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

FINAL REPORT OF THE CATHODIC PROTECTION SYSTEMS

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REPORT

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:

- Post-installation

  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.

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. Rate of Corrosion Measurements - 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. Electrical Resistance Measurements - 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. System Adjustments - 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.

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TABLES

TABLE 1

POST INSTALLATION SYSTEM DATA
OCTOBER 5, 1988

CKT	ANODE		REFERENCE CELLS					REBAR PROBES			
				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

NOVEMBER 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)
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-f1)

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-f1)

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)DGI.PSZ

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-f1

TABLE 8

DEPOLARIZATION TEST - 45 DAYS

	DECEMBER 13, 1988
REFERENCE CELL	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-f1)

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

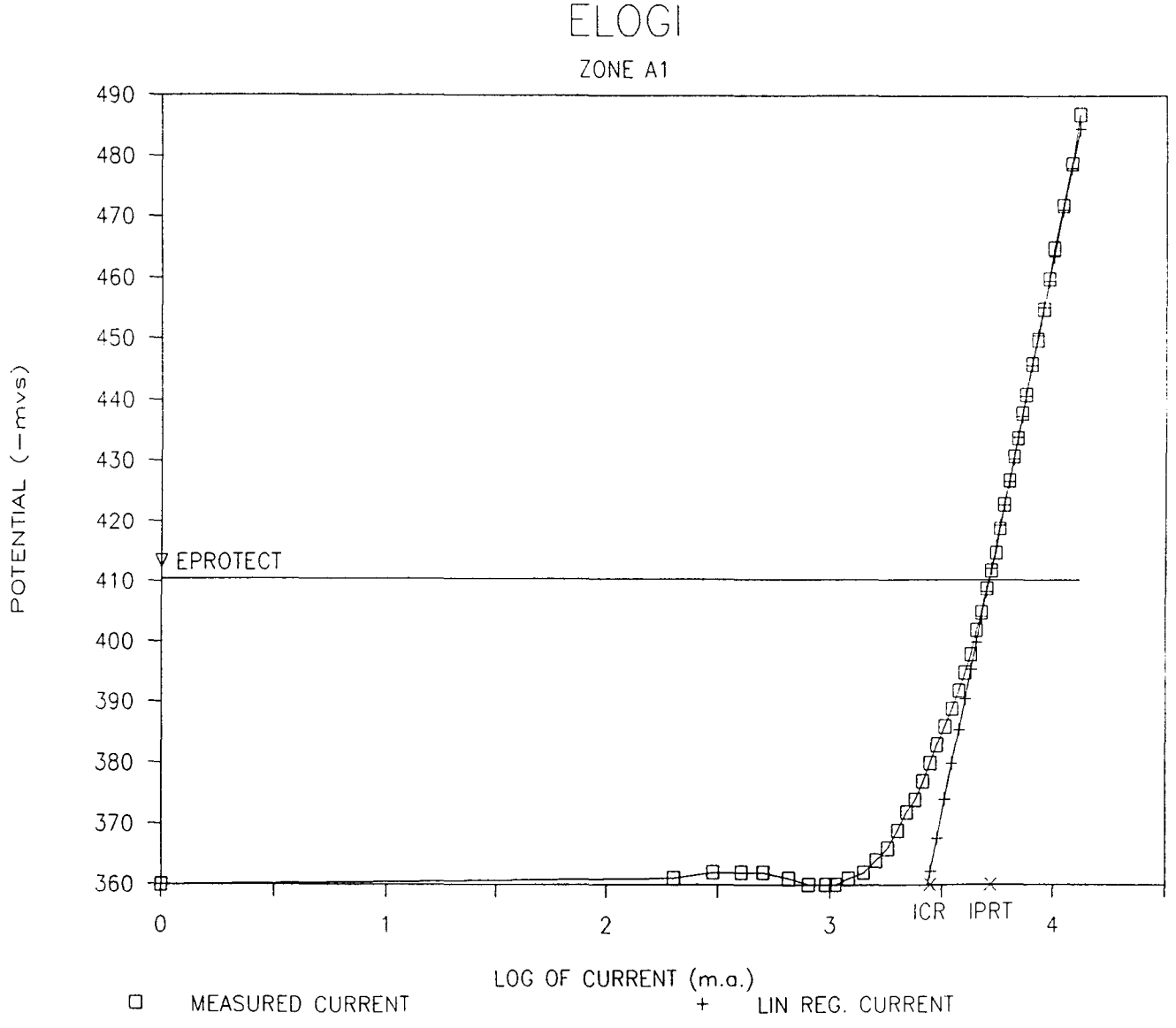


FIGURE 1

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

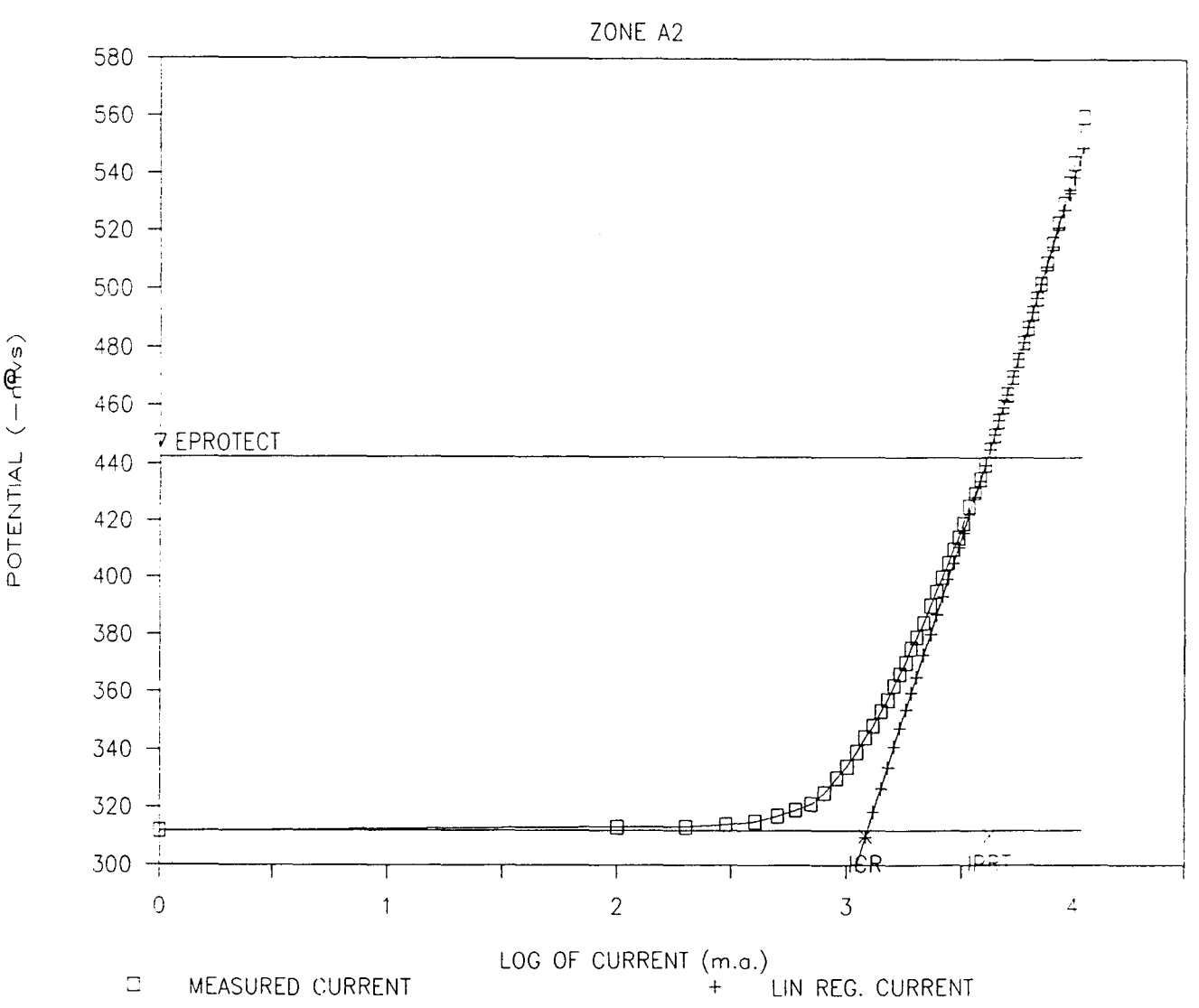


FIGURE 2

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

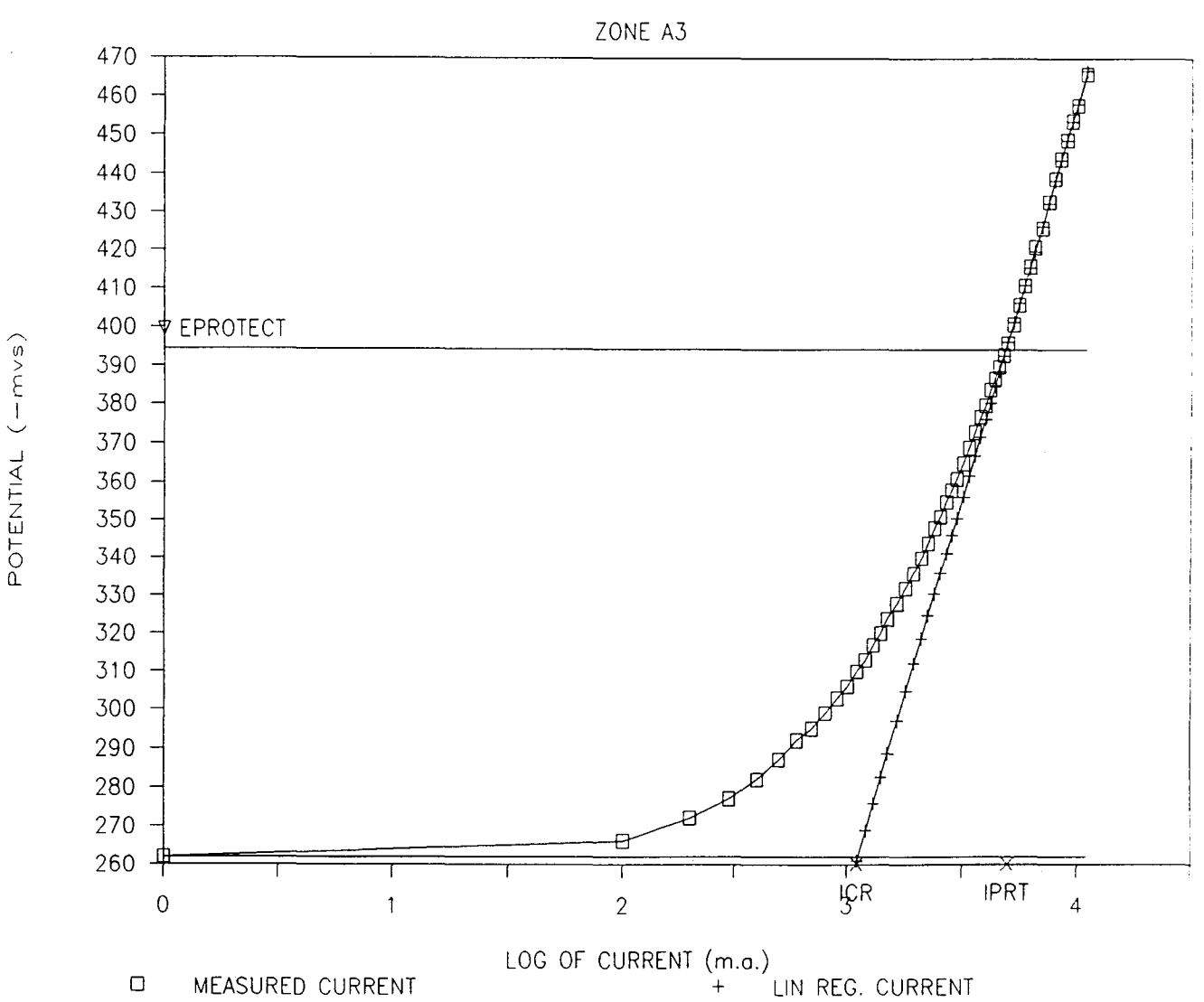


FIGURE 3

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

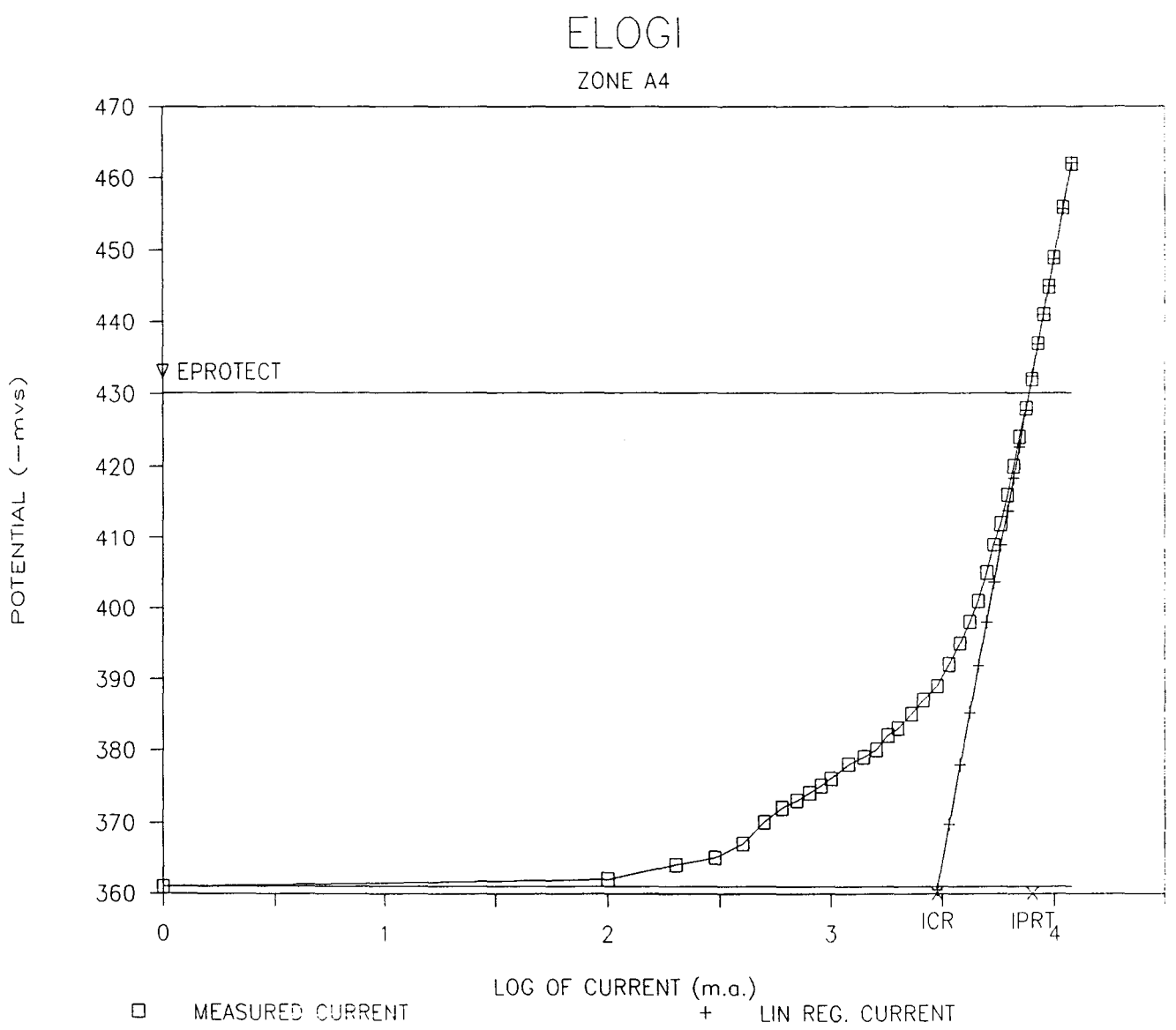


FIGURE 4

..	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

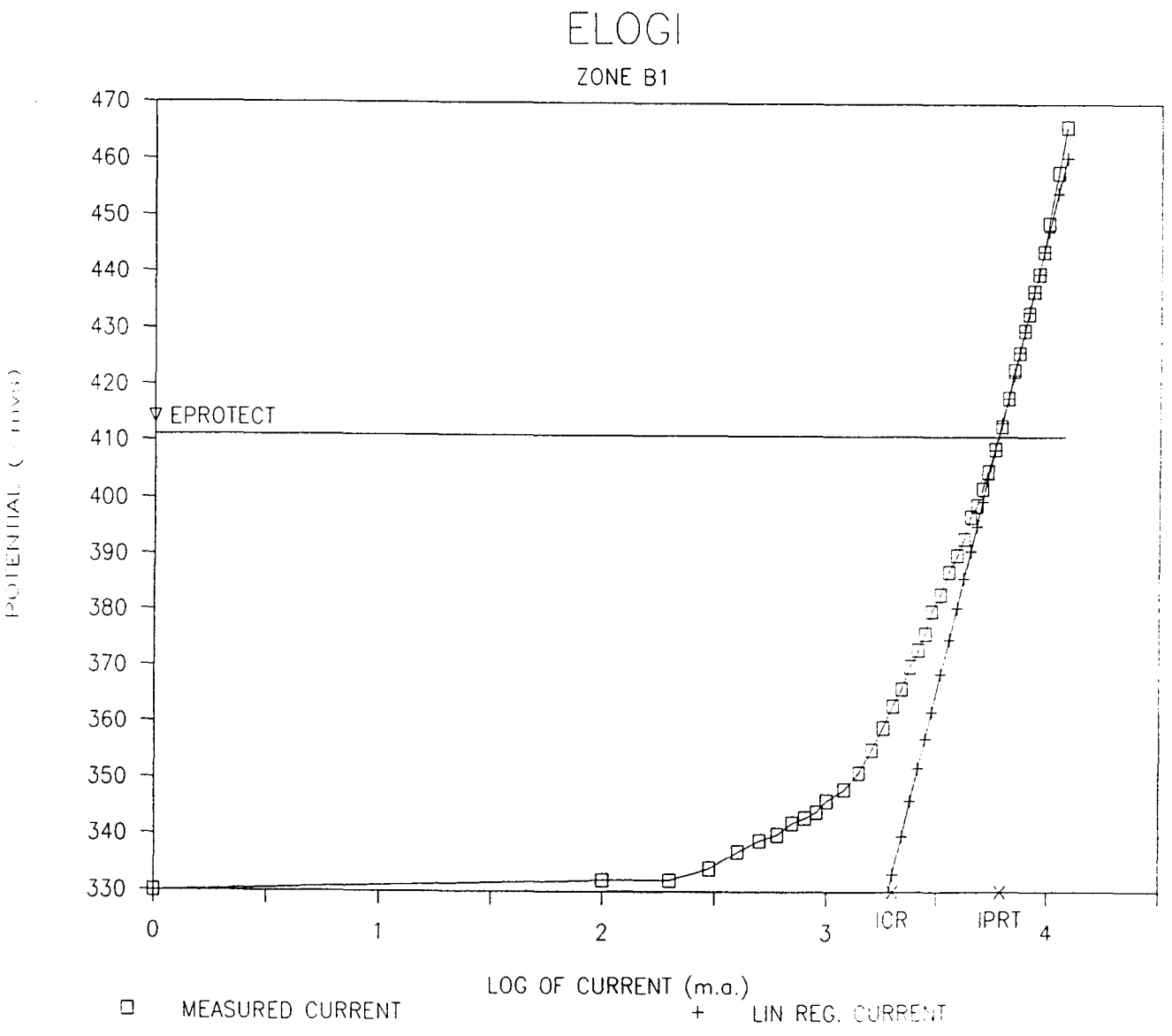


FIGURE 5

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

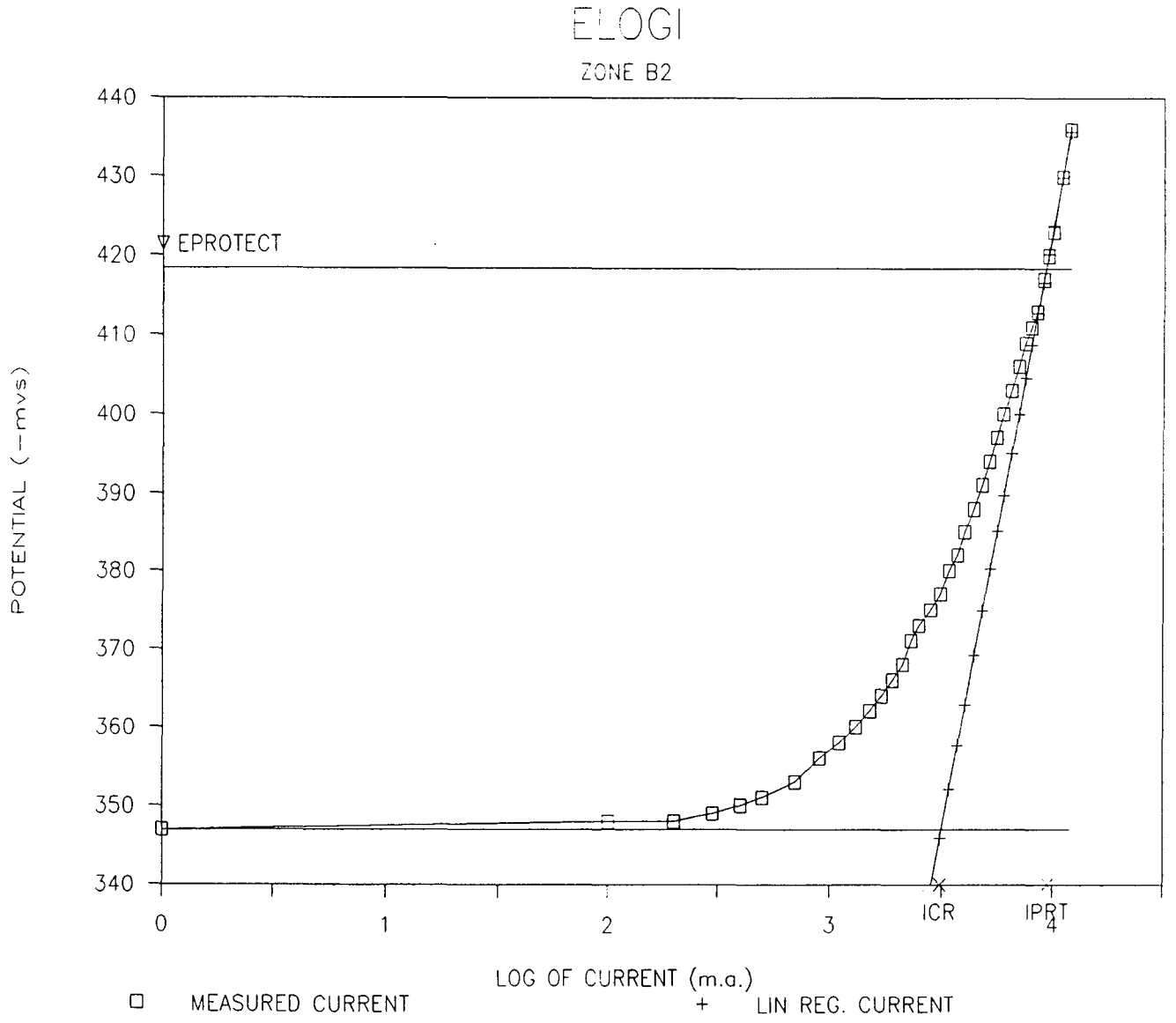


FIGURE 6

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

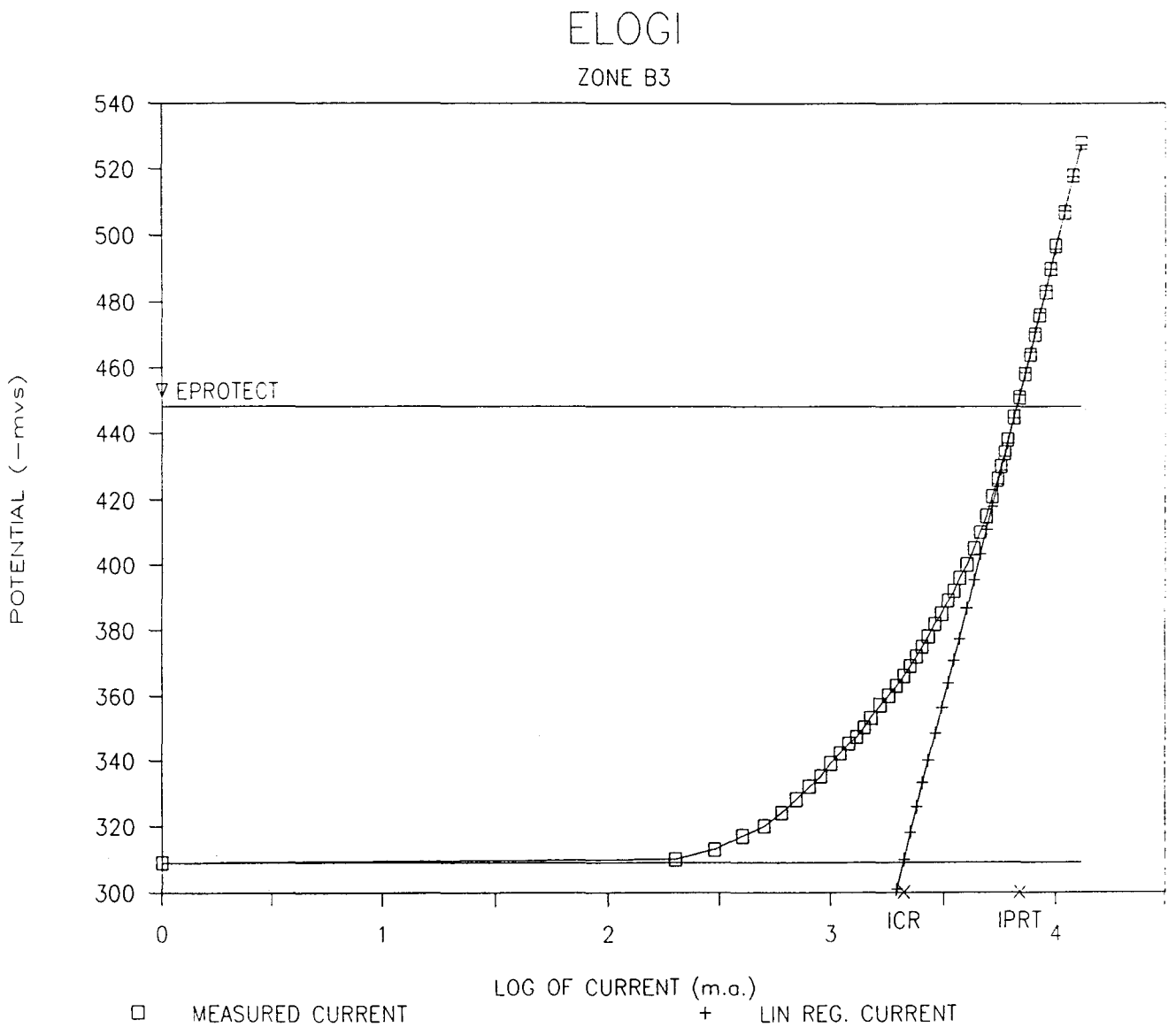


FIGURE 7

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

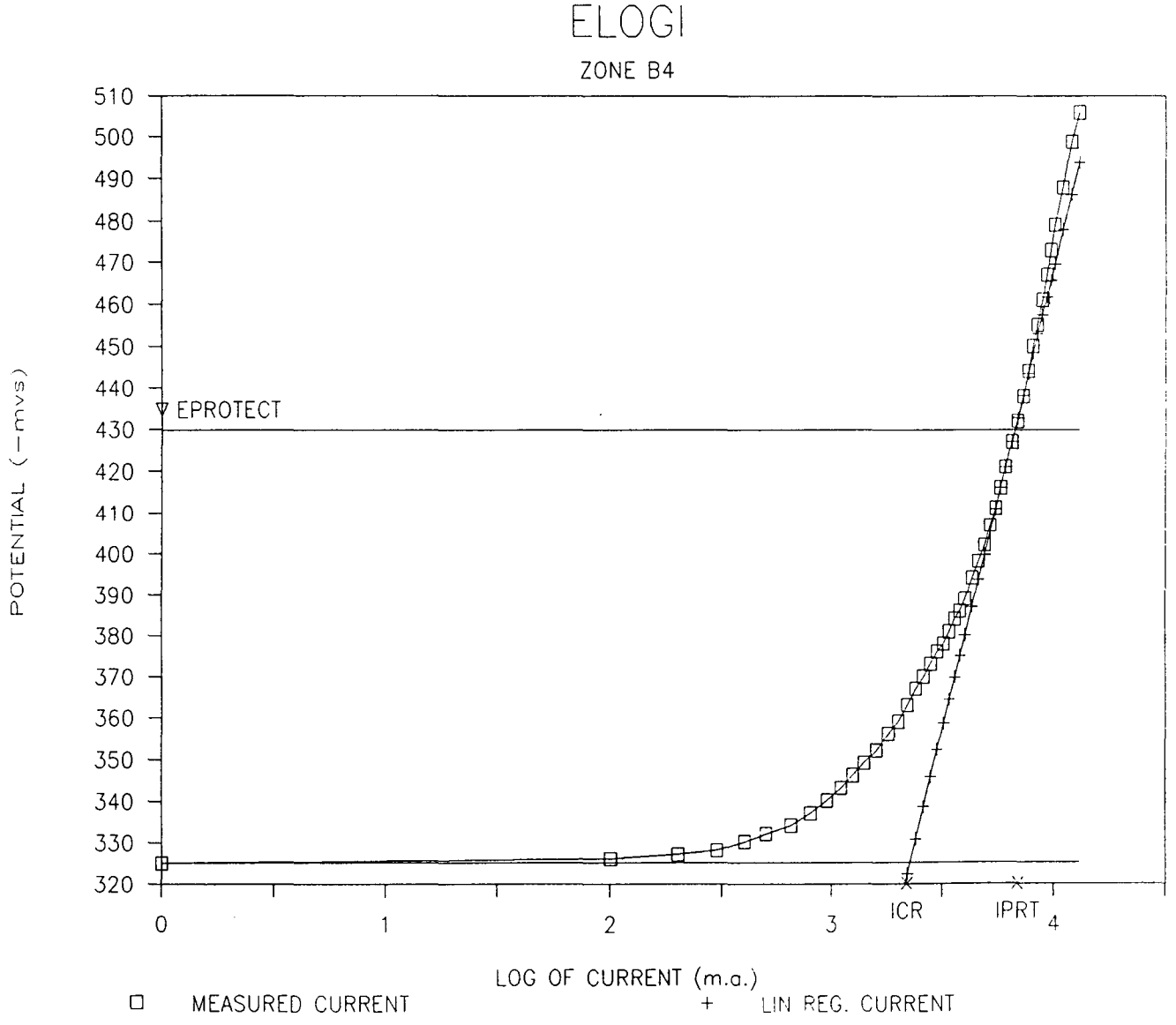


FIGURE 8

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

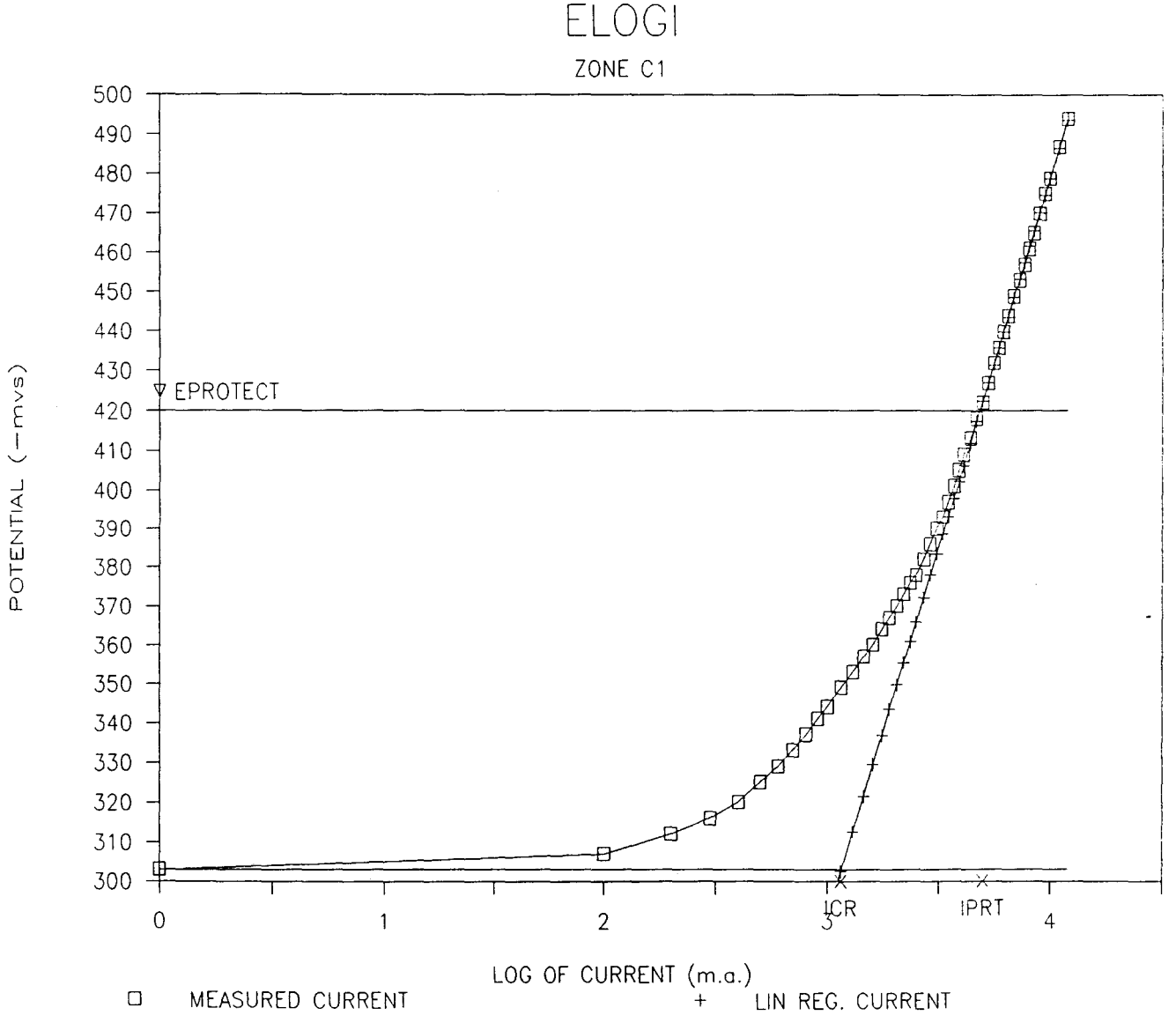


FIGURE 9

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

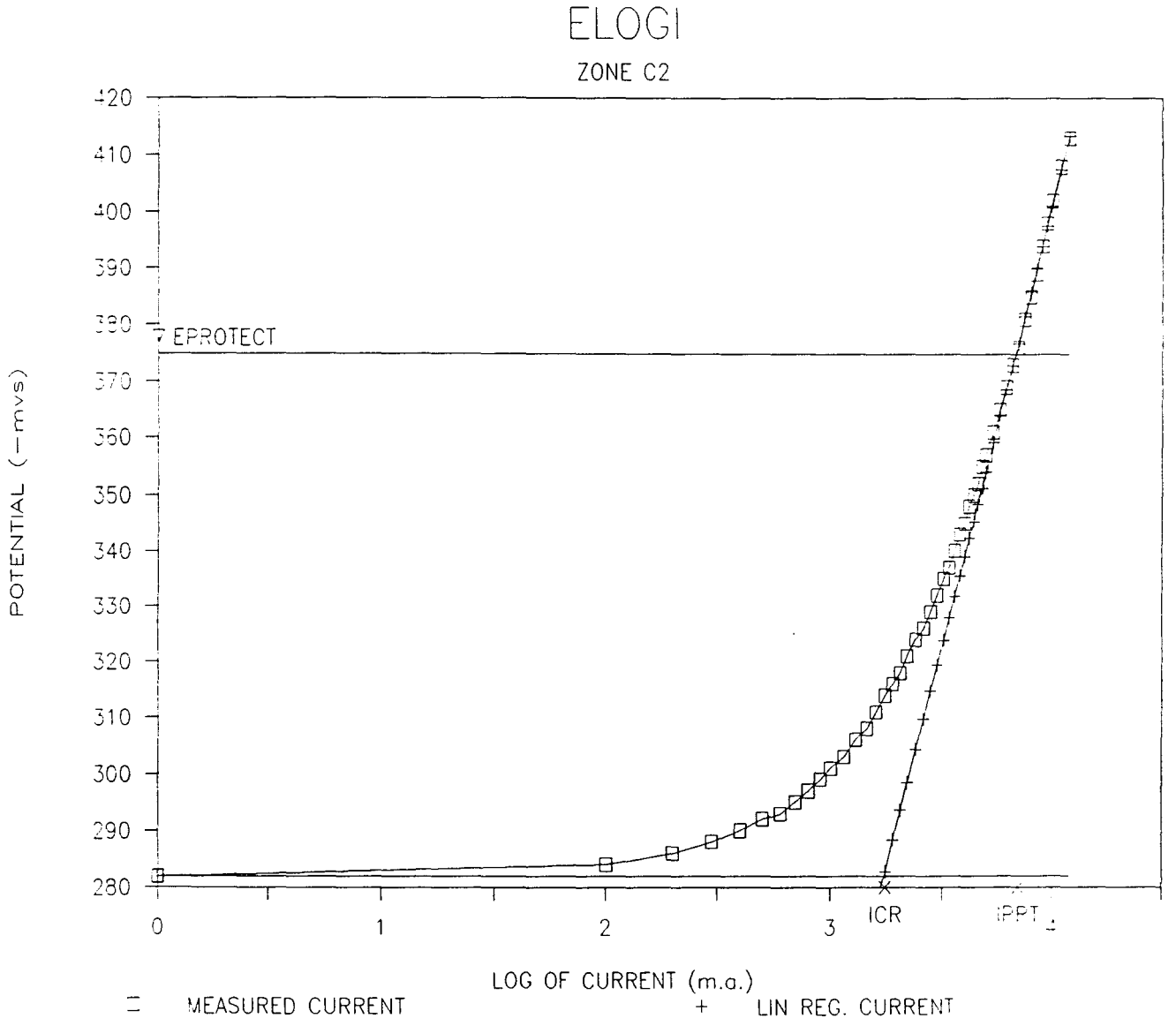


FIGURE 10

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

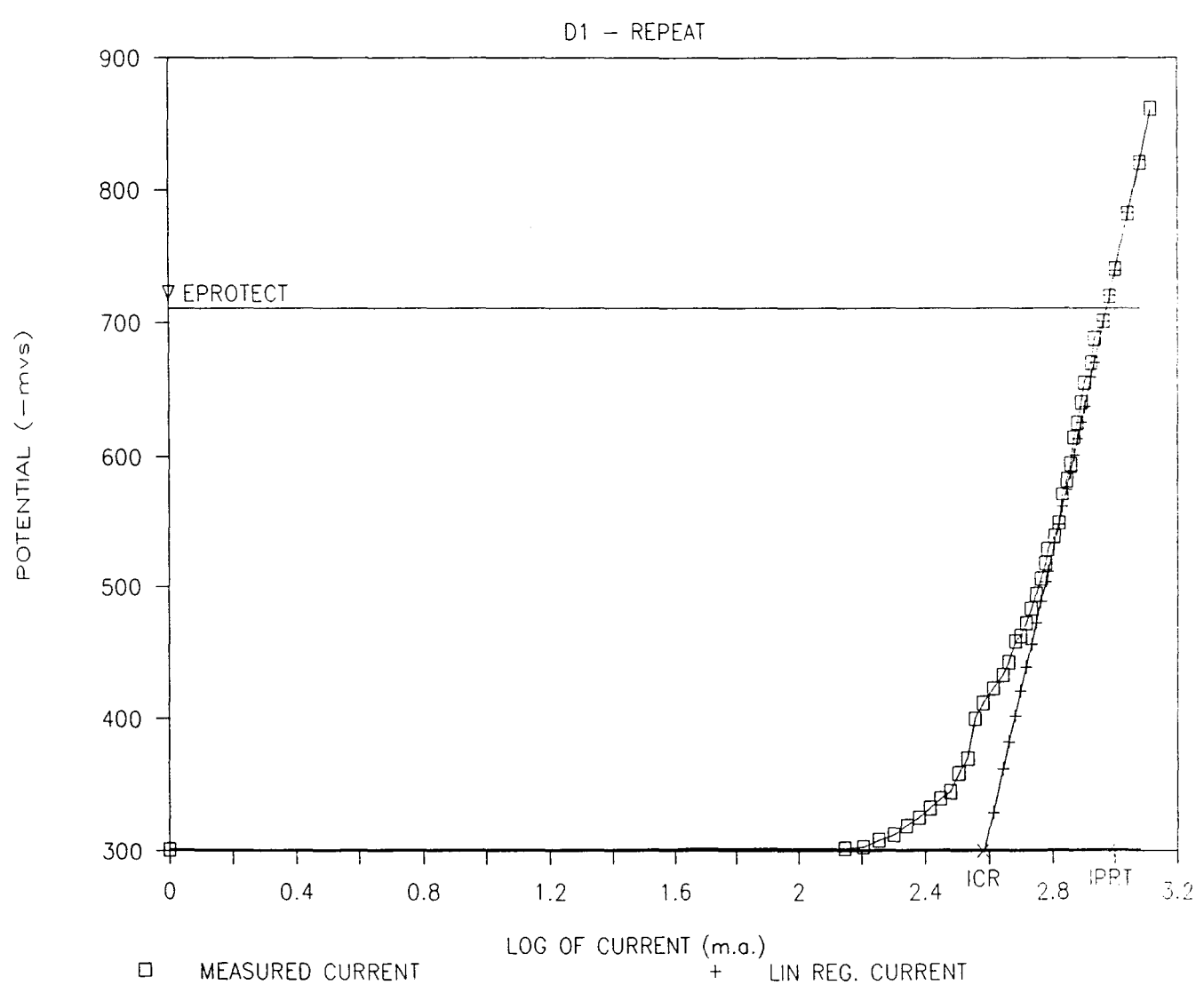


FIGURE 11

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

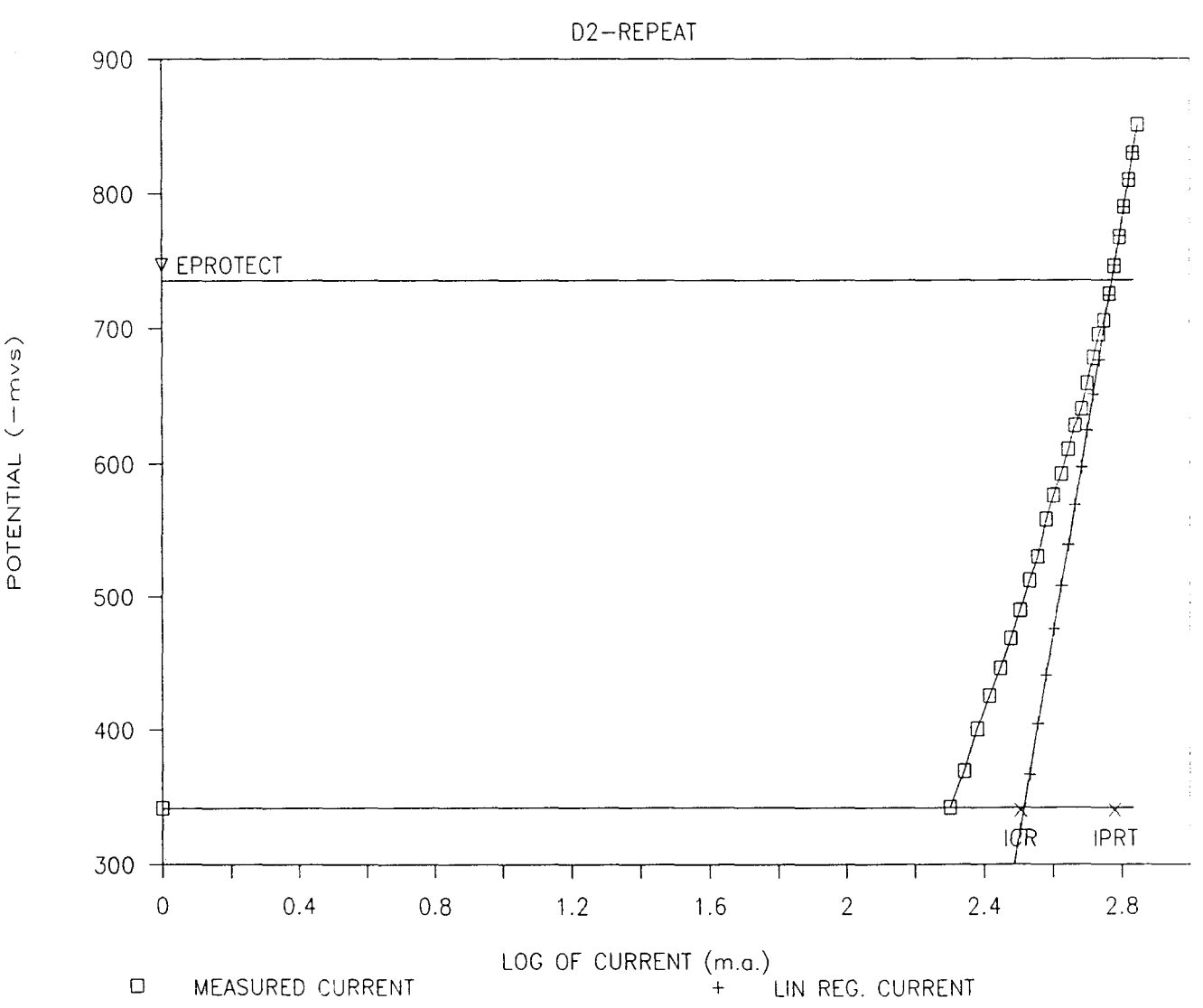


FIGURE 12

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

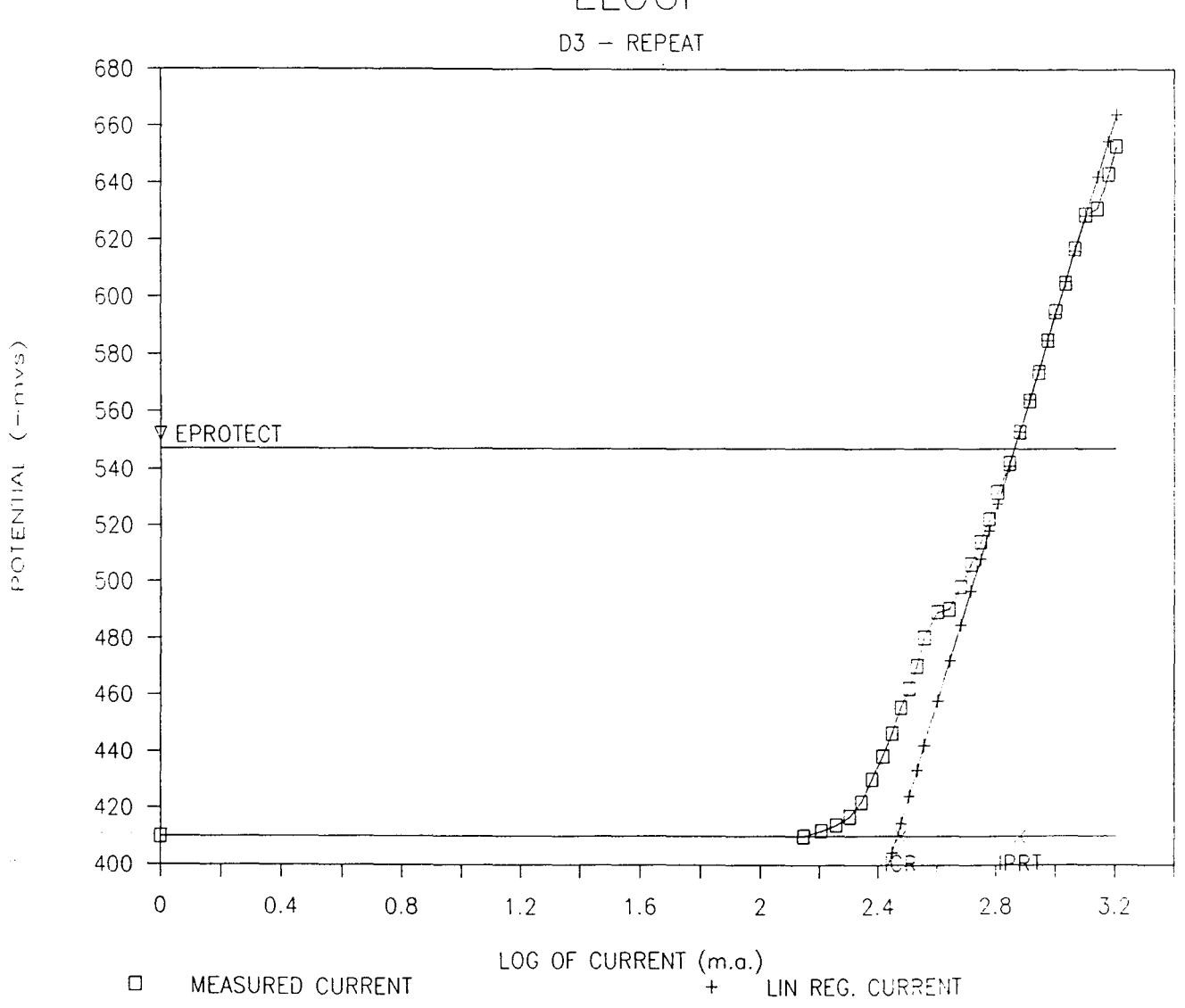


FIGURE 13

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

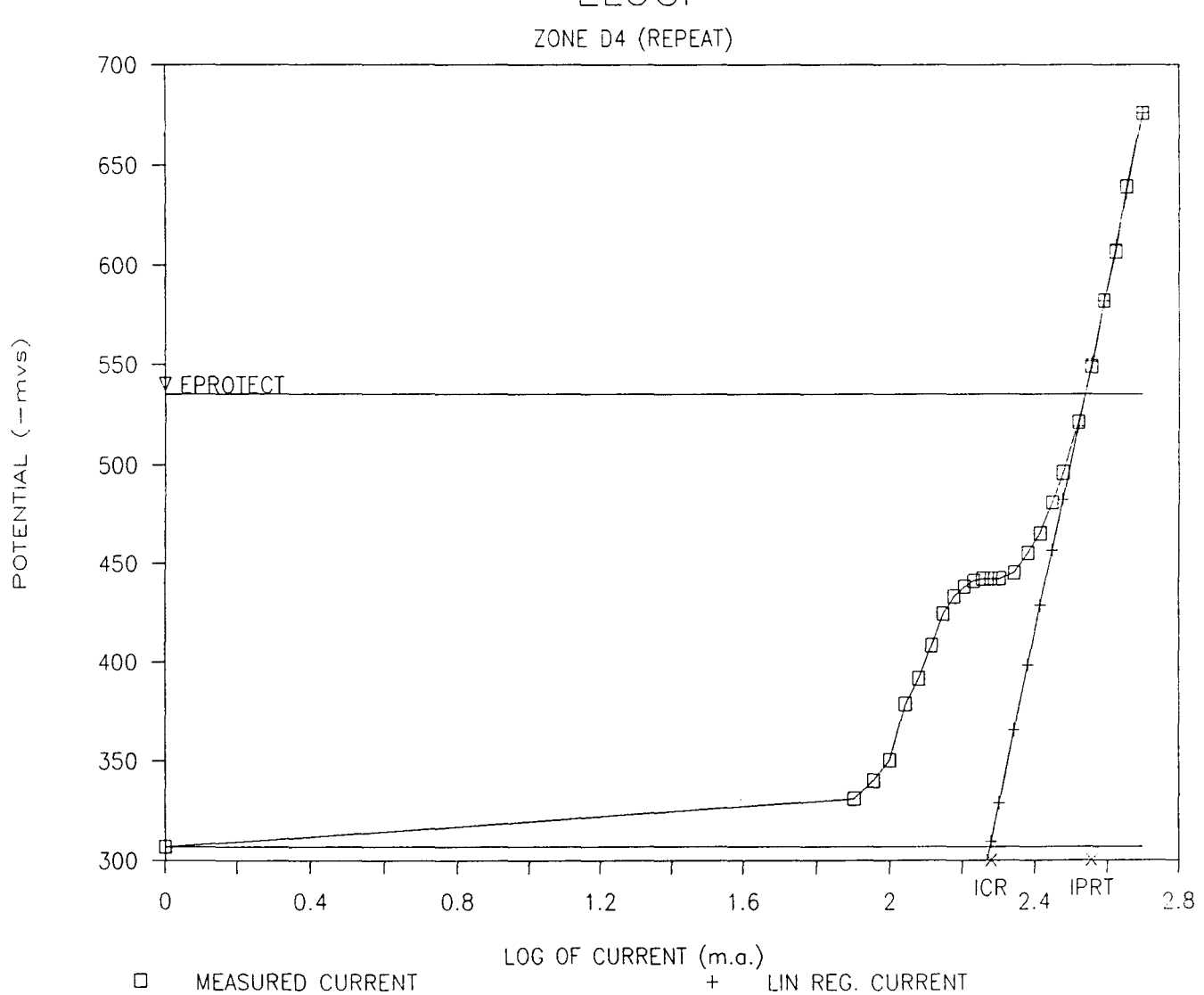


FIGURE 14

.. 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

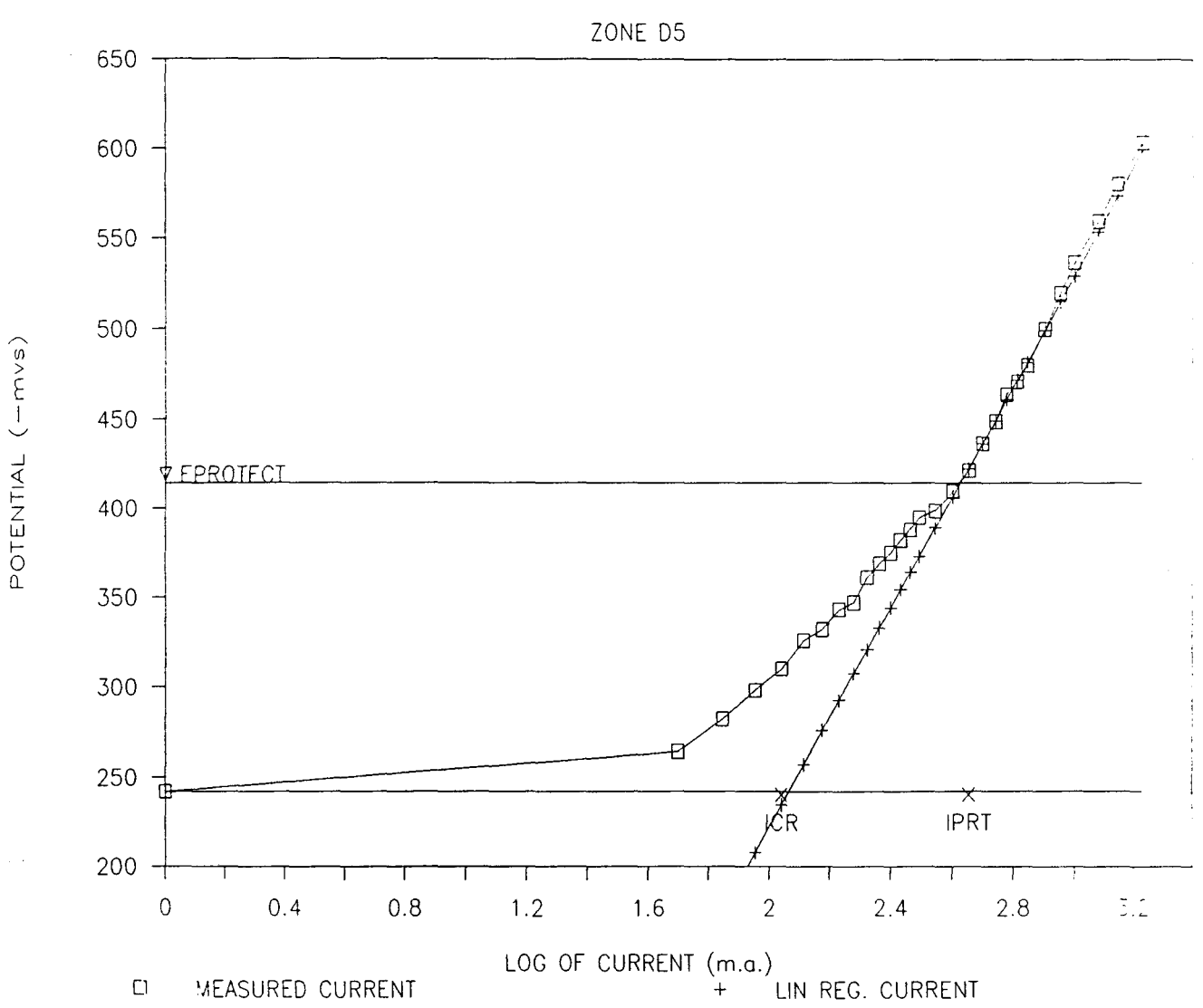


FIGURE 15

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

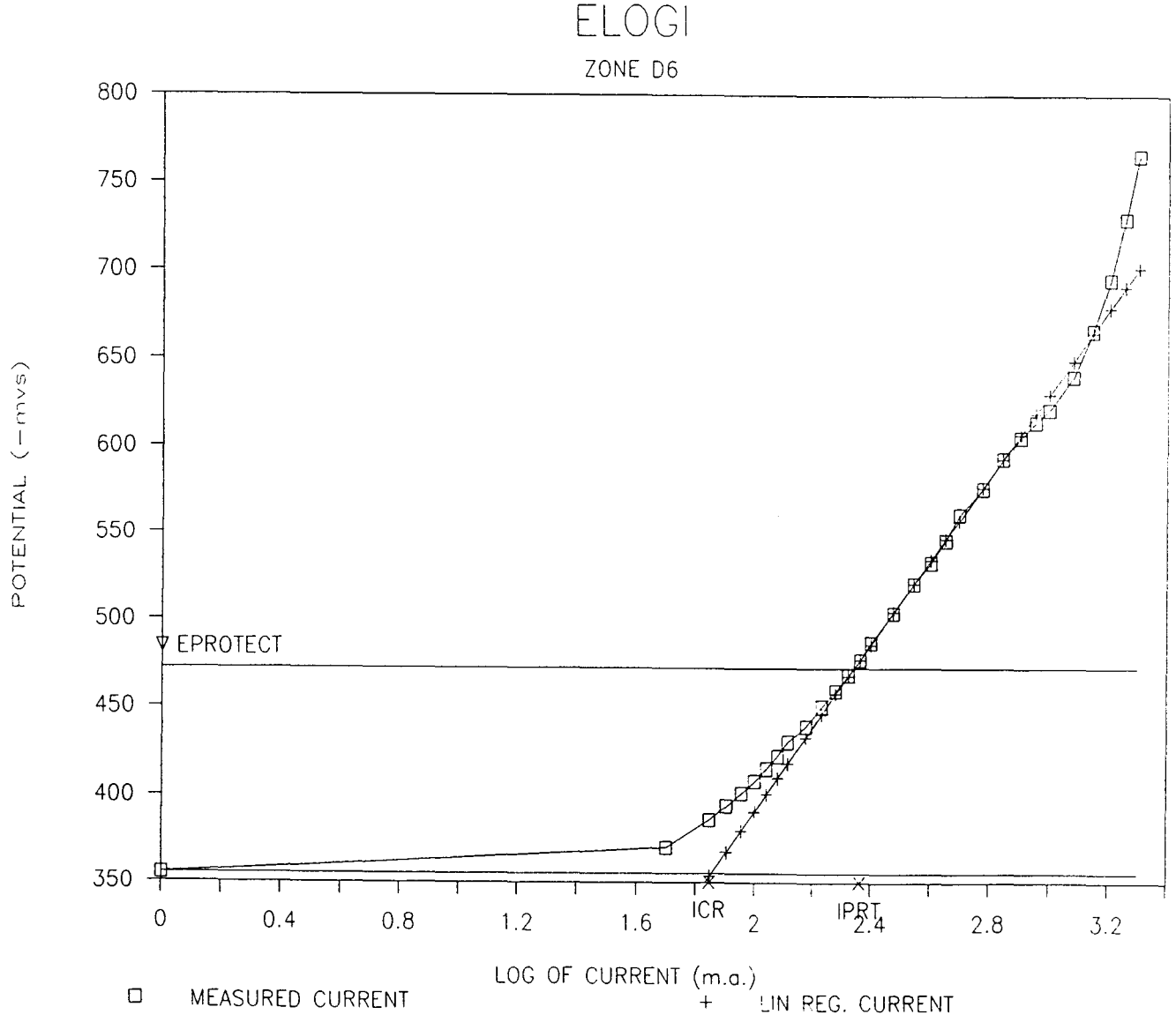


FIGURE 16

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

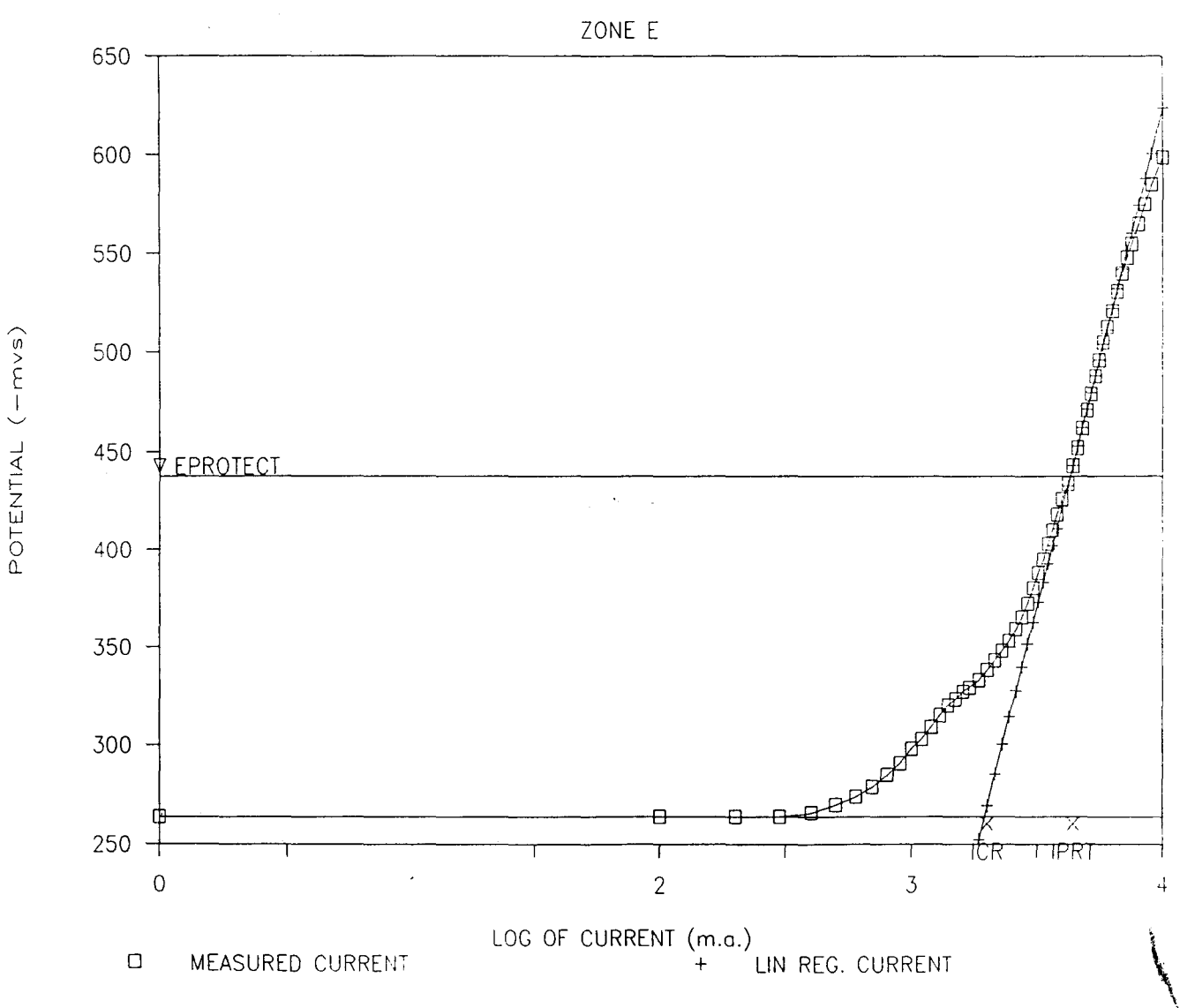
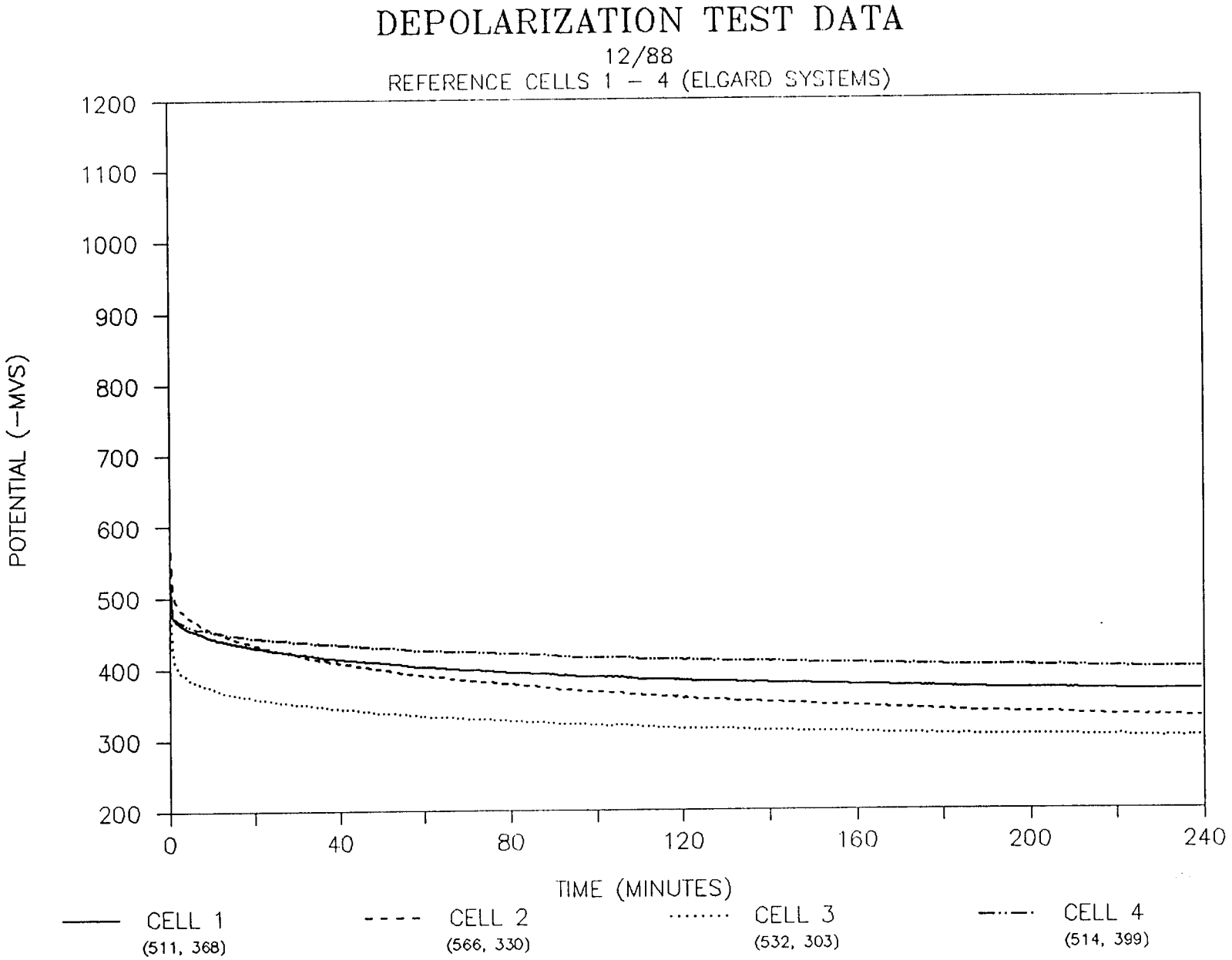
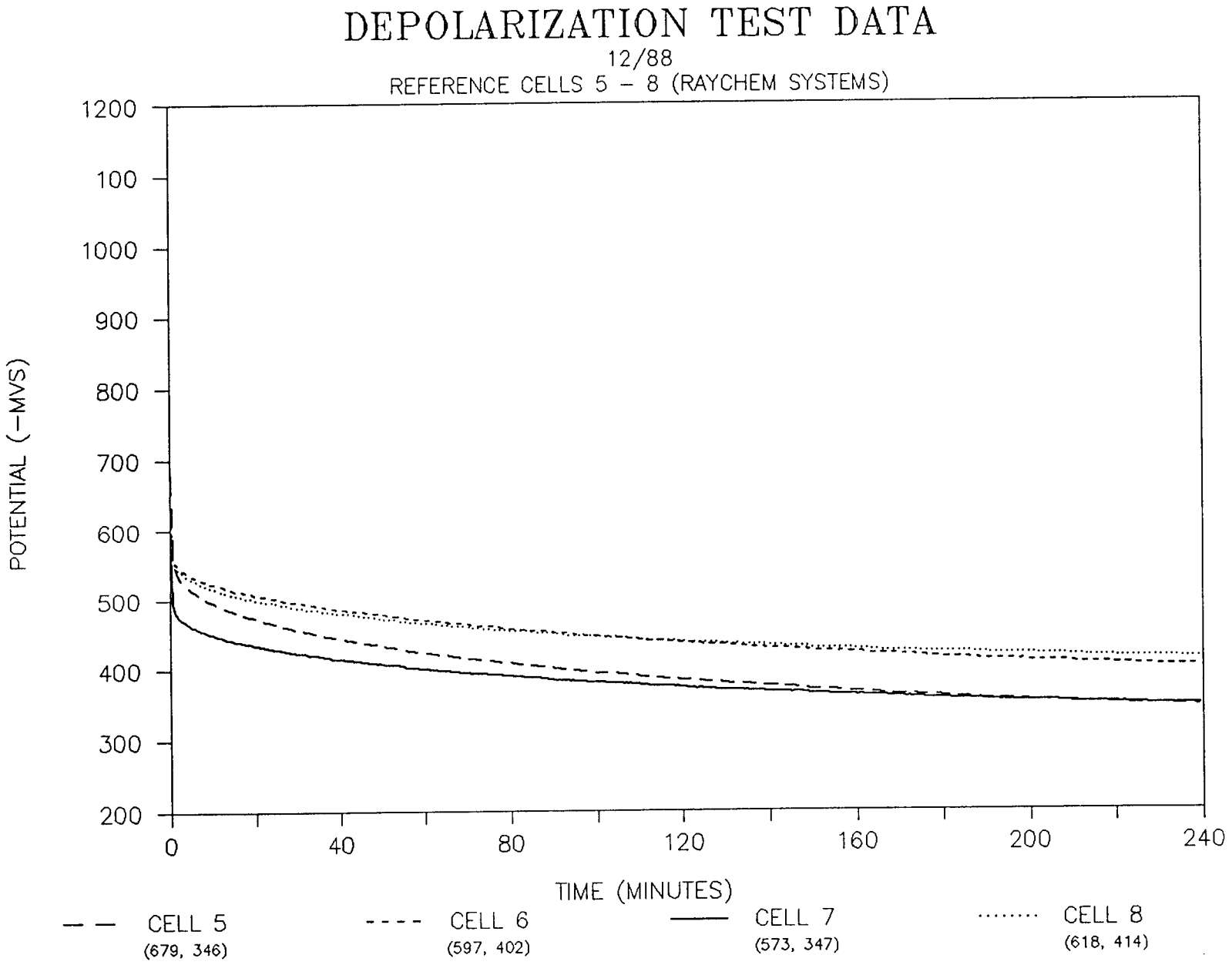


FIGURE 17



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



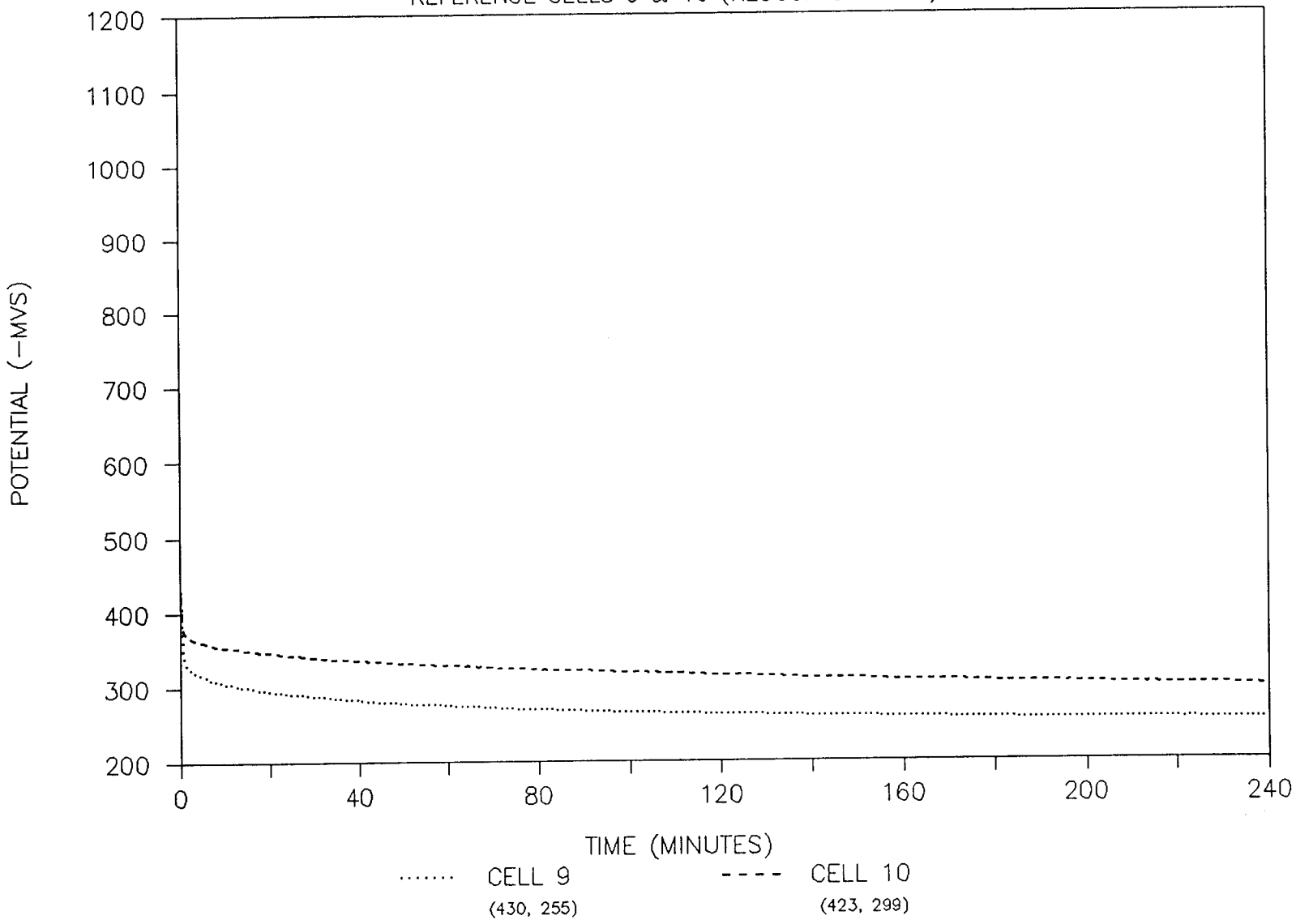
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 19

DEPOLARIZATION TEST DATA

12/88

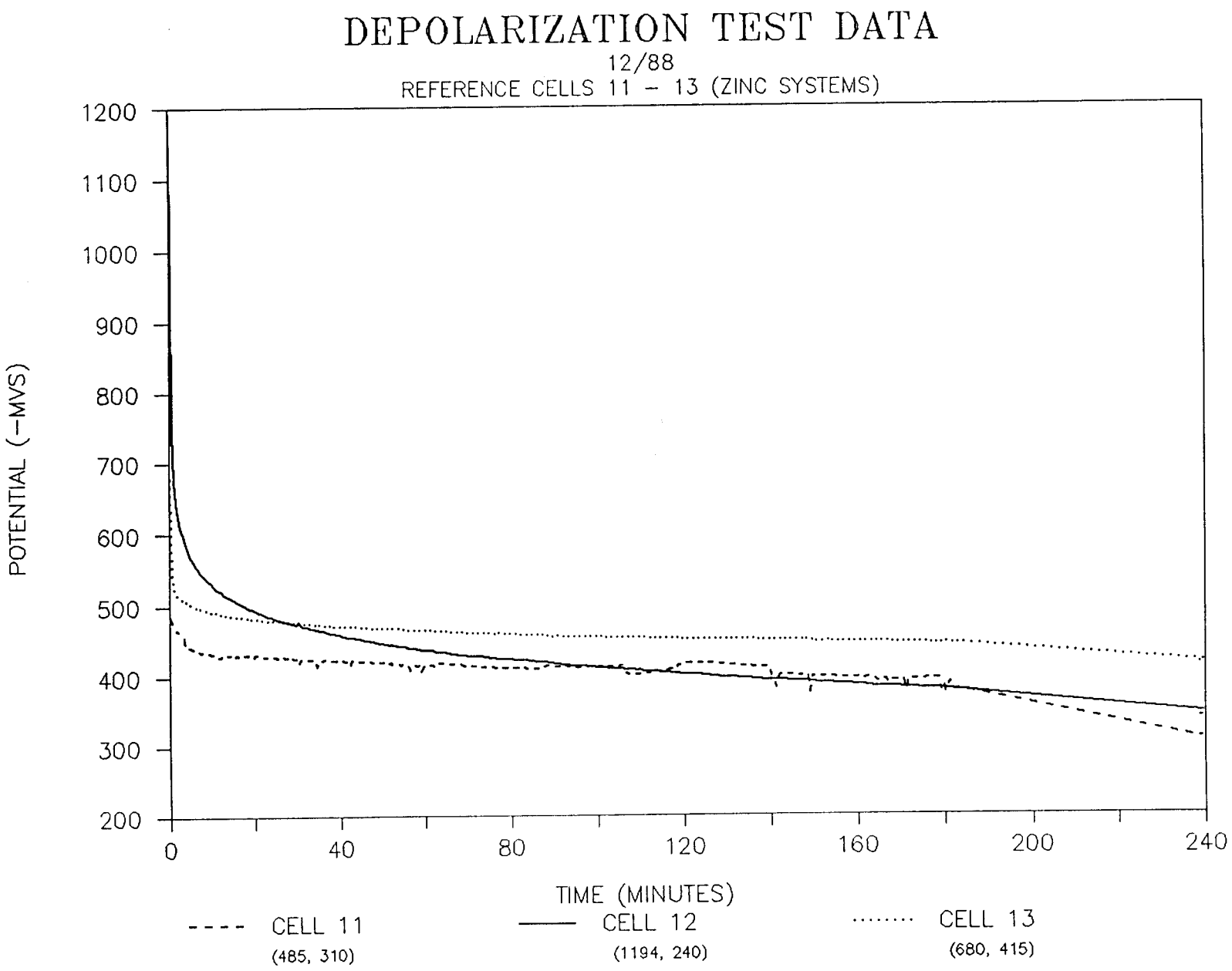
REFERENCE CELLS 9 & 10 (RESCON SYSTEMS)



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

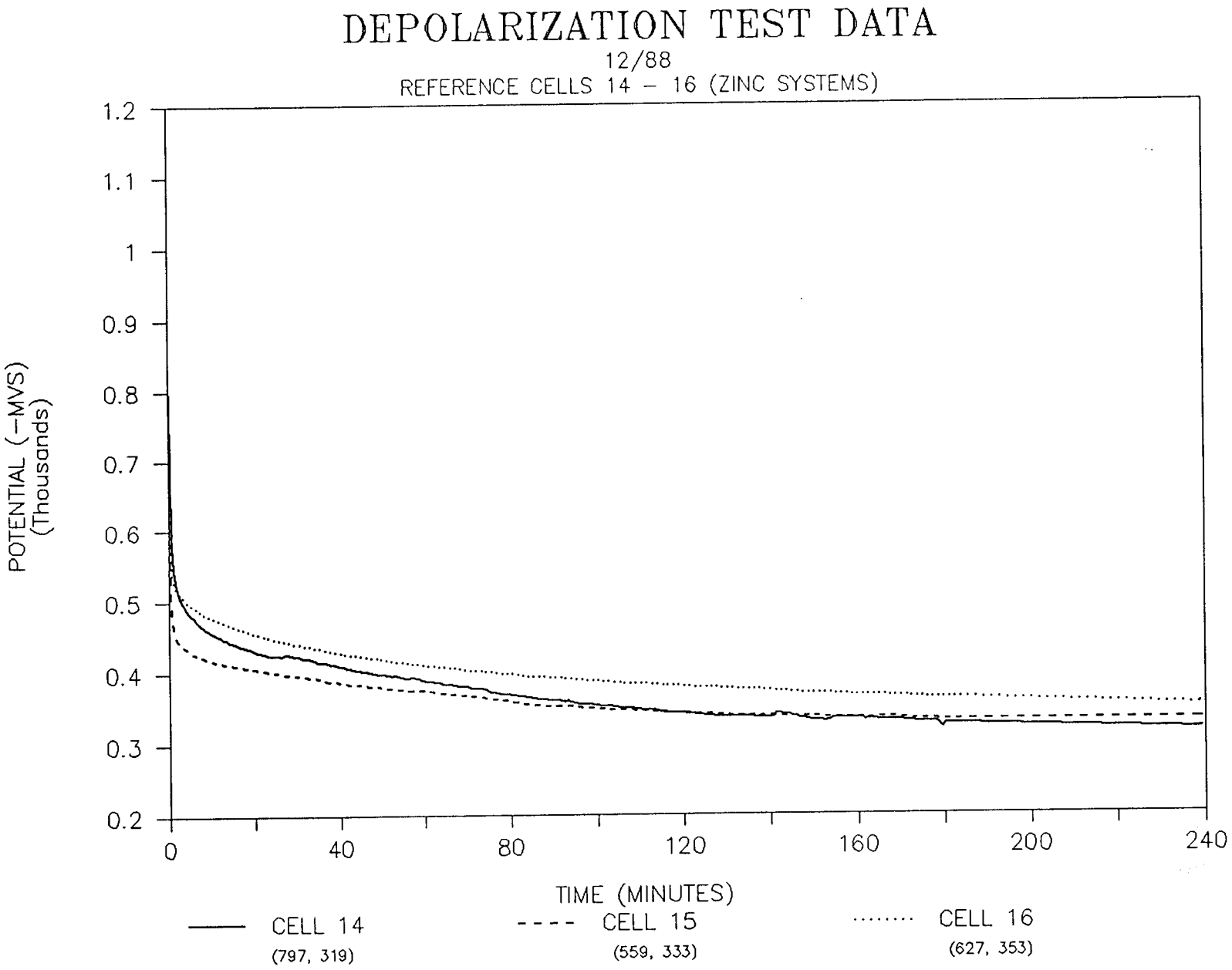
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 20



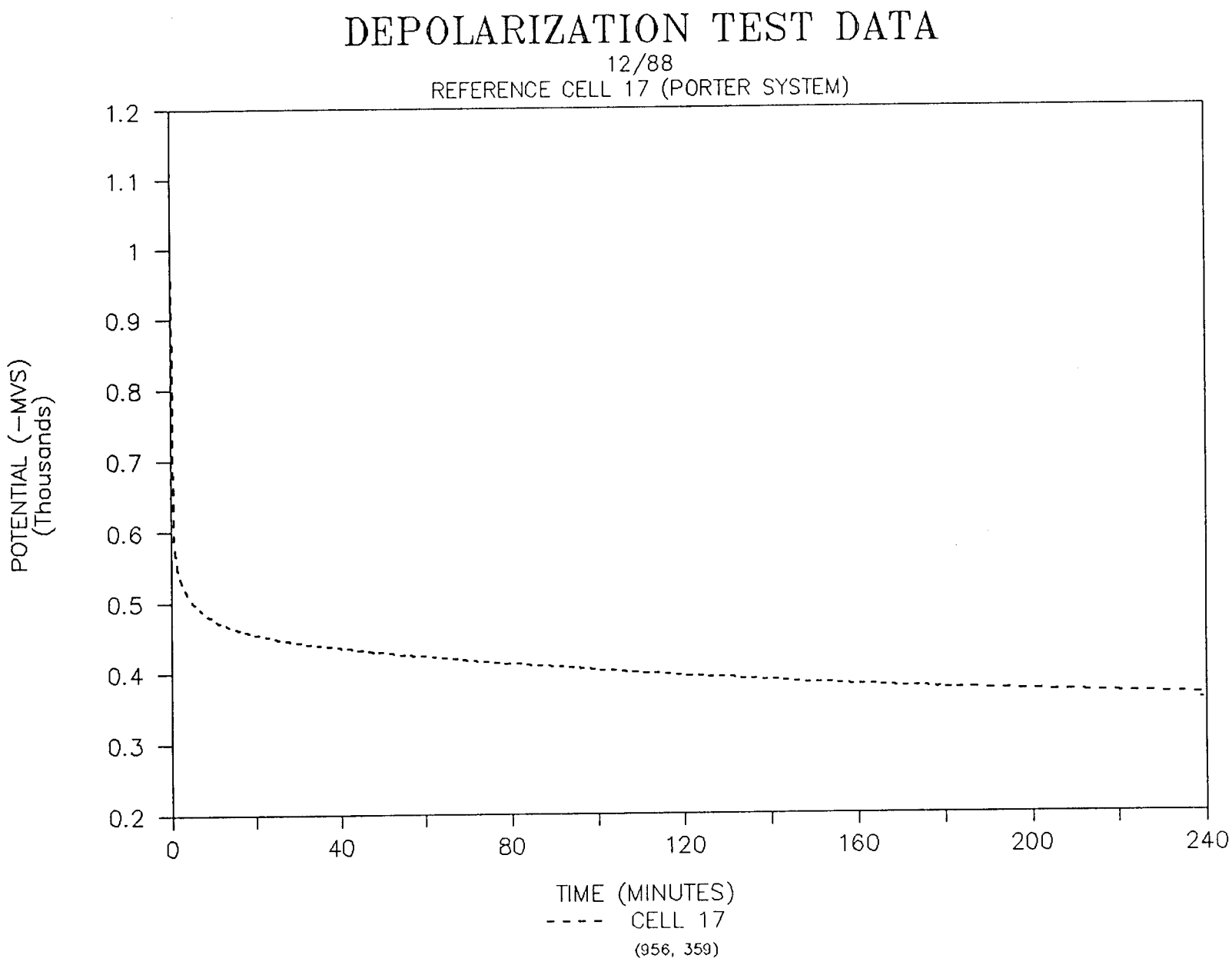
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 21



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



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

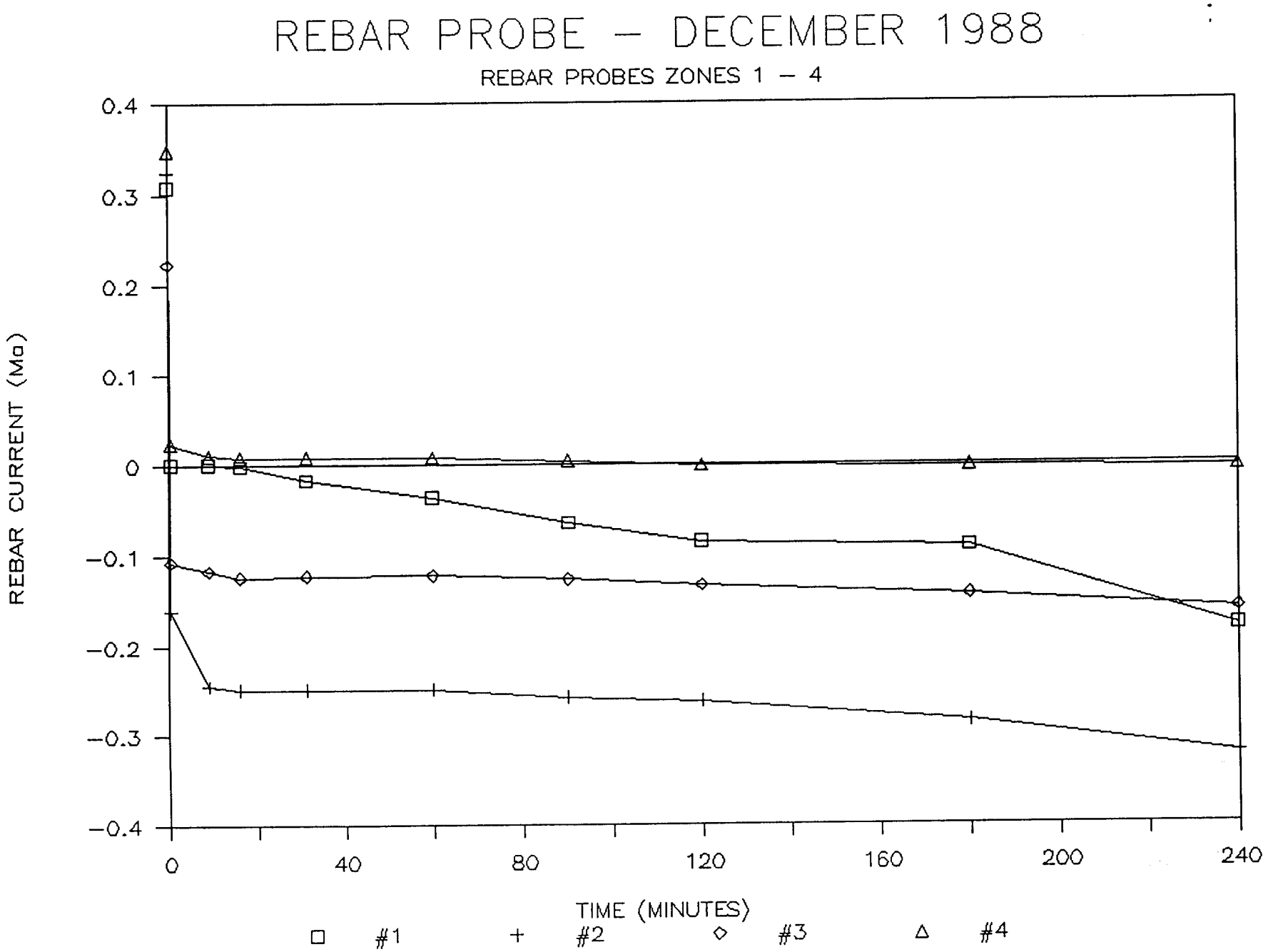

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONES 1 – 4
REBAR CURRENT (Ma)
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
0
40
80
120
160
200
240
TIME (MINUTES)
#1
#2
#3
#4

FIGURE 24

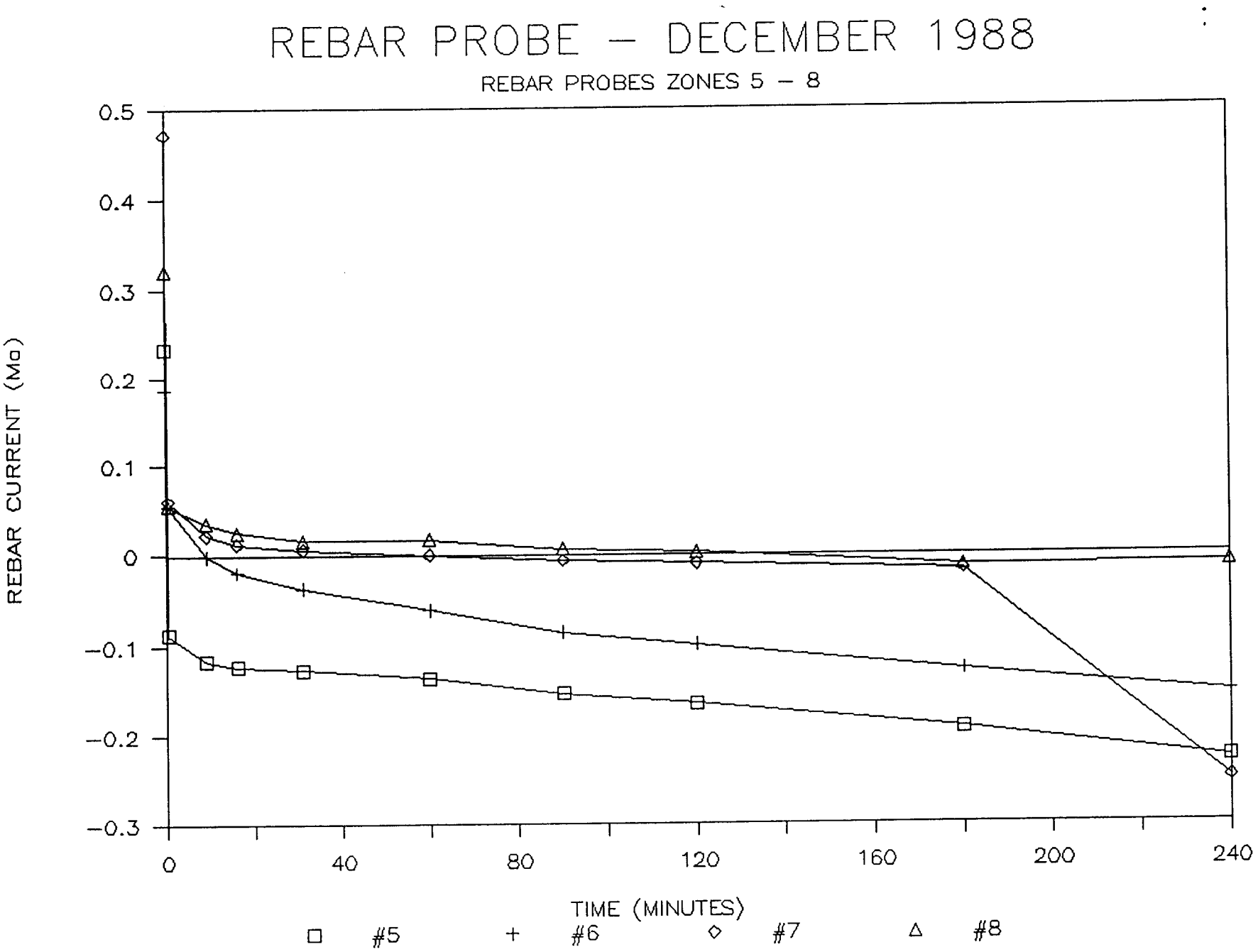

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONES 5 – 8
REBAR CURRENT (Ma)
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
0
40
80
120
160
200
240
TIME (MINUTES)
#5
#6
#7
#8

FIGURE 25

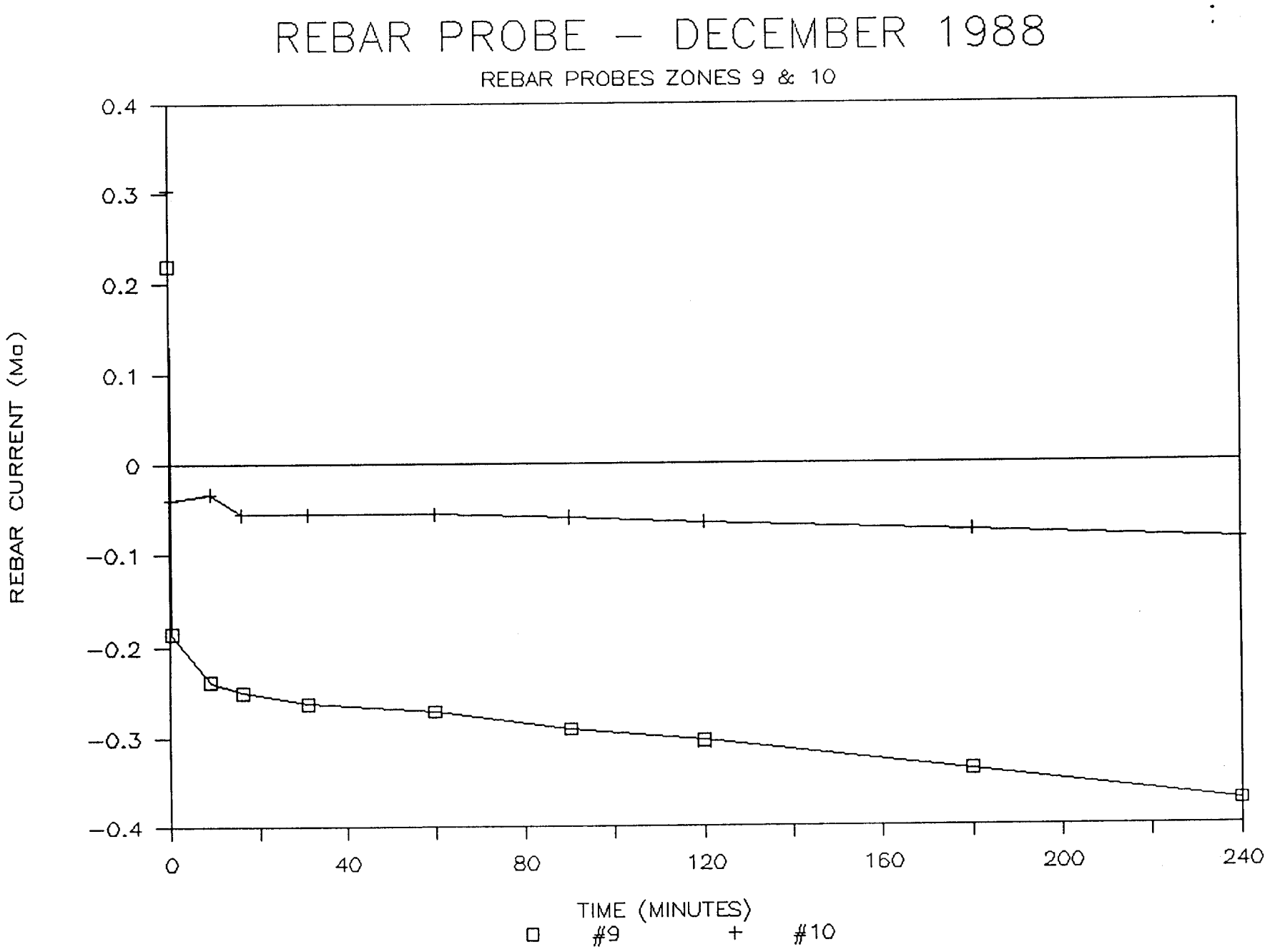

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONES 9 & 10
REBAR CURRENT (Ma)
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
0
40
80
120
160
200
240
TIME (MINUTES)
#9
#10

FIGURE 26

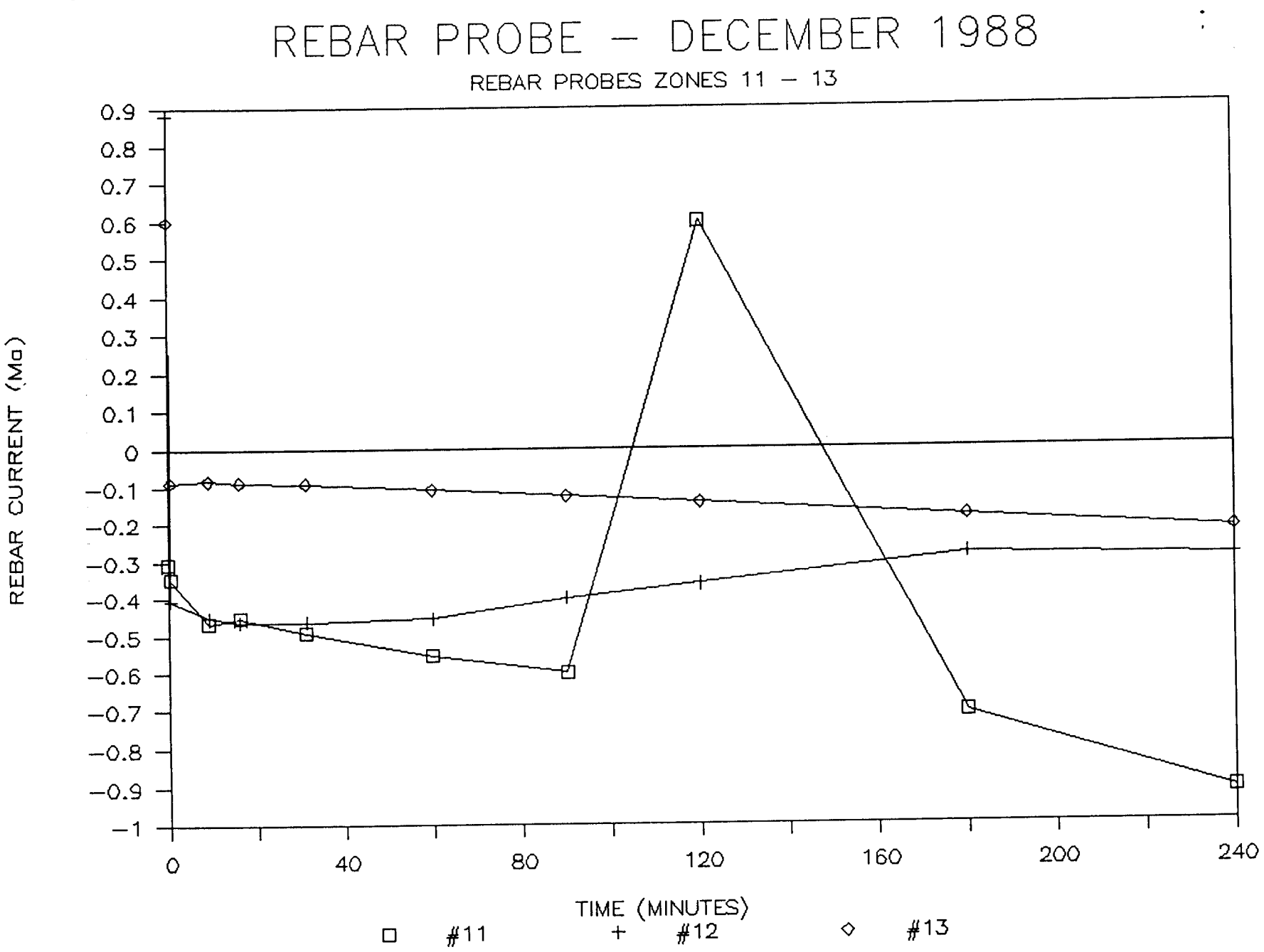

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONES 11 – 13
REBAR CURRENT (Ma)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
−1
0
40
80
120
160
200
240
TIME (MINUTES)
#11
#12
#13

FIGURE 27

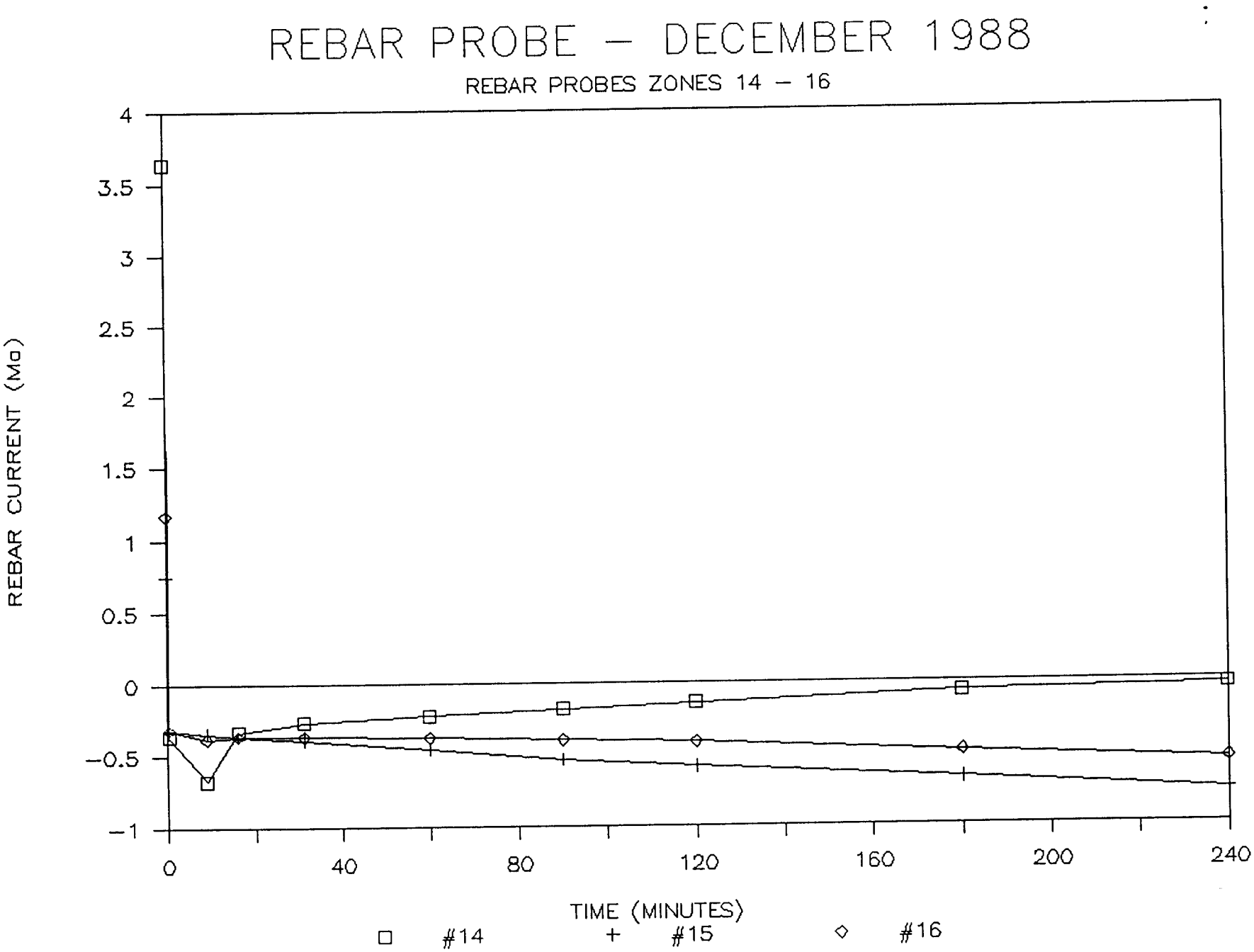

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONES 14 – 16
REBAR CURRENT (Ma)
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
0
40
80
120
160
200
240
TIME (MINUTES)
□ #14
+ #15
◇ #16

FIGURE 28

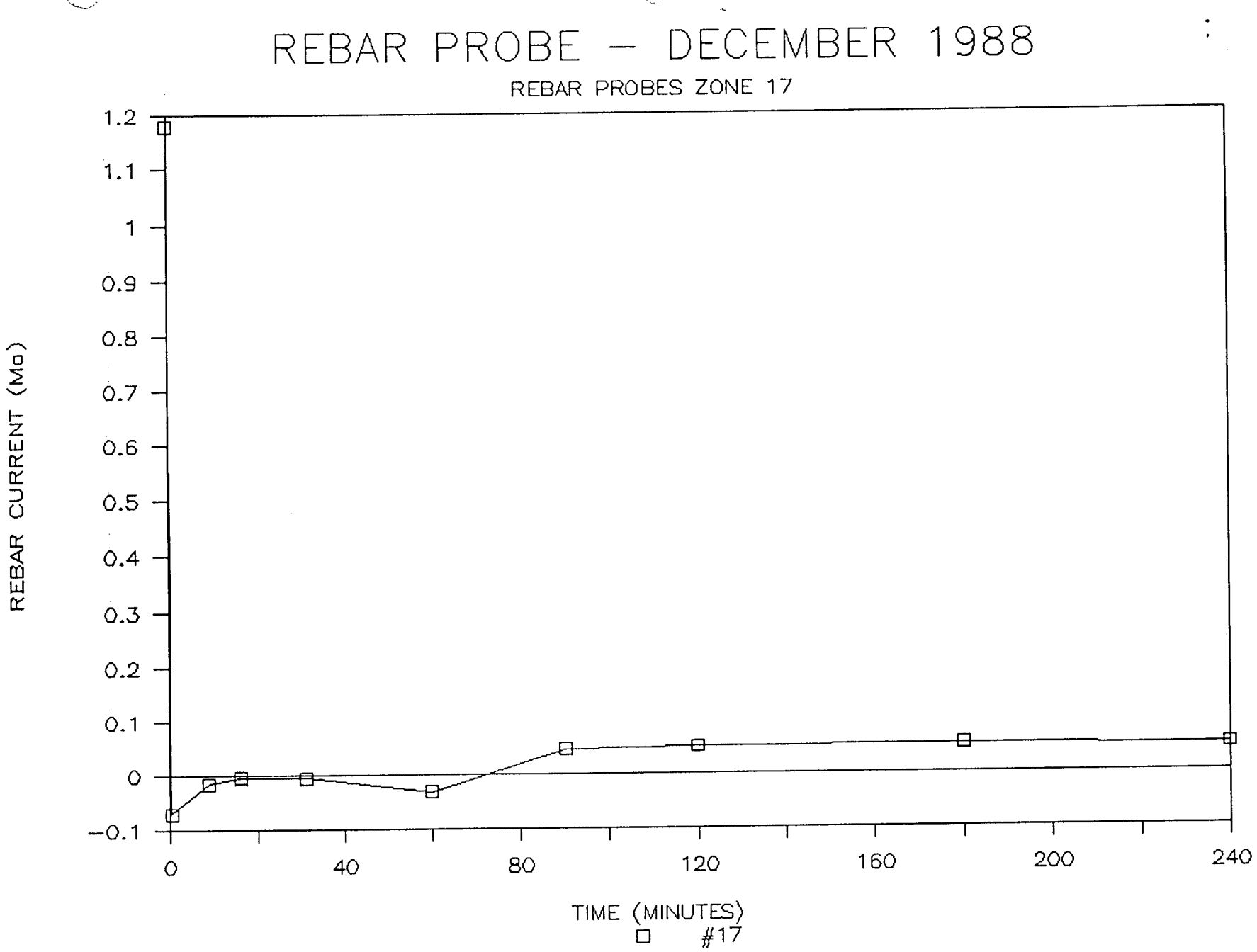
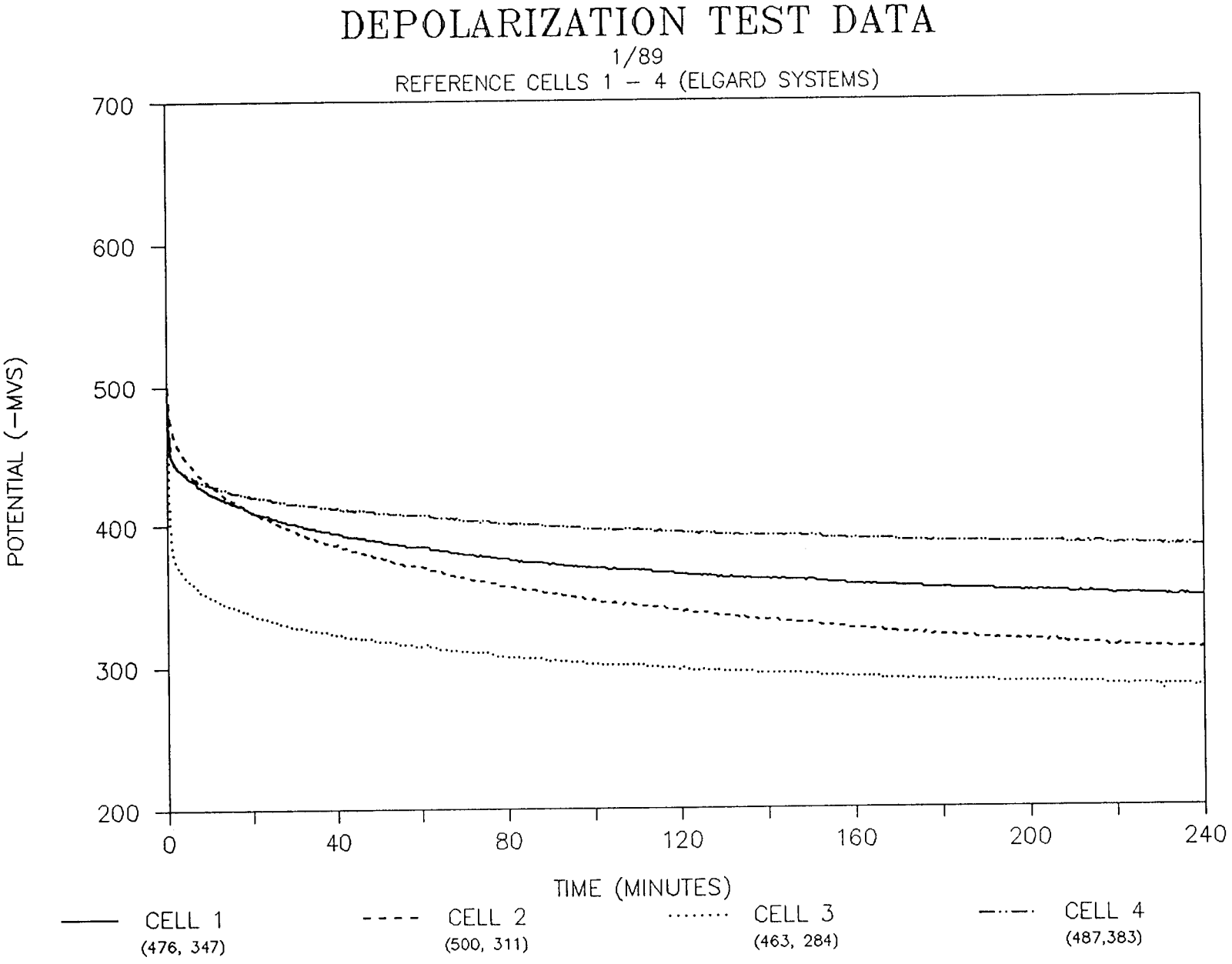
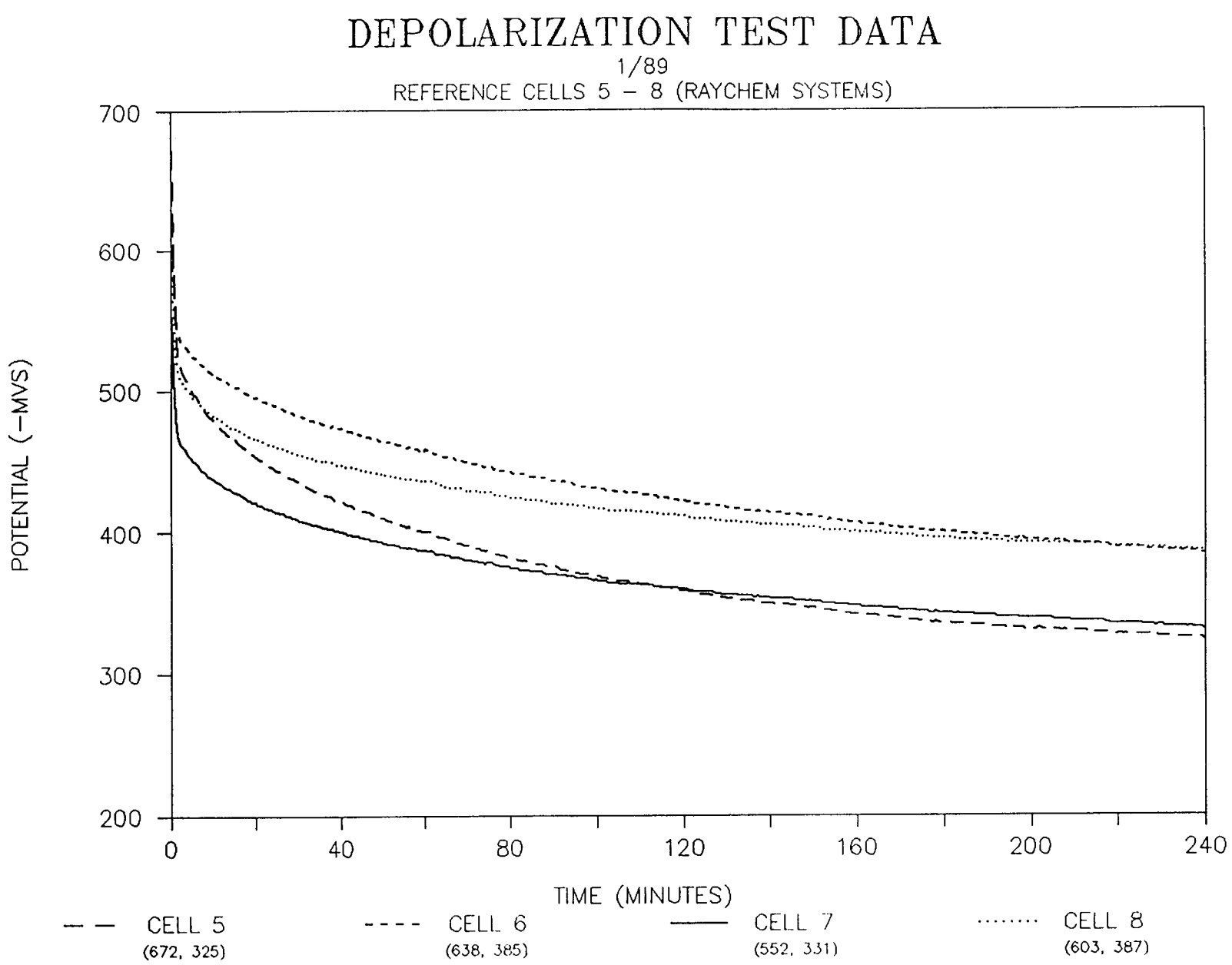

REBAR PROBE – DECEMBER 1988
REBAR PROBES ZONE 17
REBAR CURRENT (Ma)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
40
80
120
160
200
240
TIME (MINUTES)
#17

FIGURE 29



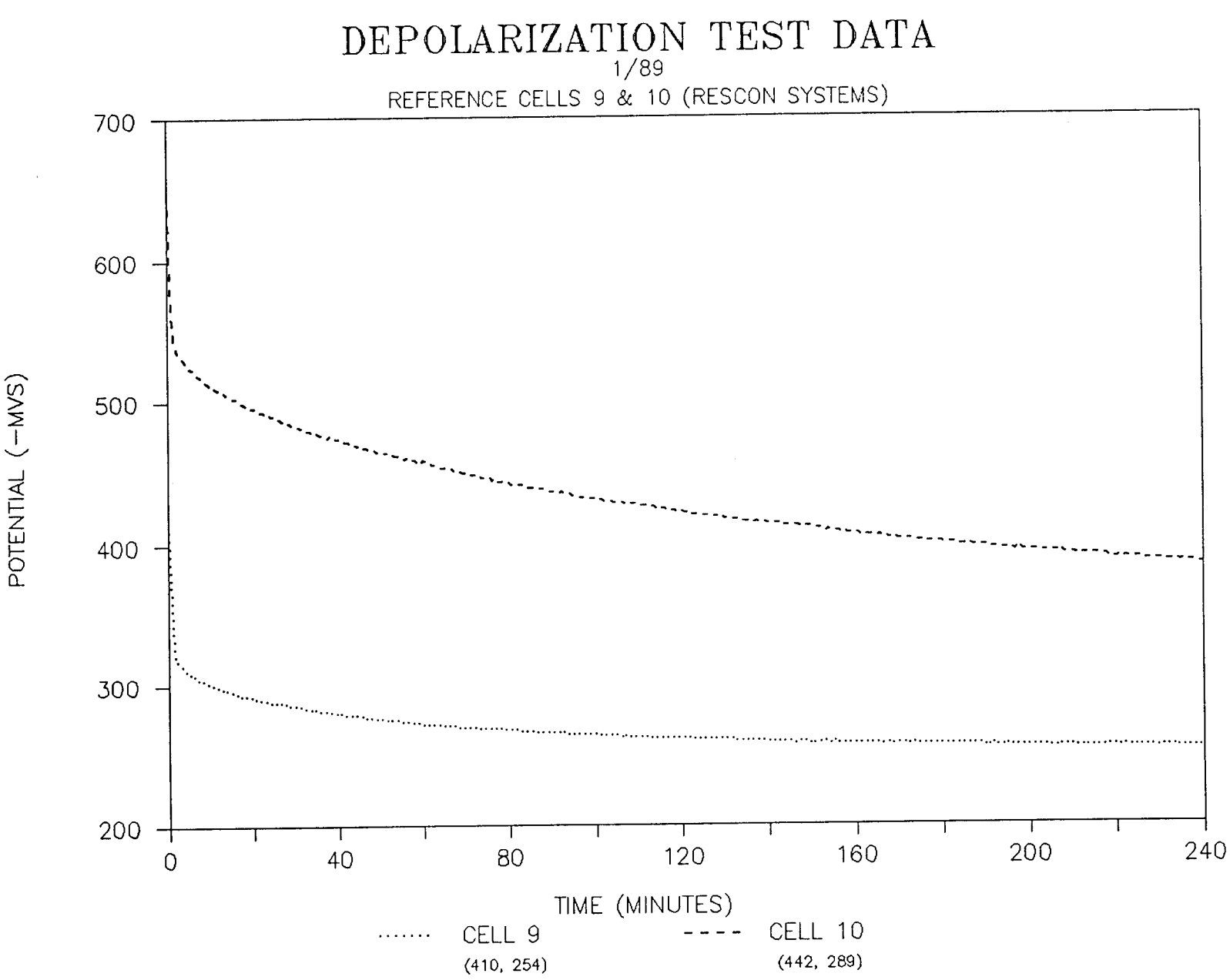
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 30



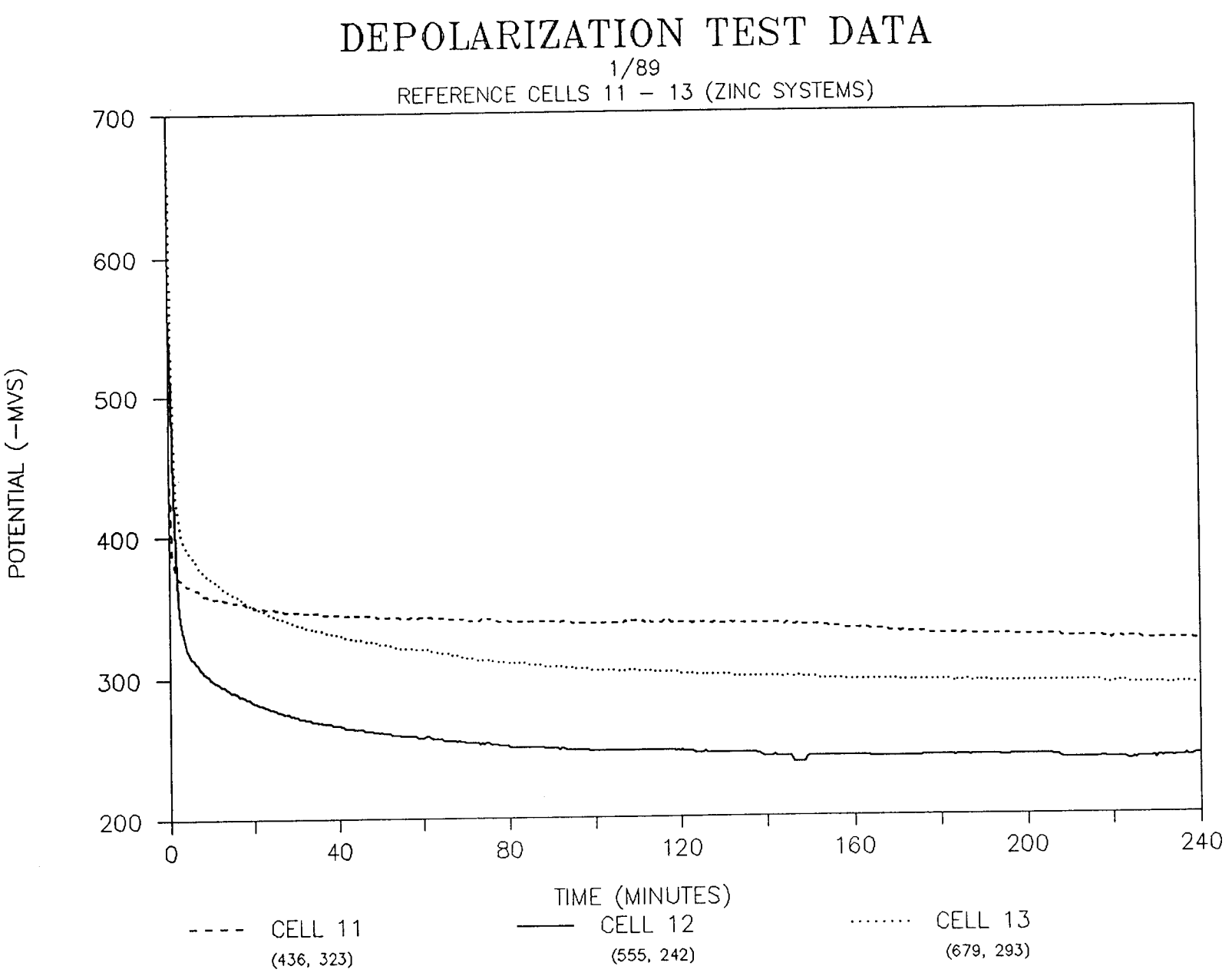
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 31



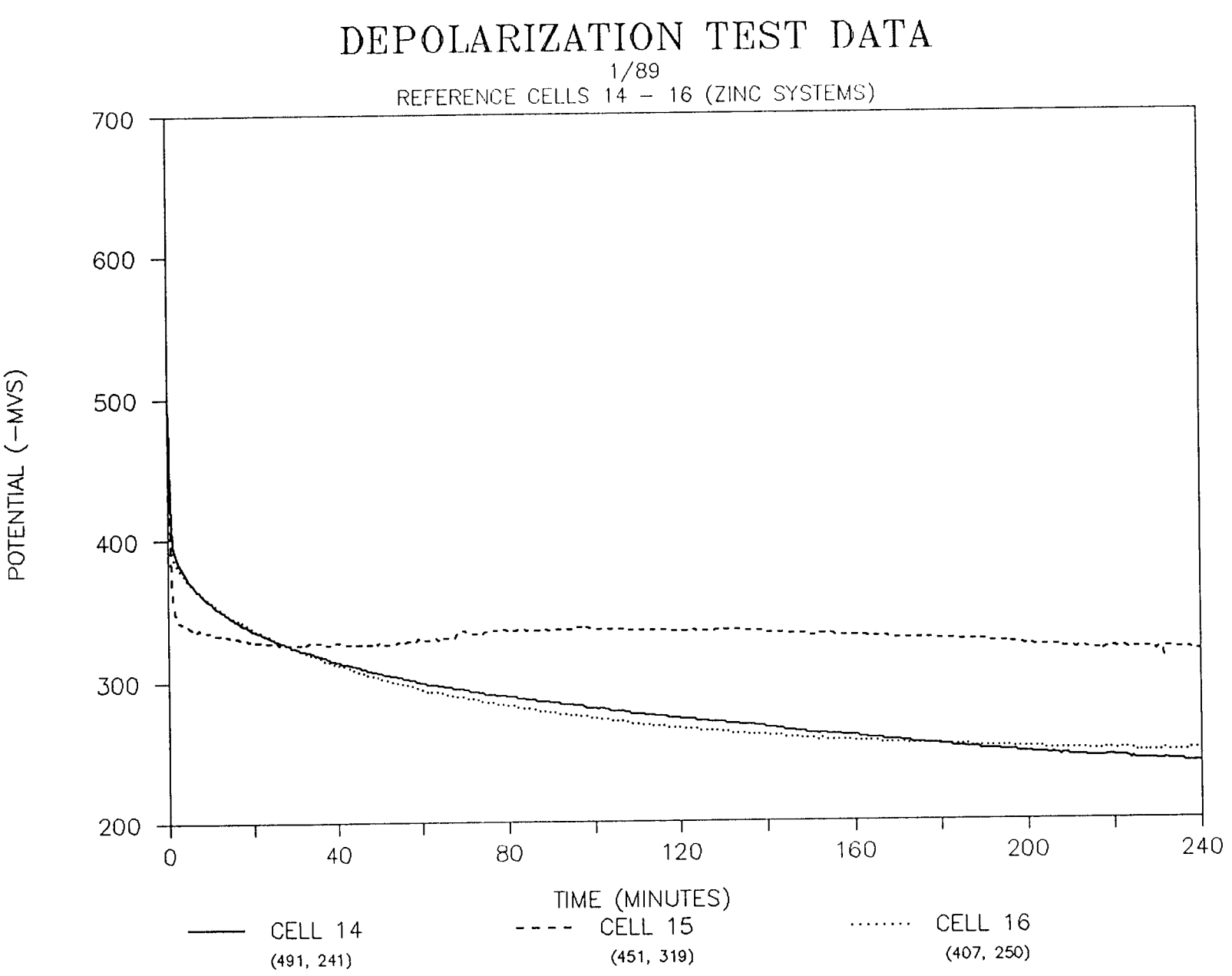
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 32



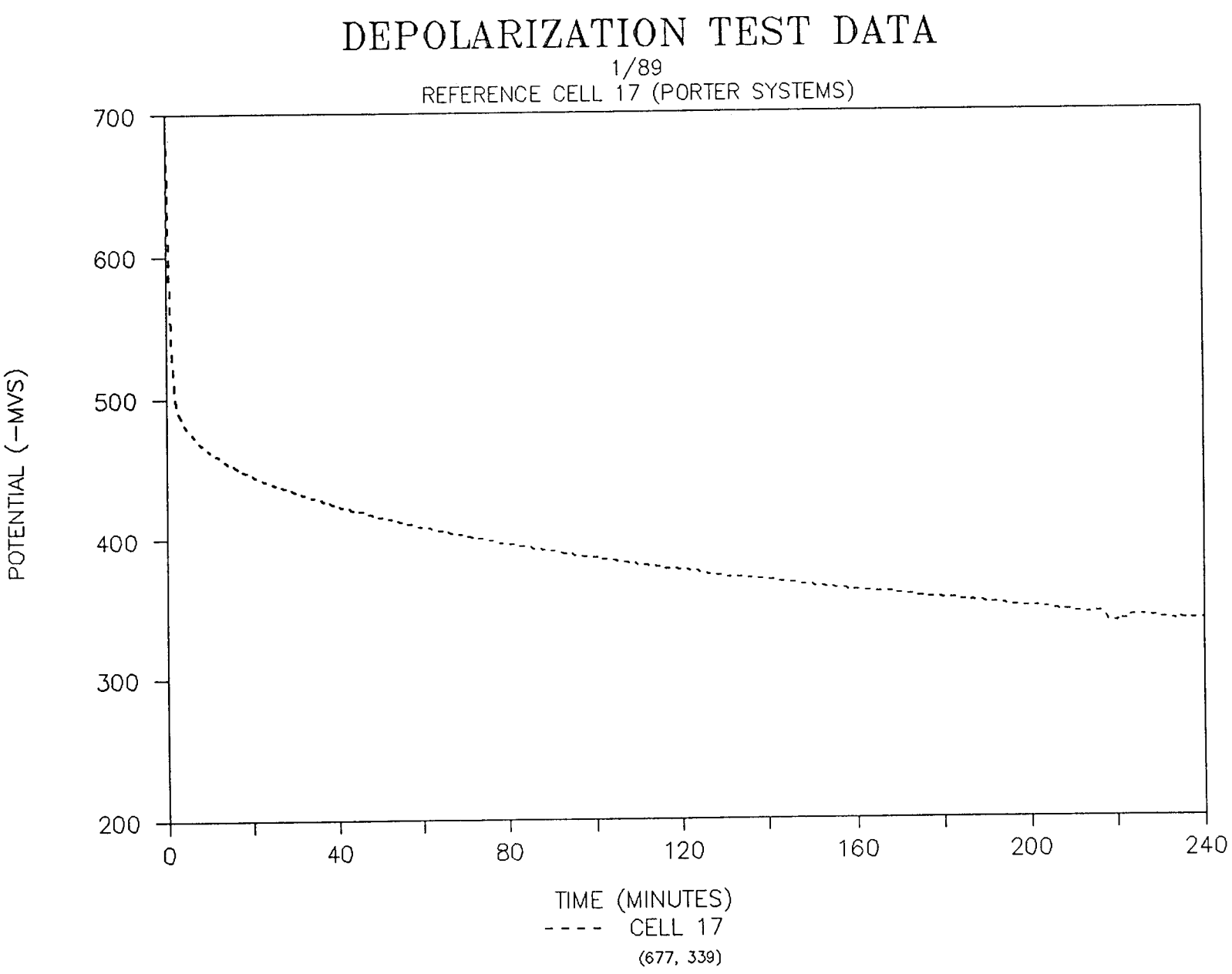
Note: x,y x: Instant-off reference cell potential measurement
y: Reference cell potential measurements taken after 4 hrs of system power shut-off.

FIGURE 33



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



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 35

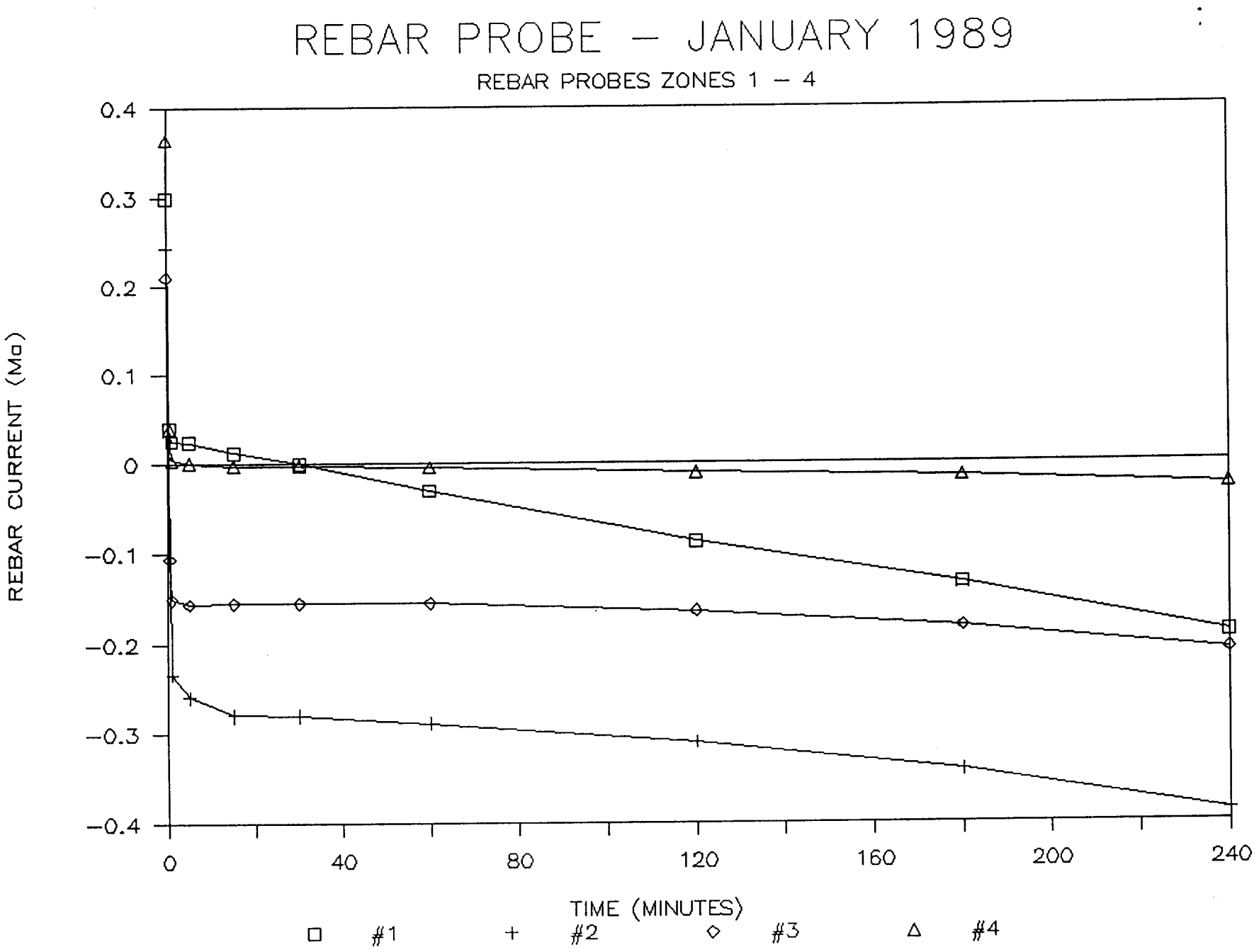

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONES 1 – 4
REBAR CURRENT (Ma)
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
0
40
80
120
160
200
240
TIME (MINUTES)
#1
#2
#3
#4

FIGURE 36

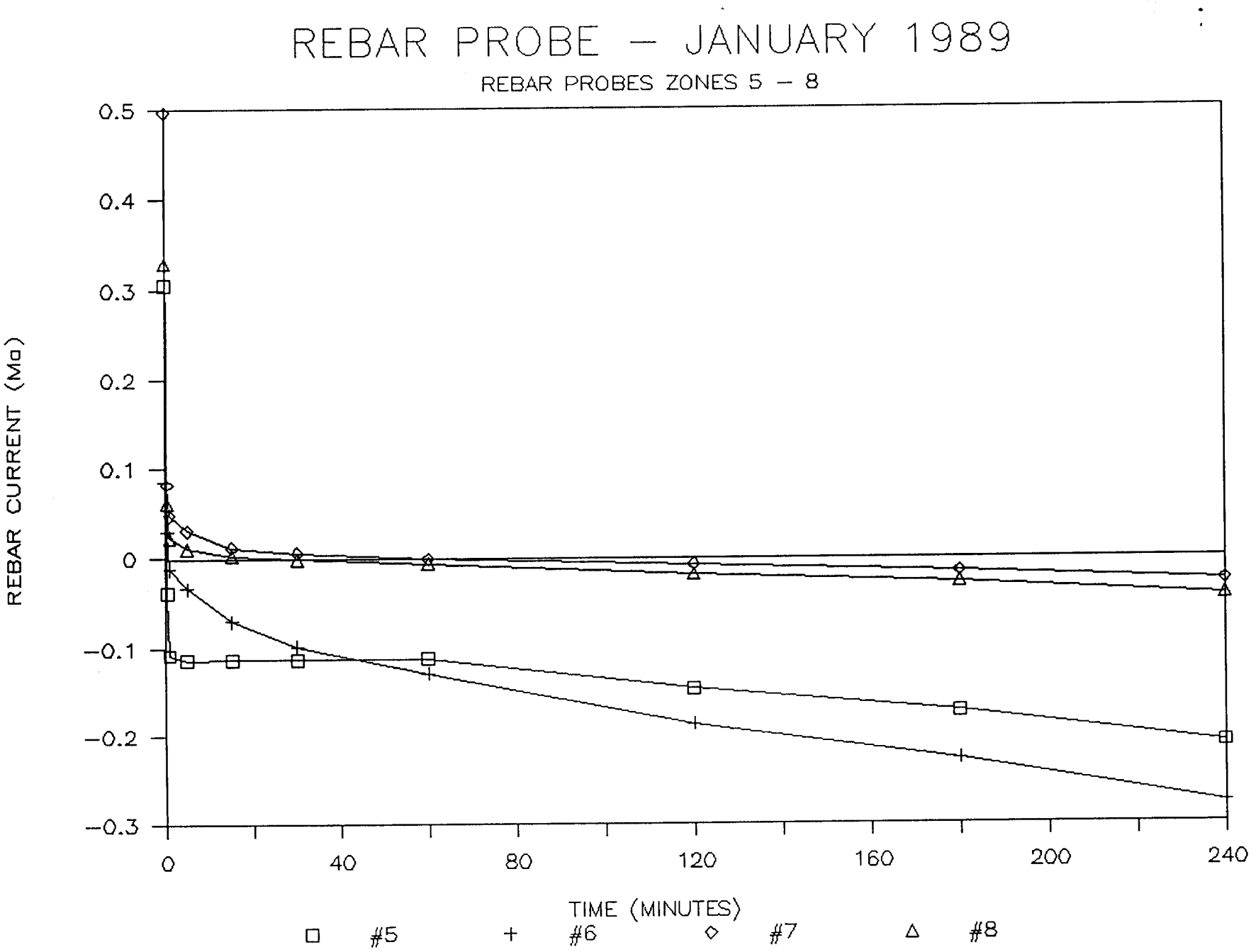

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONES 5 – 8
REBAR CURRENT (Ma)
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
0
40
80
120
160
200
240
TIME (MINUTES)
#5
#6
#7
#8

FIGURE 37

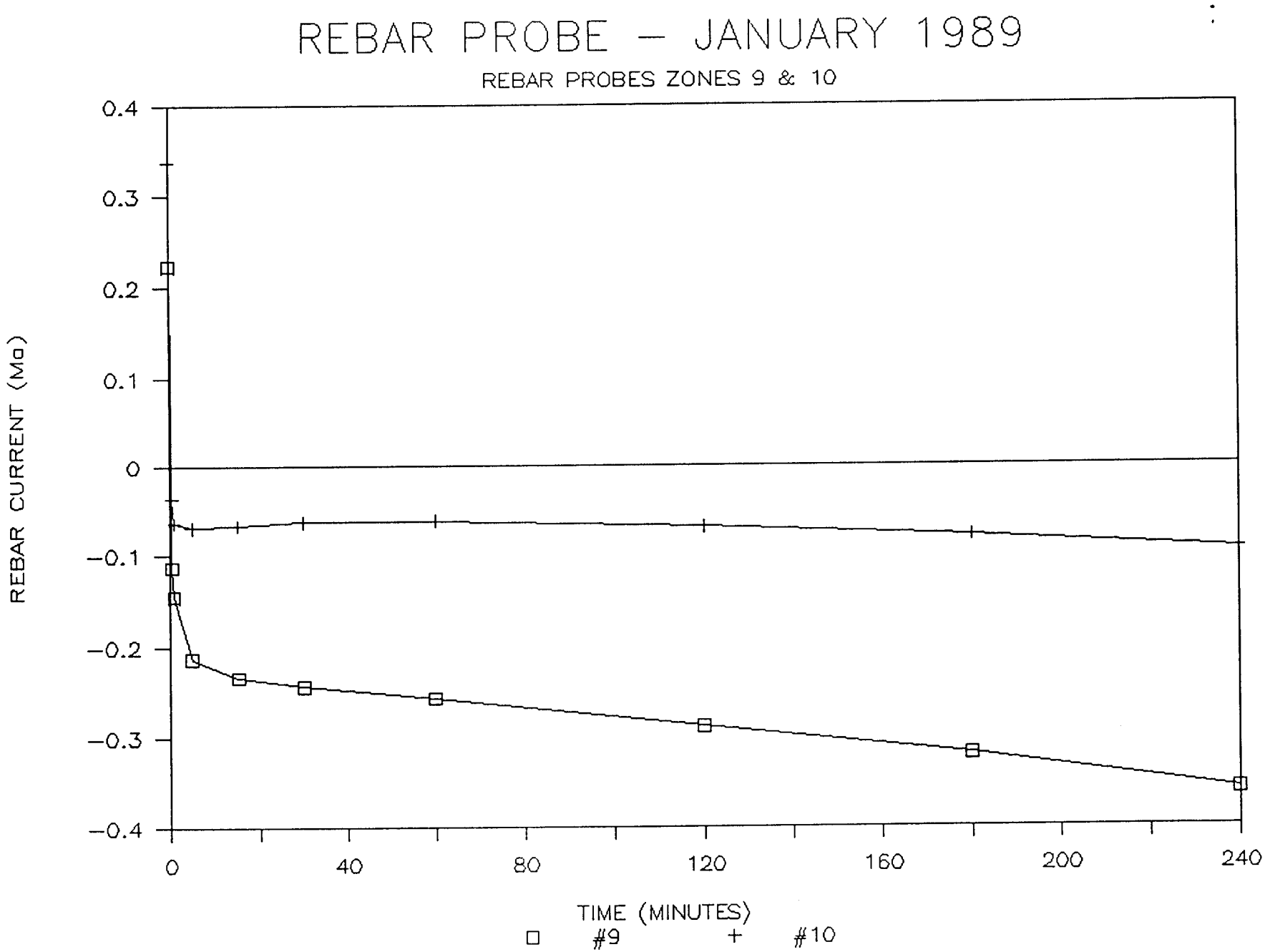

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONES 9 & 10
REBAR CURRENT (Ma)
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
0
40
80
120
160
200
240
TIME (MINUTES)
□ #9
+ #10

FIGURE 38

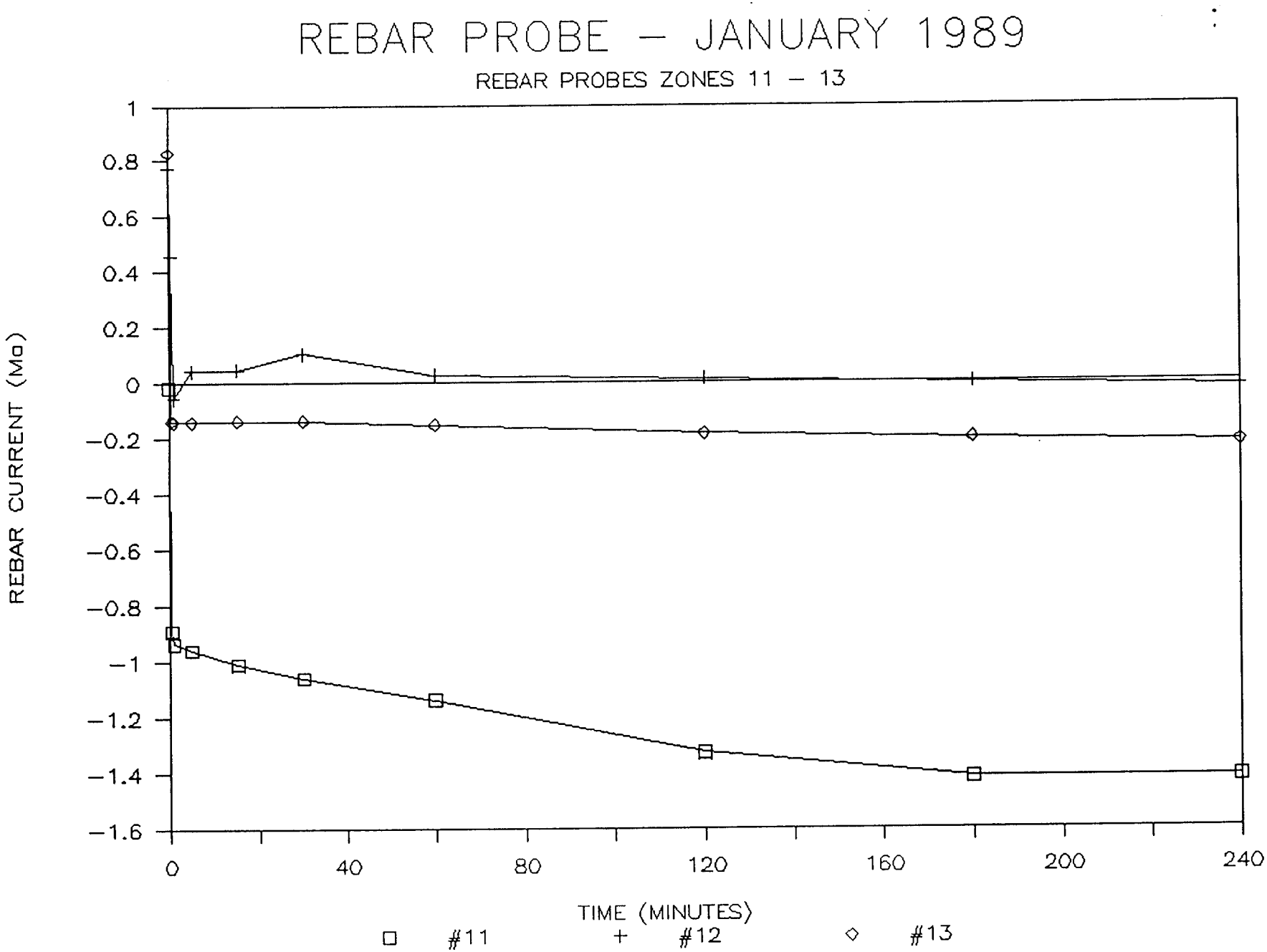

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONES 11 – 13
REBAR CURRENT (Mo)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
0
40
80
120
160
200
240
TIME (MINUTES)
#11
#12
#13

FIGURE 39

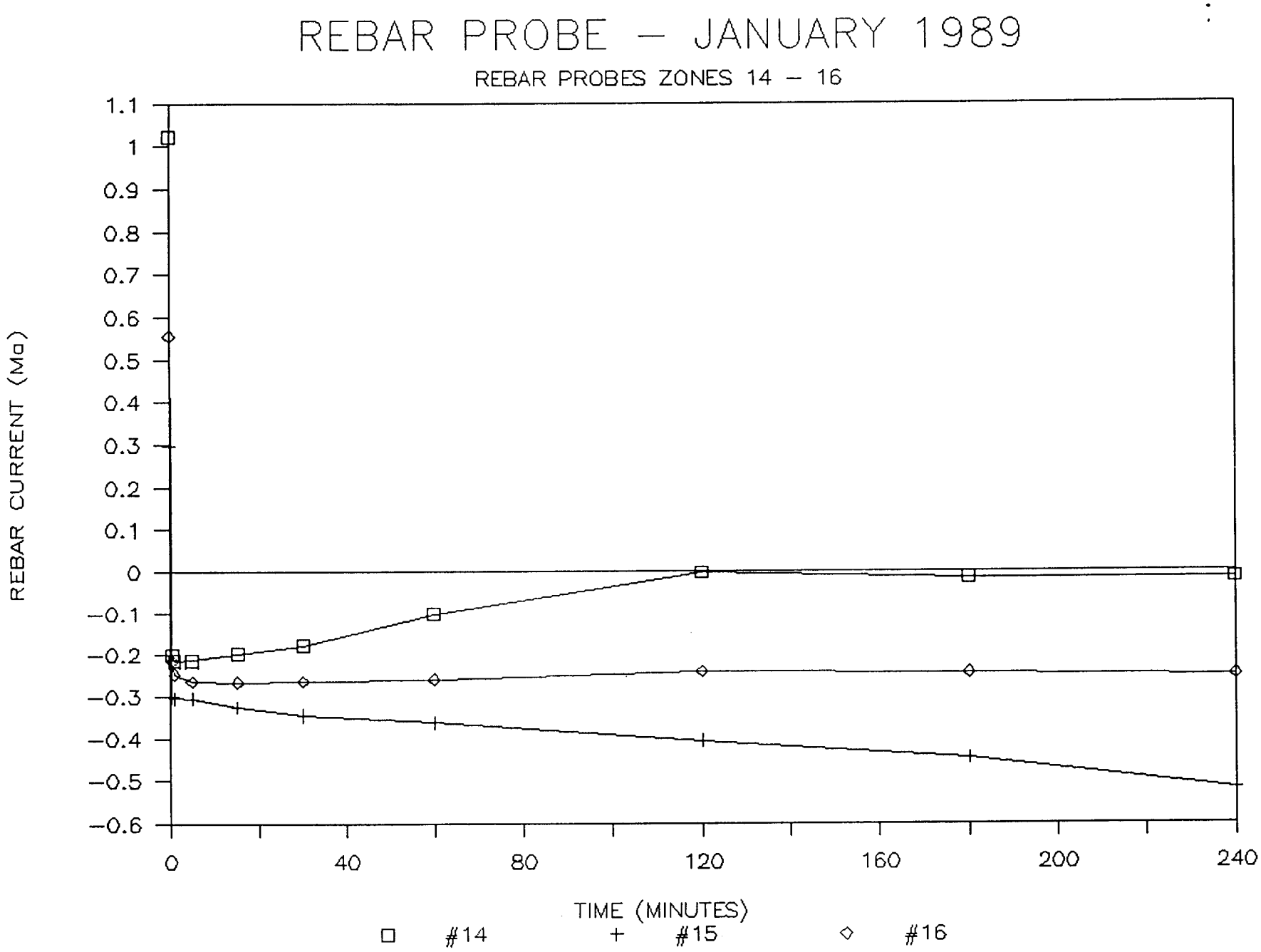

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONES 14 – 16
REBAR CURRENT (Ma)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
0
40
80
120
160
200
240
TIME (MINUTES)
#14
#15
#16

FIGURE 40

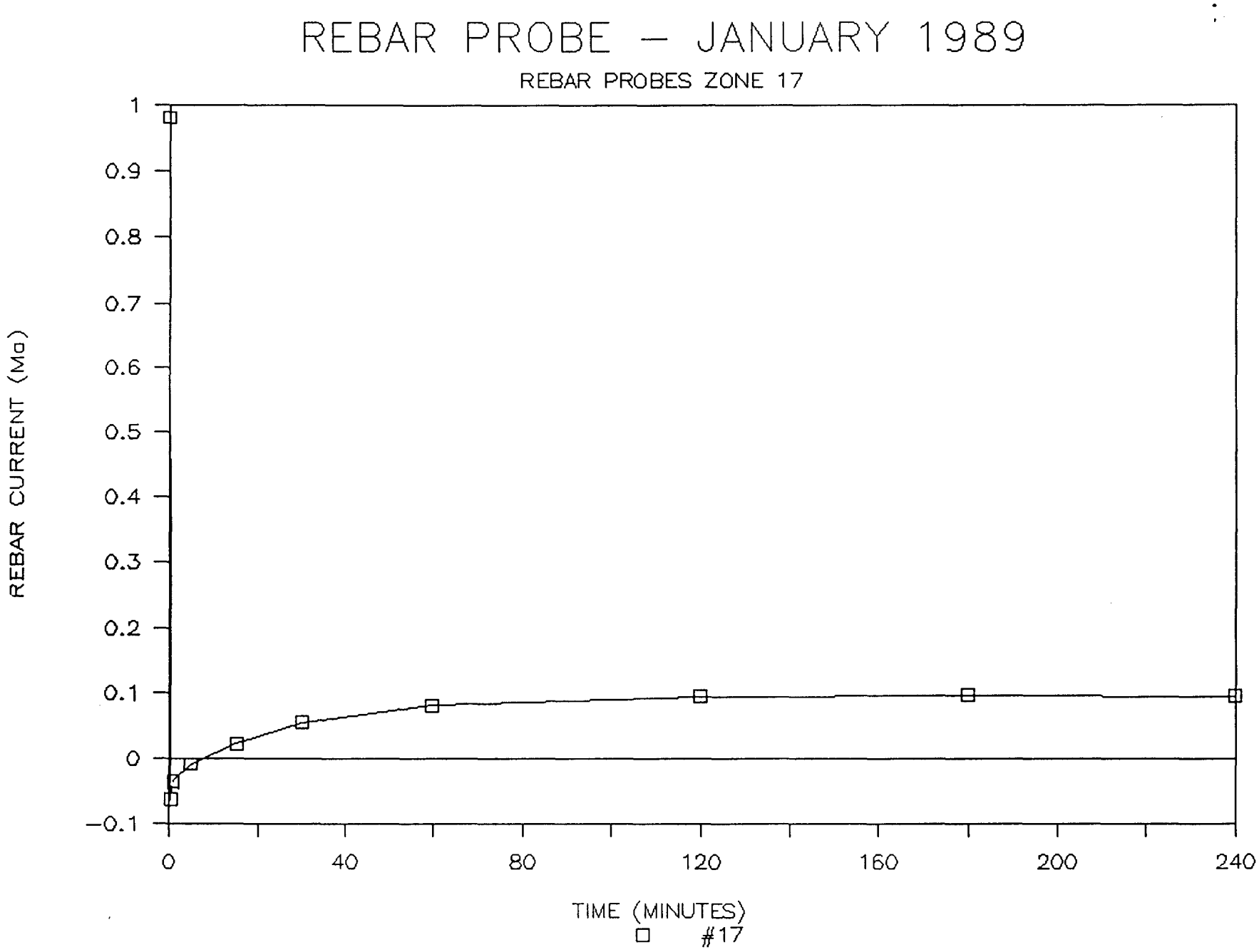

REBAR PROBE – JANUARY 1989
REBAR PROBES ZONE 17
REBAR CURRENT (Ma)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
0
40
80
120
160
200
240
TIME (MINUTES)
#17

FIGURE 41

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

NOVEMBER 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)
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–f1)

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-f1)

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