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1997 Annual Cathodic Protection Survey Report For PFP

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Abstract: This report is the first annual cathodic protection report for PFP. The report documents annual polarization, voltage, amperage, and continuity survey data from 1994 to 1997.

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1997 ANNUAL CATHODIC PROTECTION SURVEY REPORT FOR PFP

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	3
2.0	LAYOUT OF CATHODIC PROTECTION SYSTEMS AND PIPING SYSTEMS IN PFP AREA	3
3.0	DATA COLLECTION	4
4.0	WASHINGTON STATE CATHODIC PROTECTION REQUIREMENTS	4
5.0	CATHODIC PROTECTION CRITERIA	4
6.0	CATHODIC PROTECTION SYSTEM TESTING PROCEDURE	5
7.0	1997 POLARIZATION SURVEY RESULTS AND ANALYSIS	6
8.0	1997 CONTINUITY AND AMPERAGE TESTING RESULTS AND ANALYSIS	10
9.0	CONCLUSIONS	12
10.0	RECOMMENDATIONS	14
11.0	REFERENCES	14
APPENDIX A	Cathodic Protection testing requirements of WAC 173-303-640 and Acceptance Standards of NACE Standard RP0285-95	15
TABLE 1	Attributes of Rectifier 45 system within PFP property	17
TABLE 2	Attributes of Rectifier 22 system within PFP property	17
TABLE 3	Attributes of Rectifier 23 system within PFP property	17
TABLE 4	Attributes of PFP area piping	18
TABLE 5	Rectifier Nameplate Data	18
TABLE 6	Continuity and Polarization Testing during 1996 annual survey	18
TABLE 7	Continuity Testing during 1997 annual survey	18
TABLE 8	Amperage Testing at AJB(R45-1A) during 1997 annual survey	19
TABLE 9	Polarization Testing at T(R45-3) during 1997 annual survey	19
TABLE 10	Rectifier 45 Efficiency testing	19
SPREADSHEET 1	1997 CP Annual Survey Data	20
SPREADSHEET 2	1996 CP Annual Survey Data	21
SPREADSHEET 3	1995 CP Annual Survey Data	22
SPREADSHEET 4	1995 CP 6-Month and Coppro Survey Data	23
SPREADSHEET 5	1994 CP ATP and Baseline Survey Data	24

<u>GRAPHS (Cathodic Polarization from 1994 to 1997)</u>

<u>PFP Area (Rectifier 45)</u>

Test Station T(R45-1)	25
Test Station T(R45-2)	26
Test Station T(R45-3)	27
Test Station T(R45-6)	28
Test Station T(R45-4)	29
Test Station T(R45-7)	30
Test Station T(R45-8)	31
Test Station T(R45-5)	32

<u>PFP Area (Rectifier 23)</u>

Test Station T(19-1)	33

TABLE OF CONTENTS (continued)

	Page
GRAPHS (Cathodic Polarization from 1994 to 1997)	
PFP Area (Rectifier 22)	
Test Station T(18-11)	34
Test Station T(18-9)	35
Test Station T(18-12)	36
Test Station T(18-4)	37
Test Station T(18-3)	38
Test Station T(18-2)	39
GRAPHS (Rectifier DC Outputs during 1994 to 1997 surveys)	
Rectifier 45 volts and amps	40
Rectifier 22 volts and amps	41
Rectifier 23 volts and amps	42

1997 ANNUAL CATHODIC PROTECTION SURVEY REPORT FOR PFP

1.0 INTRODUCTION

This cathodic protection (CP) report for the PFP area encompasses the following information:
1. 1994 to 1998 CP survey data of voltage and continuity measurements at the test stations on the PFP property;
2. Spreadsheets and tables to tabulate the data, and graphs to trend the data;
3. Analysis and recommendations of the 1997 annual CP survey results;
4. Tables listing the attributes of the three rectifier systems associated with the PFP area;
5. Table listing the attributes of the cathodically protected piping of the PFP area;
6. Tables listing continuity measurements at the PFP area test stations;
7. Table listing DC amperage measurements at an anode junction box;
8. Table listing the nameplate output data of the three rectifiers servicing the PFP property;
9. Graphs of three rectifiers DC outputs during the 1994 to 1997 annual surveys; and
10. Appendix documenting applicable Washington Administrative Code (WAC) requirements and National Association of Corrosion Engineers (NACE) standard recommended practices pertaining to CP criteria of corrosion protection.

2.0 LAYOUT OF CATHODIC PROTECTION SYSTEMS AND PIPING SYSTEMS IN PFP AREA

The CP systems operating within the PFP property consist of the Rectifier 45 system, Rectifier 22 System, and the Rectifier 23 system.

Rectifier 45 system it totally contained within PFP property and is operated and inspected by the PFP personnel. Rectifier 45 system is designed to protect the LSW, LSW spare, HSW, and HSW spare piping from 236-Z to 241-Z. The attributes of the Rectifier 45 system within PFP property are documented in Table 1. The attributes of the cathodically protected piping of Rectifier 45 system are documented in Table 4.

Rectifier 22 system it totally contained within PFP property with the exception of the rectifier itself. The power feed to the rectifier is within PFP property. West area personnel inspect the operation of the rectifier bimonthly. PFP personnel perform the annual polarization surveys of Rectifier 22 system test stations on PFP property. All Rectifier 22 system test stations are located on PFP property. Rectifier 22 system is designed to protect the 202 and 203 transfer piping from 241-Z to the PFP Badgehouse area. The attributes of the Rectifier 22 system within PFP property are documented in Table 2. The attributes of the cathodically protected piping of Rectifier 22 system in PFP area are documented in Table 4.

Rectifier 23 system it totally contained within West area property with the exception of one test station and six anodes within PFP property, north of the badgehouse. West area personnel inspect the operation of the rectifier bimonthly and perform polarization surveys annually on West area property. PFP personnel perform an annual polarization survey at one Rectifier 23 test station on PFP property. Rectifier 23 system is designed to protect the 202 and 203 transfer piping from the PFP Badgehouse area to 244-TX in TX-Farm.

The attributes of the Rectifier 23 system within PFP property are documented in Table 3. The attributes of the cathodically protected piping of Rectifier 23 system in PFP property are documented in Table 4.

Complete generalized CP system detail is documented in the 1995 ANNUAL CATHODIC PROTECTION SURVEY REPORT FOR THE HANFORD 200 AREA.

3.0 DATA COLLECTION

The collection of survey data for this report was accomplished as follows:

8/94 ATP
Data was collected in WHC-SD-C031H-ATP-110 Rev. 0 by ICF KH.

1/95 6-month survey
Data was collected by PFP and TWRS engineering, Internal Memo 71420-95-JHH-004.

1995 annual survey
Data was collected by PFP and TWRS engineering per PFP procedure 2Z22161, Inspection of Cathodic Protection Rectifier Plutonium Finishing Plant.

1996 and 1997 Test Station Surveys
Data was collected by PFP and TWRS engineering per 6-TF-357, Cathodic Protection System Testing and per 6-TF-357WT, Cathodic Protection System Testing West Tank Farms (WT). The 1997 annual survey on PFP property was performed per work package 2Z-97-02626 and the 1996 annual survey was performed per work package 2Z-96-03279.

4.0 WASHINGTON STATE CATHODIC PROTECTION REQUIREMENTS

WAC 173-303-640 requires corrosion protection of the waste storage and transfer systems. The applicable sections of WAC to cathodic protection inspection are given in Appendix A. Bimonthly rectifier inspections and annual CP surveys are mandated by the State of Washington per WAC 173-303-640.

Proper operation of cathodic protection systems are implicitly defined in WAC 173-303-640 by meeting the recommended practices of National Association of Corrosion Engineers (NACE) Standard RP0285-95. Pertinent sections of NACE Standard RP0285-95 are stated in Appendix A.

5.0 CATHODIC PROTECTION CRITERIA

Corrosion protection is afforded to the outer surface of metallic piping through the application of earthen ionic currents onto the surface of the piping. This method of corrosion mitigation is called cathodic protection. Cathodic protection is used in conjunction with the protective coatings that are applied upon the piping.

The operating criteria to which the Hanford CP systems are evaluated is the NACE Standard Recommended Practice RPO285-95, Item No. 21030, "Corrosion Control of Underground Storage Tank Systems by Cathodic Protection". Either of the three acceptance criteria specified in NACE RPO285-95 can be used as standards at Hanford. The widely accepted criterion of a polarized pipe-to-soil potential of -0.85 volt DC, relative to a copper/copper sulfate reference electrode, on buried steel structures is believed to afford practically complete corrosion mitigation to steel and stainless steel in ambient, aerobic, and sulfate-reducing bacteria-free environments. The typical Hanford

environment around the piping is believed to fall into the aforementioned category.
The polarized potential measured by specialized instrumentation during the "OFF" cycle of the rectifiers DC output is judged against the polarized (IR-error free) standard of -0.85 volts. The 1995 Annual Cathodic Protection Survey for the Hanford 200 Area provides a detailed description of the testing equipment.

A second criterion to which cathodic protection is judged protective is described in RP0285-95 as the 100 mV potential shift. A structure is judged to be suitably protected from corrosion if a measurable potential shift of 100 mV or more in the negative direction occurs upon rectifier system energization. The 100 millivolt shift occurs when the instant "OFF" potential as read on the testing equipment is at least 100 mV more negative than the "NATIVE" potential. The NATIVE potential of an underground structure is measured with the rectifier systems not energized. Each 100 millivolts of cathodic polarization gain across a piping surface is believed to reduce the corrosion rate by a factor of 10. Tests with mild steel coupons placed at five feet in Hanford soil in the 200 West area exhibited corrosion losses of 8 mils in 3.5 years (See reference section).

6.0 CATHODIC PROTECTION SYSTEM TESTING PROCEDURE

Portable vs Permanent Reference Electrodes

Tank Farm Maintenance Procedure 6-TF-357, Cathodic Protection System Testing, directs the measurement and recording of total potentials and polarized potentials across the underground structures. The voltage measurements are taken with respect to copper/copper sulfate reference electrodes.

Permanent reference electrodes are buried next to the piping being measured. A portable reference electrode is placed upon the ground above the piping being measured. The portable electrode is usually three feet from the closest underground structure while the permanent electrode is designed to be placed within six inches of the piping. The half cell electrodes will give a mean potential over an area of the surface which is a circle whose diameter is approximately four times the structure to half cell electrode distance; the central area will contribute more than the periphery. As a consequence of the distance between piping and electrodes, the portable electrode will measure an integrated potential representing six times the area of the permanent electrode measurement.

The portable electrode cell is measured against other portable electrodes prior to use in the field. The deviation between portable electrodes is usually less than 2 millivolts. With the rectifier turned off, the portable electrode measured against the permanent electrodes should be close to zero. It is impractical to turn off the rectifiers during the annual surveys so it is not known from survey to survey the extent of permanent reference electrode deviation from standards.

The portable reference electrode is considered more accurate than the permanent electrodes. However, the placement of the portable reference electrode around the test stations varies from survey to survey and this affects the value of the voltage measurements by the portable electrodes at some test stations.

Permanent reference electrodes usually measure a more positive pipe-to-reference electrode voltage. A high resistance at the electrode to soil interface would cause the voltage values across the piping to measure more positive. The longer the permanent electrode is in the ground the greater chance of the electrode to soil interface area to dry out. A significant increase in resistance, i.e., 1 Mohm, at the electrode interface would diminish the voltage measurement by 10%. The testing instrumentation has an internal resistance of 10 Mohms. It has not been definitively established as to why the permanent electrodes read more positive.

Based on the above discussion, the portable reference electrode measurements are used to judge the CP performance against the acceptance criteria.

Continuity Effect upon voltage measurements
Low electrical resistance exists in electrically continuous structures. A stationary reference electrode will measure the same voltage no matter where the connection to electrically continuous structures are made. If the voltage is different between any two structures at a test station it indicates poor or no electrical contact between the structures. Any low voltage readings measured during the survey at a test station indicated a high resistance or isolated structure.

Continuity tests were performed in conjunction with polarization tests to identify those structures and test leads not continuous with the CP systems. These tests were performed by measuring the resistance between one of the conductor test leads from each pipe.

CP System Configuration During Polarization Surveys
Rectifiers 45, 22, and 23 were all equipped with pulse generators during the annual surveys, the ATP, and the six month survey. The pulse generators allow the "polarized potential" across the piping to be calculated. The pulse generators do not drift and do not have to be synchronized with each other. The "polarized potential" data that was collected for Rectifier 45 system during its 8/94 ATP was not valid because the pulse generator in Rectifier 45 was not interrupting the DC output amperage.

7.0 1997 POLARIZATION SURVEY RESULTS AND ANALYSIS

History of modification and testing the Rectifier 45 system

The analysis of the cathodic protection surveys of Rectifier 45 system requires a chronology of the events that have affected Rectifier 45 system.

During 8/94, Rectifier 45 system was initially tested. Before polarization testing was commenced, a short under the 243-Z building and between two anode junction boxes was discovered. New header and loop cabling was routed around the 243-Z building. The cabling and anodes underneath the building were isolated. New anodes were repositioned around the edges of the building to protect the LSW and HSW piping underneath the building.
The ATP was conducted but the pulse generator in the rectifier circuit was not functioning properly. No valid polarized potentials were measured. Total potentials were recorded with respect to permanent reference electrodes. Portable reference electrodes were not used in the ATP. Rectifier 45 was running at the A-5 tap settings. The rectifier delivered 7.75 amps to the underground piping during the ATP testing. The system resistance during start-up testing was 1.55 ohms.

During 1/95, a six-month operational test was conducted. The polarization data was collected with respect to a portable reference electrode. Rectifier 45 was running at the A-5 tap setting. The rectifier delivered 4.6 amps to the underground piping during the operational test. The system resistance increased by a factor of 1.8 (from 1.55 ohms to 2.8 ohms) during the five month time period of Rectifier 45 system operation. The Rectifier 45 tap settings were changed to C-1 after the test. This increased the DC amperage output to the underground piping from 4.6 amps to 12 amps.

Before the 8/95 annual survey, a sink hole developed between test stations T(45-7) and T(45-8). Anode A(R45-17), a reference electrode, and transfer lines were exposed. The sink hole area was filled in and the system components were repaired and the system was energized prior to the 1995 annual survey.
Additionally, the HR45-1A header cable that is located between the rectifier and anode junction box AJB(R45-1) was disconnected at the rectifier because the header was shorting out in this region. The rectifier had been blowing fuses regularly (See reference section). The five anodes designed to deliver current to the piping beneath test stations T(R45-1), T(R45-2), and T(R45-3) were deactivated by disconnecting the HR45-1A header cable.

During the 8/1995 annual survey, testing was conducted at the C-1 tap settings. Rectifier 45 system was delivering 5.3 amps to the underground piping. The system resistance increased by a factor of 3.1 (from 1.55 ohms to 5.5 ohms) in the year since the start-up date. Five of the twenty system anodes were not energized during the survey.

After the 8/95 annual survey, ECN 625805 and ECN 625127 were implemented to route new header cable HR-45-1A to a new anode junction box AJB(R45-1A). Anodes A(R45-3), A(R45-4), and A(R45-5) were connected to the new anode junction box. Anodes A(R45-1) and A(R45-2) were abandoned in place. Two new anodes were installed to compensate for the abandoned anodes. The anodes were placed about twice the distance away from the piping that the original anodes were positioned. The new anodes affect the polarization readings at T(R45-1), T(R45-2), and T(R45-3).

During the 1996 annual survey, testing was conducted at the C-1 tap settings. Rectifier 45 system was delivering 3.3 amps to the underground piping. Two years and three months past the start-up date, the system resistance had increased by a factor of 5.8 (from 1.55 ohms to 9.0 ohms).

During the 1997 annual survey, testing was conducted at the C-3 tap settings. Rectifier 45 system was delivering 4.75 amps to the underground piping. An electrical jumper wire was added at T(R45-3) per ECN 643225 to bond an isolated pipe. Three years and five months past the start-up date, the system resistance increased by a factor of 4.7 (from 1.55 ohms to 7.3 ohms). However, the system resistance had diminished from the previous year by 19%.

Rectifier 45 system Test Stations

Cathodic polarization is measured across the LSW, LSW spare, HSW, and HSW spare piping at eight test stations between the 236-Z and 241-Z facilities. Rectifier 45 system delivers practically all of the current to the aforementioned piping. Rectifier 22 system has anodes within 140 feet of the nearest Rectifier 45 system test station but current delivered by these anodes would add very little voltage to the polarization measurements. The Rectifier 45 system anodes are about nine feet from the pipes.
During the 1997 annual survey, Rectifier 45 system was running at 4.75 DC amps (nameplate = 12 amps) and at 34.9 DC volts (nameplate = 50 volts).

T(R45-3) and T(R45-7)

Measurements at two of the eight test stations showed that the underground piping was protected above the NACE RP0285-95 4.2.1.2 standard (a negative polarized potential of at least 850 millivolts relative to a saturated copper/copper sulfate electrode). Reference the polarization graphs of test stations T(R45-3) and T(R45-7).

The two-year polarization trend at T(R45-3) reflects the fact that very little current was received at the test station during the 1995 annual survey. The polarization values have been fairly constant once the anodes that are nearest to T(R45-3) were energized in 1996.
The two-year polarization trend at T(R45-7) is fairly constant.

T(R45-4), T(R45-5), T(R45-6), T(R45-8)
Measurements at four of the eight Rectifier 45 test stations gave polarization values of -0.60 to -0.84 volts. Reference the polarization graphs of test stations T(R45-4), T(R45-5), T(R45-6), and T(R45-8).
Native potentials have not been measured at the four test stations. However, the native potential across the piping is estimated between -0.35 and -0.42 volts. These voltage readings were recorded during 1995 polarization testing at T(R45-1), T(R45-2), and T(R45-3). The 1995 testing at these test stations was conducted with the nearby anodes not energized. With the above assumption, the piping at the four test stations gained from 180 to 420 millivolts of polarization. NACE RP0285-95 4.2.1.3 standard (a minimum of 100 mV of cathodic polarization) would be exceeded by 80 to 320 millivolts. The additional 80 to 320 millivolts would decrease the corrosion rate at the specific locations by an additional factor of 6.3 to 1580, assuming each 100 millivolts of cathodic polarization gain diminishes corrosion current rate by a decade.
The two-year polarization trends at test stations T(R45-4) and T(R45-5) show a moderate polarization loss.
The three-year polarization trends at test stations T(R45-6) and T(R45-8) show relatively constant polarization values.

T(R45-1) and T(R45-2)
Measurements at two of the eight Rectifier 45 test stations gave polarization values of -0.50 volts. Reference the polarization graphs of test stations T(R45-1) and T(R45-2).
The native potential across the piping underneath these two test stations averages -0.42 volts. These voltage readings were recorded during 1995 polarization testing at T(R45-1) and T(R45-2). The 1995 testing at these test stations was conducted with the nearby anodes not energized.
The piping at the two test stations gained 80 millivolts of polarization during the 1997 annual survey. NACE RP0285-95 4.2.1.3 standard (a minimum of 100 mV of cathodic polarization) was not satisfied. Twenty additional millivolts of cathodic polarization is required to meet the aforementioned standard. Eighty millivolts of cathodic polarization gain across the piping decreases the corrosion rate around the area of these two test stations by a factor of 6.3, assuming each 100 millivolts of cathodic polarization gain diminishes corrosion current rate by a decade.
The two-year polarization trend at test station T(R45-2) shows the very moderate gain in cathodic polarization once the anodes around the test stations were energized. Anodes A(45R-1) and A(45R-2) were abandoned and replaced at a further distance from T(R45-2). The 1997 amperage testing at anode junction box AJB(R45-1A) revealed that only 80 milliamps of current was flowing from the new anodes. The average anode in Rectifier 45 system delivered 230 milliamps during the 1997 polarization testing.
The three-year polarization trend at test station T(R45-1) shows that the piping under T(R45-1) received quite adequate cathodic polarization during the six month survey of 1/95. The anodes were then isolated during the 1995 annual survey and no current was received at the pipes. The new anodes were installed and a very moderate gain of cathodic polarization was realized in 1996 and 1997. The 1997 amperage testing at AJB(R45-1A) showed only 80 milliamps of current flowing from the anodes around the test station. The amperage testing at AJB(R45-1A) is discussed later in this report.

Rectifier 23 system Test Stations

Cathodic polarization is measured across the 202 and 203 piping at one test station between the badgehouse and the east PFP fenceline. Rectifier 23 system delivers practically all of the current to the aforementioned piping. Rectifier 22 system has one anode within 100 feet of the Rectifier 23 system test station but current delivered by this anode would add very little voltage to the polarization measurements. The Rectifier 23 system has three anodes within 30 feet of the test station.

During the 1997 annual survey, Rectifier 23 system was running at 9 DC amps (nameplate = 50 amps) and at 82.5 DC volts (nameplate = 120 volts).

T(19-1)

Measurements at the test station showed that the underground piping was protected above the NACE RP0285-95 4.2.1.2 standard (a negative polarized potential of at least 850 millivolts relative to a saturated copper/copper sulfate electrode). Reference the polarization graph of test station T(19-1). The four-year polarization trend at T(19-1) shows a slight diminishment of polarization gain. The four-year rectifier output trend shows fairly constant current output.

Rectifier 22 system Test Stations

Cathodic polarization is measured across the 202 and 203 piping at five test stations between the badgehouse and the 241-Z building. Rectifier 22 system delivers practically all of the current to the aforementioned piping within the aforementioned boundaries. Rectifier 23 system has three anodes within 380 feet of the Rectifier 22 systems' nearest test station. Rectifier 45 system has three anodes within 150 feet of the Rectifier 22 systems' nearest test station but current delivered by these anodes would add very little voltage to the polarization measurements.

Cathodic polarization is measured across the 8" CI sanitary water piping at one test station located northeast of 241-AB.

During the 1997 annual survey, Rectifier 22 system was running at 4.8 DC amps (nameplate = 24 amps) and at 96.3 DC volts (nameplate = 120 volts).

T(18-9) and T(18-11)

Measurements at the test stations showed that the underground piping was protected above the NACE RP0285-95 4.2.1.2 standard (a negative polarized potential of at least 850 millivolts relative to a saturated copper/copper sulfate electrode). Reference the polarization graphs of test station T(18-9) and T(18-11).

The four-year polarization trends for both test stations show a fairly consistent polarization value. The four-year rectifier output trend shows fairly constant current output.

T(18-2) and T(18-4)

Measurements at two of the six Rectifier 22 test stations gave polarization values of -0.59 and -0.77 volts. Reference the polarization graphs of test stations T(18-2) and T(18-4).

Native potentials have not been measured at the two test stations. However, the native potential across the piping is estimated between -0.35 and -0.42 volts. These voltage readings were recorded during 1995 polarization testing at T(R45-1), T(R45-2), and T(R45-3). With the above estimation, the piping at the two test stations gained 170 and 350 millivolts of polarization. NACE RP0285-95 4.2.1.3 standard (a minimum of 100 mV of cathodic polarization) would be exceeded by 70 and 250 millivolts. The additional 70 and 250 millivolts would decrease the corrosion rate at the specific locations by an additional factor of 5.0 and 315, assuming each 100 millivolts of cathodic polarization gain diminishes corrosion current rate by a decade.

The three-year polarization trend at test stations T(18-2) shows a fairly

constant polarization.
The three-year polarization trend at test station T(18-4) shows a moderate polarization loss.

T(18-3)
Measurements at one of the six Rectifier 22 test stations gave polarization values of -0.51 volts. Reference the polarization graph of test station T(18-3).
The native potential across the piping underneath the test station is estimated to be between -0.35 to -0.42 volts. These voltage readings were recorded during 1995 polarization testing at T(R45-1), T(R45-2), and T(R45). The 1995 testing at these test stations was conducted with the nearby anodes not energized.
Assuming the most conservative native polarization value of -0.42 volts, the piping at the test station gained 90 millivolts of polarization during the 1997 annual survey. NACE RP0285-95 4.2.1.3 standard (a minimum of 100 mV of cathodic polarization) would not be satisfied. Ten additional millivolts of cathodic polarization is required to meet the aforementioned standard. Ninety millivolts of cathodic polarization gain across the piping decreases the corrosion rate around the area of the test station by a factor of 7.9, assuming each 100 millivolts of cathodic polarization gain diminishes corrosion current rate by a decade.
The four-year polarization trends for the test station shows a lower polarization value during the 1997 annual survey. The four-year rectifier output trend shows that the amperage diminished slightly from 1996 to 1997. The rectifier tap setting was dropped to C-5 before the 1997 survey in order for the DC voltage output to be below 100 volts.

T(18-12)
Measurements at one of the six Rectifier 22 test stations gave a polarization value of -0.43 volts. Reference the polarization graph of test station T(18-12).
The 8" CI sanitary water line underneath the test station is not designed to be protected and does not have to meet the cathodic polarization standards. Continuity tests were conducted at this test station during the 1997 annual survey and the results of the survey are discussed later in this report.

8.0 1997 CONTINUITY AND AMPERAGE TESTING RESULTS AND ANALYSIS

Test stations are purposefully placed in areas where unprotected piping crosses paths with protected piping. The purpose of placing the test stations above unprotected lines is to allow the continuity testing of the unprotected lines. Conductor leads extend from the unprotected piping up to the test stations. The resistance between the conductors of the protected lines and the conductors of the unprotected lines will show if the unprotected lines are bonded into the CP rectifier system.

The possibility exists that the unprotected lines will pick up CP currents from the nearby CP anodes. If the unprotected piping is not bonded into the CP rectifier system, then any CP current picked up by the unprotected piping will have to be discharged to maintain a charge balance. The CP current discharge from piping that is not bonded to the CP rectifier system is in the form of corrosion, i.e., dissolution of the piping. Every pipe at a test station should be bonded into the CP rectifier system.

1996 Continuity Testing at Rectifier 45 system test stations
Continuity measurements were performed during the 1996 annual survey at the eight test stations of Rectifier 45 system. The results are tabulated in Table 6 (Continuity and Polarization Testing during 1996 annual survey). The

piping tested for bonding is listed in Table 1 (Attributes of Rectifier 45 system within PFP property).

Only one pipe at test station T(R45-3) was not sufficiently bonded into the Rectifier 45 system. One of the unknown pipes had a resistance of 2 Mohms with respect to a HSW pipe. The unknown pipe polarized to 76 millivolts below the polarization values that were measured across the remaining piping at the test station.

The piping located at the seven remaining test stations showed adequate bonding. All pipes at these test stations gained cathodic polarization to the same extent as the protected pipes in the test stations.

1997 Testing at Rectifier 45 system and Rectifier 22 system test stations
Continuity measurements were performed during the 1997 annual survey at two test stations of Rectifier 45 system and at two test stations of Rectifier 22 system. The results are tabulated in Table 7 (Continuity Testing during 1997 annual survey).

The unknown pipe at test station T(R45-3) was checked for bonding before and after an electrical jumper was installed between the unknown pipe and the HSW pipe. Lack of continuity was confirmed before the jumper installation. Once the jumper was installed, continuity was confirmed.

The unknown pipes at test station T(R45-2) were checked for bonding because these pipes were the only two pipes of the Rectifier 45 system not surveyed for continuity during the 1996 annual survey. The resistances of the unknown pipes were 49 and 85 ohms with respect to the LSW pipe. These resistances are of no concern since it was shown that the unknown piping gained the same amount of polarization as the protected piping during the 1996 annual survey.

The 8" Cast Iron sanitary water pipe that is located underneath test station T(18-12) was checked for continuity to the Rectifier 22 system. A wire was extended from T(18-12) to T(18-4). T(18-4) piping is bonded to the Rectifier 22 system through the 202 and 203 piping. The continuity between the 202 piping and the sanitary water showed a resistance value of 1.7 Kohms. The 8" sanitary water piping does not cross the anode voltage field of Rectifier 22 system and is located 65 feet from the nearest Rectifier 22 system anode. The low polarization and the low total voltage values at T(18-12) show the sanitary line is picking up little or no stray current from anodes of Rectifier 22 system.

DC amperage testing of Rectifier 45 system during the 1997 annual survey
DC amperage tests were conducted at anode junction box AJB(R45-1A) during the 1997 survey. The measurements were conducted with an uncalibrated DC clamp-on ammeter. The anode junction box was installed per ECN 625805 and ECN 625127. The tabulated results are shown in Table 8 (Amperage Testing at AJB(R45-1A) during 1997 annual survey).

The input amperage measured into the anode junction box was measured around cables LR45-1 and HR45-1. The total of the two measurements added up to 3.98 amps. The output amps at the anode junction box consists of the LR45-1A cable, the HR45-1 cable, and the five anode lead cables. The total output amperage amounted to 4.96 amps. The input-output balance measurements were off by 20%. Three of the input/output wires require documentation per ECN.

Comparing two measurements of amperage through the rectifier loop cable resulted in measuring 3.33 amps at the rectifier versus 3.26 amps at the anode junction box. The comparison showed good accuracy.

Comparing two measurements of amperage through the rectifier header cable resulted in measuring 1.29 amps at the rectifier versus 0.72 amps at the anode junction box. This comparison showed a 45% error.

Comparing the amperage DC output at the rectifier, 4.62 amps, versus the amperage output at the anode junction box, 4.96 amps, resulted in a 7% error.

Clearly, the testing at the anode junction box did not produce consistent readings. The meter used was not calibrated. Future tests should be used with a calibrated meter.

Despite the lack of accuracy in the tests, the tests showed that two of the anode lead cables were delivering 20mA and 60 mA to two of the five anodes. The average amperage delivered to the twenty anodes of the entire system was 230 mA. It appear the low current delivery was directed to the two anodes located around test stations T(R45-1) and T(R45-2). The polarization gain at these test stations was 80 mV during the 1997 survey. A minimum of 100 mV gain is required to meet the 4.2.1.3 standard.

Bonding affect at T(R45-3) during the 1997 annual survey

An electrical jumper was installed at T(R45-3) between pipes HSW and an unknown pipe per ECN 643225 during the 1997 annual survey. Polarization testing was conducted before and after the jumper installation. The testing results are documented in Table 9 (Polarization Testing at T(R45-3) during the 1997 annual survey.

The unknown piping was polarizing at 50 mV less than the protected piping before the bonding. After the bonding, the protected piping and the unknown piping measured the same polarization gain. The piping system after the bonding lost 10 mV as a whole. The polarization values after bonding were still above NACE 4.2.1.2 standard.

9.0 CONCLUSIONS

PFP Area Rectifier 45 system operation

During the 1997 survey, the LSW, LSW spare, HSW, and HSW spare piping underneath test stations T(R45-3), T(R45-7), T(R45-4), T(R45-5), T(R45-6) and T(R45-8) was protected to the NACE standards implicitly recommended in the WAC. T(R45-1) piping and T(R45-2) piping required an additional 20 mV of polarization gain to satisfy the NACE 4.2.1.3 standard.
Rectifier 45 was running at 34.9 DC volts/4.75 DC amps. The nameplate DC output for Rectifier 45 is 50 volts/12 amps. With a 50 volt DC limit, the rectifier can deliver any additional 2 DC amps to the underground piping.
The wiring configuration at AJB(R45-1A) does not match ECN 625805 or ECN 625127.

PFP Area Rectifier 22 system operation

During the 1997 survey, the 201 and 202 piping underneath test stations T(18-9), T(18-11), T(18-2), and T(18-4) was protected to the NACE standards implicitly recommended in the WAC. T(18-3) piping required an additional 10 mV of polarization gain to satisfy the NACE 4.2.1.3 standard. T(18-12) piping is not required to meet NACE standards. The piping at T(18-12) is not bonded to the Rectifier 22 system and showed little or no stray current pickup.
Rectifier 22 was running at 96.3 DC volts/4.8 DC amps. The nameplate DC output for Rectifier 22 is 120 volts/24 amps. With a 100 volt DC limit imposed by the testing equipment, the Rectifier 22 system can not deliver any additional DC amps to the underground piping.

PFP Rectifier 23 system operation

During the 1997 survey, the 201 and 202 piping underneath test station T(19-1) was protected to the NACE standards implicitly recommended in the WAC. Rectifier 23 was running at 82.5 DC volts/9 DC amps. The nameplate DC output for Rectifier 23 is 120 volts/50 amps. With a 100 volt DC limit imposed by the testing equipment, the Rectifier 23 system could deliver an additional 1.9 DC amps to the underground piping.

PFP Rectifier 45 operation

During the 1997 annual survey, Rectifier 45 was running at 28% of its DC output capacity. At this moderate output, the rectifier was running at 72% efficiency. This efficiency at the moderate output is commonplace for Hanford cathodic protection rectifiers of GoodAll manufacture. The higher the DC output the higher the rectifier efficiency.

During the 1997 annual survey, Rectifier 45 system resistance was 7.4 ohms. During the ATP of 8/94, system resistance was 1.55 ohms. The system resistance had increased by a factor of 4.8 in the 3.5 year time span between the ATP and the 1997 annual survey.
The increase in system resistance is commonplace for Hanford area cathodic protection systems. The system resistance increases more substantially for CP systems under paved areas. A substantial portion of the PFP CP system is under asphalt. The system resistance increase is probably caused by a combination of following events:
The ground underneath the asphalt is depleted of water due to the electrolysis of water on the anodes and the piping;
The water is not replenished underneath the pavement because there is no access through the pavement; and
The oxidation products at the CP anodes may not have a readily available diffusion route away from the anodes because of the pavement.

The consequence of the increase in system resistance is that Rectifier 45 can operate at higher tap settings. During the ATP, the highest achievable tap setting would have been B-2. At B-2 tap settings, Rectifier 45 would have delivered 11.6 amps at 18 volts to the anodes. During the 1997 survey, the tap settings were at C-3.

If Rectifier 45 system is turned off for a length of time and allowed to depolarize completely, then upon start-up the rectifier would probably deliver amperage above the nameplate limit of 12 amps. If the system reverted to its ATP status (1.55 ohms of system resistance), then the C-3 tap settings of 34.9 DC volts would deliver 22.5 DC amps, or 10.5 DC amps above the nameplate limit.
The system would probably not revert to the exact environmental conditions realized during the ATP testing because the water underneath the paved areas would probably not be replenished. However, the oxidation products of Rectifier 45 system operation would dissipate once the Rectifier 45 system is turned off. The dissipation of the oxidation products would lower the system resistance.
It is conjecture to surmise how much the system resistance would diminish during system shutdown. If the system is shutdown for a couple weeks, then a reasonable estimate of the drying out effect on system resistance could be established.

During the 1997 survey, the system resistance was 7.4 ohm at the tap settings of C-3. When tap settings are changed, the system resistance does not change to any appreciable extent right after the settings are changed. If the tap settings of Rectifier 45 were changed from C-3 to D-3, the Rectifier 45 would deliver about 6.7 DC amps at about 50 volts. Each tap settings incremental change lowers or raises the DC output by 3 volts. Five tap setting increments above 34.9 DC volts results in 49.9 volts of DC output. The 12 amps DC output limit of Rectifier 45 is well above the 6.7 DC amps produced by D-3 tap settings.

10.0 RECOMMENDATIONS

Rectifier 45 system

1. Change tap settings from C-3 to D-3 before the 1998 annual survey.
2. Conduct rectifier efficiency test each annual survey.
3. Apply label to Rectifier 45 explaining start-up precaution after prolonged system shutdown.
4. Conduct DC amperage survey with calibrated DC ammeter at AJB(R45-1A), Rectifier 45, and AJB(R45-1) during the next annual survey.
5. Document wiring configuration at AJB(R45-1A) with an ECN.

Rectifier 22 system

1. During the 1998 annual survey, conduct continuity and polarization surveys across all the piping underneath test stations T(18-3), T(18-4), and T(18-11).

Rectifier 23 system

1. During the 1998 annual survey, conduct continuity and polarization surveys across all the piping underneath test station T(19-1).

11.0 REFERENCES

WHC-SD-WM-RPT-266, Rev. 0, 1995 Annual Cathodic Protection Survey Report for the Hanford 200 Area
NACE Standard RP0285-95, Item No. RP02085-95, Standard Recommended Practice, *Corrosion Control of Underground Storage Tank Systems by Cathodic Protection*
WHC-EP-0891 - Corrosion of Low-Carbon Steel Under Environmental Conditions at Hanford: Two-Year Soil Corrosion Test Results
WHC-SD-C031H-ATP-001 Rev. 0, Project 90L-EWC-031H, PFP Liquid Low Level Waste System Acceptance Test Procedure, Waste Treatment Facility
WHC-SD-W020H-ATP-014, Rev. 0, Acceptance Test Procedure (ATP), Project W-020H, Waste Management Facilities Cathodic Protection Upgrade, Priority 4, Rectifier #22
WHC-SD-W020H-ATP-015, Rev. 0, Acceptance Test Procedure (ATP), Project W-020H, Waste Management Facilities Cathodic Protection Upgrade, Priority 4, Rectifier #23
WAC 173-303-640 Tank Systems, Washington State Department of Ecology, Dangerous Waste Regulations, Chapter 173-303 WAC, Publication 92-91
WHC Internal Memo 71420-95-JHH-004, PFP Cathodic Protection System Survey, January 1995
WHC Internal Memo 74A40-95-JHH-046, Plutonium Finishing Plant Annual Cathodic Protection System Survey, 1995
H-2-87513 Sh 1 Rev. 1, Elec Cathodic Prot Plan Waste Retention Fac
H-2-91019 Sh 5 Rev. 1, Cathodic Protection - Plot Plan Test Stations - Jumpers -Anodes
H-2-91018 Sh 5 Rev. 2, Cathodic Protection - Plot Plan Test Stations - Jumpers -Anodes
Cathodic Protection - Theory and Data Interpretation - October 14, 1989, NACE
200 East and West Tank Farms - Cathodic Protection System Survey Report, July 1994
200 Area Tank Farms - Cathodic Protection System Resurvey, March 1995
Cathodic Protection - John Morgan, 1993

APPENDIX A

Cathodic Protection testing requirements of WAC 173-303-640 and Acceptance Standards and NACE Standard RP0285-95

Washington State Department of Ecology
Dangerous Waste Regulations
Chapter 173-303 WAC
Publication 92-91
Amended February 1998

WAC 173-303-640 Tank Systems
p. 95
(1) Applicability
(a) The regulations in WAC 173-303-640 apply to owners and operators of facilities that use tank systems to treat or store dangerous waste, ...

p. 100
(6) Inspections.

(c) The owner or operator must inspect cathodic protection systems, if present, according to, at a minimum, the following schedule to ensure that they are functioning properly:
(i) The proper operation of the cathodic protection system must be confirmed within six months after initial installation and annually thereafter; and
(ii) ...

Note: The practices described in the National Association of Corrosion Engineers (NACE) standard, "Recommended Practice (RP-02-85)-Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems," and the American Petroleum Institute (API) Publication 1632, "Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems," may be used, where applicable, as guidelines in maintaining and inspecting cathodic protection systems.

(d) ...

NACE Standard RP0285-95
Item No. 21030
Standard Recommended Practice
Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

Note: This standard was originally published in 1985 as "Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems."

Section 4: Criteria for Cathodic Protection

4.2 Criteria for Steel Structures

4.2.1 Corrosion control can be achieved at various levels of cathodic polarization depending on the environmental conditions. However, in the absence of data which demonstrate that adequate cathodic protection has been achieved, one or more of the following shall apply:

APPENDIX A (continued)
Cathodic Protection testing requirements of WAC 173-303-640 and acceptance standards of NACE Standard RP0285-95

4.2.1.1 A negative (cathodic) potential of at least 850 mV with the cathodic protection applied. This potential is measured with respect to a saturated copper/copper sulfate reference electrode contacting the electrolyte. Voltage drops other than those across the structure/electrolyte boundary must be considered for valid interpretation of this voltage measurement.

4.2.1.2 A negative polarized potential (see definition in Section 1.2) of at least 850 mV relative to a saturated copper/copper sulfate reference electrode.

4.2.1.3 A *minimum of* 100 *mV of* cathodic polarization. The formation or decay of polarization can be used to satisfy this criterion.

TABLE 1
Attributes of Rectifier 45 system within PFP property
Reference WHC-SD-C031H-ATP-001 Rev. 0

Page	Rectifier	Test Station	Location	Pipes Designed For Protection	Pipes Not Designed For Protection
11	45	T(R45-1)	North of 241-Z	LSW, LSW Spare, HSW, HSW Spare	
12	45	T(R45-2)	North of T(R45-1)	LSW, LSW Spare, HSW, HSW Spare	2" SW, 8" SW
12	45	T(R45-3)	Northeast of T(R45-2)	LSW, LSW Spare, HSW, HSW Spare	Two Unknown Pipes
12	45	T(R45-4)	North of 243-Z	LSW, LSW Spare, HSW, HSW Spare	Two Unknown Pipes
13	45	T(R45-5)	West of 236-Z	LSW, LSW Spare, HSW, HSW Spare	
13	45	T(R45-6)	South of 243-Z	LSW, LSW Spare, HSW, HSW Spare	6" SW
14	45	T(R45-7)	North of T(R45-4)	LSW, LSW Spare, HSW, HSW Spare	Unknown pipe
14	45	T(R45-8)	West of T(R45-5)	LSW, LSW Spare, HSW, HSW Spare	4" Existing pipe

TABLE 2
Attributes of Rectifier 22 system within PFP property
Reference WHC-SD-W020H-ATR-014 Rev. 0

Page	Rectifier	Test Station	Location	Pipes Designed For Protection	Pipes Not Designed For Protection
13	22	T(18-2)	Southeast of 241-Z	202, 203	
13	22	T(18-3)	North of Settling Tank	202, 203	6" DR (4 mV low in 1994)
13	22	T(18-4)	East of T(18-3)	202, 203	6" CSTL Drain (5 mV low in 1994)
13	22	T(18-12)	East of 241-ZB		8" CI Sanitary Water
13	22	T(18-9)	East of 234-5Z	202, 203	
14	22	T(18-11)	South of 2701-ZA	202, 203	10" SW

TABLE 3
Attributes of Rectifier 23 system within PFP property
Reference WHC-SD-W020H-ATR-015 Rev. 0

Page	Rectifier	Test Station	Location	Pipes Designed For Protection	Pipes Not Designed For Protection
13	23	T(19-1)	North of 2701-ZA	202, 203	6" RW, 8"SW

TABLE 4
Attributes of PFP area piping

Protected Pipes	Origin	Endpoint	PFP Area Rectifier 45 Test Stations	PFP Area Rectifier 22 Test Stations	PFP Area Rectifier 23 Test Stations
LSW, LSW Spare HSW, HSW Spare	236-Z	241-Z	T(R45-1), T(R45-2), T(R45-3), T(R45-4), T(R45-5), T(R45-6), T(R45-7), T(R45-8)		
202, 203	241-Z	244-TX		T(18-2), T(18-3), T(18-4), T(18-9), T(18-11)	T(19-1)

TABLE 5
Rectifier Nameplate Data

Rectifier	Nameplate DC voltage rating	Nameplate DC amperage rating
45	50	12
22	120	24
23	120	50

TABLE 6
Continuity and Polarization Testing during 1996 annual survey

Test Station(s)	All piping tested in the Test Station, Polarization values low by at least 3 mV	All piping tested in the Test Station, Resistance values to HSW piping greater than 10 ohms
T(R45-1)	None	LSW - 11 ohms
T(R45-2)	None	Unknowns not tested
T(R45-3)	Unknown bottom piping - 76 millivolts low	Unknown bottom - 2 Mohms
T(R45-4)	None	None
T(R45-5)	None	None
T(R45-6)	None	Unknown - 35 ohms
T(R45-7)	None	None
T(R45-8)	None	None

TABLE 7
Continuity Testing during 1997 annual survey

Test Station(s)	Resistance Measurements
T(R45-2)	LSW to Unknown Top - 49 ohms LSW to Unknown Bottom - 85 ohms Unknown Top to Unknown Bottom - 36 ohms
T(18-12) to T(18-4)	8″ CI SW to 203 - 1.7 Kohms
T(R45-3)	Unknown bottom to HSW before jumper installation - 2/.6 Mohms
T(R45-3)	Unknown bottom to HSW after jumper installation - 0.4 ohms

TABLE 8
Amperage Testing at AJB(R45-1A) during 1997 annual survey

Wire Identification or Position	Function	DC amperage
LR45-1	Input loop cable	3.26 amps
HR45-1	Input header cable	0.72 amps
LR45-1A	Output loop cable	1.09 amps
HR45-1A	Output header cable	3.06 amps
#1 position	Anode lead cable	0.06 amps
#2 position	Anode lead cable	0.02 amps
#3 position	Anode lead cable	0.32 amps
#4 position	Anode lead cable	0.24 amps
#5 position	Anode lead cable	0.17 amps
HR45-1 at the rectifier	Output header cable	1.29 amps
LR45-1	Output loop cable	3.33 amps

TABLE 9
Polarization Testing at T(R45-3) during 1997 annual survey

System Configuration at T(R45-3)	Polarization values, volts
Before Jumper installation, polarization at protected pipes	0.92
Before jumper installation, Polarization at unknown bottom	0.86
After jumper installation, polarization at unknown bottom	0.91

TABLE 10
Rectifier 45 Efficiency testing

Date	AC Volts	AC Amps	DC Volts	DC Amps	Efficiency, (assume pf=.99)
11/97	116.4	1.5	29.6	3.3	57%
2/98	113.9	2.04	34.9	4.75	72%

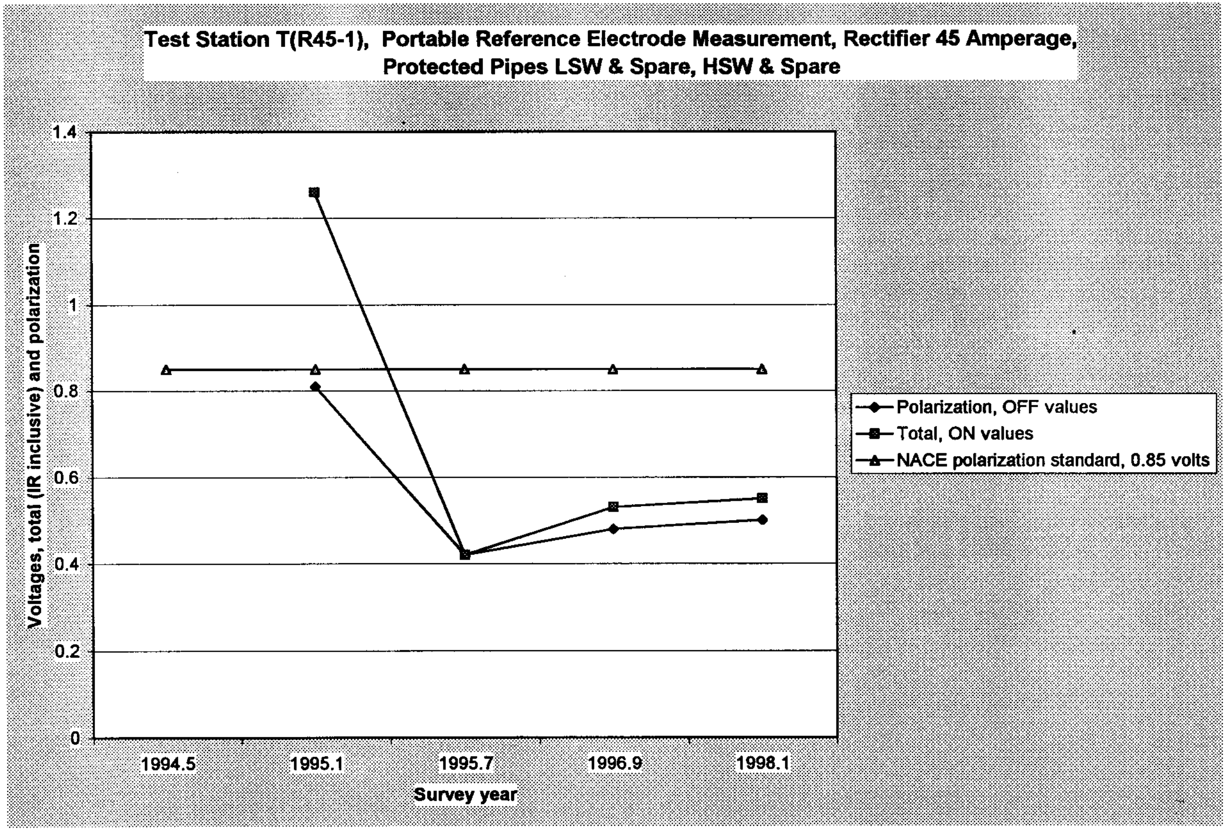
	A	B	C	D	E	F	G	H	I	J	K	L
1	SPREADSHEET 1 - 1997 CP Annual Survey Data											
2												
3	Test Station	Line numbers	Portable	Portable	Permanent	Permanent	Portable to	Portable to				
4			Reference	Reference	Reference	Reference	Permanent	Permanent				
5			ON value	OFF value	ON value	OFF value	ON value	OFF value				
6												
7			1997 Annual Cathodic Protection Survey Data									
8		1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
9	PFP											
10	Area											
11	Rectifier 23											
12	tap settings	C-3										
13	volts	82.5										
14	amps	9										
15	efficiency											
16	19-1	both	0.95	0.85	0.8	0.73	0.15	0.13				
17												
18	Rectifier 22											
19	tap settings	C-5										
20	volts	96.3										
21	amps	4.8										
22	efficiency											
23	18-11	both	1.23	0.94	1.32	0.98	-0.09	-0.04				
24	18-9	both	1.44	1.02	1.22	0.92	0.22	0.09				
25	18-12	one	0.46	0.43	0.31	0.29	0.16	0.14				
26	18-4	both	0.99	0.59	0.47	0.39	0.53	0.21				
27	18-3	both	0.56	0.51	0.44	0.4	0.12	0.11				
28	18-2	both	0.96	0.77	0.82	0.67	0.13	0.09				
29												
30		1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
31												
32												
33	Rectifier 45											
34	tap settings	C-3										
35	volts	34.9										
36	amps	4.75										
37	efficiency	72										
38	R45-1	both	0.55	0.5	0.59	0.52	-0.04	-0.03				
39	R45-2	both	0.55	0.5	0.56	0.52	-0.02	-0.02				
40	R45-3	both	1.24	0.92	0.9	0.77	0.34	0.15				
41	R45-6	both	0.72	0.6	0.52	0.5	0.21	0.1				
42	R45-4	both	1.19	0.7	0.95	0.81	0.24	-0.12				
43	R45-7	both	2.18	0.97	5.35	0.93	-3.23	0.03				
44	R45-8	both	0.84	0.66	0.93	0.76	-0.1	-0.11				
45	R45-5	both	1.21	0.84	0.66	0.62	0.55	0.22				

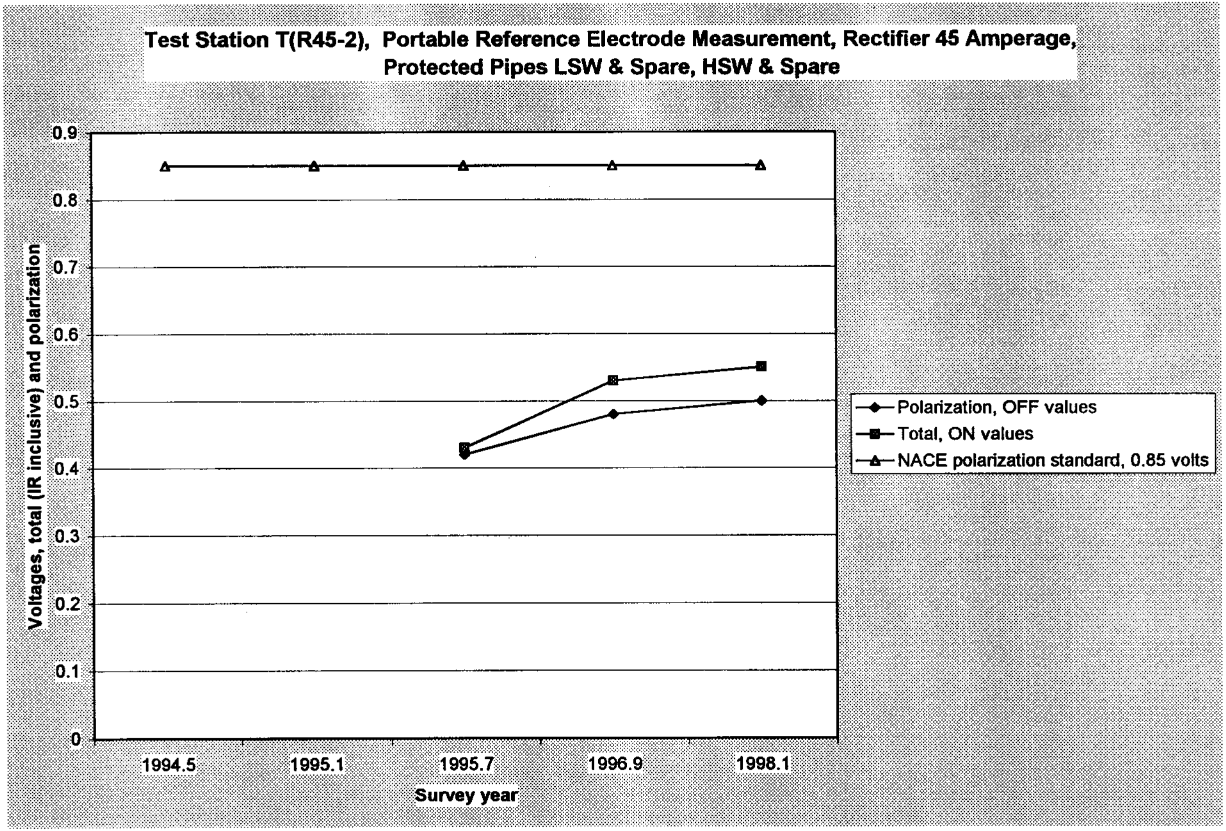
	A	B	C	D	E	F	G	H	I	J	K	L
1	SPREADSHEET 2 - 1996 CP Annual Survey Data											
2												
3	Test Station	Line numbers	Portable	Portable	Permanent	Permanent	Portable to	Portable to	Permanent	Permanent	Portable to	Portable to
4			Reference	Reference	Reference	Reference	Permanent	Permanent	Reference	Reference	Permanent	Permanent
5			ON value	OFF value	ON value	OFF value	ON value	OFF value	ON value	OFF value	ON value	OFF value
6												
7			1996 Annual Cathodic Protection Survey Data									
8		1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996
9	PFP											
10	Area											
11	Rectifier 23											
12	tap settings	C-3										
13	volts	86.3										
14	amps	11.3										
15	efficiency											
16	19-1		0.97	0.88	0.82	0.75	0.15	0.13				
17												
18	Rectifier 22											
19	tap settings	D-2										
20	volts	112.5										
21	amps	5.4										
22	efficiency											
23	18-11		1.5	1.07	1.53	1.04	-0.03	0.03				
24	18-9		1.33	0.96	1.16	0.88	0.17	0.07				
25	18-12		0.39	0.36	0.29	0.27	0.1	0.09				
26	18-4		1.27	0.67	0.56	0.44	0.71	0.23				
27	18-3		0.74	0.61	0.49	0.45	0.25	0.16				
28	18-2		1.09	0.78	0.93	0.71	0.17	0.06				
29												
30		1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996
31												
32												
33	Rectifier 45											
34	tap settings	C-1										
35	volts	29.6										
36	amps	3.3										
37	efficiency	57										
38	R45-1	six	0.53	0.48	0.5	0.46	0.03	0.02				
39	R45-2	four	0.53	0.48	0.51	0.48	0.02	0				
40	R45-3	five, sixth low	1.14	0.91	0.87	0.74	0.26	0.17	0.99	0.8	0.15	0.1
41	R45-6	five	0.65	0.55	0.43	0.41	0.23	0.14	0.44	0.42	0.21	0.13
42	R45-4	six	1.37	0.74	0.98	0.83	0.39	-0.1	1.08	0.83	0.3	-0.1
43	R45-7	five	1.33	0.72	2.55	0.68	-1.23	0.13	1.01	0.74	0.32	-0.03
44	R45-8	five	0.6	0.52	0.62	0.56	-0.02	-0.03	0.52	0.48	0.09	0.05
45	R45-5	four	0.95	0.7	0.54	0.52	0.4	0.18				

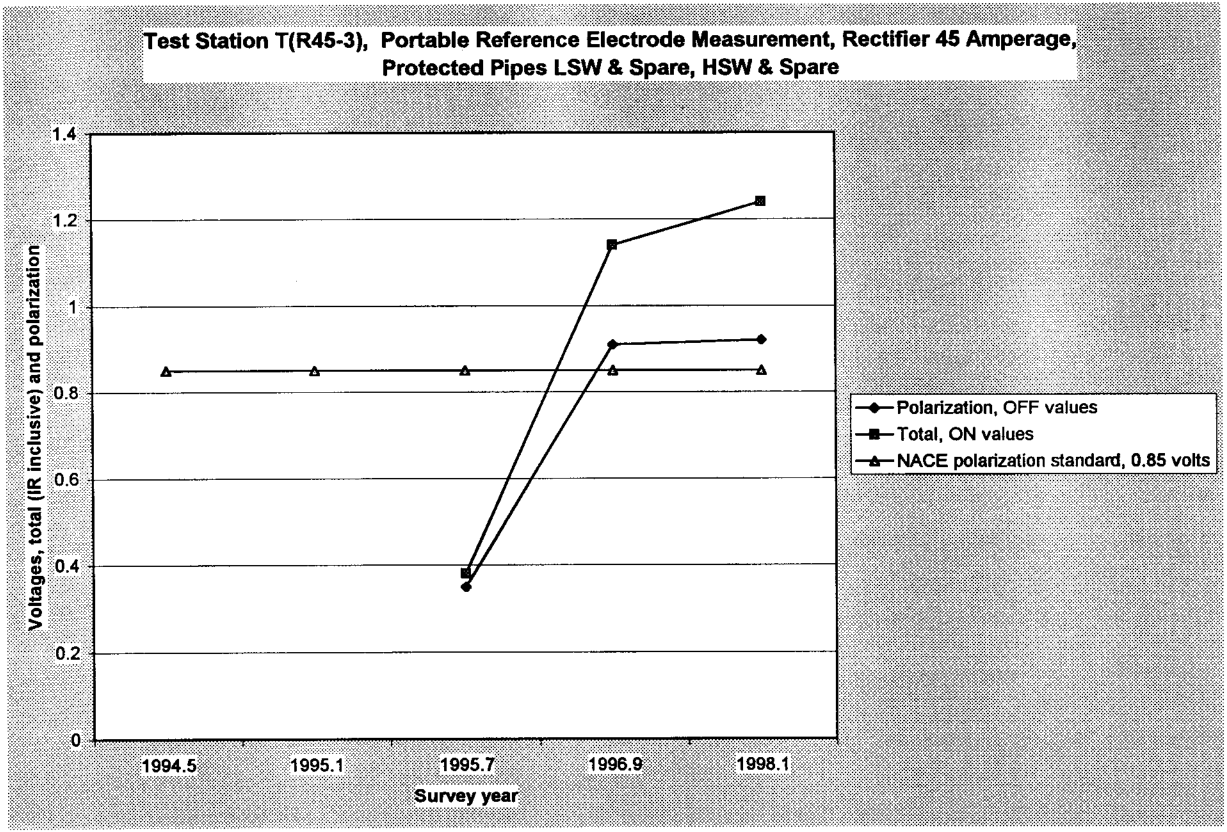
	A	B	C	D	E	F	G	H	I	J	K	L
1	SPREADSHEET 3 - 1995 CP Annual Survey Data											
2												
3	Test Station	Line numbers	Portable	Portable	Permanent	Permanent	Portable to	Portable to	Permanent	Permanent	Portable to	Portable to
4			Reference	Reference	Reference	Reference	Permanent	Permanent	Reference	Reference	Permanent	Permanent
5			ON value	OFF value	ON value	OFF value	ON value	OFF value	ON value	OFF value	ON value	OFF value
6												
7			1995 Annual Cathodic Protection Survey Data									
8		Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95
9	PFP											
10	Area											
11	Rectifier 23											
12	tap settings											
13	volts											
14	amps											
15	efficiency											
16	19-1											
17												
18	Rectifier 22											
19	tap settings											
20	volts											
21	amps											
22	efficiency											
23	18-11											
24	18-9											
25	18-12											
26	18-4											
27	18-3											
28	18-2											
29												
30		Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95	Aug-95
31												
32												
33	Rectifier 45											
34	tap settings	C-1										
35	volts	29.4										
36	amps	5.3										
37	efficiency											
38	R45-1	four	0.42	0.42	0.44	0.44						
39	R45-2	four, two mod	0.43	0.42	0.39	0.39			0.33	0.33		
40	R45-3	five, one low	0.38	0.35	0.52	0.46			0.43	0.4		
41	R45-6	both	0.79	0.61	0.49	0.45			0.46	0.43		
42	R45-4	both	2.44	0.86	1.25	0.97			1.49	0.97		
43	R45-7	both	1.66	0.8	3.14	0.67			1.34	0.71		
44	R45-8	both	0.71	0.59	0.72	0.61			0.59	0.53		
45	R45-5	both	1.31	0.87	0.6	0.26						

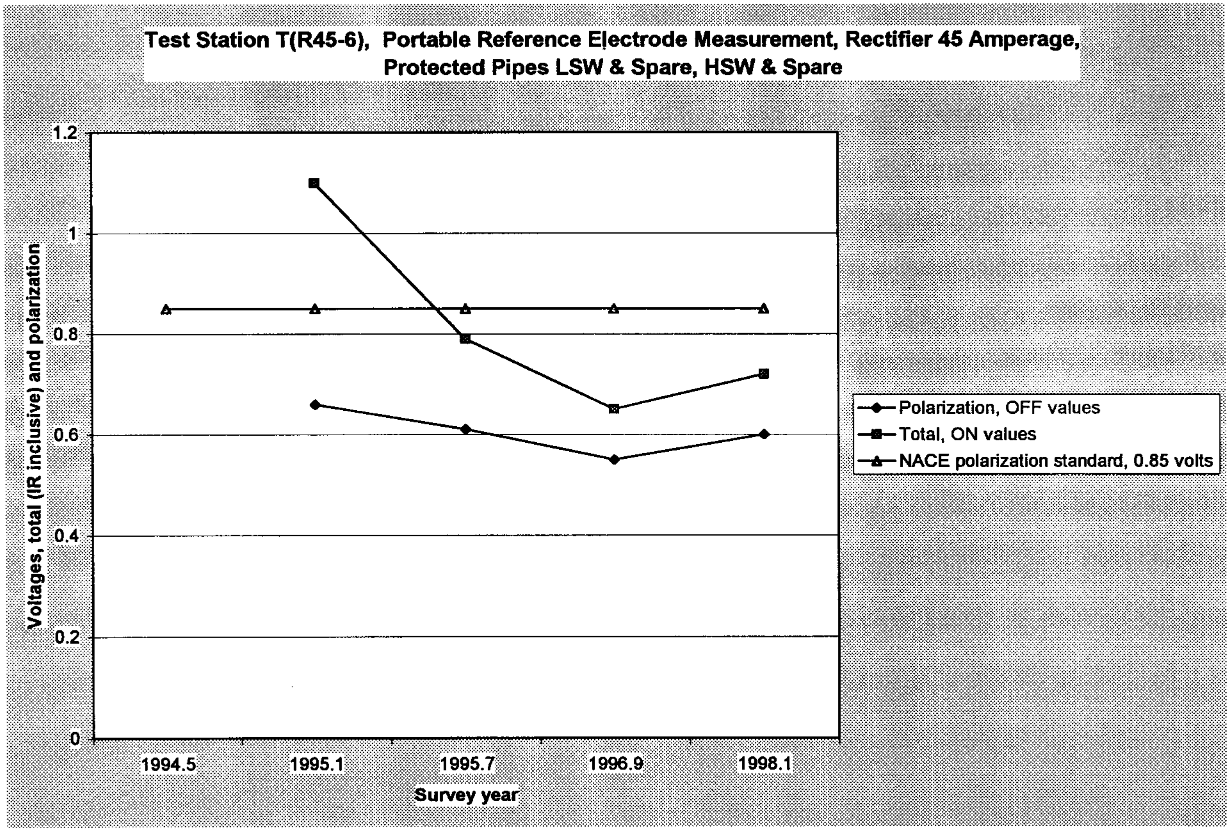
	A	B	C	D	E	F	G	H	I	J	K	L
1	*SPREADSHEET 4 - 1995 CP 6-Month and Coppro Survey Data*											
2												
3	Test Station	Line numbers	Portable	Portable	Permanent	Permanent	Portable to	Portable to	Permanent	Permanent	Portable to	Portable to
4			*Reference*	*Reference*	*Reference*	*Reference*	*Permanent*	*Permanent*	*Reference*	*Reference*	*Permanent*	*Permanent*
5			ON value	OFF value	ON value	OFF value	ON value	OFF value	ON value	OFF value	ON value	OFF value
6												
7			1995 Cathodic Protection Resurvey Data									
8		Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95
9	PFP											
10	Area											
11	Rectifier 23											
12	tap settings	C-3										
13	volts	85.9										
14	amps	8										
15	efficiency											
16	19-1											
17												
18	Rectifier 22											
19	tap settings	D-5										
20	volts	136										
21	amps	7.3										
22	efficiency											
23	18-11											
24	18-9	both	1.41	0.99								
25	18-12											
26	18-4											
27	18-3											
28	18-2	both	0.82	0.7								
29												
30		*Jan-95*	*Jan-95*	*Jan-95*	*Jan-95*	*Jan-95*	*Jan-95*	*Jan-95*	*Jan-95*	*Jan-95*	*Jan-95*	*Jan-95*
31												
32												
33	Rectifier 45											
34	tap settings	A-5										
35	volts	12.9										
36	amps	4.6										
37	efficiency	OTP test										
38	R45-1		1.26	0.81								
39	R45-2											
40	R45-3											
41	R45-6		1.1	0.66								
42	R45-4											
43	R45-7											
44	R45-8		0.86	0.63								
45	R45-5											

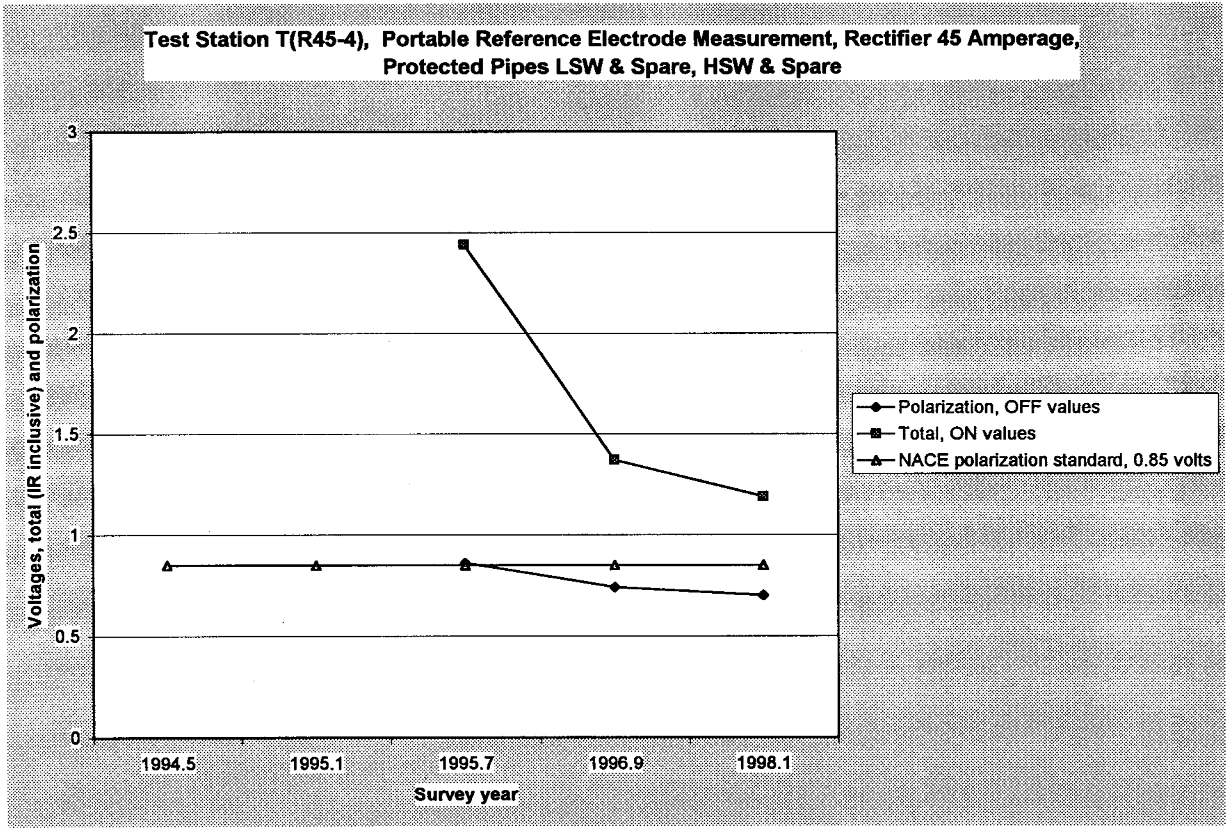
	A	B	C	D	E	F	G	H	I	J	K	L
1	SPREADSHEET 5- 1994 CP ATP and Baseline Survey Data											
2												
3	Test Station	Line numbers	Portable	Portable	Permanent	Permanent	Portable to	Portable to	Permanent	Permanent	Portable to	Portable to
4			Reference	Reference	Reference	Reference	Permanent	Permanent	Reference	Reference	Permanent	Permanent
5			ON value	OFF value	ON value	OFF value	ON value	OFF value	ON value	OFF value	ON value	OFF value
6												
7			1994 Baseline Annual Cathodic Protection Survey Data									
8		Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94
9	PFP											
10	Area											
11	Rectifier 23											
12	tap settings	C-3										
13	volts	91.4										
14	amps	11.8										
15	efficiency											
16	19-1	four	1.08	0.94	0.89	0.8	0.18	0.14				
17												
18	Rectifier 22											
19	tap settings	D-2										
20	volts	115										
21	amps	7.4										
22	efficiency											
23	18-11	three	1.19	0.89	1.24	0.86	-0.05	0.02				
24	18-9	both	1.24	0.9	1.28	0.92	-0.05	-0.02				
25	18-12	one	0.37	0.34	0.25	0.23	0.12	0.11				
26	18-4	two, one mod	0.9	0.65	0.78	0.62	0.13	0.02				
27	18-3	three	0.66	0.59	0.46	0.42	0.2	0.16				
28	18-2	both	0.91	0.76	0.85	0.68	0.06	0.07				
29												
30		Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94	Jul-94
31												
32												
33	Rectifier 45											
34	tap settings	A-5										
35	volts	12										
36	amps	7.75										
37	efficiency	ATP test			Suspect reference							
38	R45-1				1.01							
39	R45-2				1.46							
40	R45-3				0.77							
41	R45-6				0.36							
42	R45-4				1.04							
43	R45-7				1.92							
44	R45-8				0.72							
45	R45-5				0.53							

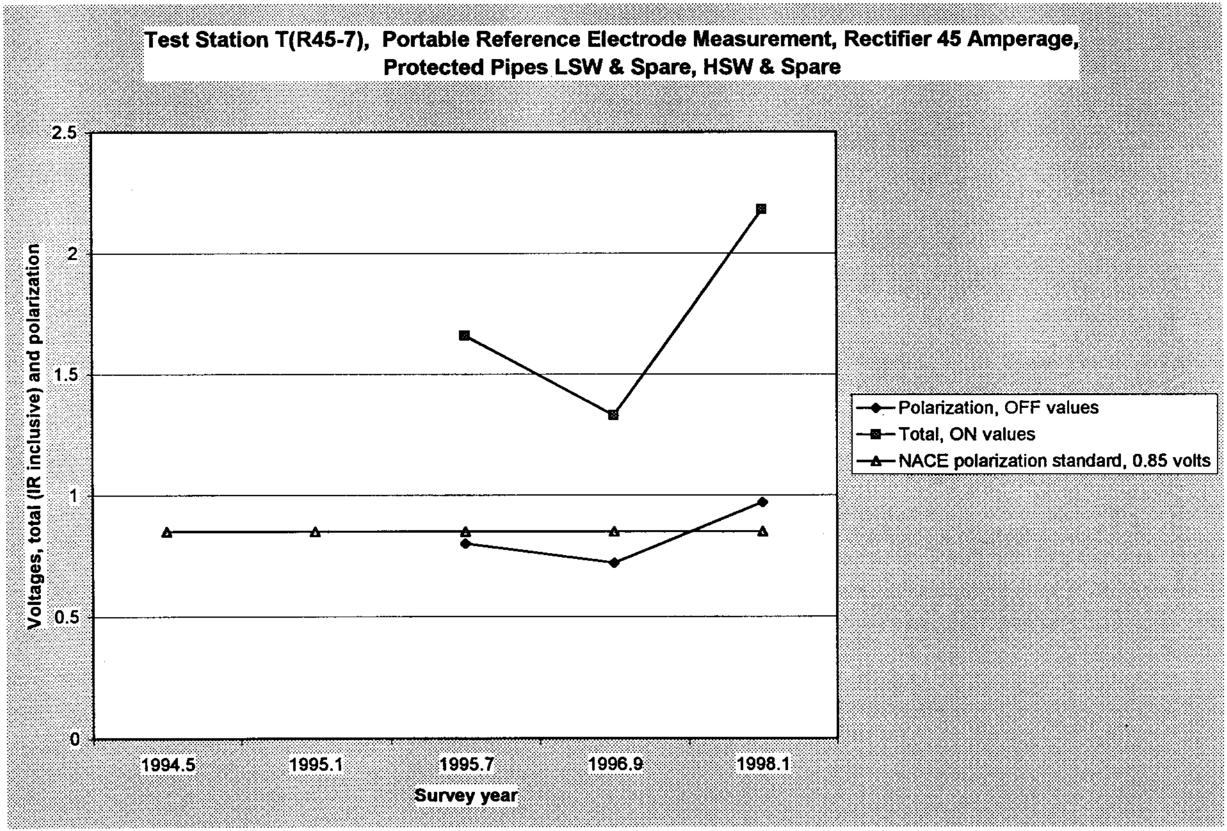

Test Station T(R45-1), Portable Reference Electrode Measurement, Rectifier 45 Amperage, Protected Pipes LSW & Spare, HSW & Spare
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Voltages, total (IR inclusive) and polarization
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

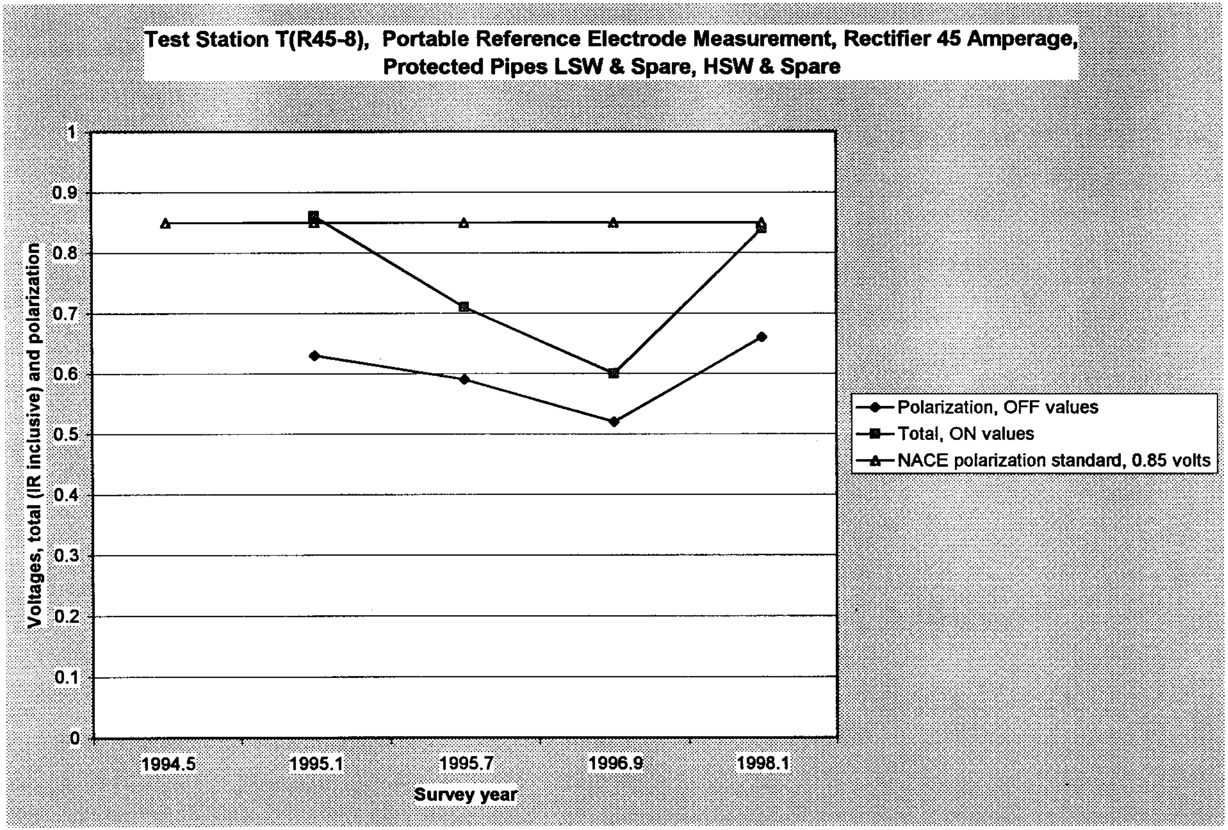

Test Station T(R45-2), Portable Reference Electrode Measurement, Rectifier 45 Amperage,
Protected Pipes LSW & Spare, HSW & Spare
Voltages, total (IR inclusive) and polarization
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

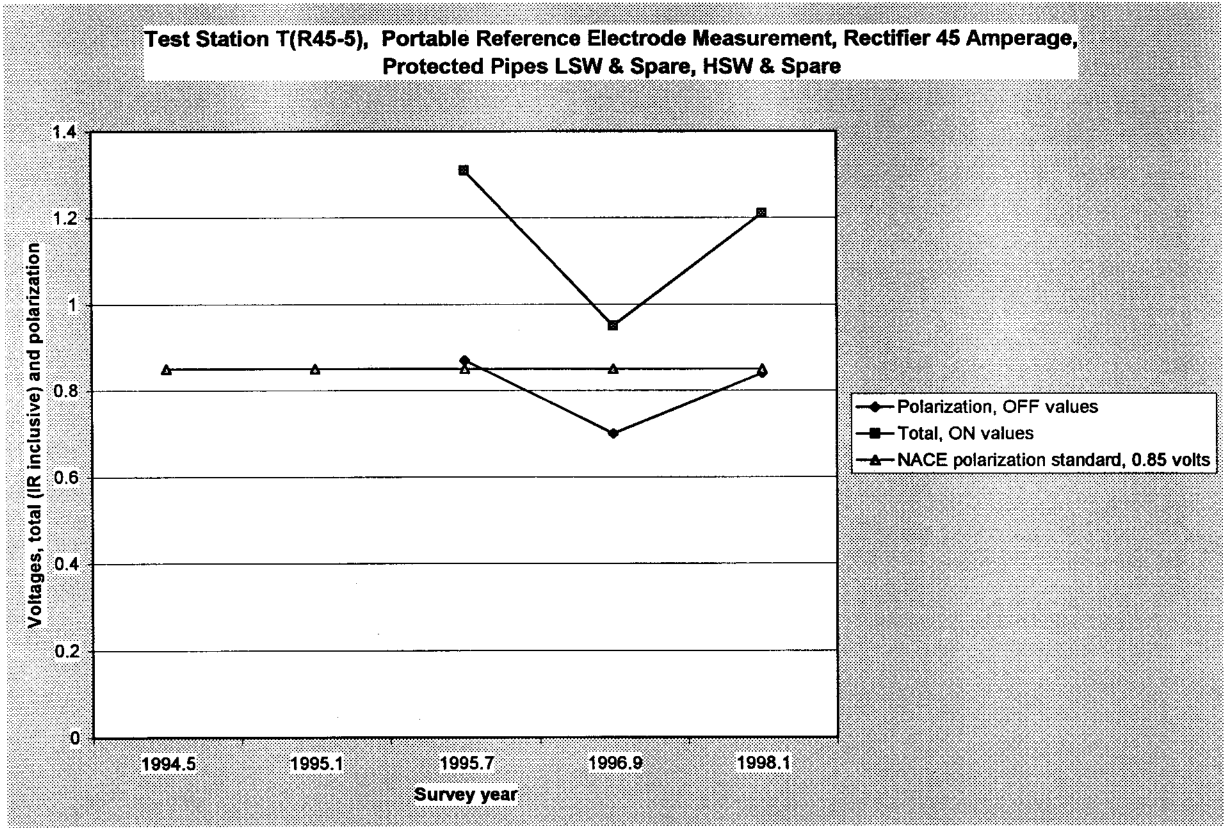

Test Station T(R45-3), Portable Reference Electrode Measurement, Rectifier 45 Amperage, Protected Pipes LSW & Spare, HSW & Spare
Voltages, total (IR inclusive) and polarization
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

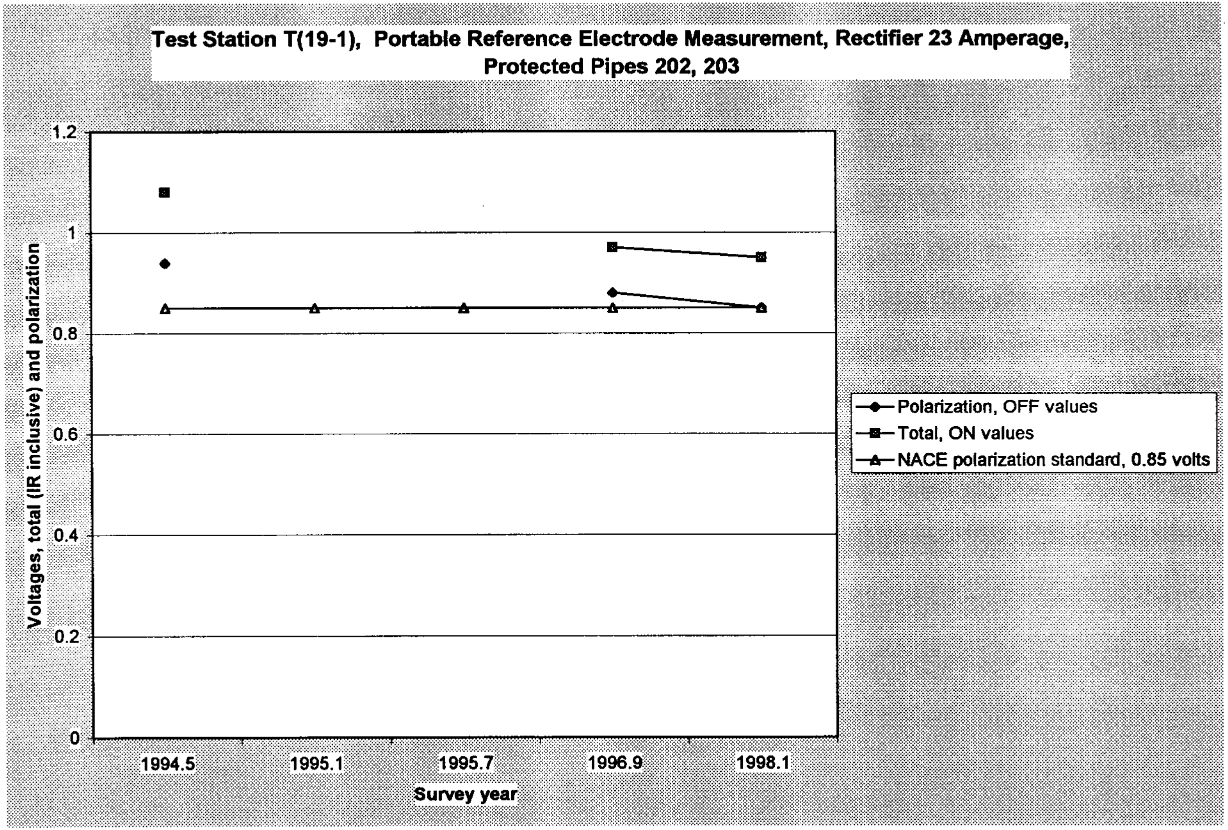

Test Station T(R45-6), Portable Reference Electrode Measurement, Rectifier 45 Amperage, Protected Pipes LSW & Spare, HSW & Spare
Voltages, total (IR inclusive) and polarization
1.2
1
0.8
0.6
0.4
0.2
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

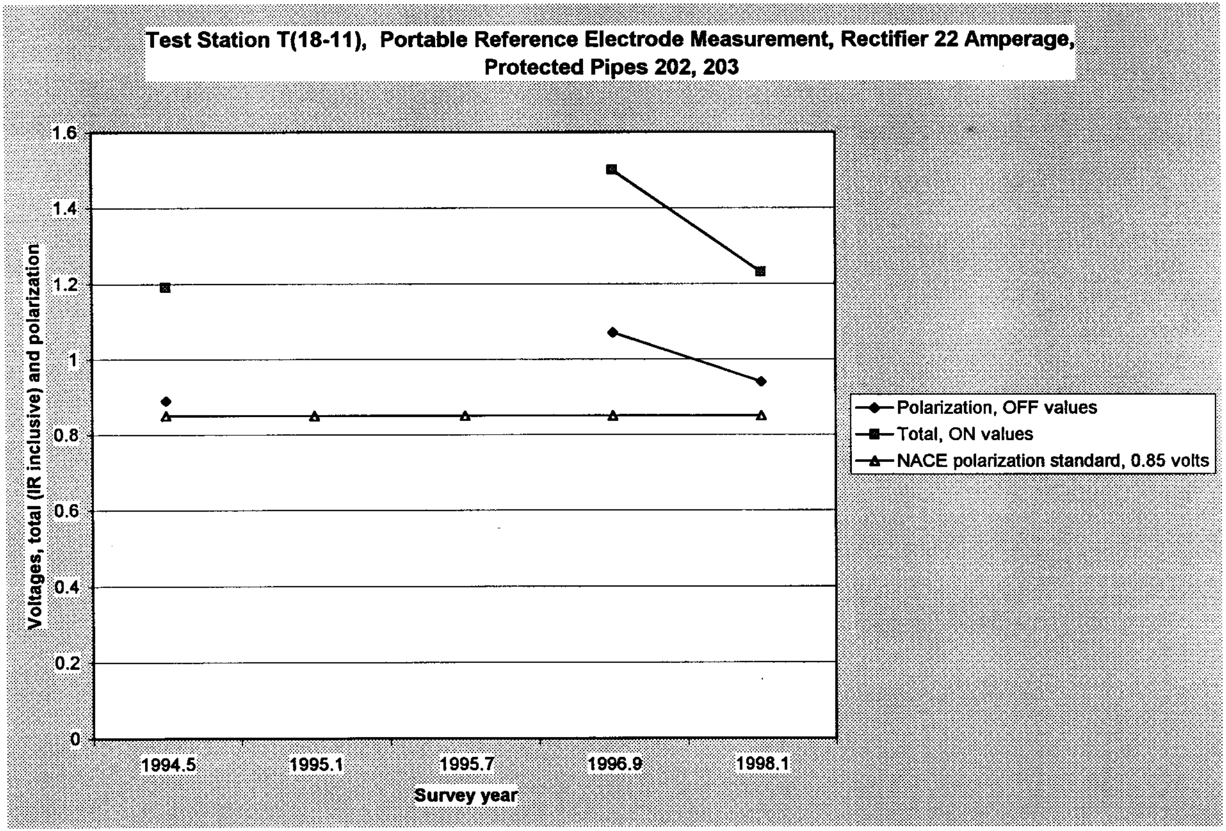

Test Station T(R45-4), Portable Reference Electrode Measurement, Rectifier 45 Amperage, Protected Pipes LSW & Spare, HSW & Spare
Voltages, total (IR inclusive) and polarization
3
2.5
2
1.5
1
0.5
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

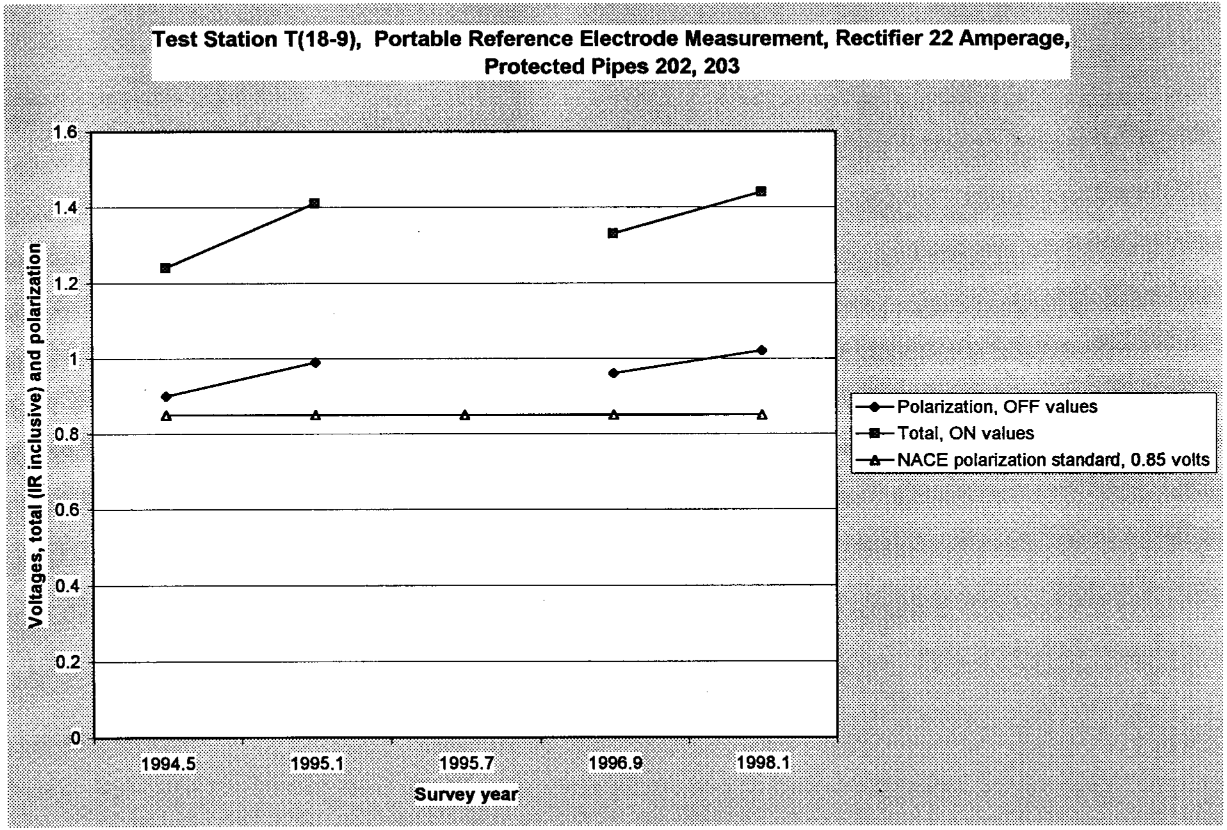

Test Station T(R45-7), Portable Reference Electrode Measurement, Rectifier 45 Amperage,
Protected Pipes LSW & Spare, HSW & Spare
Voltages, total (IR inclusive) and polarization
2.5
2
1.5
1
0.5
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

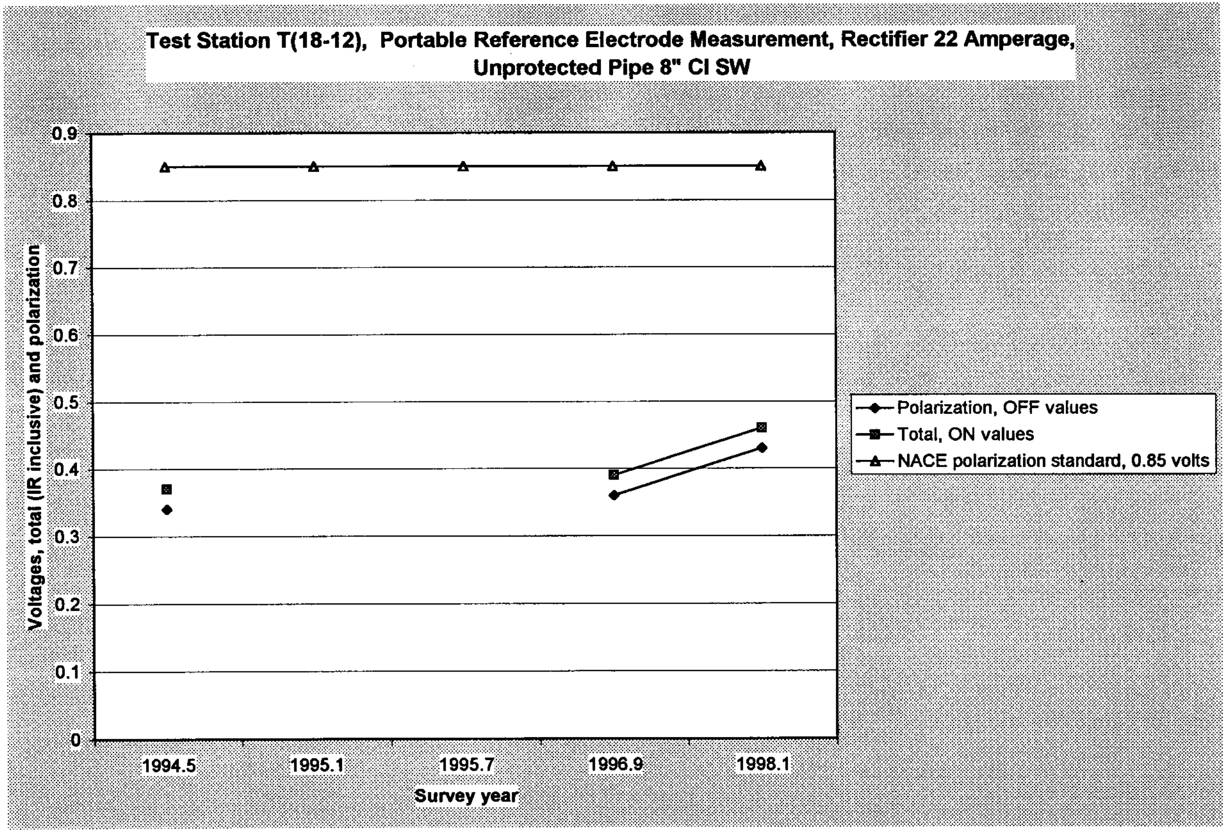

Test Station T(R45-8), Portable Reference Electrode Measurement, Rectifier 45 Amperage,
Protected Pipes LSW & Spare, HSW & Spare
Voltages, total (IR inclusive) and polarization
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

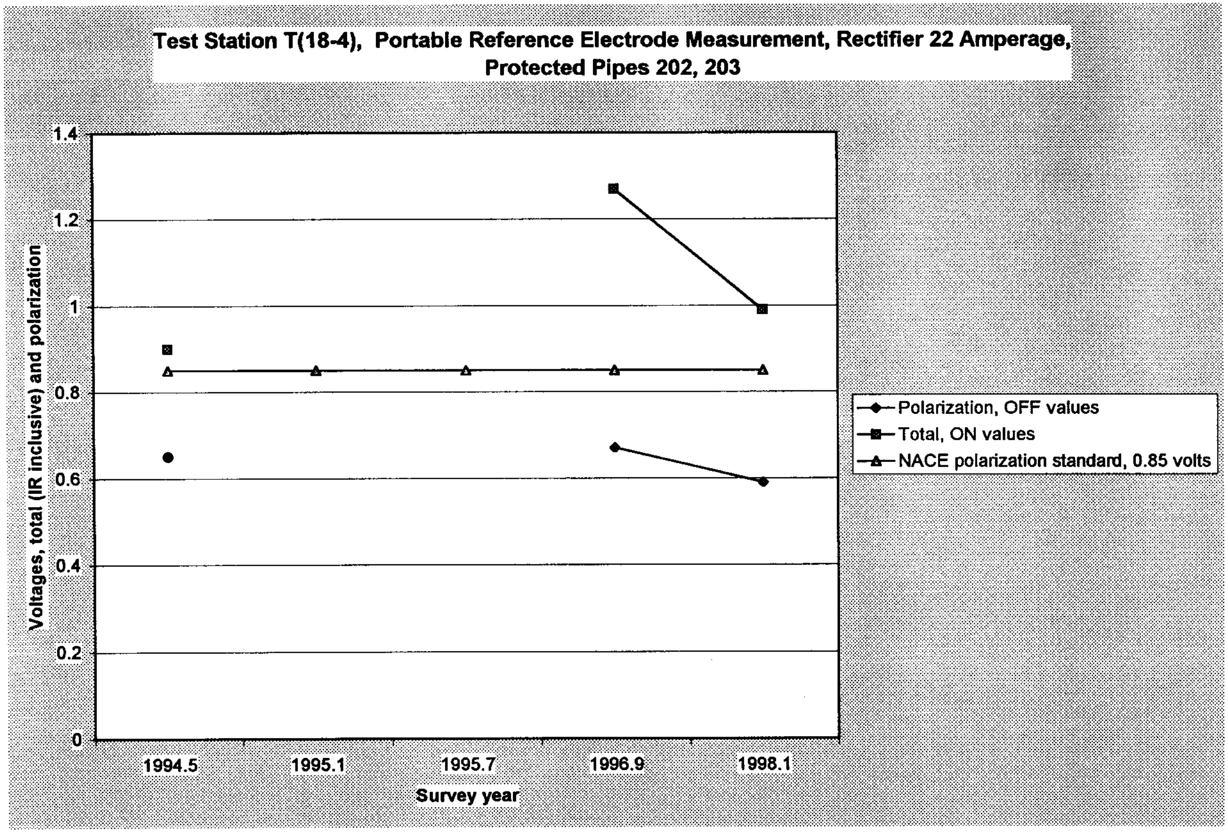

Test Station T(R45-5), Portable Reference Electrode Measurement, Rectifier 45 Amperage, Protected Pipes LSW & Spare, HSW & Spare
Voltages, total (IR inclusive) and polarization
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

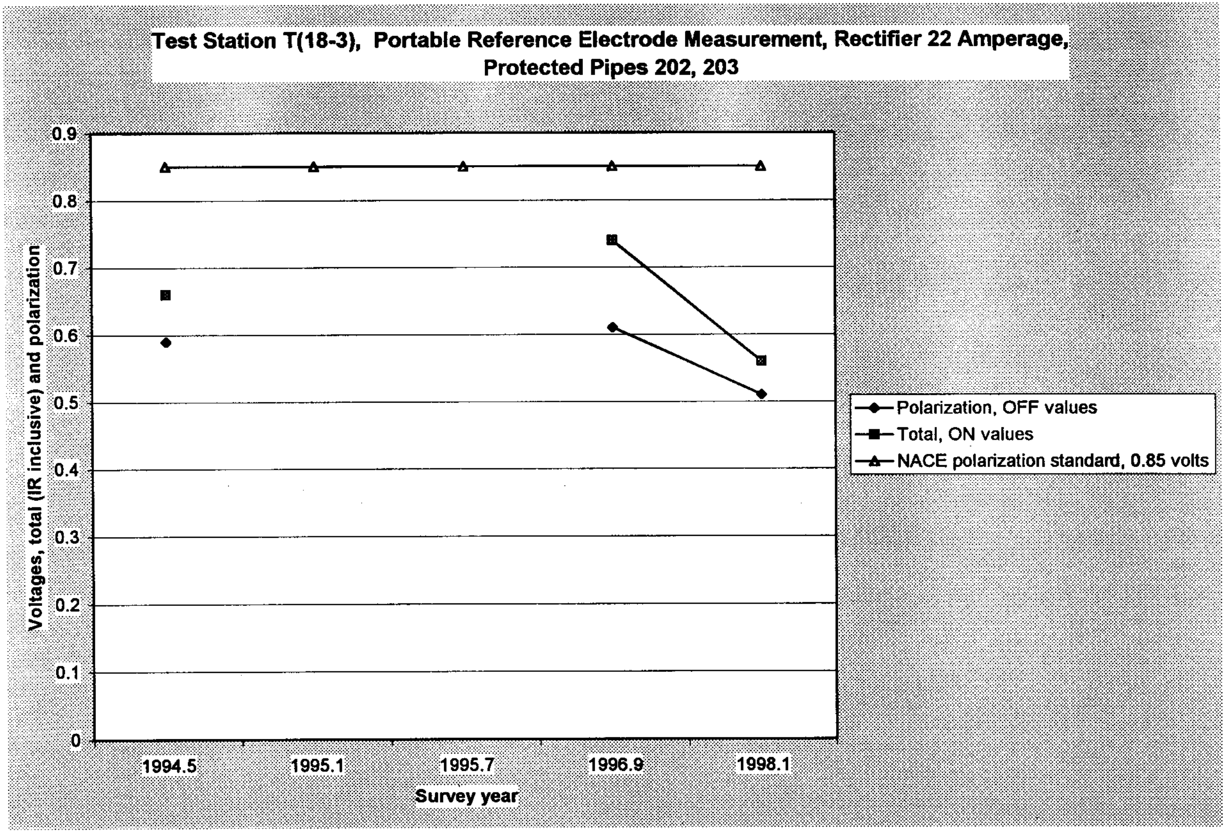

Test Station T(19-1), Portable Reference Electrode Measurement, Rectifier 23 Amperage, Protected Pipes 202, 203
Voltages, total (IR inclusive) and polarization
1.2
1
0.8
0.6
0.4
0.2
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

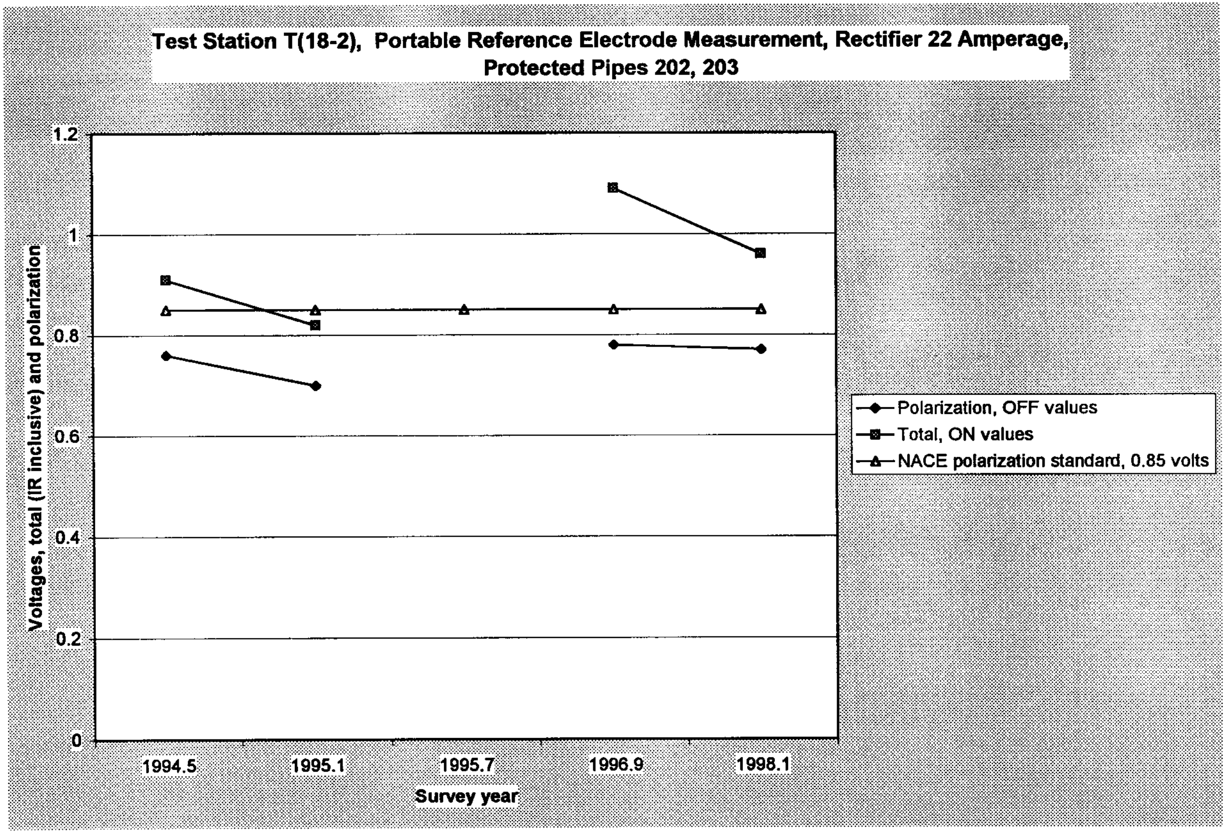

Test Station T(18-11), Portable Reference Electrode Measurement, Rectifier 22 Amperage, Protected Pipes 202, 203
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Voltages, total (IR inclusive) and polarization
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

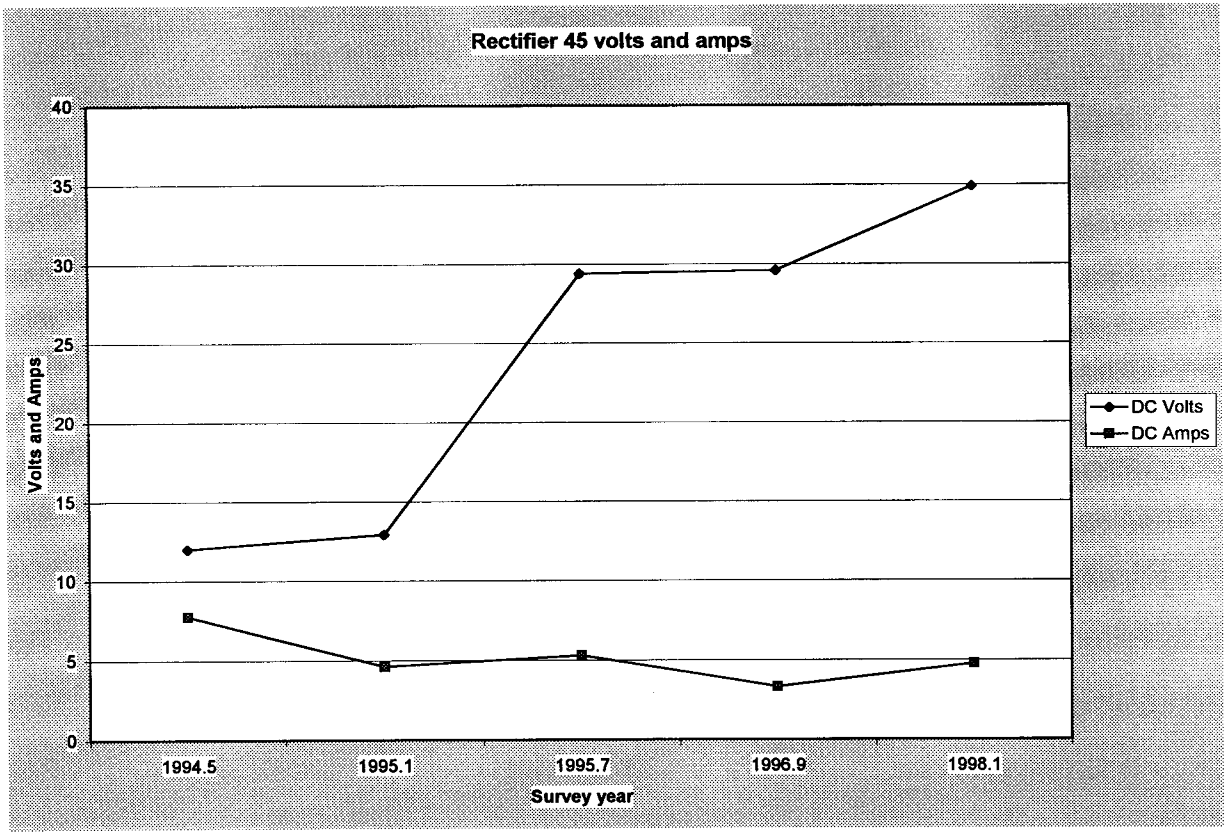

Test Station T(18-9), Portable Reference Electrode Measurement, Rectifier 22 Amperage,
Protected Pipes 202, 203
Voltages, total (IR inclusive) and polarization
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

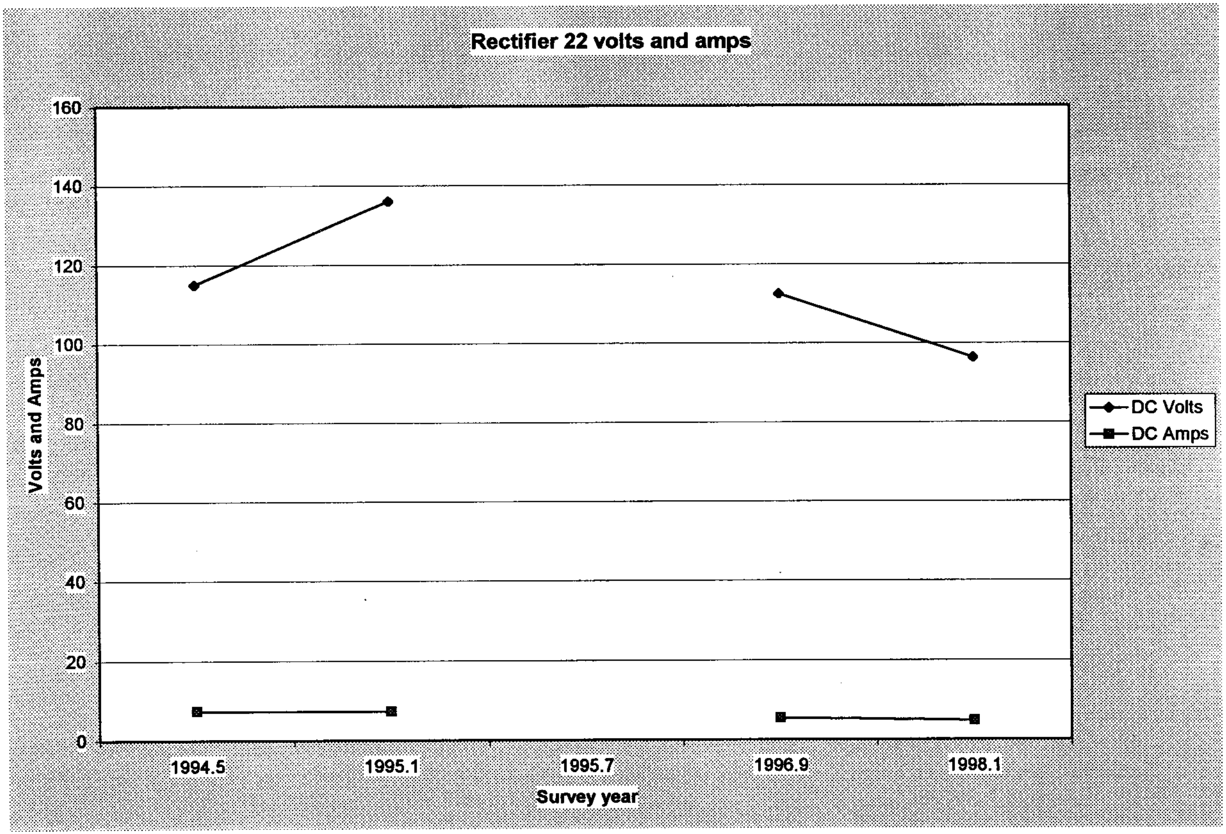

Test Station T(18-12), Portable Reference Electrode Measurement, Rectifier 22 Amperage,
Unprotected Pipe 8" CI SW
Voltages, total (IR inclusive) and polarization
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts

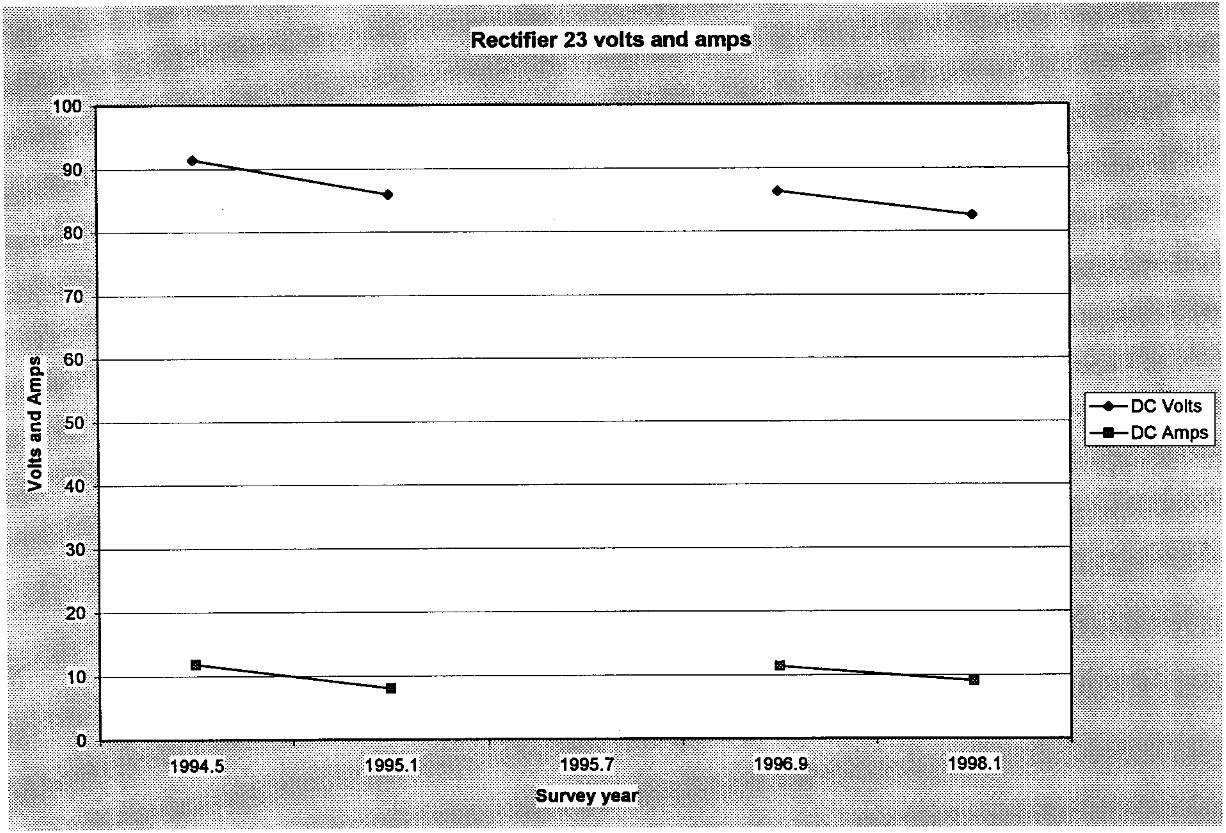

Test Station T(18-4), Portable Reference Electrode Measurement, Rectifier 22 Amperage,
Protected Pipes 202, 203
Voltages, total (IR inclusive) and polarization
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts


Test Station T(18-3), Portable Reference Electrode Measurement, Rectifier 22 Amperage, Protected Pipes 202, 203
Voltages, total (IR inclusive) and polarization
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts


Test Station T(18-2), Portable Reference Electrode Measurement, Rectifier 22 Amperage, Protected Pipes 202, 203
Voltages, total (IR inclusive) and polarization
1.2
1
0.8
0.6
0.4
0.2
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
Polarization, OFF values
Total, ON values
NACE polarization standard, 0.85 volts


Rectifier 45 volts and amps
Volts and Amps
40
35
30
25
20
15
10
5
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
DC Volts
DC Amps


Rectifier 22 volts and amps
160
140
120
100
80
60
40
20
0
Volts and Amps
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
DC Volts
DC Amps


Rectifier 23 volts and amps
Volts and Amps
100
90
80
70
60
50
40
30
20
10
0
1994.5
1995.1
1995.7
1996.9
1998.1
Survey year
DC Volts
DC Amps