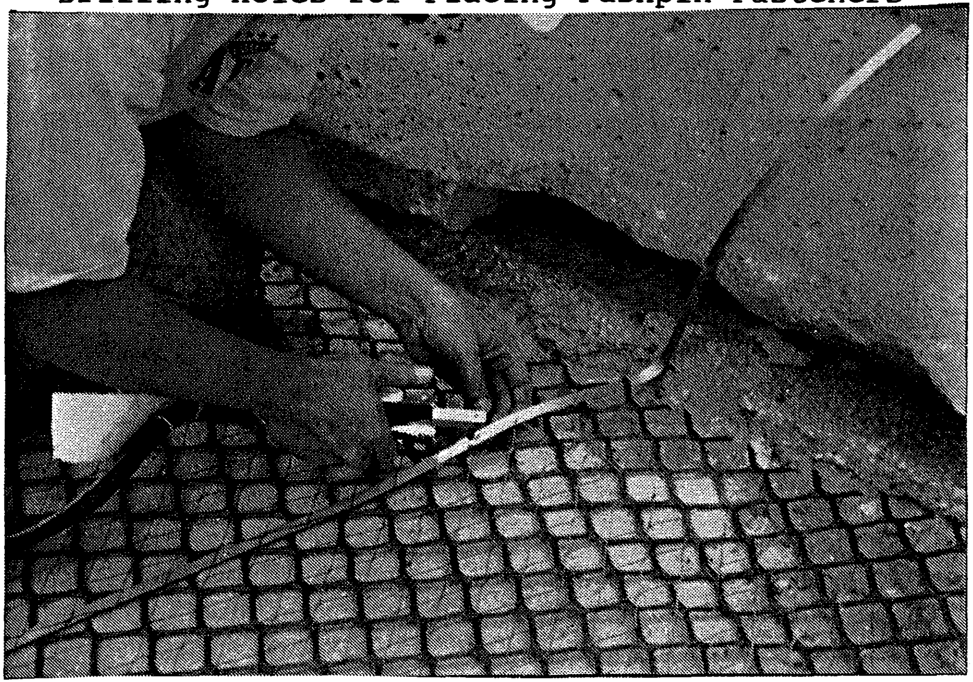


Figure 3
Welding Current Density Strip to Anode With Extra Length to Connect Both Sides of Zone

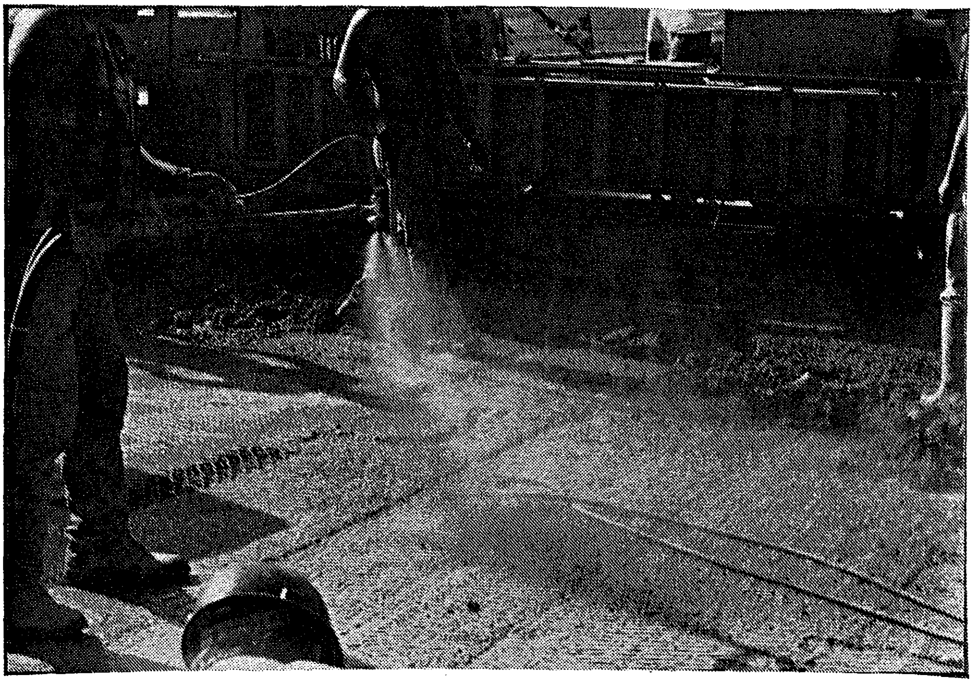


Figure 4
Spraying Grout Ahead of Paver

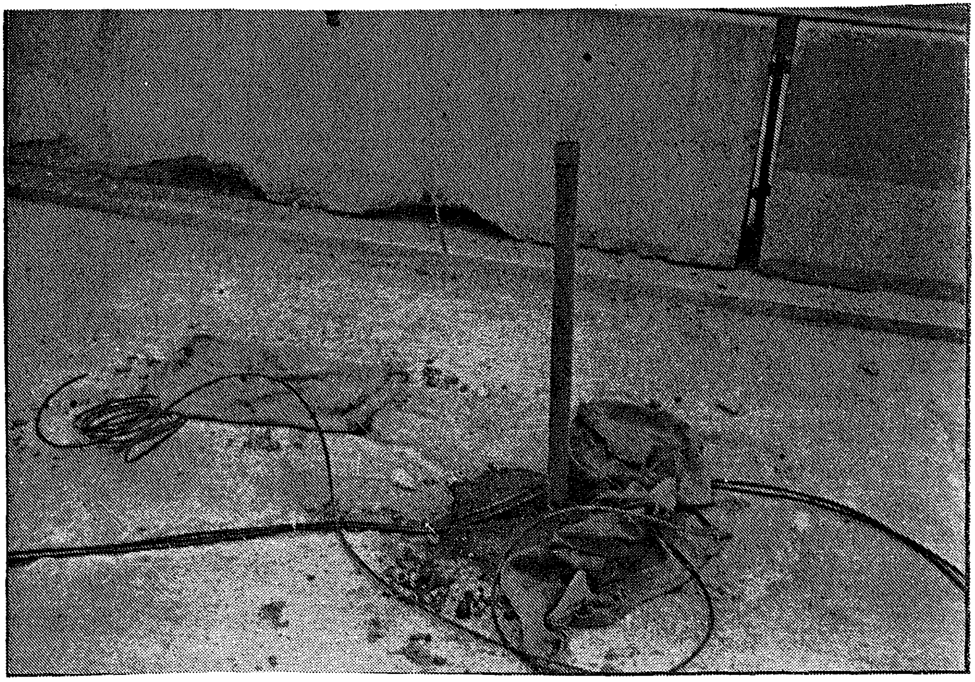


Figure 5
Access Hole in Deck

Figure 6
System Negatives and Graphite Reference Electrode

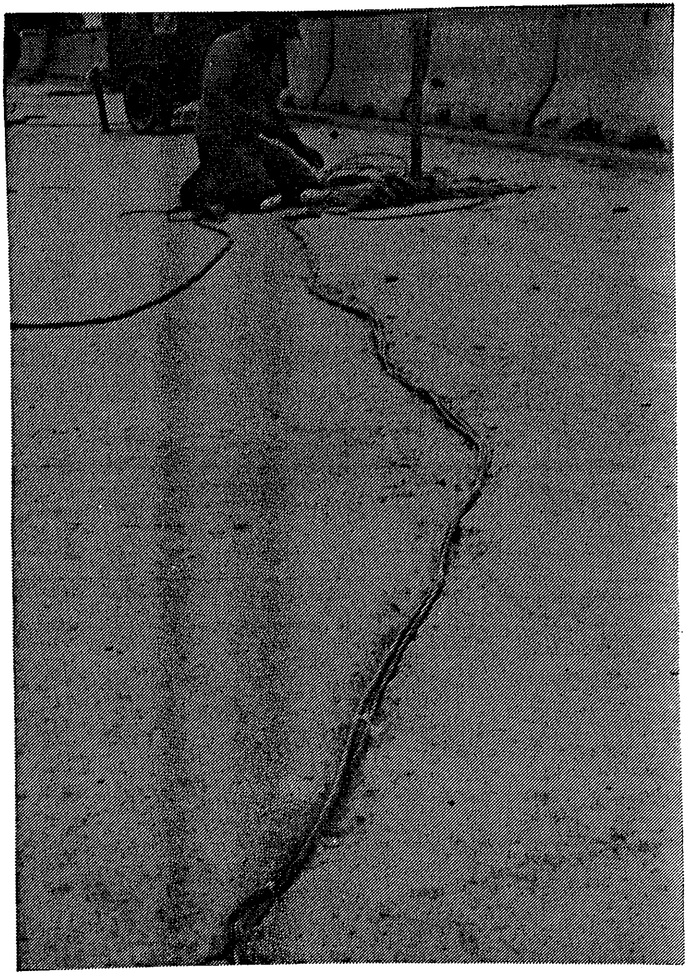


Figure 7
Electrical Connection
in Trench

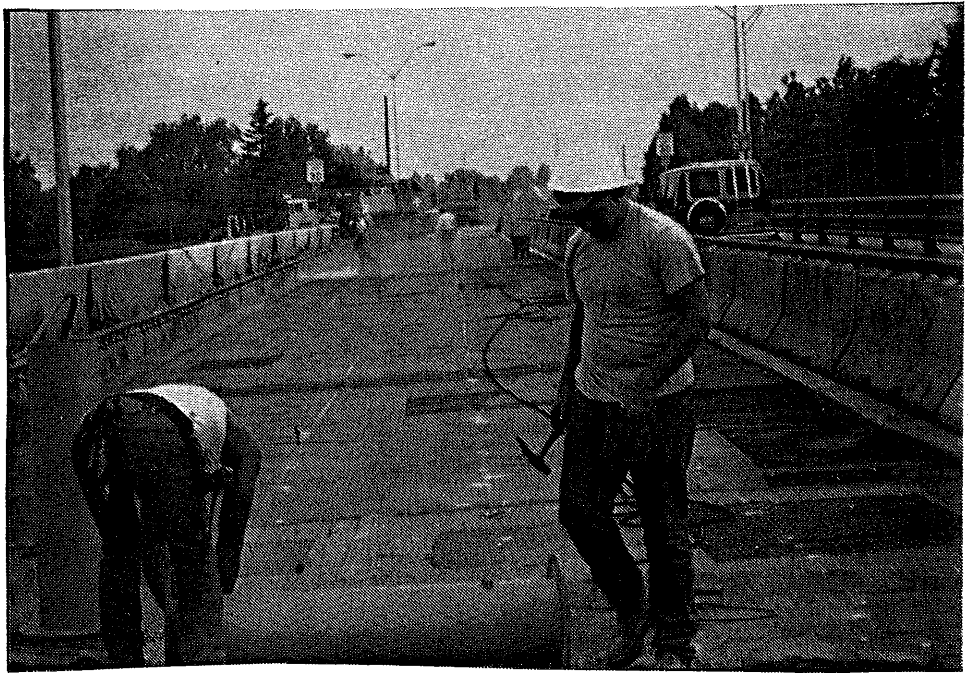


Figure 8
Overview of Deck With Anode in Place

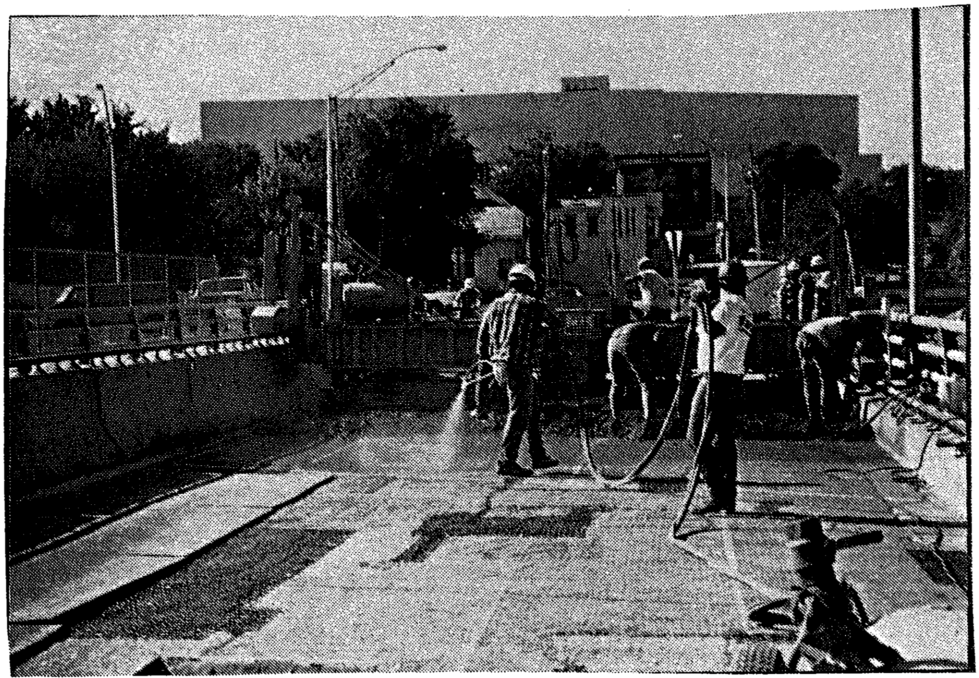


Figure 9
Placing Overlay, Spraying Grout,
and Plywood Runway for Concrete Buggies

POST CONSTRUCTION AND SYSTEM START-UP

The electrical work was completed by running the wiring through conduit placed under the deck and then through an empty conduit to a hand hole placed through a lighting contract.

The constant current rectifier/control resistance box (CRB) unit (Figure 10, Appendix J) on the electric pole approximately 180 feet southeast of the southeast corner of the bridge (Figure 11) and the deck wiring was connected.

The system began operation on October 9, 1992. Elgard Corporation was present to adjust the system to the calculated values for adequate protection (Appendix K). The system began operation at a current density of 1 ma/sq. ft.

On November 13, 1992 a four-hour depolarization test (Appendix L) was conducted to check for the 100 millwolt shift which ensures adequate protection. Each zone showed an adequate shift and the current settings were adjusted.

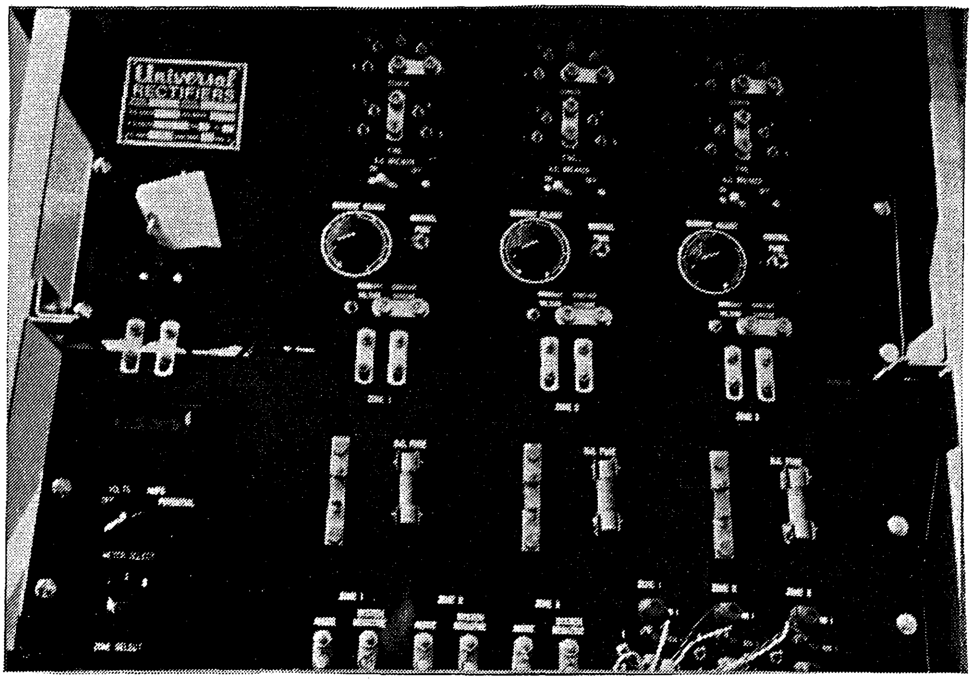


Figure 10
Rectifier/CRB Unit

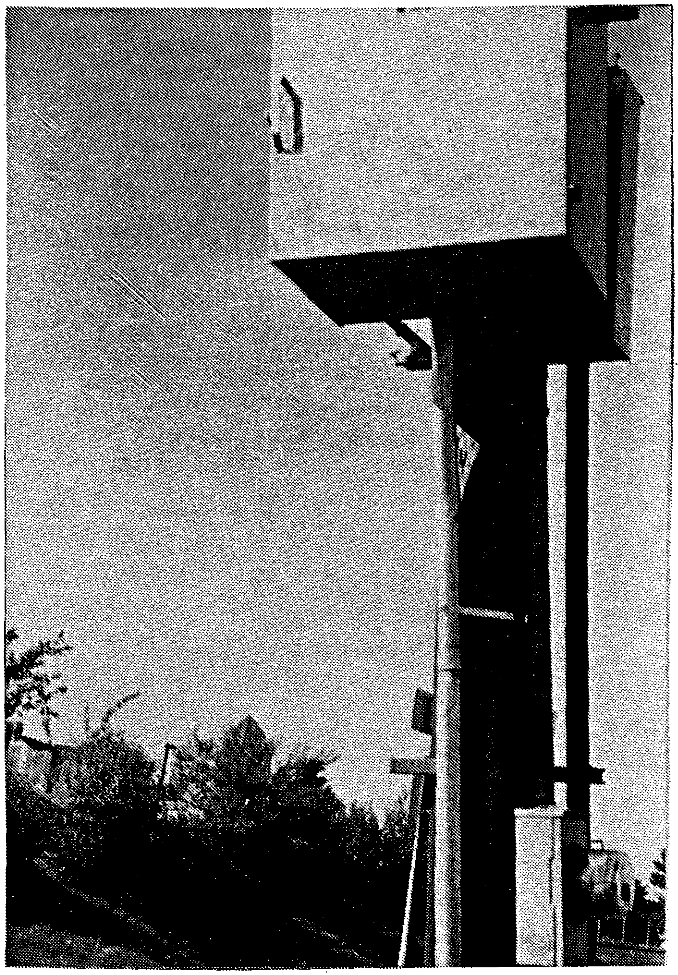


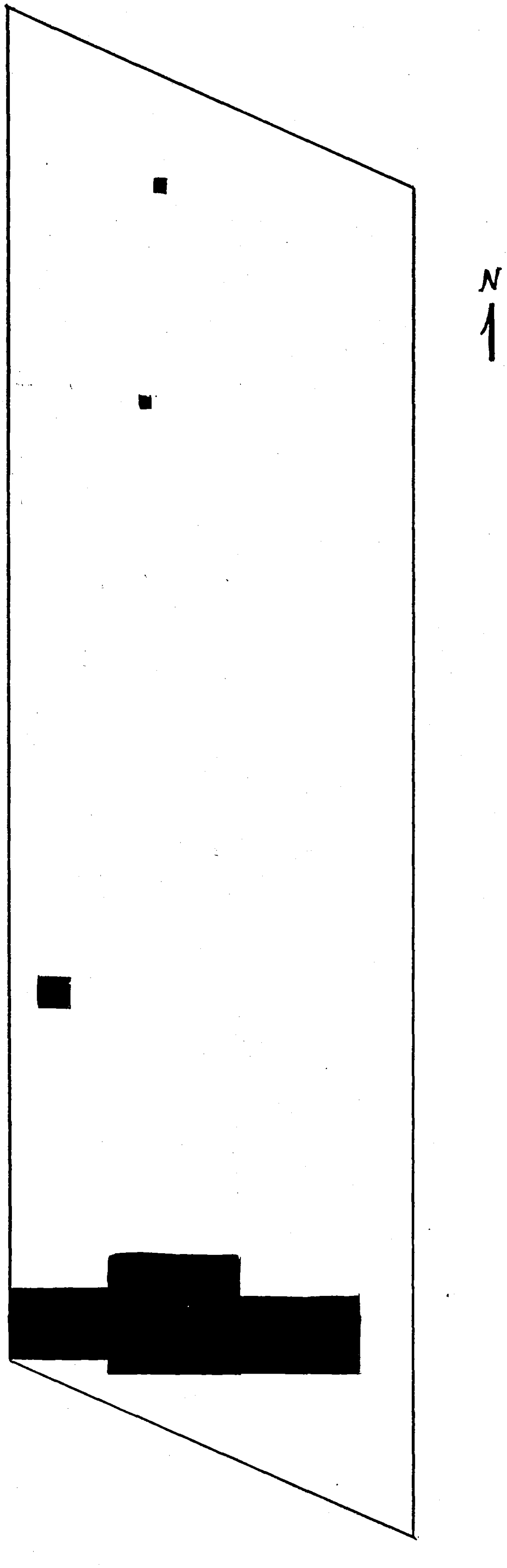
Figure 11
Rectifier/CRB Place
on Electrical Pole

CONCLUSIONS AND FUTURE PLANS

The Elgard 200 Titanium Anode Mesh Cathodic Protection System is readily adaptable to construction methods used in the Iowa System of bride deck repair. The thousands of current paths in the anode makes it a more reliable anode over time. The data to date indicates that the reinforcing steel is being adequately protected.

The cathodic protection system will continue to be monitored on a monthly basis and a four-hour depolarization test is planned in the spring of 1993.

Appendix A
Visual Survey - Patches and Spalled Areas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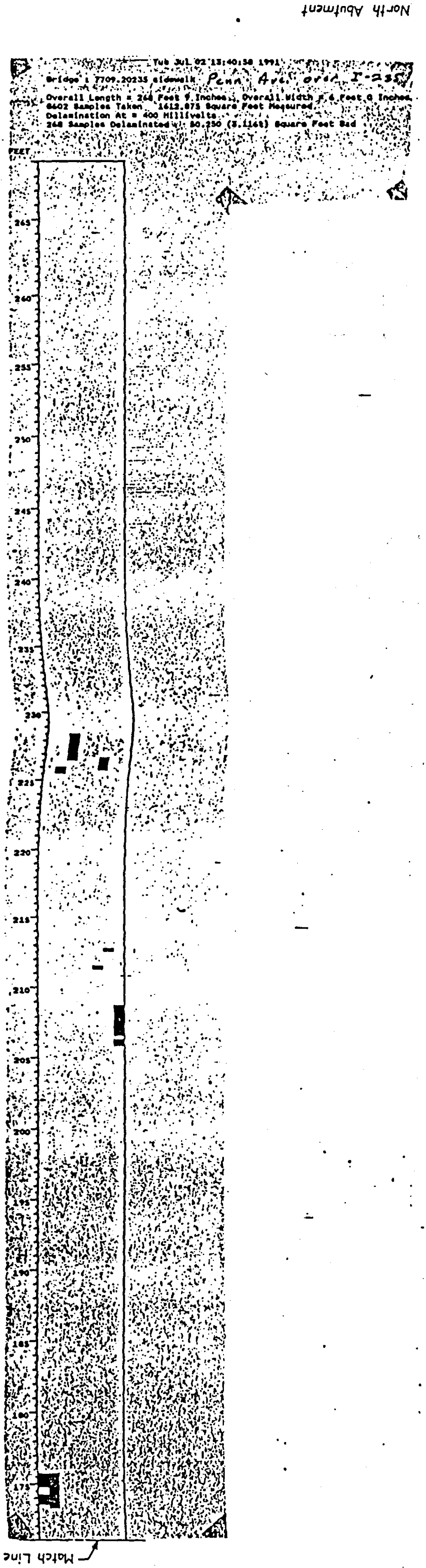
Appendix B
Delamination Survey



Tue Jul 02 13:40:58 1991

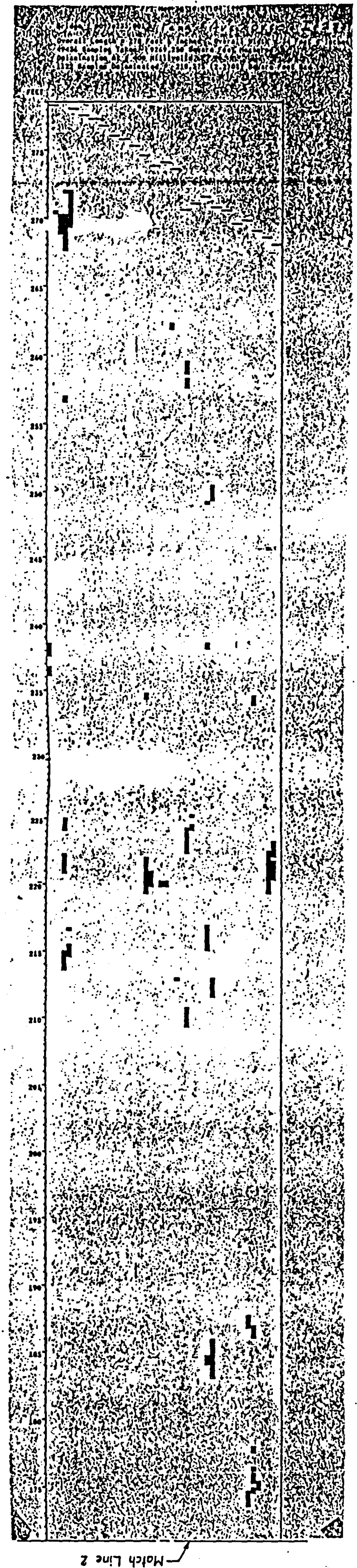
Bridge : 7709.20235 sidewalk Penn Ave over I-235

Overall Length = 264 Feet 9 Inches , Overall Width = 6 Feet 0 Inches

8602 Samples Taken 1612.875 Square Feet Measured

Delamination At = 400 Millivolts

268 Samples Delaminated : 50.250 (3.116%) Square Feet Bad

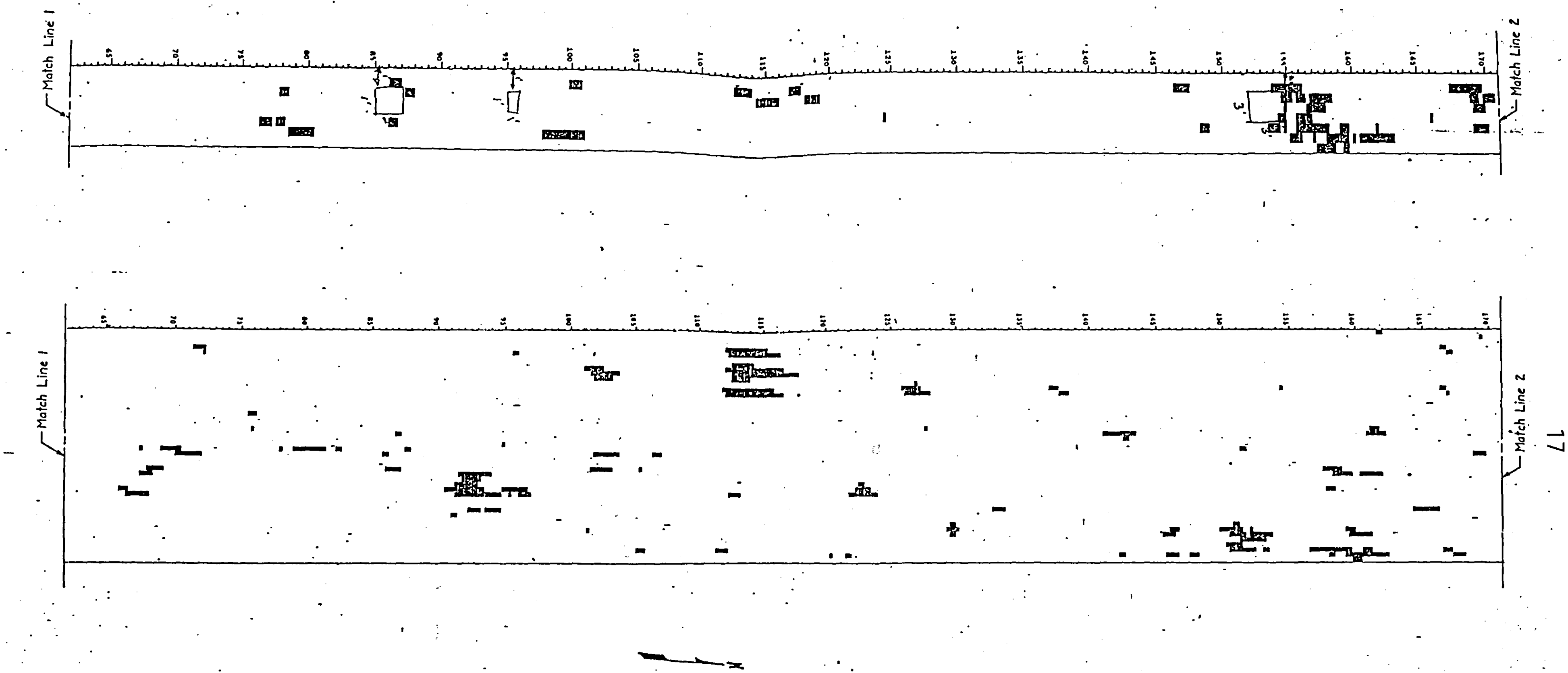


Design for Repairs to a 15° Skew
265'-6 x 36' CONTINUOUS CONCRETE
BOX GIRDER BRIDGE
32'-6, 61'-0, 61'-0, 61'-0, 50'-0 Spans

SURVEY PLOT
Station 502+78.32 ℄ I-235 September, 19
POLK COUNTY
IOWA DEPARTMENT OF TRANSPORTATION-HIGHWAY DIVISION

Design Sheet No.: 2 Of 20 File No.: 28391 Design No.: 622

Polk COUNTY



Design for: Repairs to a 13° Skew

265′-6 × 36′ CONTINUOUS CONCRET

BOX GIRDER BRIDGE

32′-6, 61′-0, 61′-0, 61′-0, 50′-0 Spans

SURVEY PLOT

Station 502+78.92 ℄ I-235 September, 1

POLK COUNTY

IOWA DEPARTMENT OF TRANSPORTATION-HIGHWAY DIVISION

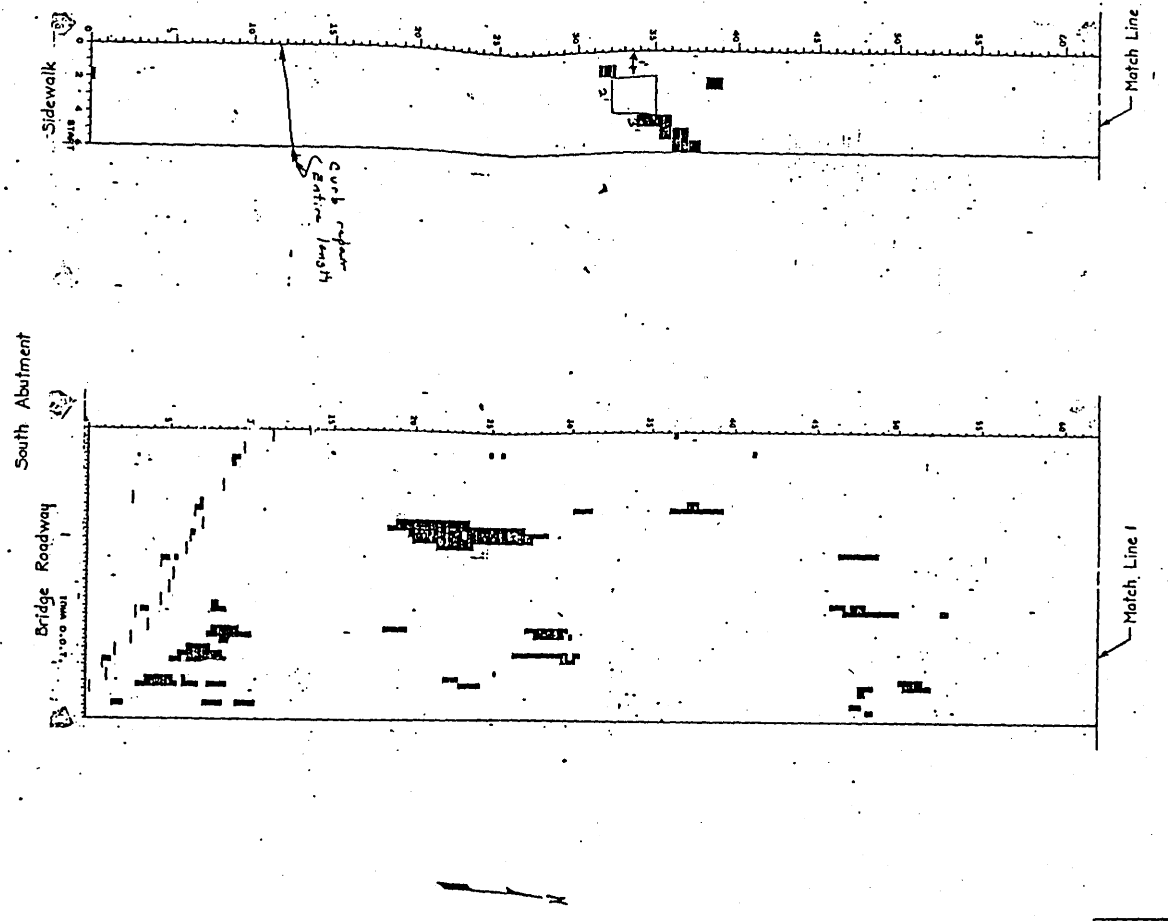
Design Sheet No.: 8 Of 20 File No.: 28391 Design No.: 6

I. Nukerbige TRACED BY M. J. Sol

Polk COUNTY

PROJECT NUMBER

STATE	FHWA Region	FISCAL YEAR	SHEET NO.
IOWA	7		



Design for Repairs to a 15° Skew
265'-6 × 36' CONTINUOUS CONCRETE
BOX GIRDER BRIDGE
32'-6, 61'-0, 61'-0, 61'-0, 50'-0 Spans

SURVEY PLOT
Station 502+78.32 ℄ I-235 September, 1
POLK COUNTY
IOWA DEPARTMENT OF TRANSPORTATION-HIGHWAY DIVISION
Design Sheet No.: 7 Of 20 File No.: 28391 Design No.: 69

Polk COUNTY

Appendix C
Chloride Contents

Form 1311
5-75

Report to: Chloride Sec.
C. Narotam
T. Hanson
C
. Anderson

DEPARTMENT OF TRANSPORTATION
Division of Highways
Bureau of Operations
Office of Materials

Samples for Chloride Determination

Design No. ____ Project IR-235-2(213)80--12-77 County Polk

Samples from Pennsylvania Ave. Bridge Samples taken by C. Anderson & T. Hanson Date 5-13-92

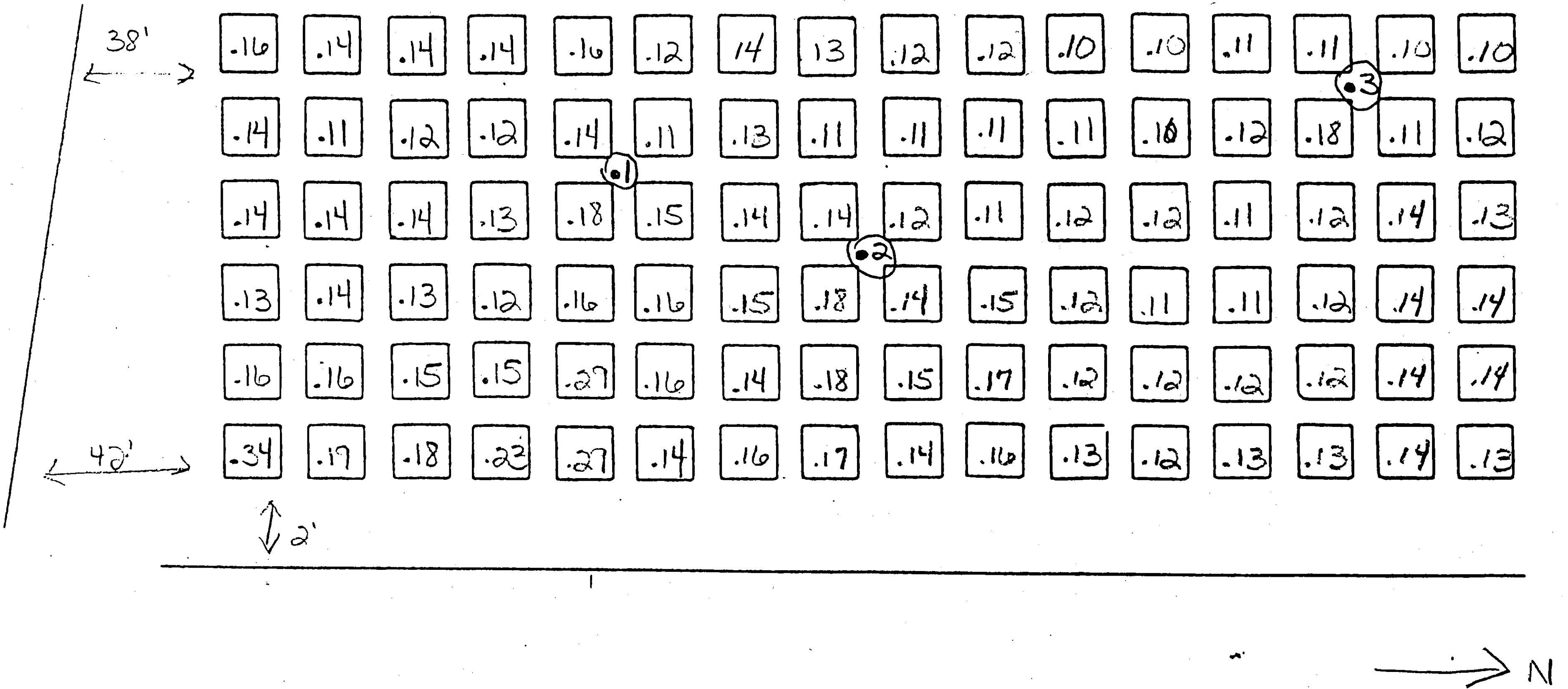
Bridge Dim. L= 270 W= 36 Samples submitted by C. Anderson Date 5-20-92

Location ____ Date Reported ____

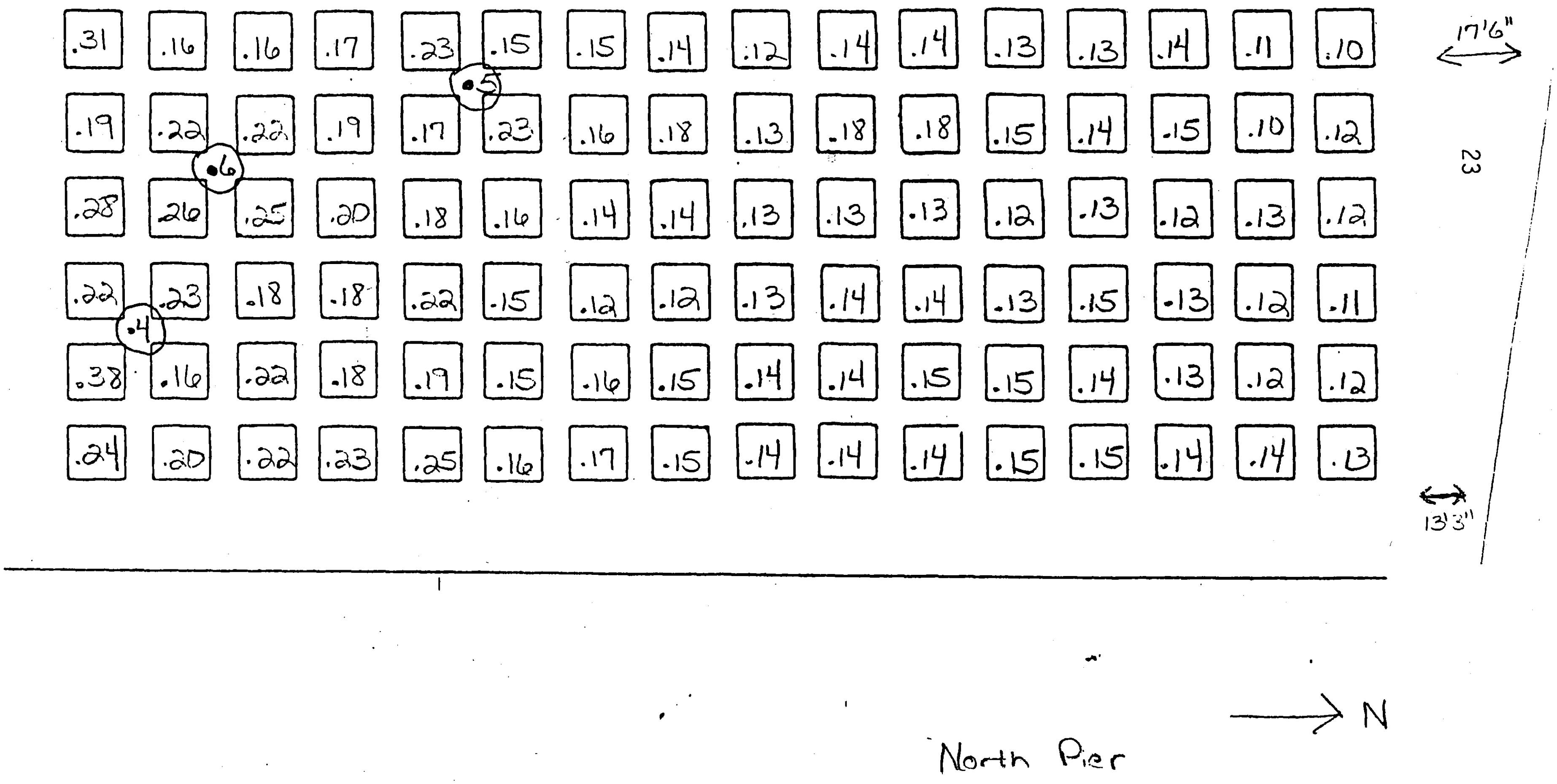
Submission Report No. ____

Lab. No.	Core Number	Station	Dist. from ¢ or	Dist. from	lbs/cu. yd.			Sub Sample Depths					Depth of Res.
					A	B	C	D	E	F	G	H	
ACH-2													
57	201				16.45	9.61	6.19	3.91	3.91				
58	202				24.05	9.50	2.01	1.14	2.28				20
59	203				18.13	11.67	9.77	3.42					
60	204				16.07	9.77	2.55	.87	3.04				
61	205				19.76	12.92	9.61	4.67	4.29	3.91	2.28		
62	206				13.68	8.63	2.01	2.55					

Appendix D
Corrosion Potentials



.16	.14	.14	.14	.16	.12	14	13	.12	.12	.10	.10	.11	.11	.10	.10
.14	.11	.12	.12	.14	.11	.13	.11	.11	.11	.11	.10	.12	.18	.11	.12
.14	.14	.14	.13	.18	.15	.14	.14	.12	.11	.12	.12	.11	.12	.14	.13
.13	.14	.13	.12	.16	.16	.15	.18	.14	.15	.12	.11	.11	.12	.14	.14
.16	.16	.15	.15	.27	.16	.14	.18	.15	.17	.12	.12	.12	.12	.14	.14
.34	.17	.18	.22	.27	.14	.16	.17	.14	.16	.13	.12	.13	.13	.14	.13



.31	.16	.16	.17	.23	.15	.15	.14	.12	.14	.14	.13	.13	.14	.11	.10
.19	.22	.22	.19	.17	.23	.16	.18	.13	.18	.18	.15	.14	.15	.10	.12
.28	26	.25	.20	.18	.16	.14	.14	.13	.13	.13	.12	.13	.12	.13	.12
.22	.23	.18	.18	.22	.15	.12	.12	.13	.14	.14	.13	.15	.13	.12	.11
.38	.16	.22	.18	.19	.15	.16	.15	.14	.14	.15	.15	.14	.13	.12	.12
.24	.20	.22	.23	.25	.16	.17	.15	.14	.14	.14	.15	.15	.14	.14	.13

Appendix E
Contract

County POLK Project No. IR-235-2(213)80--12-77
Res. Engr. WAYNE SUNDAY Address DES MOINES RCE 521200
Letting Date JANUARY 22, 1992 Liquidated Damages $200 PER DAY
Special Prov. FHWA-1273 08/01/89, SP-1043 01/07/92, SS- 964 07/31/84,
SS-1062 08/01/88, SS-1073 12/20/88, SS-1089 12/05/89,
SS-1093 12/05/89, SS-5003 05/01/90, SS-5025 03/26/91,
SS-5040 01/07/92

Date Started ________ Field Comp. ________ Cert. Comp. ________

Form 650019 4-88 H-6288

CONTRACT NO. 33911

County POLK Project No. IR-235-2(213)80--12-77
Type of Work BRIDGE FLOOR REPAIR Miles ________
Cost Center 601000 Object Code 892 Milepost ________ TO
OVER I-235, ON PENNSYLVANIA AVENUE IN THE CITY OF
DES MOINES.

This agreement made and entered by and between the IOWA DEPARTMENT OF TRANSPORTATION AUSTIN TURNER, DOUGLAS SHULL, ROBERT H. MEIER, SHELDA HERTZKE BEENER, SUZAN STEWART, CATHERINE DUNN & MARLIN VOLZ JR. Contracting Authority, and CRAMER AND ASSOC., INC. OF DES MOINES, IOWA 00010200 Contractor.

It is agreed that the notice and instructions to bidders, the proposal filed herein, the general specifications of the Iowa Department of Transportation for 1984, together with supplemental specifications and special provisions, together with the general and detailed plans, if any, for said project IR-235-2(213)80--12-77, together with Contractor's performance bond, are made a part hereof and together with this instrument constitute the contract. This contract contains all of the terms and conditions agreed upon by the parties hereto. A true copy of said plans and specifications is now on file in the office of the Contracting Authority under date of JANUARY 17, 1992.

Contractor, for and in consideration of $ ****234,473.10, payable as set forth in the specifications constituting a part of this contract, agrees to construct various items of work and/or provide various materials or supplies in accordance with the plans and specifications therefor, and in the locations designated in the Notice to Bidders.

Contractor certifies by his signature on this contract, under pain of penalties for false certification, that he has complied with Iowa Code Section 324.17(8) (1985) as amended, if applicable.

In consideration of the foregoing, Contracting Authority hereby agrees to pay the Contractor promptly and according to the requirements of the specifications the amounts set forth, subject to the conditions as set forth in the specifications.

It is further understood and agreed that the above work shall be commenced or completed in accordance with the following schedule:

	START. DATE	COMPL. DATE	WORK. DAYS
GROUP 1		09/25/92	70

Time is the essence of this contract.

To accomplish the purpose herein expressed, Contracting Authority and Contractor have signed this and four other identical instruments as of the ________ day of ________.

IOWA DEPARTMENT OF TRANSPORTATION

By ________________
Contracting Authority

CRAMER AND ASSOC., INC. OF DES MOINES, IOWA

By ________________

Form 650031 8-87 H-6288

CONTRACT PRICES

CONTRACT NO. 33911

Proposal I.D. No. 920138

Bid Order No. 34

Contractor's No. 1 0 2 0 0

County POLK

Page No. 1

Project No. IR-235-2(213)80--12-77

Type of Work BRIDGE FLOOR REPAIR

Line No.	Item	Item Quantity and Units	Unit Price		Amount	
			Dollars X,XXX,XXX	Cents XXXX	Dollars XX,XXX,XXX	Cents XX
GROUP 1						
0010	BRIDGE FLOOR REPAIR, CLASS A	177 SQ. YDS.	50.0000		8,850.00	
0020	BRIDGE FLOOR OVERLAY	1356 SQ. YDS.	45.0000		61,020.00	
0030	HANDRAIL, HAULING & STORING EXISTING	1 LUMP SUM	3000.0000		3,000.00	
0040	RAIL, STEEL SIDEWALK	299.6 LINEAR FT	35.0000		10,486.00	
0050	REPAIR, CONCRETE	1 LUMP SUM	4500.0000		4,500.00	
0060	TEMPORARY BARRIER RAIL, FURNISH ONLY	450 LINEAR FT	8.0000		3,600.00	
0070	TEMPORARY BARRIER RAIL, PLACE ONLY	900 LINEAR FT	2.0000		1,800.00	
0080	SEALER, CONCRETE, AS PER PLAN	1250 SQUARE FT	1.5000		1,875.00	
0090	RAIL, CONCRETE BARRIER (CAST-IN-PLACE)	611.7 LINEAR FT	37.0000		22,632.90	
0100	CATHODIC PROTECTION SYSTEM	1 LUMP SUM	75000.0000		75,000.00	
0110	FENCE, CHAIN LINK, AS PER PLAN	2.98 STAS.	840.0000		2,503.20	
0120	BARRIER, CONCRETE, APPROACH, MODIFIED	2 ONLY	1500.0000		3,000.00	
0130	GROUND ROD, AS PER PLAN	6 ONLY	70.0000		420.00	
0140	JUNCTION BOX, RM-9, AS PER PLAN	2 ONLY	460.0000		920.00	
0150	HANDHOLE, RM-17, AS PER PLAN	7 ONLY	370.0000		2,590.00	
0160	BASE, ADAPTOR, AS PER PLAN	2 ONLY	360.0000		720.00	
0170	CONNECTOR, RM-12, AS PER PLAN	20 ONLY	35.0000		700.00	
0180	CONDUIT, RIGID STEEL, 2 IN. DIA.	695 LINEAR FT	7.0000		4,865.00	
0190	CONDUIT, RIGID STEEL, 3/4 IN. DIA.	20 LINEAR FT	5.0000		100.00	
0200	CONDUIT, PLASTIC, TYPE 2, 2 IN. DIA.	260 LINEAR FT	5.0000		1,300.00	
0210	CABLE, 1/C NO. 8 AWG 600 V	1720 LINEAR FT	0.6000		1,032.00	
0220	GROUND WIRE, BARE COPPER, 6 AWG	860 LINEAR FT	0.6500		559.00	

Form 650031 8-87 H-6288

CONTRACT PRICES

Proposal I.D. No. 920138

CONTRACT NO. 33911

Bid Order No 34

Contractor's No. 1 0 2 0 0

County POLK

Page No. 2

Project No. IR-235-2(213)80--12-77

Type of Work BRIDGE FLOOR REPAIR

Line No.	Item	Item Quantity and Units	Unit Price		Amount	
			Dollars X,XXX,XXX	Cents XXXX	Dollars XX,XXX,XXX	Cents XX
GROUP 1	(CONTINUED)					
0230	TRAFFIC CONTROL	1 LUMP SUM	8000.	0000	8,000.	00
0240	MOBILIZATION	1 LUMP SUM	15000.	0000	15,000.	00
		TOTAL FOR GROUP 1			$234,473.	10
			TOTAL		$234,473.	10

LAST PAGE

Appendix F
Standard Specification for Deck Preparation

2413.05 PREPARATION OF SURFACE FOR REPAIR AND OVERLAY. Concrete shall be removed from each area, designated on the plans or by the Engineer, to a depth and in a manner consistent with the classification for that area. Areas as shown on the plans are based on the best information available; actual areas will be determined by the Engineer.

A. Class A Bridge Floor Repair. Concrete may be removed by chipping or by a combination of scarifying and chipping, except that final clean up, in any case, shall be by use of hand tools. Class A repair removal shall be considered to start 1/4 inch below the existing surface, but this shall not preclude removal coincidental with preparation for overlay. Removal for Class A repair shall extend at least to the level of the top of the top reinforcing bars, and the removal shall extend deeper, as necessary, to remove unsound concrete. All reinforcing bars and newly exposed concrete shall be thoroughly cleaned by sandblasting or shotblasting. Where bond between existing concrete and reinforcing steel has been destroyed, the concrete adjacent to the bar shall be removed to a depth that will permit new concrete to bond to the entire periphery of the bar so exposed. A minimum of 3/4-inch clearance shall be required around the bar. Care shall be exercised to prevent cutting, stretching, or damaging any exposed reinforcing steel. The Engineer may require enlarging a designate portion should inspection indicate deterioration of concrete or corrosion of reinforcing beyond the limits previously designated.

B. Class B Bridge Floor Repair. Within all areas designated for Class B repair, and any designated areas of Class A repair in which the depth of the remaining sound concrete is less than 50 percent of the original depth of the bridge floor, all concrete shall be removed. Designated Class A repair areas shall be measured as Class B Bridge Floor Repair when full-depth removal is required. At the direction of the Engineer, limited areas of removal greater than 50 percent of the floor thickness, such as beneath reinforcing, may be allowed; these limited areas of excess depth will be measured as Class A Bridge Floor Repair. Concrete may be removed by chipping or by a combination of scarifying and chipping, except that the final removal at the periphery of Class B repair areas shall be accomplished by 15-pound chipping hammers or hand tools. Class B repair removal shall be considered to start 1/4 inch below the existing surface, but this shall not preclude removal coincidental with preparation for overlay. All exposed reinforcing bars and newly exposed concrete shall be thoroughly cleaned by sandblasting or shotblasting. Care shall be exercised to prevent cutting, stretching, or damaging exposed reinforcing.

Forms shall be provided to enable placement of new concrete in the full-depth opening. The forms shall preferably be suspended from existing reinforcing bars by wire ties. Forms may, in the case of large-area openings, be supported by blocking from the beam flanges. Forms will in all cases be supported by elements of the existing superstructure unless specifically noted or shown otherwise on the plans.

C. Bridge Floor Overlay. The entire, existing concrete floor area shall be uniformly scarified or prepared to a depth of ¼ inch, except over areas of Class A and B repair where the ¼-inch removal may be coincidental with operations for repair removal. Removal to a greater depth will be required at drains and elsewhere, as noted on the plans.

D. General. The thickness of concrete above the prepared surface or reinforcing steel shall be at least 3/4 inch and shall be greater if specified on the plans. The clearance shall be checked in the following manner before concrete is placed. A filler block having a thickness 1/8 inch less than the overlay thickness shall be attached to the bottom of the screed; with screed guides in place, the screed shall be passed over the area to be concreted. As an alternate to passage of the finishing machine, an approved template, supported by the screed guides, may be passed over the overlay area. Where the intended clearance does not allow use of this method, a stringline or other means shall be used, subject to approval of the Engineer. All old concrete which does not have sufficient clearance shall be removed. All reinforcing steel which does not have sufficient clearance shall be depressed and fastened down. It may be necessary to remove concrete beneath some reinforcement to permit depressing the reinforcement adequately. The minimum clear distance around these bars for placement of new concrete shall be 3/4 inch.

Areas from which concrete has been removed shall be kept free of slurry produced by wet sawing of concrete joints. All such slurry shall be removed from prepared areas before new concrete is placed.

Hand tools shall be used to remove final particles of concrete or to achieve the required depth. The entire surface, including curbs and exposed reinforcement, against which new concrete is to be placed shall be sandblasted or shotblasted. The cleaning shall be of such extent as to remove all dirt, oil, and other foreign material, as well as any unsound concrete. Immediately before applying grout in preparation for placement of new concrete, the surface shall be cleaned with air blast. For the portland cement concrete, it is not intended or desired that existing concrete, prepared for repair or overlay be presaturated with water before grout and new concrete is placed. The prepared surface shall be dry to allow some absorption of the grout.

At the time of placement of either PCC or latex-modified concrete, the area shall be clean and the reinforcement free of rust; rust forming because of dew on clean reinforcement overnight will not be considered objectionable, but reinforcement with a greater amount of rust shall be subject to recleaning before the concrete is placed. The area shall be cleaned by air blast before the concrete is placed.

For latex-modified concrete, the surface shall be flushed with water and kept wet for at least one hour before concrete placement. Puddles of free water shall be removed before covering with concrete.

2413.06 PROPORTIONING AND MIXING. The mixture shall be proportioned and mixed at the project site. Ready-mixed concrete shall not be approved.

The water-reducing admixture for improved workability of portland cement concrete shall be incorporated and mixed into

Appendix G
Class A Areas

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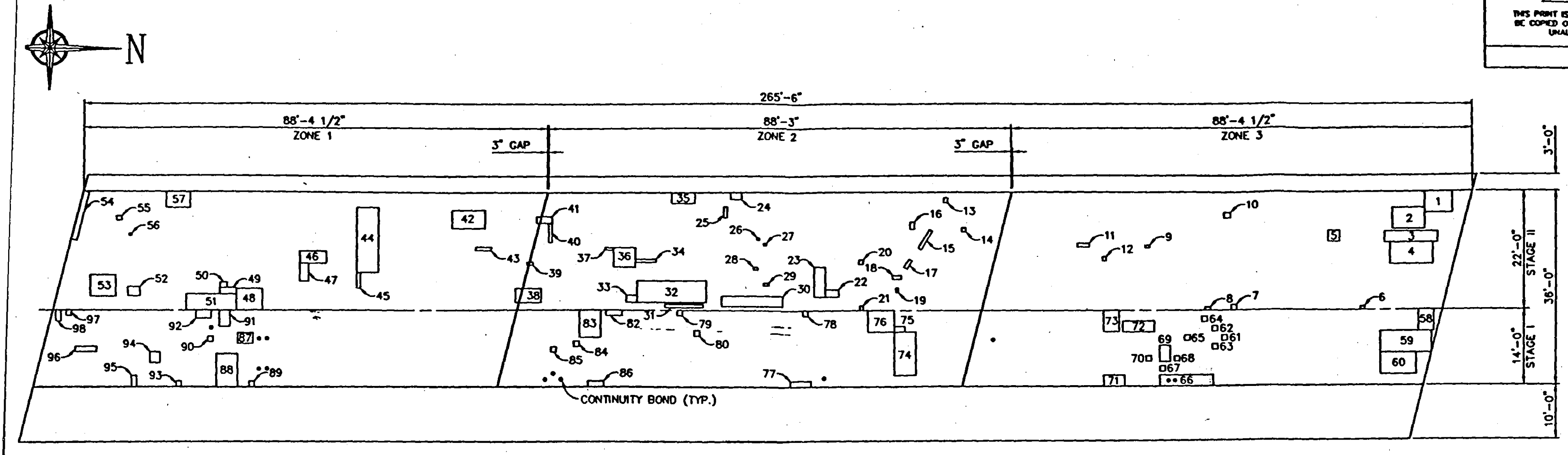
NOTES



PLAN VIEW DECK

LOCATION	DELAM. SIZE
1	48" X 65"
2	48" X 75"
3	24" X 124"
4	48" X 100"
5	24" X 27"
6	8" X 10"
7	12" X 12"
8	7" X 12"
9	6" X 10"
10	12" X 15"
11	8" X 28"
12	8" X 10"
13	9" X 12"
14	9" X 9"
15	8" X 48"
16	10" X 16"
17	8" X 22"
18	8" X 20"
19	5" X 10"
20	10" X 10"
21	8" X 10"
22	16" X 31"
23	26" X 66"
24	16" X 25"
25	8" X 25"
26	6" X 6"
27	6" X 6"
28	6" X 10"
29	6" X 12"
30	23" X 140"

LOCATION	DELAM. SIZE
31	7" X 86"
32	48" X 157"
33	16" X 24"
34	7" X 48"
35	25" X 53"
36	44" X 48"
37	6" X 20"
38	32" X 60"
39	7" X 14"
40	8" X 43"
41	15" X 36"
42	40" X 75"
43	8" X 36"
44	48" X 146"
45	8" X 34"
46	27" X 60"
47	20" X 40"
48	48" X 61"
49	15" X 37"
50	12" X 16"
51	36" X 116"
52	20" X 28"
53	48" X 57"
54	13" X 110"
55	9" X 12"
56	5" X 6"
57	36" X 56"
58	36" X 48"
59	48" X 120"
60	47" X 84"

LOCATION	DELAM. SIZE
61	12" X 12"
62	12" X 12"
63	12" X 12"
64	12" X 12"
65	12" X 12"
66	24" X 120"
67	12" X 12"
68	12" X 12"
69	24" X 36"
70	12" X 12"
71	24" X 48"
72	24" X 72"
73	36" X 48"
74	48" X 96"
75	12" X 24"
76	48" X 60"
77	12" X 48"
78	12" X 12"
79	12" X 12"
80	12" X 12"
81	12" X 12"
82	12" X 36"
83	48" X 60"
84	12" X 12"
85	12" X 12"
86	12" X 36"
87	24" X 36"
88	48" X 72"
89	12" X 12"
90	12" X 12"

LOCATION	DELAM. SIZE
91	24" X 36"
92	18" X 36"
93	12" X 12"
94	24" X 24"
95	12" X 24"
96	12" X 48"
97	12" X 12"
98	12" X 24"

REVISION DESCRIPTION	DATE	BY	CHKD	APP'D	REV	REVISION DESCRIPTION	DATE	BY	CHKD	APP'D	TOLERANCES FRACTIONS±	DWG. APPROVALS	DATE	REV.	JOB APPROVALS	DATE
											XX ±		12-14-92	A		
											XXX ±		12-14-92	A		

ELGARD Corporation
A Subsidiary of ELTECH Systems Corp.
100 Seventh Avenue Suite 300
Chardon, Ohio 44024

REFERENCE DRAWING:

JOB TITLE
IOWA DEPARTMENT OF TRANS

DWG. TITLE
ELGARD CATHODIC PROTECTION
OF PENNSYLVANIA AVE. OVER
DES MOINES, IOWA
SPACER MESH LOCATIONS

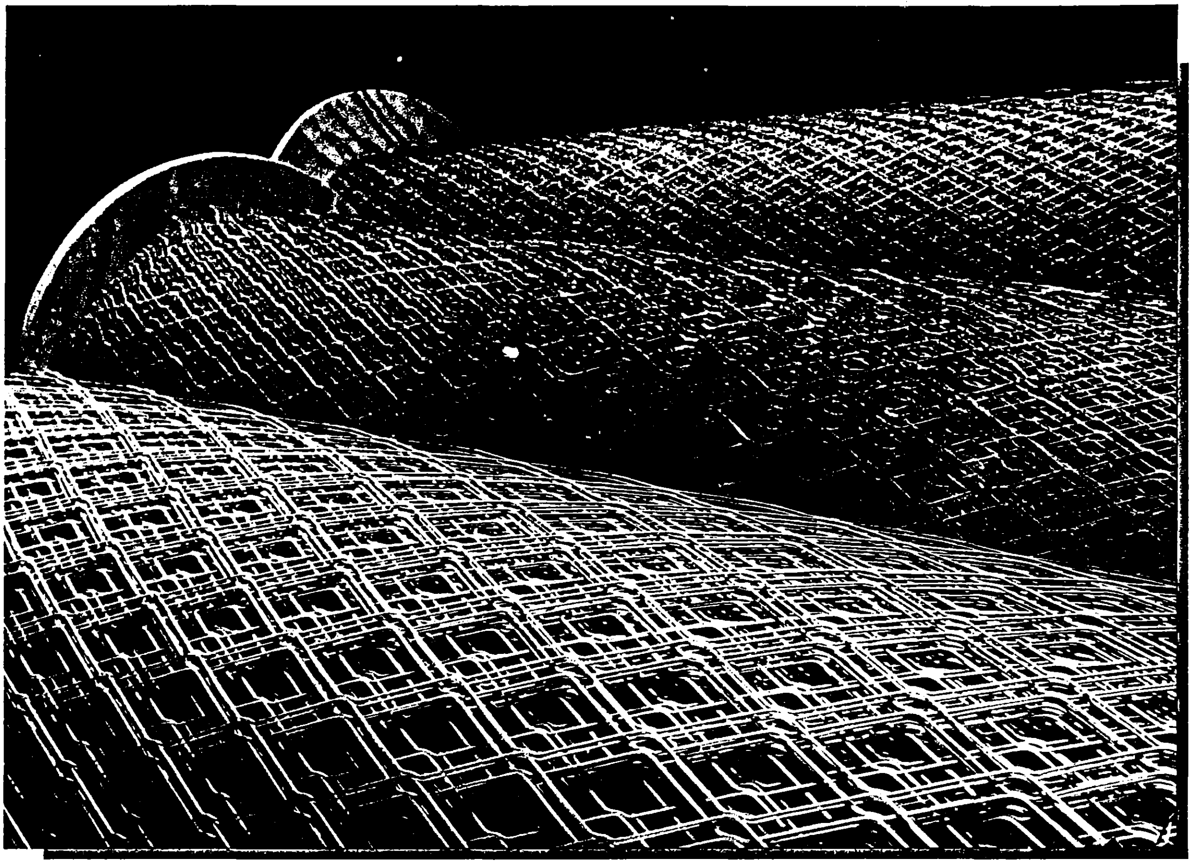
FILE NAME
0462EF07

DWG. UNIT NO.
0462EF07

Appendix H
Anode Mesh Specifications

ELGARD™ DATA SHEET

Anode Mesh



Advanced Cathodic Protection System for Steel-Reinforced Concrete

Description:
ELGARD Anode Mesh is a key component of the ELGARD CP System. It is composed of a precious metal oxide catalyst sintered to a highly expanded titanium mesh substrate. ELGARD's proprietary CP technology is based on the dimensionally stable anode (DSA®) which draws upon patents granted and pending. Applications include structures such as bridge decks, substructures, sidewalks and abutments, elevated expressways, tunnels, parking garages, and industrial facilities.

Special Features:

- The ELGARD Anode Mesh does not affect the surrounding concrete and remains unchanged in shape, geometry, and dimension during its lifetime.
- The ELGARD Anode Mesh provides low electrical resistance, chemical stability, and much redundancy in the number of electrical paths.
- The ELGARD Anode Mesh is simple to install. Standard construction crews unroll the lightweight anode onto the concrete surface. The anode cuts easily with hand tools and can be flexibly bent, wrapped, and fitted around drains, curbs, columns, and other irregular configurations.

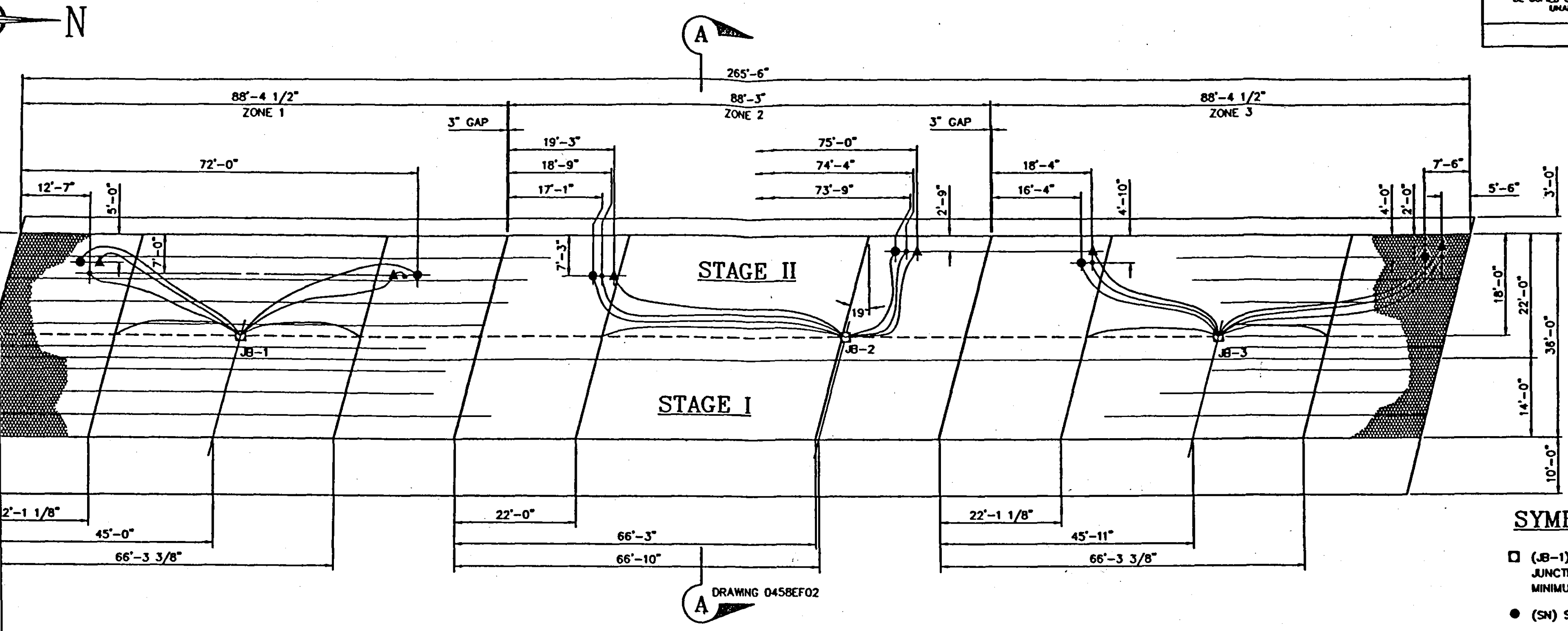
ELGARD™ Anode Mesh

MATERIAL SPECIFICATIONS

	150 Anode Mesh	210 Anode Mesh	300 Anode Mesh
MAXIMUM CONCRETE STRUCTURE CURRENT DENSITY	2.0 mA/ft^2	2.7 mA/ft^2	3.9 mA/ft^2
CATALYST			
Composition	Mixed precious metal oxide	Mixed precious metal oxide	Mixed precious metal oxide
Specificity	Oxygen	Oxygen	Oxygen
Maximum anode-concrete interface current density	13 mA/ft^2	13 mA/ft^2	13 mA/ft^2
MESH			
Composition	Titanium Gr. 1	Titanium Gr. 1	Titanium Gr. 1
Width of roll	45 in	4 ft	4 ft
Length	267 ft	250 ft	250 ft
Diamond dimension	3 in LWD x 1⅓ in SWD	3 in LWD x 1⅓ in SWD	2 in LWD x 0.92 in SWD
Resistance lengthwise (45 in wide)	.026 ohm/ft	.014 ohm/ft	.008 ohm/ft
Resistance widthwise with current distributor	.007 ohm/ft	.005 ohm/ft	.004 ohm/ft
Bending radius	3/32 in	3/32 in	3/32 in
Bending radius in mesh plane	50 ft	50 ft	50 ft
CURRENT DISTRIBUTOR			
Width	.5 in	.5 in	.5 in
Thickness	.040 in	.040 in	.040 in
Typical distance separating current distributors (mesh lengthwise)	100 ft	100 ft	100 ft
Typical distance separating power feeds (mesh widthwise)	30 ft	30 ft	30 ft
TITANIUM SUBSTRATE PROPERTIES			
Density	0.163 lb/in^3	0.163 lb/in^3	0.163 lb/in^3
Melting point	3040°F	3040°F	3040°F
Coefficient of thermal expansion	4.8x10^{-6} in/in/°F	4.8x10^{-6} in/in/°F	4.8x10^{-6} in/in/°F
Modulus of elasticity	14.9x10^6 PSI	14.9x10^6 PSI	14.9x10^6 PSI
Thermal conductivity @ room temperature	9.0 BTU/hr/ft^2/°F/ft	9.0 BTU/hr/ft^2/°F/ft	9.0 BTU/hr/ft^2/°F/ft
Specific heat @ room temperature	0.124 BTU/lb/°F	0.124 BTU/lb/°F	0.124 BTU/lb/°F
Resistivity	56 x 10^{-6} ohm-cm	56 x 10^{-6} ohm-cm	56 x 10^{-6} ohm-cm
Weldability	Good	Good	Good
Tensile strength	35,000 PSI min	35,000 PSI min	35,000 PSI min
Yield strength, 0.2% offset	25,000 PSI min	25,000 PSI min	25,000 PSI min
Elongation, sheet > .025 thick	24% min	24% min	24% min
Chemical composition	0.08 C	0.08 C	0.08 C
	0.20 Fe	0.20 Fe	0.20 Fe
	0.03 N	0.03 N	0.03 N
	0.18 O	0.18 O	0.18 O
	0.015 H max	0.015 H max	0.015 H max

ELGARD Corporation
ELTECH 100 Seventh Avenue, Suite 300 • Chardon, OH 44024-1095
Telephone: (216) 285-0380 • Fax: (216) 285-0379

Appendix I
Layout of Zones and Electrical Connections



PLAN VIEW DECK

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NOTES

SYMBOL LEGEND

- ☐ (JB-1) ACCESS HOLE WITH JUNCTION BOX (6" X 6" X 6" MINIMUN)
- ● (SN) SYSTEM NEGATIVE
- ▲ (RC) REFERENCE CELL
- ⌒ (RCG) REFERENCE CELL GROUND
- — — — UNDERDECK CONDUIT

0462EF02	STAGING SECTION VIEWS
0462EF03	STANDARD DETAILS
0462EF04	STANDARD DETAILS
0462EF05	STANDARD DETAILS
0462EF06	ELECTRICAL SCHEMATIC

REFERENCE DRAWINGS

JOB TITLE
IOWA DEPARTMENT OF TRANSPORTATIO

DWG. TITLE
ELGARD CATHODIC PROTECTION SYSTEM
OF PENNSYLVANIA AVE. OVER I-235
DES MOINES, IOWA
PLAN VIEW BRIDGE DECK AS-BUILT

ION DESCRIPTION	DATE	BY	CHK'D	APP'D	REV	REVISION DESCRIPTION	DATE	BY	CHK'D	APP'D
	02-92	RLM	JPJ	JPJ						
	02-92	RLM	JPJ	JPJ						
	12-92	RLM	JPJ	JPJ						

TOLERANCES
FRACTIONS ±
.XX ±
.XXX ±
ANGLES ±

DWG. APPROVALS	DATE	REV.
	02-10-92	A
	12-14-92	C
DRAWN	02-03-92	A
CHK'D	02-10-92	A

JOB APPROVALS	DATE

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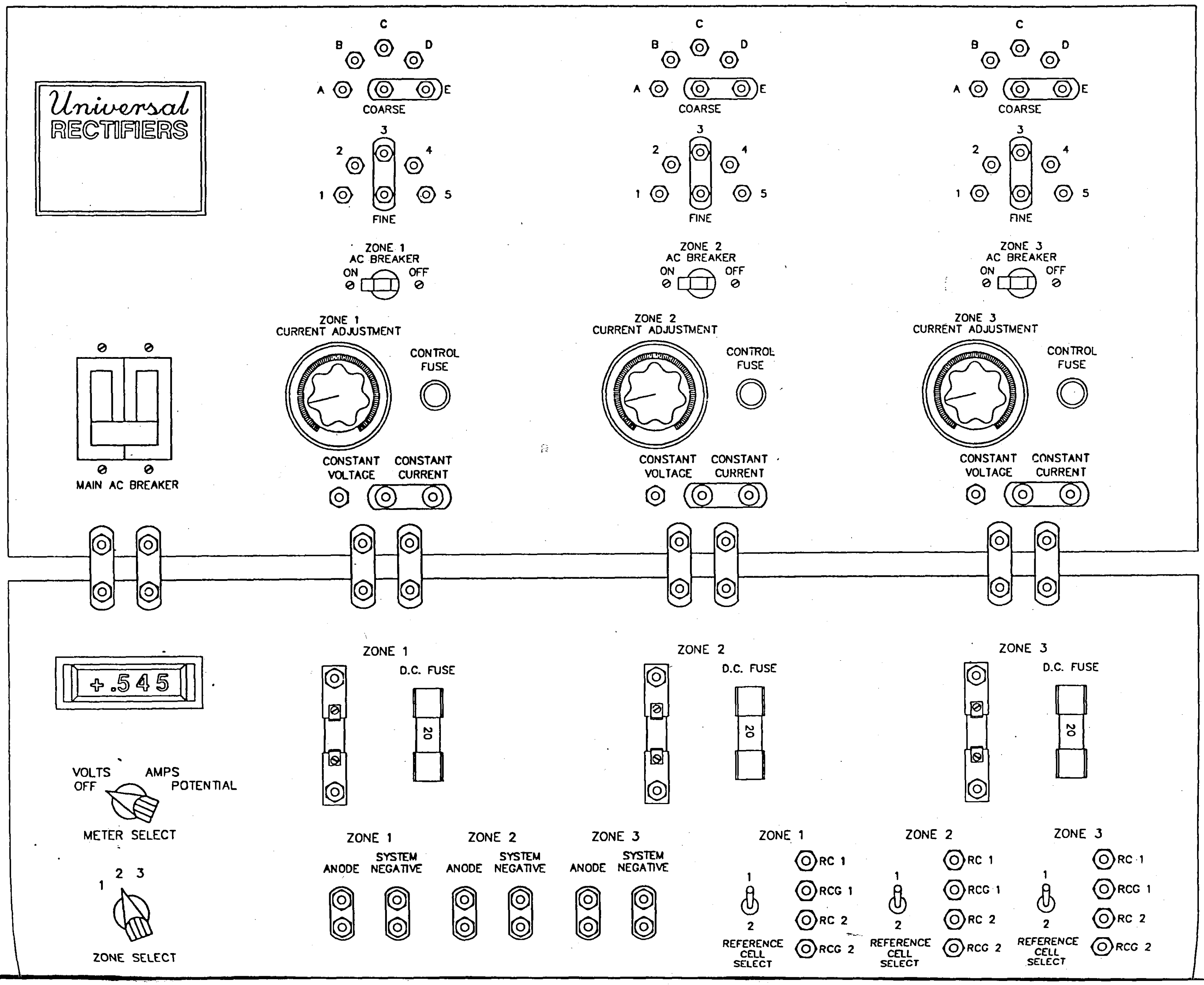
100 Seventh Avenue Suite 300
Chardon, Ohio 44024
ELTECH

FILE NAME
0462EF01

ENG. NO.
0462

DWG. UNIT NO.
0462EF01

Appendix J
Rectifier/CRB Unit


Universal
RECTIFIERS
C
B
D
A
E
COARSE
3
2
4
1
5
FINE
ZONE 1
AC BREAKER
ON
OFF
ZONE 2
AC BREAKER
ZONE 3
AC BREAKER
ZONE 1
CURRENT ADJUSTMENT
ZONE 2
CURRENT ADJUSTMENT
ZONE 3
CURRENT ADJUSTMENT
CONTROL
FUSE
CONSTANT
VOLTAGE
CONSTANT
CURRENT
MAIN AC BREAKER
+.545
ZONE 1
ZONE 2
ZONE 3
D.C. FUSE
20
VOLTS
AMPS
OFF
POTENTIAL
METER SELECT
1 2 3
ZONE SELECT
ANODE
SYSTEM
NEGATIVE
RC 1
RCG 1
RC 2
RCG 2
REFERENCE
CELL
SELECT

Appendix K
Initial Settings

Iowa Department of Transportation
Pennsylvania Avenue Bridge over I-235
Startup Data Sheet

Data Taken By: SDS

Date: 10/2/92

Rectifier Serial No: 920944

Weather Conditions: Sunny, 65 Degrees Fahrenheit

Zone No.	Reference Cell No.	Resistance		DC mV		Rebar Static Potential (mV) vs. Graphite
		SN/RCN (DC) ohms	Anode/SN (AC) ohms	SN/RCN	Anode/SN	
1	1	2.2/2.3	0.58	0.0	188	-72
	2	2.2/2.4		0.0		-99
2	1	2.9/3.0	0.74	0.0	168	-65
	2	3.0/3.2		0.0		-168
3	1	3.5/3.5	0.88	0.0	35	-91
	2	3.8/3.2		0.1		-3

Zone No.	Zone Voltage (Volts)	Current Output (Amps)	Reference Cell No.	Rebar "On" Potential	Rebar "Instant Off" Potential
1	2.5	3.2	1	-391	-339
			2	-473	-398
2	3.1	3.2	1	-466	-367
			2	-467	-417
3	3.3	3.2	1	-367	-240
			2	-302	-161

NOTES: Reference Cell Ground Wire is the White Wire from the Shielded Twisted Pair

Reference Cell Wire is the Black Wire from the Shielded Twisted Pair

Appendix L
Depolarization Test

Iowa Department of Transportation
Pennsylvania Avenue Bridge over I-235
Depolarization Test

Data taken by: SDS

Date: 11/13/92

Rectifier Serial No.: 920944

Weather: 28 Degrees F, Cold and Windy

			Rebar Static Potential					
			RC mV = -mV vs. Reference Cell					
	Elapsed Time,min.	Actual Time of Reading	Zone No. 1		Zone No. 2		Zone No. 3	
			RC-1	RC-2	RC-1	RC-2	RC-1	RC-2
	▨		mV	mV	mV	mV	mV	mV
On Potential	0	8:14	695	872	929	939	549	358
Instant-Off Potential	<1 sec.	8:15	486	599	607	667	262	117
	1	8:16	410	505	495	573	131	28
	2	8:17	361	457	440	530	86	2
	3	8:18	333	427	405	504	59	18
	4	8:19	308	405	379	488	41	25
	5	8:20	291	388	361	476	30	27
	6	8:21	275	372	341	465	22	26
	7	8:22	262	360	330	457	17	24
	8	8:23	254	352	322	453	15	22
	9	8:24	249	347	317	450	14	20
	10	8:25	241	346	309	445	12	16
	20	8:35	199	301	270	420	27	23
	30	8:45	176	281	250	404	46	53
	40	8:55	164	270	239	394	57	68
	50	9:05	155	259	230	384	64	76
	60	9:15	150	252	223	377	68	79
	90	9:45	141	239	211	362	71	77
	120	10:15	142	224	200	345	53	70
	150	10:45	138	222	198	342	54	68
	180	11:15	132	216	194	334	52	65
	210	11:45	129	211	190	328	50	62
	240	12:15	125	206	186	322	48	59
	DELTA		361	393	421	345	214	58

Delta is the difference between readings at "Instant-Off" and "Time 240".

NOTES: Settings Before Testing:
Zone 1: 3.2 A, 3.0 V
Zone 2: 3.2 A, 3.6 V
Zone 3: 3.2 A, 3.6 V

Settings After Testing:
Zone 1: 2.8 A, 2.4 V
Zone 2: 2.8 A, 3.0 V
Zone 3: 3.2 A, 3.1 V