Technical Report Documentation Page

1. Report No. TX/91-500/554-1F	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Cathodic Bridge Deck Protection		5. Report Date: August 1990
		6. Performing Organization Code
7. Author(s): Linda Smith, Research Engineer		8. Performing Organization Report No. 500/554-1F
9. Performing Organization Name and Address: State Department of Highways and Public Transportation, Transportation Planning Division, P.O. Box 5051, Austin, Texas 78763		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 1-10-85-500 & 1-10-84-554
12. Sponsoring Agency Name and Address: U.S. Department of Transportation, Federal Highway Administration, Austin, TX 78701		13. Type of Report and Period Covered
		14. Sponsoring Agency Code

15. Supplementary Notes

(DTFH-84-34-TX-18) (DTFH-71-83-TX-07)

Work performed in cooperation with the Federal Highway Administration, U.S. Dept. of Transportation

16. Abstract

Five systems of cathodic protection were installed on the US 87 Missouri-Pacific Railroad overpass in Big Spring, Texas. The design and construction of the systems are summarized in this report. The Federal Highway Administration sponsored the demonstration project intended to be used as a means of comparing the various systems. Later reports will provide updates of how effectively the systems operate in this installation.

17. Key Words: cathodic protection, bridge deck, corrosion		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages: 165	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

CATHODIC BRIDGE DECK PROTECTION

FHWA Demonstration Project

No. 1-10-85-500 & 1-10-84-554

Design and Construction

TEXAS STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

TRANSPORTATION PLANNING DIVISION

September, 1990

ACKNOWLEDGEMENTS

Appreciation for their comments and assistance is extended to the following:

Mr. William G. Burnett, P.E. – District 8, SDHPT
Mr. Michael V. Chetty, P.E. – District 8, SDHPT
Mr. William Leach – District 8, SDHPT
Mr. Steve Strain – J.H. Strain and Sons, Inc.
Mr. H.D. Butler, P.E. – Bridge Division, SDHPT

Special thanks are also extended to Corrpro Companies, Inc. and Mr. James B. Bushman, P.E. of Corrpro for permission to include their report in our publication.

LIST OF FIGURES

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CHAPTER 1

INTRODUCTION

Deterioration of bridge decks and substructures due to corrosion of reinforcing steel is a nationwide problem which has already reached alarming proportions. In Texas, damage is not confined to northern districts where freeze cycles necessitate the use of deicing salts, but is also prevalent in coastal areas where salt-laden air and seawater splash zones occur.

Conventional methods to inhibit corrosion rates, such as deck surface treatment and epoxy-coated reinforcement, are under examination; however, their effectiveness is not fully certain. The Texas State Department of Highways and Public Transportation (SDHPT), District 8, in cooperation with the Federal Highway Administration (FHWA) Demonstration Division have applied cathodic protection systems to the U.S. 87 Missouri Pacific Railroad overpass structure in Big Spring, Texas. The structure is 67 feet wide by 581 feet long and was constructed approximately 30 years ago. The structure has very steep grades (approximately 7.5%) and is treated with deicing salts frequently during winter months. Active corrosion, not surprisingly, was evident on the structure.

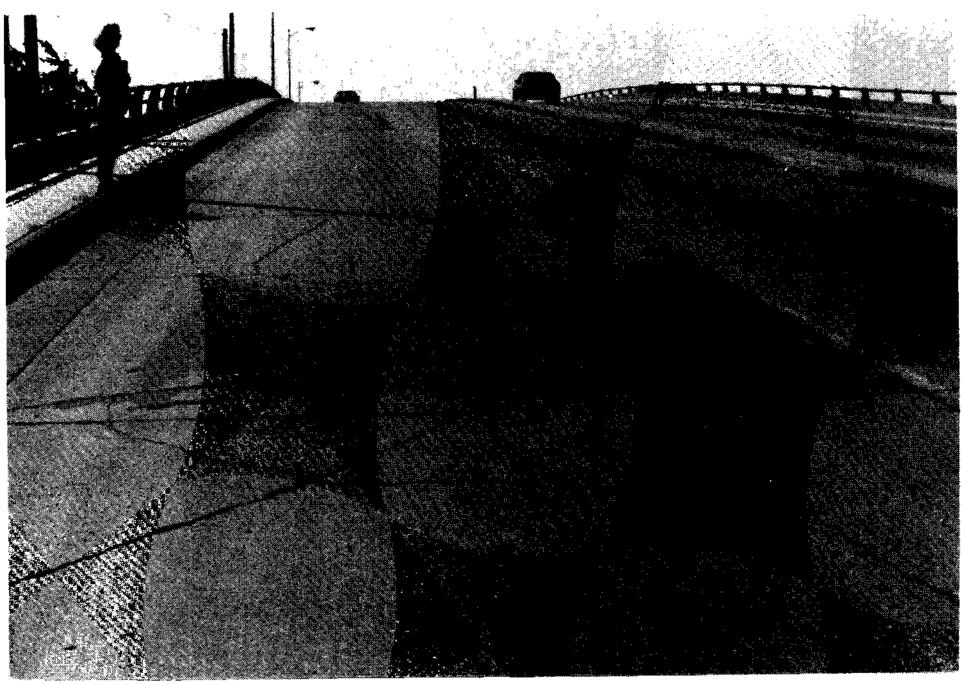


Figure I.1 U.S. 87 at M.P.R.R. Overpass, Big Spring, TX

Figure I.2 U.S. 87 Overpass, August 1986

Figure I.3 U.S. 87 Bridge Deck

Cathodic protection is defined as the reduction or elimination of corrosion by making the reinforcing steel a cathode by means of an impressed current. [Ref. 1, p. 1] Corrosion (metal loss through oxidation) occurs when current passes from an iron anode into concrete. As this current passes, oxides of iron form on the anode, often doubling the volume of the equivalent iron and giving rise to the mechanical pressure which may result in cracking and, ultimately, delamination of the concrete deck.

The U.S. 87 installation involved five individual cathodic systems on a single structure. This project will provide a systematic and comparative evaluation of these systems with regard to the ease of installation, effectiveness of operation and ease of routine and major maintenance. In this initial report, the design, construction and initial testing of the five systems will be discussed.

CHAPTER 2

PRELIMINARY TESTING

A thorough preliminary investigation of the existing deck was performed prior to installation of the cathodic protection. The tests conducted during the preliminary investigation on the U.S. 87 structure included the following:

1. Half-cell potentials
2. Chloride content
3. Percent delamination

Figure II.1 SDHPT District 8 personnel conducting preliminary testing

Based upon the test results (summarized in Table II.1), the decision to pursue cathodic protection was confirmed. The following indicators for each test were utilized to determine the practicality of the cathodic application: [Ref. 2, p. 5]

1. Delamination: Percent delamination ≤ 30% = Economic Feasibility

2. Half-Cell Potential: Readings ≤ .35V = Active Corrosion

3. Chloride Content: Content (Lbs/C.Y) > 2 lbs./c.y. = Active Corrosion

SUMMARY OF TEST RESULTS

Slab No.	Station (Area)	Test Results: Delamination Area, Sq. Ft. / % of slab	Half-cell Potential Average of Readings (Negative Volts)	Chloride Cont. (Pounds per Cubic Yard)
	8+19.28			
1	<2314.28> 8+60.61	141.2 / 6.10	0.30	---*
2	<2301.60> 9+01.71	96.6 / 4.20	0.25	---*
3	<2301.60> 9+42.81	341.8 / 14.85	0.22	---*
4	<2301.60> 9+83.91	250.8 / 10.90	0.18	---*
5	<2301.60> 10+25.01	474.0 / 20.59	0.24	3.3
6	<2301.60> 10+66.11	462.6 / 20.10	0.22	4.8
7	<2301.60> 11+07.21	435.0 / 18.90	0.20	2.9
8	<2301.60> 11+48.31	233.6 / 10.15	0.16	3.7
9	<2301.60> 11+89.41	284.2 / 12.35	0.19	---*
10	<2314.48> 12+30.74	247.6 / 10.70	0.19	3.6
11	<1848.00> 12+63.74	63.7 / 3.45	0.16	---*
12	<1904.00> 12+97.74	285.6 / 15.00	0.22	3.2
13	<1904.00> 13+31.74	261.8 / 13.75	0.17	---*
14	<1904.00> 13+65.74	326.5 / 17.15	0.15	---*
15	<1680.00> 13+98.74	19.4 / 1.15	0.11	---*
	<32,281.76>	3924.4 / 12.16		

* no samples were taken in this area

Table II.2

DESIGN

The design approach taken by SDHPT personnel, in conjunction with the FHWA, was to use available "off-the-shelf" systems offering sufficient cathodic protection. Of the five systems used, three were installed within the bridge deck itself and two were surface coatings of the sidewalk portion of the deck and one of the bents.

The plan drawings indicated the locations of the various systems and details of construction not related to the cathodic protection. In preparation for the cathodic system installations and the application of a dense concrete overlay, the traffic lanes were milled approximately 2 inches on the bridge and approaches. The milling necessitated replacement of a steel finger-type expansion joint at Bent 4 and two armor joints at the bridge ends.

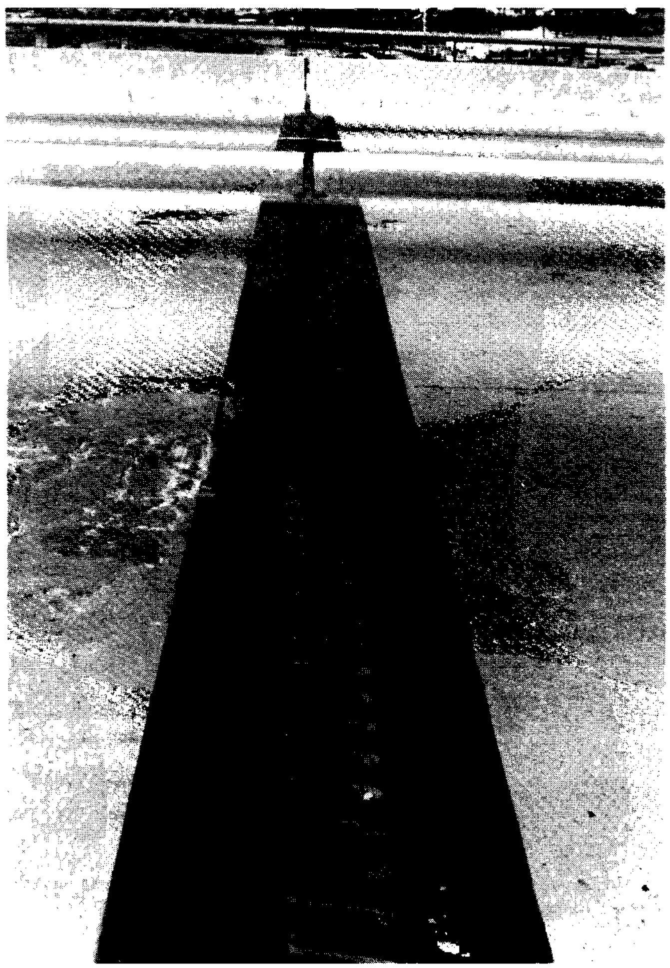


Figure II.3 U.S. 87 Overpass, Bent 4 armor joint

The plans, as developed for contract letting and construction, are included as Appendix A.

A special specification was developed to describe the details of the cathodic protection systems and their installation. This specification, along with other required contract documentation, was included as part of the contract proposal and is included in this report as Appendix B.

The five systems used were the following:

System "A" — titanium wire mesh
System "B" — conductive cable system
System "C" — carbon strand system
System "D" — hot-sprayed zinc
System "E" — conductive paint

As mentioned earlier, the special specification was the bulk of the plans, describing the requirements of the proposed systems. One of the most essential requirements of the contractor was the provision of a technical representative specializing in cathodic protection. This representative was to supervise the installation, energizing and adjustment of all the systems.

The contractor was also required to furnish to the SDHPT all instruments and training necessary for monitoring the cathodic systems. These instruments as well as the cathodic systems were specified by a known brand name or equivalent. As the field of cathodic protection grows, it may be possible to specify the type of system without brand names, thus providing more competitive bidding.

CHAPTER 3

CONSTRUCTION PHASE

The first operation during construction was milling of the bridge deck surface. This served a dual purpose by exposing the badly delaminated areas and preparing a surface for the dense concrete overlay. All delaminated areas were removed and patched by normal concrete repair methods, utilizing Class A "Concrete for Structures" from the Texas Standard Specifications.

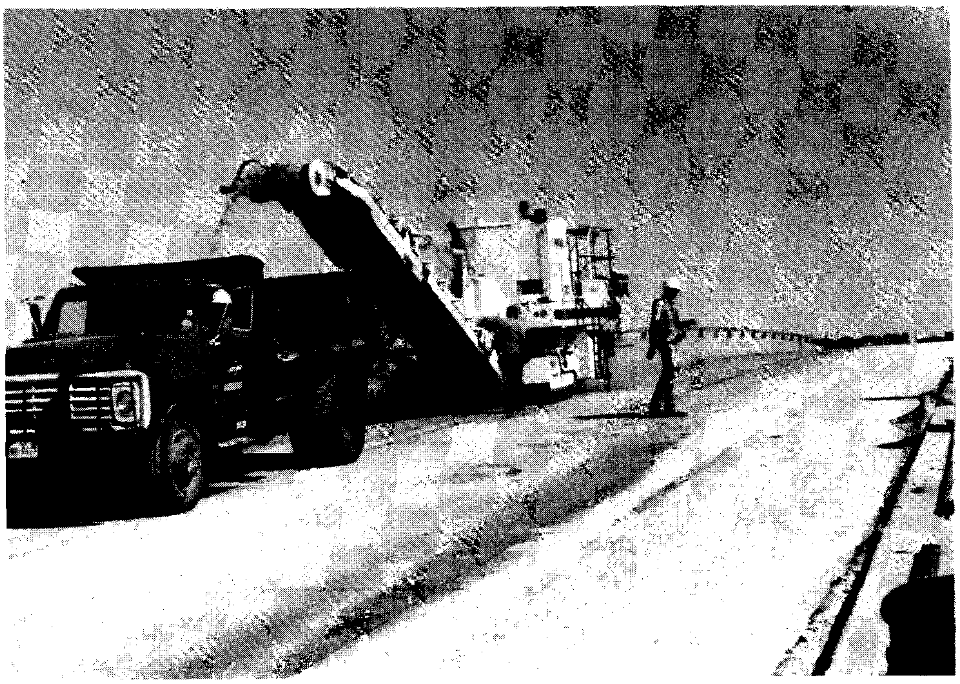


Figure III.1 U.S. 87 Overpass, milling operation by the contractor

Figure III.2 Condition of delaminated area after milling

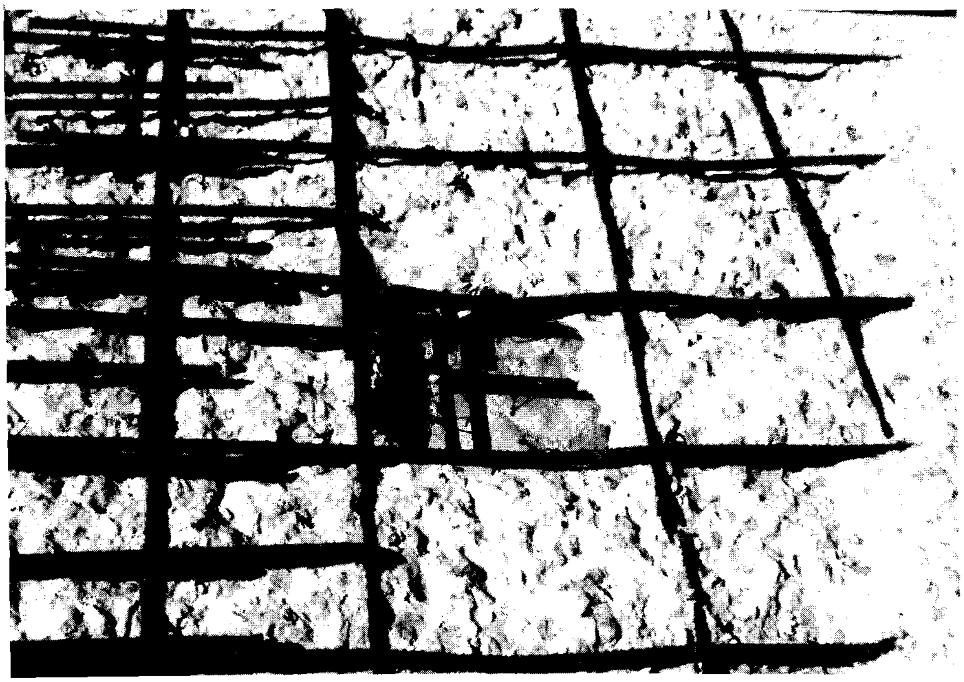


Figure III.3 Delaminated area after removal of damaged concrete

Figure III.4 Bridge deck prepared for placement of concrete repair

Figure III.5 Placement of concrete repair

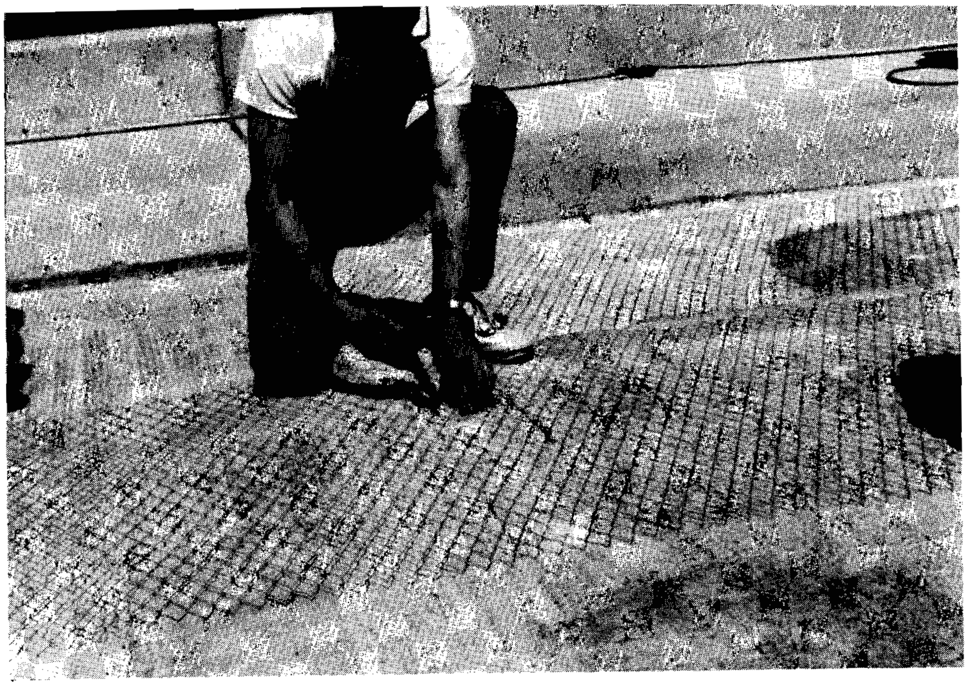
Figure III.6 Completed concrete deck repair

The electrician then checked to see that a current could be provided continuously through the deck, thus assuring that the cathodic systems could operate, if installed properly. Probes were installed throughout the bridge deck to provide for initial and final monitoring of the systems.

Figure III.7 Continuity splice

Three types of probes were specified; two types measure the rate of corrosion, and the other is a reference cell for the rectifier, assuring maintenance of current flow.

Figure III.8 Probe installation



Figures III.9 & 10 System "A" installations

The installation of System "A", an expanded titanium mesh (manufactured by Elgard), was completed first. The system was very easy to install (simply rolled out onto the deck); however, it was the most difficult to maintain during placement of the dense concrete overlay. The mesh tended to float, requiring very close monitoring by the work crew placing the concrete. A "short-out" also occurred during placement of the dense concrete overlay. The problem was easily located, in that one of the strands had made contact with an exposed tie wire, and was resolved quickly.

Figure III.11 Verification of System "A" continuity

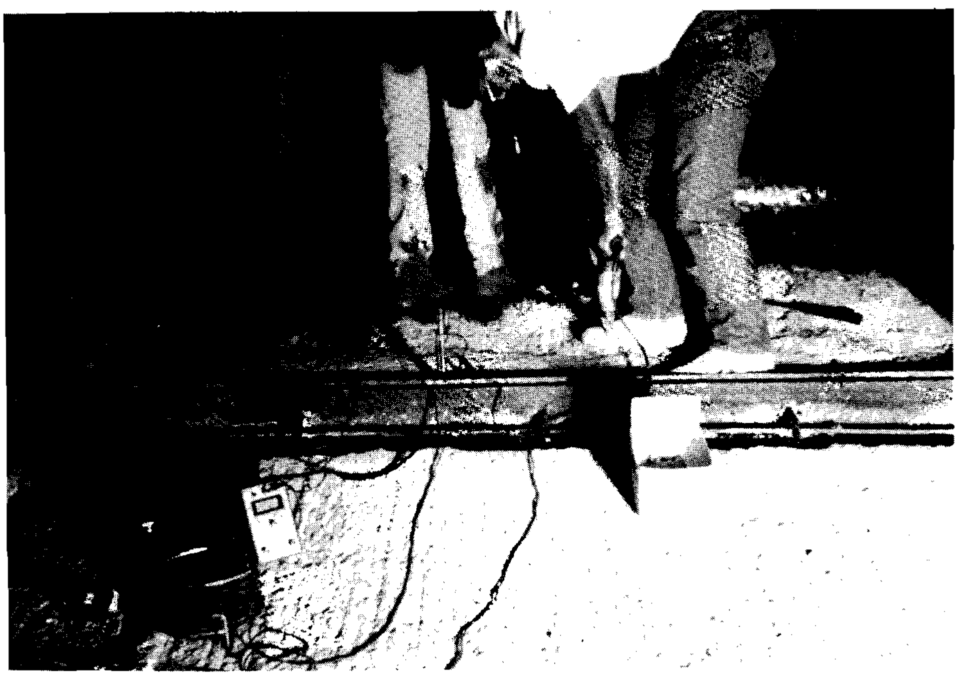


Figure III.12 Repair of System "A" short-out

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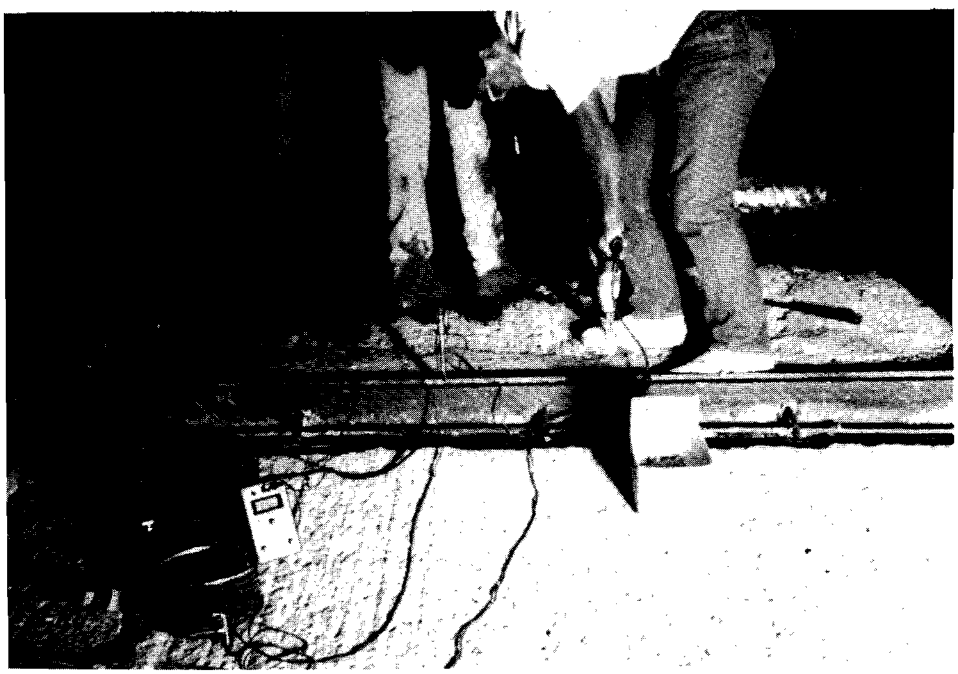


Figure III.12 Repair of System "A" short-out

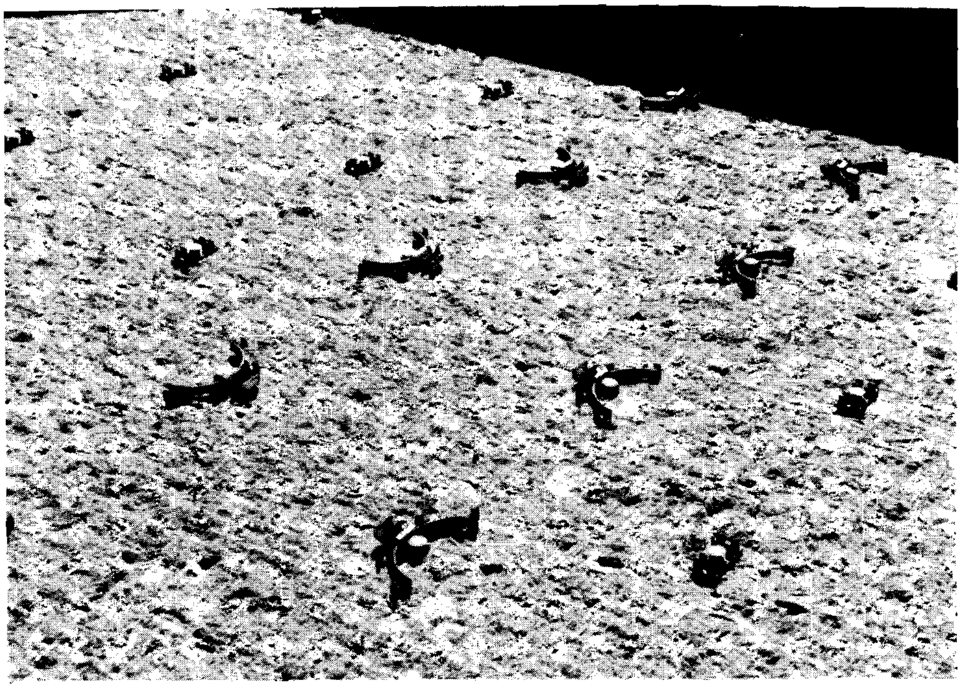


Figure III.13 System "B" conduit connectors

Figure III.14 System "B" installation of conduit

The next installation was System "B", an anode strand system (manufactured by Raychem). Installation involved placing fasteners in the deck by drilling, then placing the strands through the fasteners. Placement was slightly more time consuming than System "A", but the system provided no interference to the placement of the dense concrete overlay.

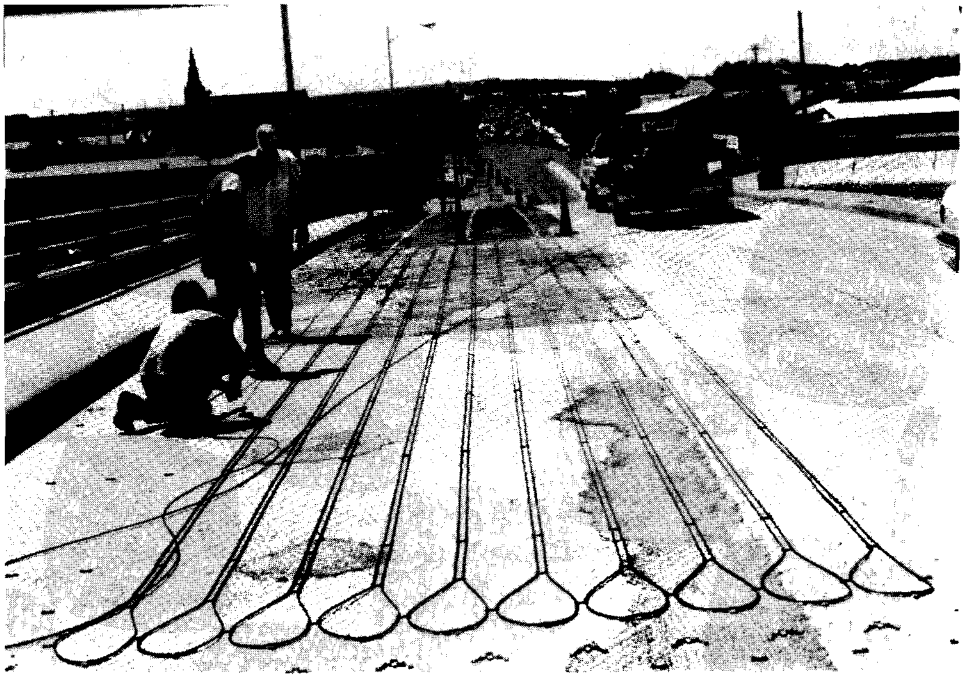


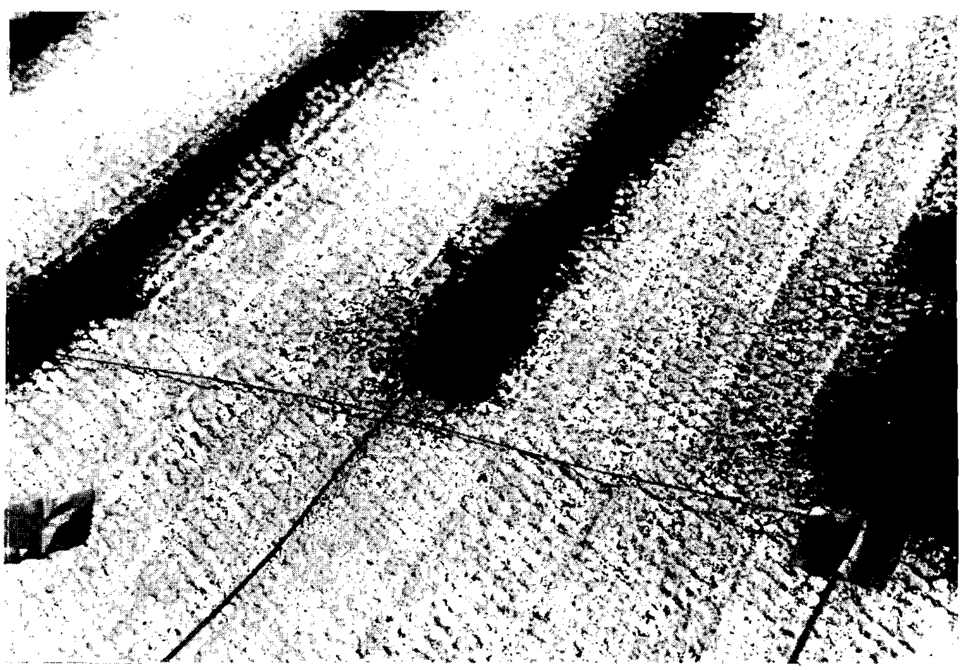
Figure III.15 System "B" installation of conduit

Figure III.16 System "B"
Placement of dense concrete overlay

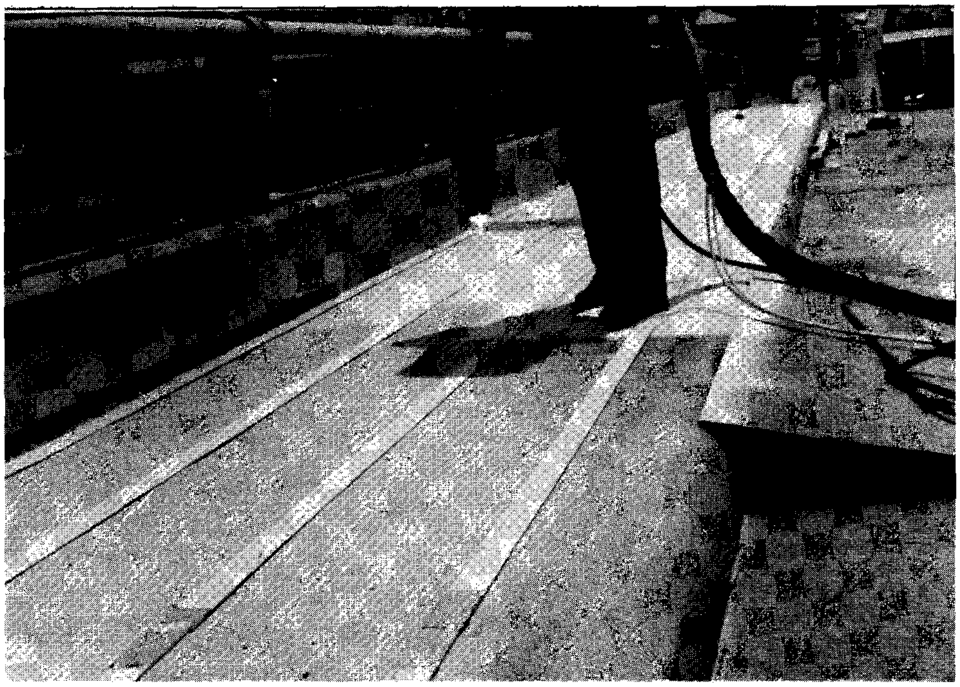
Figure III.17 System "C"
Preparation of carbon mixture

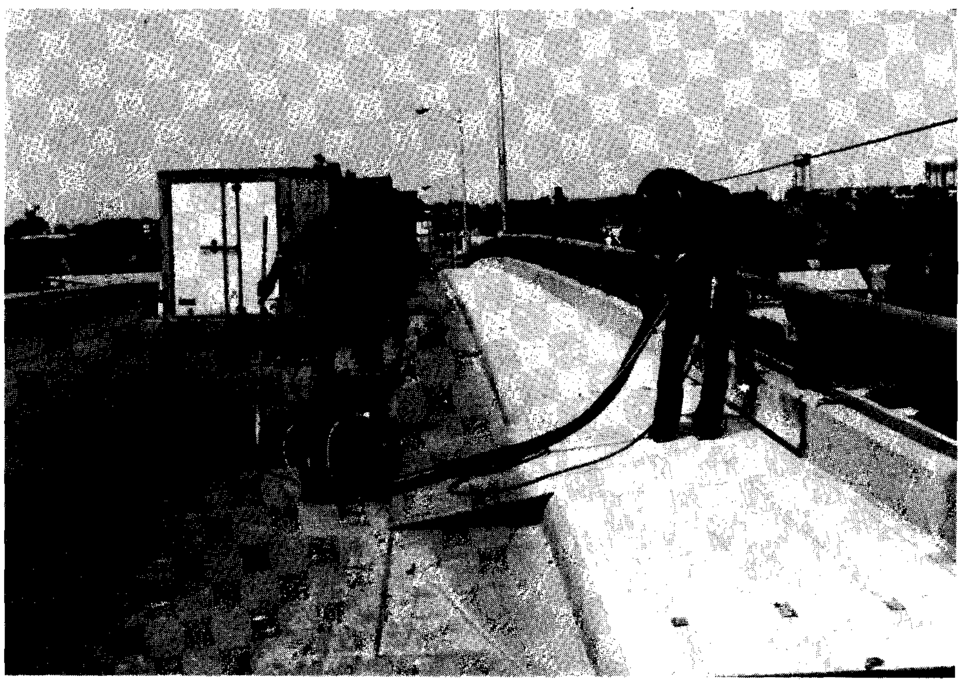
Figure III.18 System "C"
Transfer of mixture to placement bags

The installation of System "C" was rated as the most difficult to place. The process involved placing the wire element and then filling over the wire with a carbon-based material. A technical representative from the manufacturer was required to mix the material, and placement was very primitive, funneling the material out of plastic bags. The placement took several days, and produced very toxic fumes, requiring frequent rotation of workers. Placement of the dense concrete overlay was trouble-free, however, with no complications arising during that phase of construction.



Figures III.19 & 20 System "C"
Placement of mixture over strands





Figures III.21 & 22 System "D"
Hot-sprayed zinc

The zinc spray, System "D", also required placement by a licensed individual. The application was uneven, causing later difficulties. Because the location was on the sidewalk, exposing pedestrians to the system, an application of a non-conductive surface was required.

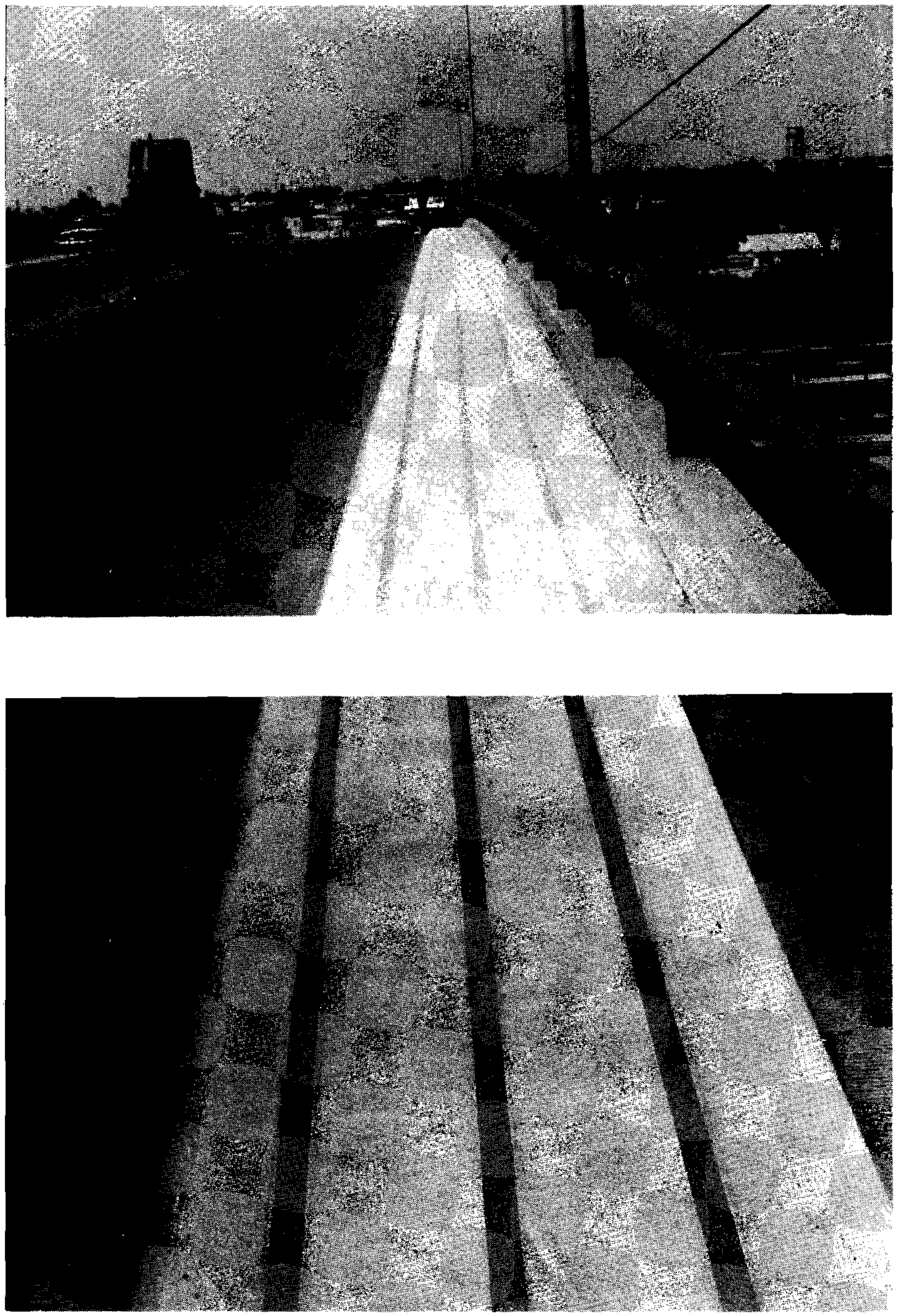


Figure III.23 System "D"
Completed placement of hot-sprayed zinc

Figures III.24 & 25 System "E"
Condition of Bent 4 before repair

System "E" called for a conductive coating to be placed on an interior cap of the structure. Placement was fairly simple, similar to many other operations of cap repair and maintenance.

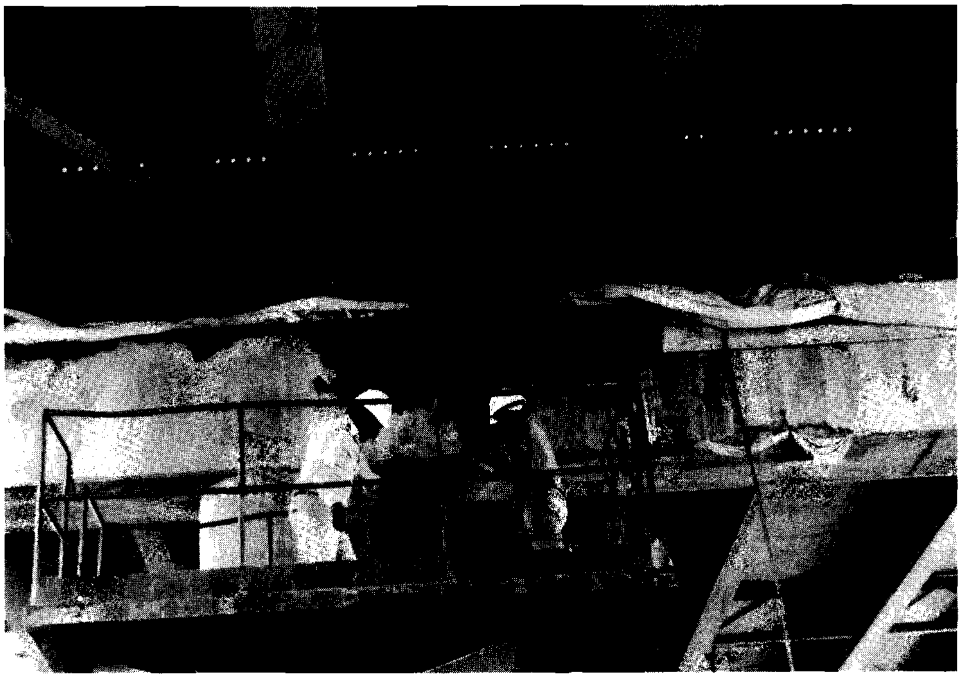


Figure III.26 System "E"
Placement of conductive coating after concrete repairs

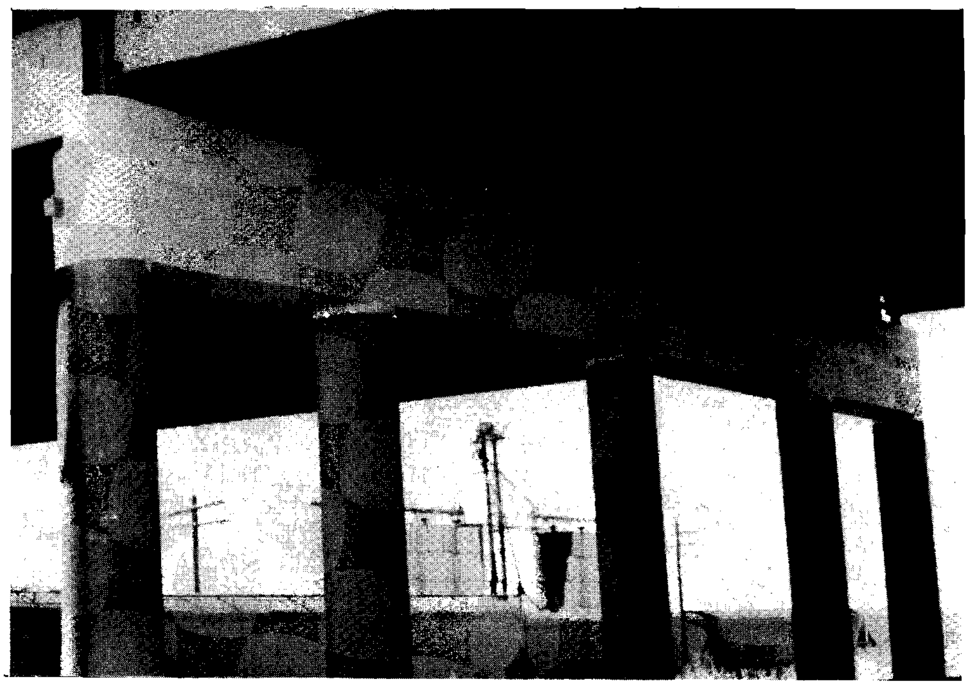


Figure III.27 System "E"
Final condition after placement of coating

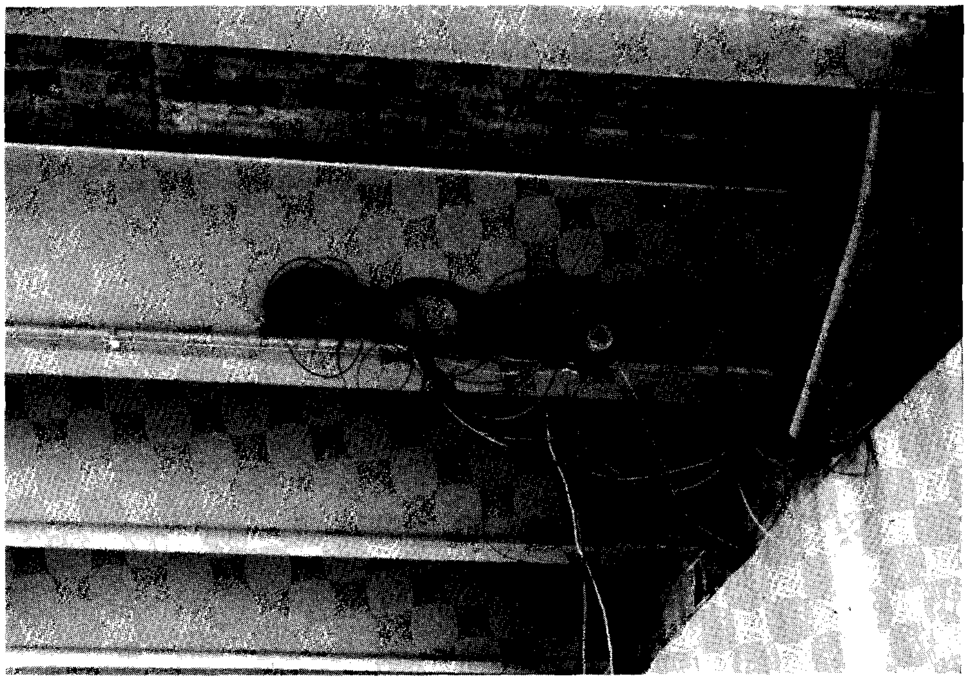


Figure III.28 Wiring for the various systems

Figure III.29 Conduit runs under the structure

The final phase of construction involved connecting all of the systems to the rectifier. The state-of-the-art rectifier enables SDHPT personnel to monitor the functioning of the systems.

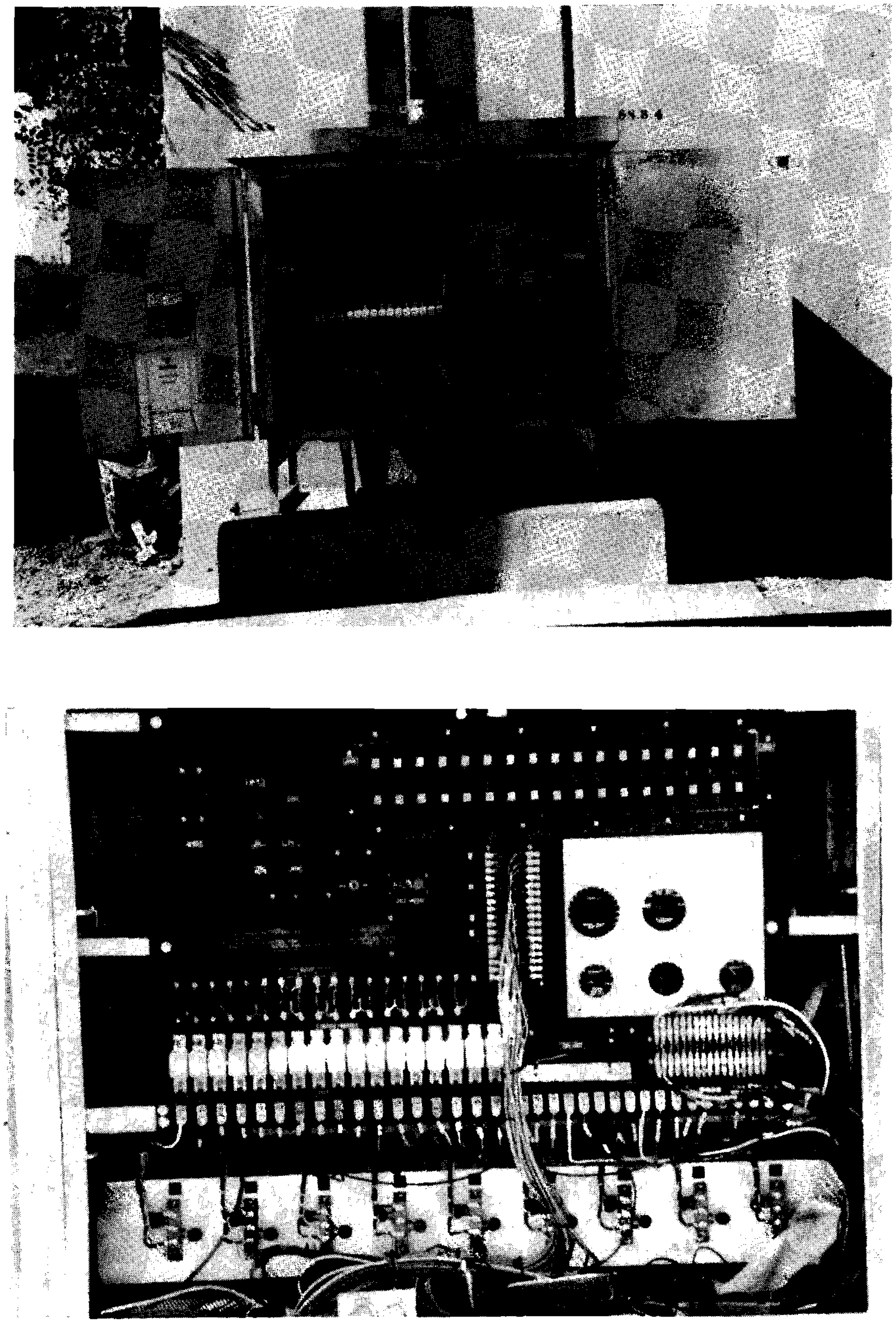


Figure III.30 Rectifier controller

Further discussion of the system installation and monitoring is included in Appendix "C", Howard County, US 87 Railroad Overpass Bridge, Big Spring, Texas, a report prepared by the contractor's engineer.

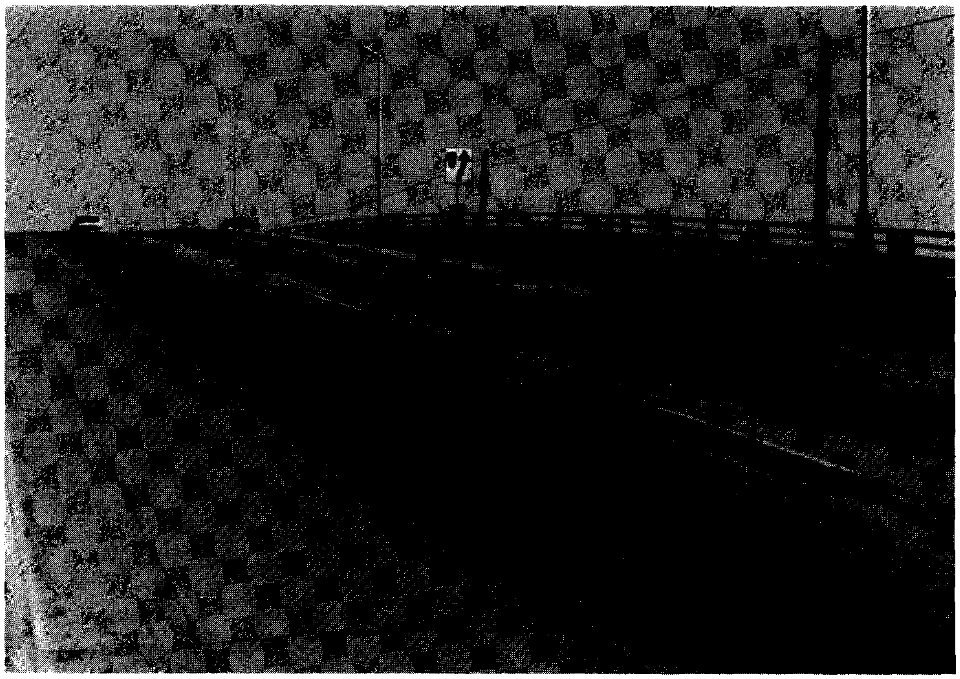


Figure III.31 U.S. 87 at M.P.R.R. Overpass, August 1986

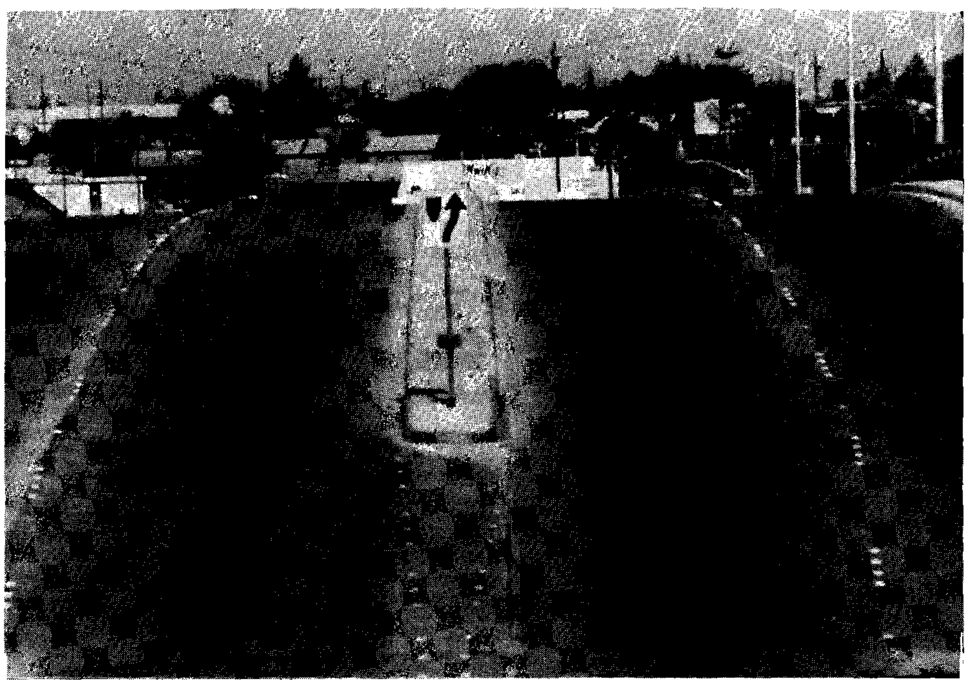


Figure III.32 U.S. 87 at M.P.R.R. Overpass, October 1988

CHAPTER 4

COST ANALYSIS

The project was let for bids in October of 1987. The lowest bid for the entire project was $608,962.50, significantly over the estimate for the project ($373,429.10). The unit price for the item "Cathodic Bridge Deck Protection" as a part of the low bid was $260,000.00, again significantly over the estimate of $165,000.00.

A breakdown of the overall actual cost, submitted by the contractor for this report is as follows:

System	Area (sq. ft.)	% of Total	System Cost	assigned incidental cost	Total Cost per System	Cost per S.F.
A	11,543	29.5	$34,000	$46,256	$80,256	$ 6.95
B	11,542	29.5	22,000	46,256	68,256	5.91
C	9,450	24.1	30,000	37,789	67,789	7.17
D	5,810	14.8	37,000	23,306	60,206	10.36
E	820	2.1	7,000	3,293	10,293	12.55

The assigned incidental cost shown in the table is the percent of the total area covered by each system multiplied by the total cost of the following items:

Rectifier, Cathodic Engineer (professional services), monitoring probes and system training, and certified electrician services.,

A review of the last column compared to the 1990 average cost of reinforced concrete bridge slabs ($5.87 per square foot) would indicate that this process was an expensive one. The costs listed in the table do not include the cost of milling and placing the dense concrete overlay. These additional expenses bring the price per square foot expended on the least expensive treatment (Raychem anode strand) to $11.24 per square foot.

The true cost, however, can only be determined by monitoring the system over a period of at least 15 to 25 years. This is the range of lifespan for the cathodic systems. While the venture was expensive for the single structure, a means has been provided to compare the various systems over this extended period of time, and thus determine the value of cathodic treatment to similar structures.

REFERENCES

REFERENCES

1. Crawford, Gary L. and Jackson, Donald R., "Cathodic Protection for Reinforced Concrete Bridge Decks - Helpful Hints for the Successful Installation of a Cathodic Protection System," FHWA Report No. FHWA-DP-34-3, (October 1985), Demonstration Project No. 34.

2. Jackson, Donald R., "Cathodic Protection for Reinforced Concrete Bridge Decks," FHWA Report No. FHWA-DP-34-2, (October 1982), Demonstration Project No. 34.

3. Chetty, Michael V., "U.S. 87 Cathode Protection Project," 1988 Texas State Department of Highways and Public Transportation Short Course, Session 6.

APPENDICES

APPENDIX A

	STATE	PROJECT NO.	SHEET NO.
8	TEXAS	C 68-8-34	1
STATE DIST. NO.	COUNTY	STATE CONTROL NO.	HIGHWAY NO.
8	HOWARD	68-8-34	US87

Design Speed · 30MPH

STATE OF TEXAS
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

PLANS OF PROPOSED STATE HIGHWAY IMPROVEMENT

STATE PROJECT. C 68-8-34

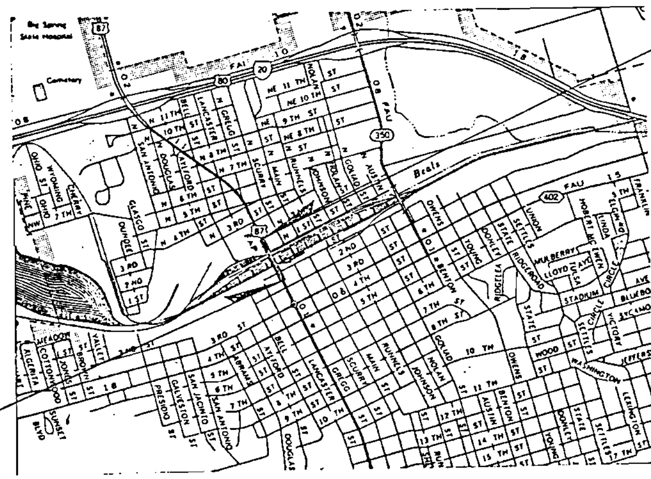
SCALES:
PLAN: 1 IN. = 100 FT.
PROFILE: 1 IN. HOR. = 100 FT., 1 IN. VERT. = 10 FT.
CROSS SECTIONS: 1 IN. HOR. AND VERT. = 5 FT.
OTHERS AS NOTED

NET LENGTH OF PROJECT = 1,009 FT. = 0.191 MI. ROADWAY = 428 FT. = 0.081 MI.
BRIDGE = 581 FT. = 0.110 MI.

U.S. 87 HOWARD COUNTY
RAILROAD OVERPASS BRIDGE AT UNION PACIFIC RAILROAD IN BIG SPRING
CATHODIC BRIDGE DECK PROTECTION

INDEX OF SHEETS

45



STA. 16+00 END CONTROL 68-8-34
END PROJECT

STA. 5+91 BEGIN CONTROL 68-8-34
BEGIN PROJECT

Barricades Type III(C) with signs G20-1, G20-2, G20-6, & R20-3 at each end of the project. Signs CW20-1D & G20-2 at all city street intersections that are open to traffic during construction.

CONVENTIONAL SIGNS
STATE OR NATIONAL LINE
CITY OR VILLAGE LINE
COUNTY LINE
BASE OR SURVEY LINE
RIGHT OF WAY LINE
RIGHT OF WAY MARKERS
FENCE LINE
RAILROAD
TRAVELLED WAY
CULVERT OR BRIDGE
POWER LINE
TELEGRAPH OR TELEPHONE
CONTROL OF ACCESS

Specifications adopted by the Texas State Department of Highways and Public Transportation, September 1, 1982 and Specification items listed and dated as follows shall govern on this project: Special Labor Provisions for State Projects (000---011).

NO EQUATIONS
NO EXCEPTIONS
NO RAILROAD CROSSINGS

LAYOUT SCALE: 1 IN. = 1,320 FT.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

Correct: July 6 1987
Assistant District Engineer

Approved: ______

Recommended For Approval: July 6 1987 ______ Bridge Engineer

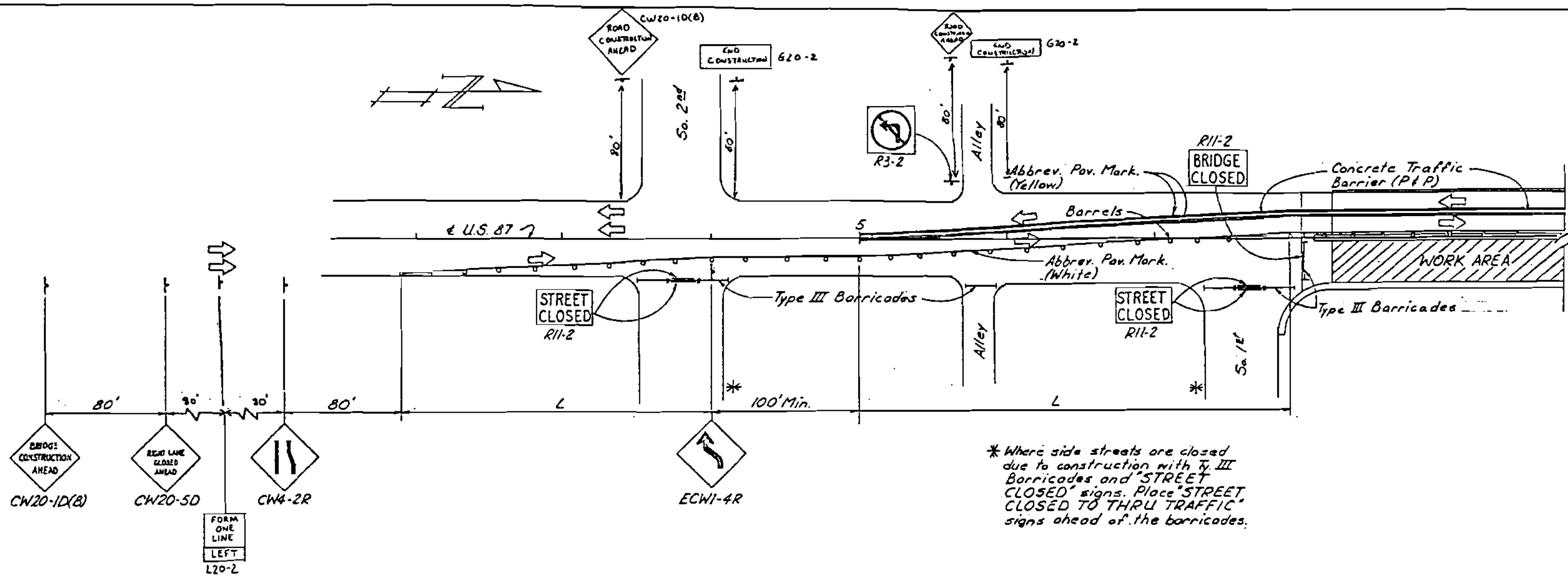
Approved For Letting: ______

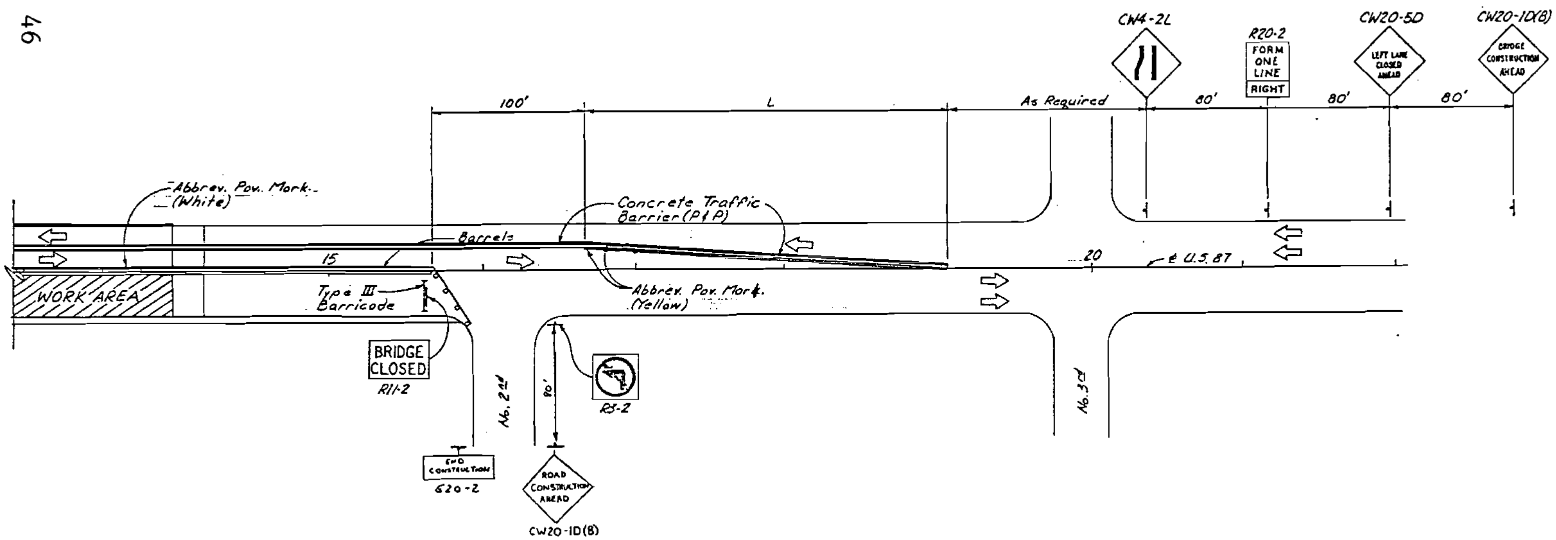
District Engineer

For Chief Engineer, Highway Design

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
APPROVED:
DIVISION ADMINISTRATOR DATE

COUNTY HOWARD PROJ. NO. ______
HWY. NO. US87 LETTING DATE ______
DATE ACCEPTED ______





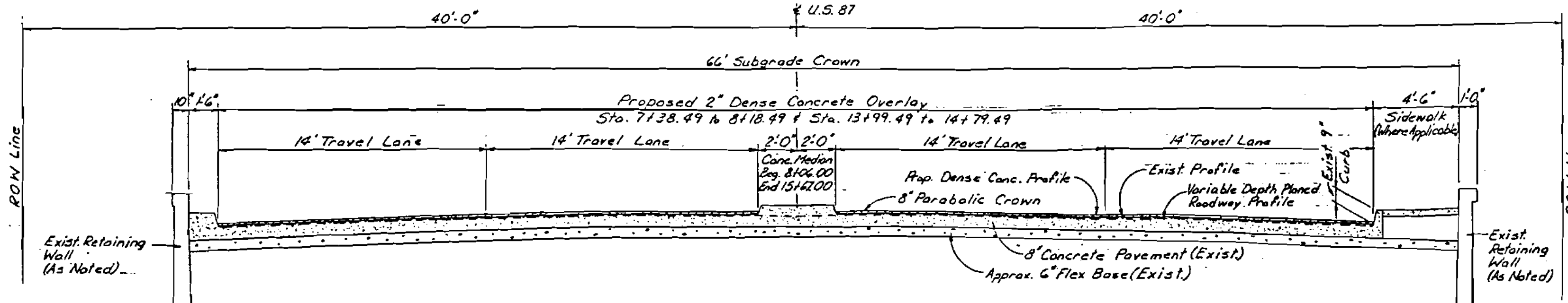
GENERAL NOTES:

1. Refer to standards BC(1)-82 thru BC(7)-82 for the length of tapers and spacing of delineators.
2. Reverse layout when work is moved to the opposite side of the bridge.
3. It should be noted that no other signs than those shown on the Traffic Control Plan, are anticipated; but conditions change as the project progresses and other minor signs may be needed. Signs such as "BUMP", "SOFT SHOULDERS", advisory speed signs, etc. are not shown but the Contractor's sequence of work may warrant the use of these signs.
4. At any time during the prosecution of this project that other minor signs are needed to control traffic and provide safety for the traveling public, the Contractor will provide these signs. Pay for these standard signs will be included in the bid item for "Barricades, Signs, and Traffic Handling" no extra pay will be allowed.

TRAFFIC CONTROL PLAN

This is a suggested Signing and Barricade Layout and may be altered as approved by the Engineer.

FED. RD. DIV. NO.	STATE	FEDERAL PROJECT NO.			SHEET NO.
6	TEXAS	C 68-8-34			2
STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.
8	Howard	68	8	34	US 87



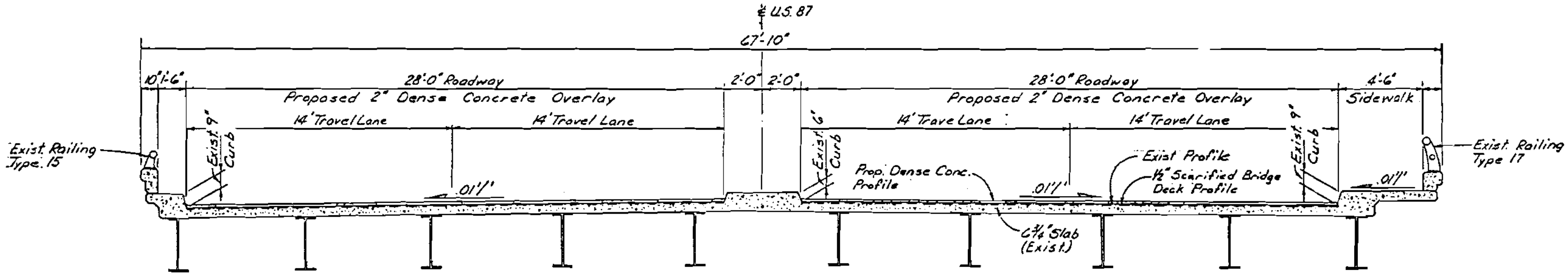
TYPICAL ROADWAY SECTION

(Section subject to Crown Transition and Curb Return at Street Intersections)

Left-Half Section
Sta. 7+38.49 to Sta. 8+18.49
Sta. 13+99.49 to Sta. 14+79.49

Right-Half Section
Sta. 7+38.49 to Sta. 7+78.05 (NRW) *
Sta. 7+78.05 to Sta. 8+18.49
Sta. 13+99.49 to Sta. 14+79.49

* No Retaining Wall, 9" Curb and Gutter usual



TYPICAL BRIDGE SECTION

Sta. 8+18.49 to Sta. 13+99.49

47

TYPICAL SECTIONS

Scale: 1" = 3'

State	Federal Project No.	Sheet No.
Texas	C 68-8-34	3

State Dist. No.	County	Cont.	Sect.	Job	Highway No.
8	Howard	68	8	34	U.S. 87

GENERAL NOTES AND SPECIFICATION DATA--

BEFORE BEGINNING WORK ON THIS PROJECT, THE CONTRACTOR SHALL SUBMIT, FOR APPROVAL BY THE ENGINEER, A PLAN OF CONSTRUCTION OPERATIONS OUTLINING IN DETAIL A SEQUENCE OF WORK TO BE FOLLOWED SETTING OUT THE METHOD HANDLING TRAFFIC. IF AT ANY TIME DURING THE CONSTRUCTION THE CONTRACTOR'S PROPOSED PLAN OF OPERATION FC HANDLING TRAFFIC DOES NOT PROVIDE FOR SAFE, COMFORTABLE MOVEMENT, THE CONTRACTOR SHALL IMMEDIATELY CHANG HIS OPERATIONS TO CORRECT THE UNSATISFACTORY CONDITION.

THE CONTRACTOR'S ATTENTION IS HEREBY DIRECTED TO UTILITIES EXISTING IN OR NEAR THE WORK AREAS OF THIS PROJECT. ANY ACTIVE UTILITIES THAT ARE ENCOUNTERED BY THE CONTRACTOR SHALL IMMEDIATELY BE BROUGHT TO TH ATTENTION OF THE ENGINEER.

ANY WORKSITE OUTSIDE THE RIGHT-OF-WAY AND CLOSE ENOUGH TO THE HIGHWAY FOR ITS CONDITION TO ADVERSELY AFFECT THE VIEW FROM THE HIGHWAY SHALL BE LEFT IN A NEAT AND PRESENTABLE CONDITION ACCEPTABLE TO THE ENGINEER.

---ITEM 421---
THE ENGINEER WILL SAMPLE ALL CONCRETE AND MAKE AND TEST ALL TEST BEAMS AND CYLINDERS IN ACCORDANCE WITH TEST METHODS TEX-418-A AND TEX-420-A. ALL TEST MOLDS WILL BE FURNISHED BY THE ENGINEER AND THE CONTRACT(SHALL MAINTAIN THEM IN THE PROPER CONDITION. IN ADDITION, THE CONTRACTOR SHALL BE RESPONSIBLE FOR FURNISHING PERSONNEL TO REMOVE THE TEST SPECIMENS FROM THE MOLDS AND TO TRANSPORT THEM TO THE PROPER CURING LOCATION AT THE SCHEDULE DESIGNATED BY THE ENGINEER AND IN ACCORDANCE WITH THE GOVERNING SPECIFICATION. FOR ALL CONCRETE ITEMS THE CONTRACTOR SHALL HAVE A WHEELBARROW, OR OTHER CONTAINER ACCEPTABLE TO THE ENGINEER, AVAILABLE TO USE IN THE SAMPLING OF CONCRETE. ALL LABOR AND EQUIPMENT FURNISHED BY THE CONTRACTOR WILL BE CONSIDERED SUBSIDIARY TO THE VARIOUS BID ITEMS AND WILL NOT BE PAID FOR DIRECTLY.

---ITEM 437---
HIGH RANGE WATER REDUCERS WILL BE USED ONLY TO MEET SPECIAL REQUIREMENTS AND WILL REQUIRE THE WRITTEN APPROVAL OF THE ENGINEER ON EACH SPECIFIC PROJECT. A SATISFACTORY WORK PLAN FOR CONTROL SHALL BE SUBMITTED BY THE CONTRACTOR FOR APPROVAL AND AN EVALUATION OF THE CONCRETE CONTAINING THE ADMIXTURE WILL BE PERFORMED BY THE ENGINEER.

---ITEM 446---
PAINT PURCHASED FROM THE DEPARTMENT WILL BE CHARGED AS FOLLOWS:

PROTECTION SYSTEM I PRIME COAT $63.08/5 GAL.
PROTECTION SYSTEM II PRIME COAT $24.39/1 1/4 GAL.

---ITEM 442---
NEW STRUCTURE STEEL ARMOR JOINTS SHALL RECEIVE PROTECTIVE SYSTEM I.

---ITEM 512---
FOR THIS PROJECT THE STATE SHALL FURNISH 1415 FEET OF PORTABLE CONCRETE TRAFFIC BARRIER (PCTB) SECTIONS AND 2 TERMINAL SECTIONS, STOCKPILED ON IH 20 AT EAST HOWARD FIELD ROAD, NEAR THE MITCHELL COUNTY LINE. UPON REMOVAL, THE PCTB AND TERMINAL SECTIONS, SHALL BE RETURNED TO THE STORAGE AREA. THE CONTRACTOR SHAL MAKE ARRANGEMENTS FOR THE LOADING AND UNLOADING OF THE PCTB AT THE STORAGE AREA.

ITEM 618---
ALL CONDUIT RUNS CROSSING THE BRIDGE SHALL BE SECUERLY ATTACHED TO THE SUBSTRUCTURE OF THE BRIDGE. CLAMF EQUIVALENT TO APPLETON CH-50S(1/2- 3/4") AND CH-125S(1") SHALL BE USED. THE NUMBER OF CLAMPS REQUIRED AN THEIR SPACING SHALL BE DETERMINED BY THE ENGINEER. THIS WORK SHALL NOT BE PAID FOR DIRECTLY, BUT SHALL E CONSIDERED AS SUBSIDIARY TO ITEM 4642, "CATHODIC BRIDGE DECK PROTECTION SYSTEM".

---ITEM 664---
IF ABBREVIATED PAVEMENT MARKINGS ARE NEEDED FOR TEMPORARY ALIGNMENT ON ON A FINAL SURFACE, THESE MARKINGS SHALL BE APPLIED IN A MANNER THAT WILL ALLOW EASY AND COMPLETE REMOVAL WITH NO UNDUE INJURY TO THE FINAL SURFACE.

YELLOW ABBREVIATED PAVEMENT MARKINGS SHALL BE USED TO SEPARATE TRAFFIC FLOW IN OPPOSITE DIRECTIONS. WHIT ABBREVIATED PAVEMENT MARKINGS SHALL BE USED TO SEPARATE TRAFFIC FLOW IN THE SAME DIRECTION.

---ITEM 676---
BITUMINOUS ADHESIVE SHALL BE USED ON THIS PROJECT.

---ITEM 3003---
SURFACE TEXTURE AND SURFACE TEXTURE TESTS WILL NOT BE REQUIRED.

---GENERAL---
ALL PAVEMENT MARKING SHALL BE IN ACCORDANCE WITH THE M.U.T.C.D..

---ITEM 4685---
A 90 DAY TEST PERIOD IS REQUIRED AFTER INSTALLATION OF THE CATHODIC PROTECTION SYSTEM IS COMPLETED.

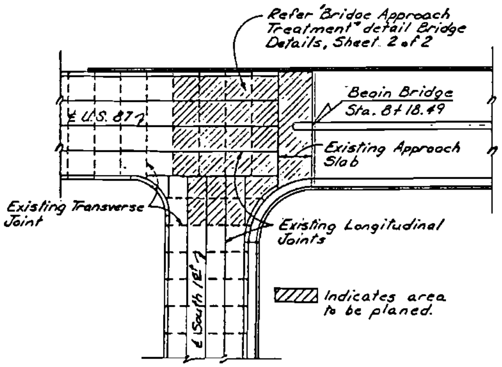
BRIDGE SUMMARY

NAME	SHEET NO.		STATION		LENGTH	SIZE	DESIGN	DESCRIPTION	Scarify Conc. Br. Slab SY	Dense Concrete Overlay SY	Conc Surf Treat SY	Str Stl (HYC) LB	Str Stl (Armor Jt) LB	Traffic Button (Ty IC) EA	Traffic Button (Ty W) EA	Cathodic Protection System LS		
	Plan Profile	Layout	Beg.	End														
M.P. RR & Gregg St. Ovpss	11	-	8+18.49	13+99.49	581.0'	111.0'-185.0'-115.5' 56.0'-56.0'-56.0'	Special	411.5' Cont. R Girder 168.0' Cont. I-Beam	3615	3615	3615	10204	1545	28	112	1		

ROADWAY SUMMARY

Sta. to Sta.	Planing & Text Pavement SY	Dense Concrete Overlay SY	Conc Surf Treat SY	Conc Traf Bar (Move & Reset) LF	Conc Traf Bar (Remove) LF	Traffic Button (Ty IC) EA	Traffic Button (Ty II AA) EA	Traffic Button (Ty W) EA	Traffic Button (Ty Y) EA					
7+38.49 - 8+18.49	658	658	658	2864	1432	4	6	16	18					
13+99.49 - 14+79.49	498	498	498			4		16						
	1156	1156	1156	2864	1432	8	6	32	18					

49



PLANED AREA
SOUTH OF BRIDGE

SUMMARY OF ABBREVIATED PAV MARK

Station to Station	4 In Dashed (White) LF	4 In Solid (White) LF	4 In Solid (Yellow) LF	
7+38.49 - 8+18.49	40		160	
8+18.49 - 13+99.49	291			
13+99.49 - 14+79.49	40			
Approx. 2+00 - Approx. 16+00.		1400		
Approx. 5+00 - Approx. 19+32.			2864	
Approx. 6+00 - Approx. 20+00		1400		
Approx. 2+68 - Approx. 17+00			2864	
Totals	371	2800	5888	

SUMMARY SHEET

FED. RD. DIV. NO.	STATE	FEDERAL PROJECT NO.				SHEET NO.
6	TEXAS	C 68-8-34				6
STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB		HIGHWAY NO.
8	Howard	68	8	34		US87

ESTIMATE SUMMARY

PROJECT C 68-8-34

CONTROL 68-08-034

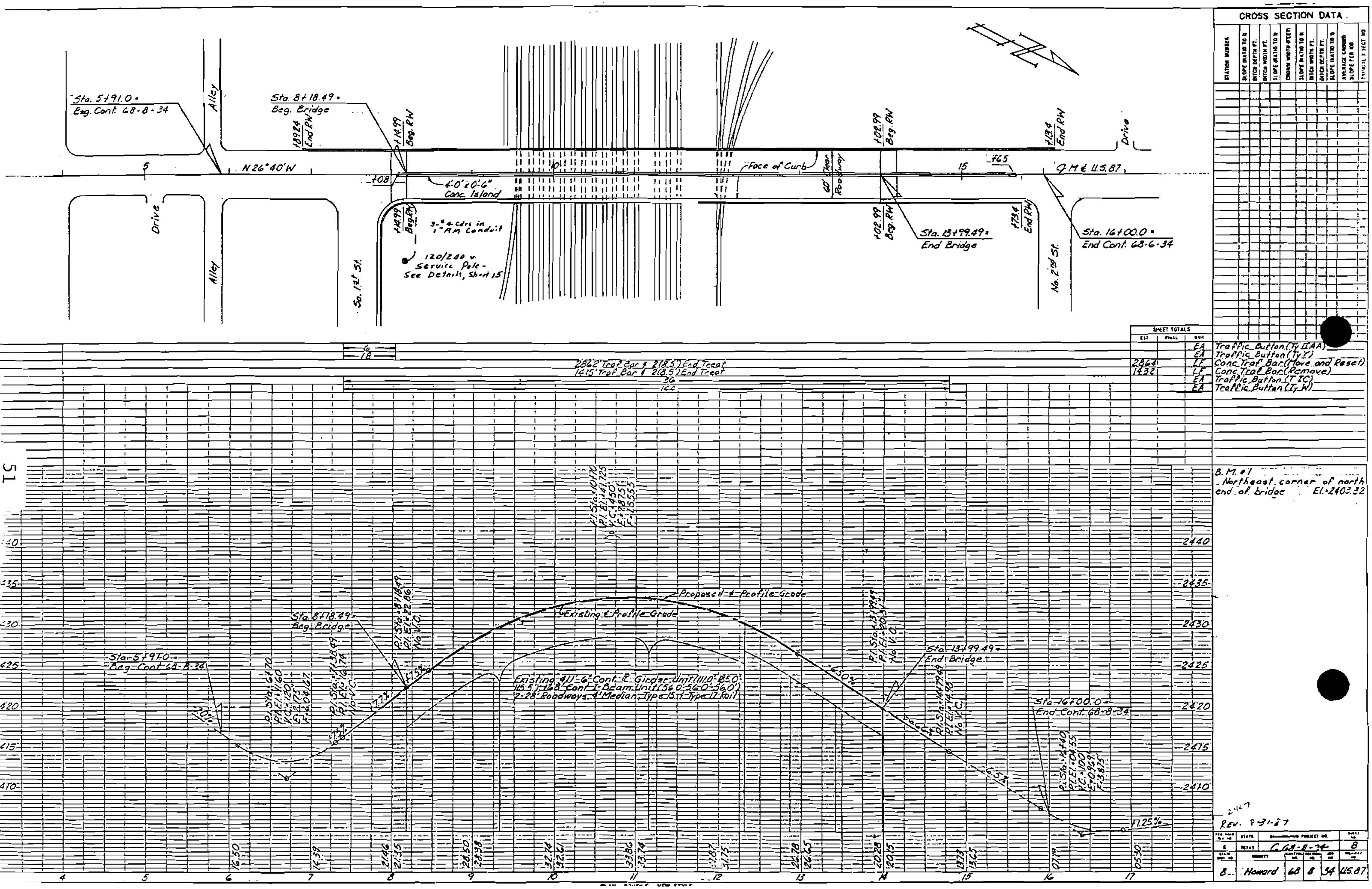
						BRIDGE US 87		ROADWAY US 87		ALT	ITEM-CODE			DESCRIPTION	UNIT	TOTAL	
EST.	FINAL	EST.	FINAL	EST.	FINAL	EST.	FINAL	EST.	FINAL		ITEM NO	DESC CODE	SP NO			EST.	FINAL
						3615.000		1156.000			428	001		CONC SURF TREAT	SY	4771.000	
						3615.000		1156.000			438	002		DENSE CONC OVERLAY (2 IN)	SY	4771.000	
						10204.000					442	001	002	STR STL (HYC)	LB	10204.000	
						1545.000					442	003	002	STR STL (ARMOR JT)	LB	1545.000	
						3615.000					483	001		SCARIFY CONC BRIDGE SLAB (1/2 IN)	SY	3615.000	
								1.000			500	001	001	MOBILIZATION	LS	1.000	
								4.000			502	001		BARCD.SIGN AND TRAF HANDLING	MO	4.000	
								2864.000			512	002		CONC TRAF BAR (MOVE AND RESET)	LF	2864.000	
								1432.000			512	003		CONC TRAF BAR (REMOVE)	LF	1432.000	
						1453.000		1718.000			664	002	002	ABBREVIATED PAV MARK (WHITE)	LF	3171.000	
						2324.000		3564.000			664	003	002	ABBREVIATED PAV MARK (YELLOW)	LF	5888.000	
						28.000		8.000			676	002	011	TRAFFIC BUTTON (TY IC)	EA	36.000	
								6.000			676	004	011	TRAFFIC BUTTON (TY IIAA)	EA	6.000	
						112.000		32.000			676	006	011	TRAFFIC BUTTON (TY W)	EA	144.000	
								18.000			676	007	011	TRAFFIC BUTTON (TY Y)	EA	18.000	
								1156.000			3003	009	001	PLANING CONC PAV CL C(2)(2 IN)	SY	1156.000	
						1.000					4685	001		CATHODIC BR DECK PROTECTION	LS	1.000	
														RAILROAD FORCE ACCOUNT WORK			
														MPRR CO. FORCE ACCOUNT WORK			
														FLAGGING		1.000	

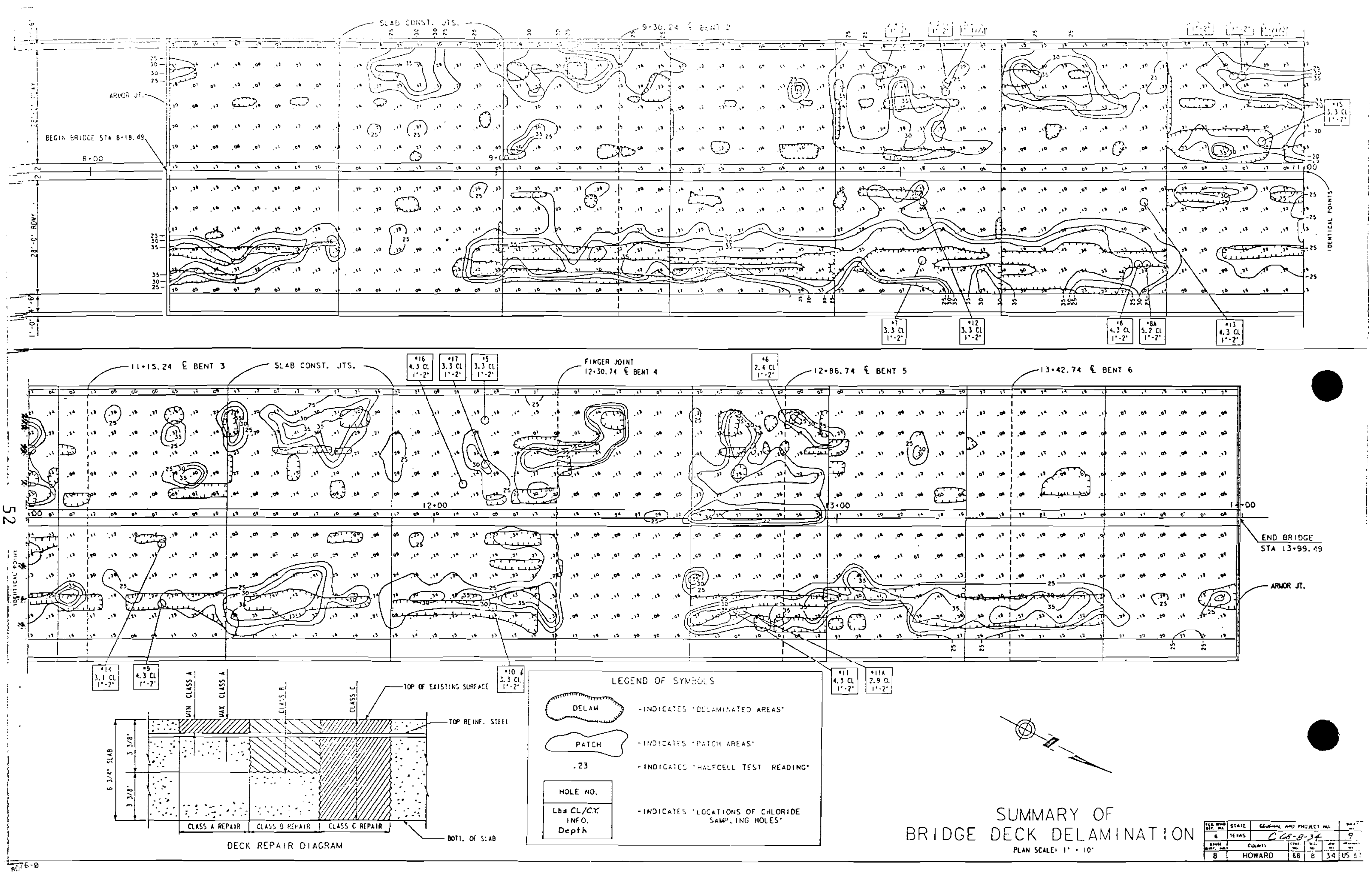
50

ESTIMATE & QUANTITY SHEET

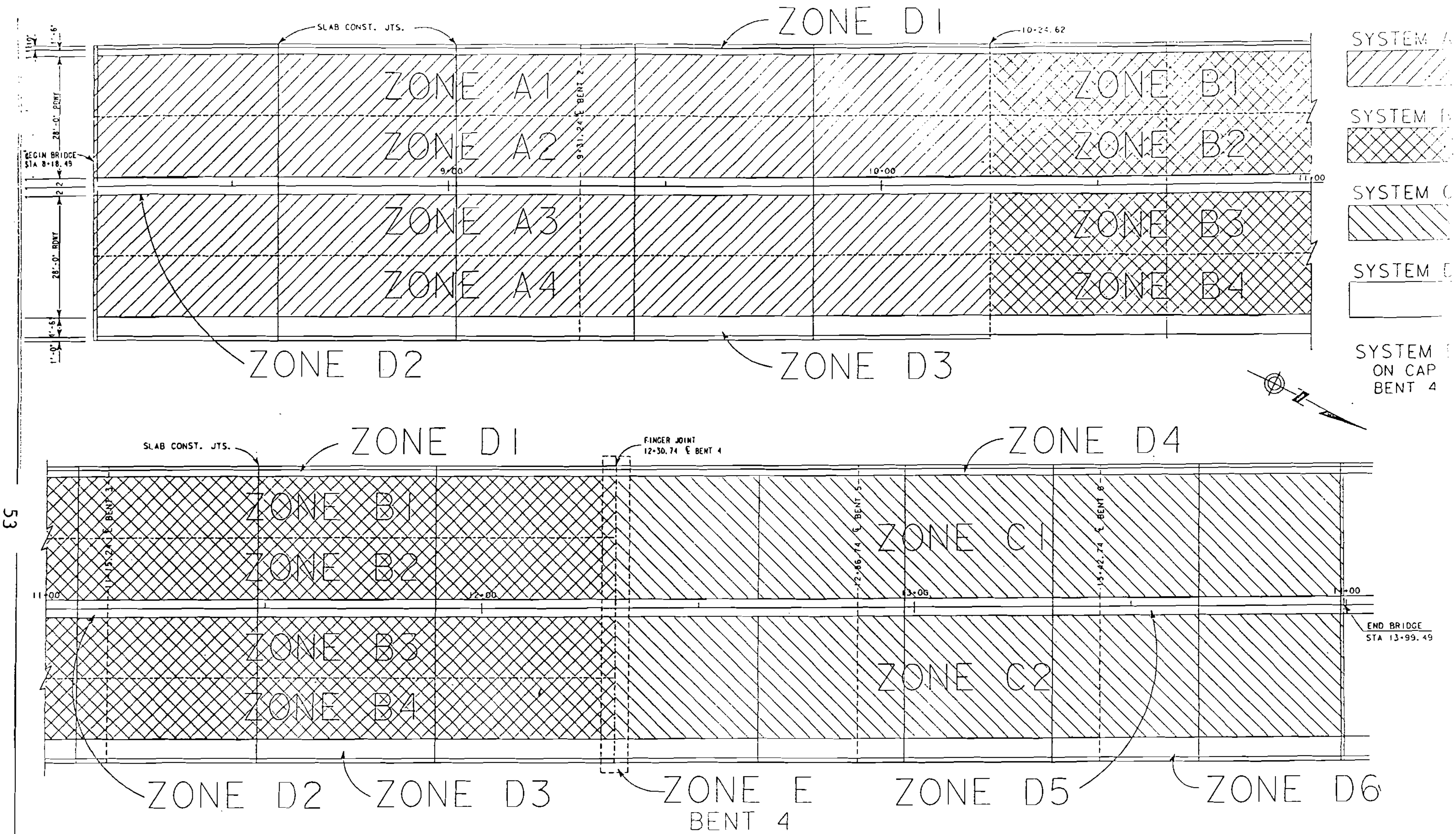
REV. 7-24-87
REV. 9-17-87

STATE DIST. NO.	COUNTY	PROJECT NO.	SHEET NO.
8	HOWARD	C 68-8-34	7


CROSS SECTION DATA
Sta. 5+91.0 = Beg. Cont. 68-8-34
Alley
Sta. 8+18.49 = Beg. Bridge
+89.24 End RW
+14.99 Beg. RW
+102.99 Beg. RW
+13.4 End RW
Drive
N 26°40'W
+08
4'-0" x 0'-6" Conc. Island
Face of Curb
60' Clear Roadway
+65
Q M ₵ U.S. 87
3-#4 cdrs in 1" RM Conduit
120/240 v. Service Pole - See Details, Sheet 15
So. 1st St.
Sta. 13+99.49 = End Bridge
Sta. 16+00.0 = End Cont. 68-6-34
No. 2nd St.
SHEET TOTALS
2864 LF Conc Traf Bar (Move and Reset)
1432 LF Conc Traf Bar (Remove)
EA Traffic Button (Ty II AA)
EA Traffic Button (Ty Y)
EA Traffic Button (T IC)
EA Traffic Button (Ty W)
2862' Traf Bar + 2(18.5') End Treat
1415' Traf Bar + 2(18.5') End Treat
B.M. #1 Northeast corner of north end of bridge El. = 2403.32
P.I. Sta. = 10+70
P.I. El. = 41.725
V.C. = 450'
Proposed ₵ Profile Grade
Existing ₵ Profile Grade
Existing 411'-6" Cont. R. Girder Unit (111.0'-85.0'-115.5') + 168' Cont. I-Beam Unit (56.0'-56.0'-56.0') 2-28' Roadways, 4' Median, Type 15 & Type 17 Rail
Sta. 13+99.49 = End Bridge
Sta. 16+00.0 = End Cont. 68-8-34
+1.25%
-6.50%
Rev. 7-31-87
C 68-8-34
8
Howard 68 8 34 U.S. 87
2440 2435 2430 2425 2420 2415 2410
4 5 6 7 8 9 10 11 12 13 14 15 16 17


SLAB CONST. JTS.
9+30.24 ℄ BENT 2
ARMOR JT.
BEGIN BRIDGE STA 8+18.49
8+00
9+00
28'-0" RDWY.
IDENTICAL POINTS
11+15.24 ℄ BENT 3
SLAB CONST. JTS.
FINGER JOINT
12+30.74 ℄ BENT 4
12+86.74 ℄ BENT 5
13+42.74 ℄ BENT 6
12+00
13+00
14+00
END BRIDGE
STA 13+99.49
ARMOR JT.
#7 3.3 CL 1"-2"
#12 3.3 CL 1"-2"
#8 4.3 CL 1"-2"
#8A 5.2 CL 1"-2"
#13 4.3 CL 1"-2"
#15 3.3 CL 1"-2"
#16 4.3 CL 1"-2"
#17 3.3 CL 1"-2"
#5 3.3 CL 1"-2"
#6 2.4 CL 1"-2"
#14 3.1 CL 1"-2"
#9 4.3 CL 1"-2"
#10 3.3 CL 1"-2"
#11 4.3 CL 1"-2"
#11A 2.9 CL 1"-2"
MIN CLASS A
MAX CLASS A
CLASS B
CLASS C
TOP OF EXISTING SURFACE
TOP REINF. STEEL
6 3/4" SLAB
3 3/8"
3 3/8"
CLASS A REPAIR
CLASS B REPAIR
CLASS C REPAIR
BOTT. OF SLAB
DECK REPAIR DIAGRAM
LEGEND OF SYMBOLS
DELAM - INDICATES "DELAMINATED AREAS"
PATCH - INDICATES "PATCH AREAS"
.23 - INDICATES "HALFCELL TEST READING"
HOLE NO.
Lbs CL/C.Y. INFO. Depth - INDICATES "LOCATIONS OF CHLORIDE SAMPLING HOLES"
SUMMARY OF
BRIDGE DECK DELAMINATION
PLAN SCALE: 1" = 10'
6 TEXAS CC 68-8-34 9
8 HOWARD 68 8 34 US 87

52

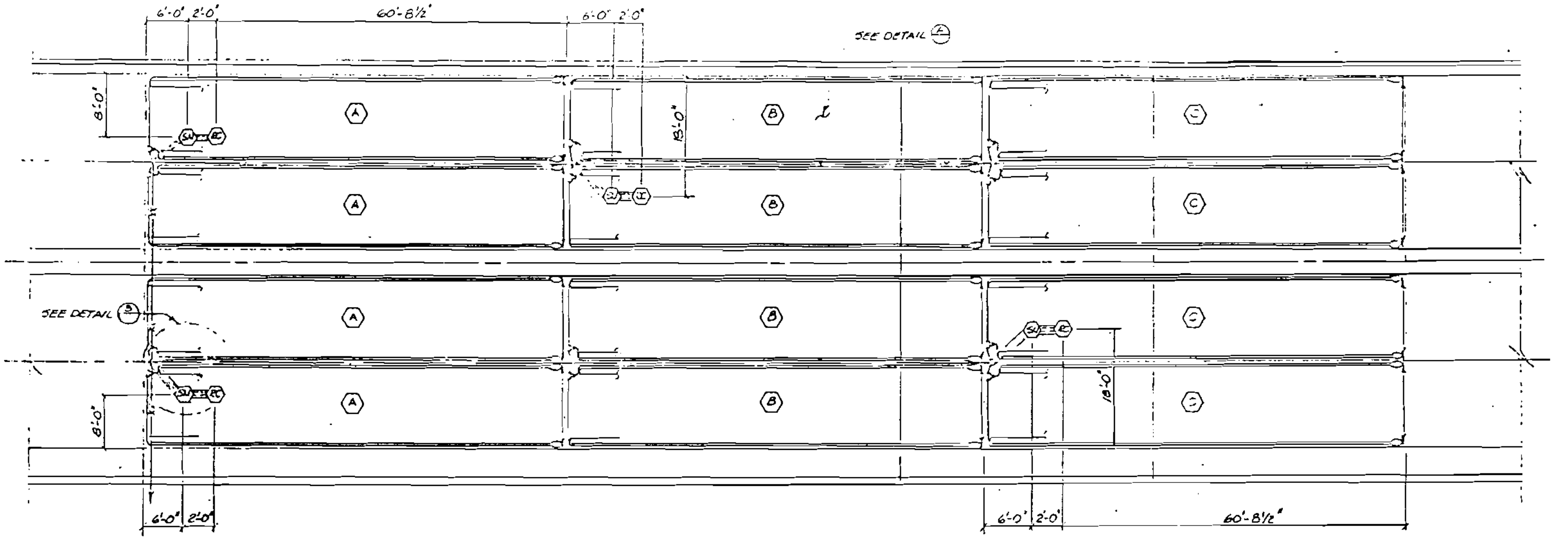


LAYOUT OF CATHODIC PROTECTION SYSTEMS

PLAN SCALE: 1" = 10'

6	TEXAS	C 68-8-3?
8	HOWARD	65

53



ANODE STRAND PLACEMENT
SCALE: 1" = 10'

LEGEND

◂ – END CAP

□x – CLEAT WITH PUSHPIN (SEE DETAIL 'E' SHT.

– CONDUCTIVE END LOOP WITH PUSHPIN (SEE DETAIL 'F' SHT.

▪ – CONDUCTIVE CLEAT, INSTALL ON OUTSIDE END PAIRS AND ON ENDS OF ANODE RUNS (SEE DETAIL 'J' SHT.

(RC) – REFERENCE CELL (SEE DETAIL 'A' SHT.

(SN) – SYSTEM NEGATIVE (SEE DETAIL 'B' SHT.

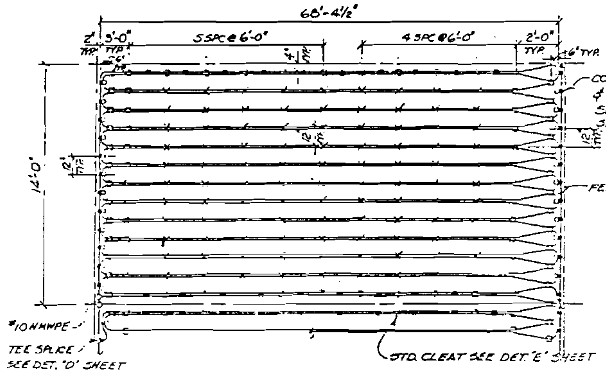
○ – CONCRETE PENETRATION (2" DIA.)

– FEREX 100 FACTORY PRE-ASSEMBLED TEE SPLICE (SEE DETAIL 'D' SHT.

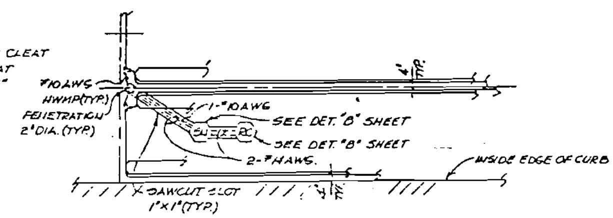
(X) – ANODE CIRCUIT X

NOTES

1) INSTRUMENTATION AND SYSTEM NEGATIVE WIRES SHALL BE ROUTED TO CONCRETE PENETRATION IN A SAWCUT SLOT 1" WIDE AND 1" DEEP.



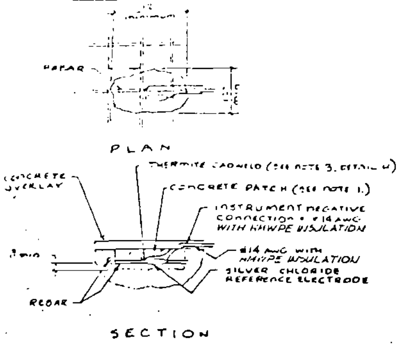
TYPICAL ANODE STRAND PLACEMENT 1
N.T.S.



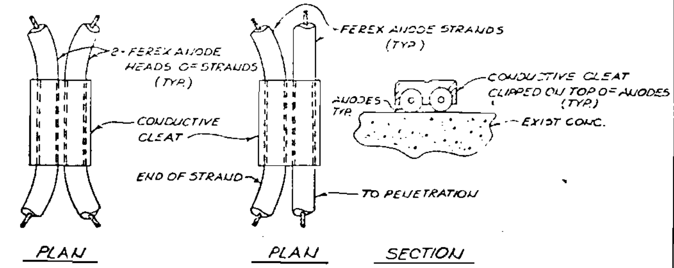
PENETRATION AND INSTRUMENTATION PLACEMENT 2
N.T.S.

SYSTEM 'B' DETAILS
Sheet 1 of 2

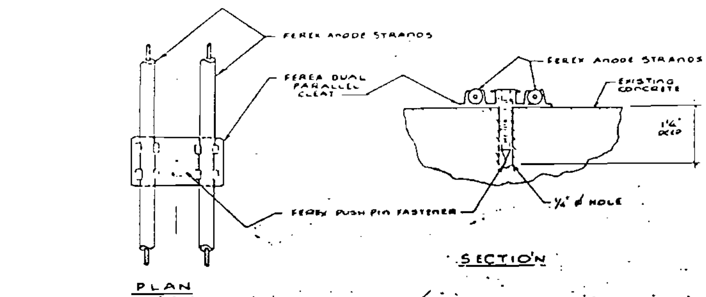
4		C 68-A-34			11	12
8	Howard	68	8	34	1587	



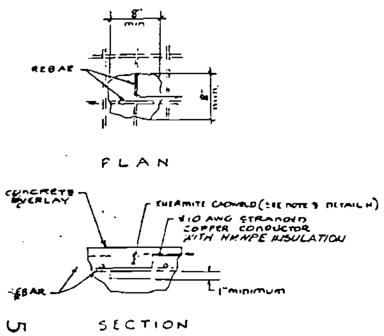
DETAIL A: REFERENCE CELL PLACEMENT (TYP)



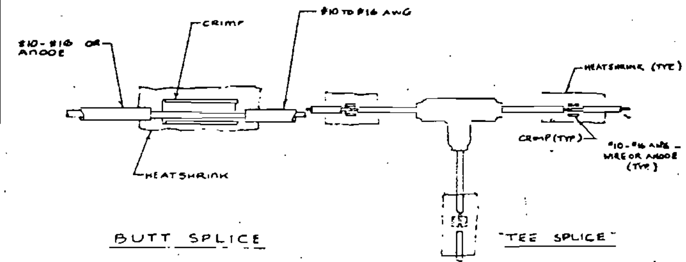
DETAIL "J" ANODE STRAND ATTACHMENT AT END OF PANEL RUNS.
NO SCALE



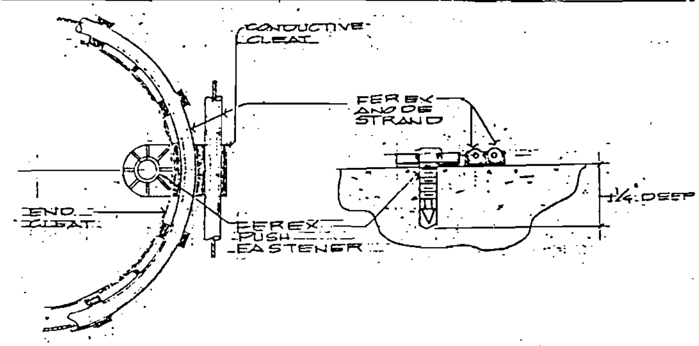
DETAIL E: ANODE STRAND ATTACHMENT AT INTERIOR POINTS (SEE NOTE 5)



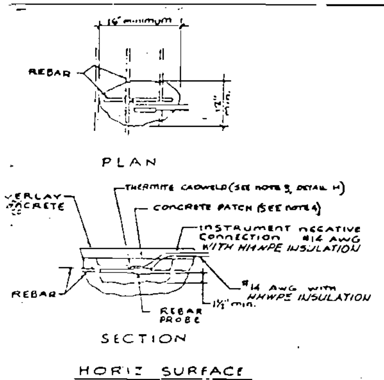
DETAIL B: SYSTEM NEGATIVE CONNECTION (TYPICAL)



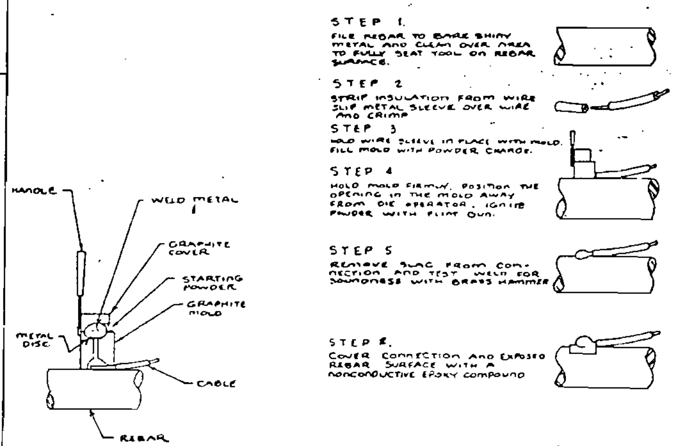
DETAIL D: ELECTRICAL SPLICES (TYPICAL)



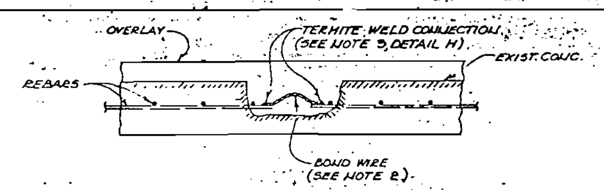
DETAIL F ANODE STRAND ATTACHMENT AT ENDS OF ANODE RUNS



DETAIL G: REBAR PROBE PLACEMENT (TYPICAL)



DETAIL H. THERMITE CADWELD INSTALLATION



DETAIL C: REBAR TO REBAR ELECTRICAL CONNECTIONS

NOTES:

1) PATCH WITH 7% ± 1% AIR ENTRAINED PORTLAND CEMENT CONC. WITH A 0.50 W/C CEMENT RATIO AND A CHLORIDE CONTENT OF 15 LBS PER CUBIC YARD OF CONC.
2) AWG. NO. 10 STRANDED COPPER WITH RHW/USE INSULATION.
3) COAT TERMITE CADWELD WITH NON-CONDUCTIVE EPOXY COMPOUND.
4) PATCH WITH 0.50 WATER-CEMENT RATIO, 7% ± 1% AIR ENTRAINED PORTLAND CEMENT WITH A SALT CONTENT OF LESS THAN 0.080 PERCENT BY WEIGHT.
5) ATTACHMENTS TO BE MADE AT 10 FEET SPACINGS OR AS SHOWN ELSEWHERE ON DWGS.

CATHODIC PROTECTION SYSTEM MISCELLANEOUS DETAILS

FED. RD. DIV. NO.	STATE	FEDERAL PROJECT NO.			SHEET NO.
6	TEXAS	C 68-8-34			17
STATE DIST. NO.	COUNTY	CONT.	SECT.	JOB	HIGHWAY NO.
8	Howard	68	8	34	US 87

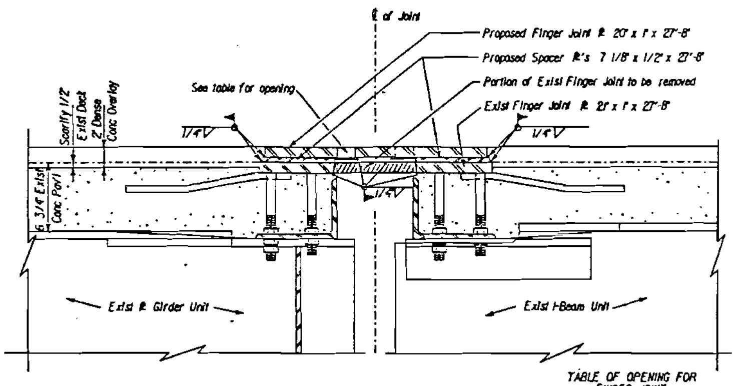
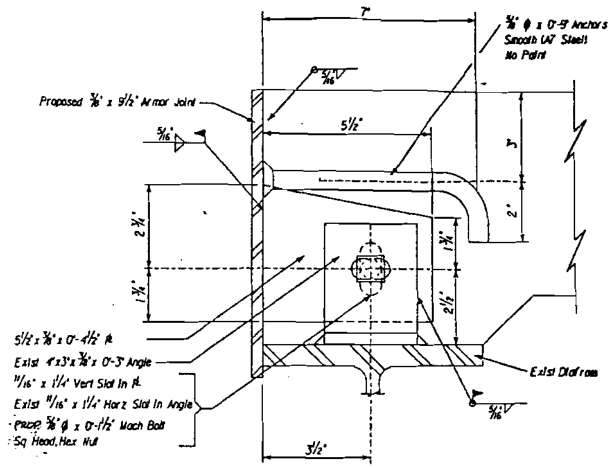


TABLE OF OPENING FOR FINGER JOINT

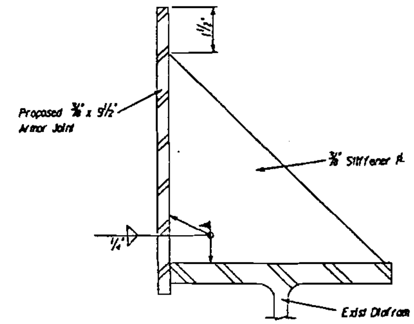
120°F	3/8"
70°F	1 3/4"
0°F	3 11/16"

SECTION THRU FINGER JOINT

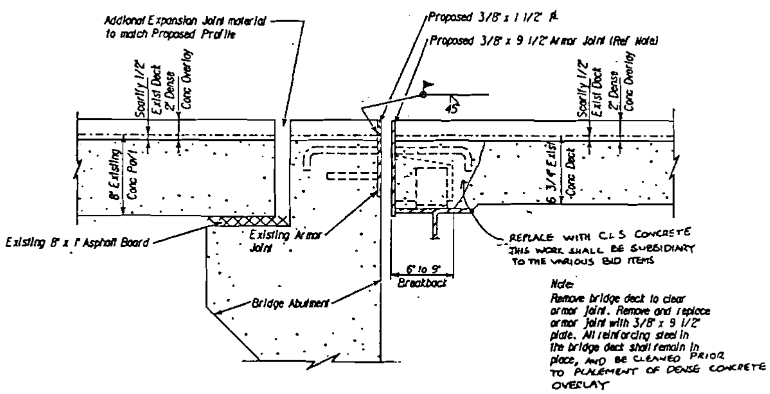
AT BENT 4



ARMOR JOINT CONNECTION DETAIL

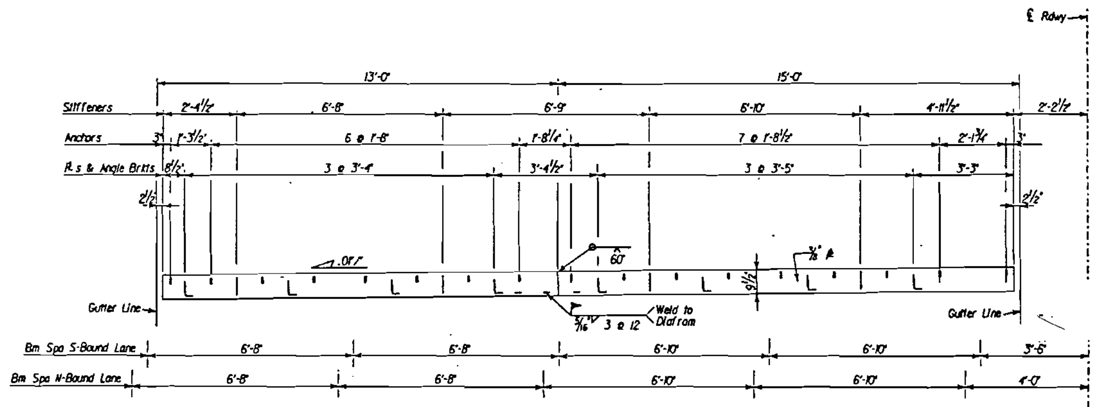


STIFFENER DETAIL



SECTION THRU ARMOR JOINT

AT ABUTMENTS 1 AND 7



PROPOSED ARMOR JOINT ELEVATION

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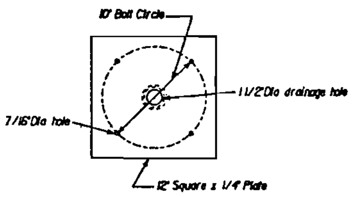
BRIDGE DETAILS

Sheet 1 of 2

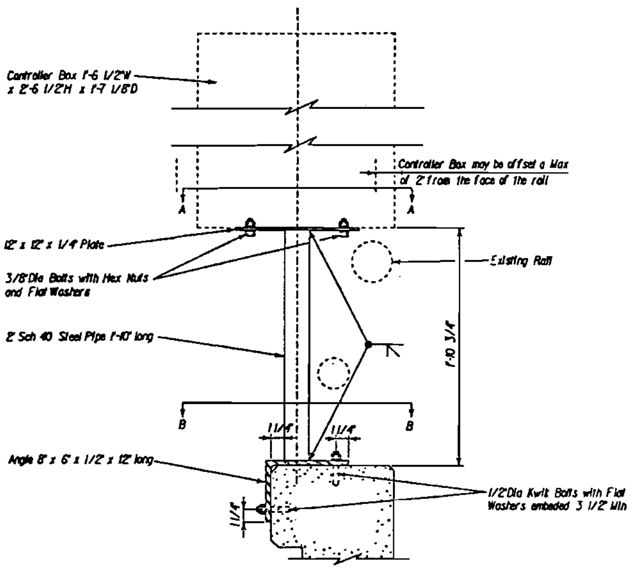
FED. ROAD DIV. NO.	STATE	FEDERAL AID PROJECT NO.			SHEET NO.
6	TEXAS	C 68-8-34			14
STATE DIST. NO.	COUNTY	CONT. NO.	SECT. NO.	JOB NO.	HIGHWAY NO.
8	HOWARD	68	8	34	US 87

-76-8

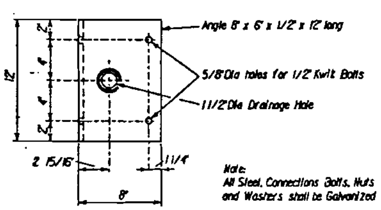
87DET1.DGN



PLAN VIEW AA



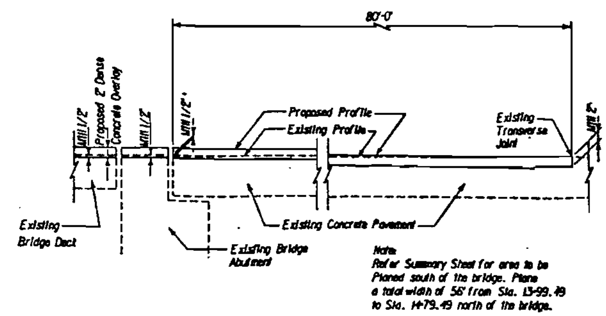
ELEVATION



Note:
All Steel, Connections Bolts, Nuts and Washers shall be Galvanized

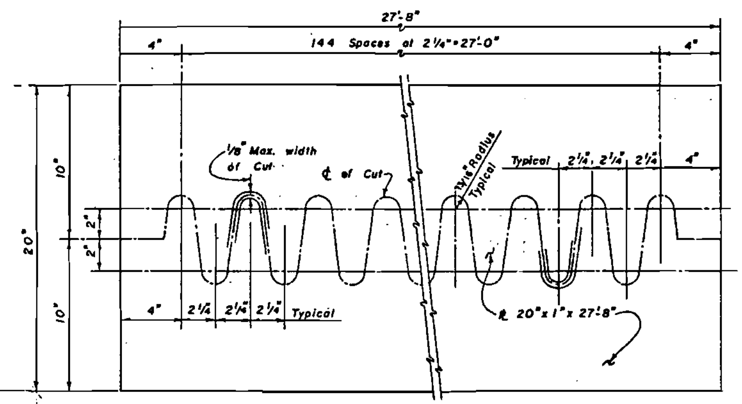
PLAN VIEW BB

CONTROLLER BOX SUPPORT



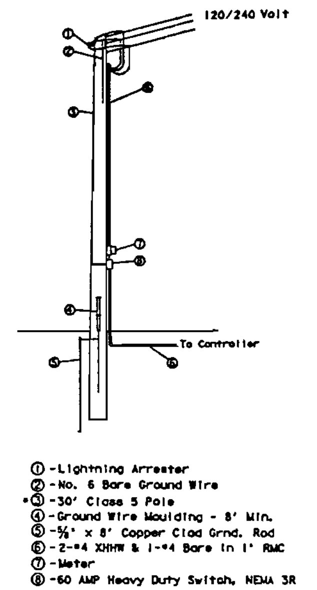
Note:
Refer Summary Sheet for area to be Planed south of the bridge. Plane a total width of 56' from Sta. 13+99.49 to Sta. 14+79.49 north of the bridge.

BRIDGE APPROACH DETAIL



DETAIL OF SCROLL

The scroll shall shall be made by a single cut of a machine guided torch. Spread as required. Grind off burrs.



① - Lightning Arrester
② - No. 6 Bare Ground Wire
*③ - 30' Class 5 Pole
④ - Ground Wire Moulding - 8' Min.
⑤ - 5/8" x 8' Copper Clad Grnd. Rod
⑥ - 2-#4 XHHW & 1-#4 Bare in 1" RMC
⑦ - Meter
⑧ - 60 AMP Heavy Duty Switch, NEMA 3R

* Or as Required By Utility Company.

All work and materials shall be in accordance with the National Electrical Code. Cathodic Protection Rectifiers shall be set to operate at 240 Volts.

SERVICE POLE AND ELECTRICAL FEEDER

Furnishing and installing service pole and electrical feeder will not be paid for directly but will be subsidiary to the item "Cathodic Protection System".

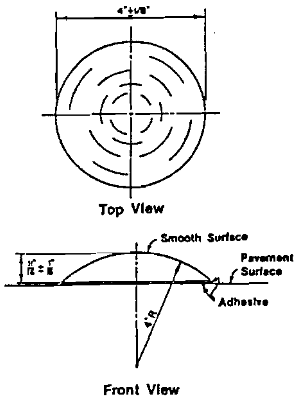
BRIDGE DETAILS

Sheet 2 of 2

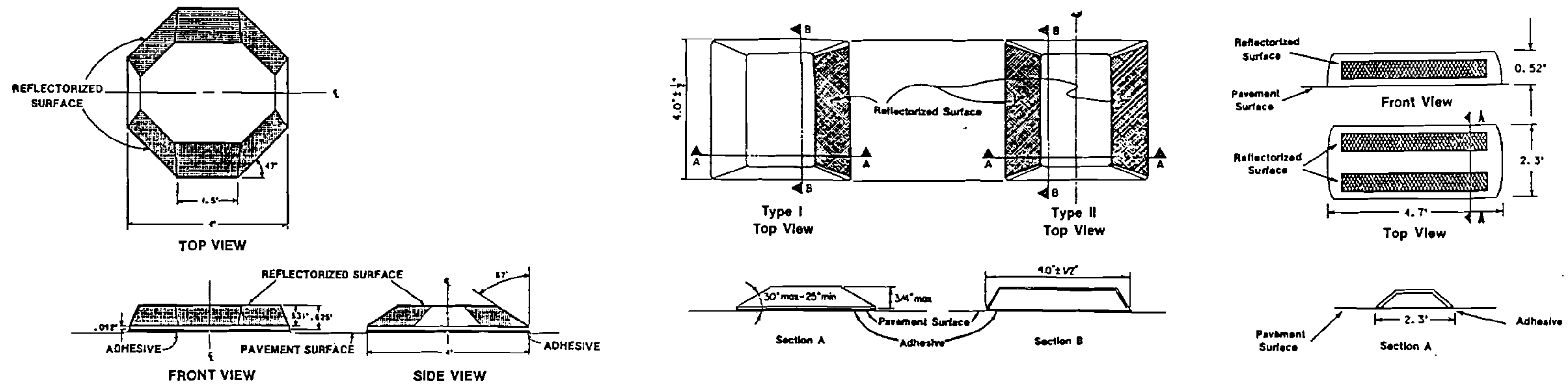
Rev. 9-1-87

FED. ROAD DIV. NO.	STATE	FEDERAL AID PROJECT NO.			SHEET NO.
6	TEXAS	C 68-8-34			15
STATE DIST. NO.	COUNTY	CONT. NO.	SEC. NO.	JOB NO.	HIGHWAY NO.
8	HOWARD	68	8	34	US 87

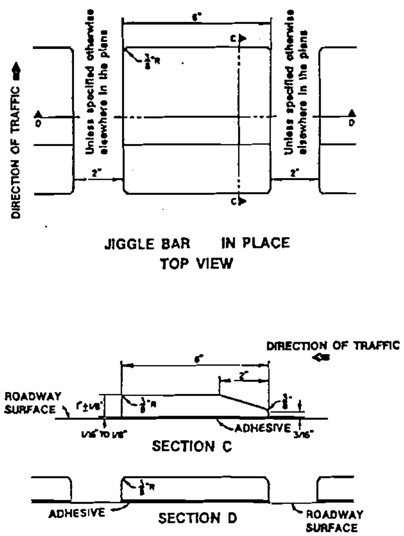
87DET2.DGN



TRAFFIC BUTTONS
(NON-REFLECTORIZED)

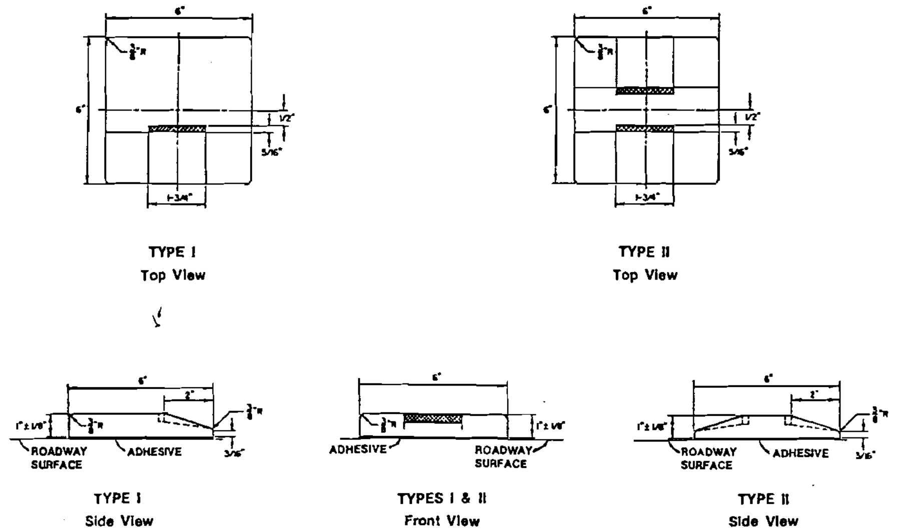


PAVEMENT MARKERS
(REFLECTORIZED)



JIGGLE BAR TILES
(NONREFLECTIVE)

"JIGGLE BARS" CONSIST OF A NUMBER OF JIGGLE BAR TILES PLACED IN A LINEAR CONFIGURATION



JIGGLE BAR TILES
(REFLECTORIZED)

NOTE

ALL DIMENSIONS ARE ± 1/8" UNLESS OTHERWISE SHOWN

GENERAL NOTES:

THE PAVEMENT UPON WHICH THE TRAFFIC BUTTONS, PAVEMENT MARKERS, AND JIGGLE BAR TILE ARE TO BE PLACED SHALL BE PREPARED SUBJECT TO THE APPROVAL OF THE ENGINEER TO INSURE PROPER CLEANING OF THE PAVEMENT SURFACE. RPM'S SHALL BE BONDED TO THE ROADWAY SURFACE WITH ADHESIVE CONFORMING WITH SPECIFICATION.

UNLESS SPECIFIED ELSEWHERE IN THE PLANS, THE USUAL JIGGLE BAR SPACING IS 50' ON MEDIAN PAVED SHOULDERS, 100' ON OUTSIDE PAVED SHOULDERS. JIGGLE BARS SHALL BE ORIENTED PERPENDICULAR TO THE ROADWAY.

JIGGLE BARS SHALL ALSO BE PLACED AT SUCH OTHER LOCATIONS AS SHOWN ON THE PLAN AND PROFILE SHEETS OR WHERE DIRECTED BY THE ENGINEER.

MARKERS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. THEY ARE NOT INTENDED TO SPECIFY ANY PARTICULAR PRODUCT.

1. TYPE OF PAVEMENT MARKERS (REFLECTORIZED) PROVIDED ON THIS PROJECT WILL BE AT THE CONTRACTOR'S OPTION.
2. ALL PAVEMENT MARKERS PROVIDED SHALL BE OF THE SAME MANUFACTURER.

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

INDIVIDUAL UNIT PAVEMENT MARKINGS REFLECTIVE PAVEMENT MARKERS, TRAFFIC BUTTONS & JIGGLE BAR TILE

IPM(1)

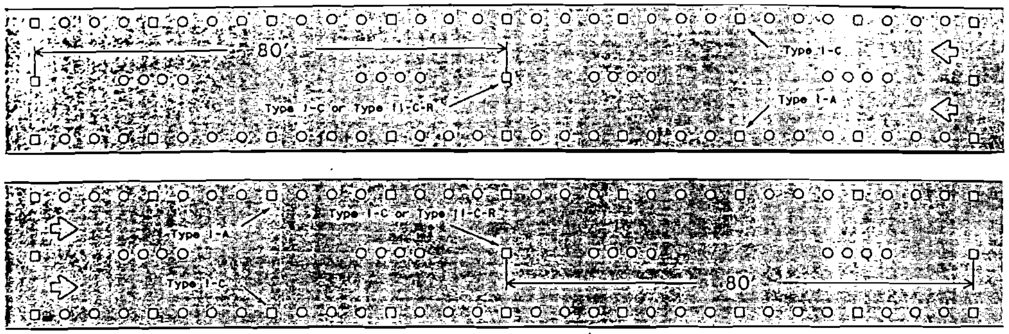
ORIGINAL DRAWING DATE: 1-81

REVISIONS: 2-82, 7-85, 11-85, 7-86, 10-86

STATE DISTRICT	FEDERAL REGION	PROJECT	SHEET
8	6	C 68-8-34	16

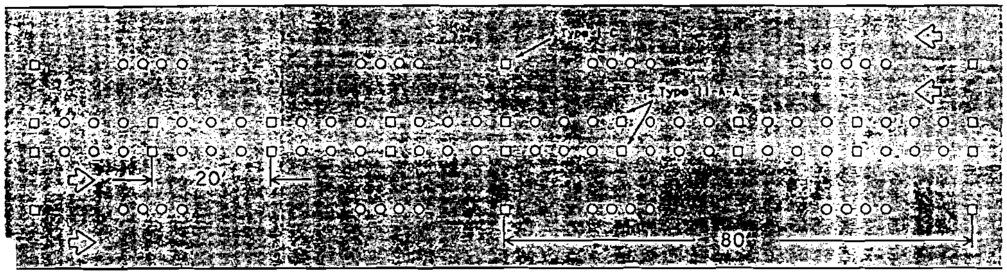
COUNTY	CONTROL	SECTION	JOB	HIGHWAY
Howard	68	8	34	IS.T7

21A



EDGE LINES AND LANE LINES
FOR DIVIDED HIGHWAYS

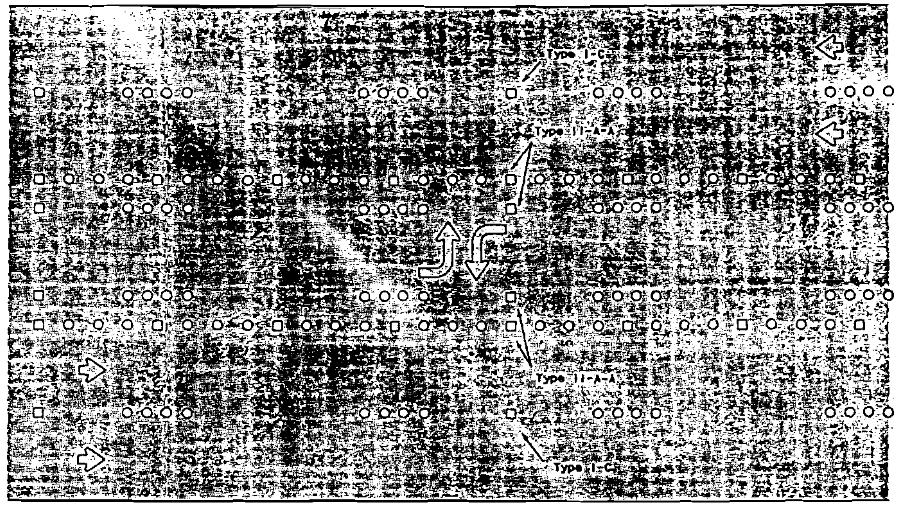
INDIVIDUAL UNIT MARKER TYPE II-C-R, CRYSTAL FACE TOWARD NORMAL TRAFFIC AND RED FACE TOWARD WRONG-WAY TRAFFIC, SHALL BE SPACED ON 80-FOOT CENTERS EXCEPT ON VERTICAL CURVES; GRADES OVER 2 PER CENT, LESS THAN 1000 FEET LONG; HORIZONTAL CURVES, AND ON CONTINUOUSLY ILLUMINATED SECTIONS OF HIGHWAY WHERE THEY MAY BE PLACED ON 40-FOOT CENTERS IF DEEMED NECESSARY BY THE ENGINEER.



LANE LINES & CENTER LINES
FOR MULTI-LANE UNDIVIDED HIGHWAYS

INDIVIDUAL UNIT MARKER TYPE I-C, CLEAR FACE TOWARD NORMAL TRAFFIC, SHALL BE PLACED ON 80-FOOT CENTERS.

59



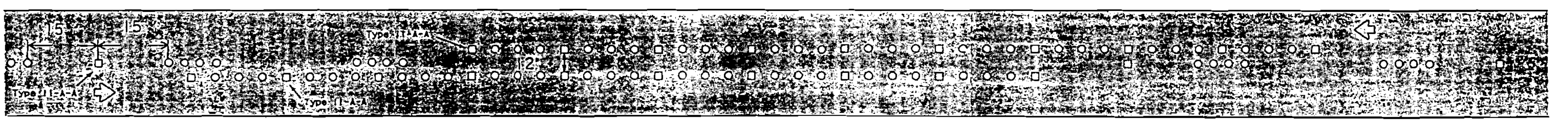
PAVEMENT MARKINGS FOR
TWO-WAY LEFT TURN LANE

GENERAL NOTES:

ALL INDIVIDUAL UNIT MARKERS PLACED IN DASHED LINES SHALL BE PLACED IN LINE WITH AND MIDWAY BETWEEN THE STRIPES.

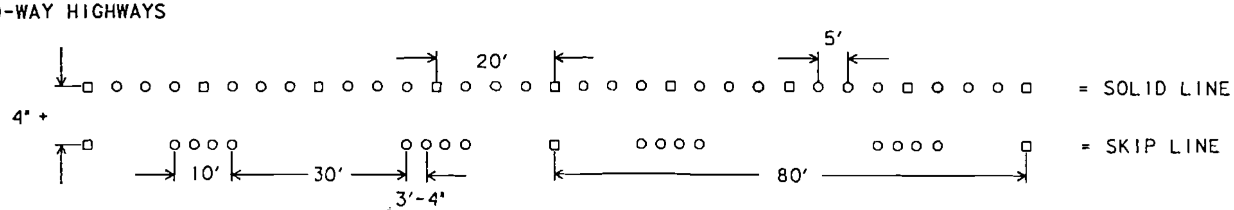
FIRST AND LAST INDIVIDUAL UNIT MARKERS IN A NO-PASSING ZONE BARRIER LINE ARE TO BE LOCATED ADJACENT TO EITHER THE MIDPOINT OF THE GAP OF THE CENTERLINE MARKING OR TO THE MIDPOINT OF THE STRIPE OF THE CENTERLINE MARKING.

BUTTON SPACING FOR CENTER LINES AND LANE LINES MAY BE 5 FEET IF DIRECTED BY THE ENGINEER.



CENTER LINE & NO PASSING ZONE BARRIER LINES
FOR TWO-LANE TWO-WAY HIGHWAYS

INDIVIDUAL UNIT PAVEMENT MARKINGS
○ = TRAFFIC BUTTON (NONREFLECTORIZED)
□ = TRAFFIC MARKER (REFLECTORIZED)



PATTERN DETAIL

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

INDIVIDUAL UNIT PAVEMENT
MARKINGS USED TO SIMULATE
STANDARD PAVEMENT MARKINGS FOR
CENTER LINES AND LANE LINES
PM(3)

REVISIONS	2-82	8	6	C 68-8-34		17
	7-86	Howard	68	8	34	US 87
	10-86					220

CONSTRUCTION PAVEMENT MARKINGS

..hen required elsewhere in the plans, the Contractor will be ..sponsible for maintaining pavement markings on all roadways that ..e open to traffic within the limits of the project. On projects in..olving roadway surfacing which will require pavement marking for ..ntrol of traffic during construction, the markings may include ..th standard and abbreviated markings as defined below:

1. Standard Pavement Markings - Standard markings placed in conformance with the requirements of the Texas MUTCO. Such markings should be placed on all roadways open to traffic during construction, including new pavement, resurfacing, detours or other roadways where construction activities may have covered or obliterated existing markings. Standard markings should be placed as soon as possible and practical. When it is not practical or possible to place standard markings at the end of each day's work, abbreviated markings may be utilized for short periods until standard markings can be placed.

2. Abbreviated Pavement Markings - Abbreviated pavement markings are shorter in length than standard markings. The length and spacing of these markings shall be as specified elsewhere in the plans or specifications. Abbreviated pavement markings may be used to delineate lane continuity only until such time as standard markings can be placed. They are not intended to substitute for standard markings for periods greater than two (2) weeks. To separate traffic flows in opposing directions, the pavement markings shall be yellow. White pavement markings shall be used to delineate the seperation of traffic flows in the same direction.

When abbreviated pavement markings are used, a DO NOT PASS sign shall be used to mark the beginning of the section where passing is to be prohibited and a PASS WITH CARE sign shall be used to mark the beginning of a section where passing is permitted.

REMOVAL OF PAVEMENT MARKINGS

..oval of Pavement Markings - Includes centerline, barrier lines, lane .., edge lines, and raised pavement markings.

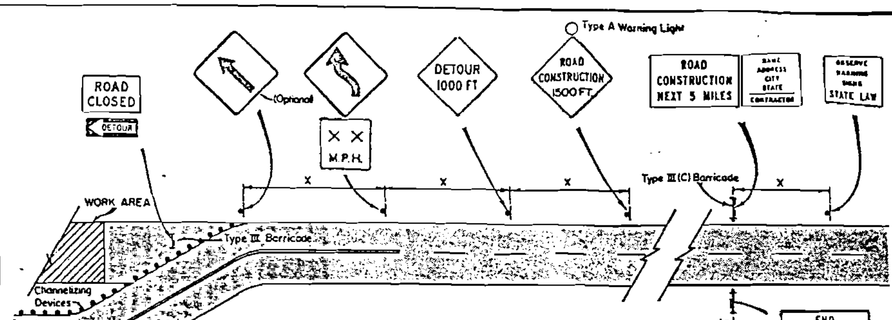
..ediately upon opening a detour to traffic, any pavement markings ..he existing original roadway in the detour transition area that are no ..er applicable and which may create confusion or direct a motorist toward or into the closed portion of the roadway, shall be removed or obliterated. In addition, when a detour is to be discontinued any pavement markings used to transition traffic into the detour which may create confusion or direct a motorist into the discontinued detour shall likewise be removed or obliterated. The above shall not apply to detours of a short time duration of a few hours where flagman or sufficient channelizing devices are used to outline the detour route and the detour is not to be maintained overnight.

The removal of pavement markings shall be an integral part of establishing the detour. Detours shall be planned and scheduled well enough in advance to allow adequate time to complete all phases of the operation prior to darkness. If inclement weather or darkness becomes a factor, it will be the contractors decision to continue with the detour operation or retain the existing travelway open to traffic when any or all of the requirements of the detour cannot be accomplished.

Pavement markings shall be removed to the fullest extent possible, so as not to leave a discernible marking, by any method that does not materially damage the surface or texture of the pavement. Subject to the approval of the Engineer, any method that proves to be successful on a particular type pavement may be used. Sandblasting may be used but will not be required unless specifically shown in the plans. Over-painting of the marking will not be permitted. Removal of raised pavement markings shall be as directed by the Engineer.

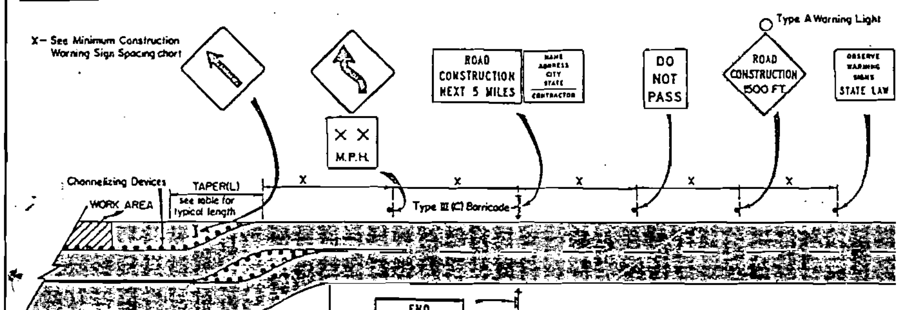
Where mechanical means of marking removal have been employed to completely remove the marking and its reflectivity, paint of a color matching the pavement surface or used crankcase oil may be employed if necessary as a means of covering contrasting pavement texture. Nighttime inspections are needed to verify the continued effectiveness of the change.

Pavement markings to be removed shall be as shown in the plans or as directed by the Engineer. Removal of pavement markings will be considered subsidiary to the item BARRICADES, SIGNS AND TRAFFIC HANDLING. Any sandblasting required by the plans for marking removal shall be measured and paid for as a bid item in the contract.



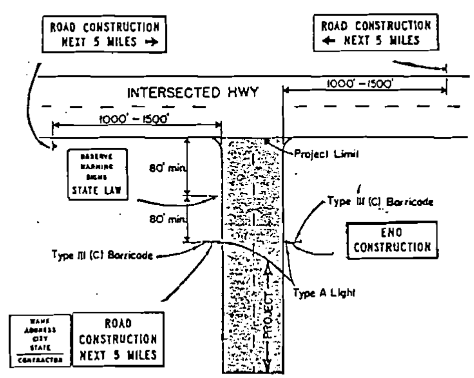
PROJECT LIMITS AWAY FROM WORK AREA

(Greater than 2000ft. between project limits and work area)



PROJECT LIMITS ADJACENT TO WORK AREA

(Less than 2000ft. between project limits and work area)



PROJECT LIMITS AT T-INTERSECTION

SPECIAL NOTES

1. The ROAD CONSTRUCTION NEXT X MILES (← OR →) sign should be erected on the intersected highway as detailed above.

2. On the intersected highway, additional traffic control devices, such as a flagman and accompanying signs or other signs, should be used when work is being performed at or near the intersection.

Project Limit
Traffic Control Devices

GENERAL NOTES

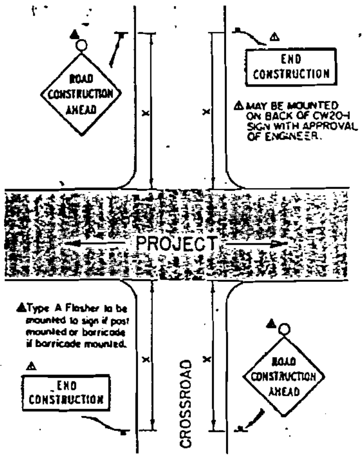
1. As detailed above and on sheet BC(2), the ROAD CONSTRUCTION NEXT X MILES, CONTRACTOR NAME and END CONSTRUCTION signs shall be erected on Type III(C) Barricades at or near the project limits and the OBSERVE WARNING SIGNS STATE LAW sign shall be erected in advance of the Type III(C) Barricades.
2. Appropriate standard traffic control devices shall be used within the project limits to adequately warn, advise, control and guide traffic around and/or through all areas of work activity, detours and other such hazardous locations.
3. As a general rule, additional traffic control devices in advance of the project limits should only be used in those cases where a work area, a detour, or a hazardous location is less than 2,000 feet inside of the project limits.
4. Duplicate construction warning signs should be erected on the median side of divided highways where median width will permit and traffic density justifies the signing.
5. Except for devices required by Note 1, traffic control devices should be in place only while work is actually in progress or a definite need exists such as for detours and hazards, otherwise, they should be removed or covered.
6. The traffic control devices used in the above illustrations are examples only. Field conditions should dictate the most appropriate traffic control devices to be used within a construction project.

CROSSROAD SIGNING AND BARRICADING

Except as noted below or elsewhere in the plans, the minimum signing on a crossroad approach should be one CW20-1 ROAD CONSTRUCTION AHEAD sign with a Type A Warning Light when work is actually in progress or a hazard exists in the vicinity of the intersection. Where speeds and volumes are relatively low the MCW 20 may be used, provided that a minimum letter size of 5 inches can be accommodated on this size with the appropriate legend. Additional signs such as FLAGMAN AHEAD, LOOSE GRAVEL, or other appropriate signs may be required; and when required, such signs will be considered part of the minimum requirements. When Type III Barricades are used on the project roadway, where practical, it is desirable that they be placed 30 feet or more from the crossroad.

EXCEPTIONS - TO BE NOTED ELSEWHERE IN THE PLANS

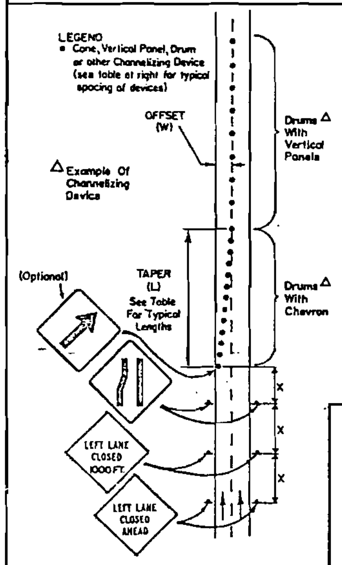
1. On higher volume crossroads or where major construction in the intersection area may require more than normal warning, more signing and barricading than the minimum specified above may be required. In some cases the Type III (C) Barricade plan along with the advance signing may be required during all or certain sequences of the work. However, unless the need for additional signs and/or barricades is noted elsewhere in the plans, the minimum requirements specified above will prevail.
2. On low volume crossroads the minimum signing required above may be omitted or modified if exceptions are noted elsewhere in the plans.
3. The G20-1c may be required on major crossroads to advise motorists of the length of construction in either direction from the intersection.



MINIMUM CONSTRUCTION WARNING SIGN SPACING

POSTED SPEED OR 85% SPEED	30 or less	35	40	45	50	55 ⊡
X MINIMUM DISTANCE (FT.)	80	120	160	240	320	500

⊡ For roads with a 55 MPH posted speed limit, advance wa[illegible] signs should be placed approximately 1,500 feet in advance of the condition to which they are calling attention. Where a series of advance warning signs are used, the warning sign nearest the work site should be placed approximately 500 feet from the point of restriction with the additional signs at approximately 500-1000 foot intervals.



TYPICAL TRANSITION FOR SHORT DURATION LANE CLOSURE

For Long Duration Lane Closure, Pavement Markings In The Transition Area Shall Be Removed.

TYPICAL TRANSITION LENGTHS AND SUGGESTED MAXIMUM SPACING OF CHANNELIZING DEVICES

Posted Speed*	Formula	Minimum Desirable Taper Lengths** 10' Offset	11' Offset	12' Offset	Suggested Maximum Spacing of Device On a Taper	On a Tangent
30	$L=\frac{WS^2}{60}$	150'	165'	180'	30'	60'-75'
35		205'	225'	245'	35'	70'-90'
40		265'	295'	320'	40'	80'-100'
45	$L=WS$	450'	495'	540'	45'	90'-110'
50		500'	550'	600'	50'	100'-125'
55		550'	605'	660'	55'	110'-140'
60		600'	660'	720'	60'	120'-150'

*85th Percentile Speed may be used on roads where traffic speeds normally exceed the posted speed limit.

**Taper lengths have been rounded off.

L=Length of Taper (FT) W=Width of Offset (FT) S=Posted Speed (MPH)

STATE DEPARTMENT OF HIGHWAY
AND PUBLIC TRANSPORTATION

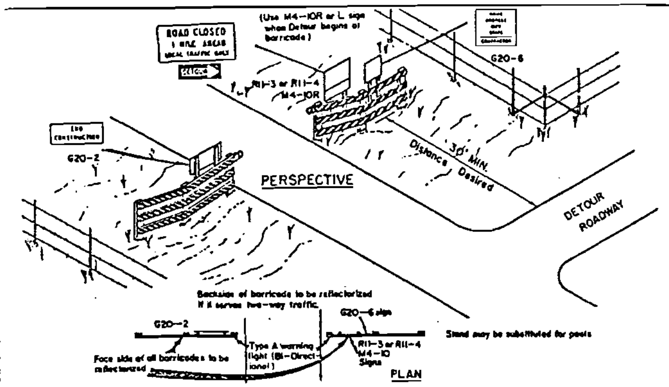
BARRICADE AND CONSTRUCTION STANDARDS

ADVANCE SIGNING
CROSSROAD SIGNING
PAVEMENT MARKINGS

BC(1)-82

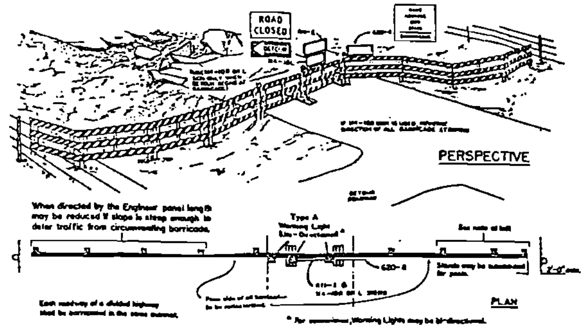
6

2-82



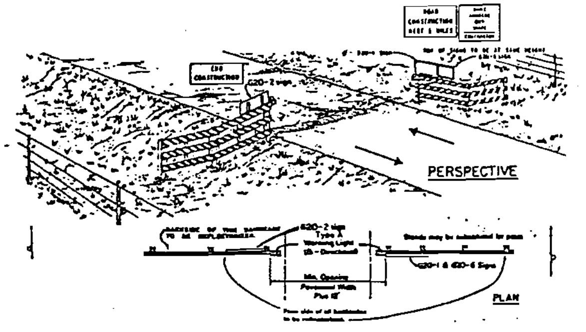
TYPE III (A) BARRICADE

1. The plan shown above is to be used when local traffic is permitted inside project or permitted to use the road beyond the intersection with the temporary route. Other signs and barricades (Type I, II or III) may be required inside the project limits based upon the contractor's sequence of work and other conditions.
2. Where conditions will permit, minimum length of barricade on each side of roadway should be 12 feet.
3. First barricade panel on each side of roadway should be approximately level. Additional panels, if needed, may follow contour of right-of-way.
4. Advance signing, including construction warning signs, and detour signing shall be as specified elsewhere in the plans.

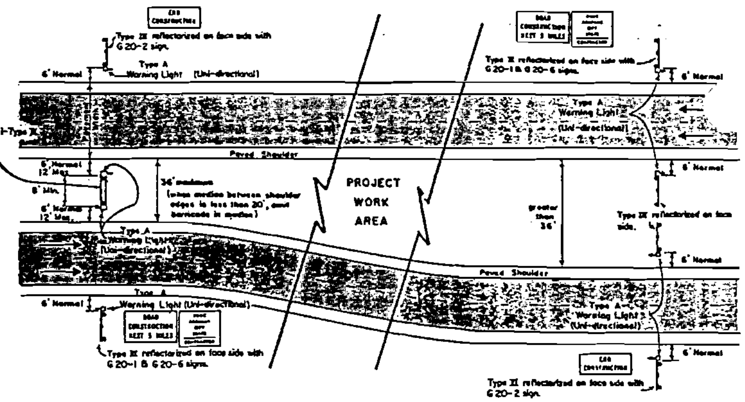


TYPE III(B) BARRICADE

1. The plan shown above is to be used when no local traffic is permitted inside the project. Contractor may locate his access gate anywhere in barricade except at center of roadway where R11-2 and M4-10 signs must be mounted on fixed barricade section.
2. Advance signing, including construction warning signs, and detour signing shall be as specified elsewhere in the plans.



TYPE III(C) BARRICADE FOR TWO WAY UNDIVIDED ROADWAY



TYPE III(C) BARRICADE FOR DIVIDED HIGHWAYS

NOTES FOR TYPE III (C) BARRICADES

1. The plans shown above are to be used when all traffic is maintained through the project. The signs shown apply to the first and last barricades of a project. Other signs and barricades (Types I, II or III) will be required inside the project limits based upon the contractor's sequence of work and other conditions.
2. Where conditions will permit, minimum length of barricade on each side of roadway should be 12 feet except as noted.
3. First barricade panel on each side of roadway should be approximate level. Additional panels, if needed, may follow contour of right-of-way.

GENERAL NOTES FOR TYPES I, II & III BARRICADES

Type I or II Barricades (see Sheet BC(3)) are for temporary use to control traffic within the limits of a project whenever it is necessary to confine traffic to a specific area because of some particular construction operation. Type I Barricades would normally be used on conventional roads or urban streets and arterials. As Type II Barricades have more reflective area, they are intended for use on expressway and freeways or other high speed roadways.

Type III(A) Barricades and accompanying signs are to be used at each end of construction projects closed to all but local traffic.

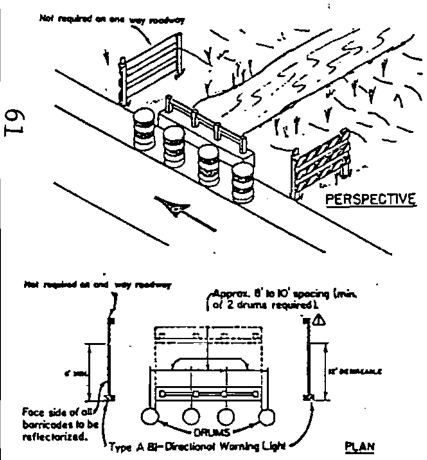
Type III(B) Barricades and accompanying signs are to be used at each end of construction projects closed to all traffic.

Type III(C) Barricades and accompanying signs are to be used at each end of construction projects where traffic is maintained through the project. Type III(C) Barricades may also be used where traffic from other highways, county roads or city streets is permitted to enter the project area. Typical signing for Type III(C) Barricades in shown on Sheet BC(1).

Type III(D) Barricades are to be used on culvert widening projects where traffic is routed over the structure. They shall be erected so as to provide the maximum roadway width for traffic and to allow sufficient space for construction operations behind the barricades.

Warning Lights placed on Type III(A), (B) or (C) barricades should be mounted at a minimum height of 36 inches to the bottom of the lens and may be attached to the barricade or mounted on a separate channelizing device. Barricades used at each end of the project shall be supplemented with warning lights as detailed on this sheet. For all other barricades, used at night, warning lights are to be used as detailed on Sheet BC(3).

For dimensions of barricade panels see Sheet BC(3).

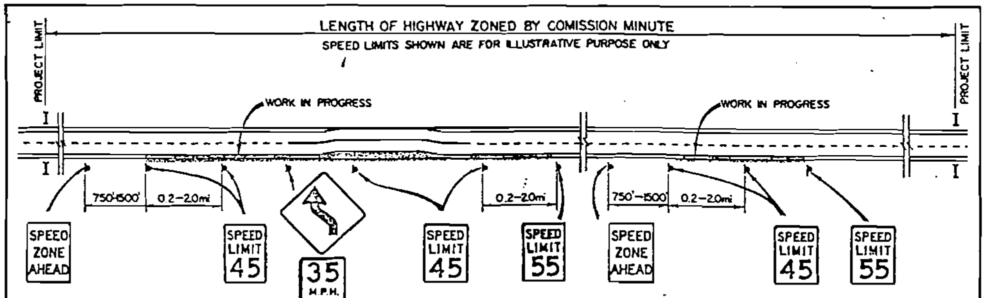


TYPE III (D) BARRICADE

FOR CULVERT WIDENING SITE WITHIN THE PROJECT LIMITS

NOTES:

1. Where positive redirectional capability is provided, drums and barricades may be omitted.
2. On streets or roads with posted speeds of 35 MPH or less, Type III Barricades may be used in lieu of barrels where necessary for pedestrian safety.



TYPICAL APPLICATION OF SPEED ZONE SIGNS

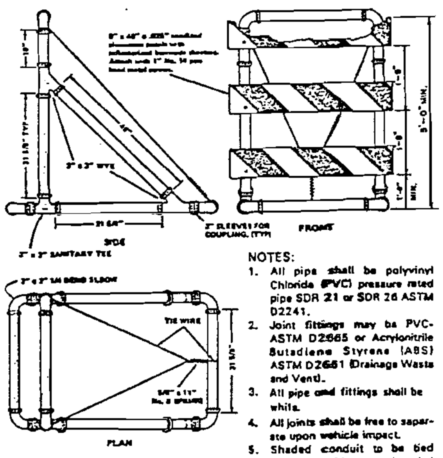
NOTES
- Frequency of speed limit signs should be every 0.2 to 2.0 miles for speeds 40 MPH and above and 0.2 to 1.0 miles for speeds 35 MPH and below.
- Reduce speeds when required should only be posted in the vicinity of work being performed or other areas when needed rather than throughout the entire project.
- SPEED ZONE SIGNS ARE ILLUSTRATED FOR ONE DIRECTION OF TRAVEL ONLY AND ARE NORMALLY POSTED FOR EACH DIRECTION OF TRAVEL
- REGULATORY CLASS SPEED ZONE SIGNS SHALL HAVE BLACK LEGEND ON A WHITE REFLECTIVE BACKGROUND

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

BARRICADE AND CONSTRUCTION STANDARDS

BARRICADES
SPEED ZONING

BC(2)-82



NOTES:
1. All pipe shall be polyvinyl Chloride (PVC) pressure rated pipe SDR 21 or SDR 26 ASTM D2241.
2. Joint fittings may be PVC-ASTM D2665 or Acrylonitrile Butadiene Styrene (ABS) ASTM D2661 (Drainage Waste and Vent).
3. All pipe and fittings shall be white.
4. All joints shall be free to separate upon vehicle impact.
5. Shaded conduit to be tied together with rope threaded into pipe interior. Use 3/16" No. 6 solid braided nylon or equivalent.
6. A fixed frangible pavement connection is preferred. Sand Bags may be substituted.

OPTIONAL
TYPE III PVC BARRICADES
TYPICAL DESIGN DETAILS

May be used at the option of the Contractor

STRIPING FOR BARRICADE

Where a barricade extends entirely across a roadway, it is desirable that the stripes slope downward in the direction toward which traffic must turn in detouring. When both right and left turns are provided for, the chevron striping may slope downward in both directions from the center of the barricade.

Striping should cover the full width of the rail. Striping of rails, panels and gates for the right side of the roadway is shown above. For the left side of the roadway, striping should slope downward to the right.

For all types of barricades with rails less than 3'-0" long, stripes 4" wide shall be used.

The 8" rail width is a nominal dimension for rails made of lumber.

Identification markings may be shown only on back side of barricade rails.

BARRICADE NOTES

Channelizing devices other than barricades should normally be used for channelization purposes.

Barricades should normally be placed perpendicular to the traffic flow. Other channelizing devices, such as drums, vertical panels or portable barriers, should be used where needed to separate traffic from the work area. In all cases, the barricades should be so located as to most advantageously warn and direct traffic.

Barricades may be designed and constructed from wood, PVC pipe or any other suitable material in a manner approved by the Engineer. The construction details shown hereon are typical and are suggested details for wood and PVC pipe support systems for barricades. The details of rail width and striping, number and spacing of rails, minimum length and height (above pavement) of rails must be adhered to when alternate designs are used.

When signs are placed on barricades, a maximum number of 2 signs should be visable to the motorist.

Barricades are to be constructed in a first-class workmanship manner of clean sound material. All surfaces above ground, which are not striped, shall be white except the unpainted galvanized metal or aluminum components may be used. Components made of lumber shall be painted with a minimum of two coats of an approved brand of white paint to secure thorough coverage and a uniform white color.

The Contractor shall maintain each barricade in a clean and good condition.

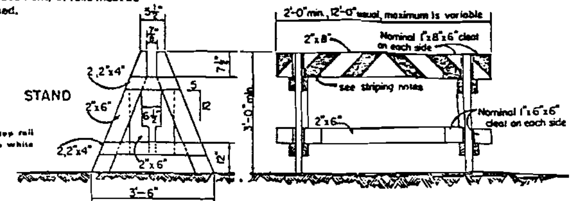
Barricades shall be removed upon completion of the work and/or the elimination of the hazard on any section.

BARRICADE DETAILS

All lumber sizes are nominal dimensions
Fabrication Details ± 1/2"

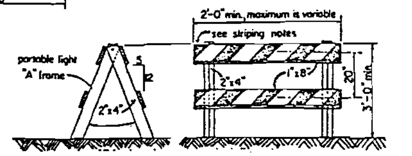
TYPE I BARRICADE

For Type I Barricades, both sides of the top rail shall have reflective orange and reflective white striping.

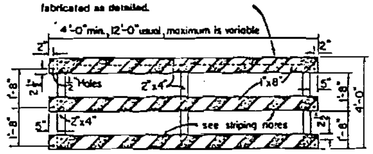


TYPE II BARRICADE

For Type II Barricades, all four (4) rail faces shall have reflective orange and reflective white striping.



When Wood Barricades are used and when orange and white stripes are required on the backside, a 2" x 8" rail may be used in lieu of the 1" x 8" rail and 2" x 4" stiffener. Otherwise the rail should be fabricated as detailed.

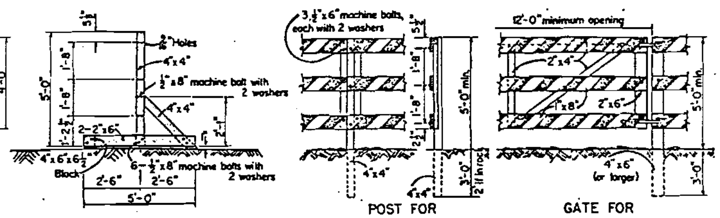


TYPE III BARRICADE

For Type III Barricades, the three (3) rails shall be reflective orange and reflective white stripes on one side if it is facing traffic in one direction only, and on both sides if it serves traffic in two directions. See Barricade Layouts on Sheet BC (2).

Use 1/2" x 3 1/2" machine bolts, with two washers each

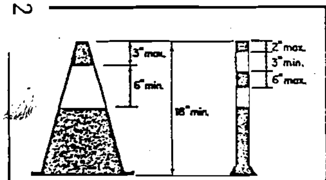
PANEL FOR
TYPE III BARRICADE



STAND FOR TYPE III BARRICADE

POST FOR
TYPE III BARRICADE

GATE FOR
TYPE III BARRICADE



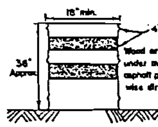
CONES

Traffic cones and tubular markers shall be a minimum of 18 inches in height with a broadened base and may be made of various materials to withstand impact without damage to themselves or to vehicles. Larger sizes should be used on freeways and other roadways where speeds are relatively high or wherever more conspicuous guidance is needed. Orange shall be the predominant color on cones and tubular markers. They should be kept clean and bright for maximum target value. For nighttime use they shall be reflectorized or equipped with lighting devices for maximum visibility. Reflectorized material shall have a smooth, sealed outer surface which will display the same approximate color day and night.

Reflectorization of tubular markers shall be a minimum of two three-inch bands placed a maximum of 2" from the top with a maximum of 6" between the bands. Reflectorization of cones shall be provided by a minimum 6" band placed a maximum of 3" from the top.

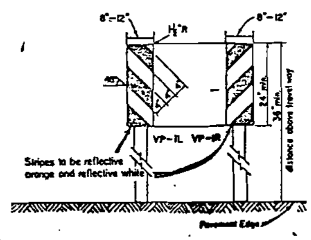
Cones or tubular markers are generally only suitable for temporary usage (up to 8 hours) with other channelization devices such as vertical panels or barricades preferred for longer term usage. Care should be taken to insure that they remain in their proper location and in an upright position.

DRUMS



Drums, set on end, and used for traffic warning or channelization shall be approximately 36" in height and minimum of 18" in diameter. The contractor, at his option, may use drums made from steel barrels or black polyethylene plastic drum liners weighing approximately eight pounds each. The markings on drums shall be horizontal, circumferential, reflectorized orange and reflectorized white stripes, 4 to 8 inches wide. The first reflectorized stripe should start within two (2) inches of the top of the drum. There shall be at least two orange and two white stripes on each drum. If there are non-reflectorized spaces between the horizontal orange and white stripes, they shall be no more than 2 inches wide. Metal drums shall be painted black or orange before reflectorized stripes are added. All drums on a project will be the same color. When drums are placed in the roadway, appropriate warning signs should be used. During hours of darkness, a flashing warning light should be placed on drums used singly as a warning device. Steady burn electric lights or delineators should be placed on drums used in series for traffic channelization. Drums should not be weighted with sand, water or other material to the extent that it would make the drums dangerous to motorists.

CW1-8 CHEVRON signs, CW1-8A ARROW signs or VP-1 Vertical Panels mounted above drums may be used as supplements to drum delineation.

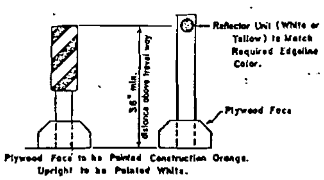


VERTICAL PANELS (VP)

Vertical Panels are normally used as channelizing devices to indicate tangent or nearly tangent roadway alignment where good target value of a device is needed in daytime as well as the nighttime. In addition, vertical panels should be used at the edge of shoulder drop-offs and other areas such as lane transitions where positive day and night delineation may be required. Vertical panels should be mounted back to back if used at the edge of cuts adjacent to two-way two lane roadways. Stripes should always slope downward toward the traveled way.

CHANNELIZING DEVICES

The Type or Types of Channelizing Devices used are to be as specified by the Engineer.



TYPICAL PORTABLE VERTICAL PANEL OR DELINEATOR

Other similar supports may be used when approved or directed by the Engineer.

GENERAL NOTES

REFLECTORIZATION

The reflectorized white and reflectorized orange stripes for barricades, drums and vertical panels shall be constructed of retroreflective sheeting in conformance with project specifications and shall be maintained to meet the appearance, color, and reflectivity requirements of those specifications.

WARNING LIGHTS

Warning lights are portable lens directed, enclosed lights. The color of the light emitted shall be yellow. The lights should be mounted at a minimum height of 36 inches to the bottom of the lens.

Type A-Low Intensity Flashing Warning Lights are commonly mounted on barricades, other channelization devices or advance warning signs and are intended to warn the driver that he is approaching a hazardous area. Their use shall be as specified elsewhere in the plans, on Sheets BC(1) and BC(2), or as directed by the Engineer.

Type B High Intensity Flashing Warning Lights are normally used when approaching extremely hazardous site conditions within the construction area. They may be mounted on barricades, signs or other supports. As these lights are effective in daylight as well as dark, they are designed to operate 24 hours per day. Their use should be specified elsewhere in the plans or as directed by the Engineer. Flashing warning lights shall not be used in a series.

Type C Steady Burn Lights are intended to be used in a series for delineation to supplement other traffic control devices used to delineate the edge of the traveled way on detour curves, lane changes, lane closures, shoulder drop-offs and other similar conditions or hazards. The series of Steady [illegible] should have a Type B High Intensity Flashing Warning Light at [illegible] and end of the series to mark the hazard. Where Steady Burn Lig[illegible] be used for delineation, the contractor may at his option, utilize delineators.

Contractors shall furnish a copy of a certification from the manufacturer of the lights that the warning lights meet the requirements of the ITE Standard For Flashing and Steady Burn Warning Lights as contained in the latest edition of the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways."

DELINEATORS

Delineators are normally used to indicate roadway alignment where improved nighttime visibility is needed but other roadway features are sufficient for daytime alignment. They should generally be used on high fills and horizontal and vertical curves where only nighttime delineation is needed. Delineators, when required for temporary use to control traffic through construction areas, will be considered subsidiary to the item BARRICADES, SIGNS AND TRAFFIC HANDLING. Delineators shall meet the material requirements of the project specifications. When used, delineators on the right side of the roadway facing traffic shall be white. The color of delineators used along the left edge of divided streets and highways and one-way roadways shall be yellow.

SPACING OF DELINEATORS

Spacing of Delineators on curves should be according to the Table below. Spacing of delineators on tangent sections should normally be between 100 and 200 feet with the closer spacing for lower speeds and greater spacing for higher speeds.

RADIUS OF CURVE (FEET)	50	150	200	250	300	400	500	500	700	800	900	1000
APPROX. SPACING ON CURVE (FEET)	20	30	35	40	50	55	65	70	75	80	85	90

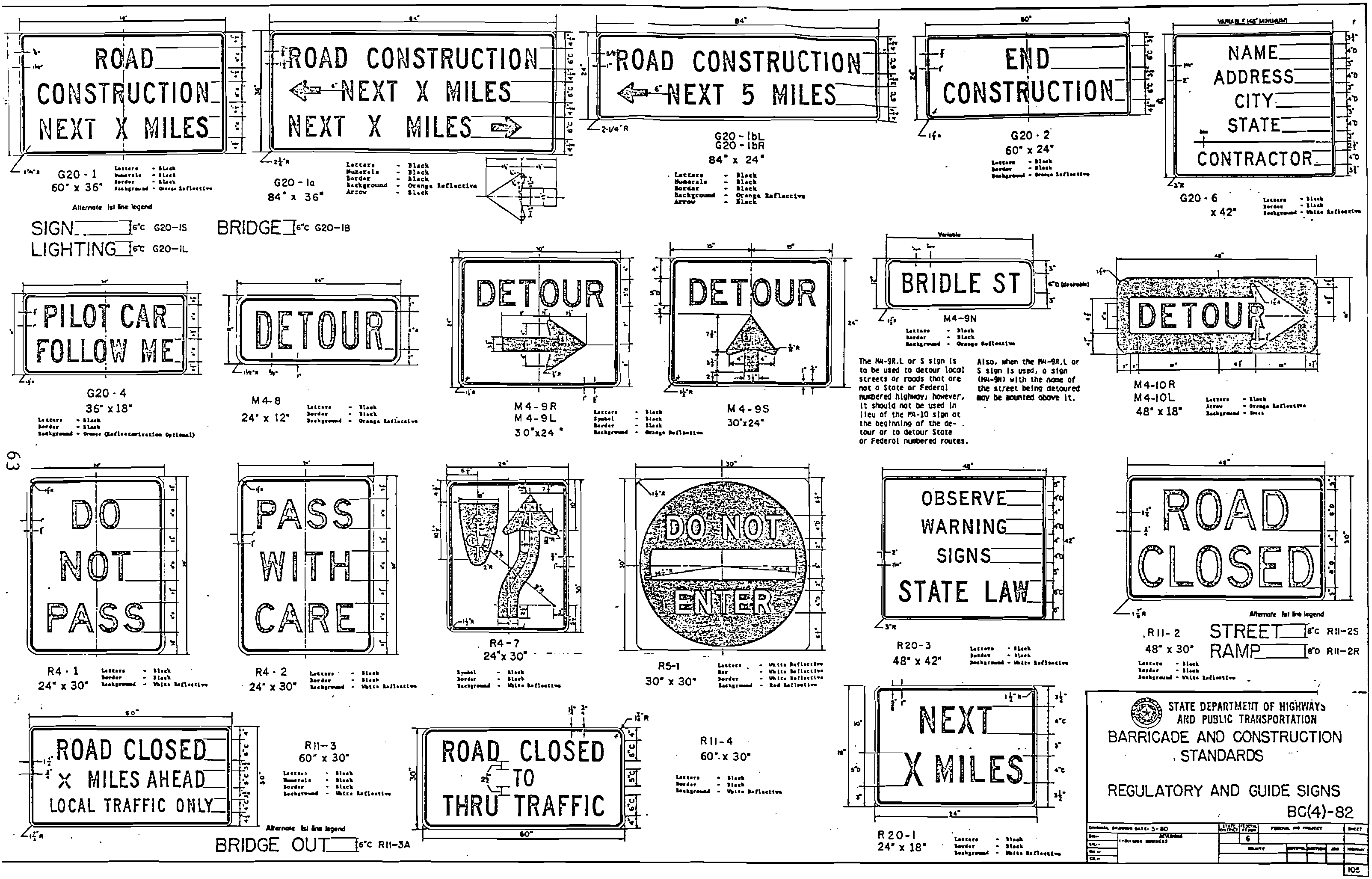
STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

BARRICADE AND CONSTRUCTION STANDARDS

BARRICADE DETAILS
DELINEATORS & VERTICAL PANELS
DRUMS & CONES
REFLECTORIZATION
WARNING LIGHTS

BC(3)-82

ORIGINAL DRAWING DATE: 3-80	REVISIONS	STATE DISTRICT	FEDERAL REGION	FEDERAL AID PROJECT	SHEET
	2-82		6		


ROAD CONSTRUCTION NEXT X MILES
G20-1
60" x 36"
Alternate 1st line legend
SIGN 6"C G20-1S
LIGHTING 6"C G20-1L
ROAD CONSTRUCTION
NEXT X MILES
NEXT X MILES
G20-1a
84" x 36"
Letters - Black
Numerals - Black
Border - Black
Background - Orange Reflective
Arrow - Black
BRIDGE 6"C G20-1B
ROAD CONSTRUCTION
NEXT 5 MILES
G20-1bL
G20-1bR
84" x 24"
Letters - Black
Numerals - Black
Border - Black
Background - Orange Reflective
Arrow - Black
END CONSTRUCTION
G20-2
60" x 24"
NAME
ADDRESS
CITY
STATE
CONTRACTOR
G20-6
x 42"
PILOT CAR FOLLOW ME
G20-4
36" x 18"
DETOUR
M4-8
24" x 12"
DETOUR
M4-9R
M4-9L
30"x24"
DETOUR
M4-9S
30"x24"
BRIDLE ST
M4-9N
The M4-9R,L or S sign is to be used to detour local streets or roads that are not a State or Federal numbered highway; however, it should not be used in lieu of the M4-10 sign at the beginning of the detour or to detour State or Federal numbered routes.
Also, when the M4-9R,L or S sign is used, a sign (M4-9N) with the name of the street being detoured may be mounted above it.
DETOUR
M4-10R
M4-10L
48" x 18"
DO NOT PASS
R4-1
24" x 30"
PASS WITH CARE
R4-2
24" x 30"
R4-7
24" x 30"
DO NOT ENTER
R5-1
30" x 30"
OBSERVE WARNING SIGNS STATE LAW
R20-3
48" x 42"
ROAD CLOSED
R11-2
48" x 30"
Alternate 1st line legend
STREET 8"C R11-2S
RAMP 8"D R11-2R
ROAD CLOSED X MILES AHEAD LOCAL TRAFFIC ONLY
R11-3
60" x 30"
Alternate 1st line legend
BRIDGE OUT 6"C R11-3A
ROAD CLOSED TO THRU TRAFFIC
R11-4
60" x 30"
NEXT X MILES
R20-1
24" x 18"
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
BARRICADE AND CONSTRUCTION STANDARDS
REGULATORY AND GUIDE SIGNS
BC(4)-82
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CONSTRUCTION SIGN NOTES

Construction signs shall be made from wood or metal. The designation of metal and wood as primary materials for signs shall not be interpreted to exclude other suitable rigid materials now or hereafter available.

Wood for signs shall be waterproof resinbonded exterior grade plywood, Douglas Fir Plywood Association, or equal, of minimum 1/2 inch thickness. All wood signs made up of 2 or more pieces shall have one or more cleats, 1/2 inch by 6 inch plywood fastened to the back of the sign and extending fully across the sign. On plywood signs cleats shall be used as splice plates running the length of the joints. In localities where untreated wood rots rapidly, it is recommended that wood used for signs be treated either with chromated zinc chloride, Wolman salts, or pentachlorophenol.

Aluminum sign blanks shall have a minimum thickness of 0.080". Steel sign blanks shall have a minimum thickness of 14 gauge.

On secondary roads or city streets where speeds are low, smaller size construction warning signs may be used with the approval of the Engineer and if the sign size is in accordance with the "Typical Construction Warning Sign Size and Spacing Chart" shown on page 6B-2.2 of the Texas MUTCD.

Reflectorized signs shall be constructed of retro-reflective sheeting and shall be maintained to meet the requirements for appearance, color and retro-reflectivity of the project specifications. Signs shall comply with the general requirements specified in the "Standard Specifications for Construction of Highways, Streets and Bridges" in effect at the time of contract award.

All sign lettering shall be clear, open rounded type capital letters as approved by the National Committee on Uniform Traffic Control Devices and its sponsoring agencies, and as published by the Federal Highway Administration. Signs and lettering shall be of first class workmanship equivalent to that of the Department's standard signs.

Standard signs shall be used as required by Sheets BC(1) thru BC(7), the plans, or as directed by the Engineer to regulate, warn, and guide traffic. All sign erection and usage shall be in strict accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways." The Contractor shall maintain each sign in a clean and good condition.

Signs shall be removed upon completion of the work.

Signs may be erected on portable, temporary, or fixed supports, for use on construction projects to warn or guide the traffic through and/or around the actual construction area. However, at the end of the workday if the signs do not warn or regulate traffic relative to night time roadway conditions or whenever the specific danger of which the particular sign warns has ceased to exist, the signs shall be either removed, turned away from the view of any traffic or covered. When signs are turned away from the view of any traffic the sign shall not be ed 90° to the direction of traffic and on two-way roadways or expressways or ways with medians less than 12' (when the sign is installed in the median area) sign shall not be turned 180° to the direction of traffic. When signs are covered the erial used shall be opaque such as heavy mill black plastic. Burlap shall not be us- o cover signs.

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ns erected on portable supports for use on construction projects normally .an signs which are used during the day to warn or guide traffic through and/or around the actual construction area, but at the end of the workday such signs are either removed or turned away from the view of traffic. Portable supports shall be as shown on this sheet or as approved by the Engineer. The bottom of the sign shall be a minimum of one (1) foot above the pavement edge. Signs required for nighttime usage should not normally be mounted on portable supports, except when approved by the Engineer.

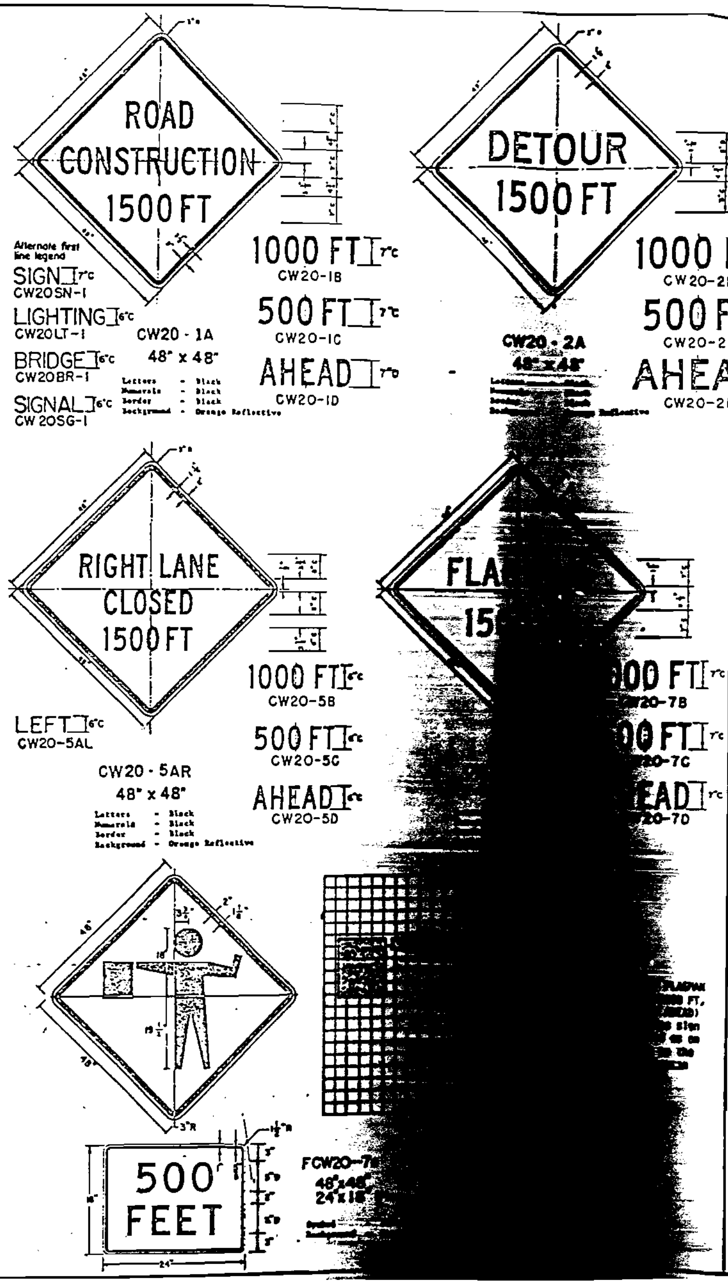
Signs erected on fixed supports for use on construction projects normally mean signs that are to remain in place for both day and night usage to regulate, warn and guide traffic in advance of and within the limits of the project including the crossroad approaches. However, under certain conditions, such as where a sign may be required for a few days duration and then is no longer needed or where a sign is moved from location to location every few days or where it is not practical or desirable to provide a fixed mounting, such signs may be erected on a temporary type of support. Temporary supports shall be as shown on this sheet or as approved by the Engineer. Signs erected on temporary supports should be at a minimum height of 3 feet. Signs erected on fixed supports should be at a minimum height of five (5) feet in rural areas and seven (7) feet in urban areas and other rural locations where sight distance obstructions are present. Regardless of the type of support used, regulatory signs should not be erected at height less than the 5 or 7 foot minimum specified above unless a lower height is approved by the Engineer. Posts for fixed supports should be set in the ground without concrete footings.

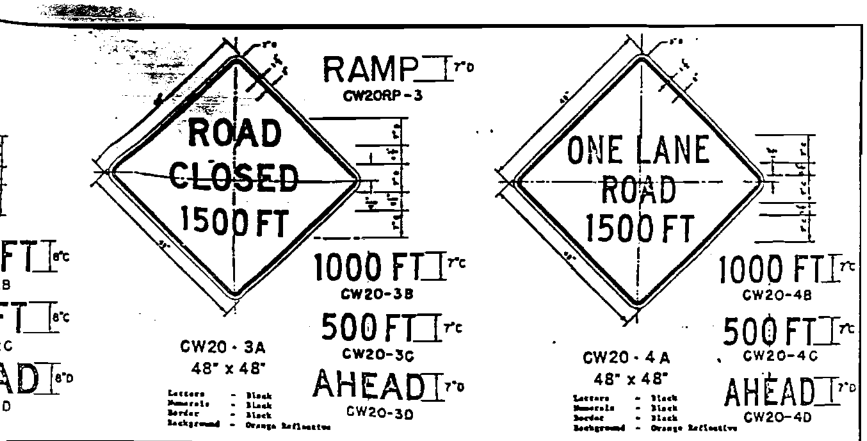
Wood sign post supports shall be painted white.

Where portable or temporary supports require the use of weights to keep a sign or barricade from turning over, the use of some type of sandbag is recommended. The use of places of concrete, rocks, iron, steel or other solid objects will not be permitted.

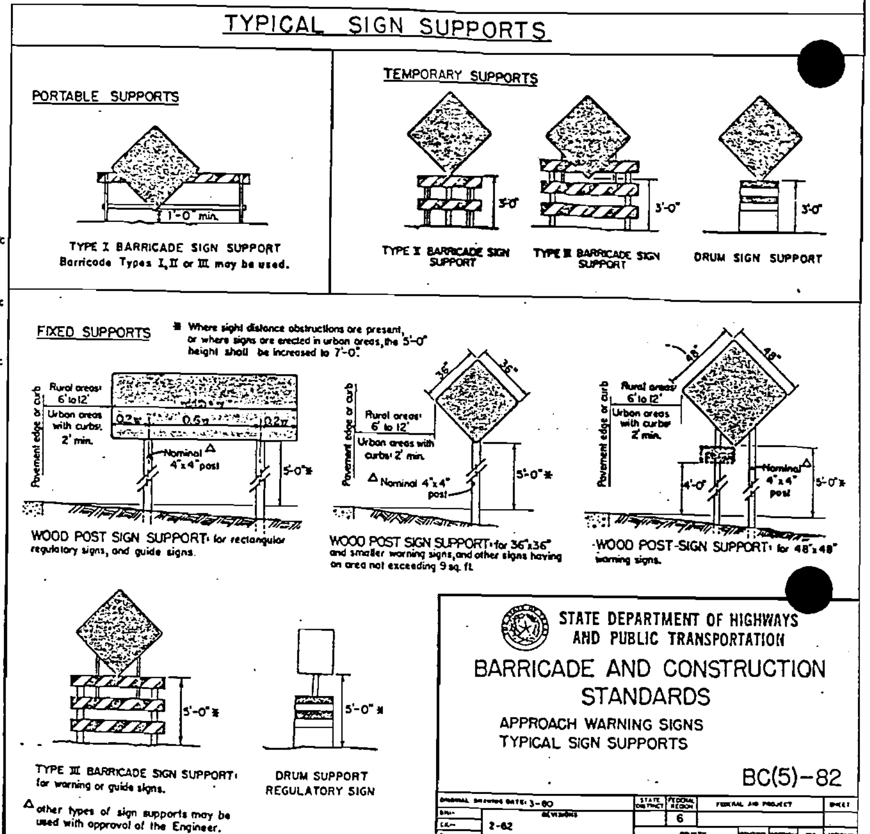
All traffic control devices shall conform with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways."

Contractors may use either the sign designs shown on sheets BC-(4), BC-(5), BC-(6) and BC-(7) or those sign designs shown in the U.S. Department of Transportation's latest edition of "Standard Highway Signs" when the required sign is illustrated in the "Standard Highway Signs" book. All construction type signs provided for in "PART VI" of the Texas MUTCD, but not detailed in the plans, may be used when so directed by the Engineer.





TYPICAL SIGN SUPPORTS

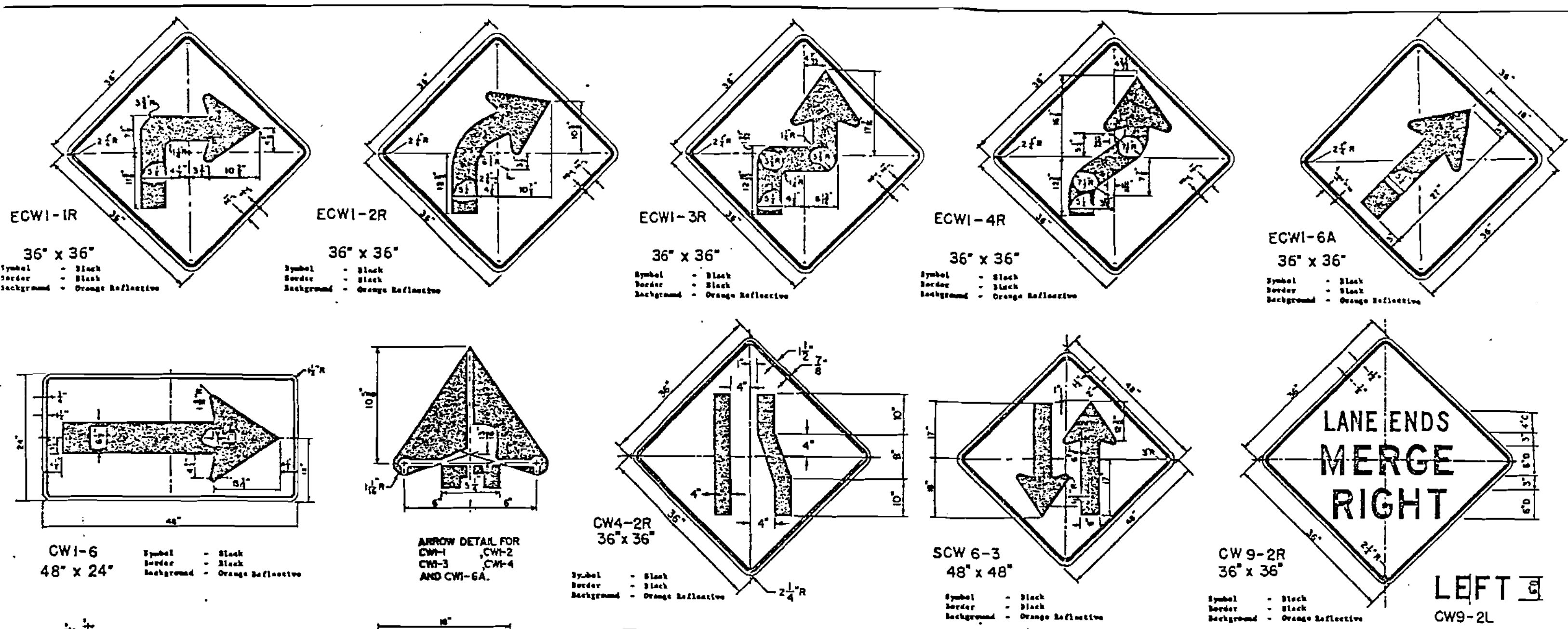


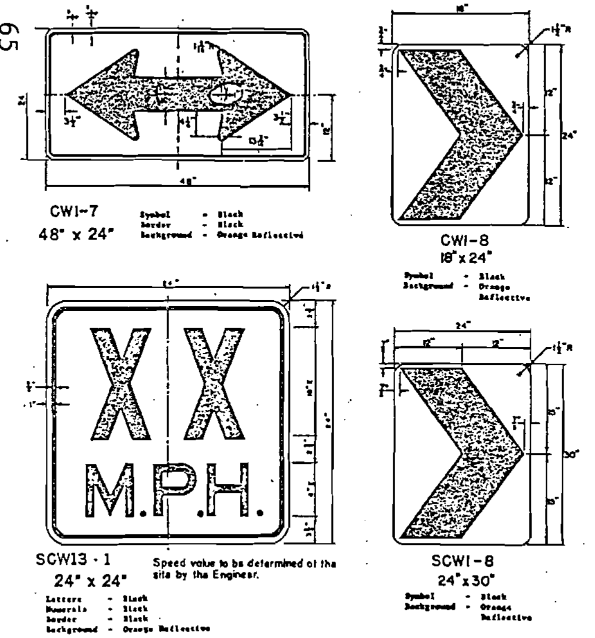
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

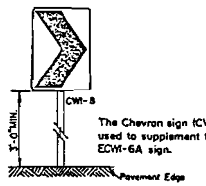
BARRICADE AND CONSTRUCTION STANDARDS

APPROACH WARNING SIGNS
TYPICAL SIGN SUPPORTS

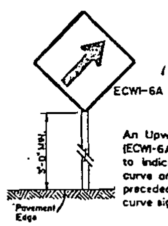
BC(5)-82



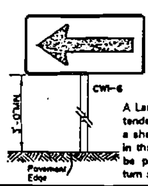




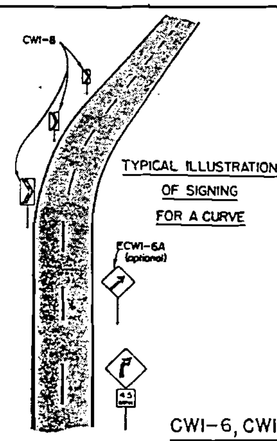
The Chevron sign (CW1-8) may be used to supplement the CW1-6 or ECW1-6A sign.



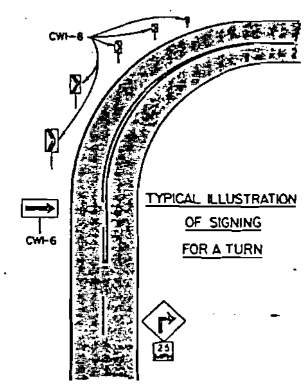
An Upward Sloping Arrow sign (ECW1-6A) is intended to be used to indicate the beginning of a curve or transition. It should be preceded with an appropriate curve sign when needed.



A Large Arrow sign (CW1-6) is intended to be used to give notice of a sharp change in alignment (turn) in the direction of travel. It should be preceded with an appropriate turn sign.



TYPICAL ILLUSTRATION OF SIGNING FOR A CURVE

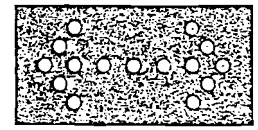


TYPICAL ILLUSTRATION OF SIGNING FOR A TURN

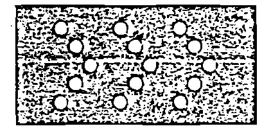
USAGE OF CW1-6, CW1-6A, AND CW1-8 SIGNS

NOTES:

- CW1-6 , ECW1-6A & CW1-8 Signs may be mounted on temporary supports.
- Chevron Alignment signs, when used, are erected on the outside of a curve, sharp turn or on the far side of an intersection, in line with and at right angles to approaching traffic. Spacing of the signs should be such that two are visible throughout the change in horizontal alignment.
- For two-way traffic, use same arrangement of signs on outside of curve for each direction of travel.
- Appropriate Advance Warning Turn or Curve sign with Advisory Speed plaque should be used when needed.



FLASHING ARROW PANEL



SEQUENCING ARROW PANEL

ADVANCE WARNING FLASHING OR SEQUENCING ARROW PANELS

The Advance Warning Flashing Arrow and Sequencing Arrow Panels are intended to supplement existing traffic control devices. They provide additional advance warning and directional information to assist in diverting and controlling traffic around construction or maintenance activities being conducted on or adjacent to the traveled way.

The Advance Warning Arrow Panel may be used for day or night closures, slow moving maintenance or construction activities on the traveled way, or extremely hazardous high density and speed conditions.

Necessary signs, barricades or other traffic control devices should be used in conjunction with the Advance Warning Arrow Panel.

Arrow panels should have the capability of the following mode selections: Left Arrow, Right Arrow, Left and Right Arrow and caution. The caution mode consists of four or more lamps, arranged in a pattern which will not indicate a direction.

Arrow panels shall be capable of minimum 50 percent dimming from rated lamp voltage. The flashing rate of the lamps shall not be less than 25 times per minute.

REQUIREMENTS

TYPE	MINIMUM SIZE	MINIMUM NUMBER OF PANEL LAMPS	MINIMUM VISIBILITY DISTANCE
B	30" x 54"	13	3/4 mile
C	48" x 96"	15	1 mile

The panels shall be mounted on a vehicle, trailer or other suitable support.

STATE DEPARTMENT OF HIGHWA. AND PUBLIC TRANSPORTATION

BARRICADE AND CONSTRUCTION STANDARDS

CONSTRUCTION WARNING SIGNS
ADVANCE WARNING ARROW PANELS

BC(6)-82

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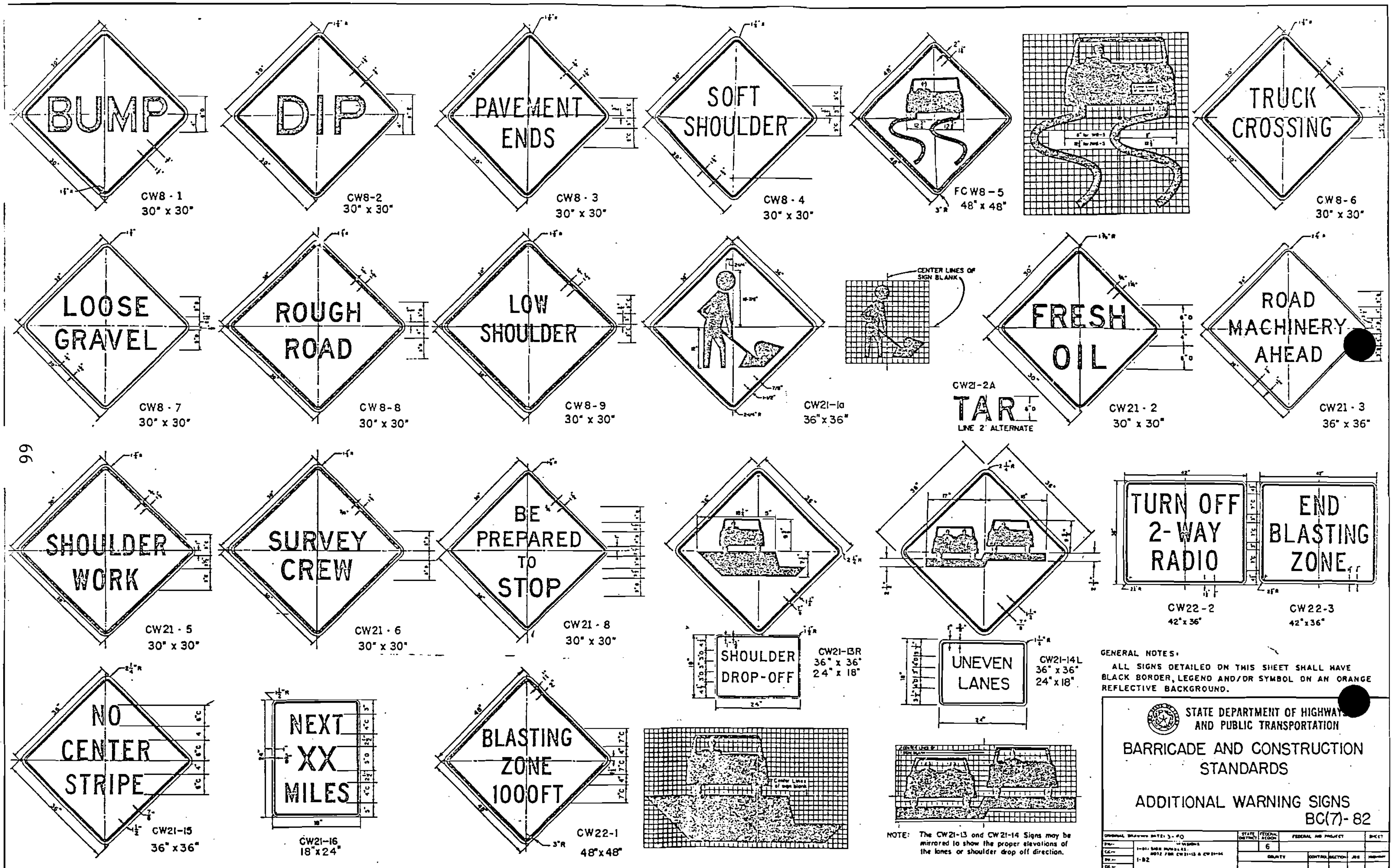

GENERAL NOTES:

ALL SIGNS DETAILED ON THIS SHEET SHALL HAVE BLACK BORDER, LEGEND AND/OR SYMBOL ON AN ORANGE REFLECTIVE BACKGROUND.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

BARRICADE AND CONSTRUCTION STANDARDS

ADDITIONAL WARNING SIGNS

BC(7)-82

APPENDIX B

Control: 68-8-34
Project: C 68-8-34
Highway: US 87
County: Howard

SPECIAL SPECIFICATION

ITEM 4685

CATHODIC BRIDGE DECK PROTECTION SYSTEM

I. JOB DESCRIPTION: Five impressed current cathodic protection systems will be installed on the U.S. 87 overpass in Big Spring, Texas in Howard County. There shall be 5 separate systems. Each system will utilize a different type of anode material. These five systems shall be further sub-divided into zones. Each zone shall be separately energized from an enclosed rectifier assembly.

A. Terms and definitions

Resident Engineer: The representative of the state who shall have the final decision in all matters concerning this job.

Contractor: The company or business that this job is awarded to.

Cathodic Protection Engineer: A professional Engineer supplied by the contractor who shall be licensed and fully accredited in the area of bridge deck cathodic protection systems. (The Cathodic Protection Engineer shall assist the Resident Engineer in all aspects of the complete cathodic protection installation).

Manufacturer: The company that manufactures the anode material used in each system.

Technical Representative: A representative chosen by each anode material manufacturer to assist in the installation of the represented material.

B. General Information

1. Material suppliers should attend the pre-letting conference at the Resident Engineer's office in Big Spring on September 16, 1987 at 10:00 a.m.

2. The contractor shall furnish, install, and put into operation five complete impressed current cathodic protection systems as described in these plans and specifications. The contractor shall have a technical representative qualified in the field of Cathodic Protection of bridge decks to supervise the installation, energizing and adjusting of the complete systems.

3. The contractor shall have a technical representative from each manufacturer of the anode materials used in traffic lanes to advise in the installation of the represented material.

4. The contractor shall coordinate installation of the cathodic protection systems with all other construction operations. Special caution and scheduling may be required to prevent damage to installed components by subsequent operations.

5. The contractor shall contact the Resident Engineer prior to installing each system.

6. The contractor shall hold a preconstruction conference with the subcontractors installing the cathodic protection systems at least seven days before the installations. The Resident Engineer, Cathodic Protection Engineer, and the cathodic protection system manufacturer's representative(s) shall be present at the conference.

7. The cathodic protection systems shall include all the materials identified in these plans and specifications. Substitutions may be made only with the written permission of the Resident Engineer.

7. The cathodic protection systems shall be of the impressed current type and shall consist of the following:

a. Direct current power supply (rectifier) with at least seventeen (17) separate voltage and current regulated outputs meeting the requirements of the plans and specifications.

b. Seventeen (17) zones of cathodic protection consisting of five different types of anode material meeting the requirements of the plans and specifications.

c. A negative ground return (cathode) wiring system connected to the reinforcing bars as described in these plans.

d. Bonding of the following to the reinforcing bars:

(1) armor joints (2) guard rail supports (3) dowel bars used to connect adjacent deck slabs (4) steel diaphrams and girder supports under or contacting a cathodically protected member (5) illumination poles, clamps, conduit, electrical enclosures, supports or metallic members in contact with a cathodically protected member.

e. Reference cells in each zone with continuous lead wires terminating at rectifier enclosure.

9. The electrical installation shall in all applicable ways conform with the National Electrical Code and all local codes.

10. The contractor shall arrange for power service and the connection to the system. The contractor shall arrange for all inspections and obtain all necessary permits.

11. The contractor shall furnish all material to the Resident Engineer for inspection and samples for testing when specified or requested. The Resident Engineer may accept material on the basis of the manufacturer's certification when testing is performed by a qualified independent laboratory. A copy of the independent laboratory report documenting the test results and testing procedures shall accompany the certification. The Engineer may accept or reject these materials on the basis of these certifications or other tests performed by or for the Department.

12. SPECIAL NOTE:

THE RESIDENT ENGINEER SHALL BE INFORMED OF ANY FUTURE SLAB WORK OR EQUIPMENT MOUNTING ON THE NEW OVERLAY SURFACE. CONCRETE CHIPPINGS, HOLE DRILLING OR CORING, DETECTOR LOOP SAWCUTTING AND OTHER SUCH OPERATIONS MUST NOT BE PERFORMED UNTIL THE ENGINEER HAS BEEN CONSULTED.

13. The Contractor shall purchase the following instruments for use by State personnel for taking measurements of the performance of the various cathodic bridge deck protection systems being installed on the bridge structures:

Portable "Three Electrode Linear Polarization Rate of Corrosion Device", complete package with single portable probe and twenty (20) permanent probes.

The device purchased shall include training for at least three personnel into the operation and use of the device and any related computer programs.

Currently the only known portable device of this type is a "3LP" unit made by Ken Clear, Inc. The permanent probes to be used with this unit are "3LP" permanent probes and must be installed according to the manufacturer's specifications. Complete package by Ken Clear, Inc. is as follows:

(1) Three Electrode Linear Polarization Device (Portable)
(2) PC-8 Pocket Computer with Printer
(3) "Corrate II" Program for use on IBM PC
(4) Single Portable Probe
(5) Permanent Probes as Required
(6) Training for Personnel

Two permanent probes shall be provided by the Contractor in each zone on the bridge deck traffic lanes. A total of twenty (20) permanent probes will be provided by the Contractor for the complete cathodic protection installation.

Two areas per zone will be provided for portable rate of corrosion measurements in zones not in the traffic lanes. These measurement areas consist of locations on the sidewalks, median and on a bent below the bridge deck.

II. Structural Integrity of Bridge

A. After scarification of the deck surface, the contractor shall verify that the concrete surface is sound. The contractor shall correct unsatisfactory conditions before continuing with the installation of the cathodic protection systems. The Resident Engineer will determine that the structure is sound and has been prepared according to specification.

B. Removal of concrete will be necessary to:

1. Expose the top and bottom (or outer and inner) rebar mats for continuity testing

2. Install reference electrodes

3. Install instrument and system negatives

4. Install rebar bonds

5. Install rebar probes

6. Install "3-LP" probes

C. The contractor shall be responsible for the physical concrete removal and bar exposure. The contractor shall ensure all exposed steel is cleaned to bare gray metal and all debris is removed from the cavities.

D. The reference electrodes, rebar probes, instrument negative and system negative installation cavity shall be located within ten (10) feet of the location marked on the drawings, or as determined by the Cathodic Protection Engineer and approved by the Resident Engineer. An existing cavity from delamination removal may be used if approved by the Cathodic Protection Engineer and Resident Engineer.

E. The contractor shall be responsible for proper repair of all concrete of the bridge structure. An anode system will not be installed until repairs have been completed on the area of installation.

III. Rebar Preparation and Connections

A. The contractor shall have the responsibility of making sure that the entire bridge structure has been made electrically continuous.

B. Following the continuity survey and before any anode materials are installed, it is the responsibility of the contractor to ensure that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

1. Rebar bond wiring is not shown in the plans. Rebar bond wiring shall be installed as directed by the Cathodic Protection Engineer and approved by the Resident Engineer.

2. REBAR BOND WIRES SHALL BE COPPER WIRE WITH WHITE INSULATION. WHITE INSULATED WIRE MAY NOT BE USED FOR ANY OTHER CONNECTIONS. (Except where local electrical codes specify otherwise.)

3. Wherever possible the bond wires shall be thermite brazed to the rebar or metallic fixtures. Where this is not possible the bond shall be established as directed by the Cathodic Protection Engineer and approved by the Resident Engineer.

4. Rebar bonds shall be made to reinforcing bars having no more than 5% section loss at the connection location.

5. Rebar bond wires do not have to be labeled except for the wires within the rectifier enclosure.

6. The length of the bond wire shall be kept to a minimum.

7. Bond wiring shall be well secured to the structure using cable ties.

8. Bond wires shall be anchored within six (6) inches of their termination (thermite braze).

9. Bond wires may not be spliced.

10. All reinforcing steel lead wire and other metal to metal permanent lead wire connections, except those in the junction boxes and rectifier enclosure shall be made using the thermite welding process in accordance with the manufacturer's instructions.

11. The discontinuous objects must be connected (bonded) to a rebar which is electrically continuous with the rest of the structure using copper wire with white insulation.

12. All mats not electrically connected shall be connected together using copper wire and thermite bonding.

13. A discontinuous rebar or metallic fixture shall be bonded to a nearby continuous rebar.

14. Bonding shall be provided for all of the following to the reinforcing bars:

a. Armor joints
b. Guard rail supports
c. Dowel bars used to connect adjacent deck slabs
d. Steel diaphrams and girder supports under the deck or other structures contacting a cathodically protected member

e. Illumination poles, clamps, conduit, electrical enclosures, supports or metallic members in contact with a cathodically protected member.

C. All wire to rebar connections shall be made using thermite brazing techniques unless otherwise directed by the Cathodic Protection Engineer and approved by the Resident Engineer.

1. Specific attention shall be directed to the processes of connecting lead wires to reinforcing steel and other metallic components.

2. Each project thermite weld shall be made to the satisfaction of the Resident Engineer and may be hammer impact tested.

3. Slag from the thermite weld operation shall be removed and the weld approved by the Resident Engineer before a coating is applied.

4. All thermite brazing connections shall be coated with a non-conductive epoxy as directed by the Cathodic Protection Engineer and approved by the Resident Engineer.

IV. Reference Cells

A. The contractor shall install reference cells in each zone. Locations for reference cells are to be determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

1. At least one reference cell shall be installed in each zone in an area of high chloride content.

2. Reference cells shall be silver-silver chloride furnished in an ion trapping, chloride rich backfill or equal approved by the Resident Engineer.

3. The reference cell assembly shall be approximately five (5) inches long and one (1) inch in diameter.

4. The reference cells shall not be placed in direct contact with reinforcing steel or other metallic embedments.

5. The reference cell lead wires shall be No. RG-58U coax-cable or approved equal. The lead wires shall be continuous from the reference cell to the rectifier enclosure.

6. An instrument negative lead wire will be attached to the reinforcing steel by a thermite weld not more than twelve (12) inches from the cell location, coated with non-conductive epoxy. No splices shall be allowed in the instrument negative lead wire.

7. Instrument negative lead wire shall be made only to reinforcing bars having no more than 5% section loss at the connection location.

8. Each reference cell lead wire and corresponding instrument negative lead wire shall be brought through a 1/2 inch diameter hole drilled in the deck. The hole shall be filled with a non- conductive epoxy approved by the Engineer.

9. The reference cells shall be positioned as determined by the Cathodic Protection Engineer and approved by the Resident Engineer. The reference cells shall be located within one (1) inch, but not in direct contact with top-mat reinforcing steel.

10. Each reference cell shall be cast in an air- entrained portland cement concrete patch with a chloride content about equal to that of the surrounding concrete and a water-cement ratio of about 0.50.

11. Rebar probes shall be installed by the contractor as necessary.

V. Wiring

A. The contractor shall be responsible for installation of all wiring concerning the five cathodic protection systems, system negatives and related instrumentation.

B. The Cathodic Protection Engineer shall consult each of the anode material manufacturers and prepare a complete wiring diagram subject to the Resident Engineer's approval. All wiring changes made during the project shall be documented and subject to the Resident Engineer's approval.

1. Wiring shall run according to plans prepared by the Cathodic Protection Engineer and approved by the Resident Engineer.

2. All wires shall be properly labeled. Labels used shall have a long life expectancy and be resistant to destruction by insects local to the region. Each label used shall not easily separate from the wire that it has been attached to.

3. Wiring shall be run in conduit or saw cuts as determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

4. Wiring run in saw cuts shall be fastened down every twenty (20) feet.

5. Wiring connected to reinforcing steel shall be securely anchored to the rebar with a cable tie within six (6) inches of the thermite braze.

6. Care shall be taken during cathodic protection system installation and concrete overlay installation to avoid damaging the wiring.

7. Any damaged wiring shall be repaired or replaced as directed by the Cathodic Protection Engineer prior to placing the concrete overlay. All repaired or replaced wiring shall be documented and approved by the Resident Engineer.

8. Wiring shall be spliced only at locations determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

9. All direct current and instrumentation conduit shall be PVC. PVC conduit size shall be 1.5 inch inside in diameter for all runs except as otherwise designated in the plans.

10. All PVC used on the project shall be Polyvinyl- chloride (PVC) conduit conforming to NEMA TC-2, Schedule 40.

11. PVC conduit expansion and contraction sections shall be placed at all appropriate locations and not to exceed 75 feet apart. These sections shall provide at least 4 inch of movement.

12. Rectifier power supply (AC) shall be run in Galvanized Rigid Steel conduit (RSC) which conforms to ANSl C 80.1 and bears the U.L. Label. RSC conduit size shall be 1 inch diameter with RSC fittings unless otherwisedetemined by the Cathodic Protection Engineer and approved by the Resident Engineer.

13. All components of conduit hangers and clamps shall be made of stainless steel or galvanized steel approved by the Engineer. Conduit clamps for PVC conduit shall permit movement of the conduit and shall be placed at 4 foot maximum spacing.

14. CARE SHALL BE TAKEN TO MAKE SURE THAT CONDUIT HANGERS AND CLAMPS DO NOT CAUSE SHORT CIRCUITS WITHIN THE CATHODIC PROTECTION ZONES.

15. All connections and splices shall be made in junction boxes approved by the Resident Engineer.

16. All wires within junction boxes shall be properly labeled.

17. Junction boxes shall be constructed of the same material as joining conduit, of sufficient size to house wiring and splices and shall be sealed against entry by nest building insects and have provisions to prevent water retention.

18. All wires within the rectifierinclosure shall be properly and thoroughly labeled.

19. All conduit shall enter the rectifier inclosure from the bottom with provisions for drainage of conduit water at a level beneath the rectifier. The drainage site shall be sealed against entry by nest building insects.

B. Size of wire to be used will be determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

C. All wiring shall conform to the following specifications for color, mimimum size and insulation type.

1. White = Cathode leads for System negative and Rebar bond wiring

a. Minimum 8 AWG stranded copper
b. Type HMWPE on the deck or within structures
c. Type XHHW or approved equal below deck to the rectifier inclosure

2. Red = Anode leads

a. Minimum 8 AWG stranded copper
b. Type HMWPE on the deck or within structures
c. Type XHHW or approved equal below deck to the rectifier inclosure

3. Brown = Reference cell rebar grounds

a. Minimum 14 AWG stranded copper
b. Type HMWPE on the deck or within structures
c. Type XHHW or approved equal below deck to the rectifier inclosure

4. Black = Reference cell lead wires and rebar probe lead wires

a. RG-58U or equivalent

5. Green = Rectifier cabinet ground

a. Minimum 4 AWG
b. Type XHHW or approved equal

D. Color code for AC line power shall be per all applicable National and local codes.

VI. Rectifier Specifications

A. The contractor shall locate the rectifier enclosure in an area accessible to maintenance personnel.

B. The rectifier enclosure shall be attached to a controller box support as shown in the plans.

C. The contractor shall take care to avoid damaging the rectifier. Any damage caused by the contractor's operations shall be repaired at the contractor's expense.

D. The contractor shall connect the rectifier as determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

1. All wiring shall be fully documented. A copy of the final wiring diagram with all corrections noted shall be stored in the rectifier enclosure for future reference by maintenance personnel.

E. The rectifier shall conform to the following specifications:

1. The rectifier shall be suitable for cathodic protection of a bridge. It shall operate from 120/240 VAC single phase 60 Hz mains and provide seventeen (17) independent and individually controlled outputs for connection to seventeen (17) independent anode zones.

2. The unit shall be designed for a 20 year minimum working life under continuous operation. The unit shall be convection cooled with no fans or moving parts and shall operate at full capacity in ambient temperatures from 0 degrees F to 110 degrees F.

3. Each zone shall be controlled independently using modular DC controllers.

A. Output DC controllers shall be of modular plug in construction for simple field replacement.

B. Each module shall be removed and replaced from the front of the rectifier enclosure.

C. Each module shall have a method of current limiting which does not require manual resetting.

D. Each module shall be independently controlled.

E. Output adjustment of one circuit must not effect the output of any other module and must be continuous over the entire rated range of output current.

F. Each module shall be capable of supplying continuous full-rated output at temperatures from 10 F to 140 F.

G. Each module shall be air cooled by natural convection.

H. Each module shall be provide with lightning protection separate from AC power lightning protection.

I. The rectifying elements shall be silicon diodes. The diodes shall be protected against high voltage surges with metal oxide varistors.

J. The peak inverse voltage rating of the SCR's shall be no less than 600 volts. Protection.

K. Following assembly of the modules, each module shall have been individually tested over the full range of its rated current to insure proper operation. The card shall then be coated with a heavy coating of Dow Corning 2577 or equivalent conformal coating.

4. An LCD meter coupled with suitable switching arrangement shall be provided to monitor DC voltage, current, structure to electrolyte and rebar to probe potentials. A power on/off switch shall be provided to remove AC power from the meter when it is not in use. Meter jacks shall be provided which enable all readings to be taken using a portable hand held meter.

5. An AC circuit breaker shall be provided. It shall be of the manually reset type.

6. THE STATE OF THE AC CIRCUIT BREAKER SHALL BE INDICATED BY A LIGHT VISIBLE FROM OUTSIDE THE INCLOSURE THAT CAN BE SEEN FROM TRAFFIC LANES ON THE BRIDGE.

7. Protection against lightning surges shall be provided to protect against 1) AC line to ground overvoltage, 2) ground to structure overvoltage, and 3) structure to anode overvoltage.

9. A service manual shall be provided with each unit which explains operation, operating principles, maintenance, installation, and schematics.

10. The rectifier shall be equipped with compression type connectors for all positive and negative output cables and be sized for up to No. 6 AWG wire.

11. Acceptable line input voltage shall be 120 VAC or 240 VAC +10% - -5%, 60 HZ, single phase.

12. The instrument panel shall be clearly labeled as to the functions it performs.

13. All switches and instruments shall be clearly labeled as to their functions.

14. A light shall be provided which is easily visible from the traffic lanes. This light shall indicate the status of the AC circuit breaker within the rectifier assembly. The light shall be armor encased for protection from vandalism.

F. Rectifier Enclosure

1. The enclosure shall meet all the requirements of NEMA STANDARD MR-20-1958, "CATHODIC PROTECTION RECTIFIER UNITS".

2. The enclosure shall be NEMA 4 water tight and dust tight with conduit access in the bottom to accommodate AC and DC wiring.

3. The enclosure shall have a front opening door.

4. Provisions for padlocking shall be provided.

5. The rectifier cabinet shall be constructed of one of the following materials or equal approved by the Resident Engineer:

A. One-eighth inch aluminum sheet (5052-H32) and one-quarter inch aluminum back panel or

b. Minimum 11 gauge galvanized steel and coated with white baked on enamel.

6. A grounding lug for connecting No. 4 AWG wire to earth ground shall be provided on the enclosure exterior.

7. All components shall be mounted on the back panel easily removable through the front opening door.

8. Mounting bolt holes shall allow for 3/8" diameter bolts.

9. A hinged door with over-center latches and locking hasp shall be provided. A neoprene gasket 1/5" thick and 1" wide shall seal the door opening against moisture and dust. When closed, the door shall form a dust tight, water tight closure and shall be equipped with lift off type hinges providing easy removal of the door for access to internal components.

10. Each rectifer shall have provisions for permanent storage of the manual, schematic, and system wiring diagram in the door of the rectifier.

11. The cabinet and door shall be essentially "square and true" such the the door does not sage when opened and does not require force when opening or closing.

12. The cabinet shall be equipped with panel support a brackets with hinges and panel stops which are of sufficient strength to support the instrument panel in both the closed and open positions.

13. All welds and sharp edges shall be completely deburred and rounded.

G. Transformers

1. Power transformers shall provided rated output over the full range of input voltages, be of E-I laminated construction to provide isolated secondary voltages appropiate for circuit operation, and have independent primary and secondary windings. Adjustment of output by tap bars is not acceptable. Varnish impregnation and Farraday shield between primary and secondary must be provided. Transformer efficiency shall be at least 95% and the regulation shall not exceed 3% when measured from 1/4 to full load.

2. Control transformers for module power shall be of E-I lamination construction and shall have primary power supplied from the power transfomer secondary for line surge isolation.

H. Filter Chokes

1. Filter chokes of E-I lamination or other suitable core construction shall be used in each rectifier output circuit to:

a) Improve efficiency

b) Provide some surge protection from transients externally generated

c) Provide full outtput current capability at low output voltage

d) To reduce R.F.I. In the load circuit.

I. Circuit Breaker

1. A two (2) pole fully magnetic circuit breaker shall be provided as an input power switch and for protection to the line against rectifier fault.

2. The breaker shall be rated for 240 volt AC.

3. The breaker must hold 101% rated current and must trip at 125% of rated current.

J. Meter

1. Metering shall be provided for monitoring the operating current, operation voltage, and reference electrode potentials.

2. A 3 1/2 digit L.C.D. (Liquid crystal display) meter with 200 MV 2000 count sensitivity shall be provided to take readings.

2. The meter shall have input impedance sufficiently high to cause no appreciable (1 micro amp max) loading of circuits connected to it such as sensitive half cell.

3. Appropiate scaling and switching circuits shall be provided to give direct meter displays in amperes and volts.

4. Structure potentials shall be displayed in volts up to 1.999 either positive or negative with respect to the half cell.

5. The meter shall have the capability of being removed from the circuit when readings are not being taken.

6. The meter shall have the capability of monitoring reference electrodes when the rectifier is shut off.

K. Wiring inside the enclosure

1. Wiring shall be sized for a minimum of 500 CM/ampere for power circuits and No. 28 AWG minimum for signal circuits.

2. Power wires shall have 600 volt insulation and be stranded copper wire such as MTW or similar.

3. Wires shall be neatly bundled, tied and clamped as necessary to provide a clean neat appearance.

4. Signal wires shall be stranded copper and routed separately from power leads wherever possible.

5. All wiring shall be of sufficient length to avoid tension at terminal connections.

6. All connections either electrical or mechanical shall be tightly secured with lock washers.

7. Any electrical connection through the instrument panel shall not rely on pressure to the panel to maintain good connection.

L. Cable Entry

1. All wiring shall enter through the bottom of the cabinet.

2. AC INPUT AND DC OUTPUT BE KEPT SEPARATE.

3. Reference cell leads shall be kept separate from all other anode and cathode wiring.

M. Complete Rectifier Dielectric Test

The insulation and spacings of a rectifier unit shall be capable of with-standing without breakdowm, for a period of one minute, the application of a 60 cycle alternating-current rms voltage of 1000 volts plus twice the rated primary voltage between current-carrying parts of the primary circuit and (1) non-conductive-carrying metal parts which may be grounded and (2) current- carrying metal parts of an insulated secondary circuit. When operating below 60 volts, an insulated secondary circuit shall be capable of withstanding an alternating-current rms test voltage of 600 volts to any non-current-carrying metal parts which may be grounded; when operating within the range of 60 to 90 volts, the alternating-current rms test voltage shall be 900 volts.

If the rectifier unit includes devices which normally fall within the scope of other recognized standards requiring dielectric test voltages lower than the foregoing, such devices shall be disconnected before the remainder of the equipment is subjected to the test. The disconnected devices shall be tested separately for dielectric strength in accordance with the applicable standards.

N. Circuit Operation Test

Each circuit shall be tested to insure that all of its components are properly interconnected and function normally at 5% low and 10% high AC input line voltage. The unit shall then be tested with all circuits energized and operating at rated output current to insure normal operation at 5% low and 10% high input line voltages. If the rectifier is designed for more than one input line voltage, the test shall be run at each.

With all circuits energized, an adjustment of one or more of the circuits' output current shall not effect any of the other circuits' output amps. Any circuit must be able to be adjusted over its full range without changing the output of any other circuit.

O. Current Regulation

The current regulation of each circuit shall be checked and shall not exceed +- 1 when the load resistance is varied between 0 and rated load resistance. The current regulation of the entire unit with all circuits energized shall not exceed +- 1% when the total load resistance is varied between 0 and total rated load resistance.

VII. Post Installation Tests.

The contractor shall be responsible for performing the following tests as detailed in this specification and will be required to document results, procedures and train at at least three State employees to conduct subsequent required tests as directed by the Resident Engineer.

A. E log I tests shall be performed prior to system energizing at each of the reference locations in each zone. The data shall be plotted and explanations of the data shall be provided to State personnel. The system will be adjusted based on this data.

B. Two sets of polarization tests ,shall be performed by the contractor and adjustments made if the system is not within a minimum of 100 millivolts to a maximum of 150 millivolts range.

1. The first set of tests shall be performed after 45 days of continuous system operations. Adjustments to the system shall be made as necessary by the contractor and explanation of the adjustments shall accompany the data.

2. The second set of tests shall be performed after 90 days of continuous system operations. Adjustments to the system shall be made as necessary by the contractor and explanation of the adjustments shall accompany the data.

C. Rate of corrosion tests shall be performed by the contractor prior to system energizing and upon each depolarization test. The rate of corrosion test shall be performed for each of the two areas per zone. The data from these tests shall be documented and analyzed using the Corrate II computer program.

VIII. System "A"

A. This system shall utilize an anode of expanded titanium metal mesh anode as manufactured by Eltech or equivalent. The installation will be on the bridge deck main lanes between Station 8+18.49 and Station 10+24.62.

B. Zones

There shall be four separately energized zones in this system. The areas of coverage for these zones shall be determined by the anode manufacturer's representative and approved by the Resident Engineer.

C. General Information

1. Traffic on the Deck

After installation of the anode strands, traffic on the deck shall be limited to vehicles required for delivery and installation of the overlay. Recesses or grade changes of greater depth that one (1) inch must be temporarily bridged for vehicles with gross vehicle weight greater than two (2) tons.

2. Gasoline and Oil on the Deck

When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing of the equipment shall be performed off any deck covered with exposed anode materials.

3. Installation

a. Anode material installation shall not begin until all concrete surface preparation is complete and installation of all the cathodic protection instruments is complete.

b. The Resident Engineer shall determine that the concrete surface is sound and has been prepared according to specification. The contractor responsible for concrete work shall correct unsatisfactory conditions before installation of the anode material.

C. Prior to installing the anode material, the contractor shall verify that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

d. Where concrete cover over the steel reinforcement is one-quarter (1/4) inch or less, one of the following procedures must be followed:
(1) Epoxy coat the exposed rebar surface.
(2) Add one-quarter (1/4) inch maximum layer of cementitious material.
(3) Insert insulating spacers.
(4) Route the anode material to avoid the area with shallow cover.

The appropriate procedure shall be specified by the Cathodic Protection Engineer and approved by the Resident Engineer. The Cathodic Protection Engineer shall ensure that the minimum anode to cathode separation is one-quarter (1/4) inch.

e. Anodes shall be fastened to the deck with insulating fasteners supplied with the anode material and approved by the Resident Engineer, to not more than one-half (1/2) inch (may be more or less depending on the thickness of the overlay) from the surface of the deck. At least one fastener shall be used for every five (5) square feet of deck surface.

f. As directed by the Resident Engineer, fasteners may need to be attached to the concrete to ensure the anode mesh lies flat during concrete overlay placement.

g. The contractor shall take care to prevent damage to the anode mesh during anode installation and concrete overlay placement. Damaged anode mesh shall be repaired or replaced as directed by the Resident Engineer.

h. Anode fasteners and installation aids shall be supplied by the anode material manufacturer.

i. Anodes shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of the deck. Layout of anodes and anode zones shall be determined by the anode manufacturer's representative after scarification of the bridge deck and approved by the Resident Engineer.

j. Current shall be distributed to the anodes via titanium current distributor bars or equal approved by the Resident Engineer.

k. Current distributors shall be attached to the anode mesh by resistance welded metallurgical bonds. There shall be at least one weld for every three linear inches of distributor bar.

l. Current distributors shall be at locations determined by the anode manufacturer's representative and approved by the Resident Engineer.

M. Current distributors shall be bent to extend through a one inch diameter hole to junction boxes located beneath the deck as shown by the plans. Current distributors shall be covered within this hole by an insulating heat-shrinkable sleeve approved by the Resident Engineer. Holes shall then be filled with a non-conductive epoxy approved by the Resident Engineer.

n. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Anode lead wires shall be attached to current distributors external to the concrete using spade lug connectors, and connections shall be coated with an epoxy approved by the Resident Engineer. Wires shall be tagged to indicate their position. No splices shall be allowed.

IX. <u>System "B"</u>

A. This system shall utilize Ferex 100 anode strand as manufactured by Raychem Corporation or equivalent. The installation will be on the bridge deck main lanes between Station 10+24.62 and Station 12+30.74.

B. Zones

There shall be four separately energized zones in this system. The areas of coverage for these zones shall be determined by the anode manufacturer's representative and approved by the Resident Engineer.

C. General Information

1. Traffic on the Deck

After installation of the anode strands, traffic on the deck shall be limited to vehicles required for delivery and installation of the overlay. Recesses or grade changes of greater depth that one (1) inch must be temporarily bridged for vehicles with gross vehicle weight greater than two (2) tons.

2. Gasoline and Oil on the Deck:

When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing of the equipment shall be performed off any deck covered with exposed anode materials.

3. Installation

a. Anode strand installation shall not begin until all concrete surface preparation is complete and installation of all the cathodic protection instruments is complete.

b. The Resident Engineer shall determine that the concrete surface is sound and has been prepared according to specification. The contractor responsible for concrete work shall correct unsatisfactory conditions before installation of the anode material.

C. Prior to installing the anode strand, the contractor shall verify that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

d. Where concrete cover over the steel reinforcement is one-quarter (1/4) inch or less, one of the following procedures must be followed:

(1) Epoxy coat the exposed rebar surface.
(2) Add one-quarter (1/4) inch maximum layer of cementitious material.
(3) Insert plastic cleats or rebar clips as spacers.
(4) Route the anode material to avoid the area with shallow cover.

The appropriate procedure shall be specified by the Cathodic Protection Engineer and approved by the Resident Engineer. The Cathodic Protection Engineer shall ensure that the minimum anode to cathode separation is one-quarter (1/4) inch.

e. The contractor shall fasten each anode strand end loop to the concrete. The anode strand shall be fastened to the concrete a minimum of every five (5) feet at cleat locations between end loops.

f. As directed by the Resident Engineer, additional cleats may need to be fastened to the concrete to ensure the anode strand lies flat during concrete overlay placement.

g. The contractor shall take care to prevent damage to the anode strands during anode installation and concrete overlay placement. Anode strands shall not be bent through a radius smaller than two (2) inches. Damaged anode strands shall be repaired or replaced directed by the Resident Engineer.

h. Anode splicing shall be done in accordance with the anode manufacturer's representative and shall be subject to the Resident Engineer's approval. Anode splicing material shall be supplied by the anode manufacturer.

i. Anode to anode or anode to insulated wire splices shall be covered with a heavy wall heat shrinkable tubing internally coated with a specialized meltable sealant as supplied by the manufacturer. Substitutions shall be made only with the anode manufacturer representative's recommendation and the Resident Engineer's approval. Only the appropriate heat shrinkable splice seal shall be used.

j. Anode strand fasteners and installation aids shall be supplied by the anode material manufacturer.

k. Anodes shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of the deck. Layout of anodes and anode zones shall be determined by the anode manufacturer's representative after scarification of the bridge deck and approved by the Resident Engineer.

L. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Anode lead wires shall be attached to current distributors external to the concrete using connectors supplied by the anode manufacturer and approved by the Engineer. Connections shall have non- conductive coatings approved by the Engineer. Wires shall be tagged to indicate their position. No splices shall be allowed in the anode lead wires.

X. Bu System "C"

A. This system shall utilize an anode of platinized primary wire, carbon filament secondary strands and anodecrete backfill. The installation will be on the bridge deck main lanes between Station 12+30.74 and Station 13+99.49.

B. Zones

There shall be two separately energized zones in this system. The areas of coverage for these zones shall be determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

C. General Information

1. Traffic on the Deck

After installation of the platinized wire and anode strands, traffic on the deck shall be limited to vehicles required for delivery and installation of the overlay. Recesses or grade changes of greater depth that one (1) inch must be temporarily bridged for vehicles with gross vehicle weight greater than two (2) tons.

2. Gasoline and Oil on the Deck:

When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing of the equipment shall be performed off any deck covered with exposed anode materials.

4. Anode Materials and Backfill

a. Compostion of Primary Anode Wire

Each primary anode wire shall be a continuous length of 0.062 inch diameter platinized niobium copper core wire. The wire shall have a minimum coating of 25 micro-inches of platinum. At least 35% of the wire cross sectional area shall be niobium (outside the copper core). Electrical resistance of the wire shall not exceed 4.0 milliohms per foot.

B. Composition Secondary Anode Strands

Secondary anode strand shall be a 20,000 filament high purity carbon strand (99% minimum carbon) with a tensile strength of at least 250,000 P.S.I., a cross sectional area of 240 x 10 exp -5 inches squared, a resistivity of .00075 ohm-cm and a maximum electrical linear resistance of 2.0 ohms per foot. The strand shall be wrapped with Dacron or equivalent thread, to prevent fraying during handling.

C. Anode Backfill

(1) The anode backfill material shall be extremely resistant to degradation by acid, chlorine, freezing, thawing, and thermal cycling while bonded to concrete, and shall have the following properties:

(A) compressive strength, more than 4,000 psi (4 hrs. @ 70 F)

(b) electrical resistivity, less than 10 ohm-cm

(c) water absorption (24 hrs.), less than 0.5%

(2) Composition

The composition of the anode backfill shall be as follows unless otherwise approved by the Engineer.

% by wt.	
35.	Resin - Vinyl Ester Resin D-1115 Hetron as manufactured by Ashland Chemical Co., Columbus, Ohio.
0.35	Silane Coupling Agent - A-174
0.35	Wetting Agent - S-440
0.35	Cobalt Naphthemate (Con)
0.70	Titanium Dioxide (TiO2) RHD 6x
65.	Coke Breeze DW1
0.70	Methyl Ethyl Ketone Peroxide (MEXP)

4. Installation of the Anodes

a. The deck surface shall be cleaned immediately prior to placing the anodes. The deck surface shall be free of moisture, dirt, grease, oil, asphalt, or other foreign matter when laying out anode materials. Anodes shall be held in place by a method approved by the Resident Engineer until placement of the anodecrete backfill.

B. All exposed reinforcing bars and other metallic material shall be covered with a non-conductive epoxy, approved by the Engineer.

c. Testing to prevent shorts in the anode system shall be conducted by the contractor to insure that no reinforcing steel or other material continuous with the reinforcing steel is within 1/2 inch of the primary or secondary anode materials. Areas found to be in such condition shall be covered with non- conductive expoxy prior to placing the anode system.

d. Primary anodes, secondary anodes and anodecrete shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of the deck. Layout of anodes and anode zones shall be determined by the Cathodic Protection Engineer after scarification of the bridge deck. Layouts shall be approved by the Resident Engineer.

e. The primary anode wire shall not be kinked or scored. Damage to the anode wire shall be grounds for rejection.

f. Current shall be distributed to the anodes via platinized wire approved by the Resident Engineer. The current distributors shall be laid perpendicular to the carbon strands. At the end opposite the current distributor for the carbon strands, another platinized wire shall be placed. The platinized wire shall be attached at each end of the carbon filaments.

g. Current distributors shall be at locations determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

h. Current distributors shall be bent to extend through a 1 inch diameter hole to junction boxes located beneath the deck as shown by the plans. Current distributors shall be covered within this hole by an insulating heat-shrinkable sleeve approved by the Resident Engineer. Holes shall then be filled with a non-conductive epoxy approved by the Resident Engineer.

i. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Anode lead wires shall be attached to current distributors external to the concrete using methods specified by the Cathodic Protection Engineer and approved by the Resident Engineer. Connections shall have non-conductive coatings approved by the Resident Engineer. Wires shall be tagged to indicate their position. No splices shall be allowed in the anode lead wires nor in the primary anodes.

5. Installation of the Backfill Material

a. The anodecrete backfill shall be packaged in kits sized for the project.

B. The quantity of backfill material mixed at any time shall not be in excess of the amount that can be used within 30 minutes.

c. The backfill material shall be installed only when the deck temperature is expected to be about 40 degrees fahreheit for at least four (4) hours following the installation.

d. The manufacturer's instructions, including likely safety and handling measures, must be followed explicitly.

e. The deck surface shall be free of moisture, dirt, grease, oil, asphalt, or other foreign matter when covering the anodes with anodecrete backfill.

f. The anodecrete backfill shall be mounded over the primary and secondary anodes immediately after the anodes have been placed and any drill holes are completely sealed.

g. The backfill material must not come in contact with the reinforcing rods or any other metallic object of the bridge.

h. The anodecrete backfill mounded over the anodes shall be approximately one (1) inch wide and three-eights (3/8) inch high.

i. The mounded anodecrete backfill shall have dry, fine silica sand broadcast to excess over them within 15 minutes of pouring. The excess sand shall be broomed from the surface after the material has set.

6. Laboratory Tests

a. Prior to contract approval the contractor must submit independent laboratory tests certifying that the material proposed for use on this project meets the requirements as specified.

b. A sample shall be obtained from every fourth batch of material produced in the field. The sample shall be evaluated by an independent engineering laboratory to assure compliance with the resistivity and water absorption requirements. The test results shall be submitted to the Resident Engineer for approval.

c. The independent laboratory shall not be owned or connected in any way with the contractor, material supplier or Cathodic Protection Engineer.

XI. System "D"

A. This system shall utilize an anode of hot sprayed zinc, 20 mils plus or minus 3 mils thick. The installation will be on the bridge sidewalks and median between Station 8+18.49 and Station 12+30.74.

B. Zones

There shall be six separately energized zones in this system. The areas of coverage for these zones shall be determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

C. General Information

1. Gasoline and Oil on the Sidewalks and/or Median

2. When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing equipment shall be performed away from the area of coverage by the anode material.

3. Installation

a. Anode material installation shall not begin until all concrete surface preparation is complete and installation of all the cathodic protection instruments is complete.

b. The Resident Engineer shall determine that the concrete surface is sound and has been prepared according to specification. The contractor responsible for concrete work shall correct unsatisfactory conditions before installation of the anode material.

c. Prior to installing the anode material, the contractor shall verify that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

d. Where concrete cover over the steel reinforcement is one-quarter (1/4) inch or less, one of the following procedures must be followed:

(1) Epoxy coat the exposed rebar surface.
(2) Add one-quarter (1/4) inch maximum layer of cementitious material.
(3) Use approved masking to avoid the area with shallow cover.

The appropriate procedure shall be specified by the Cathodic Protection Engineer and approved by the Resident Engineer.

e. The contractor shall take care to prevent damage to the anode material during the installation. Damaged anode areas shall be repaired or resprayed as directed by the Resident Engineer.

f. Areas not to be sprayed shall be masked off with an appropriate masking material. Anode material application shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of application area. Layout of masking for anode zones shall be determined by the Cathodic Protection Engineer after any repairs have been made. Layout approval by the Resident Engineer must be obtained.

G. Current distributors shall as determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

h. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Wires shall be tagged to indicate their position. No splices shall be allowed in the anode distributor lead wires.

i. The Cathodic Protection Engineer shall be responsible for determining what type of coating (if any) is required to alleviate any hazards to pedestrian traffic as a result of the installation of the cathodic protection material.

j. The contractor is required to take all necessary precautions to protect contractor personnel and pedestrians.

XII. System "E"

A. This system shall utilize an anode of Porter DAC-85 Conductive coating or equivalent. The installation will be on bent 4 located at Station 12+30.74 of the bridge.

B. Zones

There shall be one zone in this system. The areas of coverage for this zones shall be all surfaces of the bent.

C. General Information

1. Gasoline and Oil on the Bent

2. When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing of the equipment shall be performed away from the area of coverage by the anode material.

3. Installation

a. Anode material installation shall not begin until all concrete surface preparation is complete and installation of all the cathodic protection instruments is complete.

b. The Resident Engineer shall determine that the concrete surface is sound and has been prepared according to specification. The contractor responsible for concrete work shall correct unsatisfactory conditions before installation of the anode material.

c. Prior to installing the anode material, the contractor shall verify that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

d. Where concrete cover over the steel reinforcement is one-quarter (1/4) inch or less, one of the following procedures must be followed:

(1) Epoxy coat the exposed rebar surface.
(2) Add one-quarter (1/4) inch maximum layer of cementitious material.
(3) Use approved masking to avoid the area with shallow cover.

The appropriate procedure shall be specified by the Cathodic Protection Engineer and approved by the Resident Engineer.

E. The contractor shall take care to prevent damage to the anode material during the installation. Damaged anode areas shall be repaired or re-applied as directed by the Resident Engineer.

F. Areas not to be coated shall be masked off with an appropriate masking material. Anode material application shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of the bent. Layout of masking for anode zones shall be determined by the Cathodic Protection Engineer after any repairs have been made. Approval of layouts by the Resident Engineer must be obtained.

G. Current distributors shall as determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

H. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Wires shall be tagged to indicate their position. No splices shall be allowed in the anode distributor lead wires.

I. The Cathodic Protection Engineer shall be responsible for determining what type of coating (if any) may be required to alleviate possible shorting of the system due to small debris falling onto the bent. (Note: The current configuration of the finger joint immediately above the bent allowed a significant amount of trash to collect on the top surface of the bent - ie. Cans, bottle tops

4. The conductive coating system shall employ platinum wire primary anodes layed on the surface and covered with fiberglass screen adhesive tape.

5. The conductive coating shall be graphite/acrylic consisting of 42% solids.

6. The conductive coating shall have a resistivity of 1 ohm-cm. or less after curing.

7. The applied dry film thickness shall not be less than 16 mils.

XIII. <u>MEASUREMENT</u>. The complete Cathodic Protection System as indicated on the plans and as described herein when completely installed will be measured by the complete Cathodic Protection System.

XIV. <u>PAYMENT</u>. Payment shall be made at the contract lump sum bid for "Cathodic Protection System", which price shall be full compensation for all tools, labor, equipment, and incidentals necessary to complete the work.

APPENDIX C

HOWARD COUNTY
U.S. 87
RAILROAD OVERPASS BRIDGE
BIG SPRING, TEXAS

FINAL REPORT OF THE CATHODIC PROTECTION SYSTEMS

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April, 1989

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SUMMARY

A cathodic protection system for corrosion mitigation of the reinforcing steel was installed on US 87 railroad overpass bridge in Big Spring, Texas. Five anode materials were used as a research effort to study their performance under similar operating condition. The five anode materials are as follows:

1. Elgard 150 mesh (Bridge deck - Zones A1-A4; Rectifier circuits 1-4)
2. Raychem Ferex 100 (Bridge deck - Zones B1-B4; Rectifier circuits 5-8)
3. Rescon conductive polymer concrete (Bridge deck - Zones C1-C2; Rectifier circuits 9-10)
4. Sprayed zinc (Sidewalks and median - Zones D1-D6; Rectifier circuits 11-16)
5. Porter DAC-85 (Pier cap - Zone E; Rectifier circuit 17)

Upon completion of the installations, Corrpro Companies, Inc. conducted post-installation testing and energizing of the systems. Evaluation of each system performance in mitigating corrosion was then conducted 45 days and 90 days after initial energization. The results are as follows:

<u>Post-installation</u>

All system components were checked and tested for proper installation and operation.

Embedded silver/silver chloride reference cell potential and macro-cell rebar probe current baseline measurements were obtained for each system.

Corrosion rate measurements were taken in accordance with the manufacturers instructions, K.C. Clear Inc. These measurements will serve as baseline data for future analysis.

E Log I testing conducted for all zones provided the suggested protection current for each zone.

Each system was energized under the constant current control of the rectifier.

Rectifier meter malfunctions and rebar probe measuring circuit corrections were determined and corrected by manufacturer.

Electrical contact between the zinc anode and the rebar was detected in zones D1, D2, D3 and D6. These contact points were found and eliminated.

Electrical isolation of the zinc anode was found in zone D3. Anode continuity was re-established.

- 45 Day Evaluation

All system components were re-checked for proper operation.

Depolarization testing conducted after 45 days of continuous system operation confirmed that the reinforcing steel is being cathodically protected by meeting or exceeding the 100 millivolt polarization decay criterion.

Higher than needed potential shifts were calculated for all zones except zones A1, A4 and C2 (rectifier circuits 1, 4 and 10). The current settings were reduced for these zones.

Corrosion rate measurements suggest that the reinforcing steel showed no further corrosion.

Disbonded areas of the Sika Top 122 overlay for the zinc anode on the median and the sidewalk were detected.

The repair technique used to re-establish electrical continuity of the zinc anode on zone D3 was still operational.

- 90 Day Evaluation

    All system components were re-checked for proper operation.

    Depolarization testing conducted after 90 days of continuous system operation confirmed that the reinforcing steel is being cathodically protected by meeting or exceeding the 100 millivolt polarization decay criterion.

    The reduction in current output adopted for some zones during the 45 day evaluation period were effective in reducing the high polarization shift.

    Again, corrosion rate measurements showed no increase in rebar corrosion rate.

    Disbondments of the Sika top 122 overlay from the zinc anode on the median and sidewalk increased from the previous evaluation.

    Erratic behavior of the zinc anode was found in several areas of the sidewalks, especially in zones D1 and D3. This behavior was determined to be erratic electrical isolation of the zinc anodes were concrete cracks beneath the zinc reflected through the zinc. Long term cathodic protection for the entire area of the sidewalk and median is therefore considered questionable and future maintenance of this system is expected.

The rectifier operating data should be recorded monthly. Should any discrepancies be noted, a qualified corrosion engineer should be contacted in order to insure continuous protection of the reinforcing steel structure. It is also recommended to conduct a detailed evaluation of the systems on a yearly basis to insure optimum system performance and corrosion control of the reinforcing steel.

REPORT

I. INTRODUCTION

After the cathodic protection system installations were completed, the post-installation and activation testing was performed by Corrpro Companies, Inc. The testing included the following.

1. Inspection of the cathodic protection system components to meet specification requirements.

2. Electrical resistance measurements between the various components of the cathodic protection system.

3. Embedded reference cell potential and macro-cell rebar probe current baseline measurements.

4. Rate of corrosion measurements using both embedded and portable corrosion rate probes.

5. E Log I testing.

6. System adjustment and initial activation.

The cathodic protection systems were adjusted and energized for continuous operation based on the evaluation of the data collected during the post-installation testing and performance criteria set forth in the project specifications. All data collected during the testing are included in this report.

At approximately 45 days and 90 days after initial energization, evaluation testing of each systems performance was conducted. The testing included the following:

1. Inspection of the cathodic protection systems.

2. Depolarization testing.

3. Macro-cell rebar probes current measurements.

4. Rate of corrosion measurements.

5. Electrical resistance measurements.

6. System adjustments.

The cathodic protection systems were then re-energized based on data analysis of the data collected. All data collected during the 45 and 90 day evaluation periods are included in this report.

II. CATHODIC PROTECTION SYSTEMS DESCRIPTION

Five cathodic protection systems for corrosion mitigation of the reinforcing steel were installed on the U.S. 87, Howard County, railroad overpass bridge in Big Spring, Texas. The bridge structure was divided into seventeen zones using five anode materials as follows:

1. Elgard 150 mixed metal oxide mesh anode (Zones A1-A4, deck slab; rectifier circuits 1-4)
2. Raychem Ferex 100 flexible conductive polymer anode (Zones B1-B4, deck slab; rectifier circuits 5-8)
3. Rescon rigid conductive polymer anode (Zones C1-C2, deck slab; rectifier circuits 9 and 10)
4. Metallized spray zinc anode (Zones D1-D6, sidewalks and median; rectifier circuits 11-16)
5. Porter DAC-85 conductive paint anode (Zone E, pier cap; rectifier circuit 17)

The different anode materials were employed as a research effort to study their performance under the same operational conditions. The protective current is supplied using a rectifier manufactured by Goodall Electric Inc.

The performance of each cathodic protection system is monitored using embedded and fixed location portable monitors. One silver/silver chloride reference cell and one macro-cell rebar probe is embedded in every zone. In addition, two corrosion rate probes are embedded in every zone (except for zones D1 through D6 and zone E where portable corrosion rate probes are used) and periodically tested according to the manufacturer's test procedures to monitor corrosion control effectiveness by cathodic protection.

III. TEST PROCEDURES

The following test procedures were used during the post-installation and activation testing:

1. Inspection of the Cathodic Protection Systems - All system wiring was tested for proper installation. The rectifier was also inspected to insure proper operation.

2. Electrical Resistance Measurements - Electrical resistance measurements were taken between the various components of the cathodic protection system at the rectifier. The measurements were obtained using a Nilsson Model 400 AC resistance meter.

3. Reference Cell Potential and Rebar Probe Current Measurements - The static potential of all reference electrodes and the corrosion current of all macro-cell rebar probes were measured using a Miller model LC-4 voltmeter.

4. Rate of Corrosion Measurements - Corrosion rate measurements were conducted using the K.C. Clear Inc. 3LP corrosion rate instrument and probes. The measurements were taken according to the manufacturer's instructions and recommendations.

5. E Log I Testing - E Log I testing was performed for each zone using its embedded silver/silver chloride reference cell and a portable test rectifier capable of reading "IR-drop free" potentials. The protective currents were increased at approximately two minute intervals. Instant-off reference cell potential, current and voltage

between the anode and the reinforcing steel were recorded at each current increment. Analysis was done by computer.

The following test procedures were used 45 days and 90 days after initial system energization.

1. Depolarization Testing - After the cathodic protection systems were energized with protective current, depolarization testing was conducted for all cathodic protection zones. Depolarization potentials were measured with respect to the embedded silver/silver chloride reference cells. The potential decays were recorded every 30 seconds and monitored for 4 hours using two Omnidata data loggers connected to the reference cell terminals at the rectifier.

2. Rebar Probe Current Measurements - Each rebar probe current was measured just before and during depolarization testing. The measurements were taken at the rectifier across a 10 ohm-shunt resistor using a Miller Model LC4 voltmeter. The positive lead of the meter was connected to the rebar probe and the negative lead to the bridge reinforcing steel.

3. Electrical Resistance Measurements - Electrical resistance measurements were taken between the various components of each cathodic protection system at the rectifier. The measurements were obtained using a Nilsson Model 400 AC resistance meter.

IV. RESULTS AND ANALYSIS

POST INSTALLATION

1. Inspection of the Cathodic Protection System Components - System wiring errors were found and corrected at the rectifier. In addition, wiring errors were found and corrected in the junction boxes corresponding to zones B1 (Raychem anode system) and D3 (Zinc sprayed anode system).

Direct electrical contact between the anode and the reinforcing steel were detected in zones D1, D2, D3 and D6 (these zones are zinc sprayed anode material) during testing. These contact points were located and eliminated.

The rectifier unit was inspected to insure proper operation. The rectifier meter was found unable to display circuit voltage and current. In addition, the rectifier did not measure the voltage drop across the 10 ohm resistor of the macro-cell rebar probes. Instead, the rectifier meter was displaying the direct potential difference between the macro-cell rebar probe and the reinforcing steel. The contractor notified the rectifier manufacturer for correction of these malfunctions.

During testing of the zinc systems, some areas of zinc coating were found electrically isolated (zone D3). Further investigation revealed that concrete stress cracks running transverse and full width of the sidewalk reflected through the thin zinc anode coating. Electrical continuity of the zinc anode coating was re-established using flame sprayed zinc. The system repair would be evaluated during the next two evaluation visits.

2. Electrical Resistance Measurements - Table 1 documents the resistance data taken between the various components of each cathodic protection system.

The anode-to-system negative resistance measurement for each zone verifies that the systems will operate within the rectifier's design capacity. The zinc zones (circuits 11-16) displayed high circuit resistance due to the small size of these zones.

The reference cell-to-reference cell ground resistances as well as the macro-cell rebar probe to rebar probe ground resistances were considered normal for continuous operation. All other resistance measurements documented in table 1 verify that the system is able to provide protective current to the reinforcing steel of this structure. All the resistance measurements recorded will serve as a baseline for future system monitoring.

3. Anode Potential, Reference Cell Potential and Rebar Probe Current Measurements - Shown in table 1 are potential measurements taken between the anode and the system negative of each zone. This "open circuit potential" verifies that the anode and the reinforcing steel network are electrically isolated and installed correctly.

   Also included in table 1 are the corrosion potentials of the embedded reference cell and each macro-cell rebar probe corrosion current. The negative value of the rebar probe corrosion current is an indication of the anodic (corroding) behavior of the rebar probe to the surrounding reinforcing steel. The corrosion potential of the embedded reference cells indicate the cells are installed near corroding rebars.

4. Corrosion Rate Measurements - Two permanent corrosion rate probes are embedded in each of the 10 zones in the bridge deck (circuits 1-10). Portable probes are being used to measure corrosion rates on the sidewalk, median and pier cap. Table 2 documents the corrosion rate data results. Presently, there is no definite corrosion rate threshold value for reinforcing steel in concrete above which concrete corrosion damage occurs. Such criteria has not yet been clearly established, but is being researched. However, the rate of corrosion measured and calculated on this project will serve as a baseline for future monitoring of the system and can be used to assess and evaluate the effectiveness of each cathodic protection system.

5. E Log I Tests - The polarization data collected during E Log I testing is plotted by computer and shown in figures 1 through 17. The E Log I tests were conducted using the embedded silver/silver chloride reference cell in each zone. The purpose of performing the E Log I test is to determine corrosion and cathodic protection data. According to theory, as increments of current are applied to a structure, oxidizing and reduction reactions occur on the steel surface. When the reduction reaction dominates, a plot of the applied current versus the polarized structure potentials on a semi-log graph gives a straight line called Tafel behavior. The polarized potential at the beginning of the Tafel segment is the value which indicates cathodic protection is achieved. Using the above theory, the amount of cathodic protection current is determined for each zone. The interpretation of the linear portion of the curve and the break is subject to individual opinion.

Therefore, to obtain the best fit straight line of the Tafel slope, a linear regression technique using a computer was adapted by Corrpro Companies, Inc. This computerized method enables evaluation of all possible linear portion of the graph to determine the most linear portion of the curve. The linear regression program then calculates the Tafel slope (Bc), corrosion current (I-corr), corrosion potential (E-corr), cathodic protection current (I-prot), cathodic protection potential (E-prot), standard deviation of potential estimate (standard error), closeness of fit of the estimated data to actual data (R^2) and the number of observations used. Table 3 summarizes the results of the E Log I test for each zone. Table 3 also shows protective current requirements as determined by the E Log I test.

6. Initial Rectifier Setting and Operating Data - This project utilized different anode material which have.different anode current density limitations. The operational current density was kept approximately equal to or less than two milliamperes per square foot of concrete surface area (as shown in table 4) except for the Elgard 150 anode material where anode current limitations necessitated a current density limit of approximately 1.5 milliamperes per square foot of concrete surface area. The effectiveness of the systems in mitigating corrosion of the reinforcing steel would be evaluated 45 days after initial energization. Tables 5 and 6 show rectifier operating data taken before and after initial energization, respectively.

FORTY-FIVE DAY EVALUATION

1. Inspection of the Cathodic Protection System - After 45 days of initial system energization, the rectifier was inspected for proper operation. No rectifier malfunctions were detected during this inspection.

   A visual inspection of the cathodic protection zones yielded the following:

   In zone D3 (zinc anode with Sika top 122 thin cementatious coating), two areas of Sika top disbondments were detected.

A small number of dot like rust stains were observed at the east most bottom face of the pier cap (Porter DAC 85 anode system). The development of these dots will be monitored during the next evaluation visit.

The repair technique adopted during the post-installation testing on zone D3 anode was still providing effective electrical continuity of the zinc anode coating. The repairs will again be evaluated during the next evaluation visit.

2. Depolarization Testing - The specified criterion required that the half-cell potential depolarize at least 100 millivolts more positive from the "instant-off" potential of the reinforcing steel when the cathodic protection current is first turned off. The polarization shift should occur in a reasonable time period which is generally accepted to be 4 hours maximum. Table 7 documents rectifier operating data taken before depolarization testing. Depolarization testing was then conducted using two Omnidata data loggers connected to the embedded silver/silver chloride reference cell terminals at the rectifier. Instant-off reference cell potentials were obtained by momentarily interrupting the current for every zone. After power shut off, the potential decay was automatically recorded by the data loggers at 30 second intervals. However, potential data logging was terminated after 3 hrs and 4 minutes for circuits 11 through 17 due to instrument malfunction. The data for these circuits were then recorded by hand. Figures 18 through 23, show computer generated plots of the data collected for each zone. The depolarization graphs showed typical potential decay behavior.

Table 8 summarizes the 4 hour polarization shift on each reference cell for all zones. The specifications recommend a depolarization range of 100-150 millivolts. Current settings were re-adjusted accordingly. It should be noted, however, that recent research has shown that the 100 millivolts may be too conservative and that higher polarization shift may be desired.

Depolarization testing will also be conducted approximately 90 days after initial system energization.

3. Rebar Probe Current Measurements - Rebar probe current measurements were taken before and during the depolarization test as shown in table 9. By monitoring the electrical current produced by electrochemical reactions on the probe and the surrounding reinforcing steel, whether or not the probe is an anode (corroding, negative polarity) or a cathode (non-corroding, positive polarity) is determined. All rebar probes (except rebar probe 11, zone D1) were cathodic with the protective current applied. When the cathodic protection current was first interrupted, all rebar probes drifted anodic or less cathodic as expected. This shows that the for cathodic protection is effective, and that continuous system operation is vital. Rebar probe 11, although anodic at the beginning of the test, drifted considerably more anodic by the end of the test. Rebar probe 17 drifted anodic after the current was turned off, but then went cathodic. This behavior suggests that the rebar probe is no longer anodic to its surrounding rebar and therefore can no longer be used to observe current reversal. Since other tests indicate that rebar probe 17 is functional, whether this behavior is due to condition at the time of the test or polarization due to protection current is unknown. Figures 24 through 29 show computer generated plots of the rebar probe current data collected during the depolarization testing.

   It should be noted that there is no set criteria for macrocell rebar probes' behavior or a recommended maximum corrosion current value. Rebar probes are used as an indication that the cathodic protection current is being effective in supplying protection to the steel rebar. By forcing this artificial, highly anodic corrosion cell to be cathodic or to drift considerably less anodic, it can be assessed that the cathodic protection current is providing corrosion control to the reinforcing steel.

4. Rate of Corrosion Measurements - Rate of corrosion measurements were conducted 24 hours after the depolarization. Table 10 documents the results of the data collected. Table 11 shows a comparison between the corrosion rate results obtained during the post-installation testing and this test. Table 11 shows that no significant change in corrosion rate was measured.

5. Electrical Resistance Measurements - Table 12 documents electrical resistance measurements taken between the different components of the system during this test period and during the post-installation testing. The resistance between each

reference cell and its ground and between each rebar probe and its ground increased, a well expected behavior. All monitors are still considered normal for operation.

A slight increase in anode to system negative is also noted for most of the cathodic protection circuits. This increase was expected due to curing of the concrete and temperature effects.

6. System Adjustments - A preliminary analysis of all the data collected during the 45 day evaluation period necessitated protective current adjustments. Table 13 documents the new current settings adopted as well as a summary of the initial settings. The rectifier control for zone D5 (rectifier circuit 15) was unable to maintain constant current at the very low current requirement. Slightly higher current was set to insure continuous current control for this zone. Lower protective currents were adopted for 77 percent of the circuits due to higher than specified reference cell polarization shifts. The effectiveness of the new current settings will be evaluated during the final (90 day) evaluation visit.

   Table 14 documents rectifier operating data taken after re-energization of the system for continuous operation at the 45 day site evaluation.

NINETY DAY EVALUATION

1. Inspection of the Cathodic Protection System - After 90 days of initial system energization (and 45 days after completion of the first evaluation study of the systems), the rectifier was inspected for proper operation. No malfunctions were detected as the rectifier was able to effectively control the current output of every circuit.

   Inspection of the cathodic protection zones yielded the following:

   The number and size of Sika top disbondments and cracks increased on the zinc anode zones (zone D).

A large number of dot like rust stains were found on the bottom face of the pier cap (zone E). The number of these "dots" increased during the past 45 days of system operation.

The repair technique adopted on zone D3 anode during the post-installation testing and evaluated during the 45 day evaluation period was again tested during this visit. The repairs made are still providing electrical continuity of the anode. However, more cracked areas were found especially in zones D1 and D3. Effective cathodic protection of these zones becomes questionable due to the possible electrical isolation of the anode at active cracks.

2. Depolarization Testing - Table 15 documents rectifier operating data taken before depolarization testing. The rebar probe embedded in zone 12 displayed a negative voltage drop reading across the 10-ohm shunt. The cathodic protection current supplied to this zone did not overcome the exceptionally strong corrosion cell of this rebar probe.

   Depolarization testing was then conducted using two Omnidata data loggers connected to all the silver/silver chloride reference cell terminals at the rectifier. Instant-off reference cell potential for every zone were taken and the potential decays were automatically recorded by the data loggers. Figures 30 through 35 show computer generated plots of the data collected for each zone. The depolarization graphs show expected potential decay shifts for all the reference cells. All zones are considered to be cathodically protected as per the minimum 100 millivolts polarization shift specification. The 4 hour polarization shift data is summarized in table 16 along with the previous test results of the 45 day evaluation.

3. Rebar Probe Current Measurements - Rebar probe current measurements were taken before and during depolarization testing. The change in polarity and magnitude of each macrocell current is documented in table 17. All rebar probes (except rebar probe 11, zone D1) were cathodic with the protective current applied. With the cathodic protection current turned off, the macrocell rebar probes drifted cathodic or less anodic as expected.

Figures 36 through 41 show the computer generated plots of the rebar probe current data collected.

4. <u>Rate of Corrosion Measurements</u> - Corrosion rate measurements were conducted 24 hours after the depolarization tests. Table 18 documents the results of the data collected. Table 19 shows a comparison of all the corrosion rate data obtained according to specifications for the three test periods. It is noted that no significant change in corrosion rate was measured during our evaluation periods.

5. <u>Electrical Resistance Measurements</u> - Table 20 documents electrical resistance measurements taken between the different components of the cathodic protection system and after the 90 day depolarization test and during the previous tests. All resistance measurements obtained between each reference cell and reference cell ground and between each rebar probe and rebar probe ground are considered normal for operation. The resistance measured between the anodes and the system negative are within acceptable limits except for zones 11, 12 and 14 which show a large increase in circuit resistance. This increase is due to a combination of factors such as the small size of the zones and the erratic behavior of the zinc anode due to temporary electrical isolation by reflective concrete cracking.

6. <u>System Adjustments</u> - Based on the data collected during our testing, the current output of specific zones was re-adjusted to provide optimum performance as shown in table 21. The new current settings are believed to provide effective corrosion mitigation of the reinforced steel structure. Table 22 documents rectifier operating data taken the day after final re-energization. Reference cell 11 and rebar probe 11, although found normally operating before depolarization testing started, show no sign of receiving cathodic protection current despite the fact that the rectifier is supplying a current output to that zone. This erratic behavior is believed to be caused by the active concrete cracks of the sidewalk and future performance of this zone is questionable.

   Table 23 documents the current setting for every zone throughout the specified three testing periods.

V. CONCLUSION AND RECOMMENDATIONS

1. The cathodic protection systems can provide effective corrosion mitigation to the reinforced concrete structure.

2. Depolarization test results conducted for all zones during both evaluation periods meet the specified minimum 100 millivolt polarization shift criterion.

3. The corrosion cells produced by the rebar probes were greatly reduced by the cathodic protection current.

4. The corrosion rate measurements taken before and during the evaluation periods suggest that no further corrosion is occurring. It is recommended to periodically conduct this test to establish a statistical record of the corrosion rate of the reinforcing steel and the effectiveness of the systems in preventing further corrosion damage.

5. General appearance of the cathodic protection systems are in good condition. However, cracking of the Sika Top overlay applied over the zinc anode was visible especially in zones D3 and D6.

6. Cathodic protection of the entire area of the median and the sidewalk are considered questionable due to the discovery of several erratic electrical isolations in the zinc anode coating.

7. The rectifier operating data should be collected monthly. This data provides important information about the operation of the systems and will alert the existence of any malfunction. These data sheets should be reviewed by a qualified engineer should any discrepancy or abnormality be noted. It is also recommended to conduct a yearly detailed evaluation of the systems to insure optimum protection of the reinforcing steel structure.

tr004(70)

TABLES

TABLE 1

POST INSTALLATION SYSTEM DATA
OCTOBER 5, 1988

	ANODE		REFERENCE CELLS					REBAR PROBES			
CKT				RESISTANCE					RESISTANCE		
	OPEN CKT POT (mv)	RESISTANCE ANODE GRND/ TOTAL GRND (ohm)	CORROSION POTENTIAL (-MV)	RC/ RCG (ohm)	RC GRND/ TOTAL GRND (ohm)	RC GRND/ RP GRND/ (ohm)	RC GRND/ INDV GRND/ (ohm)	CORROSION CURRENT (MA) *	RP/ RPG (ohm)	RP GRND/ TOTAL GRND (ohm)	RP GRND/ INDV GRND (ohm)
1	572	0.67	363	520	4.0	4.50	4.1	-1.376	91	0.780	1.40
2	454	0.67	310	430	3.2	3.70	3.9	-0.671	160	0.620	1.30
3	460	0.69	263	1100	3.1	3.60	3.7	-0.291	360	0.640	1.30
4	452	0.64	259	560	3.7	4.20	4.3	-0.199	290	0.690	1.40
5	153	0.75	331	820	2.8	3.00	3.2	-0.624	150	0.710	1.20
6	147	0.70	346	1300	2.8	4.00	3.3	-1.040	110	0.900	1.10
7	190	0.73	318	1300	2.6	2.90	3.0	-0.197	370	0.550	0.96
8	172	0.61	331	1300	2.8	3.20	3.2	-0.175	310	0.560	0.96
9	244	0.29	301	580	1.5	1.70	1.5	-0.961	130	0.340	0.40
10	-236	0.30	285	2000	1.3	1.40	1.4	-0.296	300	0.280	0.38
11	-232	2.80	192	790	3.2	3.60	3.8	-1.225	130	0.610	1.20
12	-149	5.50	372	300	2.3	2.40	2.7	-0.845	100	1.060	1.30
13	-239	1.80	386	470	2.3	2.70	3.2	-0.693	110	0.610	1.20
14	-357	9.40	252	420	1.3	1.50	2.2	-0.848	170	0.340	0.88
15	-231	2.70	214	1100	1.3	1.20	2.0	-1.489	97	0.470	1.00
16	-349	3.40	330	460	4.6	0.89	1.4	-1.234	130	0.260	0.49
17	26	1.60	279	1100	2.5	0.95	1.8	-0.509	200	0.340	1.10

* NOTE: (-) Negative current indicates macro-cell rebar probe is anode (corroding)

TABLE 2

CORROSION RATE DATA RESULTS - INITIAL
OCTOBER 16, 1988

TEMP: 68 DEGREES F   DECK DRY

LOCATION	ECORR (-MVS)	POLARIZATION RESISTANCE (ohm)	CORROSION CURRENT (MA)	RATE OF CORROSION (MPY)
LP1	170	23.20	1.75	0.8
LP2	162	54.54	0.74	0.3
LP3	180	19.83	2.05	1.0
LP4	88	14.70	2.77	1.3
LP5	209	31.34	1.30	0.6
LP6	278	11.65	3.49	1.7
LP7	144	11.45	3.55	1.7
LP8	165	16.18	2.51	1.2
LP9	238	25.13	1.62	0.7
LP10	38	20.89	1.95	0.9
LP11	181	13.17	3.09	1.5
LP12	216	12.62	3.23	1.5
LP13	218	11.01	3.70	1.8
LP14	175	16.23	2.51	1.2
LP15	178	17.48	2.33	1.1
LP16	216	10.80	3.77	1.8
LP17	167	17.36	2.34	1.1
LP18	243	13.77	2.96	1.4
LP19	234	9.91	4.11	2.0
LP20	256	9.37	4.35	2.1
D1N	337	122.24	0.33	0.1
D1S	507	53.71	0.75	0.3
D2N	251	221.57	0.18	0.0
D2S	223	590.86	0.06	0.0
D3N	165	590.86	0.06	0.0
D3S	396	17.37	2.34	1.1
D4N	197	1181.73	0.03	0.0
D4S	167	90.90	0.44	0.2
D5N	230	49.23	0.82	0.4
D5N	197	354.52	0.11	0.0
D6N	230	177.26	0.23	0.1
D6S	260	54.54	0.74	0.3
EN	305	53.71	0.75	0.3
ES	285	22.72	1.79	0.8

NOTE: ALL D & E LOCATIONS WERE TESTED USING A PORTABLE RATE OF CORROSION PROBE WITH A COPPER/COPPER SULFATE REFERENCE CELL

TABLE 3

SUMMARY OF ELOGI TEST RESULTS

(INITIAL ENERGIZATION)
(10/11 - 10/13 1988)

ZONE	TAFEL SLOPE MV/DECADE	ICORR (MA)	ECORR (-MV)	IPROT (MA)	EPROT (-MV)
1	183.67	2724.6	360	5123.6	410.4
2	249.00	1225.4	312	4098.7	442.6
3	205.90	1113.3	262	4894.8	394.5
4	168.80	3019.3	361	7746.1	430.1
5	163.80	1914.9	330	5996.7	411.2
6	152.80	3152.8	347	9246.4	418.2
7	274.70	2085.9	309	6697.9	448.2
8	222.50	2262.7	325	6696.9	429.9
9	187.70	1156.2	303	4847.9	419.8
10	156.10	1727.6	282	6797.1	374.8
11	1403.90	451.9	274	589.9	432.6
12	1060.99	386.2	301	939.8	710.8
13	343.51	291.0	410	729.4	547.1
14	872.30	188.8	307	344.7	535.1
15	307.60	116.4	242	424.3	414.8
16	239.30	71.0	355	219.8	472.5
17	507.30	1951.7	264	4298.9	438.0

TABLE 4

PROTECTIVE CURRENT SETTINGS - INITIAL

CKT	CONCRETE SURFACE AREA (FT SQ)	NOVEMBER 1988 ELOGI CURRENT (A)	ELOGI CURRENT DENSITY (mA/SQ FT)	ACTUAL CURRENT SETTING (A)	CURRENT DENSITY (MA/SQ FT)
1	2884	5.124	1.78	4.5	1.56
2	2884	4.099	1.42	4.0	1.39
3	2884	4.899	1.70	3.5	1.21
4	2884	7.746	2.69	4.5	1.56
5	2884	5.997	2.08	5.8	2.01
6	2884	9.246	3.21	5.8	2.01
7	2884	6.697	2.32	5.0	1.73
8	2884	6.697	2.32	5.8	2.01
9	4704	4.845	1.03	4.5	0.96
10	4704	6.797	2.36	6.0	1.28
11	412	0.590	1.43	0.4	0.85
12	1648	0.940	0.57	0.9	0.55
13	1854	0.730	0.39	0.9	0.46
14	168	0.345	2.05	0.2	0.89
15	672	0.424	0.63	0.3	0.37
16	756	0.220	0.29	0.3	0.4
17	1180	4.299	3.64	2.3	1.91

* MINIMUM CURRENT OUTPUT ALLOWED BY THE CONTROL CARD OF THE CIRCUIT

TABLE 5

MAINTENANCE DATA SHEET

Bridge Deck Identification: US 87 Railroad Overpass – Howard County, Big Spring, Texas

Rectifier Location: N.E. Abutment Wall   Deck Condition: Dry

Date: 10/28/88   Time: Ambient Temperature: 55 ° F

Tester(s): TR   Rectifier Model No.: TIACE 40/20-10(17)DGNPSZ

Rectifier S/N: 88A1052 Type 0033052   Rectifier DC Rating: DC Amps 10 (ckts 1–17) DC Volts 20 (ckts 1–13) 40 (ckts 14–17)

General Remarks: Pre-energization data. Rectifier "OFF." Voltage measurements are open circuit potential between anode and structure negative. Open circuit potential for zones 11–16 negative due to zinc anode material.

Circuit	Control Light (on/off)	Rebar Probe (volts)	Reference Cell (volts)	Voltage (volts)	Current (amps)	Instant-off Reference cell (volts)*	Remarks
1	OFF	-.0138	.360	.57	0		Rebar probe measurements were taken using a portable voltmeter
2	OFF	-.0067	.304	.45	0		
3	OFF	-.0029	.266	.46	0		
4	OFF	-.0020	.352	.45	0		
5	OFF	-.00625	.331	.15	0		
6	OFF	-.00104	.335	.15	0		
7	OFF	-.00197	.302	.19	0		
8	OFF	-.00175	.323	.17	0		
9	OFF	-.00961	.299	.24	0		
10	OFF	-.00296	.280	.24	0		
11	OFF	-.01225	.271	-.23	0		
12	OFF	-.00845	.255	-.15	0		
13	OFF	-.00693	.361	-.24	0		
14	OFF	-.00848	.297	-.36	0		
15	OFF	-.01489	.295	-.23	0		
16	OFF	-.00123	.380	-.35	0		
17	OFF	-.00509	.253	.026	0		
				Total current	0		

Note: Refer to instruction sheet concerning all measurements.
* Measurements require a portable voltmeter.

bstx2(w1-fl)

TABLE 6

MAINTENANCE DATA SHEET

Bridge Deck Identification: US 87 Railroad Overpass - Howard County, Big Spring, Texas

Rectifier Location: N.E. Abutment Wall   Deck Condition: Dry

Date: 10/28/88   Time: Ambient Temperature: 55° F

Tester(s): TR   Rectifier Model No.: TIACE 40/20-10(17)DGNPSZ

Rectifier S/N: 88A1052 Type 0033052   Rectifier DC Rating: DC Amps 10 (ckts 1-17) DC Volts 20 (ckts 1-13) 40 (ckts 14-17)

General Remarks: Initial energization data. Rebar probe measurements were taken using a portable voltmeter.

Circuit	Control Light (on/off)	Rebar Probe (volts)	Reference Cell (volts)	Voltage (volts)	Current (amps)	Instant-off Reference cell (volts)*	Remarks
1	ON	-.00200	.449	4.98	4.50	.401	
2	ON	.00200	.588	4.71	4.00	.416	
3	ON	.00200	.427	4.68	3.50	.360	
4	ON	.00200	.460	4.83	4.50	.410	
5	ON	.00015	.837	13.79	5.80	.470	
6	ON	.00101	.644	13.63	5.80	.479	
7	ON	.00202	.518	13.30	5.00	.399	
8	ON	.00212	.587	14.77	4.80	.410	
9	ON	.00105	.490	2.99	4.50	.397	
10	ON	.00215	.429	3.51	6.00	.355	
11	ON	-.00290	1.420	5.62	.35	.572	
12	ON	.04550	1.220	10.95	.90	.570	
13	ON	.00425	2.140	13.46	.85	.830	
14	ON	.03010	2.730	6.39	.15	.610	
15	ON	.00620	1.290	3.81	.25	.540	
16	ON	.00967	1.050	6.85	.30	.450	
17	ON	.00851	1.160	7.06	2.25	.400	
				Total current	54.0		

Note: Refer to instruction sheet concerning all measurements.
* Measurements require a portable voltmeter.

bstx1(w1-fl)

TABLE 7

MAINTENANCE DATA SHEET

Bridge Deck Identification: US 87 Railroad Overpass – Howard County, Big Spring, Texas

Rectifier Location: N.E. Abutment Wall   Deck Condition: Dry

Date: 12/15/88   Time: Ambient Temperature: 33° F

Tester(s): TR   Rectifier Model No.: TIACE 40/20–10(17)DGNPSZ

Rectifier S/N: 88A1052 Type 0033052   Rectifier DC Rating: DC Amps 10 (ckts 1–17) DC Volts 20 (ckts 1–13) 40 (ckts 14–17)

General Remarks: Before depolarization testing.

Circuit	Control Light (on/off)	Rebar Probe (volts)	Reference Cell (volts)	Voltage (volts)	Current (amps)	Instant-off Reference cell (volts)*	Remarks
1	ON	.006	.541	5.6	4.62	.511	
2	ON	.006	.711	5.3	4.11	.566	
3	ON	.006	.668	5.9	3.62	.532	
4	ON	.005	.546	5.7	4.62	.514	
5	ON	.004	1.092	11.4	5.98	.679	
6	ON	.005	.751	10.7	5.92	.597	
7	ON	.005	.773	10.9	5.09	.573	
8	ON	.005	.926	10.3	5.93	.618	
9	ON	.005	.551	4.1	4.46	.430	
10	ON	.004	.515	5.4	6.17	.423	
11	ON	−.003	.364	1.9	.44	.485	
12	ON	.0085	Out of Scale	17.7	.98	1.194	Meter out of scale for reference cell measurements
13	ON	.01	.815	2.5	.86	.680	
14	ON	.034	1.464	7.8	.25	.797	
15	ON	.011	1.030	2.4	.33	.559	
16	ON	.012	.825	6	.4	.627	
17	ON	.013	Out of Scale	9.9	2.39	.956	Meter out of scale for reference cell measurements
				Total current	56.75		

Note: Refer to instruction sheet concerning all measurements.
* Measurements require a portable voltmeter.

bstx3'w1-4

TABLE 8

DEPOLARIZATION TEST - 45 DAYS

REFERENCE CELL	DECEMBER 13, 1988 4 HR POLARIZATION SHIFT (-MVS)
1	143
2	236
3	229
4	115
5	333
6	195
7	226
8	204
9	175
10	124
11	175
12	954
13	265
14	478
15	226
16	274
17	597

TABLE 9

DEPOLARIZATION TEST DATA - 45 DAY

REBAR PROBE CORROSION CURRENT (MA) *

DECEMBER 13, 1988

REBAR PROBE NUMBER

MINUTES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
**	0.308	0.324	0.223	0.348	0.233	0.186	0.471	0.320	0.219	0.303	-0.305	0.881	0.600	3.640	0.750	1.166	1.177
0.5	0.001	-0.161	-0.106	0.024	-0.088	0.055	0.060	0.055	-0.186	-0.039	-0.347	-0.404	-0.087	-0.365	-0.317	-0.318	-0.071
9	0.001	-0.245	-0.116	0.011	-0.117	-0.001	0.022	0.035	-0.238	-0.033	-0.466	-0.450	-0.082	-0.673	-0.345	-0.383	-0.016
16	-0.001	-0.249	-0.123	0.009	-0.123	-0.019	0.012	0.025	-0.250	-0.055	-0.452	-0.463	-0.087	-0.335	-0.365	-0.364	-0.004
31	-0.016	-0.249	-0.122	0.009	-0.127	-0.037	0.006	0.016	-0.262	-0.055	-0.492	-0.463	-0.092	-0.267	-0.393	-0.371	-0.006
60	-0.036	-0.249	-0.121	0.008	-0.136	-0.061	0.000	0.017	-0.271	-0.055	-0.554	-0.454	-0.108	-0.226	-0.457	-0.379	-0.032
90	-0.064	-0.258	-0.126	0.004	-0.154	-0.086	-0.007	0.006	-0.291	-0.059	-0.600	-0.401	-0.127	-0.179	-0.539	-0.395	0.045
120	-0.085	-0.263	-0.133	-0.001	-0.165	-0.100	-0.010	0.002	-0.304	-0.065	0.599	-0.363	-0.144	-0.142	-0.589	-0.416	0.050
180	-0.090	-0.285	-0.143	-0.002	-0.193	-0.128	-0.017	-0.013	-0.336	-0.074	-0.707	-0.285	-0.182	-0.070	-0.677	-0.489	0.053
240	-0.180	-0.322	-0.160	-0.004	-0.227	-0.155	-0.250	-0.011	-0.372	-0.086	-0.915	-0.295	-0.223	-0.039	-0.767	-0.552	0.050

NOTES:

* Negative current indicates the macro-cell rebar probe is anodic (corroding) and positive current indicates the macro-cell rebar probe is cathodic (protected).

** Measurement obtained just before depolarization test started (i.e. before rectifier shut off)

TABLE 10

CORROSION RATE DATA RESULTS - 45 DAYS
DECEMBER 14, 1988

TEMP: 45 DEGREES F DECK DRY

LOCATION	ECORR (-MVS)	POLARIZATION RESISTANCE (OHM)	CORROSION CURRENT (MA)	RATE OF CORROSION (MPY)
LP1	145	28.25	1.44	0.7
LP2	137	51.94	0.78	0.3
LP3	166	24.34	1.67	0.8
LP4	145	22.63	1.80	0.8
LP5	174	28.11	1.45	0.7
LP6	280	14.24	2.86	1.4
LP7	117	11.26	3.61	1.7
LP8	143	13.80	2.95	1.4
LP9	202	29.16	1.39	0.6
LP10	89	20.89	1.95	0.9
LP11	156	11.26	3.61	1.7
LP12	202	12.45	3.27	1.6
LP13	193	14.74	2.76	1.3
LP14	127	14.35	2.84	1.3
LP15	139	16.83	2.42	1.1
LP16	164	10.04	4.05	1.9
LP17	157	14.20	2.87	1.4
LP18	272	13.30	3.05	1.4
LP19	233	11.90	3.42	1.6
LP20	232	9.95	4.09	2.0
D1N	382	94.39	0.43	0.2
D1S	352	160.71	0.38	0.1
D2N	491	409.06	0.09	0.0
D2S	360	245.43	0.16	0.0
D3N	290	153.39	0.26	0.1
D3S	219	93.39	0.43	0.2
D4N	494	144.37	0.28	0.1
D4S	485	29.21	1.39	0.6
D5N	238	31.46	1.29	0.6
D5N	263	35.78	0.73	0.3
D6N	258	90.90	0.44	0.2
D6S	178	33.62	1.21	0.5
EN	326	76.69	0.53	0.2
ES	301	33.62	1.22	0.5

TABLE 11

SUMMARY OF CORROSION RATE RESULTS
INITIAL AND 45 DAYS OF CONTINUOUS C.P.

LOCATION	10/6/88 68 F (MPY)	12/14/88 45 F (MPY)
LP1	0.8	0.7
LP2	0.3	0.3
LP3	1.0	0.8
LP4	1.3	0.8
LP5	0.6	0.7
LP6	1.7	1.4
LP7	1.7	1.7
LP8	1.2	1.4
LP9	0.7	0.6
LP10	0.9	0.9
LP11	1.5	1.7
LP12	1.5	1.6
LP13	1.8	1.3
LP14	1.2	1.3
LP15	1.1	1.1
LP16	1.8	1.9
LP17	1.1	1.4
LP18	1.4	1.4
LP19	2.0	1.6
LP20	2.1	2.0
D1N	0.1	0.2
D1S	0.3	0.1
D2N	0.0	0.0
D2S	0.0	0.0
D3N	0.0	0.1
D3S	0.1	0.2
D4N	0.0	0.1
D4S	0.2	0.6
D5N	0.4	0.6
D5N	0.0	0.3
D6N	0.1	0.2
D6S	0.3	0.5
EN	0.3	0.2
ES	0.8	0.5

TABLE 12

SUMMARY OF RESISTANCE MEASUREMENTS (OHMS)
INITIAL AND 45 DAY

	INITIAL OCTOBER 5, 1988				45 DAY DECEMBER 13, 1988			
CKT	ANODE/ TOTAL GRND	ANODE/ INDV. GRND	RC/ RCG	RP/ RPG	ANODE/ TOTAL GRND	ANODE/ TOTAL GRND	RC/ RCG	RP/ RPG
1	0.67	1.30	520	91	0.67	1.30	1200	220
2	0.67	1.30	430	160	0.68	1.50	1200	350
3	0.69	1.30	1100	360	0.73	1.40	2600	780
4	0.64	1.25	560	290	0.67	1.30	1100	700
5	0.75	1.20	820	150	0.77	1.30	1800	300
6	0.70	1.20	1300	110	0.75	1.30	3100	240
7	0.73	1.20	1300	370	0.83	1.30	2900	900
8	0.61	1.00	1300	310	0.76	1.20	3500	740
9	0.29	0.35	580	130	0.31	0.34	1500	280
10	0.30	0.34	2000	300	0.32	0.37	4100	720
11	2.80	2.00	790	130	2.95	2.00	720	220
12	5.50	6.00	300	100	5.65	6.20	1200	350
13	1.80	2.00	470	110	1.90	2.30	1150	260
14	9.40	9.70	420	170	15.00	15.00	690	450
15	2.70	3.00	1100	97	2.90	3.00	1800	200
16	3.40	3.60	460	130	4.80	4.90	1700	400
17	1.60	1.80	1100	200	2.30	2.40	1700	570

TABLE 13

SUMMARY OF PROTECTIVE CURRENT SETTINGS
INITIAL AND 45 DAYS

		INITIAL NOVEMBER 1988				45 DAYS DECEMBER 1988	
CKT	CONCRETE SURFACE AREA (FT SQ)	ELOGI CURRENT (A)	ELOGI CURRENT DENSITY (mA/sq ft)	ACTUAL CURRENT SETTING (A)	CURRENT DENSITY (MA/SQ FT)	CURRENT SETTING (A)	CURRENT DENSITY (MA/SQ FT)
1	2884	5.124	1.78	4.5	1.56	4.50	1.56
2	2884	4.099	1.42	4.0	1.39	3.50	1.21
3	2884	4.899	1.70	3.5	1.21	3.20	1.11
4	2884	7.746	2.69	4.5	1.56	4.50	1.56
5	2884	5.997	2.08	5.8	2.01	5.00	1.73
6	2884	9.246	3.21	5.8	2.01	5.50	1.91
7	2884	6.697	2.32	5.0	1.73	4.70	1.63
8	2884	6.697	2.32	5.8	2.01	5.50	1.91
9	4704	4.845	1.03	4.5	0.96	4.20	0.89
10	4704	6.797	2.36	6.0	1.28	6.00	1.28
11	412	0.590	1.43	0.4	0.85	0.30	0.73
12	1648	0.940	0.57	0.9	0.55	0.35	0.21
13	1854	0.730	0.39	0.9	0.46	0.50	0.27
14	168	0.345	2.05	0.2	0.89	0.10	0.60
15	672	0.424	0.63	0.3	0.37	0.25 *	0.37
16	756	0.220	0.29	0.3	0.4	0.20	0.26
17	1180	4.299	3.64	2.3	1.91	1.50	1.27

* MINIMUM CURRENT OUTPUT ALLOWED BY THE CONTROL CARD OF THE CIRCUIT

TABLE 14

MAINTENANCE DATA SHEET

Bridge Deck Identification: US 87 Railroad Overpass – Howard County, Big Spring, Texas

Rectifier Location: N.E. Abutment Wall   Deck Condition: Dry

Date: 12/15/88   Time: ____   Ambient Temperature: 33° F

Tester(s): TR   Rectifier Model No.: TIACE 40/20–10(17)DGNPSZ

Rectifier S/N: 88A1052 Type 0033052   Rectifier DC Rating: DC Amps 10 (ckts 1–17) DC Volts 20 (ckts 1–13) 40 (ckts 14–17)

General Remarks: Re–energization data taken after testing was completed.

Circuit	Control Light (on/off)	Rebar Probe (volts)	Reference Cell (volts)	Voltage (volts)	Current (amps)	Instant–off Reference cell (volts)*	Remarks
1	ON	.010	.501	5.20	4.50	.450	
2	ON	.007	.640	4.60	3.48	.489	
3	ON	.004	.596	5.10	3.19	.461	
4	ON	.005	.510	5.20	4.50	.456	
5	ON	.004	.978	10.20	5.01	.612	
6	ON	.004	.758	10.40	5.50	.558	
7	ON	.004	.628	11.20	4.71	.479	
8	ON	.004	.825	11.00	5.51	.545	
9	ON	.004	.536	3.50	4.20	.426	
10	ON	.004	.487	4.90	6.03	.404	
11	ON	.010	.700	2.40	.38	.490	
12	ON	.041	Out of Scale	7.20	.33	.917	Meter out of scale for reference cell measurement.
13	ON	.011	.758	2.10	.49	.624	
14	ON	.016	.926	2.40	.08	.499	
15	ON	.011	.712	1.50	.24	.491	
16	ON	.012	.605	2.70	.20	.479	
17	ON	.011	1.945	7.30	1.52	.691	
				Total current	49.90		

Note: Refer to instruction sheet concerning all measurements.
* Measurements require a portable voltmeter.

bstx4(w1–fl)

TABLE 15

MAINTENANCE DATA SHEET

Bridge Deck Identification: US 87 Railroad Overpass – Howard County, Big Spring, Texas

Rectifier Location: N.E. Abutment Wall Deck Condition: Dry

Date: 1/31/89 Time: 8:20 AM Ambient Temperature: 45° F

Tester(s): TR Rectifier Model No.: TIACE 40/20-10(17)DGNPSZ

Rectifier S/N: 88A1052 Type 0033052 Rectifier DC Rating: DC Amps 10 (ckts 1–17) DC Volts 20 (ckts 1–13) 40 (ckts 14–17)

General Remarks: Before depolarization testing.

Circuit	Control Light (on/off)	Rebar Probe (volts)	Reference Cell (volts)	Voltage (volts)	Current (amps)	Instant-off Reference cell (volts)*	Remarks
1	ON	.005	.508	5.4	4.44	.440	
2	ON	.004	.616	4.8	3.44	.465	
3	ON	.002	.557	5.4	3.15	.425	
4	ON	.004	.505	5.5	4.44	.443	
5	ON	.004	1.055	10.0	4.97	.636	
6	ON	.003	.822	9.8	5.45	.596	
7	ON	.006	.734	10.4	4.67	.520	
8	ON	.006	.840	9.7	5.46	.563	
9	ON	.004	.522	3.6	4.13	.411	
10	ON	.005	.511	5.0	5.96	.434	
11	ON	–.002	.451	9.2	.36	.359	
12	ON	.010	.661	24.8	.22	.530	
13	ON	.011	.774	4.7	.47	.673	
14	ON	.011	.676	5.1	.11	.500	
15	ON	.006	.523	2.1	.25	.405	
16	ON	.008	.508	3.0	.19	.440	
17	ON	.011	1.929	7.9	1.49	.795	
				Total current	48.9		

Note: Refer to instruction sheet concerning all measurements.
* Measurements require a portable voltmeter.

bstx5/w1-f1

TABLE 16

SUMMARY OF DEPOLARIZATION TESTS
45 AND 90 DAYS

REFERENCE CELL	45 DAY DECEMBER 13, 1988 4 HR POLARIZATION SHIFT (-MVS)	90 DAY JANUARY 31, 1989 4 HR POLARIZATION SHIFT (-MVS)
1	143	129
2	236	189
3	229	179
4	115	104
5	333	347
6	195	253
7	226	221
8	204	216
9	175	156
10	124	153
11	175	113
12	954	313
13	265	386
14	478	250
15	226	132
16	274	157
17	597	338

TABLE 17

DEPOLARIZATION TEST DATA - 90 DAY

REBAR PROBE CORROSION CURRENT (MA)

JANUARY 31, 1989

REBAR PROBE NUMBER

MINUTES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0.299	0.243	0.210	0.364	0.306	0.085	0.496	0.329	0.223	0.336	-0.015	0.773	0.829	1.023	0.298	0.556	0.980
0.5	0.040	0.001	-0.105	0.040	-0.039	0.030	0.082	0.061	-0.113	-0.037	-0.892	0.455	-0.138	-0.199	-0.300	-0.214	-0.062
1	0.025	-0.234	-0.150	0.005	-0.108	-0.012	0.048	0.023	-0.145	-0.064	-0.938	-0.053	-0.139	-0.214	-0.304	-0.247	-0.035
5	0.024	-0.259	-0.156	0.001	-0.114	-0.033	0.031	0.011	-0.214	-0.069	-0.961	0.045	-0.141	-0.212	-0.306	-0.264	-0.009
15	0.012	-0.279	-0.155	-0.002	-0.113	-0.070	0.012	0.003	-0.234	-0.067	-1.011	0.048	-0.136	-0.198	-0.326	-0.267	0.022
30	0.000	-0.280	-0.155	-0.002	-0.113	-0.098	0.006	-0.001	-0.244	-0.063	-1.061	0.106	-0.138	-0.178	-0.345	-0.264	0.055
60	-0.030	-0.289	-0.155	-0.004	-0.112	-0.129	-0.001	-0.006	-0.257	-0.062	-1.140	0.027	-0.152	-0.103	-0.362	-0.260	0.081
120	-0.087	-0.311	-0.165	-0.011	-0.147	-0.187	-0.008	-0.019	-0.288	-0.069	-1.327	0.013	-0.184	-0.003	-0.406	-0.241	0.095
180	-0.133	-0.342	-0.182	-0.015	-0.173	-0.227	-0.016	-0.028	-0.319	-0.079	-1.417	-0.003	-0.202	-0.015	-0.446	-0.243	0.097
240	-0.190	-0.387	-0.209	-0.025	-0.209	-0.277	-0.027	-0.043	-0.359	-0.095	-1.418	-0.016	-0.219	-0.016	-0.520	-0.250	0.095

TABLE 18

CORROSION RATE DATA RESULTS - 90 DAY
FEBRUARY 2, 1989

TEMP: 68 DEGREES F DECK DRY

LOCATION	ECORR (-MVS)	POLARIZATION RESISTANCE (OHMS)	CORROSION CURRENT (MA)	RATE OF CORROSION (MPY)
LP1	118	32.65	1.24	0.6
LP2	105	60.24	0.67	0.3
LP3	136	24.45	1.66	0.8
LP4	99	22.91	1.77	0.8
LP5	140	30.47	1.33	0.6
LP6	246	9.21	4.42	2.1
LP7	85	20.89	1.95	0.9
LP8	101	17.36	2.34	1.1
LP9	170	22.08	1.84	0.9
LP10	33	16.93	2.40	1.1
LP11	130	9.09	4.48	2.1
LP12	180	16.99	2.40	1.1
LP13	175	13.04	3.12	1.5
LP14	119	13.14	3.10	1.5
LP15	116	16.57	2.45	1.2
LP16	148	11.60	3.51	1.7
LP17	133	17.36	2.34	1.1
LP18	237	13.87	2.93	1.4
LP19	214	10.19	4.00	1.9
LP20	200	10.75	3.79	1.8
D1N	178	311.66	0.13	0.0
D1S	160	311.66	0.13	0.0
D2N	376	346.49	0.11	0.0
D2S	255	311.66	0.13	0.0
D3N	240	167.82	0.24	0.1
D3S	195	167.82	0.24	0.1
D4N	278	545.41	0.07	0.0
D4S	500	727.22	0.05	0.0
D5N	285	54.54	0.74	0.3
D5N	330	75.22	0.54	0.2
D6N	221	94.85	0.42	0.2
D6S	120	311.66	0.13	0.0
EN	210	83.91	0.48	0.2
ES	191	62.33	0.65	0.3

NOTE: ALL D & E LOCATIONS WERE TESTED USING A PORTABLE RATE OF CORROSION PROBE WITH A COPPER/COPPER SULFATE REFERENCE CELL

TABLE 19

SUMMARY OF CORROSION RATE RESULTS
INITIAL, 45 AND 90 DAY

LOCATION	10/6/88 68 F (MPY)	12/14/88 45 F (MPY)	2/2/89 65 F (MPY)
LP1	0.8	0.7	0.6
LP2	0.3	0.3	0.3
LP3	1.0	0.8	0.8
LP4	1.3	0.8	0.8
LP5	0.6	0.7	0.6
LP6	1.7	1.4	2.1
LP7	1.7	1.7	0.9
LP8	1.2	1.4	1.1
LP9	0.7	0.6	0.9
LP10	0.9	0.9	1.1
LP11	1.5	1.7	2.1
LP12	1.5	1.6	1.1
LP13	1.8	1.3	1.5
LP14	1.2	1.3	1.5
LP15	1.1	1.1	1.2
LP16	1.8	1.9	1.7
LP17	1.1	1.4	1.1
LP18	1.4	1.4	1.4
LP19	2.0	1.6	1.9
LP20	2.1	2.0	1.8
D1N	0.1	0.2	0.0
D1S	0.3	0.1	0.0
D2N	0.0	0.0	0.0
D2S	0.0	0.0	0.0
D3N	0.0	0.1	0.1
D3S	0.1	0.2	0.1
D4N	0.0	0.1	0.0
D4S	0.2	0.6	0.0
D5N	0.4	0.6	0.3
D5N	0.0	0.3	0.2
D6N	0.1	0.2	0.2
D6S	0.3	0.5	0.0
EN	0.3	0.2	0.2
ES	0.8	0.5	0.3

NOTE: All D & E locations were tested using a portable rate of corrosion probe with a copper/copper sulfate reference cell.

TABLE 20

SUMMARY OF RESISTANCE MEASUREMENTS (OHMS)
INITIAL, 45 AND 90 DAY

	INITIAL OCTOBER 5, 1988				45 DAY DECEMBER 13, 1988				90 DAY JANUARY 31, 1989			
CKT	ANODE/ TOTAL GRND	ANODE/ INDV. GRND	RC/ RCG	RP/ RPG	ANODE/ TOTAL GRND	ANODE/ TOTAL GRND	RC/ RCG	RP/ RPG	ANODE/ TOTAL GRND	ANODE/ INDV. GRND	RC/ RCG	RP/ RPG
1	0.67	1.30	520	91	0.67	1.30	1200	220	0.68	1.40	1100	185
2	0.67	1.30	430	160	0.68	1.50	1200	350	0.68	1.45	1200	207
3	0.69	1.30	1100	360	0.73	1.40	2600	780	0.78	1.40	2300	585
4	0.64	1.25	560	290	0.67	1.30	1100	700	0.67	1.30	1100	520
5	0.75	1.20	820	150	0.77	1.30	1800	300	0.73	1.20	1500	250
6	0.70	1.20	1300	110	0.75	1.30	3100	240	0.67	1.20	3400	190
7	0.73	1.20	1300	370	0.83	1.30	2900	900	0.75	1.20	2400	750
8	0.61	1.00	1300	310	0.76	1.20	3500	740	0.63	1.05	3200	560
9	0.29	0.35	580	130	0.31	0.34	1500	280	0.30	0.38	1400	230
10	0.30	0.34	2000	300	0.32	0.37	4100	720	0.35	0.40	3900	525
11	2.80	2.00	790	130	2.95	2.00	720	220	14.00	15.50	890	165
12	5.50	6.00	300	100	5.65	6.20	1200	350	31.00	31.00	1050	250
13	1.80	2.00	470	110	1.90	2.30	1150	260	2.80	3.10	1050	220
14	9.40	9.70	420	170	15.00	15.00	690	450	18.00	17.50	590	350
15	2.70	3.00	1100	97	2.90	3.00	1800	200	2.00	2.10	1200	175
16	3.40	3.60	460	130	4.80	4.90	1700	400	4.50	2.10	1300	330
17	1.60	1.80	1100	200	2.30	2.40	1700	570	2.30	2.30	1500	550

TABLE 21

MAINTENANCE DATA SHEET

Bridge Deck Identification: US 87 Railroad Overpass – Howard County, Big Spring, Texas

Rectifier Location: N.E. Abutment Wall Deck Condition: Dry

Date: 2/1/89 Time: 2:20 PM Ambient Temperature: 72° F

Tester(s): TR Rectifier Model No.: TIACE 40/20-10(17)DGNPSZ

Rectifier S/N: 88A1052 Type 0033052 Rectifier DC Rating: DC Amps 10 (ckts 1-17) DC Volts 20 (ckts 1-13) 40 (ckts 14-17)

General Remarks: Re-energization data.

Circuit	Control Light (on/off)	Rebar Probe (volts)	Reference Cell (volts)	Voltage (volts)	Current (amps)	Instant-off Reference cell (volts)*	Remarks
1	ON	.002	.404	5.4	4.80	.371	
2	ON	.005	.508	4.6	3.55	.395	
3	ON	.005	.441	4.8	3.26	.380	
4	ON	.005	.428	5.3	4.81	.389	
5	ON	.005	.521	6.4	4.88	.420	
6	ON	.002	.372	6.5	5.32	.337	
7	ON	.006	.482	6.8	4.78	.388	
8	ON	.005	.577	6.7	5.56	.451	
9	ON	.003	.406	2.7	4.26	.351	
10	ON	.005	.379	3.6	6.07	.325	
11	ON	-.012	.311	9.7	.36	.312	
12	ON	.006	.353	15.8	.32	.328	
13	ON	.011	.653	2.5	.45	.569	
14	ON	.028.	.864	3.0	.13	.554	
15	ON	.002	.349	.8	.41	.289	
16	ON	.014	.434	1.9	.25	.365	
17	ON	.013	1.335	5.5	1.29	.690	
				Total current	50.2		

Note: Refer to instruction sheet concerning all measurements.
* Measurements require a portable voltmeter.

bstx6(w1-f1)

TABLE 22

MAINTENANCE DATA SHEET

Bridge Deck Identification: US 87 Railroad Overpass – Howard County, Big Spring, Texas

Rectifier Location: N.E. Abutment Wall Deck Condition: Dry

Date: 2/2/89 Time: 8:30 AM Ambient Temperature: 52° F

Tester(s): TR Rectifier Model No.: TIACE 40/20–10(17)DGNPSZ

Rectifier S/N: 88A1052 Type 0033052 Rectifier DC Rating: DC Amps 10 (ckts 1–17) DC Volts 20 (ckts 1–13) 40 (ckts 14–17)

General Remarks:

Circuit	Control Light (on/off)	Rebar Probe (volts)	Reference Cell (volts)	Voltage (volts)	Current (amps)	Instant-off Reference cell (volts)*	Remarks
1	ON	.004	.479	5.5	4.85	.418	
2	ON	.004	.574	4.7	3.56	.449	
3	ON	.005	.501	5.1	3.28	.392	
4	ON	.004	.485	5.5	4.86	.433	
5	ON	.003	.901	9.3	4.91	.570	
6	ON	.007	.692	9.3	5.34	.499	
7	ON	.005	.666	9.6	4.81	.482	
8	ON	.003	.710	9.0	5.61	.506	
9	ON	.005	.475	3.4	4.29	.387	
10	ON	.005	.463	4.5	6.13	.395	
11	ON	–.010	.318	19.5	0.42	.311	
12	ON	.008	.337	24.9	0.25	.317	
13	ON	.015	.675	4.1	0.46	.596	
14	ON	.015	.752	5.6	0.15	.536	
15	ON	.000	.315	0.9	0.45	.285	
16	ON	.008	.518	3.3	0.28	.444	
17	ON	.009	1.209	7.0	1.31	.740	
				Total current	50.70		

Note: Refer to instruction sheet concerning all measurements.
* Measurements require a portable voltmeter.

bstx7(w1-f1)

TABLE 23

SUMMARY OF PROTECTIVE CURRENT SETTINGS
INITIAL, 45 AND 90 DAYS

		INITIAL NOVEMBER 1988				45 DAYS DECEMBER 1988		90 DAYS FEBRUARY 1989	
CKT	CONCRETE SURFACE AREA (FT SQ)	ELOGI CURRENT (A)	ELOGI CURRENT DENSITY (mA/sq ft)	ACTUAL CURRENT SETTING (A)	CURRENT DENSITY (MA/SQ FT)	CURRENT SETTING (A)	CURRENT DENSITY (MA/SQ FT)	CURRENT SETTING (A)	CURRENT DENSITY (MA/SQ FT)
1	2884	5.124	1.78	4.5	1.56	4.50	1.56	4.750	1.64
2	2884	4.099	1.42	4.0	1.39	3.50	1.21	3.500	1.21
3	2884	4.899	1.70	3.5	1.21	3.20	1.11	3.200	1.11
4	2884	7.746	2.69	4.5	1.56	4.50	1.56	4.750	1.64
5	2884	5.997	2.08	5.8	2.01	5.00	1.73	4.800	1.67
6	2884	9.246	3.21	5.8	2.01	5.50	1.91	5.250	1.82
7	2884	6.697	2.32	5.0	1.73	4.70	1.63	4.700	1.63
8	2884	6.697	2.32	5.8	2.01	5.50	1.91	5.500	1.91
9	4704	4.845	1.03	4.5	0.96	4.20	0.89	4.200	0.89
10	4704	6.797	2.36	6.0	1.28	6.00	1.28	6.000	1.28
11	412	0.590	1.43	0.4	0.85	0.30	0.73	0.350	0.85
12	1648	0.940	0.57	0.9	0.55	0.35	0.21	0.325	0.21
13	1854	0.730	0.39	0.9	0.46	0.50	0.27	0.450	0.24
14	168	0.345	2.05	0.2	0.89	0.10	0.60	0.100	0.60
15	672	0.424	0.63	0.3	0.37	0.25 *	0.37	0.400	0.60
16	756	0.220	0.29	0.3	0.4	0.20	0.26	0.250	0.26
17	1180	4.299	3.64	2.3	1.91	1.50	1.27	1.250	1.06

* MINIMUM CURRENT OUTPUT ALLOWED BY THE CONTROL CARD OF THE CIRCUIT

FIGURES

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA		
BIG SPRING - TX ZONE A1		
TAFEL SLOPE	=	183.67 MILLIVOLTS/DECADE
ICORR	=	2724.63 MILLIAMPS
ECORR	=	-360 MILLIVOLTS
IPROTECT	=	5123.58 MILLIAMPS
EPROTECT	=	-410.38 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.428166
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999061
NO. OF OBSERVATIONS USED	=	11

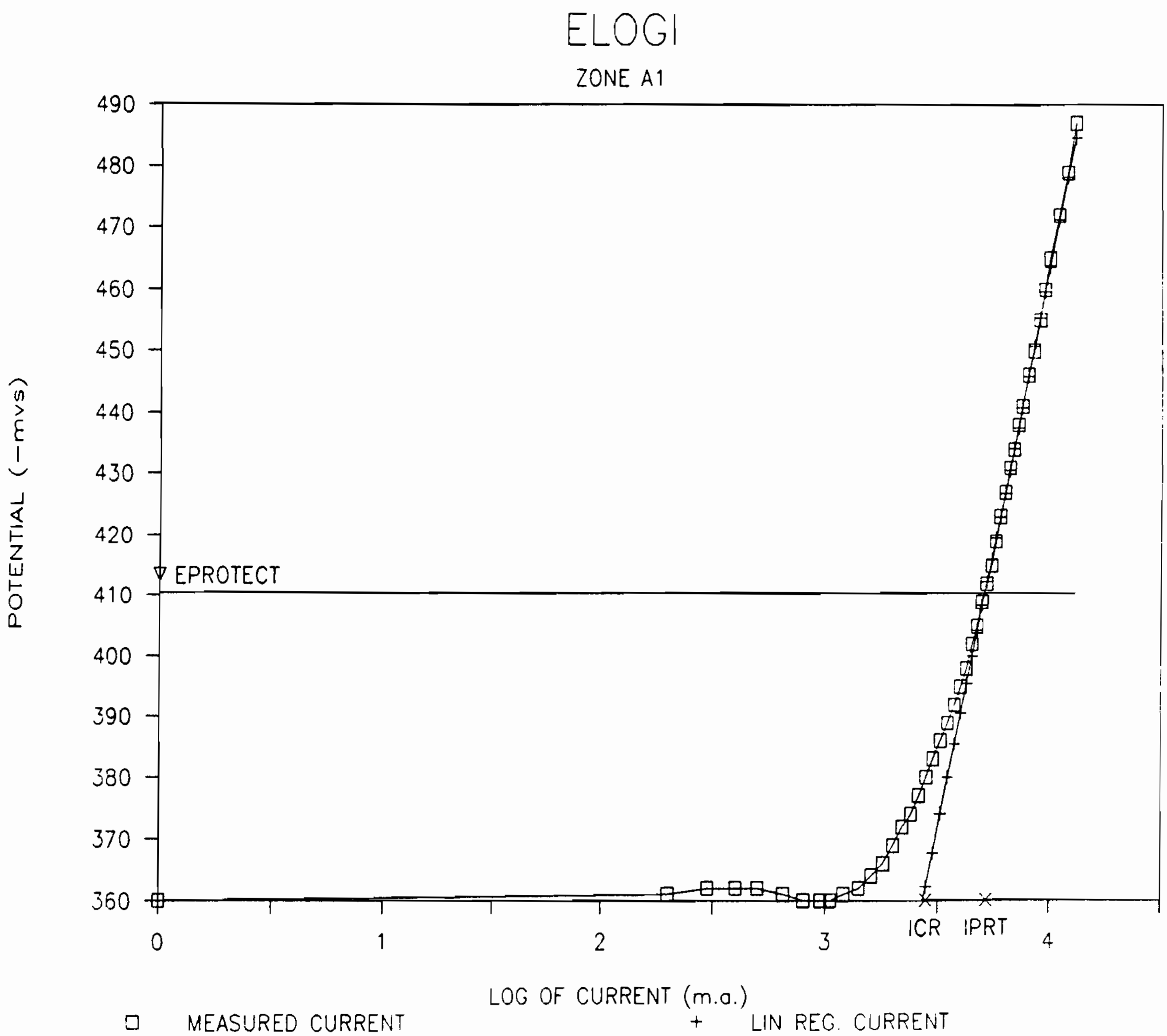

FIGURE 1

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA

BIG SPRING - TX   ZONE A2

TAFEL SLOPE	=	248.99	MILLIVOLTS/DECADE
ICORR	=	1225.44	MILLIAMPS
ECORR	=	-312	MILLIVOLTS
IPROTECT	=	4098.69	MILLIAMPS
EPROTECT	=	-442.56	MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.432262
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999685
NO. OF OBSERVATIONS USED	=	15

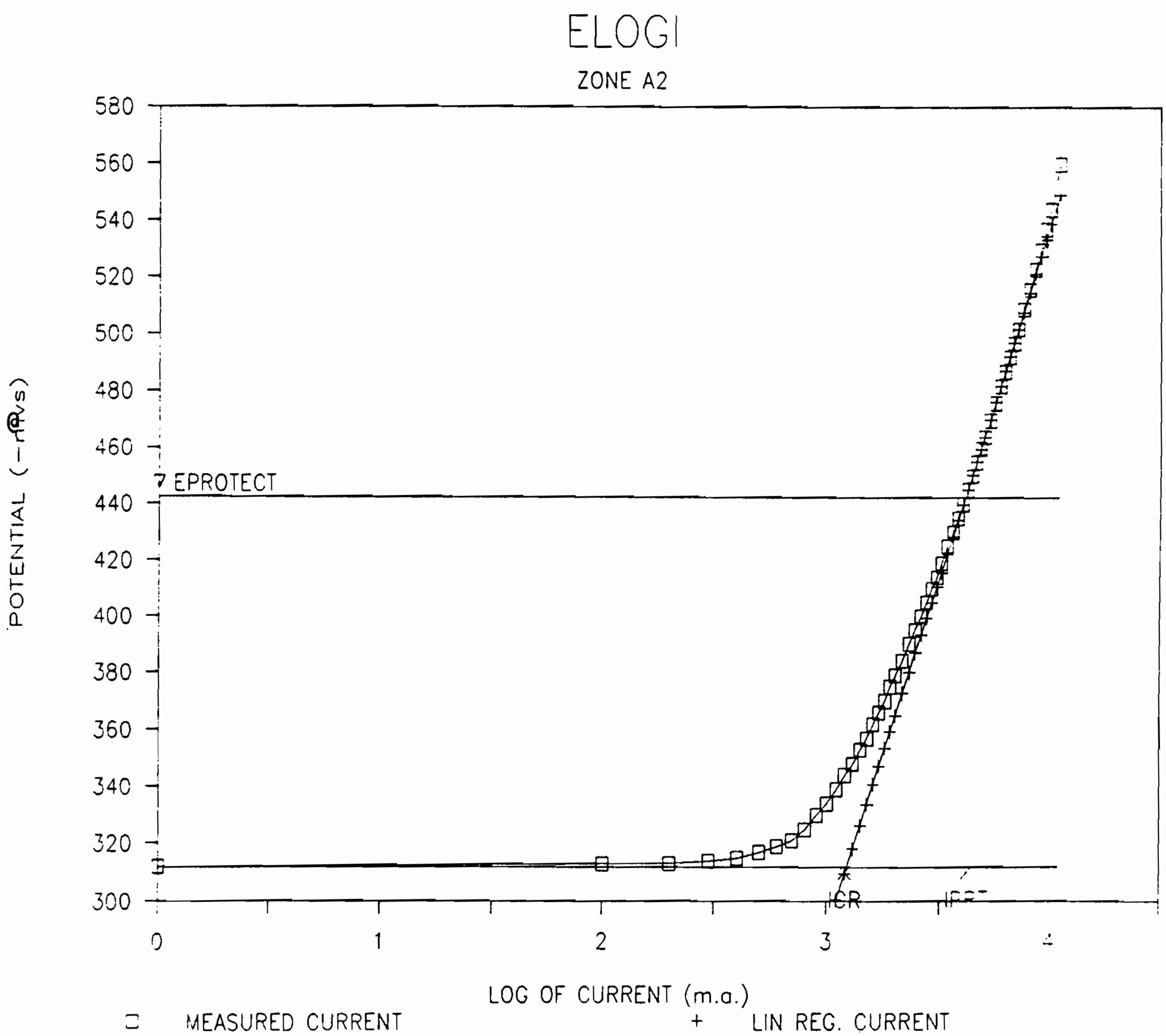

FIGURE 2

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA

BIG SPRING - TX ZONE A3

TAFEL SLOPE	=	205.94 MILLIVOLTS/DECADE
ICORR	=	1113.33 MILLIAMPS
ECORR	=	-262 MILLIVOLTS
IPROTECT	=	4898.84 MILLIAMPS
EPROTECT	=	-394.52 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.574852
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999392
NO. OF OBSERVATIONS USED	=	14

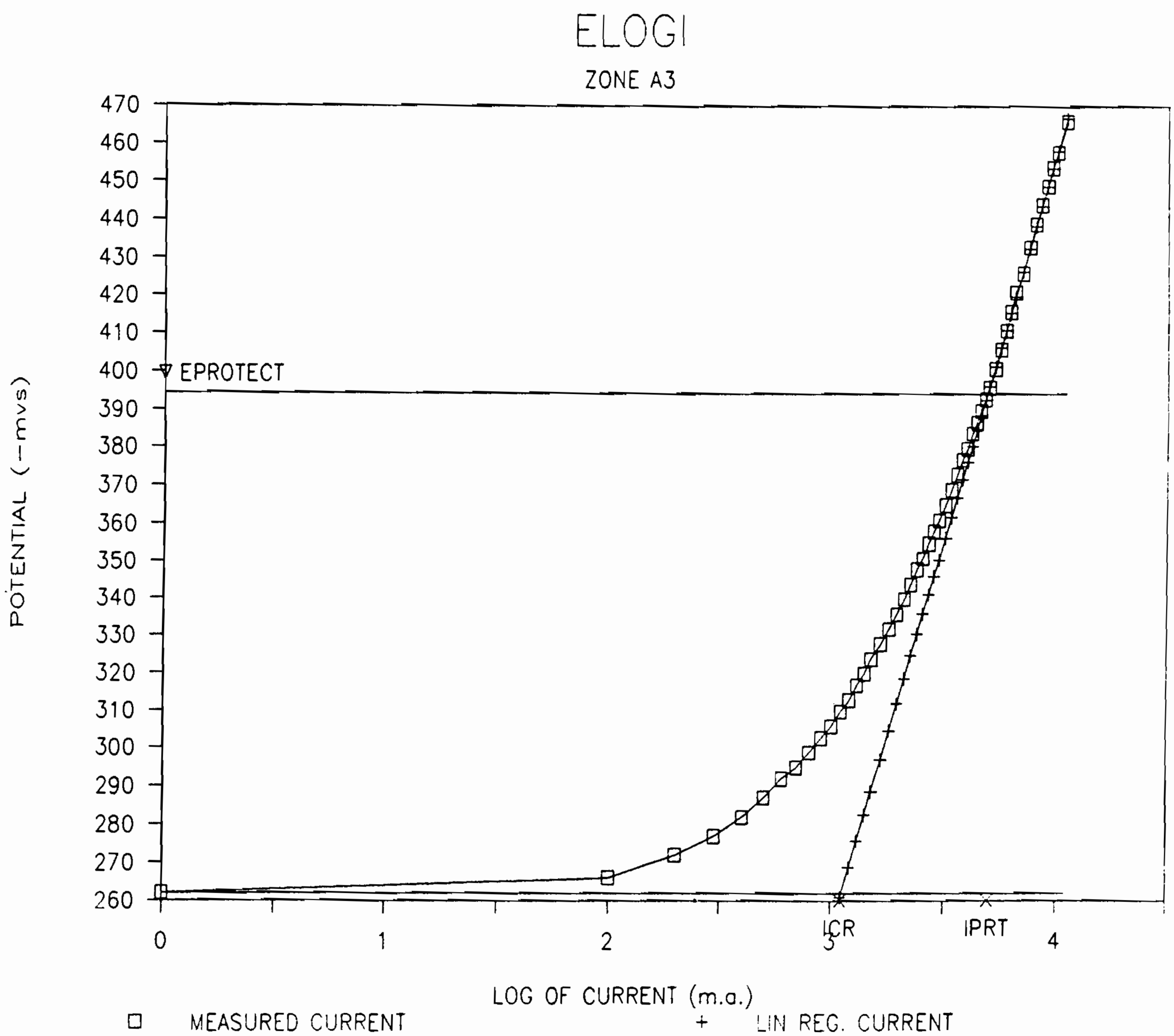

FIGURE 3

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA
BIG SPRING - TX ZONE A4

TAFEL SLOPE	=	168.84 MILLIVOLTS/DECADE
ICORR	=	3019.33 MILLIAMPS
ECORR	=	-361 MILLIVOLTS
IPROTECT	=	7746.05 MILLIAMPS
EPROTECT	=	-430.09 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.261714
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999568
NO. OF OBSERVATIONS USED	=	8

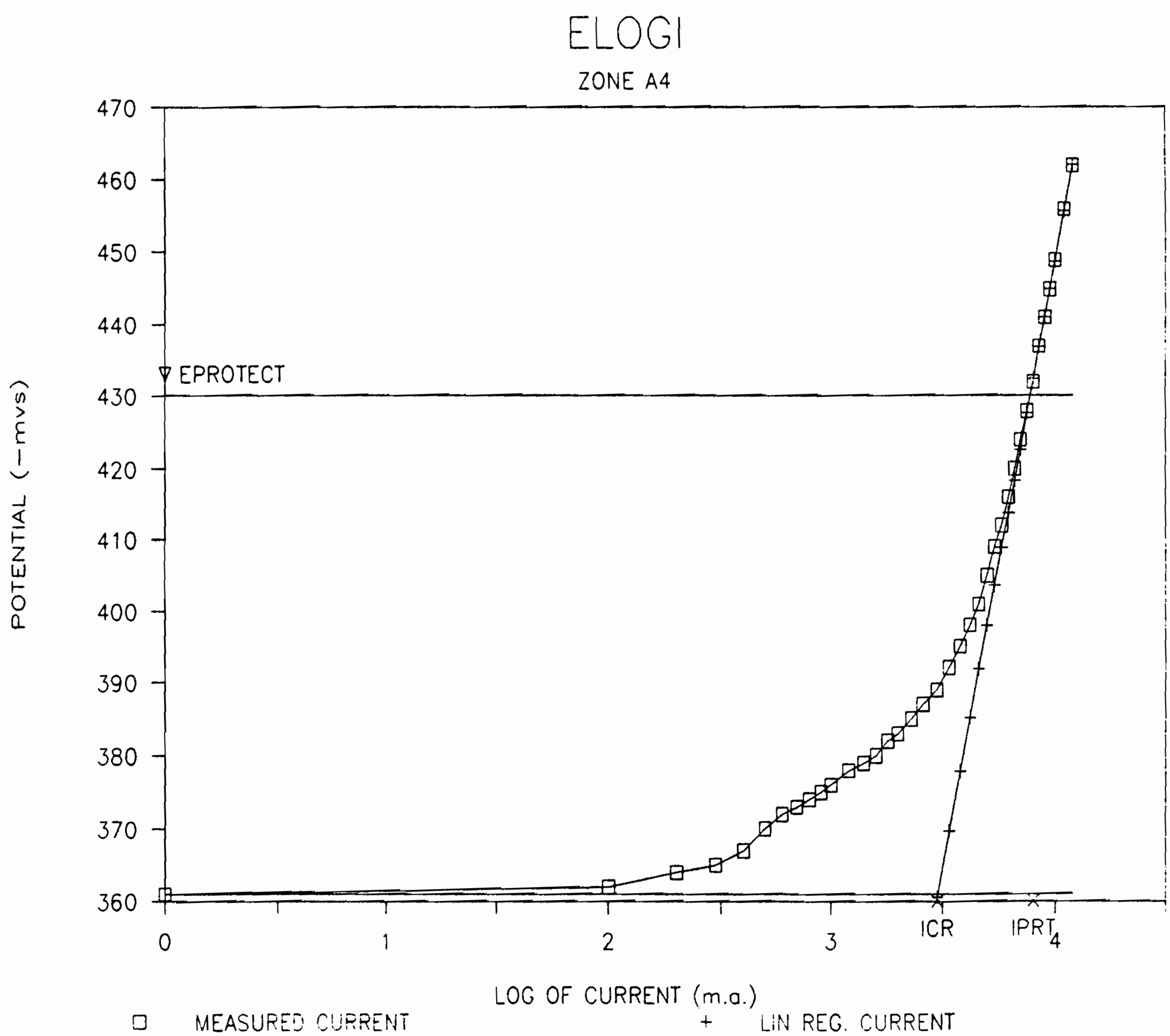

FIGURE 4

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA
BIG SPRING - TX ZONE B1

TAFEL SLOPE	=	163.79	MILLIVOLTS/DECADE
ICORR	=	1914.98	MILLIAMPS
ECORR	=	-330	MILLIVOLTS
IPROTECT	=	5996.69	MILLIAMPS
EPROTECT	=	-411.20	MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.398491
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.998958
NO. OF OBSERVATIONS USED	=	10

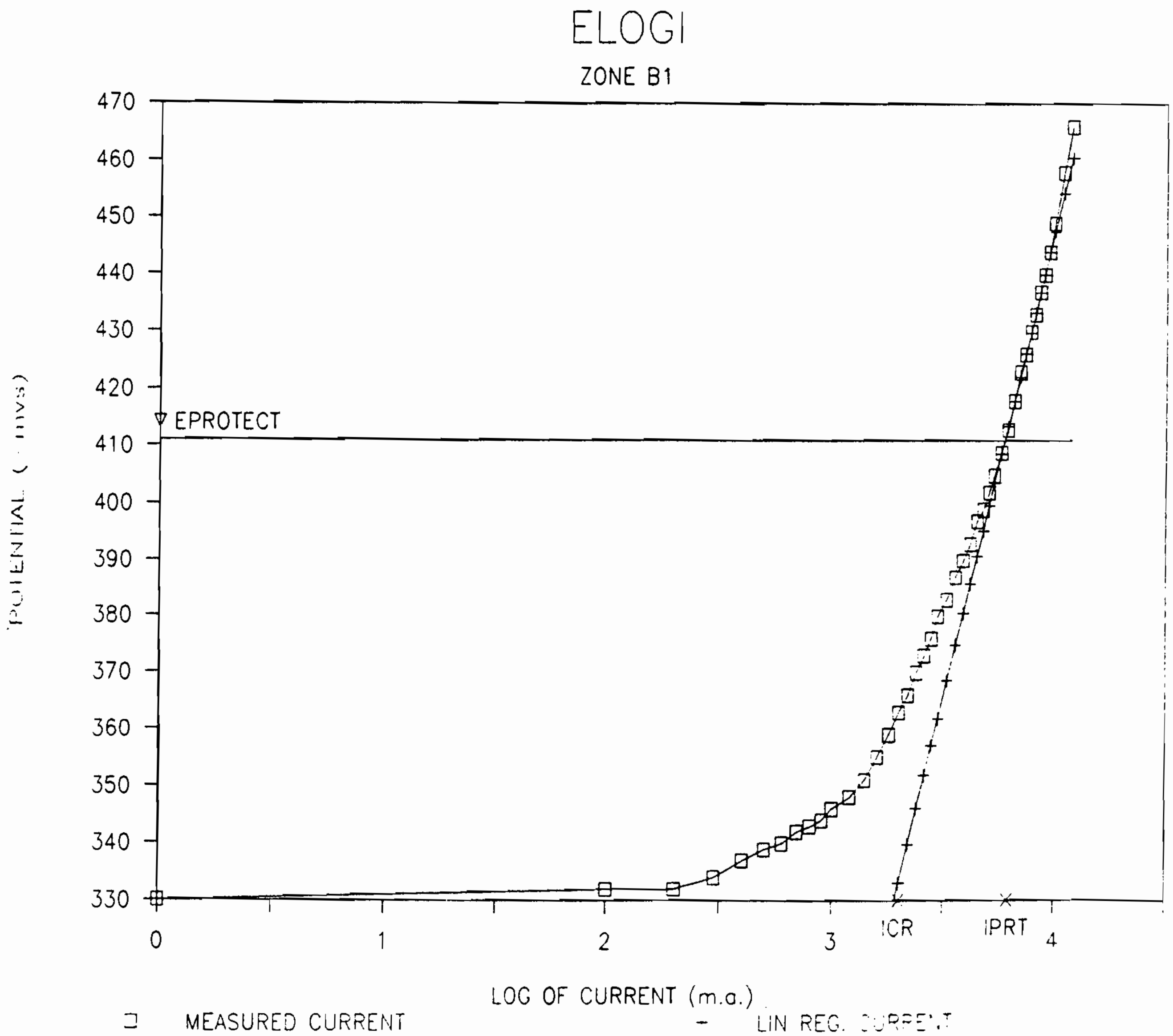

FIGURE 5

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA
BIG SPRING - TX ZONE B2

TAFEL SLOPE	=	152.85 MILLIVOLTS/DECADE
ICORR	=	3152.79 MILLIAMPS
ECORR	=	-347 MILLIVOLTS
IPROTECT	=	9246.39 MILLIAMPS
EPROTECT	=	-418.43 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.411787
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.998130
NO. OF OBSERVATIONS USED	=	6

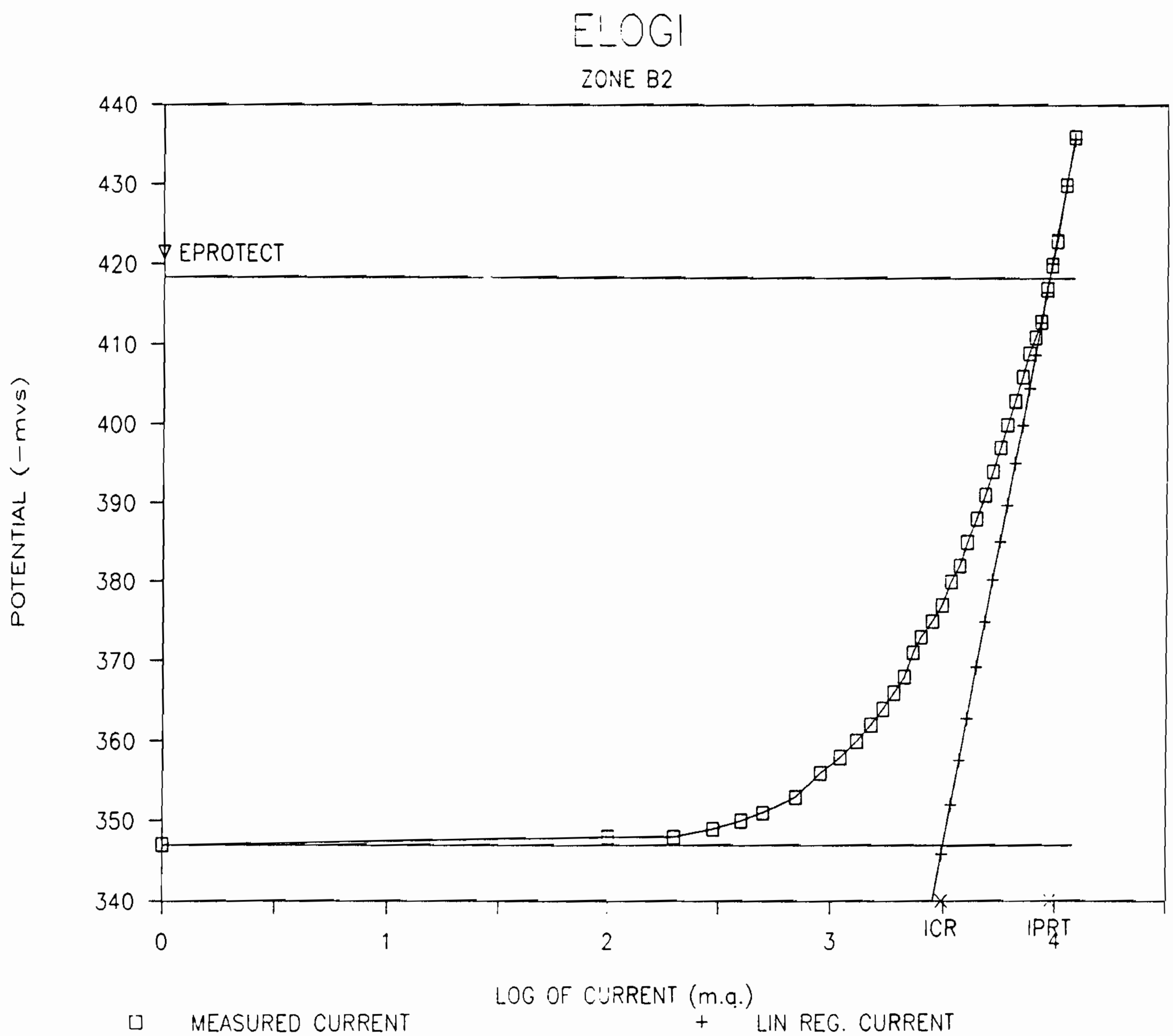

FIGURE 6

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA BIG SPRING - TX ZONE B3		
TAFEL SLOPE	=	274.73 MILLIVOLTS/DECADE
ICORR	=	2085.94 MILLIAMPS
ECORR	=	-309 MILLIVOLTS
IPROTECT	=	6697.10 MILLIAMPS
EPROTECT	=	-448.18 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT		
STANDARD ERROR OF Y ESTIMATE	=	0.730709
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999438
NO. OF OBSERVATIONS USED	=	14

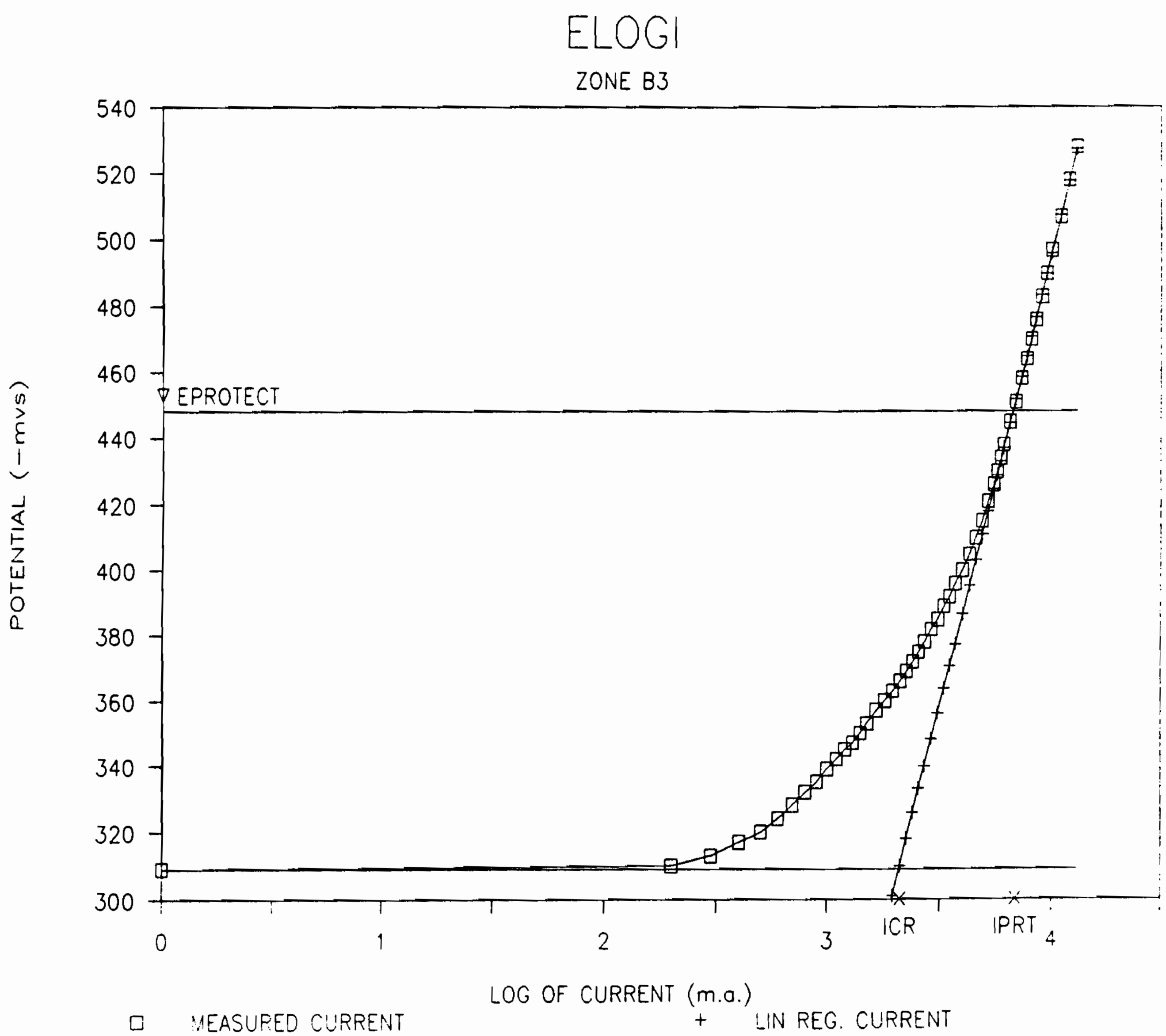

FIGURE 7

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA BIG SPRING - TX ZONE B4		
TAFEL SLOPE	=	222.54 MILLIVOLTS/DECADE
ICORR	=	2262.67 MILLIAMPS
ECORR	=	-325 MILLIVOLTS
IPROTECT	=	6696.92 MILLIAMPS
EPROTECT	=	-429.88 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT		
STANDARD ERROR OF Y ESTIMATE	=	0.463674
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.998732
NO. OF OBSERVATIONS USED	=	7

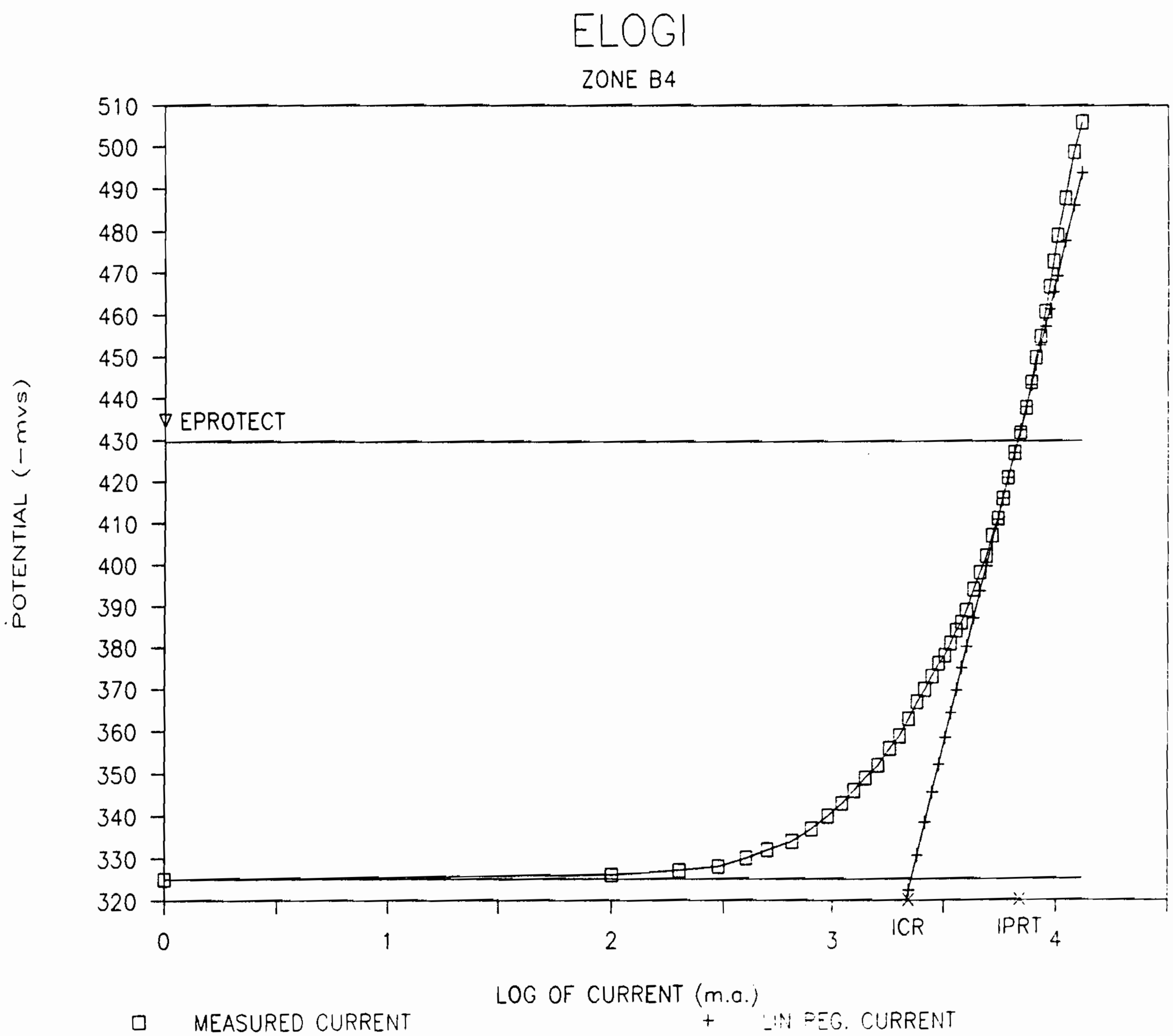

FIGURE 8

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA
BIG SPRING - TX ZONE C1

TAFEL SLOPE	=	187.69 MILLIVOLTS/DECADE
ICORR	=	1156.16 MILLIAMPS
ECORR	=	-303 MILLIVOLTS
IPROTECT	=	4847.87 MILLIAMPS
EPROTECT	=	-419.84 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.394872
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999651
NO. OF OBSERVATIONS USED	=	15

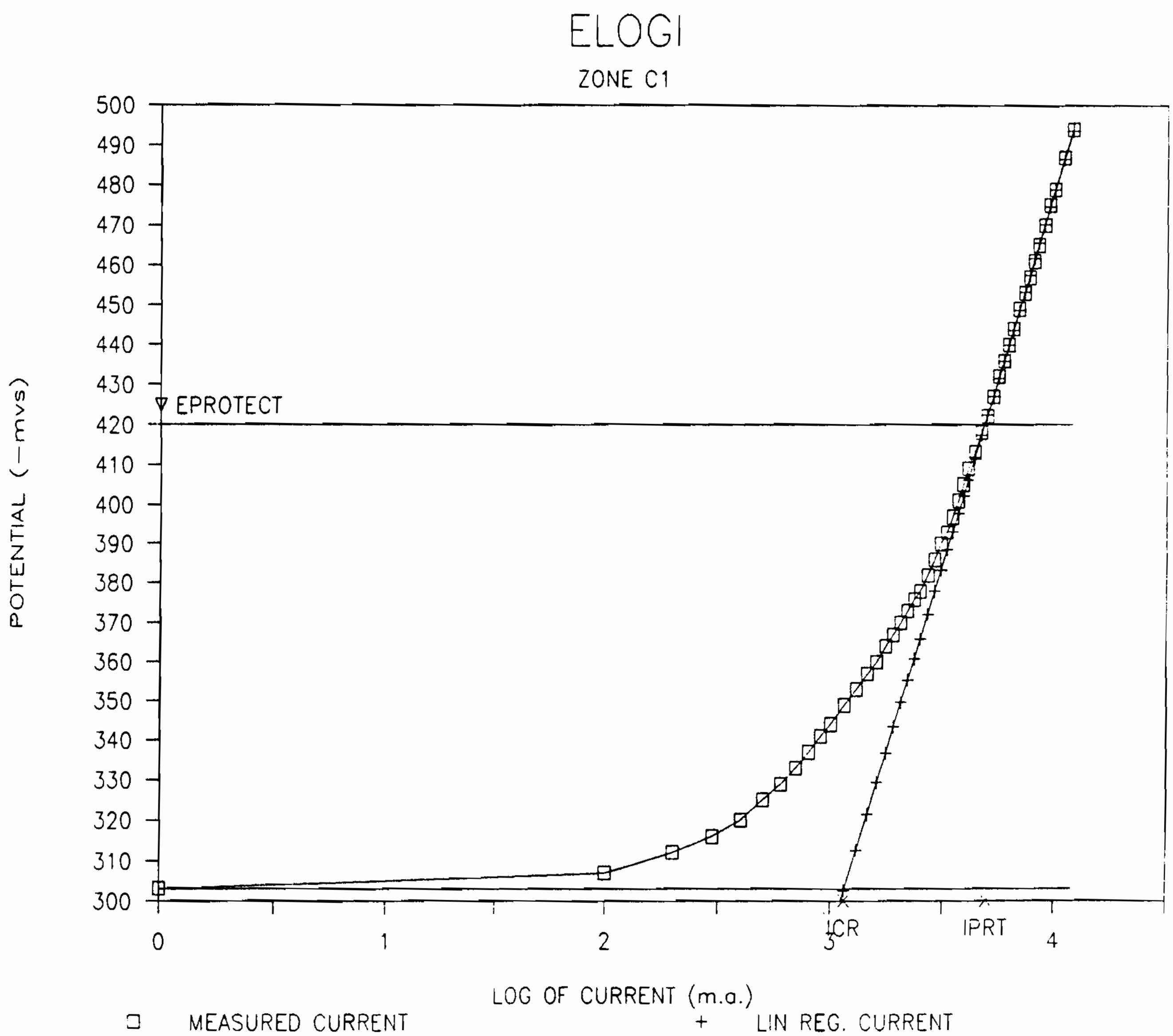

FIGURE 9

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA BIG SPRING - TX ZONE C2		
TAFEL SLOPE	=	156.06 MILLIVOLTS/DECADE
ICORR	=	1727.57 MILLIAMPS
ECORR	=	-282 MILLIVOLTS
IPROTECT	=	6797.11 MILLIAMPS
EPROTECT	=	-374.84 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT		
STANDARD ERROR OF Y ESTIMATE	=	0.732743
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.997992
NO. OF OBSERVATIONS USED	=	12

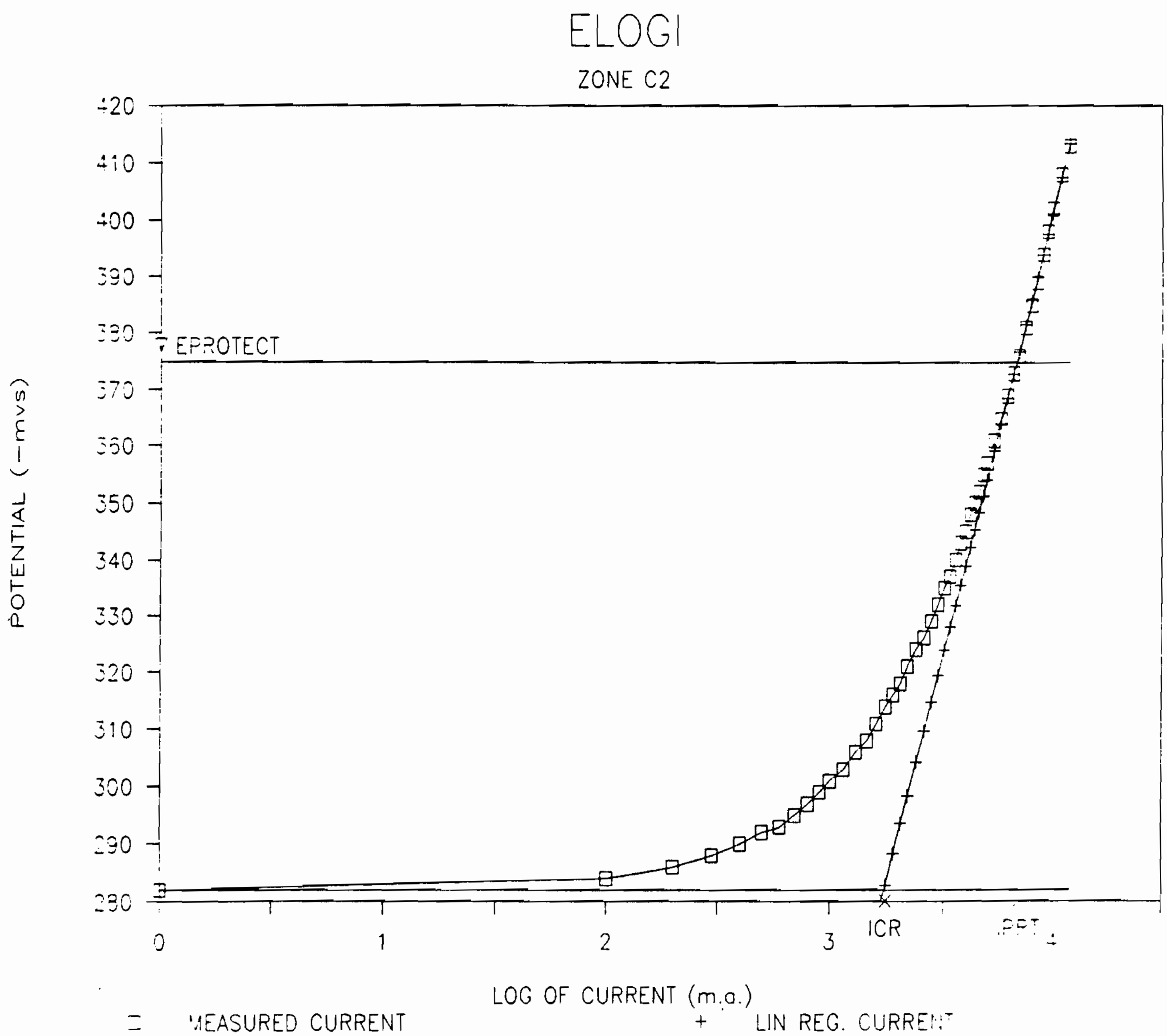

FIGURE 10

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA BIG SPRING - TX ZONE D1			
TAFEL SLOPE	=	1060.99	MILLIVOLTS/DECADE
ICORR	=	386.19	MILLIAMPS
ECORR	=	-301	MILLIVOLTS
IPROTECT	=	939.78	MILLIAMPS
EPROTECT	=	-710.79	MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT		
STANDARD ERROR OF Y ESTIMATE	=	1.712770
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999392
NO. OF OBSERVATIONS USED	=	6

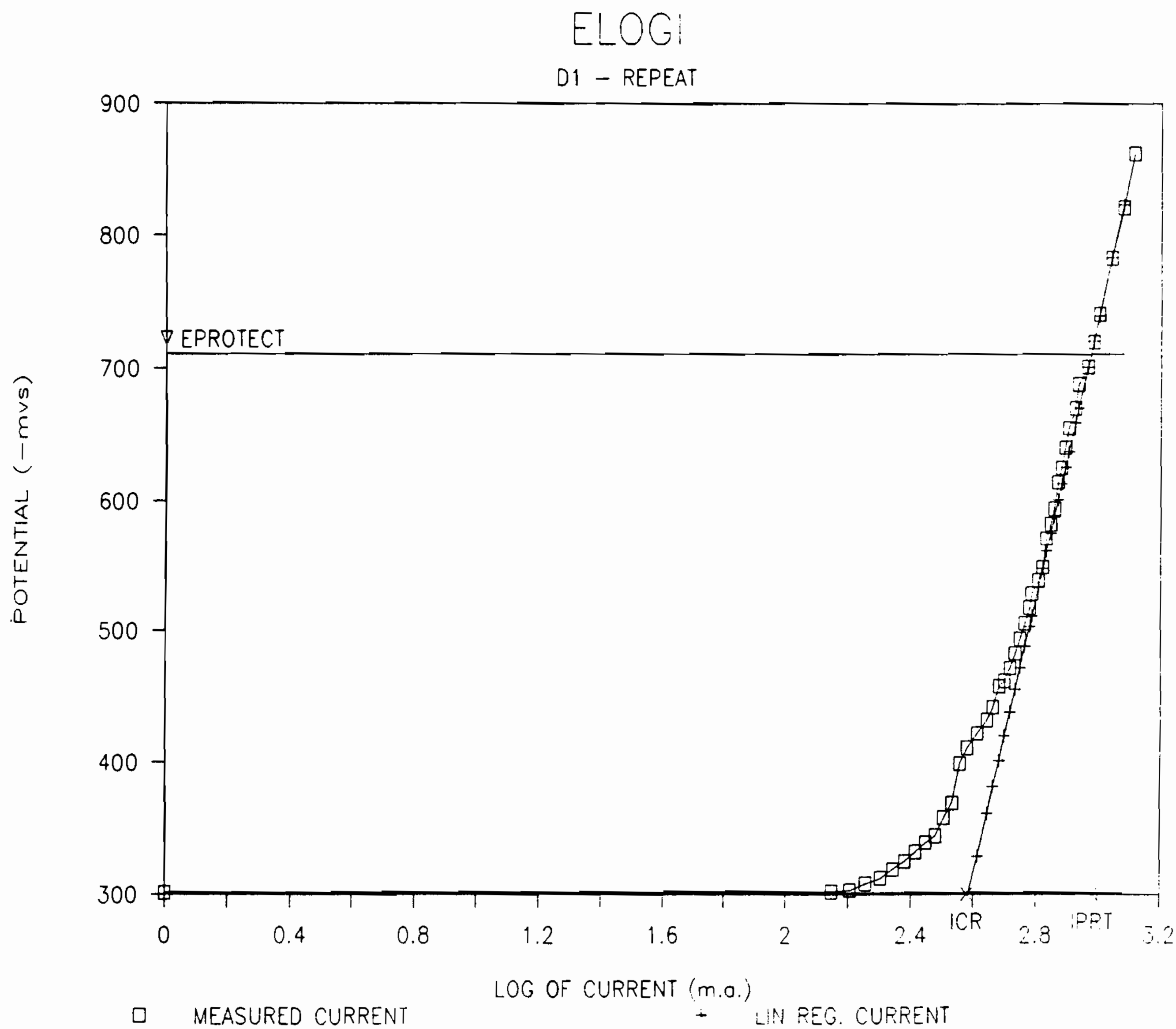

FIGURE 11

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA BIG SPRING - TX ZONE D2		
TAFEL SLOPE	=	1543.24 MILLIVOLTS/DECADE
ICORR	=	328.06 MILLIAMPS
ECORR	=	-342 MILLIVOLTS
IPROTECT	=	589.92 MILLIAMPS
EPROTECT	=	-735.27 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT		
STANDARD ERROR OF Y ESTIMATE	=	0.849529
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999707
NO. OF OBSERVATIONS USED	=	7

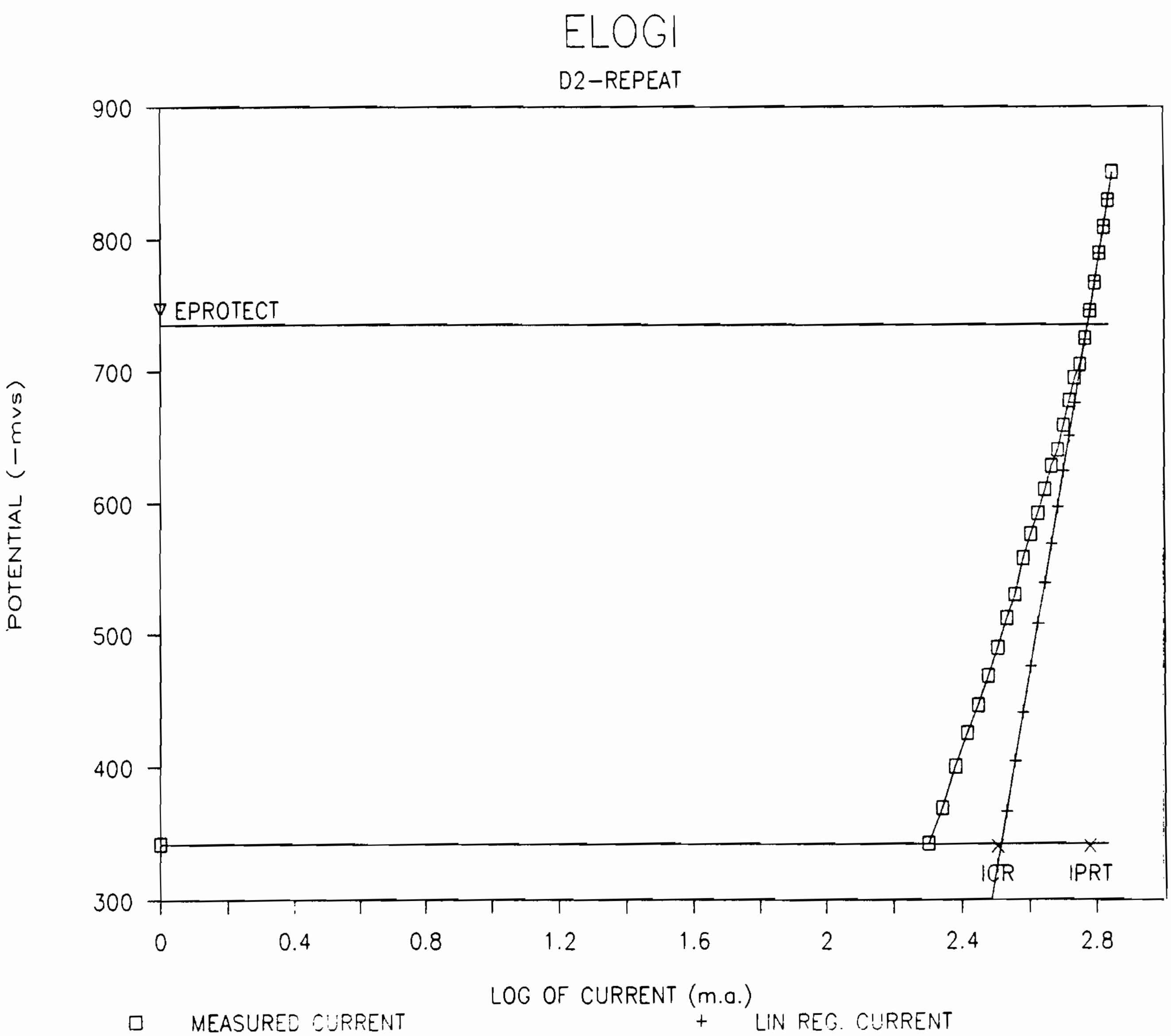

FIGURE 12

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA
BIG SPRING - TX ZONE D3

TAFEL SLOPE	=	343.51 MILLIVOLTS/DECADE
ICORR	=	290.96 MILLIAMPS
ECORR	=	-410 MILLIVOLTS
IPROTECT	=	729.39 MILLIAMPS
EPROTECT	=	-547.11 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.841697
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999096
NO. OF OBSERVATIONS USED	=	8

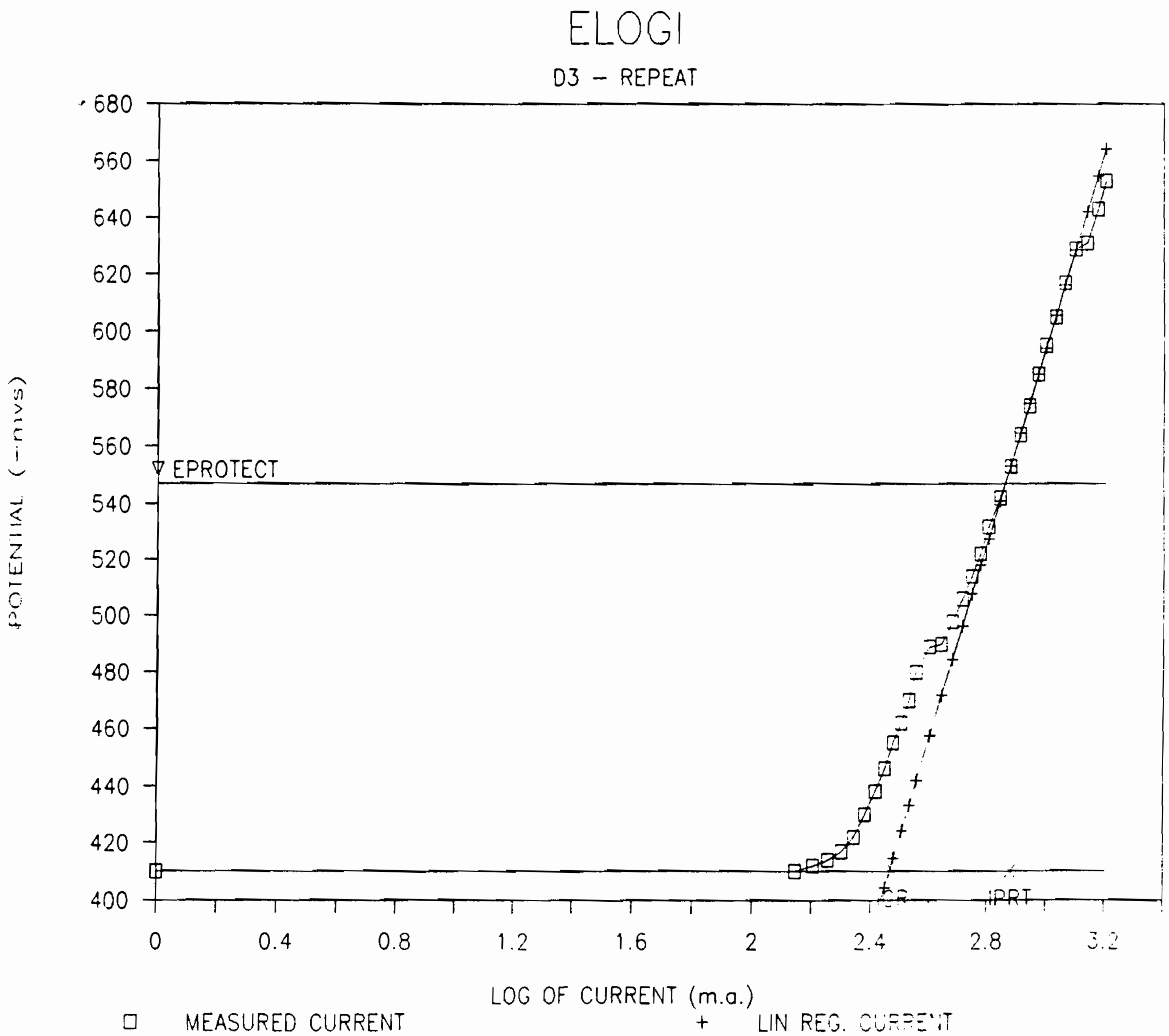

FIGURE 13

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA
BIG SPRING - TX ZONE D4

TAFEL SLOPE	=	872.33 MILLIVOLTS/DECADE
ICORR	=	188.79 MILLIAMPS
ECORR	=	-307 MILLIVOLTS
IPROTECT	=	344.67 MILLIAMPS
EPROTECT	=	-535.06 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	2.717033
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.998199
NO. OF OBSERVATIONS USED	=	6

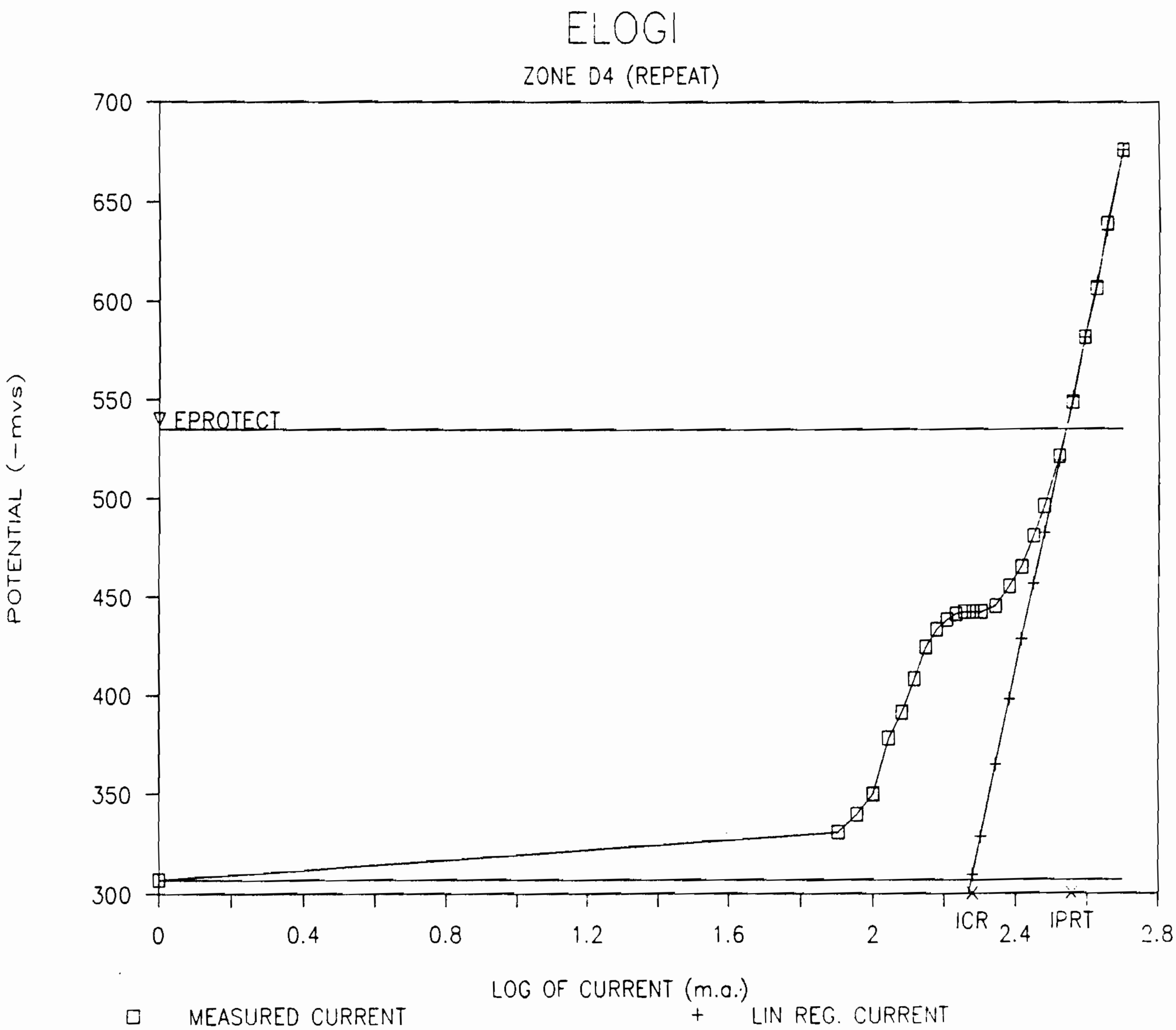

FIGURE 14

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA
BIG SPRING - TX ZONE D5

TAFEL SLOPE	=	307.58 MILLIVOLTS/DECADE
ICORR	=	116.36 MILLIAMPS
ECORR	=	-242 MILLIVOLTS
IPROTECT	=	424.27 MILLIAMPS
EPROTECT	=	-414.81 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	1.603983
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.996958
NO. OF OBSERVATIONS USED	=	7

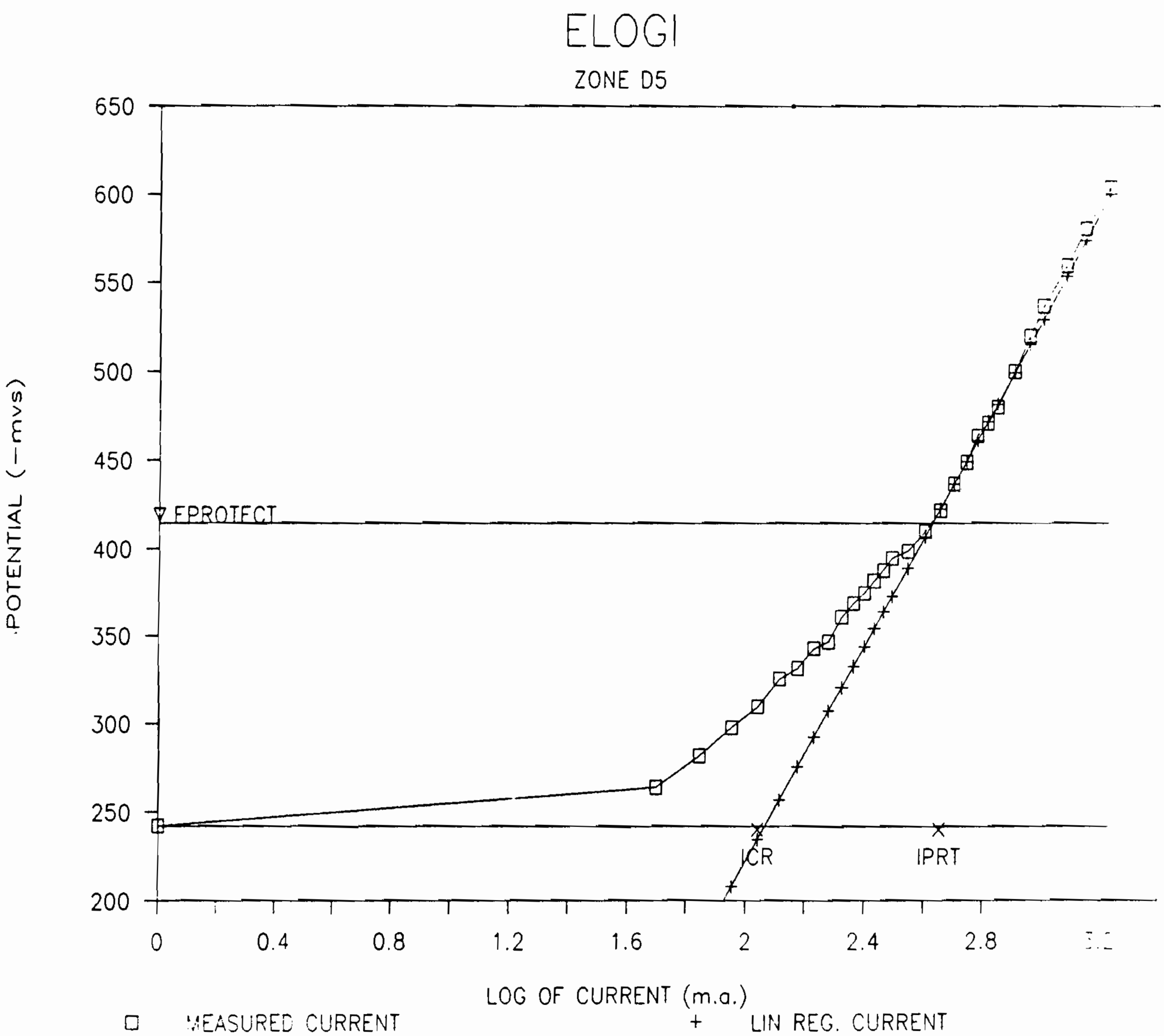

FIGURE 15

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA BIG SPRING - TX ZONE D6		
TAFEL SLOPE	=	239.34 MILLIVOLTS/DECADE
ICORR	=	71.00 MILLIAMPS
ECORR	=	-355 MILLIVOLTS
IPROTECT	=	219.78 MILLIAMPS
EPROTECT	=	-472.45 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT		
STANDARD ERROR OF Y ESTIMATE	=	1.641657
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.998120
NO. OF OBSERVATIONS USED	=	8

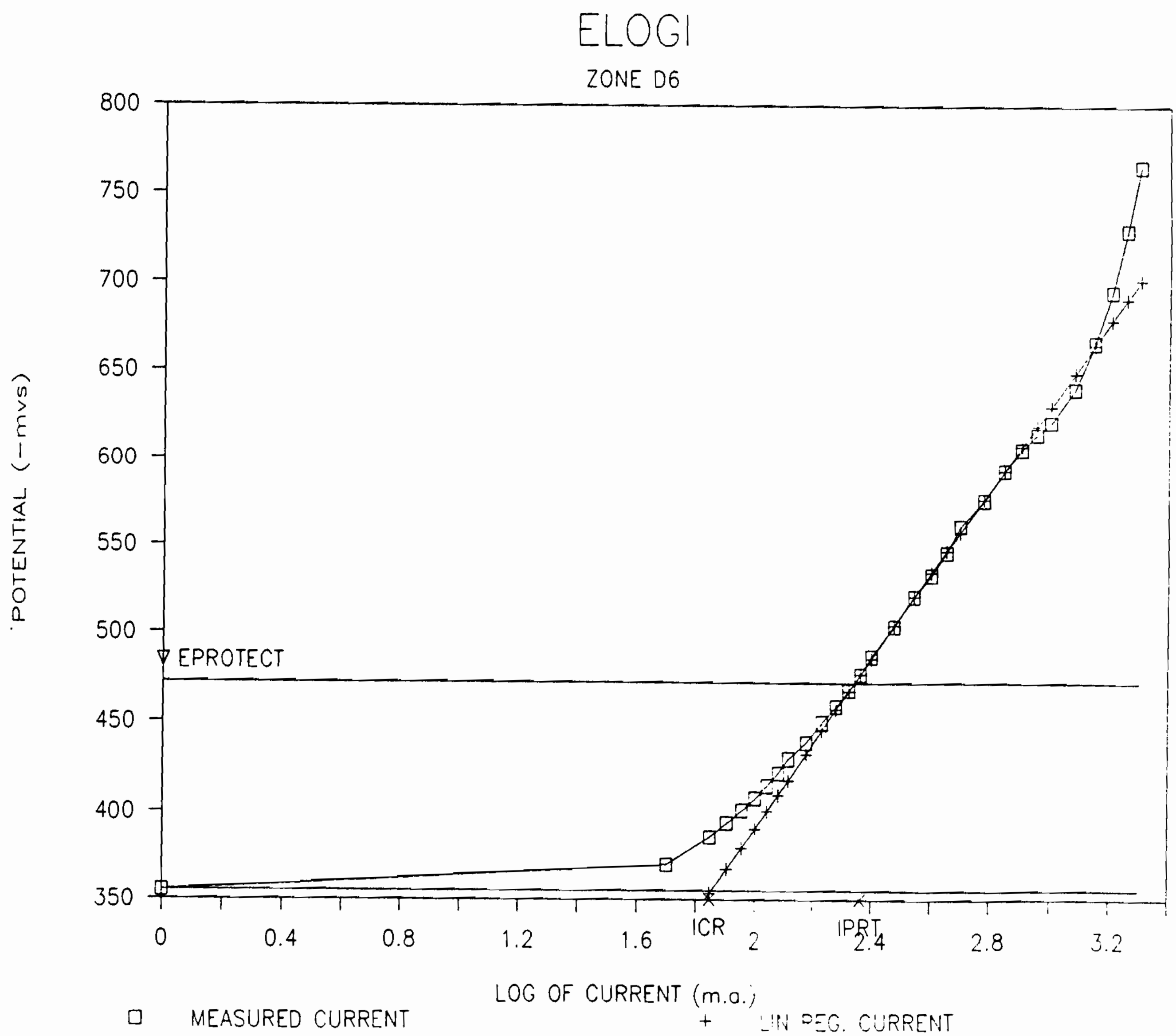

FIGURE 16

ELOGI COMPUTED CORROSION AND CATHODIC PROTECTION DATA
BIG SPRING - TX ZONE E

TAFEL SLOPE	=	507.25 MILLIVOLTS/DECADE
ICORR	=	1951.73 MILLIAMPS
ECORR	=	-264 MILLIVOLTS
IPROTECT	=	4298.91 MILLIAMPS
EPROTECT	=	-437.95 MILLIVOLTS

EVALUATION OF DATA FOR TAFEL LINE OF BEST FIT

STANDARD ERROR OF Y ESTIMATE	=	0.949378
COEFFICIENT OF DETERMINATION (R SQUARED)	=	0.999030
NO. OF OBSERVATIONS USED	=	11

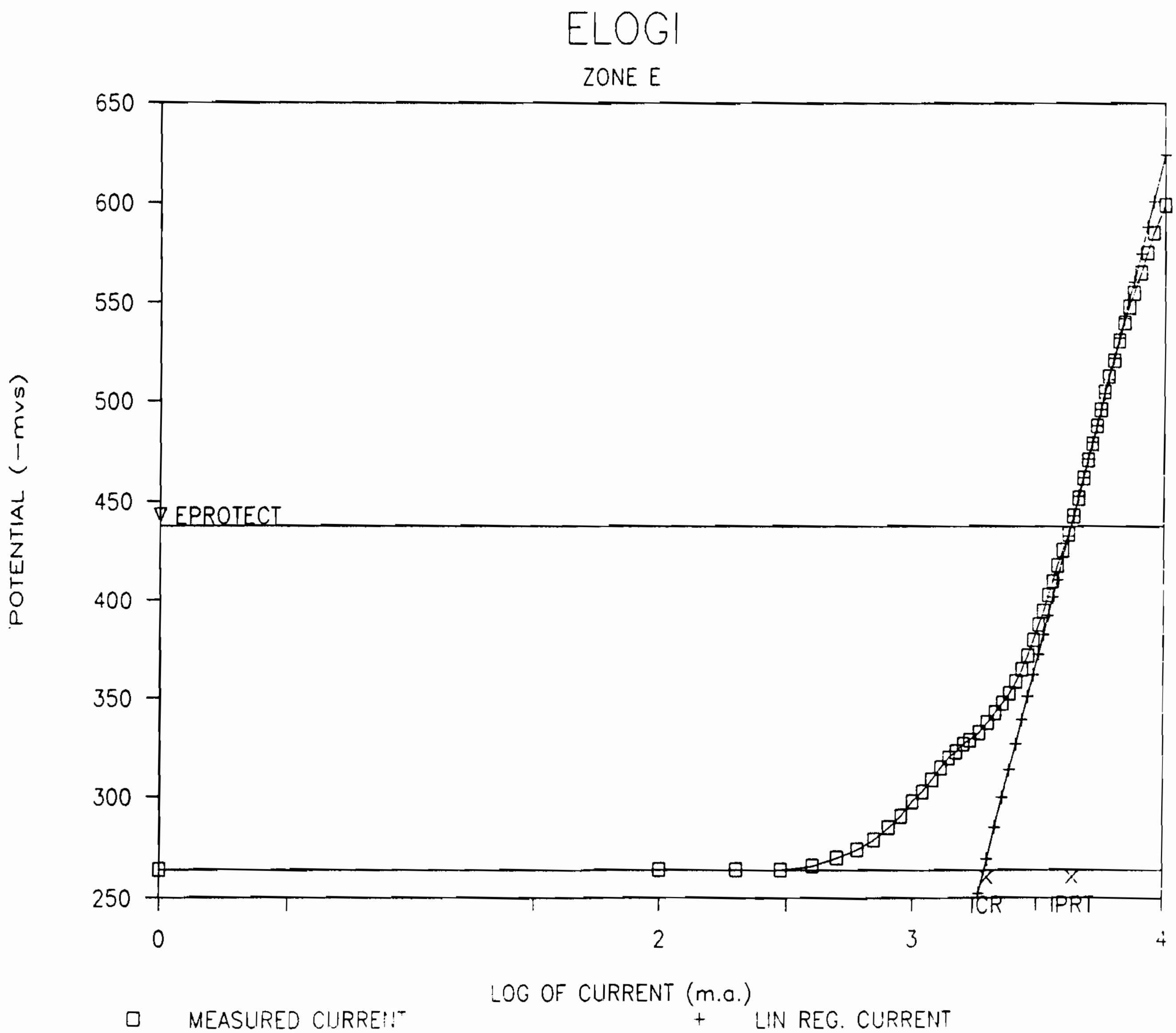

FIGURE 17

DEPOLARIZATION TEST DATA

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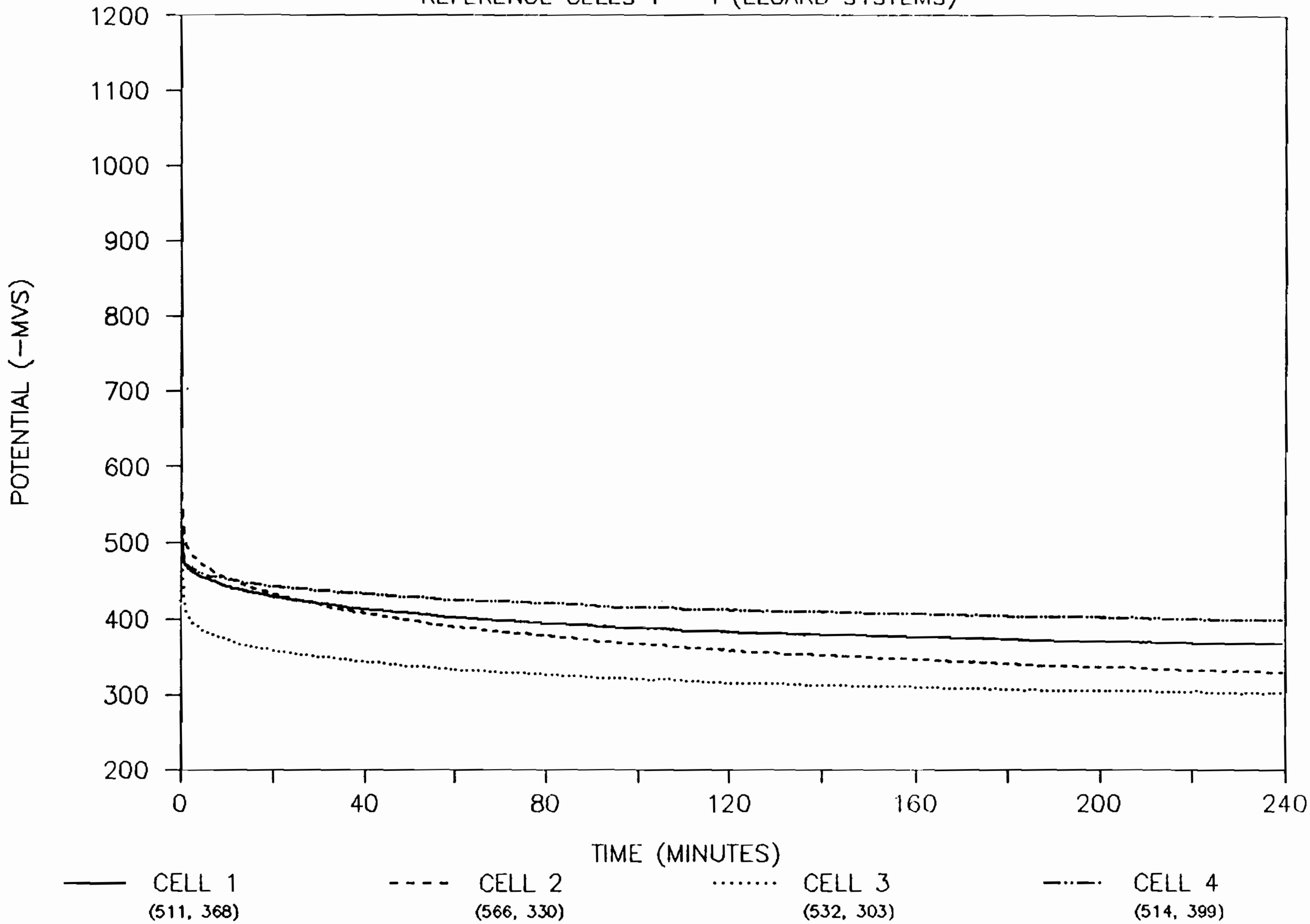
REFERENCE CELLS 1 – 4 (ELGARD SYSTEMS)



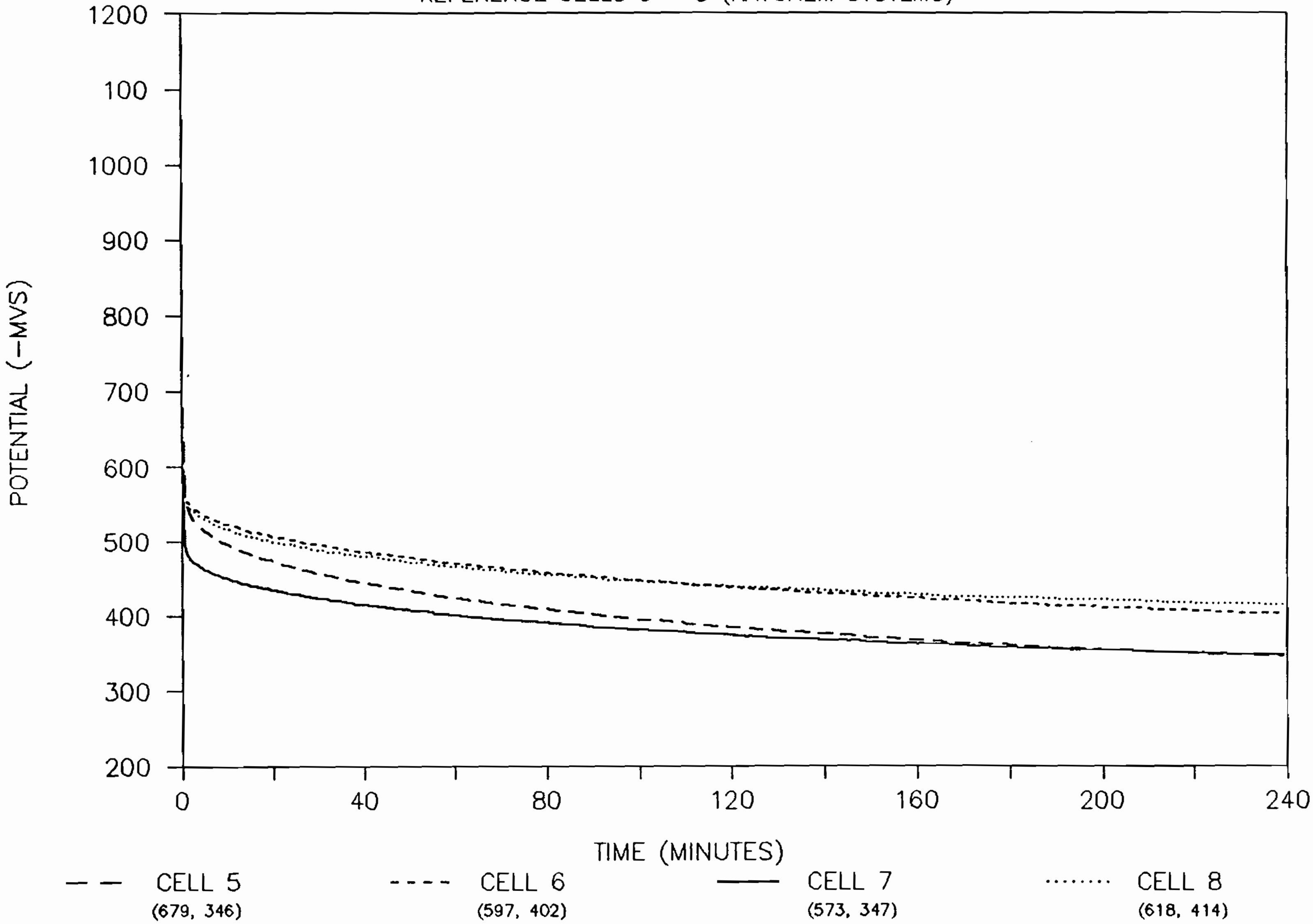
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 18

DEPOLARIZATION TEST DATA

12/88

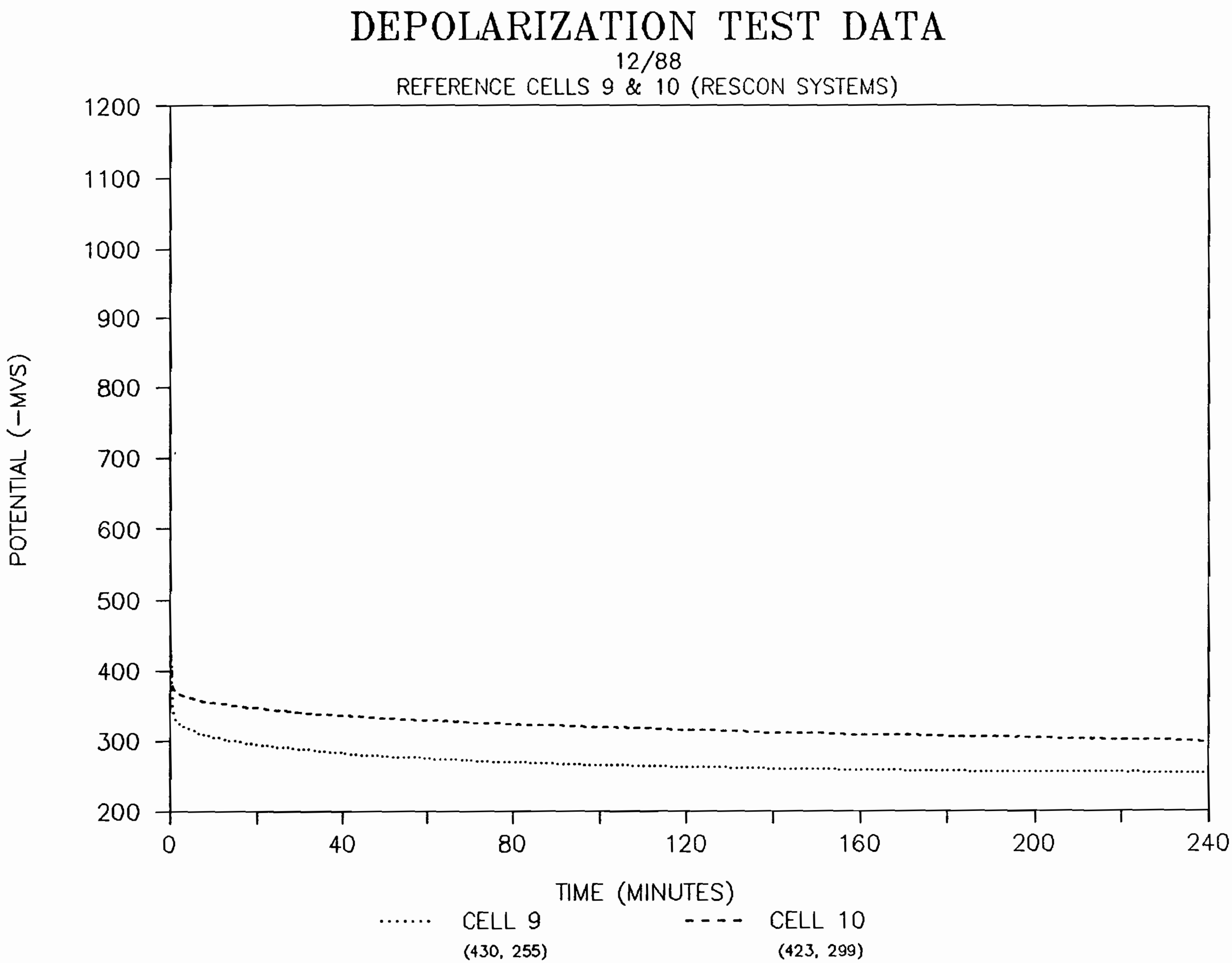
REFERENCE CELLS 5 – 8 (RAYCHEM SYSTEMS)



Note: x,y x: Instant-off reference cell potential measurement

y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 19



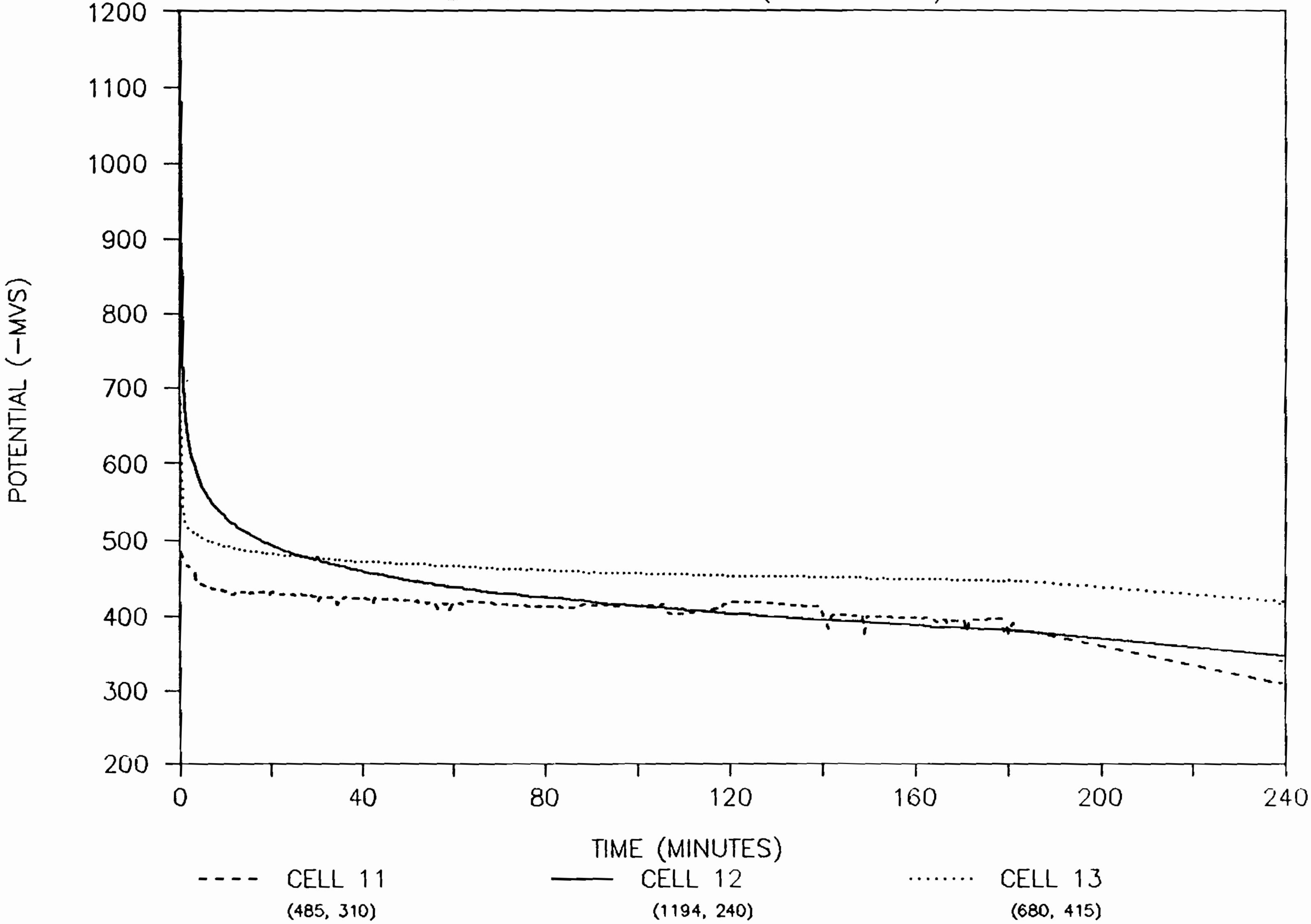
Note: x,y   x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 20

DEPOLARIZATION TEST DATA

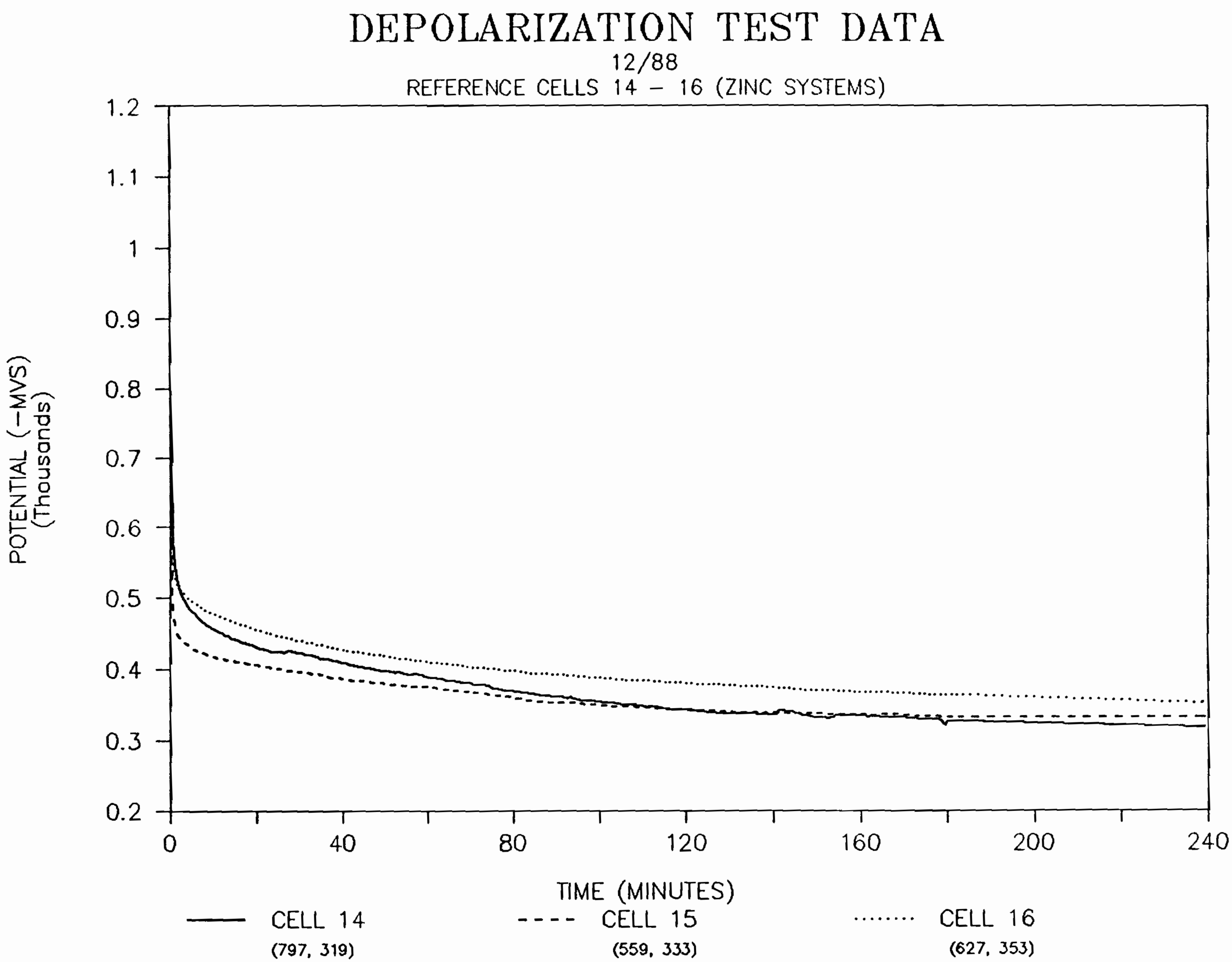
12/88

REFERENCE CELLS 11 – 13 (ZINC SYSTEMS)



Note: x,y x: Instant-off reference cell potential measurement

y: Reference cell potential measurements taken after 4 hrs of system power shut-off.



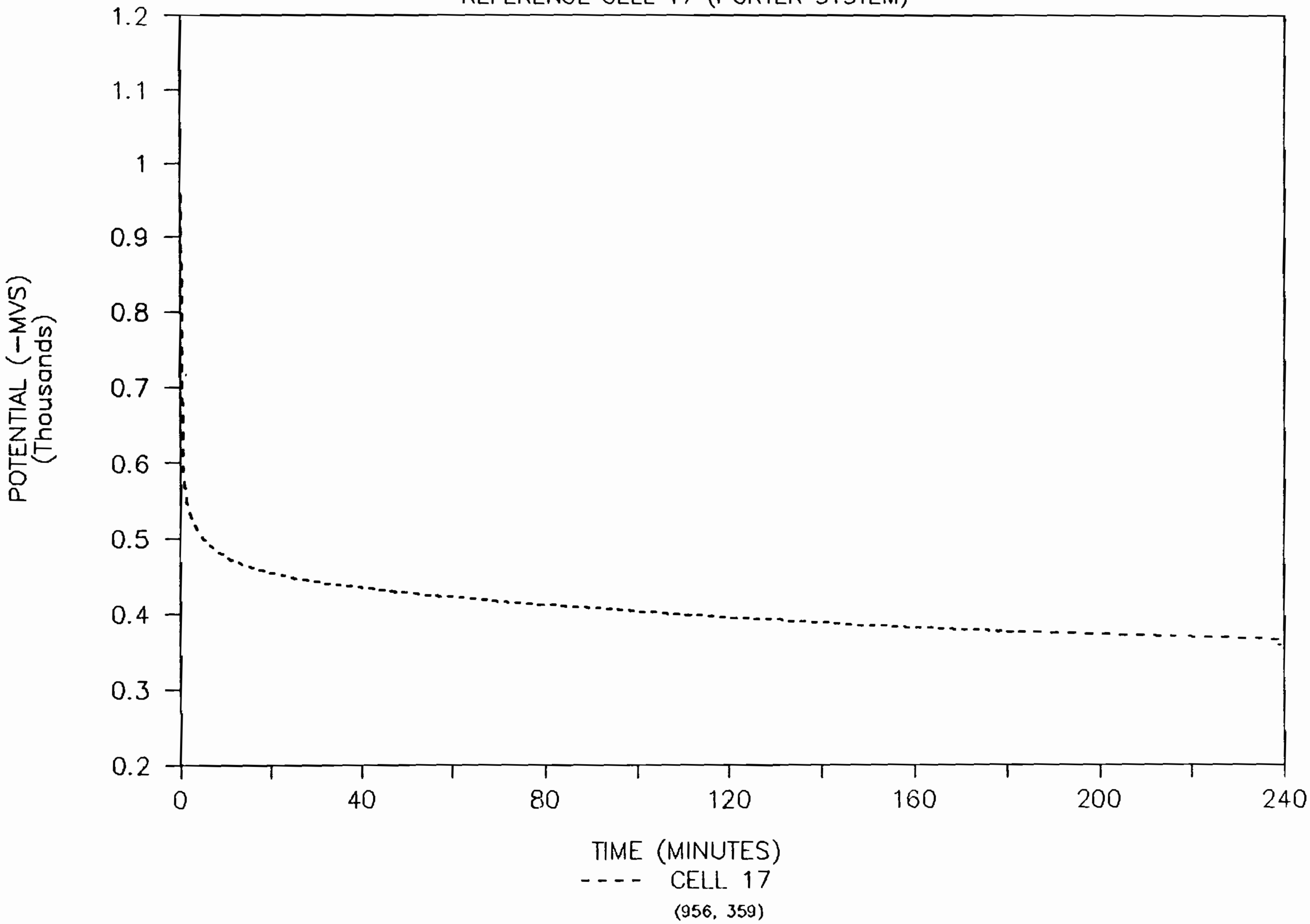
Note: x,y   x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 22

DEPOLARIZATION TEST DATA

12/88

REFERENCE CELL 17 (PORTER SYSTEM)



Note: x,y x: Instant-off reference cell potential measurement

y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 23

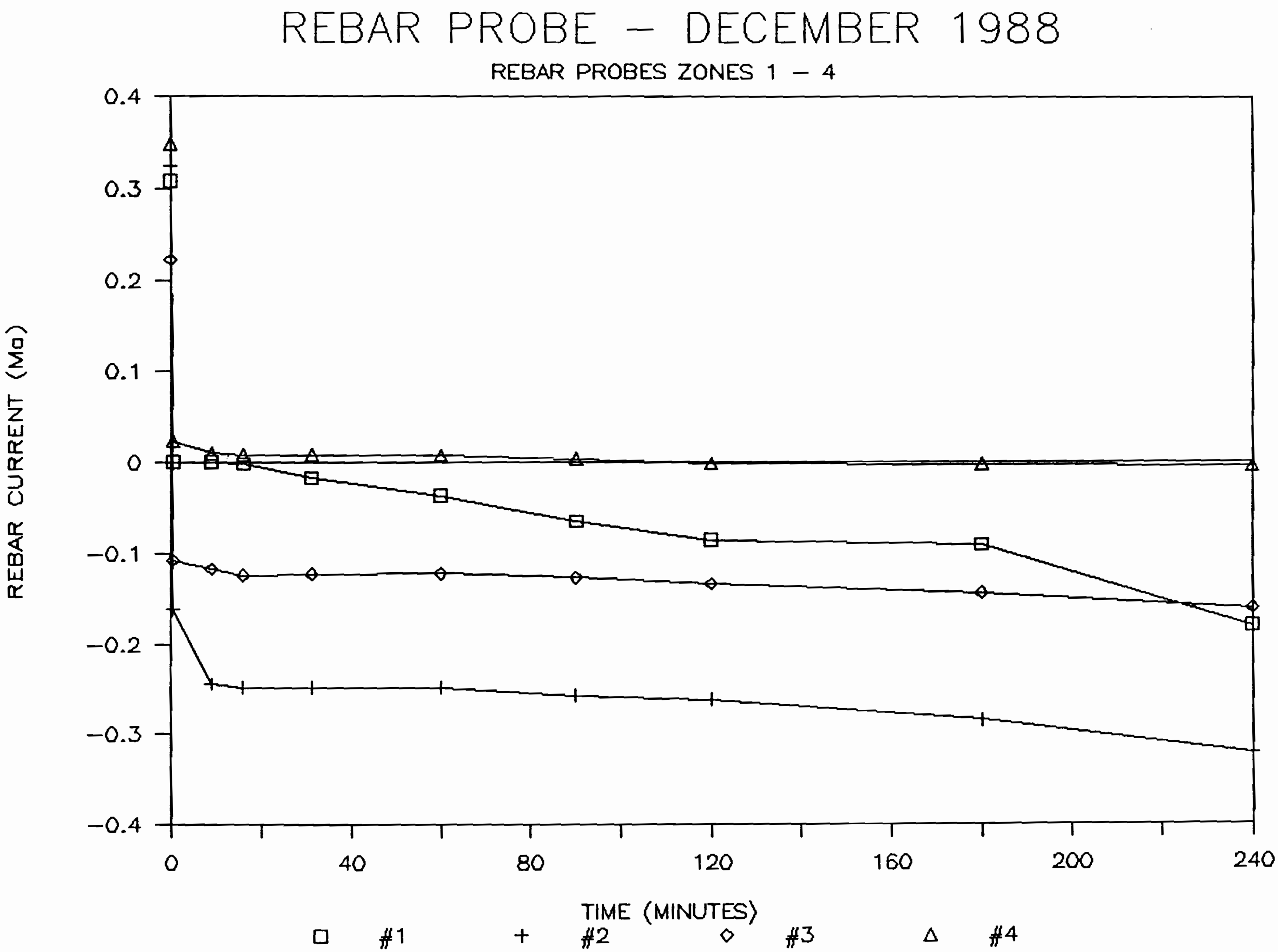
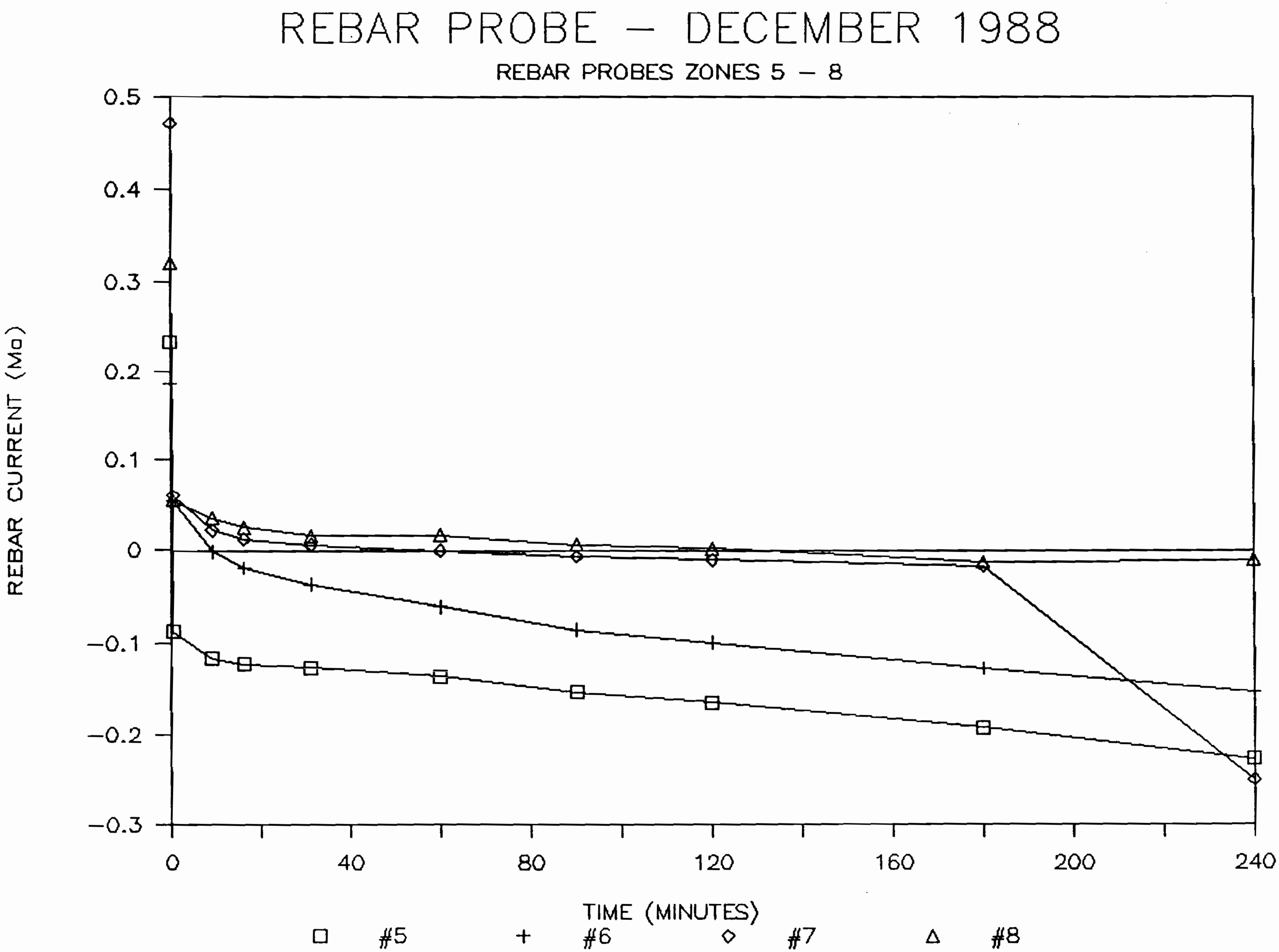

REBAR PROBE - DECEMBER 1988
REBAR PROBES ZONES 1 - 4
REBAR CURRENT (Ma)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
40
80
120
160
200
240
TIME (MINUTES)
□ #1
+ #2
◇ #3
△ #4

FIGURE 24



REBAR PROBE — DECEMBER 1988
REBAR PROBES ZONES 5 — 8
REBAR CURRENT (Ma)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
40
80
120
160
200
240
TIME (MINUTES)
#5
#6
#7
#8

FIGURE 25

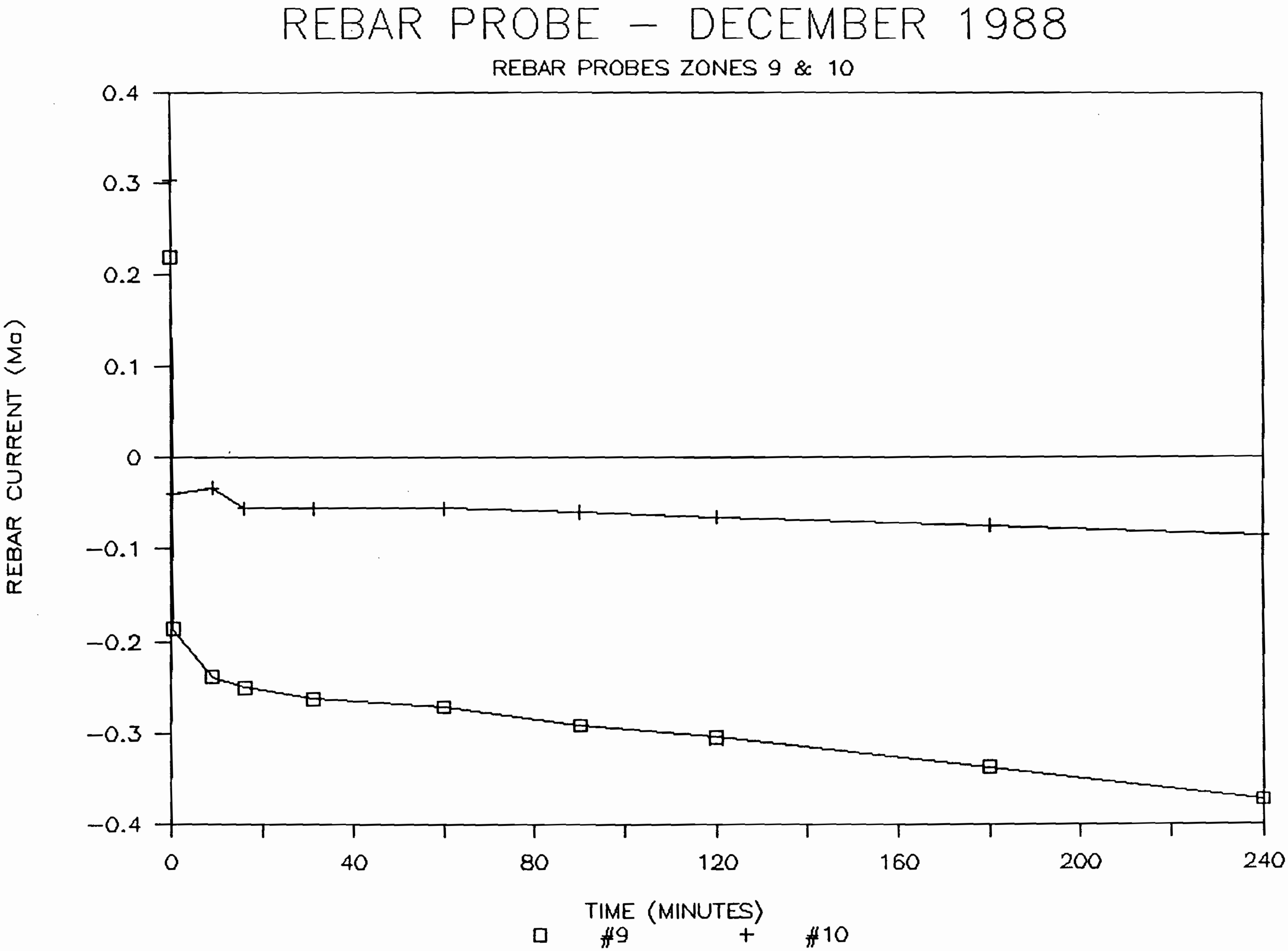

REBAR PROBE - DECEMBER 1988
REBAR PROBES ZONES 9 & 10
REBAR CURRENT (Ma)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
40
80
120
160
200
240
TIME (MINUTES)
#9
#10

FIGURE 26

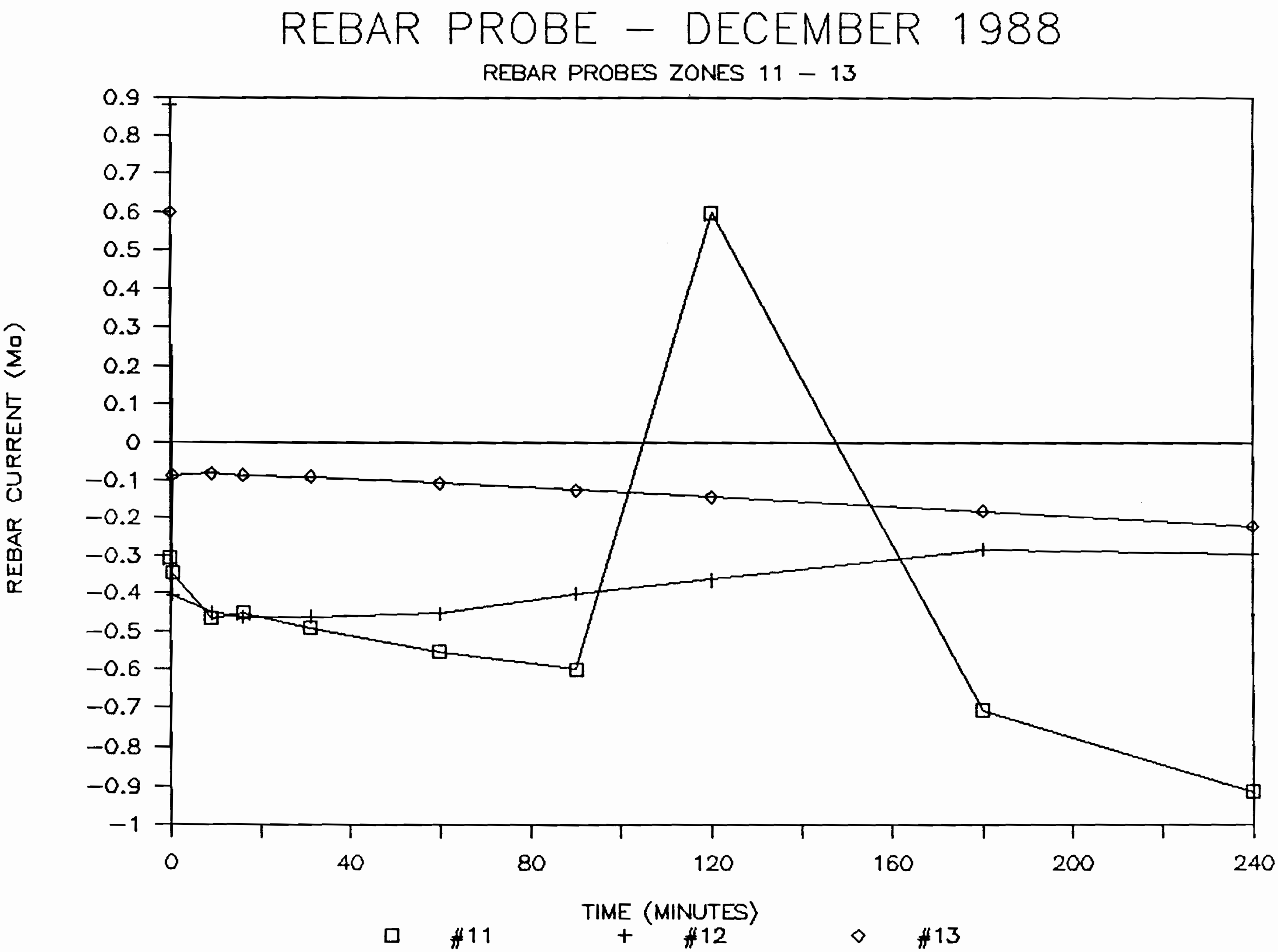

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONES 11 – 13
REBAR CURRENT (Ma)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
–0.1
–0.2
–0.3
–0.4
–0.5
–0.6
–0.7
–0.8
–0.9
–1
0
40
80
120
160
200
240
TIME (MINUTES)
#11
#12
#13

FIGURE 27

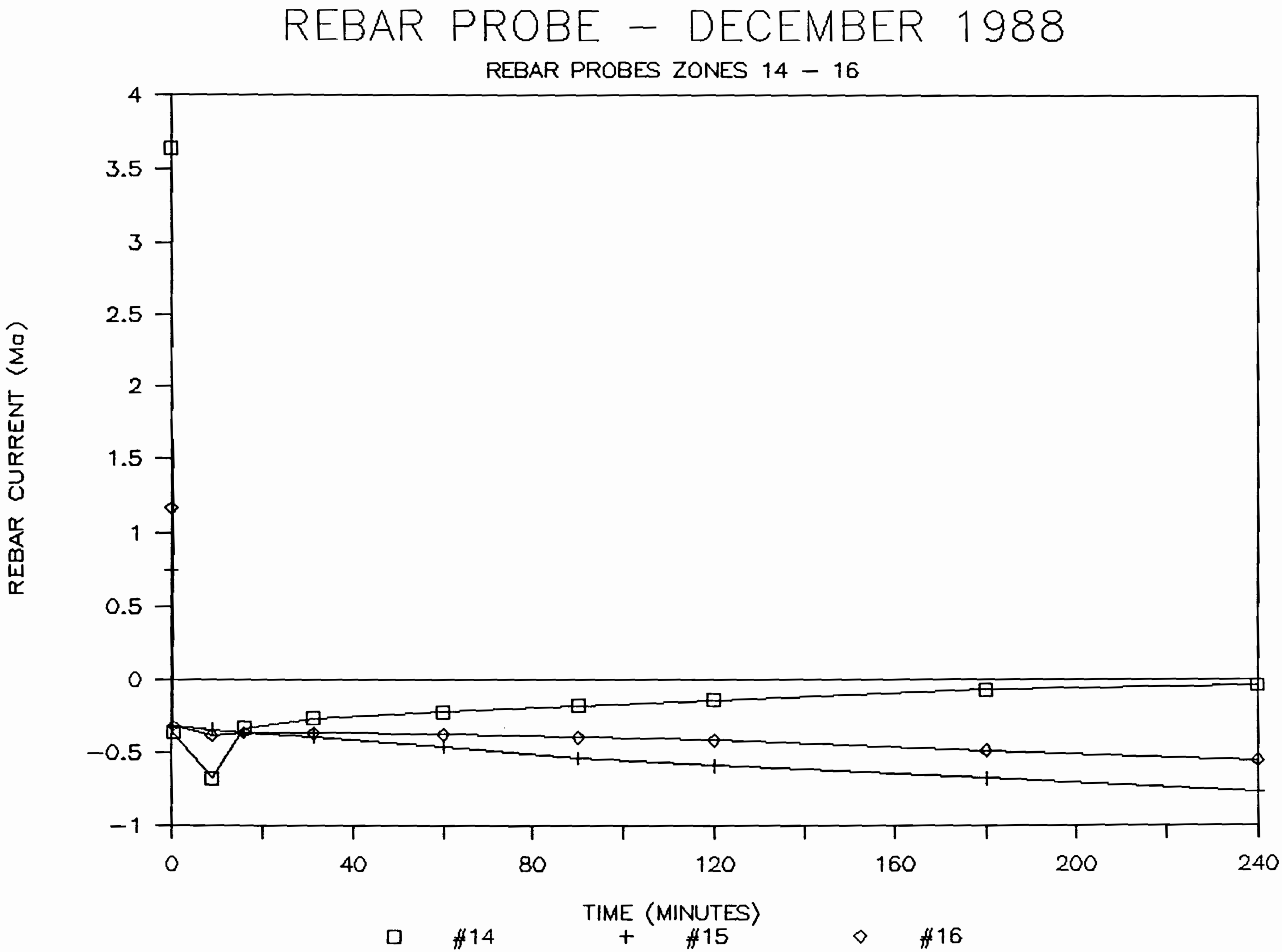

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONES 14 – 16
REBAR CURRENT (Ma)
TIME (MINUTES)
4
3.5
3
2.5
2
1.5
1
0.5
0
–0.5
–1
0
40
80
120
160
200
240
#14
#15
#16

FIGURE 28

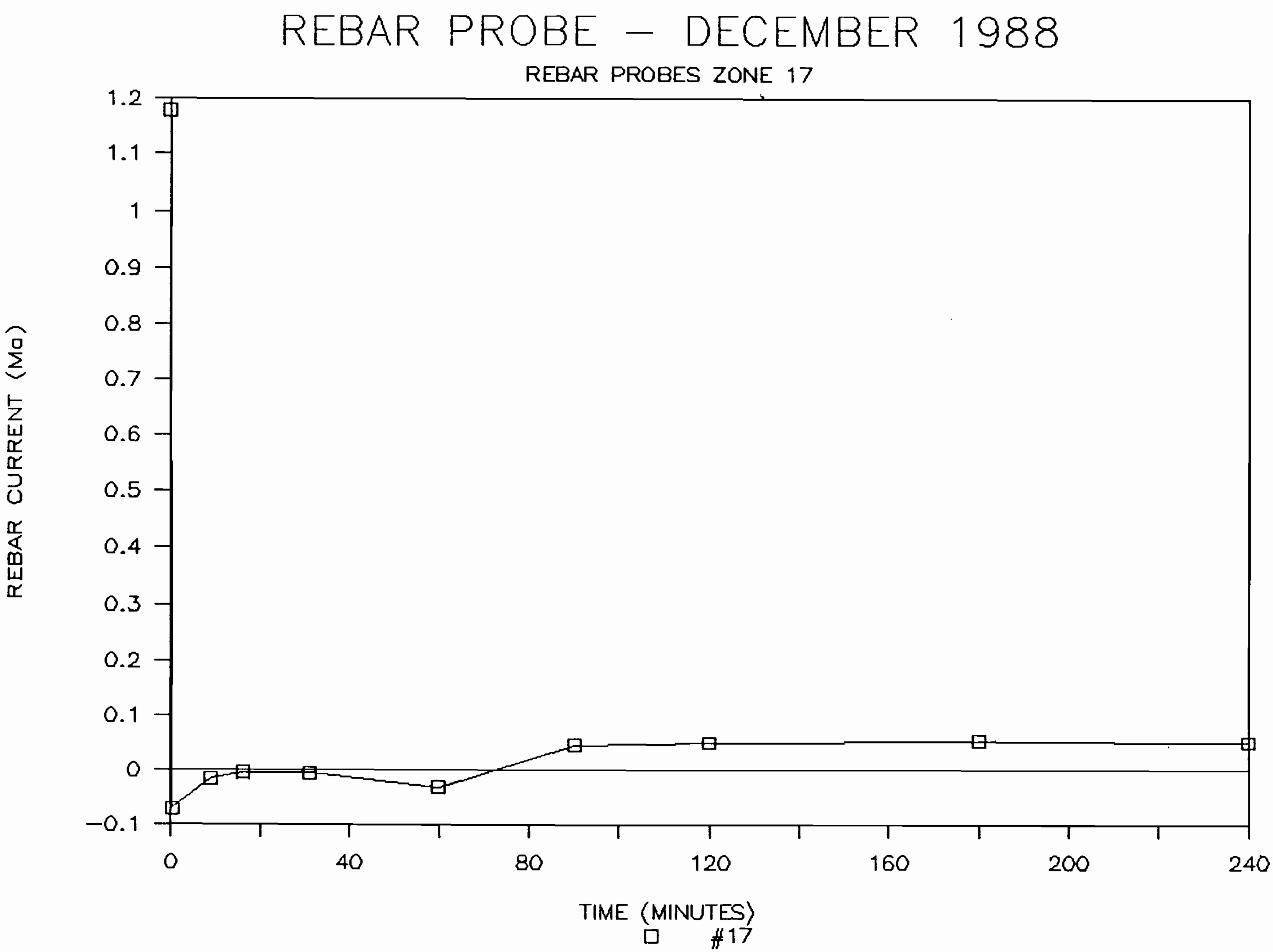

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONE 17
REBAR CURRENT (Ma)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
–0.1
0
40
80
120
160
200
240
TIME (MINUTES)
#17

FIGURE 29

DEPOLARIZATION TEST DATA

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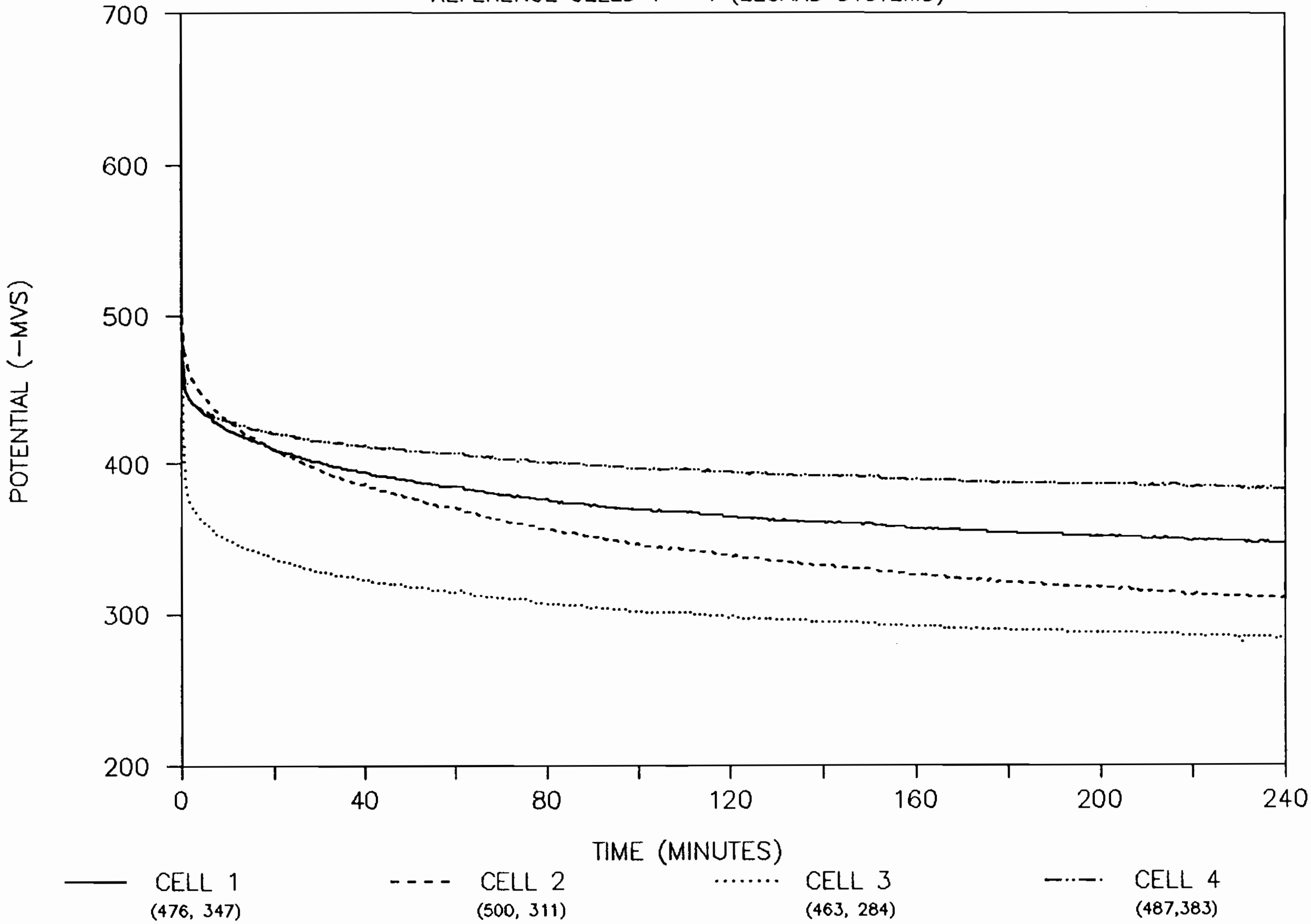
REFERENCE CELLS 1 – 4 (ELGARD SYSTEMS)



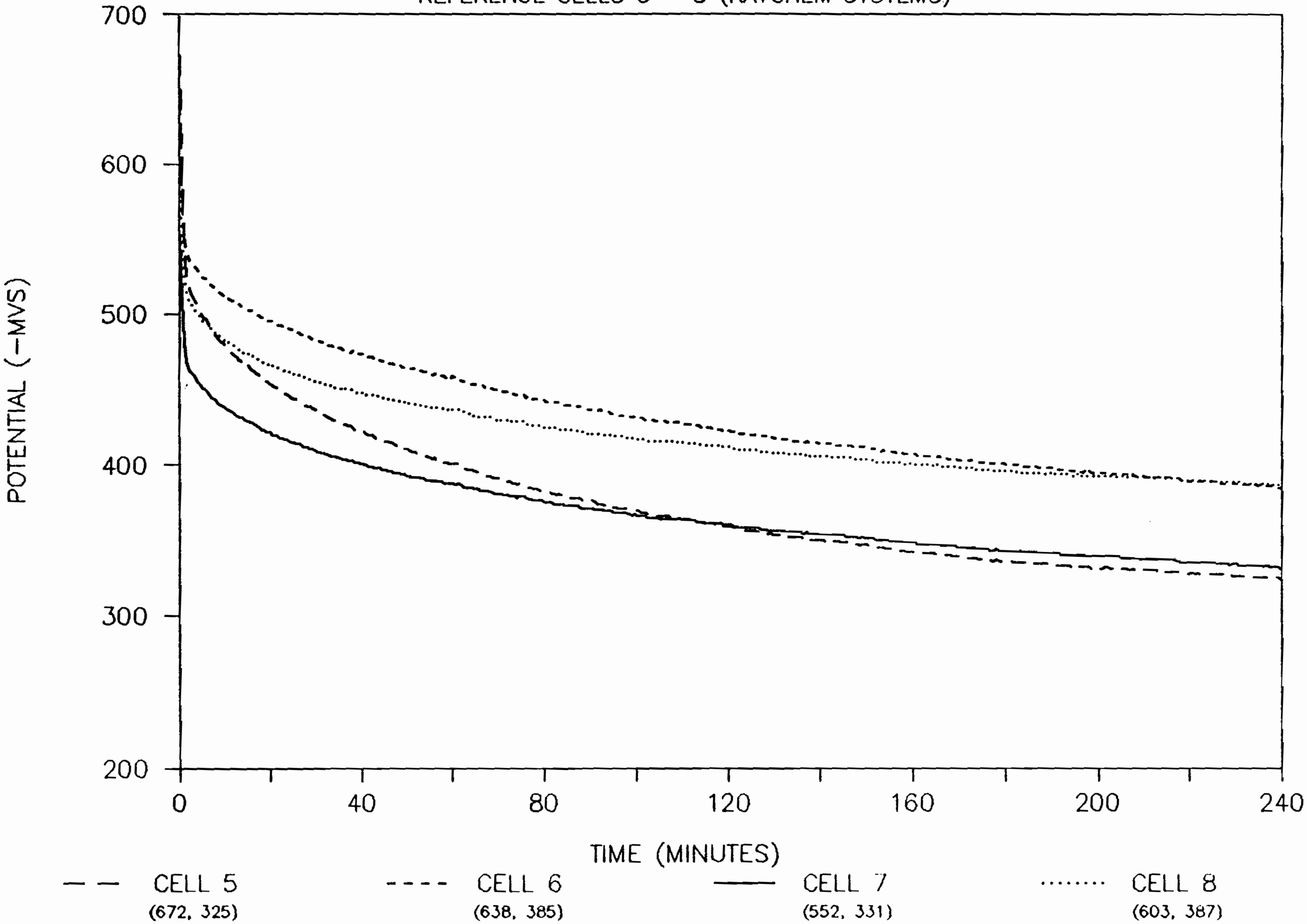
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 30

DEPOLARIZATION TEST DATA

1/89

REFERENCE CELLS 5 – 8 (RAYCHEM SYSTEMS)



Note: x,y x: Instant-off reference cell potential measurement

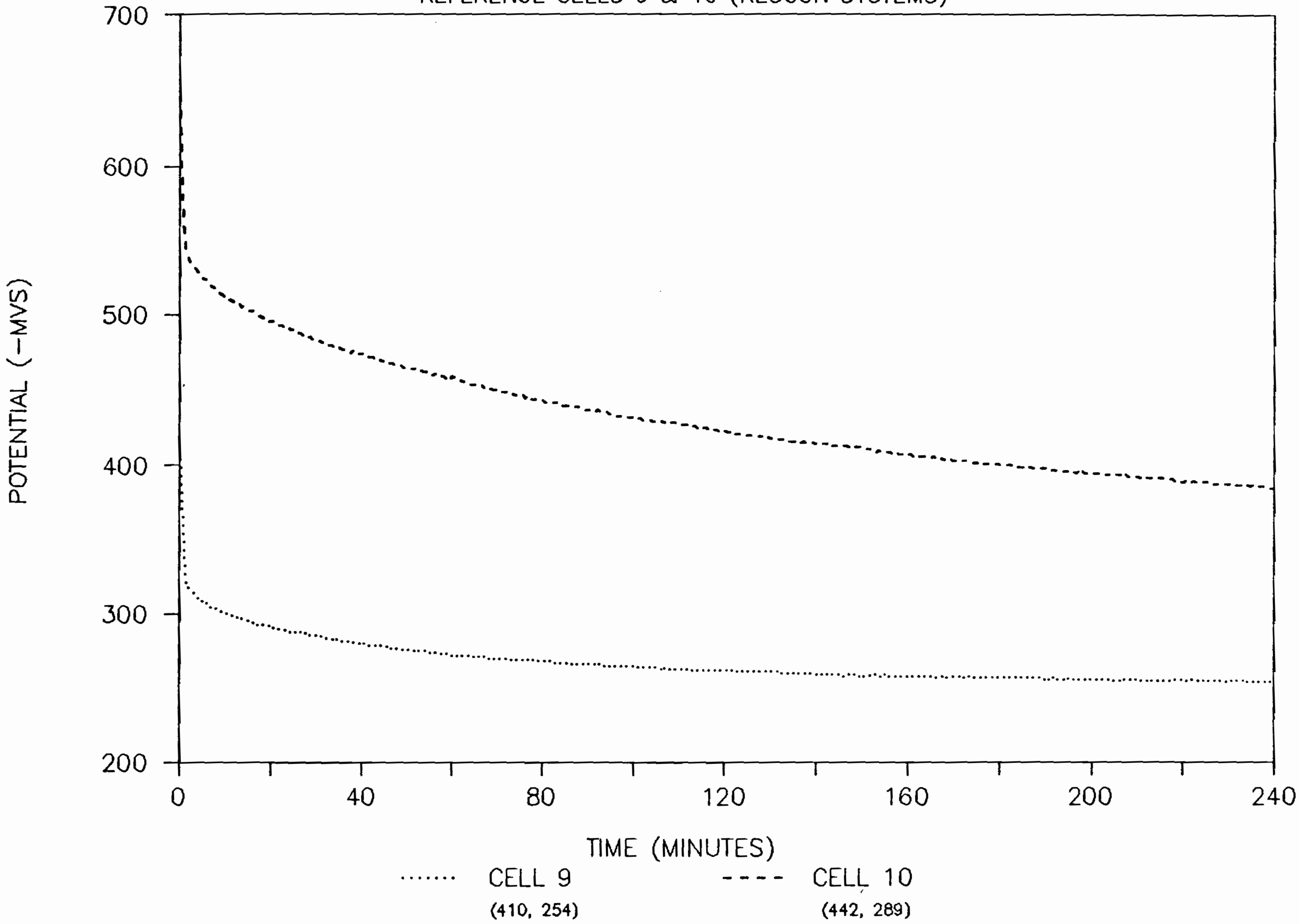
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 31

DEPOLARIZATION TEST DATA

1/89

REFERENCE CELLS 9 & 10 (RESCON SYSTEMS)



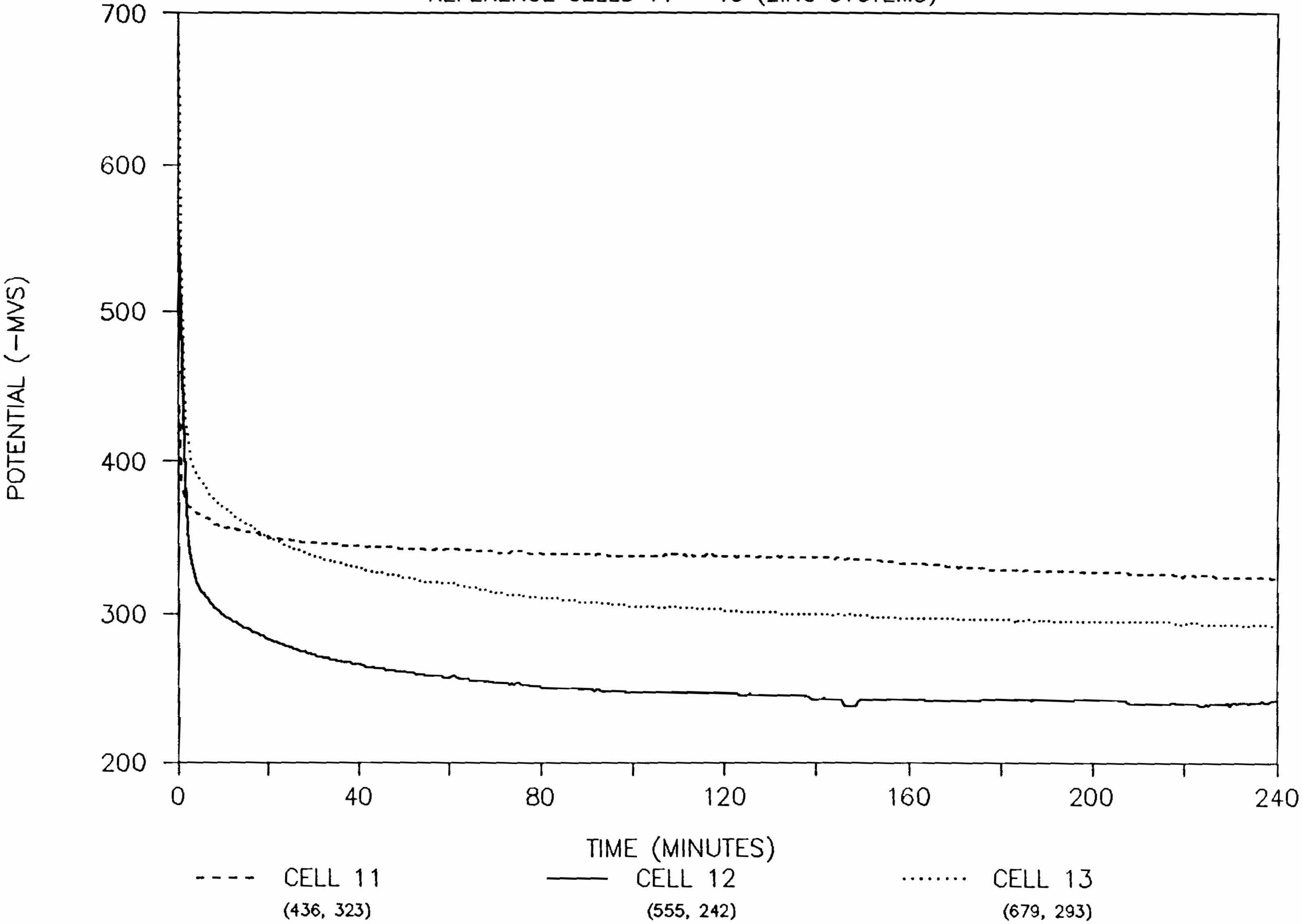
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 32

DEPOLARIZATION TEST DATA

1/89

REFERENCE CELLS 11 – 13 (ZINC SYSTEMS)



Note: x,y x: Instant-off reference cell potential measurement

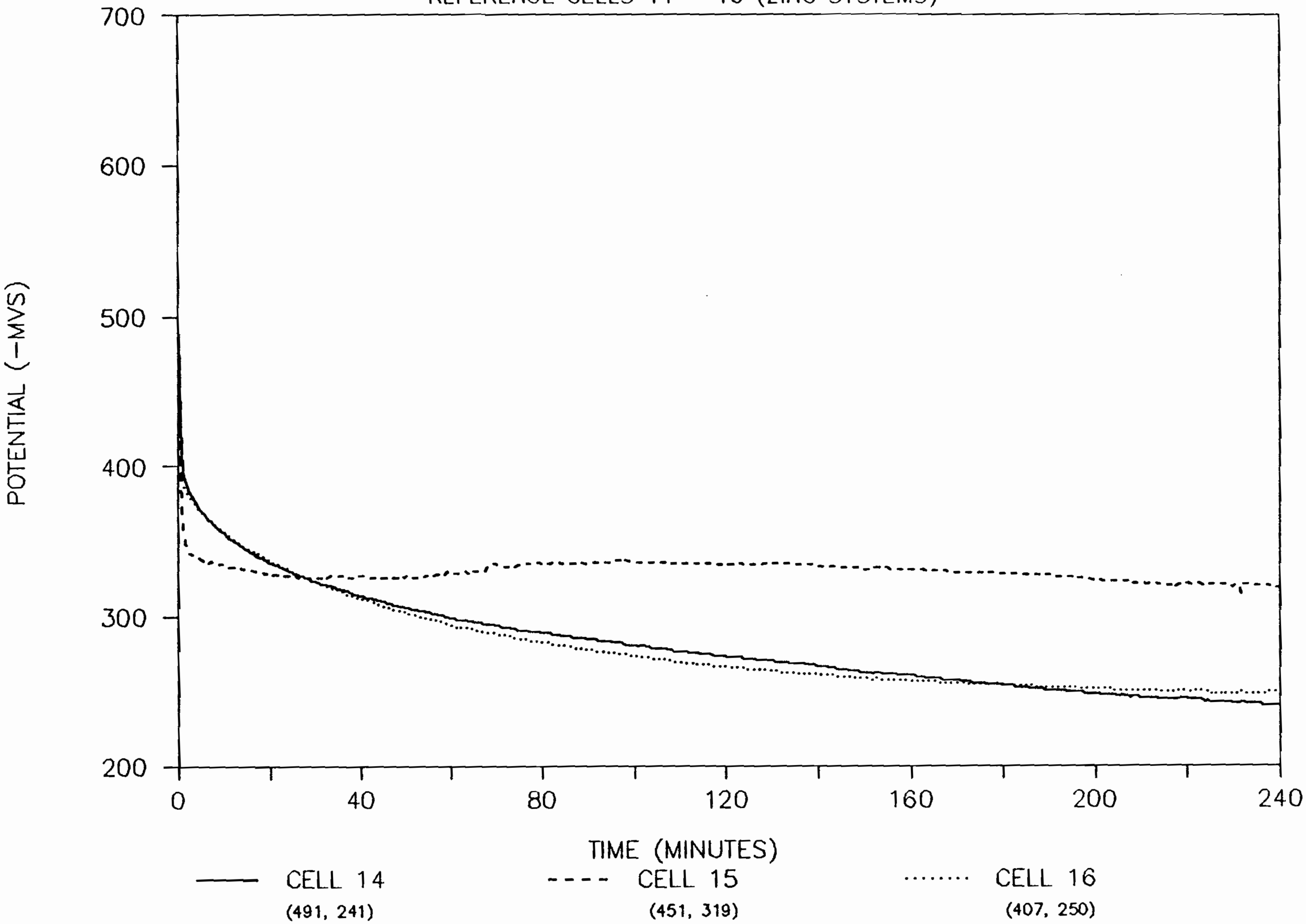
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 33

DEPOLARIZATION TEST DATA

1/89

REFERENCE CELLS 14 – 16 (ZINC SYSTEMS)



Note: x,y   x: Instant-off reference cell potential measurement

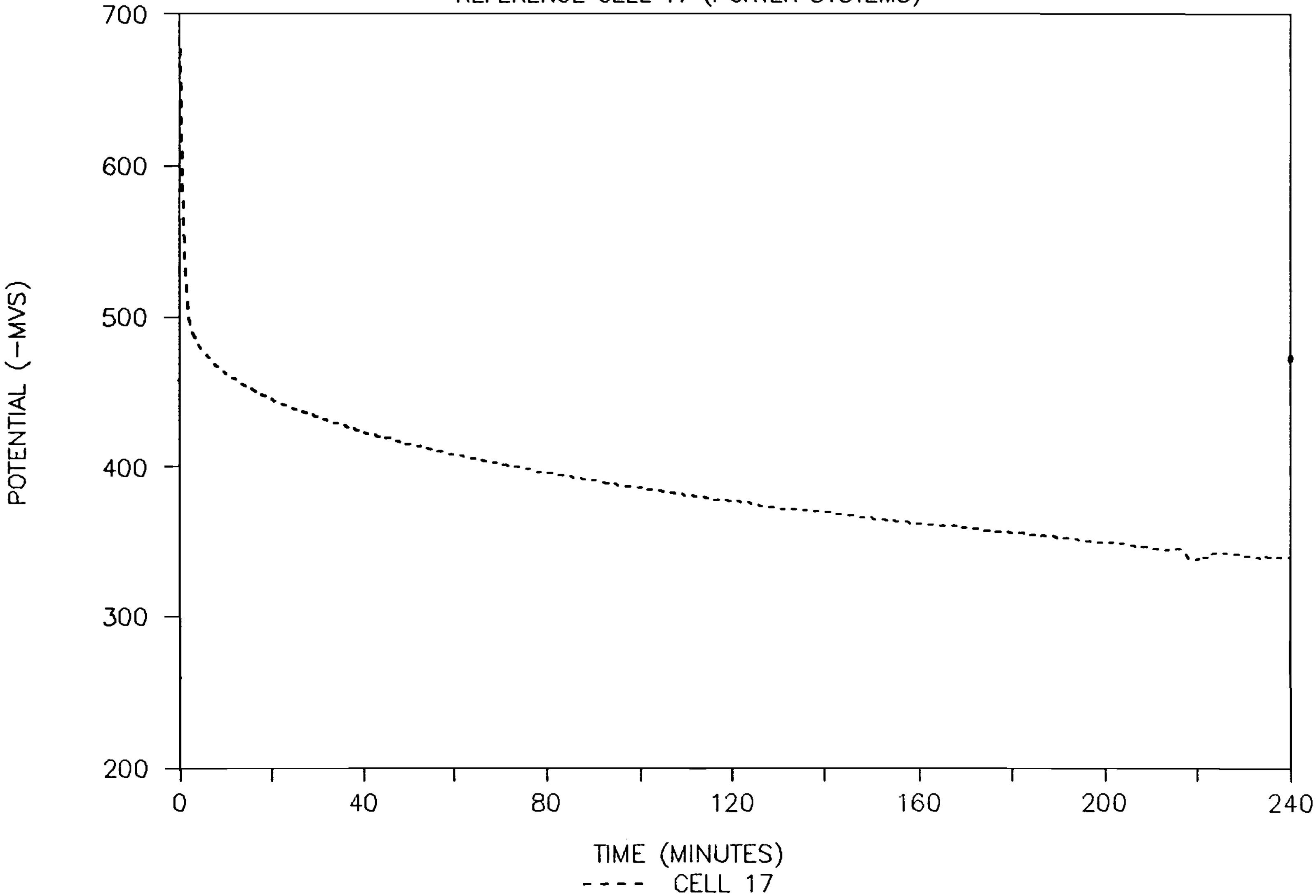
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 34

DEPOLARIZATION TEST DATA

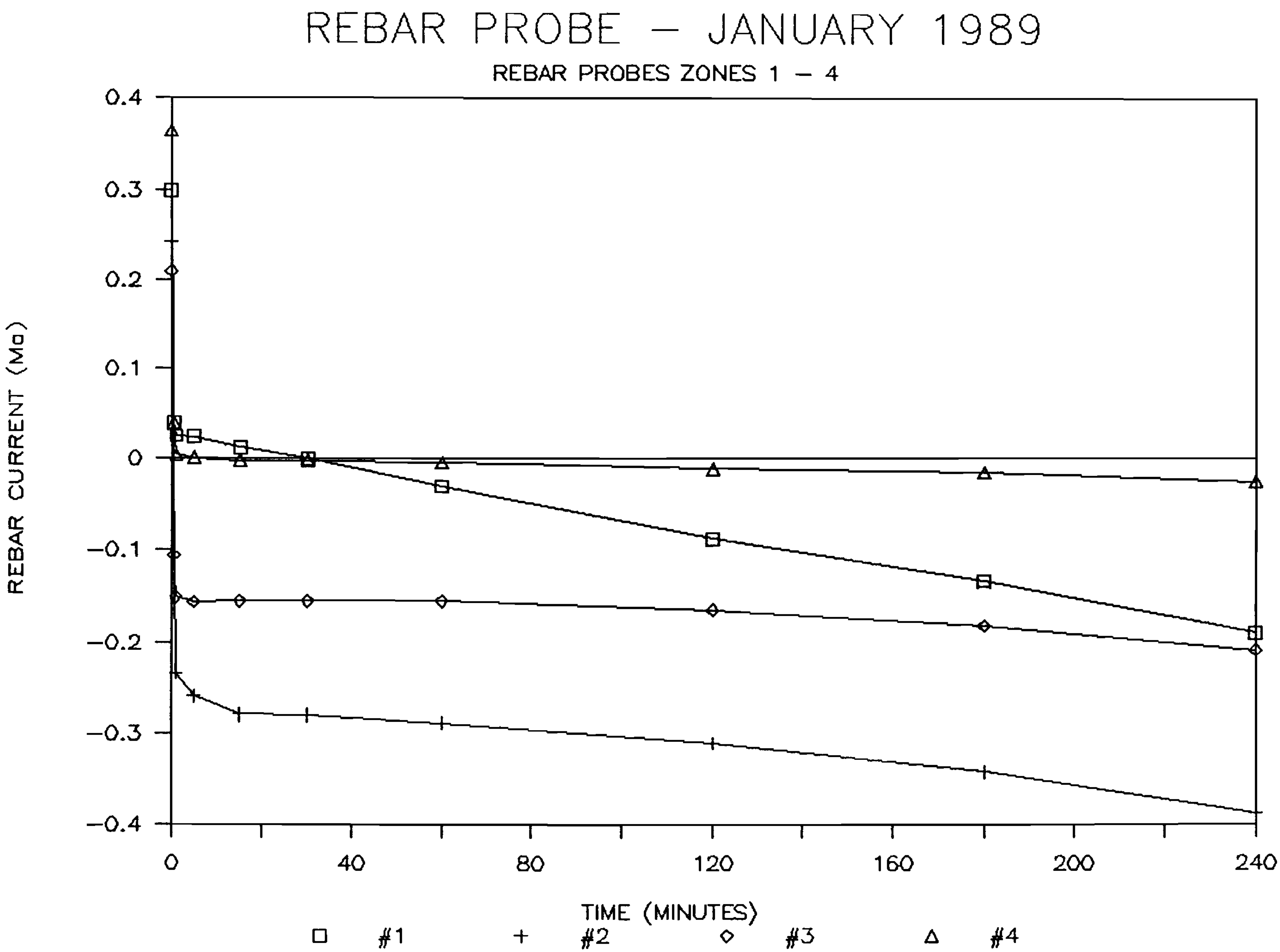
1/89

REFERENCE CELL 17 (PORTER SYSTEMS)



(677, 339)

Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.



REBAR PROBE - JANUARY 1989
REBAR PROBES ZONES 1 - 4
REBAR CURRENT (Ma)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
40
80
120
160
200
240
TIME (MINUTES)
#1
#2
#3
#4

FIGURE 36

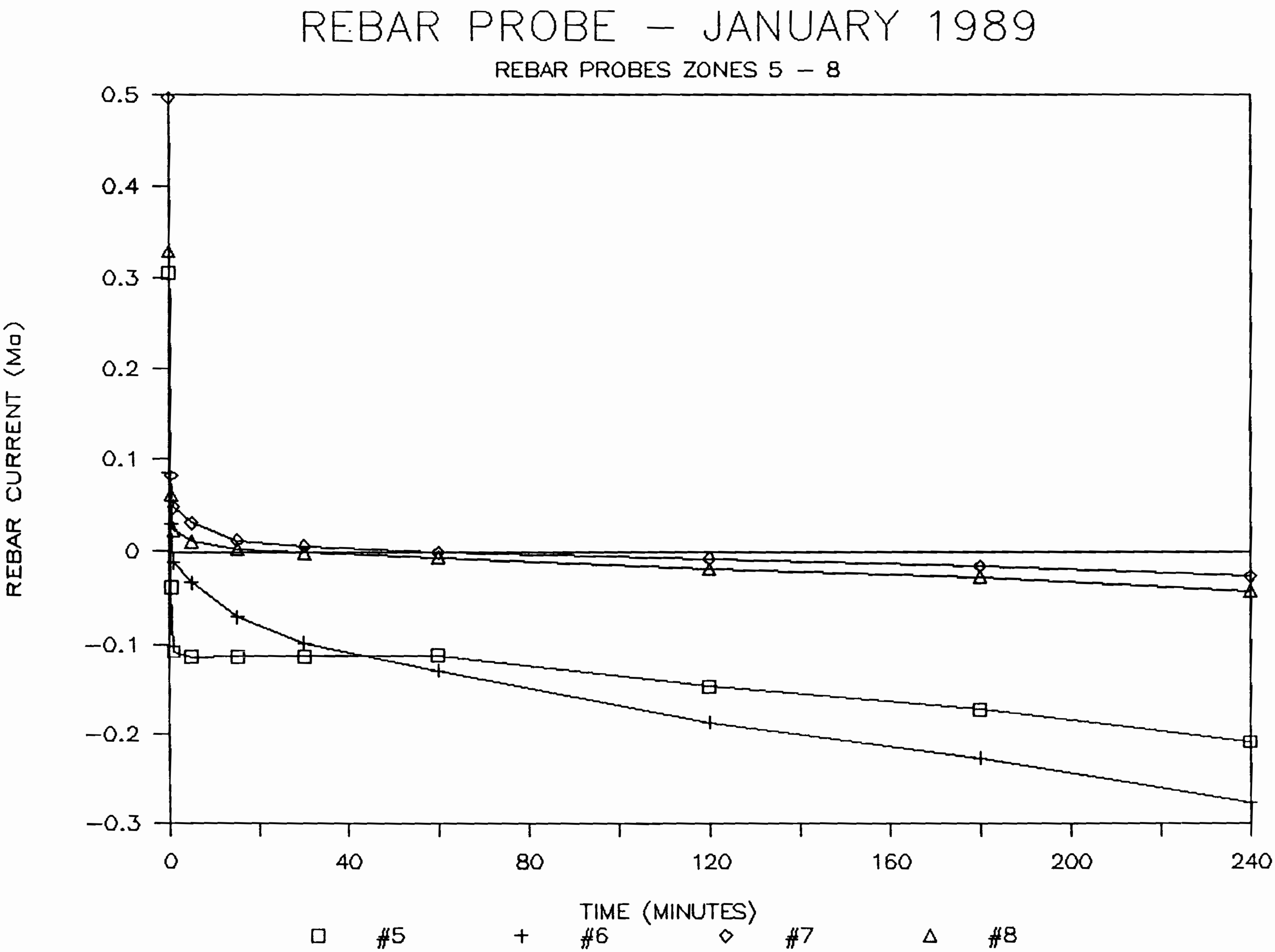

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONES 5 – 8
REBAR CURRENT (Ma)
0.5
0.4
0.3
0.2
0.1
0
–0.1
–0.2
–0.3
0
40
80
120
160
200
240
TIME (MINUTES)
#5
#6
#7
#8

FIGURE 37

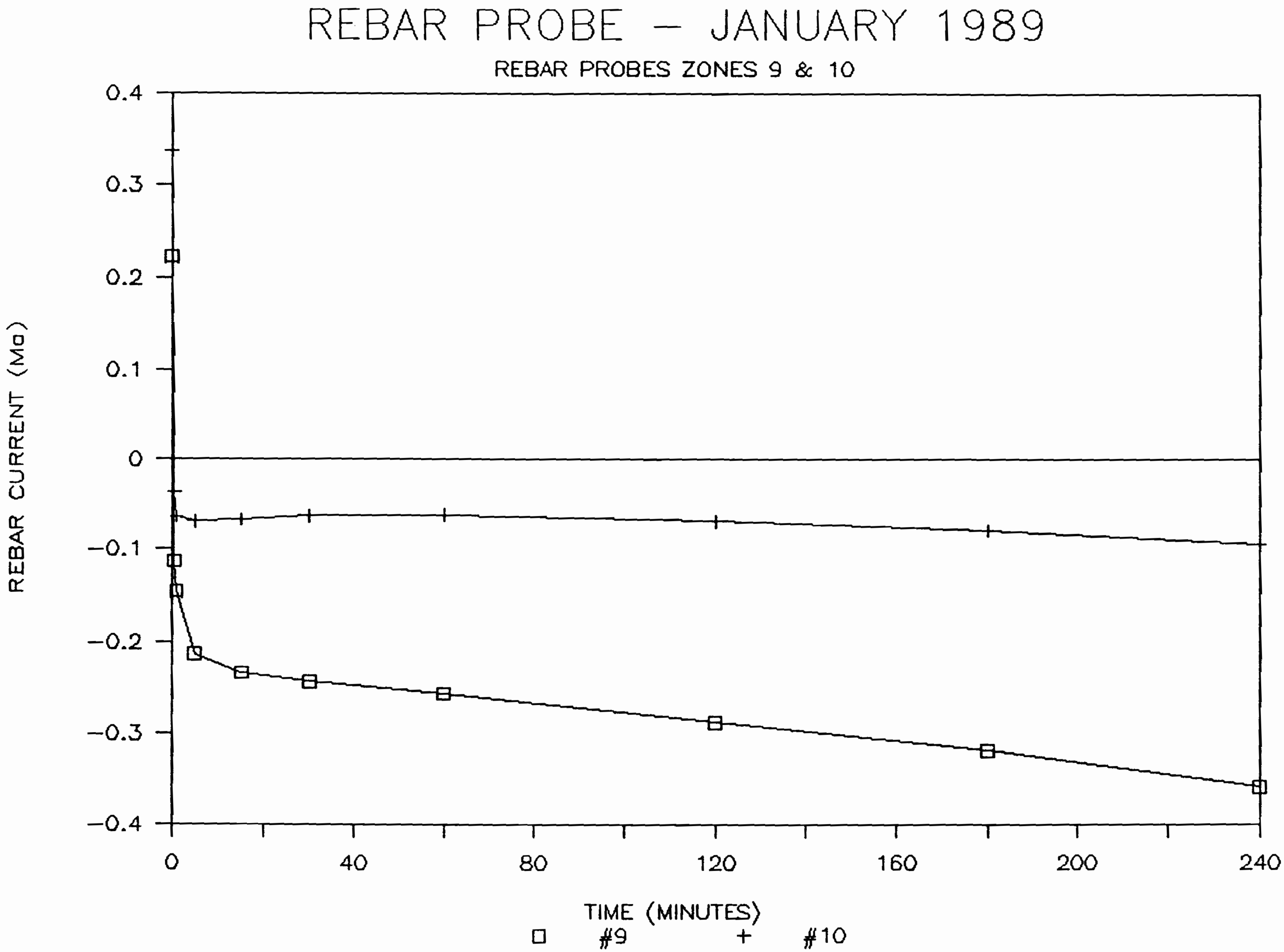

REBAR PROBE - JANUARY 1989
REBAR PROBES ZONES 9 & 10
REBAR CURRENT (Ma)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
40
80
120
160
200
240
TIME (MINUTES)
#9
#10

FIGURE 38

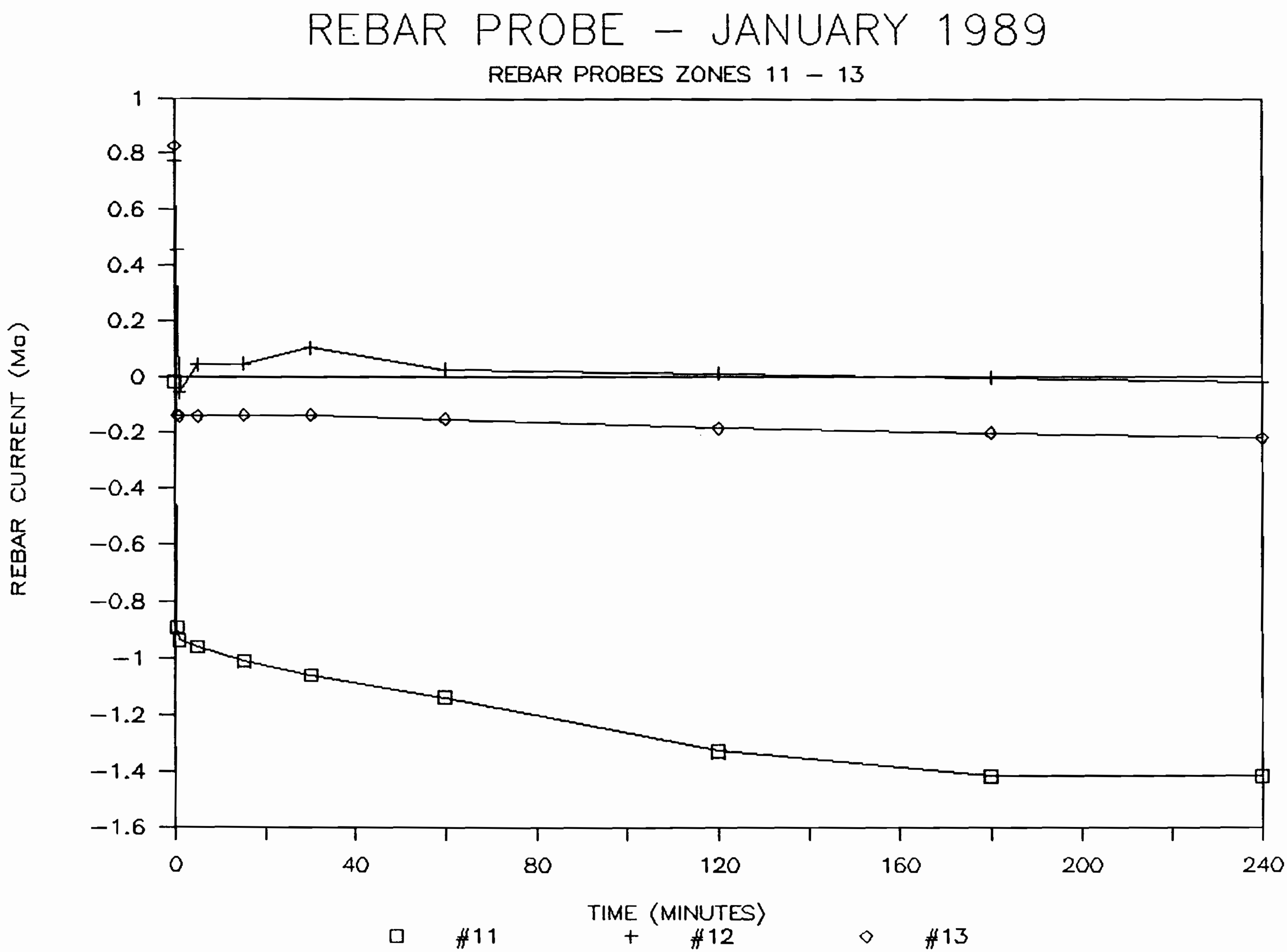

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONES 11 – 13
REBAR CURRENT (Ma)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
0
40
80
120
160
200
240
TIME (MINUTES)
□ #11
+ #12
◇ #13

FIGURE 39

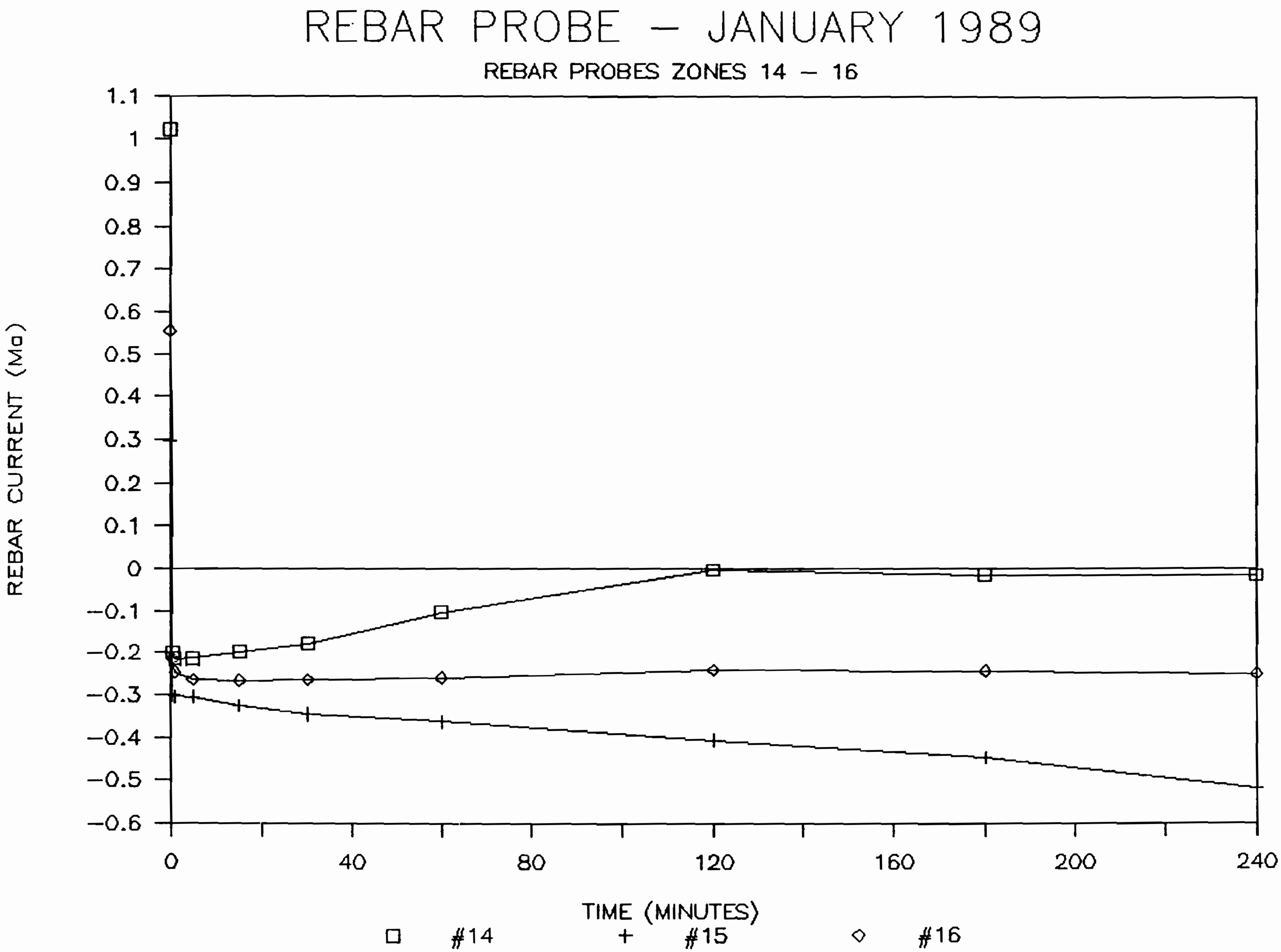

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONES 14 – 16
REBAR CURRENT (Ma)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
–0.1
–0.2
–0.3
–0.4
–0.5
–0.6
0
40
80
120
160
200
240
TIME (MINUTES)
#14
#15
#16

FIGURE 40

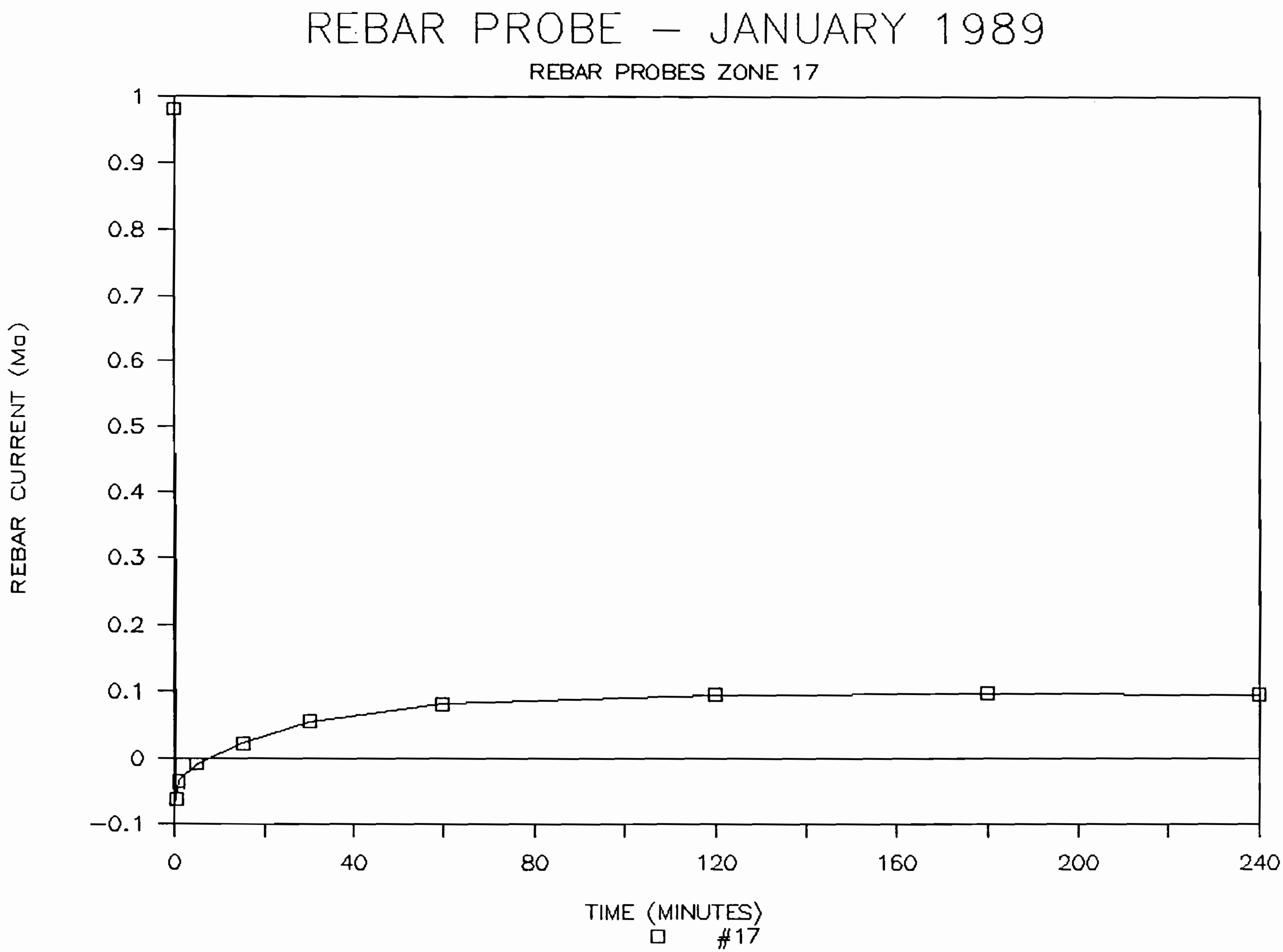

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONE 17
REBAR CURRENT (Ma)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
–0.1
0
40
80
120
160
200
240
TIME (MINUTES)
#17

FIGURE 41