CATHODIC PROTECTION
SURVEY REPORT
MCAS(H) - NEW RIVER, N.C.

MENENDEZ-DONNELL & ASSOCIATES, INC.
11999 Katy Freeway #355
HOUSTON, TEXAS 77079

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INTRODUCTION

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA

CONTRACT N62470-83-C-6148

CATHODIC PROTECTION SURVEY

at the

MARINE CORPS AIR STATION (HELICOPTER)
NEW RIVER, NORTH CAROLINA

FINAL SUBMITTAL
December 14, 1984

prepared by

MENENDEZ-DONNELL & ASSOCIATES, INC.
Houston, Texas

in association with

GENERAL CATHODIC PROTECTION SERVICES, INC.
Houston, Texas

STATE OF TEXAS
CARLOS R. MENENDEZ
38755
REGISTERED PROFESSIONAL ENGINEER

Submitted by ______________________
Carlos R. Menendez, PE

REGISTERED PROFESSIONAL ENGINEER
RALPH W. STEPHENS
NO. CR723
CORROSION
STATE OF CALIFORNIA

Submitted by ______________________
Ralph W. Stephens, PE

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SUMMARY

MENENDEZ-DONNELL & ASSOCIATES, INC., in association with its consultant, GENERAL CATHODIC PROTECTION SERVICES, INC., conducted a corrosion control survey of underground POL systems, water distribution system, elevated water tanks, and underground fuel tanks at the U.S. Marine Corps Air Station (Helicopter), New River, North Carolina, during October and November, 1984.

The corrosion survey included inspection and evaluation of any existing Cathodic Protection Systems, inspection and testing of underground steel structures, and recommendations for cathodic protection systems for proposed new construction.

Neither one of the two existing rectifier-groundbed installations on the POL Systems is in operation, and none of the POL facilities has cathodic protection.

The underground water distribution system has no cathodic protection, and it would be the most difficult and expensive of all base piping systems to protect since it consists primarily of bare or poorly coated cast iron pipe and it is not electrically continuous.

The two elevated water tanks were found to be under complete cathodic protection and with the internal coating in very good condition.

The soil resistivity tests showed a wide variation ranging from 2200 ohm-cm to 76,000 ohm-cm, however the low resistivity corrosive soils below 5,000 ohm-cm constitute only about 10% of the totals. Laboratory tests of soil samples showed the pH to be essentially neutral, but with a relatively high concentration of sulfates in some areas.

The two existing POL system rectifiers are not in use at the present time.

A new impressed current cathodic protection system should be provided for the tanks and existing steel piping at the Fuel Farm.

New sacrificial cathodic protection systems should be provided for the 20,000 gallon MOGAS Storage Tank at Building No. 142, and at Tanks A and B at the airfield.

Cathodic protection with sacrificial galvanic anodes is recommend for the underground water piping system in soils with resistivities of 5000 ohm-cm or less.

Cost estimates for the recommended work are:

1. Install 3 new rectifiers and groundbeds on tanks and piping at the Fuel Farm

$76,670.00

2. Install magnesium anodes on three underground Fuel Storage Tanks $14,847.00

1.0 INTRODUCTION AND PURPOSE

This report contains all data acquired and conclusions reached as a result of the corrosion survey of underground POL system, utility systems, water distribution systems, elevated water tanks and underground fuel storage tanks at MCAS(H), New River, North Carolina.

Field work was started on October 1, 1984, and was completed by November 14, 1984. It consisted of collecting data and studying all existing cathodic protection systems, obtaining soil resistivity measurements, obtaining soil and water samples at selective locations, conducting continuity tests, obtaining structure-to-electrolyte potential measurements, and performing current requirement tests on line sections and selected underground storage tanks.

There are two existing abandoned impressed current cathodic protection systems on the POL facilities and two operational systems on the elevated water tanks. The two abandoned systems were installed to protect the original 5-inch diameter fuel line which has recently been replaced with a new fiberglass pipeline.

No cathodic protection exists for the following facilities:

1. The underground water distribution system.
2. Tanks and Piping at the Fuel Farm.

3. Day Tanks A & B (Jet Fuel).

4. MOGAS tank at Building No. 142.

5. Isolated underground fuel storage tanks.

All data obtained during this survey is included in the tables of Appendix B. Results and analysis of the data are included in Sections 2.1.4 and 2.2.3. The test procedures used during this survey are described in Section 2.1.3 and 2.2.2 of this report. The layouts of recommended cathodic protection systems and test points used during this survey are shown on Drawings enclosed in Appendix H of this report.

Photographs were taken of underground piping systems, rectifiers and various miscellaneous structures. These may be found in Appendix G.

The purposes of this survey were to evaluate the effectiveness of the existing cathodic protection systems; to determine any additional corrosion control requirements and to establish the most feasible type of additional cathodic protection systems, where required. In addition, supportive information, such as drawings, photographs, cost estimates and specific recommendations are supplied.

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SURVEY

2.0 CORROSION CONTROL SURVEY

2.1 POL System

2.1.1 System Description

The POL system consists of fifteen tank car and truck unloading stations located West of the Fuel Farm, a truck loading station, thirteen storage tanks, refueling facilities and the connecting underground piping.

JP-5 Fuel is received at ten tank car stations and piped through a 6-inch pipeline to four underground storage tanks located at the Fuel Farm. One storage tank has a capacity of 120,000 gallons, a second tank has a capacity of 105,000 gallons, and each of the remaining two tanks has a capacity of 50,000 gallons.

AVGAS Fuel is received at five tank truck stations and stored in one 100,000 gallon underground steel tank, in one 50,000 gallon underground steel tank, and in two 10,000 gallon day tanks. All AVGAS storage tanks are located at the Fuel Farm.

MOGAS Fuel is stored in a 20,000 gallon underground tank located at Building No. 142.

JP-5 Fuel is transported in a 5-inch diameter underground pipeline to day tanks located near the airfield. All other fuels are transported by tank trucks.

2.1.2 Description and Evaluation of Existing Cathodic Protection Systems

Two existing impressed current cathodic protection systems, installed for cathodic protection of the underground POL piping at the station, were found to be out of service.

Rectifier No. 1, located at the Fuel Farm, is an air cooled unit manufactured by RIO Engineering Company, with a rated DC output of 36 volts and 20 amps. Information on the associated groundbed was not available. Field testing of this groundbed indicated that it has been depleted.

Rectifier No. 2, located at Building No. 4102 near the airfield, is an air cooled unit manufactured by GOODALL Electric Company, with a rated DC output of 40 volt and 20 amperes.

Rectifier No. 1 was tested with a temporary groundbed and seemed to be in good condition. Rectifier No. 2 was locked inside Building No. 4102 and unaccessible for inspection. It was originally installed to protect the 5-inch fuel pipeline between the Fuel Farm and the flight line, which has recently been replaced with a fiberglass pipeline. Therefore, this rectifier, if found to be in good working order, could be available for reuse at the Fuel Farm.

2.1.3 Test Procedures

Test procedures on the POL Systems included inspection of rectifiers; taking soil resistivity and structure to electrolyte potential measurements; conducting current requirement tests to determine design criteria for unprotected structures; and collecting soil and water samples for laboratory analysis.

2.1.3.1 Soil Resistivity Survey

Soil resistivity measurements were acquired at approximately 1000 ft. intervals along underground piping systems throughout the base to five feet average depths, using a Nilsson Model 400 soil resistivity meter and the "Wenner" four pin method. Measurements were also acquired to 10 ft., 15 ft., and 20 ft. depths near and around all

underground tanks within the POL system. The location of individual resistivity measurements are shown in Drawings No. 4001 through 4004, of Appendix H, and the soil resistivity data are presented in Table I, Appendix B.

2.1.3.2 Structure-to-Electrolyte Potential Survey

Structure-to-electrolyte potential measurements were taken on the POL system facilities, using a high impedance digital Beckman Model 3010 volt-ohm meter with reference to a saturated copper-copper sulfate half cell.

Potential measurements were taken at representative location including piping at pumphouses, and around storage tanks. For each measurement the reference electrode was placed directly over or as near as possible to the structure subject to test. All acquired potential measurement data are presented in Table III Appendix B. Test point locations are shown in drawing No. 4005.

2.1.3.3 Current Requirement Tests

Current requirement tests were conducted on various underground tanks to aid in determining the design criteria for POL structures not cathodically protected.

This procedure consisted of applying direct current to the structure under test using a 12-volt automobile battery as a temporary power source and 5/8-inch diameter by 5 ft. long steel rods driven into the ground for anodes. Whenever it was necessary, abandoned lines and metal post fences were used as temporary groundbeds to satisfy the high current demand.

Structure-to-electrolyte potential measurements were taken both before and during the application of the test current. The current output was determined by measuring the voltage drop across a calibrated 100mV-100A shunt. The current requirement was determined by the magnitude of potential shift between the native potential and the measured potential with current applied.

Generally accepted criteria for cathodic protection (NACE and DOT) used for this project, is a structure to electrolyte potential of minus 0.85 volts referred to a copper-copper sulfate half cell at all test points on the structure under test, or to achieve a minimum 300 millivolt negative potential shift with temporary current applied. Current requirements test data are shown in Tables III and IV, Appendix B.

2.1.3.4 Soil and Water Analysis

Soil samples were gathered from three distributed locations along the POL and water distribution systems. These samples were taken at depths from 18-inches to approximately 3 ft. A potable water sample was taken at the elevated water storage tank S-TC-606, located in Camp Geiger, which is connected to the water distribution system at the New River Air Station. Riverwater samples were gathered at the shoreline.

The soil samples were sealed in sterile Zip Lock plastic bags and the water samples were stored in sterile glass jars. They were submitted to SGS Control Services, Inc., Houston, Texas, for chemical analysis. Specific tests were for:

1. Electrical conductance
2. pH
3. Chlorides
4. Sulfates
5. Sodium
6. Phosphate
7. Carbonate

The locations from which the samples were acquired are shown on Drawings No. 4001, 4003 and 4004, and the chemical analysis data is presented in Appendix C.

2.1.3.5 Rectifier and Groundbed Investigation

The two rectifiers were visually inspected. Direct current and voltage outputs were measured with accurate portable test meters.

Rectifier No. 1 is located at the Fuel Farm and no information was available concerning its associated groundbed which appears to be depleted.

Rectifier No. 2 and its associated groundbed were installed to protect the original 5-inch underground steel pipeline between the Fuel Farm and the airfield. This pipeline has recently been replaced with a fiberglass pipeline.

All acquired test data are presented in Table VII, Appendix B, and in the discussion in Section 2.1.4.5.

2.1.4 Results and Analysis

2.1.4.1 Soil Resistivity Measurements

Soil resistivity is the reciprocal of soil conductance, and is usually expressed in ohm-cm. It is the most commonly used criterion for estimating the corrosivity of a given soil.

Soil resistivity is one of the primary factors affecting the flow of electrical currents associated with corrosion. A scale often used by corrosion engineers to classify the corrosivity of soil is as follows:

Soil Resistivity	Classification
Below 1000 ohm-cm	Extremely corrosive
1000 to 5000 ohm-cm	Very corrosive
5000 to 10,000 ohm-cm	Mildly corrosive
Above 10,000 ohm-cm	Progressively less corrosive

As shown on the data sheets in Table I, Appendix B, soil resistivity measurements near the POL facilities are generally above 5,000 ohm-cm, except in the area of Day Tanks A & B.

Serious corrosion can occur in higher resistivity soils where large variations in soil resistivity exist. These diverse resistivities indicate the existance of varying soil compositions, and such variations are conducive to concentration cell corrosion activity on the underground pipeline as it extends through the boundaries of the dissimilar soils. Corrosion is often encountered at such boundaries in the lower resistivity soils.

2.1.4.2 Structure to Electrolyte Potential Measurements

The level of cathodic protection of a given structure is evaluated by structure-to-electrolyte potential measurements. The most generally accepted criteria for cathodic protection of steel and cast iron structures buried or submerged in an electrolyte is a structure to electrolyte potential measurement of at least 0.85 volt negative to a saturated copper-copper sulfate half-cell, with DC current applied.

This is also one of the criteria established by NACE in its Recommended Practice R.P 01-69 (1983 REV); and it is one of the criteria specified by the U.S. Department of Transportation Office of Pipeline Safety Regulations for natural gas and hazardous liquid pipelines.

Analysis of the POL system structure-to-soil potential data in Table III, Appendix B, shows that none of the POL underground steel structures meet or exceed this criterion for cathodic protection.

A summary of structures not currently under the influence of cathodic protection is as follows:

1. Underground tanks and associated piping at the Fuel Farm.
2. Underground steel Day Tanks A and B.
3. Underground fuel tank at Building No. 142.
4. Miscellaneous underground tanks throughout the station.

2.1.4.3 Current Requirement Tests

Current requirement test data are presented in Tables III and IV, Appendix B. Impressed current testing of underground fuel storage tanks and associated piping at the Fuel Farm indicate that a minimum of 78 amperes, or a current density of approximately 0.0031 ampere per square foot of exterior tank wall, will be required for adequate protection.

This current requirement is somewhat higher than normal, however since it is a result of actual field test, it should be considered correct. Contributing factors to the high current requirement may be sulfate reducing bacteria, as indicated by the high (973 ppm) sulfate content of the soil or by electrical contacts with other structures, abandoned underground steel piping. See Sample S-6, Appendix C.

Another impressed current requirement test was conducted on the MOGAS Tank No. 143 located at the gas station Building No. 142. A current drain of 0.30 amperes, or a current density of 0.000222 amperes per square foot, was required to provide cathodic protection.

Calculations of tank surface areas and current densities can be found in Appendix D of the report. These calculations are based on tank dimensions and sizes provided us by station personnel. These current density values were used in the design calculations to estimate current requirements for other underground steel tanks of similar type and environment.

2.1.4.4 Soil and Water Analysis

Generally speaking, the three soil sample analyses appear

to be normal for this area except for relatively high concentrations of sulfates for Samples S-6 and S-8. These levels can be indicative of the presence of sulfate reducing bacteria which would result in higher current requirement for protecting underground steel structures.

The pH values of the soil samples range from a low of 5.8 for Sample S-7, up to a high of 6.9 for Sample S-8 which is essentially neutral. A pH of 5.8 is moderately acidic but presents no major problems for steel pipe or tanks.

Water sample W-5 taken from the New River shoreline has a high chloride content and a calculated resistivity of 65 ohm-cm. This is typical of brackish river water near the seacoast.

This water is very corrosive to any steel bulkheads that may be present. Impressed current cathodic protection would be effective in stopping much of this corrosion.

2.1.4.5 Rectifier and Groundbed Investigation

Inspection of Rectifier No. 1 at the Fuel Farm revealed that the rectifier is still in good working order. Testing revealed that the groundbed associated with this rectifier is already depleted. The rectifier was used as a supplemental DC current source during the impressed current

requirement testing of the Fuel Farm.

Access to Rectifier No. 2 was not possible because it was locked inside Building No. 4102. This rectifier is fairly new, installed in 1982, and should be found in good condition.

All rectifier test data are presented in Table VII, Appendix B.

2.2 Water Distribution System

2.2.1 System Description

The water distribution system consists of the treatment and filtration of raw water for domestic and industrial use and fire protection. Water wells scattered throughout the base constitute the primary source of raw water.

Raw water is piped to the water reservoir located at the filtration plant. The water is treated and filtered before being discharged to two elevated water tanks. The water is then piped from the individual storage facilities to station facilities.

2.2.2 Test Procedures

Test procedures on the water distribution system included soil resistivity measurements, pipe-to-soil potential measurements, electrical continuity tests, internal investigation of elevated water tanks, rectifier and anode inspection and electrolyte chemical analysis.

2.2.2.1 Soil Resistivity Survey

Soil resistivity measurements were obtained at approximately 1000 foot intervals along the right-of-way to 5 foot average depths. A Nilsson Model 400 soil resistivity meter and the Wenner four-pin method were utilized to obtain the measurements. This procedure involved driving four steel pins into the earth in a straight line, equally spaced, with the pin spacing equal to the depth to which the average soil resistivity was desired. The average soil resistivity measurement is a function of the voltage drop between the center pair of pins with current flowing between the two outside pins. Soil resistivity measurements obtained in the vicinity of the water distribution system are listed in Table I, of Appendix B.

All test locations are shown on drawings No. 4001 to 4004, Appendix H.

2.2.2.2 Structure-to-Soil Potential Survey

Structure-to-soil potential measurements were obtained on the firewater hydrants at representative locations throughout the station including the residential areas.

All potential measurements were obtained using a high input impedence voltmeter Beckman Model 3010 in conjunction with a copper-copper sulfate reference electrode placed directly over or as near as possible to the structure subject to test.

Potential measurements obtained on the water distribution system are listed in Table II of Appendix B.

All test point locations and their respective reference numbers are shown on Drawings No. 4001 to 4004, in Appendix H of this report.

2.2.2.3 Continuity Tests

Continuity tests were conducted at various locations throughout the station. A temporary groundbed consisting

of four 5 ft. long ground rods and an automobile battery were utilized. The test was performed by measuring pipe-to-soil potentials at one test point, then moving the negative connection to the next test point location with the reference electrode kept stationary. Electrical continuity between test points is indicated when both potential measurements are of the same magnitude. Electrical discontinuity between test points is indicated when potential measurements are of different magnitude.

Continuity test results are shown in Table V, Appendix B, and on Drawings No. 4001 thru 4004.

2.2.2.4 Elevated Water Storage Tank Inspection

Visual inspection of anode array, handhole inspection plates, conduits, wiring, rectifier unit and coating integrity was performed at two elevated water tanks. All observations were recorded in the field. Please refer to section 2.2.3 for Results and Analysis of this report.

2.2.2.5 Elevated Water Storage Tanks Potential Profile Survey

A potential profile of the submerged portion of each tank was conducted utilizing a standard copper-copper sulfate

reference electrode in conjunction with a high impedance Beckman voltmeter (Model 3010). The reference electrode was lowered to the bottom of each tank, and tank to water potentials were measured and recorded at 3 ft. intervals to the top. Data acquired are presented in Table VI, Appendix B of this report.

2.2.2.6 Tank Rectifiers and Anode Strings Investigations

Each rectifier was visually inspected and adjusted to provide optimum output in accordance with potential measurements taken inside the tank.

All rectifier meters were checked and calibrated as needed, using accurate portable test meters. All meters were left operating properly with no further repairs needed. Voltage measurements were taken directly off the DC stacks. Direct current outputs were determined by connecting the Beckman Voltmeter across the calibrated shunts. The meters were then adjusted to reflect the findings as accurately as possible.

Individual anode strings were inspected at each tank. Anode string current drains were measured and recorded using an SWAIN Model CP-3/4 inductive clip meter.

This data is presented in Table VI, Appendix B.

2.2.2.7 Water and Soil Analysis

A water sample was taken from one of the elevated water tanks at Camp Geiger, which are connected to the water system at the New River Air Station. This sample was placed in a sterile glass jar and submitted to SGS Control Services, Inc., Houston, Texas for analysis. Results are discussed in Section 2.2.3.5. Procedures for soil analysis are discussed in Section 2.1.3.4. Results of the analysis are presented in Appendix C.

2.2.3 Results and Analysis

2.2.3.1 Soil Resistivity Measurements

Soil resistivity is the reciprocal of soil conductance, and is usually expressed in ohm-cm. It is the most commonly used criterion for estimating the corrosivity of a given soil. The resistivity of a given soil is one of the primary factors affecting the flow of electrical currents associated with corrosion. A scale often used by corrosion engineers to classify the corrosivity of soil is as follows:

Soil Resistivity	Classification
Below 1000 ohm-cm	Extremely corrosive
1000 to 5000 ohm-cm	Very corrosive
5000 to 10,000 ohm-cm	Mildly corrosive
Above 10,000 ohm-cm	Progressively less corrosive

As shown on the data sheets in Table I, Appendix B, soil resistivity measurements are generally above 10,000 ohm-cm, with only 10% below 5,000 ohm-cm and 21% between 5,000 and 10,000 ohm-cm.

Serious corrosion can occur in higher resistivity soils where large variations in soil resistivity exist. These diverse resistivities indicate the existance of varying soil compositions, and such variations are conducive to concentration cell corrosion activity on the underground pipeline as it extends through the boundaries of the dissimilar soils. Corrosion is often encountered at such boundaries in the lower resistivity soils.

2.2.3.2 Structure to Soil Potential Measurements

The discussion of cathodic protection criteria presented in Section 2.1.4.2 is also applicable to the water distribution system.

Potential measurements obtained throughout the station's water lines were well below the negative 0.85 volt criteria, showing a lack of cathodic protection.

Structure to soil potentials taken along a bare underground pipeline undergoing active corrosion can range from a low of -0.1 to -0.3 volts in the most cathodic areas to a high approaching -0.8 volts in the most anodic areas.

Generally speaking, older pipelines that have developed a uniform rust film will have lower average potentials than newer lines that have not developed as much rust film and consequently have more bare steel in contact with the electrolyte. Potentials measured along the water system ranged from a low of -0.214 volts to a high of -0.566 volts indicating the probability of corrosion activity in some areas.

2.2.3.3 Continuity Tests

The data acquired from continuity tests at two locations (Table V, Appendix B) shows a lack of electrical continuity between joints on these sections of the water distribution system.

This is typical of mechanically coupled piping, and each joint must be electrically bonded before the system can be cathodically protected with an impressed current system. Sacrificial anodes could be installed on each joint without bonding.

2.2.3.4 Elevated Water Tanks

Normally a standard inspection of a cathodic protection system installed in a water tank encompasses an electrical potential profile on three foot intervals, a visual inspection of the anodes and associated hardware, and a calibration of the rectifier to provide optimum levels of protection to the interior submerged portions of the tank. In some cases where provisions have been made by providing access covers at designated cardinal points, additional electrical potential profiles are taken to correlate readings in order to assure proper current distribution.

Visual inspection of the coating is usually noted as an aid in the over-all analysis of the performance of the corrosion mitigation measures. Assuming anode array integrity, the quality of the coating will be the single greatest factor determining current distribution to the tank surfaces.

Analysis of current drain data from individual anode strings is helpful in verifying a functional anode array and to some extent, coating integrity. Since the anodes are wired in a series-parallel configuration with the same number and size of anodes in each string of a specific "ring", current drains should be essentially uniform if all anodes are intact and coating quality is uniform.

The findings of this report as they relate to the total current requirement to obtain effective protective levels of cathodic protection correlate coating integrity better than any other measurement used. Since in almost all cases we found that very little current was required to achieve adequate protective levels on the tank interiors, one can be reasonably assured that very little metal is exposed and the coatings are in fairly good condition.

Data acquired on elevated water tanks are presented in Table VI, Appendix B. Results and analysis on each tank are discussed in the following paragraphs.

Tank No. 4130

This rectifier (unit 9339) rated at 60 volts and 28 amperes was found operating on transformer tap setting A-2. The potential profile indicated adequate levels of protection, and anode current drains confirmed anode array integrity. The interior coating looked good, however, the manway was detached from its hinges and should be repaired. The anodes looked good and should last at least five more years. All associated hardware also looked in good condition.

Tank No. 310

This rectifier (unit 81C1216) rated at 40 volts and 12 amperes was found to be operating on tap setting A-2 providing 1.41 amps to the bowl and 0.29 amps to the riser at 3.5 volts. The potential profile indicated adequate levels of protection and anode current drains confirmed anode array integrity. The anodes appeared to be about 50% depleted and should not be expected to last more than three more years. The access handhole covers have missing bolts and bars in their square cover assemblies. The interior coating appeared to be in good condition.

2.2.3.5 Water Samples Analysis

The analysis of the treated water sample W-12 may be found in Appendix C, with the analysis of all other samples tested.

The calculated resistivity of this sample is 1355 ohm-cm which is considered low. This sample has a moderate chloride and low sulfate content; a slightly basic (alkaline) pH of 8.6; and should be considered corrosive.

Based on this analysis, cathodic protection for the internal surfaces of the water storage tanks is needed to mitigate corrosion.

2.3 Evaluation of Activity Corrosion Control Program

2.3.1 Operating and Maintenance Practices

As part of the corrosion study, station corrosion control maintenance practices were investigated. Information gathered from station personnel indicated that limited maintenance of the cathodic protection systems had been conducted.

Personnel involved with the fuel system were aware of the use of cathodic protection on the POL facilities, however, their knowledge of monitoring and field testing was limited.

A monthly inspection of the elevated water tank rectifiers is being performed by the Maintenance Department. It consists of a visual inspection, and reading and recording the DC output levels of each rectifier.

We believe that the present station personnel are very capable of incorporating a successful corrosion control maintenance program with the aid of corrosion control short courses, in-field supervised training and proper cathodic protection testing equipment.

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RECOMMENDATIONS

3.0 RECOMMENDATIONS

3.1 POL System

Based on the results of this survey, we recommend the following:

1. Utilize the existing 36 volt, 20 ampere rectifier located at the Fuel Farm in conjunction with a new distributed groundbed consisting of at least twenty 3-inch diameter by 60 inches long, specially treated, graphite anodes, or equal.

2. Relocate Rectifier No. 2, rated at 40 volt, 20 ampere to the Fuel Farm and install it in conjunction with a new distributed groundbed containing a minimum of twenty 3-inch diameter by 60 inches long specially treated graphite anodes, or equal.

3. Install an 80 volt, 50 ampere rectifier and a new distributed groundbed consisting of a minimum of forty 3-inch by 60 inches specially treated graphite anodes, to supplement above mentioned groundbeds, for cathodic protection of the Fuel Farm.

4. Because of the existing high soil resistivities, it is recommended that all new anodes be installed in 12-inch diameter by 15-foot deep augered holes containing at least ten feet of low resistivity calcined fluid petroleum coke.

5. Install nine GALVOMAG Type 20D2 prepackaged magnesium anodes and one Flush Fink test station for cathodic protection of the MOGAS tank at Building No. 142

6. Install eight GALVOMAG Type 32D3 prepackaged magnesium anodes and two Flush Fink test stations for cathodic protection of Tanks A & B at the airfield.

3.2 Water Distribution System

Recommendations for the water distribution system are as follows:

1. Inspect elevated water tanks and rectifiers on a monthly basis in order to insure uninterrupted protection. Maintain current outputs as listed on Table VI, Appendix B unless a change in current requirements is indicated by subsequent cathodic protection surveys.

2. Install sacrificial high potential magnesium anodes on individual underground pipe joints in all areas where soil resistivities are below 5000 ohm-cm as described in Appendix D.

   As an alternate, all pipe joints falling within, and adjacent to areas with soils below 5000 ohm-cm could be electrically bonded and cathodically protected with impressed current systems. However, both initial costs and maintenance costs will exceed the cost of sacrificial anode systems and chances of stray current corrosion will be greatly increased.

3. In areas where cathodic protection is to be considered, electrically bond all cast iron pipe joints exposed by maintenance or construction activities. Bonds should be minimum No. 8 AWG copper wire or equivalent copper straps. Electrical continuity of underground piping cathodically protected with sacrificial anodes is desirable since it equalizes structure-to-soil potentials and permits monitoring the effectiveness of the system without the need to contact each pipe joint.

4. Install two-wire potential test stations at preselected locations to monitor the level of cathodic protection and anode outputs.

3.3 Activity Corrosion Control Program

3.3.1 Recommendations for Maintenance Practices

The following recommendations are aimed towards aiding base personnel in developing a total corrosion control preventive maintenance program.

It is recommended that the responsibility for monitoring and maintaining of cathodic protection systems, once they are installed, be assigned to competent permanent personnel with either experience in cathodic protection or with technical backgrounds to facilitate their training as described in Section 3.3.2.

The present policy of monthly rectifier inspections should be continued. These inspections should include as a minimum, reading and recording the D.C. output levels as indicated by the panel meters, and a visual inspection of all major rectifier components. Output levels should be promptly compared with those recorded from previous inspections and any significant changes investigated. In

addition, other system components should be observed and repairs effected whenever needed.

It is further recommended that a comprehensive system-wide corrosion control survey be conducted on an annual basis by an experienced corrosion engineer. The corrosion engineer accomplishing this survey should be accompanied by the station personnel responsible for corrosion control monitoring since this would constitute valuable field experience.

Drawings provided in this report showing the location of structure-to-electrolyte potential measurements should be used as a guide in the annual survey.

It is recommended that all data pertaining to the corrosion control program be recorded for future reference. The corrosion control records program should include investigating and recording all leaks that occur. Bell hole inspections should be made and a leak report form completed, detailing the type of leak, repairs made, and their locations.

For further details in establishing a corrosion control program and for additional information on maintenance programs, refer to NAVFAC INST 11014.51 of 19 October

1983 and MO-307 of May 1981; "Cathodic Protection Systems Maintenance".

Additional assistance in establishing a corrosion control program may be obtained from the Atlantic Division, Naval Facilities Engineering Command corrosion engineer.

3.3.2 Recommendations For Training Program

The routine monitoring of cathodic protection systems is essential to maintaining adequate protection against corrosion attack in soil and water electrolytes. It is recommended that a training program involving station personnel be instituted. This program would involve the training of personnel, in both theory of cathodic protection and field training.

The following corrosion control courses are recommended for base personnel.

National Association of Corrosion Engineers (NACE) Courses:

a. "Basic Corrosion Course".
b. "Corrosion Prevention by Cathodic Protection".
c. "Corrosion Prevention by Coatings".

We recommend these courses for learning the basic theory of corrosion and methods and practices used in cathodic protection. These courses can be taken by "Home Study" with personnel working at their own pace. The courses are designed for people with no prior knowledge of cathodic protection. Further information can be obtained by writing to NACE Education Department, P. O. Box 218340, Houston, Texas 77218; or by telephoning (713) 492-0535.

Another excellent training course is the "Cathodic Protection Rectifier School" offered by Good-All Electric, Inc.

This short three-day course is designed to familiarize students with cathodic protection rectifiers. Basic theory is discussed as well as field troubleshooting. Additional information can be obtained by writing to Good-All Electric, Inc., Box 508, Ogallala, Nebraska 69153, or by calling (308) 284-4081.

A number of corrosion control short courses are offered every year by several universities and sections of NACE throughout the United States.

One of the better ones is held each May in Morgantown, West Virginia; and another excellent course is offered

each September at the University of Oklahoma, Norman, Oklahoma. These three-day seminars are taught by professional instructors and include practical field demonstrations. Details of these courses can be obtained by contacting the University of West Virginia or the University of Oklahoma, respectively.

It is also recommended that an experienced corrosion engineer accredited by NACE as corrosion specialist conduct an on-site training seminar with station personnel. By this seminar, station personnel can obtain practical training on the testing procedures used for conducting routine maintenance of cathodic protection systems. This training would include taking structure-to-electrolyte potentials, soil resistivity measurements and the basics of rectifier inspection techniques.

Additional details on training courses offered by the Atlantic Division, Naval Facilities Engineering Command, the Naval Civil Engineering Laboratory, the U.S. Air Force Institute of Technology and commercial firms may be obtained by contacting the Atlantic Division, Naval Facilities Engineering Command corrosion engineer.

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Estimates

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ESTIMATES

4.0 ECONOMIC EVALUATIONS

4.1 Fuel Farm

1. Based on detailed Cost Estimates shown on Appendix E the initial cathodic protection investment = $59,390.

2. Investment = Initial Cost x Capital Recovery Factor thus on the basis of 12 % for 20 years, the annual cost to own becomes:

   $59,390 x 0.1175 = $6,978.

   Maximum Power Cost:

   $$\text{AC Watts} = \frac{\text{DC Watts}}{\text{conversion efficiency}}$$

   Recommended Rectifiers (80 V-50A), (36V-20A), (40V-20A)

   $$\text{AC KW} = \frac{(80\times50)+(36\times20)+(40\times20)}{.68} \times \frac{1\text{KW}}{1000\text{W}} = 11.47\text{KW}$$

   Annual Power Bill:

   $$11.47\text{ KW} \times \frac{8760\text{ hr}}{\text{yr}} \times \frac{0.06}{\text{KW-h}} = \$\,6{,}029.00$$

   Estimated Annual Cost=6,029 + 6978 = $13,007.

3. Repairs and replacements on the POL system have been made in the past, but exact cost were not available.

4. The investment involved in the tanks and associated equipment, along with their importance to operations, justify the recommended cathodic protection system.

5. DOT Standards require all underground fuel gas storage and piping to be provided with cathodic protection.

4.2 Underground Fuel Storage Tanks

1. Based on detailed Cost Estimates shown on Appendix E, the initial Cathodic Protection Investment = $14,847

2. Investment = Initial Cost x Capital Recovery Factor. Thus on ths basis of 12% for 20 years, the annual cost to own becomes:

   $14,847 x .1175 = $1,759.

3. Leaks have been reported, repairs and replacements on several storage tanks have been made. Day Tanks A and B were replaced once. Day Tanks C and D were replaced with 2 new fiberglass units. The 5"

pipeline between the Fuel Farm and above tanks is being replaced with a new fiberglass pipeline.

4. Replacement and maintenance cost have been high enough to justify cathodic protection of the tanks.

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APPENDIX A

INVENTORY

APPENDIX A

NEW RIVER, NORTH CAROLINA

POL SYSTEM INVENTORY OF PRODUCT STORAGE FACILITIES

Product	Tank No.	Capacity	Type
JP-5	137	50,000 gal	Underground steel
JP-5	150	105,000 gal	Underground steel
JP-5	151	50,000 gal	Underground steel
JP-5	154	120,000 gal	Underground steel
JP-5	Day Tank A	20,000 gal	Underground steel
JP-5	Day Tank B	20,000 gal	Underground steel
JP-5	Day Tank C	20,000 gal	Underground fiberglass
JP-5	Day Tank D	20,000 gal	Underground fiberglass
Avgas	136	100,000 gal	Underground steel
Avgas	137	50,000 gal	Underground steel
Avgas	138	50,000 gal	Underground steel
Avgas	140	20,000 gal	Underground steel
Avgas	141	20,000 gal	Underground steel

POL PIPING OF INVENTORY

Product	Description	Type
Avgas	Piping at Fuel Farm	Underground steel
JP-5	Piping at Fuel Farm	Underground steel
JP-5	5" pipeline between fuel farm and airfield	Underground fiberglass

WATER DISTRIBUTION INVENTORY OF STORAGE FACILITIES

Description	Capacity	Type
Tank No. 4130	350,000 gal.	Elevated steel
Tank No. 310	350,000 gal.	Elevated steel

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APPENDIX B

DATA SHEETS

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE:

DATE 10/26/84 **ENGINEER** J.A.M. **TABLE** I **PAGE** 1 **OF** 7

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	* FACTOR	OHM-CM
1	FLOUNDER RD.	5'-3"	6.0	1.0	1000	6000
	↓	10'-6"	3.0	↓	2000	6000
		15'-9"	2.8		3000	8400
		21'-0"	1.2		4000	4800
2	FLOUNDER RD., AT BLDG. 710	5'-3"	5.4		1000	5400
3	AT BLDG. 705	↓	2.4		↓	2400
4	FLOUNDER RD.		6.8			6800
5	PARKING AT BLDG. 702		6.0	10.0		60,000
6	FLOUNDER RD.		2.5	↓		25,000
7	CURTISS RD.		3.5			35,000
	↓	10'-6"	7.3	1.0	2000	14,600
		15'-9"	4.2	↓	3000	12,600
		21'-0"	3.0		4000	12,000
8		5'-3"	4.3		1000	4300
9		↓	2.3	10.0	↓	23,000
10			1.6	10.0		16,000
		10'-6"	6.8	1.0	2000	13,600
		15'-9"	5.9	↓	3000	17,700
		21'-0"	3.4		4000	13,600
11	AT BLDG. 804	5'-3"	6.6		1000	6600

NOTES : Nilsson 400 meter & the 4Pin method were used to obtain soil resistivity measurements.

* The "K" factor is the Average depth or pin spacing in feet X a meter constant of .191.5

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE:

DATE 10/26/84 ENGINEER J.A.M. TABLE I PAGE 2 OF 7

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
12	LONGSTAFF ST.	5'-3"	1.7	10.0	1000	17,000
		10'-6"	2.4		2000	48,000
		15'-9"	3.9		3000	117,000
		21'-0"	5.7		4000	228,000
13		5'-3"	7.0	1.0	1000	7000
14			7.7			7700
15	AT BLDG. 849		2.2			2200
16	STAFF NCO CLUB BLDG.		1.1	10.0		11,000
17	LONGSTAFF ST.		6.4	1.0		6400
		10'-6"	4.9		2000	9800
		15'-9"	3.4		3000	10,200
		21'-0"	2.3		4000	9200
18	TROTTER ST.	5'-3"	1.2	10.0	1000	12,000
19	LONGSTAFF ST.		6.6			66,000
20			6.5			65,000
21			2.7			27,000
		10'-6"	1.5		2000	30,000
		15'-9"	1.1		3000	33,000
		21'-0"	5.5	1.0	4000	22,000
22		5'-3"	2.6	1.0	1000	2600
23	NORDELL ST.		2.3	10.0		23,000
24	KELLEY ST.		1.5	100.0		150,000
25	AT BLDG. 2800		4.7	10.0		47,000
26	SAND ST.		3.7	10.0		37,000

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N. C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE:

DATE 10/26/84 ENGINEER J.A.M. TABLE I PAGE 3 OF 7

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
26	SAND ST.	10'-6"	1.3	10.0	2000	26,000
	↓	15'-9"	1.0	10.0	3000	30,000
	↓	21'-0"	6.9	1.0	4000	27,600
27	AT BLDG. 2860	5'-3"	2.1	10.0	1000	21,000
28	PERIMETER ROAD	5'-3"	2.0	↓	1000	20,000
	↓	10'-6"	1.2	↓	2000	24,000
	↓	15'-9"	7.5	1.0	3000	22,500
	↓	21'-0"	7.5	1.0	4000	30,000
29	↓	5'-3"	3.5	10.0	1000	35,000
30	↓	↓	4.4	↓	↓	44,000
31	↓	↓	1.8	↓	↓	18,000
	↓	10'-6"	1.0	↓	2000	20,000
	↓	15'-9"	5.1	1.0	3000	15,300
	↓	21'-0"	3.8	1.0	4000	15,200
32	AT BLDG. 3502	5'-3"	1.5	10.0	1000	15,000
33	AT BLDG. 3504	↓	9.2	1.0	↓	9200
34	AT TANK 3500 & 3522	↓	4.7	10.0	↓	47,000
	↓	10'-6"	1.6	↓	2000	32,000
	↓	15'-9"	1.3	↓	3000	39,000
	↓	21'-0"	8.3	1.0	4000	33,200
35	CURTISS RD.	5'-3"	2.7	10.0	1000	27,000
36	↓	↓	5.0	↓	↓	50,000
37	↓	↓	2.5	↓	↓	25,000
38	↓	↓	3.5	↓	↓	35,000

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N. C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE:

DATE 10/26/84 **ENGINEER** J.A.M. **TABLE** I **PAGE** 4 **OF** 7

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
39	AT BLDG. 2002	5'-3"	9.9	1.0	1000	9900
40	AT BLDG. 840		7.8	1.0		7800
41	CURTISS RD.		1.4	10.0		14,000
42	GOODEN ST.		1.1			11,000
43	AT BLDG. 827		1.2			12,000
44	CURTISS RD		1.2			12,000
45	GRAVEL RD.		2.9			29,000
46			2.6			26,000
47			4.8			48,000
48			2.7			27,000
49			1.3			13,000
50			2.9			29,000
51			2.0			20,000
52			10.0			100,000
53	, AT BLDG. 3620		5.9			59,000
54	ASPHALT RD.		4.7			47,000
55			1.8			18,000
56			8.8			88,000
57			8.4	1.0		8400
58			1.8	10.0		18,000
59			4.8			48,000
60	PARKING AREA		2.1			21,000
61			5.7	1.0		5700
62			1.6	10.0		16,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE:

DATE 10/26/84 ENGINEER J.A.M. TABLE I PAGE 5 OF 7

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
63	PARKING AREA	5'-3"	1.0	10.0	1000	10,000
64	AT BLDG. 4122	↓	2.9	10.0	↓	29,000
65	AT BLDG. 4108		8.1	1.0		8100
66	↓		1.4	1.0		1400
67	WHITE ST.		3.6	10.0		36,000
68	AT BLDG. 4100		1.0	↓		10,000
69	AT BLDG. 4110		2.1			21,000
70	PARKING APRON		1.0	↓		10,000
71	WHITE ST.		5.1	1.0		5100
72	CAMPBELL, AT BLDG. 143		1.4	10.0		14,000
73	AT BLDG. 518		1.1	↓		11,000
74	AT BLDG. 130		2.4			24,000
75	WHITE ST.		1.2			12,000
76	AT BLDG. 414		1.1			11,000
77	CAMPBELL ST.		1.4	↓		14,000
78	PARKING APRON		5.6	1.0		5600
79	AT BLDG. 425		1.3	10.0		13,000
80	MC AVOY, AT BLDG. 230		6.6	↓		66,000
81	CURTISS RD.		2.8			28,000
82	AGAN ST.		3.6			36,000
83	↓		3.1			31,000
84	↓		1.7			17,000
85	SUMNER ST.		1.1	↓		11,000
86	MC AVOY ST.	↓	4.9	1.0	↓	4900

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE:

DATE 10/27/84 ENGINEER J.A.M. TABLE I PAGE 6 OF 7

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
87	Mc AVOY ST.	5'-3"	8.9	10.0	1000	89,000
88	↓	↓	4.8	↓	↓	48,000
89	↓		6.5			65,000
90	GRIER ST.		3.4			34,000
91	CRAWFORD ST.		2.0			20,000
92	COMPTON ST.		3.7			37,000
93	BAXTER ST.		1.7			17,000
94	↓		2.3	↓		23,000
95	↓		2.7	1.0		2700
96	JONES ST.		2.6	1.0		2600
97	HARDIN ST.		1.4	10.0		14,000
98	AT TANK A & B	↓	8.6	1.0	↓	8600
	↓	10'-6"	4.9	0.1	2000	980
	↓	15'-9"	5.0	0.1	3000	1500
99	AT TANK C & D	5'-3"	3.6	10.0	1000	36,000
	↓	10'-6"	4.9	1.0	2000	9800
	↓	15'-9"	4.9	1.0	3000	14,700
100	CURTISS RD. & WHITE ST.	5'-3"	2.1	10.0	1000	21,000
	↓	10'-6"	1.1	10.0	2000	22,000
	↓	15'-9"	7.0	1.0	3000	21,000
101	WHITE RD.	5'-3"	1.1	10.0	1000	11,000
102	↓	↓	6.1	1.0	↓	6100
103	↓		1.7	10.0		17,000
104	AT BLDG. 124	↓	1.7	10.0	↓	17,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE:

DATE 10/27/84 ENGINEER J.A.M. TABLE I PAGE 7 OF 7

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
105	AT BLDG. 209	5'-3"	1.2	10.0	1000	12,000
106	AT BLDG. 205	↓	1.1	↓	↓	11,000
107	AT BLDG. 240	↓	1.0	↓	↓	10,000
108	AT BLDG. 236	↓	1.7	↓	↓	17,000
	↓	10'-6"	4.9	1.0	2000	9800
	↓	15'-9"	4.9	1.0	3000	14,700
109	AT BLDG. 213	5'-3"	1.4	10.0	1000	14,000
110	WHITE RD.	↓	1.2	10.0	↓	12,000
111	FUEL FARM, AT TANKS 154 & 136	↓	3.1	1.0	↓	3100
	↓	10'-6"	4.8	↓	2000	9600
	↓	15'-9"	4.7	↓	3000	14,100
112	FUEL FARM, AT TANK 138	5'-3"	7.7	↓	1000	7700
	↓	10'-6"	1.3	10.0	2000	26,000
	↓	15'-9"	1.1	1.0	3000	3300
113	CANAL ST., AT BLDG. 4155	5'-3"	3.8	1.0	1000	3800
114	CANAL ST.	↓	1.0	10.0	↓	10,000
115	BANCROFT ST.	↓	2.0	10.0	↓	20,000

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

STRUCTURE - TO - ELECTROLYTE POTENTIAL MEASUREMENT

STRUCTURE: WATER DISTRIBUTION SYSTEM

DATE 10/27/84 **ENGINEER** N.E. **TABLE** II **PAGE** 1 **OF** 2

REF NO.	LOCATION	POTENTIAL MEASUREMENT (VOLT)	REMARKS
1	OFFICER'S MESS, FH	-.420	FH ⇒ FIRE HYDRANT
2	FLOUNDER RD, FH	-.422	
3	8" F.W. LINE EXPOSED AT CREEK	-.490	
4	CURTISS RD., FH	-.506	
5	AT BLDG. 812, FH	-.523	
6	NCO CLUB, FH	-.413	CONTINUITY TEST BETWEEN
6A	↓	-.420	POINTS 6 & 6A WAS PERFORMED
7	NORDELL ST. AT HOUSE #2113	-.361	
8	NORDELL ST. AT HOUSE #2093	-.214	
9	LONGSTAFF ST. AT HOUSE #2118	-.362	NOT SHOWN ON DWG.
10	MARINA OFFICE, FH	-.330	
11	LONGSTAFF & PATRICK, FH	-.329	NOT SHOWN ON DWG.
12	LONGSTAFF ST. AT HOUSE #2043	-.334	↓
13	GOODEN ST. AT BLDG. 818, FH	-.502	
14	AT TANK 4130, FH	-.406	
15	PERIMETER RD. & SCHMIDT, FH	-.566	
16	AC MAINT. HANGAR 4108, FH	-.301	
17	WHITE ST., FH	-.503	
18	WHITE & CAMPBELL ST., FH	-.451	
19	BANCROFT & CAMPBELL ST., FH	-.436	
20	CAMPBELL ST. AT BLDG. 224, FH	-.402	
21	Mc AVOY ST. AT BLDG. 302, FH	-.460	
22	SUMNER ST. AT HOUSE #1268, FH	-.470	
23	Mc AVOY ST. AT HOUSE #1208, FH	-.390	

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STRUCTURE - TO - ELECTROLYTE POTENTIAL MEASUREMENT

STRUCTURE: WATER DISTRIBUTION SYSTEM

DATE 10/27/84 ENGINEER N.E. TABLE II PAGE 2 OF 2

REF NO.	LOCATION	POTENTIAL MEASUREMENT (VOLT)	REMARKS
24	MC AVOY ST. AT HOUSE #1100, FH	-.421	
25	CURTISS RD. AT BLDG. 205, FH	-.487	
26	JONES & LANGTRY ST., FH	-.496	
27	BAXTER ST AT HOUSE #1040, FH	-.501	
28	COMPTON & BAXTER	-.483	
29	BANCROFT AT BLDG. 210, FH	-.391	CONTINUITY TEST BETWEEN
30	BANCROFT AT BLDG. 208, FH	-.411	POINTS 29 & 30 WAS PERFORMED
31	FUEL FARM, FH	-.457	

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: FUEL FARM

DATE 10/26/84 ENGINEER N.E. TABLE III PAGE 1 OF 3

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
			64 AMPS	78 AMPS	
100	4" LINE AT BOOSTER	-.507	-.870	-.988	
	PUMP TO PUMP HOUSE				
101	TANK 141, EAST	-.523	-.605	-.681	
102	↓ , NORTH	-.485	-.565	-.638	
103	4" P/L AT BOOSTER	-.476	-.566	-.643	
	TO PUMP HOUSE				
104	TANK 140, SOUTH	-.445	-.580	-.698	
105	, EAST	-.460	-.585	-.701	
106	↓ , NORTH	-.424	-.569	-.690	
	TANK 138				
107	EAST - 20'	-.440	-.680	-.743	
108	↓ 10'	-.412	-.663	-.726	
109	SOUTH - 20'	-.413	-.632	-.701	
110	↓ 10'	-.313	-.526	-.608	
111	WEST - 20'	-.382	-.544	-.632	
112	↓ 10'	-.376	-.536	-.626	
113	TOP OF TANK	-.352	-.493	-.566	
	TANK 137				
114	TOP OF TANK	-.330	-.483	-.545	
115	EAST - 20'	-.461	-.886	-1.044	
116	↓ 10'	-.426	-.802	.960	
117	WEST - 20'	-.386	-.756	-.835	
118	↓ 10'	-.390	-.684	-.762	

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: FUEL FARM

DATE 10/26/84 ENGINEER N.E. TABLE III

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
	TANK 136		64 AMPS	78 AMPS	
119	TOP OF TANK	-.307	-.438	-.501	
120	SOUTH -20'	-.459	-.684	-.780	
121	↓ 10'	-.457	-.680	-.777	
122	NORTH -20'	-.434	-.663	-.756	
123	↓ 10'	-.448	-.682	-.781	
	TANK 150				
124	TOP OF TANK	-.361	-.464	-.512	
125	WEST -20'	-.470	—	—	
126	↓ 10'	-.452	—	—	
127	SOUTH -20'	-.501	-.733	-.818	
128	↓ 10'	-.465	-.663	-.771	
129	EAST -20'	-.505	-.804	-.988	
130	↓ 10'	-.494	-.780	-.880	
	TANK 151				
131	TOP OF TANK	-.301	-.387	-.424	
132	NORTH -20'	-.422	-.677	-.774	
133	↓ 10'	-.432	-.681	-.782	
134	EAST -20'	-.446	-.691	-.786	
135	↓ 10'	-.430	-.643	-.732	
136	SOUTH -20'	-.346	-.695	-.806	
137	↓ 10'	-.318	-.688	-.790	

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: FUEL FARM

DATE 10/26/84 ENGINEER N.E. TABLE III PAGE 3 OF 3

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
	TANK 154		64 AMPS	78 AMPS	
138	TOP OF TANK	-.404	-.536	-.605	
139	NORTH - 20'	-.495	-.793	-.894	
140	↓ 10'	-.505	-.789	-.880	
141	EAST - 20'	-.500	-.839	-.916	
142	↓ 10'	-.505	-.792	-.887	
143	SOUTH - 20'	-.496	-.742	-.846	
144	↓ 10'	-.483	-.692	-.788	
145	WEST - 20'	-.481	-.784	-.883	
146	↓ 10'	-.490	-.767	-.854	

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: UNDERGROUND MOGAS TANK AT BLDG. 143

DATE 10/27/84 ENGINEER N.E. TABLE IV PAGE 1 OF 1

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
			1.3 AMPS	.30 AMPS	
200	MOGAS TANK	-.526	-.218	-1.221	
201		-.557	-2.81	-1.142	
202		-.595	-2.51	-1.186	
203		-.542	-2.72	-1.209	
204		-.535	-2.55	-1.152	
205		-.560	-2.58	-1.051	
206		-.554	-1.81	-.943	
207	↓	-.558	-1.92	-.964	

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

CONTINUITY TEST DATA

STRUCTURE: WATER DISTRIBUTION SYSTEM

DATE 10/27/84 **ENGINEER** N.E. **TABLE** V **PAGE** 1 **OF** 1

TEST NO.	SECTION OF LINE TESTED	STRUCT.-TO-SOIL POTENTIAL (VOLTS) CLOSE I-ON	CLOSE I-OFF	REMOTE I-ON	REMOTE I-OFF	REF. LOCAT.	REMARKS
	LINE SECTION AT						
	NCO CLUB,						
	BETWEEN REF.						
	POINTS 6 & 6A						
301 A	TEMPORARY	-.613	-.413	-.384	-.169	FH-6	NOT CONTINUOUS
301 B	GROUNDBED AT			-.420	-.420	FH-6A	NOT CONTINUOUS
	REF. 6						
	LINE SECTION						
	BETWEEN BLDGS.						
	208 & 210, REF.						
	POINTS 29 & 30						
302A	TEMPORARY	-.688	-.391	-.372	-.293	FH-29	NOT CONTINUOUS
302B	GROUNBED AT			-.411	-.411	FH-30	NOT CONTINUOUS
	REF. 29						

NOTES: SEE DWG. No. SK-6148-A FOR TEST PROCEDURES

RECTIFIER DATA

MFGR. HARCO SERIAL NO. 9339

DC RATING 60 VOLTS. 28 AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	A
	FINE	2	2
DC OUTPUT		4.06V	4.06V
BOWL CURRENT		1.70A.	1.70A.
RISER CURRENT		0.36A.	0.36A.

COMMENTS:

HATCH CAME OFF WHEN OPENED - HINGES NOT MATED - NEEDS REPAIR.

ANODES ~ 5YRS. LIFE

HARDWARE OK INTERIOR COATING LOOKED GOOD

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY 75% FULL TANK

BOTTOM	1.24V.	+15	1.33V.	+30	
+3	1.29V.	+18	1.33V.	+33	
+6	1.31V.	+21	1.28V.	+36	
+9	1.32V.	+24	SURFACE	+39	
+12	1.33V.	+27			

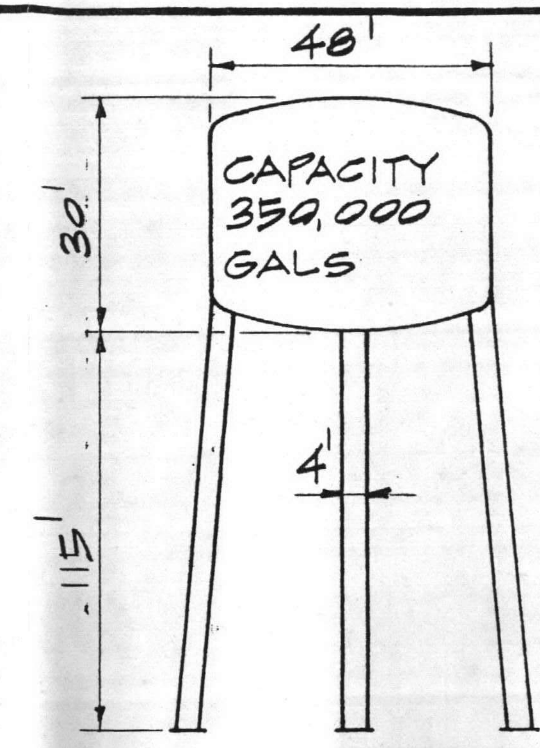
OFF POTENTIAL 1.16 V. I.R. DROP 100 MV.

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	0.18A	1	0.04A
2	0.18A	2	.038A
3	0.18A	3	.035A
4	0.18A	4	.038A
5	0.18A	5	
6	0.18A		
7	0.18A		
8	0.18A	RISER	0.32A
9			
10			

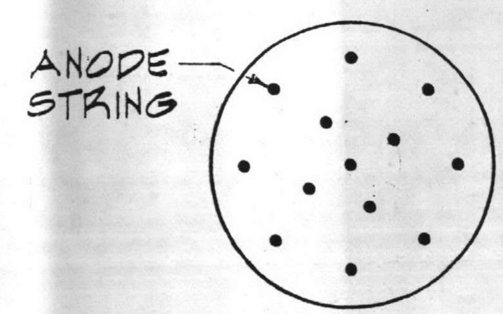
DATE OF SURVEY - NOV. 11, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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ELEVATED WATER STORAGE TANK CATHODIC PROTECTION DATA (TANK 4130)

DES. C.R.M.	CK R.S.	DWG. NO. / REV
DR. J.CRUZ	APP.	TABLE VI-A
SCALE NONE	DATE 12-14-84	

RECTIFIER DATA

MFGR. GOOD-ALL SERIAL NO. 81L1216

DC RATING 40 VOLTS. 12 AMPS.

SHUNT RATING: ______ mV. ______ AMPS. ______

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	A
	FINE	2	2
DC OUTPUT		3.5V	3.5V.
BOWL CURRENT		1.41A.	1.41A.
RISER CURRENT		0.29A.	0.29A

COMMENTS:

SQUARE HANDHOLE COVERS OVER ROUND ACCESS HOLES DO NOT FIT WELL

ANODES ~ 3 YRS. LIFE

CONDUIT & WIRING OK

INTERIOR COATING OK

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY FULL TANK

BOTTOM	1.10V.	+15	1.16V.	+30	
+3	1.13V.	+18	1.16V.	+33	
+6	1.15V.	+21	1.16V.	+36	
+9	1.15V.	+24	1.16V.	+39	
+12	1.15V.	+27	1.16V. SURFACE		

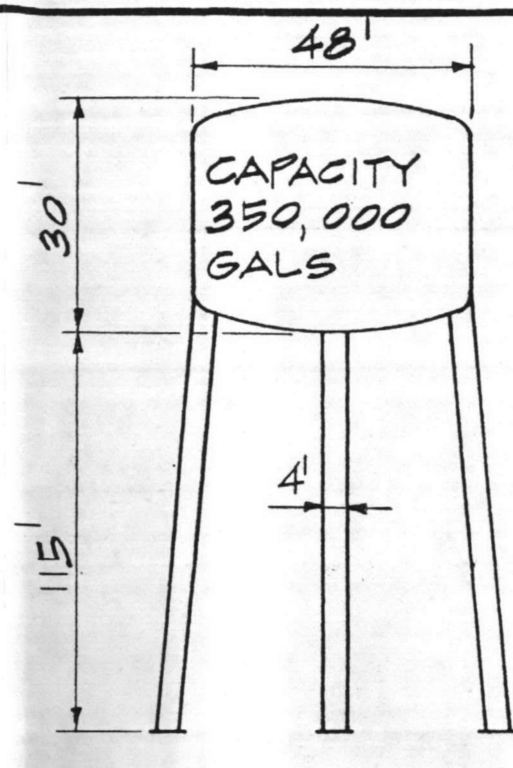
OFF POTENTIAL 1.06V. I.R. DROP 50 MV

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

	OUTER RING		INNER RING
1	0.10A.	1	.023A.
2	0.12A.	2	.019A.
3	0.10A.	3	.018A.
4	0.13A.	4	.018A.
5	0.11A.	5	
6	0.10A.		
7	0.12A.		
8	0.12A.	RISER	.25A.
9			
10			

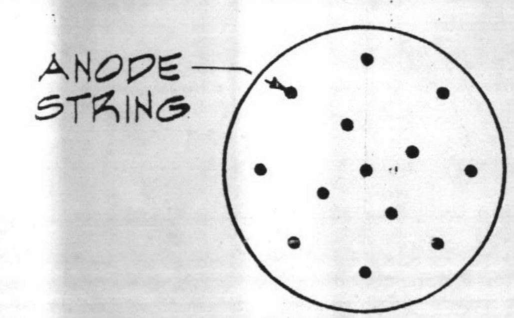
DATE OF SURVEY - NOV. 12, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



MDA MENENDEZ · DONNELL & ASSOCIATES, INC.
GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK CATHODIC PROTECTION DATA (TANK AS-310)

DES. C.R.M.	CK R.S.	DWG. NO. REV
DR. J.CRUZ	APP	TABLE VI-B
SCALE NONE	DATE 12-14-84	

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

RECTIFIER INSPECTION

SYSTEM FUEL FARM RECTIFIER LOCATION IN FUEL FARM

DATE 10/27/84 ENGINEER N.E. TABLE VII RECTIFIER NO. 1

MFGR. RIO SERIAL NO. 40742 DC RATING: 36 VOLTS 20 AMPS ______

SHUNT RATING: 30 mV 50 AMPS TAP RANGE: 3 COURSE 6 FINE

RECTIFIER INSPECTION

POWER SWITCH O.K.? ✓ GND. CONNECTION TO CASE? ✓ ROD CONNECTION? ✓

CONDITION OF CASE? O.K. CASE SUPPORTS? ✓ CABLE CLAMPS? ✓ A.C. CONDUIT & FITTINGS? ✓

AIR COOLED UNIT: AIR CIRCULATION HINDERED? NO CONDITION OF PANEL? O.K.

CONDITION OF TRANSFORMER? O.K. OVERHEATED PLATES ? NO

CALIBRATION AND ADJUSTMENT

AS FOUND	DC VOLTS	DC AMPS	AC VOLTS
RECTIFIER METER	0	0	0
CALIBRATION METER	0	0	0

AS LEFT	DC VOLTS	DC AMPS	AC VOLTS
RECTIFIER METER	0	0	
CALIBRATION METER	0	0	

TAP SETTINGS

AS FOUND	2 COURSE	1 FINE
AS LEFT	2 COURSE	1 FINE

GROUND BED INVESTIGATION

JCT. BOX NO.		JCT. BOX NO.		JCT. BOX NO.		JCT. BOX NO.	
ANODE NO.	AMPS	ANODE NO.	AMPS	ANODE NO.	AMPS	ANODE NO.	AMPS
1							
2							
3							
4							
5							

REMARKS GROUNDBED IS DEPLETED, RECTIFIER WAS FOUND "OFF", IT IS IN GOOD CONDITION, IT WAS USED AS A POWER SOURCE FOR A TEMPORARY GROUNDBED

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS AIR STATION (H), NEW RIVER, N.C.

RECTIFIER INSPECTION

SYSTEM RECTIFIER LOCATION IN BLDG. 4102

DATE 10/27/84 ENGINEER ______ TABLE VII RECTIFIER NO. 2

MFGR. GOODALL SERIAL NO. — DC RATING: 40 VOLTS 20 AMPS ______

SHUNT RATING: — mV — AMPS TAP RANGE: — COURSE — FINE

RECTIFIER INSPECTION

POWER SWITCH O.K.? ____ GND. CONNECTION TO CASE? ____ ROD CONNECTION? ____

CONDITION OF CASE? ____ CASE SUPPORTS? ____ CABLE CLAMPS? ____ A.C.CONDUIT & FITTINGS? ____

AIR COOLED UNIT: AIR CIRCULATION HINDERED? ____ CONDITION OF PANEL? ____

CONDITION OF TRANSFORMER? ____ OVERHEATED PLATES ? ____

CALIBRATION AND ADJUSTMENT

AS FOUND	DC VOLTS	DC AMPS	AC VOLTS
RECTIFIER METER	0	0	
CALIBRATION METER			

AS LEFT	DC VOLTS	DC AMPS	AC VOLTS
RECTIFIER METER	0	0	
CALIBRATION METER			

TAP SETTINGS

AS FOUND ____ COURSE ____ FINE

AS LEFT ____ COURSE ____ FINE

GROUND BED INVESTIGATION

JCT. BOX NO.		JCT. BOX NO.		JCT. BOX NO.		JCT. BOX NO.	
ANODE NO.	AMPS	ANODE NO.	AMPS	ANODE NO.	AMPS	ANODE NO.	AMPS
1							
2							
3							
4							
5							

REMARKS BUILDING 4102 WAS LOCKED, OPERATOR INDICATED THAT THE RECTIFIER IS IN GOOD WORKING CONDITION

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APPENDIX C

SOIL AND WATER ANALYSIS

LOCATION OF SAMPLES

SOIL SAMPLES

"S-6" Fuel Farm.

"S-7" Fuel farm, between Tanks No. 136 and 137.

"S-8" At Airfield underground steel Tanks A and B.

WATER SAMPLES

"W-5" At New River shoreline.

"W-12" Potable water from Tank No. S-TC-606.

SGS Control Services Inc.

1201 W. 8th Street
P.O. Box 550
Deer Park, Texas 77536
Tel: (713) 479-7170
TWX: 910 881 1681
TLX: 795065 SUPERCO DERK

November 21, 1984

MENENDEZ-DONNELL & ASSOCIATES
11999 Katy Freeway, #355
Houston, TX 77079

Analytical Report No. #97414

LAB REFERENCE NO.: L/3134/84 SAMPLE DESCRIPTION: Water / Soil

SAMPLE MARKED: SUBMITTED SAMPLES AS MARKED BELOW / RECEIVED 11-5-84

SUBMITTED BY: Menendez-Donnell & Associates

RESULTS OF ANALYSIS

Based upon samples, submitted to us, tested in our laboratory, reported to you as follows:

"SOIL"

Method	Tests
ASTM D-2976	pH
Gravimetric	Sulfate, ppm
Potentiometric	Chlorides, %
Conductimeter*	Conductivity, µmhos/cm
A. A. S.	Sodium, ppm
U. V.	Phosphate, ppm
Carbon Dioxide Apparatus	Carbonate, %

	"S-6"	"S-7"	"S-8"
pH	6.7	5.8	6.9
Sulfate, ppm	973	177	591
Chlorides, %	<0.005	<0.005	<0.005
Conductivity, µmhos/cm	390	53	61
Sodium, ppm	159	176	201
Phosphate, ppm	94	81	52
Carbonate, %	1.77	0.31	2.33

*Soil sample mixed with Deionized Water 1:1 ratio

continued. . . . . .

SGS Control Services Inc.

1201 W. 8th Street
P.O. Box 550
Deer Park, Texas 77536
Tel: (713) 479-7170
TWX: 910 881 1681
TLX: 795065 SUPERCO DERK

November 21, 1984

MENENDEZ-DONNELL & ASSOCIATES
11999 Katy Freeway, #355
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LAB REFERENCE NO.: L/3134/84

SAMPLE DESCRIPTION: Water / Soil

SAMPLE MARKED: SUBMITTED SAMPLES AS MARKED BELOW / RECEIVED 11-5-84

SUBMITTED BY: Menendez-Donnell & Associates

RESULTS OF ANALYSIS

Based upon samples, submitted to us, tested in our laboratory, reported to you as follows:

"WATER"

[Standard Methods 15th Edition]

Method	Tests	"W-12"	"W-5"
423	pH	8.6	6.9
209C	Total Dissolved Solids, mg/L	397	8998
426B	Sulfate, mg/L	21.8	664
407C'	Chlorides, mg/L	82	4538
205	Conductivity, µmhos/cm	738	15343

SGS CONTROL SERVICES INC.

By: Hugh L. Mayo

Hugh L. Mayo,
Laboratory Manager

HLM/bj

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APPENDIX D

DESIGN CALCULATIONS

I. POL SYSTEM

A. Fuel Farm

1. Current requirement test data indicated that a current of 80 amperes will be required to achieve protective potentials on underground tanks and associated piping at the Fuel Farm.

Underground tanks Surface Area:

50,000 gal. tanks:	$2816 \frac{\text{sq.ft.}}{\text{tank}}$ x 3 tanks	= 8,448 sq.ft.
100,000 gal. tank:		= 3,940 sq.ft.
105,000 gal. tank:		= 3,940 sq.ft.
120,000 gal. tank:		= 4,272 sq.ft.
10,000 gal. tank:	$779 \frac{\text{sq.ft}}{\text{tank}}$ x 2 tanks	= 1,558 sq.ft.
Total Surface Area		=22,158 sq.ft.
Allow 15% for piping		= 3,324 sq.ft.

Total exposed surface area of underground tanks and piping =25,482 sq.ft.

$$\text{Current density} = \frac{80 \text{ amperes}}{25,482 \text{ sq.ft.}} = 0.0031 \frac{\text{Amp}}{\text{sq.ft.}}$$

The current requirement is relatively high, but it is a result of an actual field test and should be considered correct.

2. An impressed current system utilizing distributed type anodes is recommended for proper current distribution around the Fuel Farm.

3. Utilize the two existing abandoned 20 ampere rectifiers and an one additional new rectifier.

4. Weight of anode materials:

Fully treated graphite anodes with calcined petroleum coke backfill are recommended for this installation:

$$\text{Weight} = 20 \text{ years} \times \frac{1\text{-lb}}{\text{amp-yr.}} \times 80 \text{ amperes} =$$

= 1,600 lbs. of anode material

5. Number of anodes required for a 20 years life:

a. Use 3" x 60" specially treated graphite anodes, fitted with epoxy and heat shrink caps.

b. Number = 1600 lbs. x 1-anode/27-bls = 59.2 anodes

59.2 anodes/0.75 = 79 anodes.
.75 is the utilization factor for the graphite anode, meaning when the anode is 75% consumed it will require replacement.

6. Groundbed design:

a. The two existing rectifiers, have a rated DC output as follows:
36V - 20 amperes.
40V - 20 amperes.

Two 20 amperes groundbeds can therefore be utilized by the above rectifiers, the following calculations are made to insure that the rated voltage of each rectifier is sufficient:

Resistance of groundbed to earth:

$$R = \frac{.00521\rho}{NM}\left[\ln\frac{8L}{D} - 1 + 2\frac{L}{S}\ln .656(N)\right]$$

L = Length of anode and coke column = 10'
D = Diameter in ft. = 1'
S = Spacing in ft. = 20
ρ = Soil resistivity in ohm-cm = 7,400
N = No. of anodes = 20

$$R = \frac{.00521(7400)}{20(10)}\left[\ln\frac{8(10)}{1} - 1 + \frac{2(10)}{20}\ln .656(20)\right]$$
= 1.15 ohms

Anode Resistance to Backfill:

$$R = \frac{0.0052\rho}{L}\left(\ln\frac{8L}{D} - 1\right)$$

L = Length of anode = 5'
D = Diameter of anode = 0.25
ρ = Resistivity pf Backfill

$$R = \frac{.00521(50)}{5}\left(\ln\frac{8(5)}{.25} - 1\right)$$
= 0.212 ohm for 1 anode
R for 20 anodes = $\frac{.212}{20}$ = 0.0106 ohms.

Total Groundbed resistance=1.15 + 0.0106 = 1.16 ohms.

Cable Resistance:

Maximum conductor length for this installation should not exceed 800 feet.
Use No. 1/0 AWG, resistance = .102 ohm/1000 ft.
Cable Resistance = 800 ft. x $\frac{.102 \text{ ohm}}{1000 \text{ ft.}}$ = .082 ohm

Total Resistance = 1.16 + .082 = 1.24 ohm.

$$\text{Rectifier Voltage } V_r = \frac{IR+2V \text{ (Back EMF)}}{.08 \text{ reserve factor}}$$

$$V_r = \frac{20(1.24) + 2V}{.08} = 33.5 \text{ volts}$$

Therefore, the two existing rectifiers can be utilized in conjunction with 20 anodes groundbed each.

7. New Rectifier Groundbed.

Resistance of Groundbed to earth:

$$R = \frac{.00521\rho}{NL}\left[\ln\frac{8L}{D} - 1 + \frac{2L}{S}\ln .656\ N\right]$$

$$R = \frac{.00521(7400)}{40\ (10)}\left[\ln\frac{8(10)}{1} - 1 + \frac{2(10)}{20}\ln .656\ (40)\right]$$

= 0.64 ohms.

$$\text{Groundbed resistance to backfill} = \frac{.212}{40} = 0.0053 \text{ohms.}$$

Total Groundbed resistance = .64+.0053 = 0.645 ohms.

Cable Resistance:
Maximum conductor length for this installation should not exceed 1500 feet.

Use No. 1/0 AWG, resistance = .102 ohm/1000 ft.

$$\text{Cable Resistance} = 1500 \text{ ft.} \times \frac{.102 \text{ ohm}}{1000 \text{ ft.}} = 0.153 \text{ ohm}$$

Total resistance = 0.645 + 0.153 = 0.8 ohm.

$$\text{Rectifier Voltage } V_r = \frac{IR+2V\text{(Back EMF)}}{0.8 \text{ reserve factor}}$$

I = 40 Amper + 25% = 50 amp.

$$V_r = \frac{(50)\ (.8) + 2V}{0.8} = 52.5 \text{ volts}$$

Use a rectifier with minimum rating = 60 volts.

II. MOGAS Tank at Building 142

1. Current requirement test data indicated that a current of 0.35 amperes will be required to achieve protective potentials on the 20,000 gallon underground MOGAS Tank at building 142.

Tank surface area = 1,350 sq. ft.

$$\text{Current density} = \frac{.30 \text{ amp.}}{1350 \text{ sq. ft.}} = .000222 \frac{\text{amp}}{\text{sq.ft.}} = 0.222 \frac{\text{ma}}{\text{sq.ft.}}$$

The low current density requirement of $0.26 \frac{\text{ma}}{\text{sq.ft.}}$ is quite reasonable for a coated tank. The coating was visually verified during the field inspection.

2. Weight of anode materials required:

Prepackage magnesium anodes will be used having an estimated deterioration rate of 1-lb. per 500 amp.-hr and an estimated life of 20 years.

$$\text{Weight} = 20 \text{ yrs.} \times \frac{1\text{-lb}}{500 \text{ amp-yr.}} \times \frac{8760\text{hr}}{\text{year}} \times 0.30 \text{ amp.}$$
$$= 105\text{-lbs. of anode material.}$$

3. Number of anodes required for 20 years life:

a. Use prepackaged 20 lb longated magnesium anode.

b. $\text{Number} = 105.6 \text{ lb} \times \frac{1\text{-anode}}{20 \text{ lb.}} = 5.25 \text{ anodes}$

$5.25 \text{ anodes} \times \frac{1}{.75} = 7.0 \text{ anodes}$

.75 is the utilization factor meaning when the anode is 75% consumed it will require replacement.

Use 8 anodes.

c. To achieve the desired current distribution the following calculations are made:

$$R = \frac{.00521\rho}{L} \left(\ln \frac{8L}{D} - 1\right)$$

ρ = Soil resistivity

L = Anode length = 5'

D = Anode Diameter = 0.266

$$R = \frac{.00521(6200)}{5} \left(\ln \frac{8(5)}{.266} - 1\right) = 25.9 \text{ ohm.}$$

$I = \frac{E}{R}$ E = Driving potential

= Solution potential of anode-protected potential

$$I = \frac{0.9}{25.9} = 0.0347 \text{ amp/anode}$$

Number of anodes:

$$0.30 \text{ amperes} \times \frac{\text{anode}}{0.0347 \text{ amp.}} = 8.64 \text{ anodes}$$

III. Day Tanks A & B at Airfield

1. The underground Day Tanks A and B have an exposed surface area of 2700 square feet. Based on the current density of .000222 amper per square foot calculated previously, total current requirement will be 0.6 amperes.

2. The low current requirement and soil resistivity of (1500 ohm cm) are suitable for a sacrificial magnesium anode installation.

3. Weight of anode material prepackage of magnesium anodes will be used having an estimated deterioration rate of 1-lb per 500 amp-hr. and an estimated life of 20 years.

$$\text{Weight} = 20 \text{ years} \times \frac{\text{1-lb}}{500 \text{ amp.-yr.}} \times \frac{\text{8760-hr.}}{\text{year}} \times .60 \text{ amps.}$$
$$= 210 \text{ lbs of anode material}$$

4. Number of anodes required for 20 years life:

   a. Use prepackaged 32-3D (32 lbs) magnesium anodes.

   b. $\text{Number} = \text{210-lbs} \times \frac{\text{anode}}{32 \text{ lb}} = 6.56 \text{ anodes.}$

   $$6.56 \times \frac{1}{.75} = 8.75 \text{ anodes}$$

   .75 is the utilization factor.

   c. Calculated current drain for a 32-D3 Galvopack anode with a driving potential of 0.9 volts.

   $$R = \frac{.00521(1500)}{5} \left(\ln \frac{8(5)}{.3125} - 1\right)$$
   $$= 6.0 \text{ ohms.}$$

   $$I = \frac{E}{R} = \frac{0.9}{6.0} = 0.15 \text{ ampere/anode}$$

   To achieve the desired current drain and a 20 years life for the system, eight 32-D3 Galvopack magnesium anodes will be scheduled for installation.

IV. WATER DISTRIBUTION SYSTEM

1. Based on a current density of 0.0015 ampere per square foot, current requirement for different standard pipe joints will be as follows:

Dimension	Current requirement
4" x 20'	0.032 A
6" x 20'	0.047 A
8" x 20'	0.063 A
10" x 20'	0.078 A
12" x 20'	0.094 A
14" x 20'	0.109 A
20" x 20'	0.157 A

2. Because of soil resistivity variations and the lack of electrical continuity, anodes are sized for each individual joint.

3. Weight of anode materials required for a 6" x 20' joint.

a. Anode life = 20 years

$$\text{weight} = 20 \text{ yrs} \times \frac{8760 \text{ hr}}{\text{yr}} \times \frac{1\text{lb}}{500 \text{ amp-hr}} \times .047\text{A} \times \frac{1}{.85} = 19.37\text{lbs}$$

b. Select (1) 20-D2 Galvopack magnesium anode for installation on each 6" x 20' joint

c. Anode Resistance:

$$R = \frac{.00521(\rho)}{L} \left(\ln \frac{8L}{D} - 1\right)$$

$$= \frac{.00521(\rho)}{5} \left(\ln \frac{8(5)}{.266} - 1\right) = 0.004 \text{ ohm}$$

Maximum current drain depends on soil resistivity.

$$I = \frac{\text{Driving Potential}}{R} = \frac{0.09V}{.004 \text{ ohm}}$$

For ρ = 1000 ohm-cm
I = .225 amperes

Therefore (1) 20-D2 anode can be used on 1 joint of 6" x 20' pipe in soil resistivities up to 5000 ohm/cm.

4. Following the above procedure the following tables were prepared:

4" x 20'

Maximum Soil Resistivity ohm-cm	No. of magnesium Anodes Re.	Maximum Current Ouput "Amperes"
1000	1-20D2	0.215
2000	1-20D2	0.1076
3000	1-20D2	0.072
4000	1-20D2	0.054
5000	1-20D2	0.043

6" x 20'

1000	1-20D2	0.215
2000	1-20D2	0.1076
3000	1-20D2	0.072
4000	1-20D2	0.054
5000	1-20D2	0.043

8" x 20'

1000	1-32-D3	0.192
2000	1-32-D3	0.096
3000	2-20D2	0.144
4000	2-20D2	0.108
5000	2-20D2	0.086

10" x 20'

1000	1-40D3	0.2432
2000	1-40D3	0.122
3000	1-40D3	0.081
4000	2-20D2	0.108
5000	2-20D2	0.086

12" x 20'

1000	1-48D5	0.152
2000	2-20D2	0.215
3000	2-20D2	0.144
4000	2-20D2	0.108
5000	2-20D2	0.086

14" x 20'

1000	1-48D5	0.152
2000	1-40D3	0.121
3000	2-20D2	0.144
4000	2-20D2	0.108
5000	3-20D2	0.135

<u>20" x 20'</u>

1000	2-40D3	0.484
2000	2-40D3	0.242
3000	2-40D3	0.161
4000	2-40D3	0.112
5000	2-40D3	0.090

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APPENDIX E

COST ESTIMATES

NAVFAC 11013/7 (1-78)
Supersedes NAVDOCKS 2417 and 2417A

COST ESTIMATE

DATE PREPARED: DEC. 14, 1984

SHEET 1 OF 3

ACTIVITY AND LOCATION: MCAS, (HELICOPTER) NEW RIVER, N.C.

CONSTRUCTION CONTRACT NO.:

IDENTIFICATION NUMBER:

ESTIMATED BY: MENENDEZ-DONNELL & ASSOC.

CATEGORY CODE NUMBER:

PROJECT TITLE: CATHODIC PROTECTION SURVEY

STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☒ Other (Specify) STUDY

JOB ORDER NUMBER:

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
FUEL FARM								
1. 3"x60" TREADED GRAPHITE ANODES W/ EPOXY & HEAT SHRINK CAPS & 5' OF #8 HMWPE LEADWIRE	80	EACH	78	6,240	120	9,600		15840
2. CALCINED PETROLEUM COKE	56,000	LB	.275	15,400		1,600		17,000
3. 80 VOLTS, 50 AMPS, OIL INMERSED RECTIFIER	1	EACH	2,070	2,070	700	700		2,770
4. #1/0 HMWPE CABLE	3,000	FT.	.95	2,850	1	3,000		5,850
5. EPOXY RESIN SPLICE KITS & PRESSURE CONNECTION	80	EACH	14	1,120	22	1,760		2,880
6. MISCELLANEOUS	1	LOT	400	400	800	800		1,200
7. POWER CONNECTION	3	EACH	250	750	750	2,250		3,000
8. FIELD ENGINEERING & SUPERVISION								7,650
9. OFFICE ENGINEERING & REPORT								2,000
10. DRAFTING & SECRETARIAL								1,200
TOTAL				28,830		19,710		59,390

S/N 0105-LF-010-1335

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NAVFAC 11013/7 (1-78)
Supersedes NAVDOCKS 2417 and 2417A

COST ESTIMATE

DATE PREPARED: DEC. 14, 1984

SHEET 2 OF 3

ACTIVITY AND LOCATION: MCAS, (HELICOPTER) NEW RIVER, N.C.

CONSTRUCTION CONTRACT NO.

IDENTIFICATION NUMBER

PROJECT TITLE: CATHODIC PROTECTION SURVEY

ESTIMATED BY: MENENDEZ-DONNELL & ASSOC.

CATEGORY CODE NUMBER

STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☒ Other (Specify) STUDY

JOB ORDER NUMBER

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
MOGAS TANK AT 142								
1. 20-D2 PREPACKED MAGNESIUM ANODE W/ 15' OF #12 AWG LEADWIRE	9	EACH	63	567	220	1,980		2,547
2. FLUSH FINK TEST STATION	1	EACH	66	66	120	120		186
3. #8 AWG-HMWPE CABLE	100	FT	.32	32	1.5	150		182
4. MISCELLANEOUS	1	LOT	150	150	300	300		450
5. FIELD ENGINEERING & SUPERVISION								1,425
6. OFFICE ENGINEERING & REPORT								800
7. DRAFTING & SECRETARIAL								600
TOTAL				815		2,550		6,190

NAVFAC 11013/7 (1-78)
Supersedes NAVDOCKS 2417 and 2417A

COST ESTIMATE

DATE PREPARED: DEC. 14, 1984

ACTIVITY AND LOCATION: MCAS, (HELICOPTER) NEW RIVER, N.C.

CONSTRUCTION CONTRACT NO.:

IDENTIFICATION NUMBER:

PROJECT TITLE: CATHODIC PROTECTION SURVEY

ESTIMATED BY: MENENDEZ-DONNELL & ASSOC.

CATEGORY CODE NUMBER:

STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☒ Other (Specify) STUDY

JOB ORDER NUMBER:

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
DAY TANKS A & B								
1. 32 LB. PREPACKAGED MAGNESIUM ANODE W/ 15' #12 AWG LEADWIRE	8	EACH	102	816	260	2,080		2,896
2. FLUSH FINK TEST STATION	2	EACH	66	132	120	240		372
3. #8 AWG - HMWPE CABLE	200	FT.	.32	64	1.5	300		364
4. MISCELLANEOUS	1	LOT	250	250	500	500		750
5. FIELD ENGINEERING & SUPERVISION								2,375
6. OFFICE ENGINEERING & REPORT								1,200
7. DRAFTING & SECRETARIAL								700
TOTAL				1,262		3,120		8,657

S/N 0105-LF-010-1335

★ U.S. Government Printing Office: 1982—606-106/0011 3-1

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APPENDIX F

CORROSION AND CATHODIC PROTECTION

CORROSION AND CATHODIC PROTECTION THEORY

Corrosion is an electro-chemical process or transformation of energy resulting in the metal of a structure in contact with an electrolyte going into solution, or reverting to its natural status as an oxide form. There is a great deal of stored energy in a piece of metal and it is not at all in accordance with the laws of nature for that piece of metal to remain intact--in fact, it cannot exist without some type or degree of maintenance by man.

There are, generally speaking, two main forms of corrosion--electrolytic and galvanic. Electrolysis is usually construed to mean the process of a stray electrical current being impressed upon a buried structure from an external and metallically unconnected source such as an electric railway (Figure 1). The current, usually relatively great in magnitude, supposedly confined to the rail as a return encounters high resistant joints, takes the path of least resistance to nearby piping, follows the pipe line back to the proximity of the source, at which point the current is discharged from the line carrying iron particles into solution with it. Due to the quantity of current usually involved, this type of corrosion is usually manifested in severe metal loss in the area of current discharge. Any uncontrolled current from a D.C. current source can result in detrimental interference effects on foreign structures within the area of influence of the D.C. source.

Galvanic corrosion is the result of the formation of galvanic cells upon the structure itself and independent of external power sources. Basic forms of galvanic cells exist as: (a) dissimilar connected metals in a common electrolyte, (b) a continuous metal structure exposed to dissimilar electrolytes, and (c) a combination of the above conditions. It is this form of corrosion which plays the major role in deterioration of underground structures in most areas.

The galvanic cell involving dissimilar metals can perhaps best be illustrated by referring to these examples taken from the Electromotive Force Series of Metals Table (Figure 2). This table is a comparative index of the solution potential or activity level of various metals ranging from potassium which has the highest relative potential to the noble metals of silver and gold which are very stable and thus reflect the lowest solution potentials. For practical purposes, the most common metals for underground construction and cathodic protection are shown. Magnesium, with a potential of -2.34, is anodic to zinc, with a

potential of -0.762. Zinc, in turn is anodic to iron, with a potential of -0.044. Iron, with a potential of -0.044, is anodic to copper, with a potential of +0.345. The term anodic is of Greek derivation meaning "up way" and indicates that the metal which has the higher potential will give up current (thus dissipating itself) to the lower potential metal which is termed cathodic or the cathode.

The common flashlight battery is a galvanic cell composed of a zinc outer case, an electrolyte, a carbon rod, and an external circuit (Fig. 3). In this case, the zinc has the higher potential and acts as the anode with the carbon rod being the cathode. When the external circuit is closed through the metallic case of a flashlight, current flows from the zinc outer case, through the electrolyte to the carbon rod, and thence through the light bulb filament. As the metallic ions go into solution, water in the electrolyte is disassociated, the zinc combining with the hydroxyl ion to form an oxide, and the atomic hydrogen released to migrate to the cathode.

Common examples of this type of galvanic cell encountered in everyday construction of underground structures are a brass fitting between steel section (Fig. 4), steel connected to cast iron, steel pipe in contact with cinders (Fig. 5), bright metal from wrench or tong from scratches (Fig. 6), mill scale patches on pipe (Fig. 7), and new pipe installed as replacement between old sections of pipe.

The other basic galvanic cell is one consisting of a common metal in dissimilar electrolytes (Fig. 8). In this case, the electrolyte surrounding the metal determines which portion of the metal is anodic and which is cathodic. The current flow is from the metal in contact with the lower resistivity electrolyte to the portion of metal in a higher resistivity environment. This case is, of course, similar to our underground pipe lines composed of the same metal, but traversing a heterogeneous mixture of soils such as sand, sandy loam, clay, loam, rock, gypsum beds, salt beds, etc. The oxygen content and moisture conditions will also vary radically for different soil types encountered. Each change of soil characteristic such as the frequency, and the degree of change of resistivity, has a great role in determining the severity and extent of corrosion.

Examples of these conditions are dramatized in Figure 9, which illustrates a continuous metal pipe in contact with a moisture retentative (thus relatively low resistivity), clay electrolyte, and also a well-drained (thus higher resistivity) sandy loam electrolyte. Current discharge is

initiated in the lower resistivity soil area with the adjacent pipe surfaces receiving the current, and the pipe wall serving as the external circuit back to the source of the galvanic cell at the corroding area. Figures 10 and 11 illustrate the dissimilarity of soil conditions which can result from normal excavation and backfill procedures of buried structures; also, the dissimilarity of electrolyte conditions encountered due to oxygen availability and presence as a result of normal construction practices.

A typical example of numerical soil resistivity value relationships over an extent of pipe line right-of-way is shown in Figure 12. Although a large percentage of detrimetnal corrosion is normally associated with the low soil resistivity ranges, severe corrosion does occur in the medium and high range categories. Thus, the frequency and magnitude of electrolyte change must be considered rather than relying solely on categorized numerical ranges.

Corrosion results are apparent in several forms--the most common being scaling, pitting, patching, graphitization, and oxide films. Some less common forms are failure within the crystaline structure itself and stress corrosion. Uniform scaling, or exfoliation, is usually associated with some of the older laminated types of pipe construction. The severity of metal loss depends essentially on the ratio of anodic area to cathodic area. In other words, if there is a small anodic area between two large cathodic areas, the small anodic area will be discharging current in quantities large enough to protect the two large cathodic areas. Since the area of current discharge is small, it follows that the metal will be removed in this area at an accelerated rate. However, if the anodic area was relatively large in comparison with the cathodic area, the penetration process would proceed much slower as it would be taking place over a much larger area. When it is realized that one ampere of D.C. current flowing continuously for a period of one year can drive 20 pounds of steel into solution, it can be ascertained that very small quantities of uncontrolled current discharge can cause failure of a thin wall metallic structure within a relatively short time.

Corrosion prevention is normally accomplished by the following procedures:

1. Judicious choice of construction materials and procedures with respect to corrosion mitigation for new construction.

2. Protective coatings.

3. Cathodic protection.

On new construction, many corrosion problems of the future can be prevented during the design stage of proposed faciliites. The type of metal most suitable for handling a given product, the type of surface treatment for the metallic structure, provisions for electrical isolation of new systems from old or foreign systems, and minimizing or avoiding coupling of dissimilar metals are but a few of the decisions which merit consideration during the project planning phase.

Protective coatings are recognized as a basic weapon in the battle against underground corrosion. It is known that if the metal of a structure does not contact an electrolyte, no corrosion will take place. Thus, the use of coatings is widespread, the desire being a coating material which is an impervious, inert substance, unaffected by temperature variance, mechanically sturdy enough to withstand soil and cyclic stress to which it is subjected underground, as well as potential damage from handling during transportation and construction. Commonly used coating materials consist of asphalt and coal tar enamels, asphalt and coal tar mastics, polyethylene and polyvinyl chloride tape applications, micro-crytaline wax compounds, and extruded plastic jackets or sleeves. Coating efficiences of the pipe line coatings in place are dependent not only on the material used, but also the care with which it was applied and the care exercised during structure installation. It is virtually a physical impossibility for any coated structure in place and backfilled to be without minute faults or "holidays", with small bare metal surfaces thus exposed and in direct contact with the surrounding soil or electrolyte. This situation is a classic example of the condition previously discussed concerning ratios of anodic and cathodic areas. Since the exposed metallic area at any coating fault will be relatively small compared to coated or cathodic areas surrounding it, corrosion activity will be concentrated on the small bare metallic area and early metal loss and penetration may be reasonably anticipated unless further protective steps are taken. In addition, all coating materials are subject to deterioration with time, thus exposing more metal surface to the corrosion process.

The accepted supplement to coating procedures is that of applying cathodic protection to the coated structure. In general, cathodic protection is a process whereby adequate quantities of D.C. current are impressed upon a given

structure to overcome the quantities of galvanic current generated and being discharged from the structure. This procedure is accomplished through the use of external current sources; either, galvanic anodes or impresssed current systems. Galvanic anodes normally consist of zinc or magnesium alloys of varying shapes and weights to accommodate differing soil resistivity values, current outputs, and design life. In both cases, the anode metal is more active or higher in the electromotive series than the steel structure to which it is attached. Thus, (Fig. 13) a large galvanic cell has been deliberately created with the metal from the sacrificial galvanic anode being dissipated to prolong the life of the structure to which it is attached. The current flow, electrically speaking, is from the sacrificial anode through the earth onto the structure and is returned to the source through the leadwire connected to the structure and the anode.

The same principle holds true for impressed current systems (Fig. 14), except that in this case power is being derived from some external source such as rectifier units which convert A.C. electrical power to D.C. current, or possibly thermoeletric units which convert heat to electric power. The D.C. current is then routed through a groundbed composed of graphite rods, cast iron rods, or junk steel, and thence through the earth to the structure to be protected. Once again, a low resistant return path is provided between the structure and the power source to complete the circuit and to provide controlled current drainage from the structure.

Cathodic protection in various forms and to varying degrees can be applied to old existing structures as well as new construction.

Naturally, the cost of providing complete overall protection to bare structures involves a much greater expenditure than for similar coated structures due to the greater exposed surface area involved on the bare structures. Thus, partial or spot protection at areas subject to deterioration, as indicated by past history or investigative procedures, is often the course followed to reduce maintenance cost and commodity loss, and to prolong useful life of the structure or system.

In any case, whether on new construction or existing facilities, the use of cathodic protection must be justified economically. Since both the initial investment and projected operating costs of cathodic protection are directly dependent upon the design and effectiveness of the installation, it is of great importance that the type of

protective system utilized, amount of current required, and location of the protective current systems must be determined by thorough preliminary field investigation conducted by experienced personnel. Many survey techniques, interpretation standards, and an array of specialized instrumentation are utilized in determining the most economical and practical protective design for providing cathodic protection to a given system or structure. Upon completion of any protective installation, the system must be adjusted and a thorough checkout conducted to determine that adequate protection is being realized over the entirety of the pertinent structure; further, that any detrimental interference effects on foreign or isolated structures are detected and removed.

In as much as electrical grounding systems frequently complicate cathodic protection efforts and contribute to corrosion of other underground structures, possible improvement of grounding procedures and effect of stray current on underground electrical structures merit the following brief discussion.

In general, electrical grounding systems must be comprised of materials that are good electrical conductors with sufficient area in contact with the soil to provide resistance of the current path within the allowable limits, and to be resistant to the corrosion process. The major material utilized for grounding systems in the past has been copper due to its excellent conductance characteristics, reasonable cost, and corrosion resistant properties. As long as overhead power transimission lines utilizing wooden supports were used, very little corrosion damage was apparent from this procedure. However, with the advent of lead sheath cable, armored cable, and galvanized conduit for underground installation, this situation has changed considerably. Potential differences, due to galvanic couples of some of the most commonly used metals for underground electrical construction, are presented in Figure 15. As indicated, the commonly used metals are all anodic to copper, i.e., when coupled with copper in a common electrolyte, the metals will be dissipated to provide current to the copper to which they are attached. Probably the most serious situation here is the couple between lead and copper where even though the potential difference is not as great as indicated for the other couples, the dissipation rate of lead, approximately 75 pounds per ampere year of current, becomes an important factor.

Conditions being what they are today, considerable thought for grounding procedures should be given to utilization of

other metals for grounding materials, the two most common substitutes being zinc and high silicon cast iron anodes. Zinc anodes are generally considered more attractive because they not only provide a degree of protection to metals to which they are attached due to being higher on the electromotive series of metals, but also they exhibit relatively long effective life in most environments. Of interest is a comparison of grounding rod resistance values between standard copper and zinc grounding rods in varying soil resistivity ranges. This comparison, as presented in Figure 16, indicates the effectivness of the zinc anode, particularly when surrounded by a prepared backfill material. Number, spacing, and configuration of grounding rods to provide a specified resistance can be readily determined in most cases when the resistivity of an electrolyte has been acquired through measurements, based upon design data for zinc anodes. High silicon content cast iron anodes are less attractive due to the galvanic couple between the cast iron alloy and steel. Although the potential difference between the two is not great, being in the neighborhood of 0.10 volt, the steel pipe is nevertheless anodic to the cast iron anode.

Another important aspect of choice of grounding system materials involves the application of cathodic protection to underground facilities within the area. In case of a copper grounding system in contact with piping or conduit to be cathodically protected, it is not uncommon to encounter current requirements 40 to 50 times as great to provide protection for both the copper grounding system and the piping as would be required to protect the piping alone if the copper grounding system was not connected to it. On the other hand, zinc grounding system under the same circumstances would actually supplement the cathodic protection system. In many areas, involving both plant piping and grounding systems, the proper choice of grounding materials thus becomes a decision of major economical importance.

Often a piping system also serves as part of a grounding system. Once again, the coupling of a copper grounding system with steel piping results in dissipation of the steel and should be avoided. In addition, today's standard acceptance of high resistance coatings for pipe line construction actually provides, in many cases, a very poor grounding device.

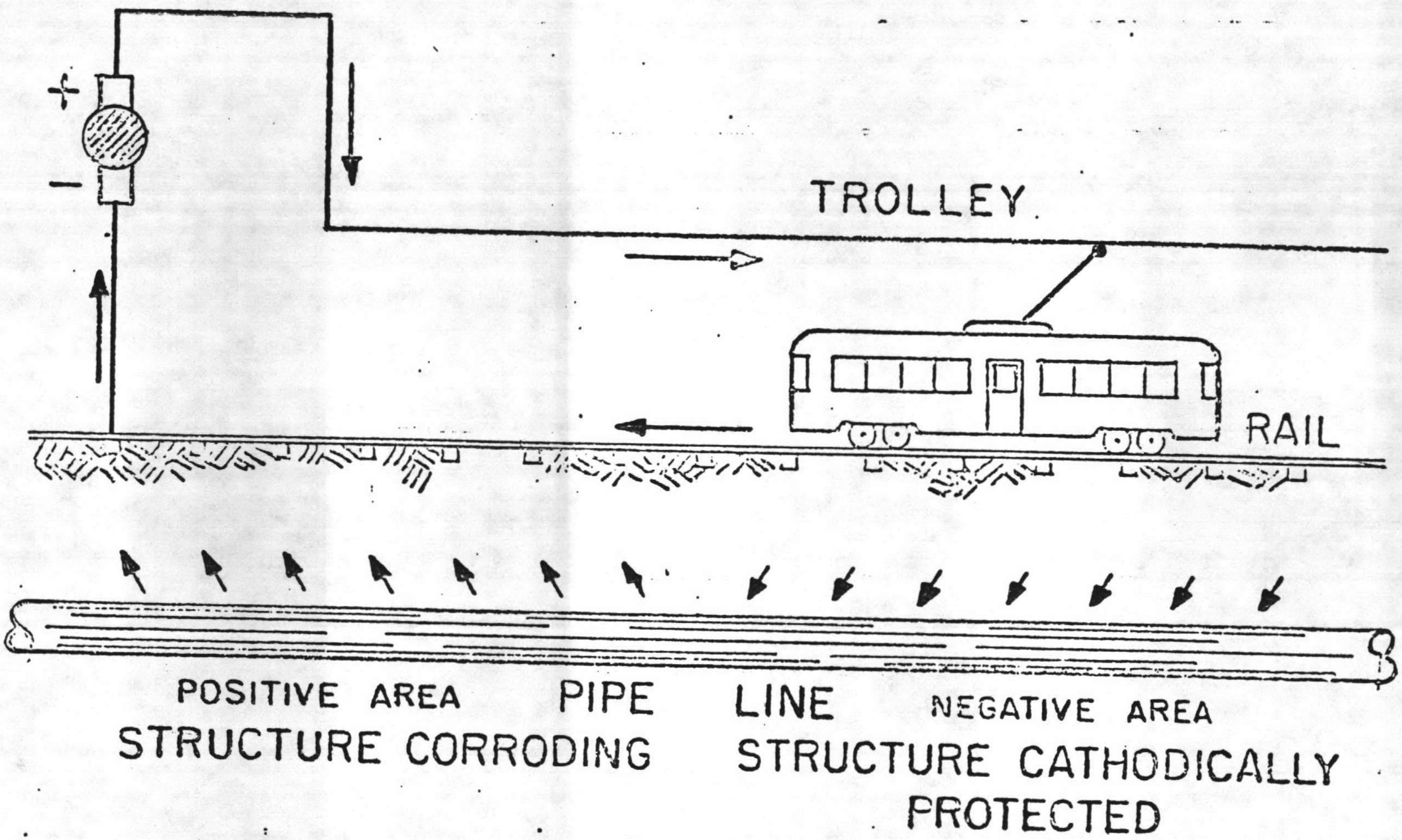
Neutral conductors for underground electrical distribution systems often consist of bare copper cables with the neutrals of transformers and electrical apparatus housings frequently grounded to the neutral conductor. Water piping

for water-cooled transformers and lead-sheath cables is also often grounded to the neutral conductor cable. Once again, the galvanic couples and resulting potential differences between copper and steel and copper and lead is encountered and deterioration of both the steel water piping and lead sheath cable may be reasonably anticipated. The answer to this problem appears to be a neutral conductor provided with a polyethylene or polyvinyl direct burial jacket which will provide insulation between the copper conductor and the earth, and also provide additional self-contained grounding rods.

Any underground power cable equipped with an adequate polyvinyl or plyethylene jacket will not be influenced by stray current from cathodic protection systems or other stray current sources. Certainly, the lead sheath cable, which parallels a cathodically-protected structure or lays within the area of influence of cathodic protection installations, is receptive to pickup and uncontrolled discharge of stray current resulting in metal deterioration. Interference testing and adequate bonding procedures are the answers to this problem. Lead sheath cable installed in metallic or non-metallic duct systems is not subject to stray current influence, but may be subject to galvanic corrosion action at points within the ducts at which moisture may collect.

Any metallic objects such as pole anchors, grounding rods, cables, or grids which fall within the area of influence of a D.C. current source are exposed to varying degrees of deterioration depending largely upon the metals involved, size of structure, and their proximity to the D.C. current source. In cathodic protection installations, judicious placement of current sources, consistent with design requirements of the structure or system to be protected, is taken into consideration to minimize the possibility of interference on foreign structures. Prior to adjustment and checkout of a protective system, native state potential values on all foreign structures within the area of influence of the current source should be acquired. Upon energizing and adjusting the protective system, potential measurements on the foreign structures involved are again acquired to determine any effects being experience from stray current. In the event that detrimental interference effects on a foreign structure are detected, the situation is relieved by either providing a controlled resistance bond from the affected structure to the current source or providing the affected structure with a small protetive system of its own, normally in the form of self-contained sacrificial anodes. The problems involved, particularly in congested areas involving a number of utilities with the

effects of stray current or interference can be complex in nature and costly in results, unless corrected. As in the case of design, installation, and checkout of protective systems, the detection and correction of interference problems can best be solved by personnel experienced in the specialized field of corrosion mitigation.



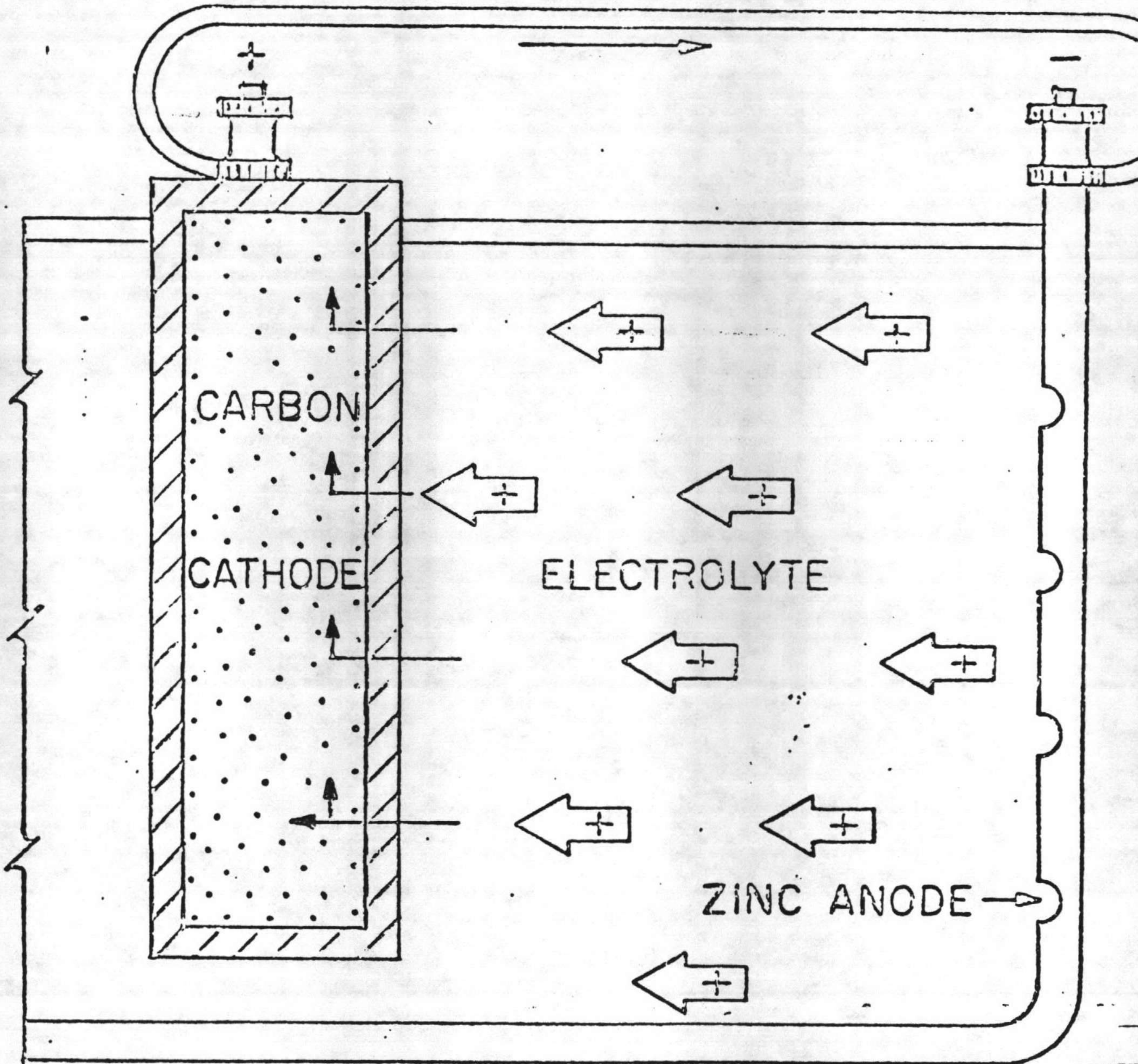
ELECTROLYSIS CORROSION

FIGURE 1

ELECTROMOTIVE FORCE SERIES

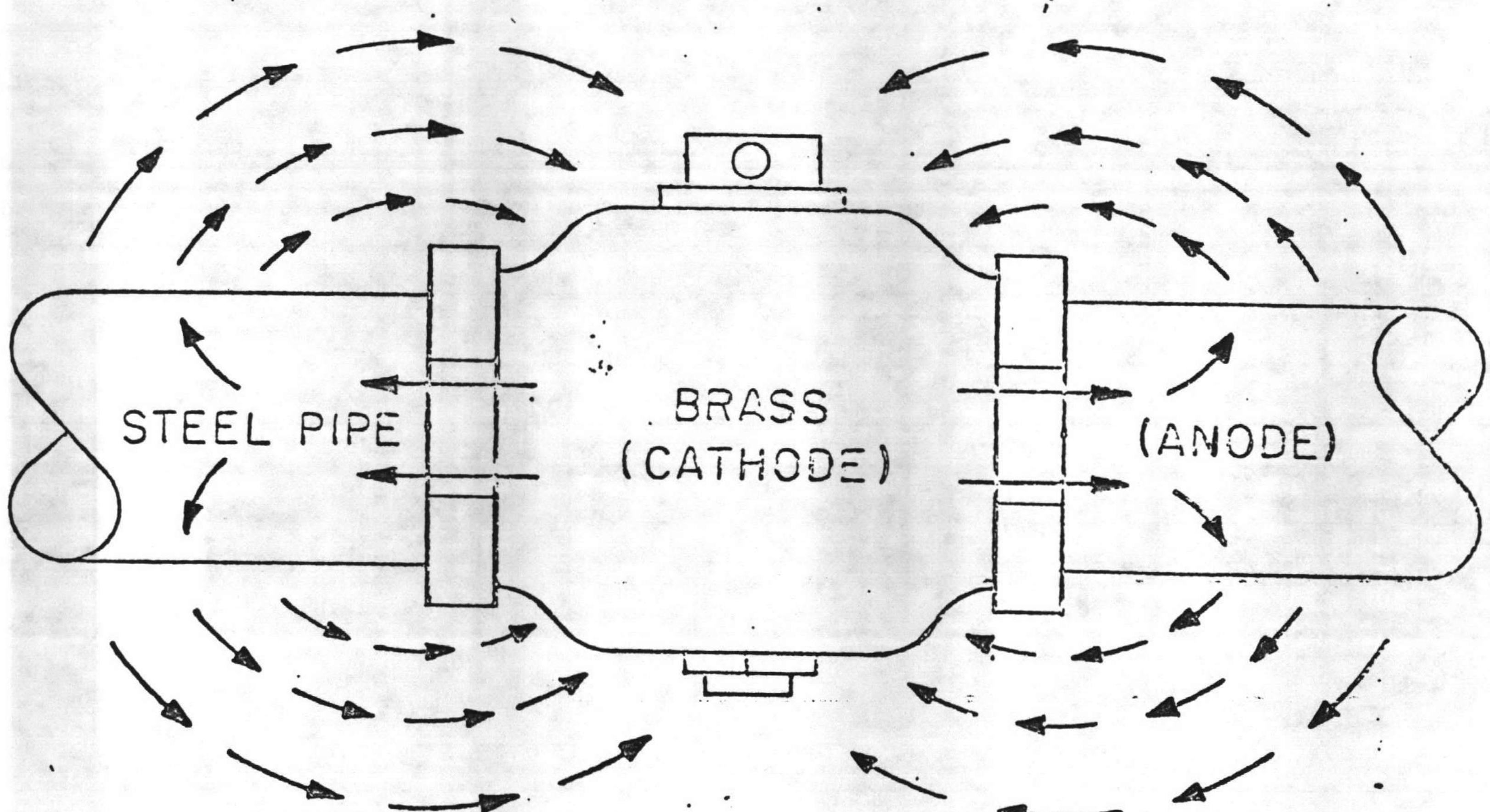
Electrode Reaction		Standard Electrode Potential E^0 (Volts), 25^0 C
Magnesium -	$Mg^{++} +2e^-$	-2.34
Zinc	$Zn^{++} +2e^-$	-0.762
Iron	$Fe^{++} +2e^-$	-0.440
Lead	$Pb^{++} +2e^-$	-0.126
Hydrogen	$ZH^+ +2e^-$	-0.00
Copper	Cu^+ _e⁻	+0.522

FIGURE 2



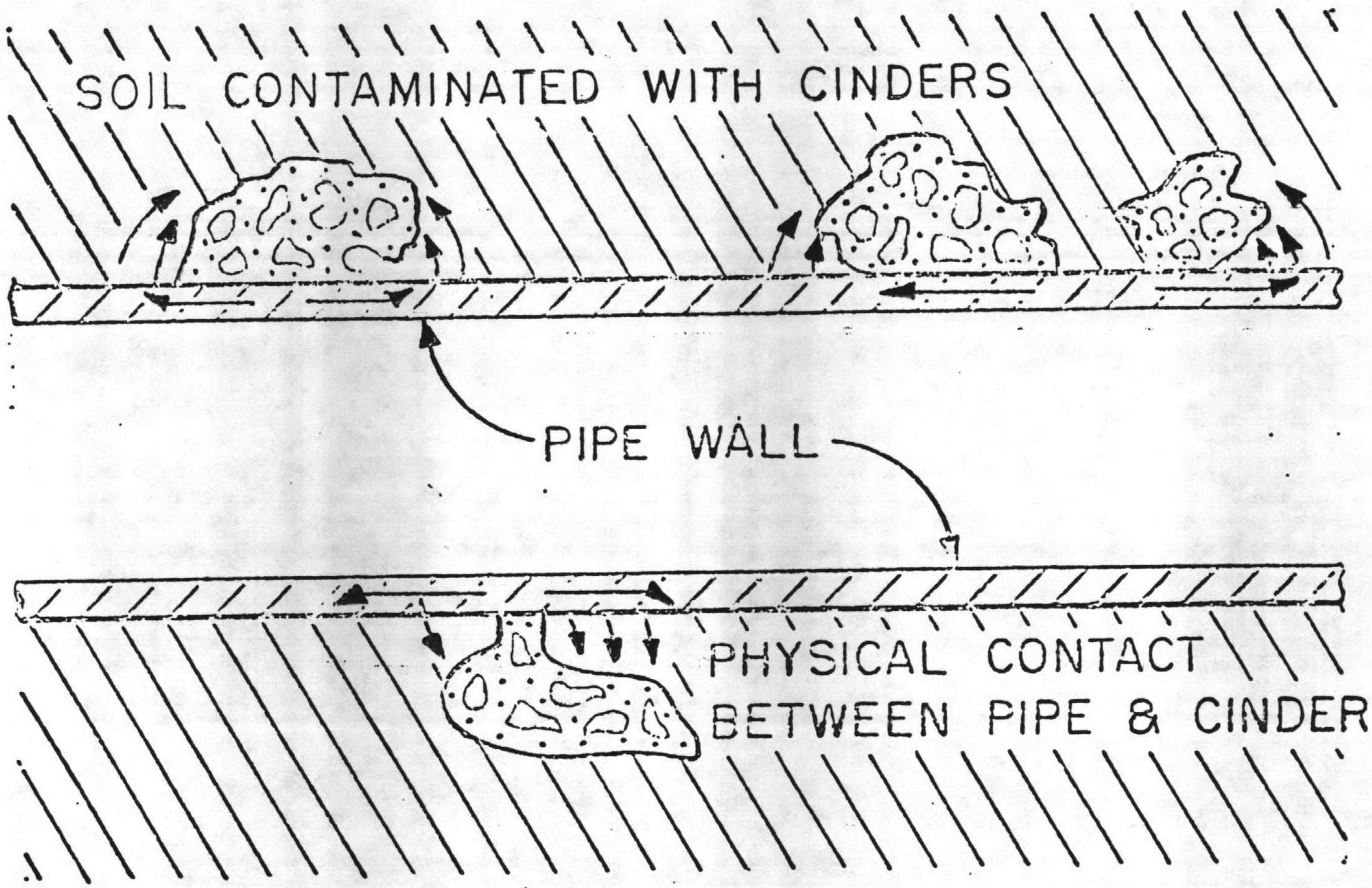
GALVANIC CELL - DISSIMILAR METALS

FIGURE 3



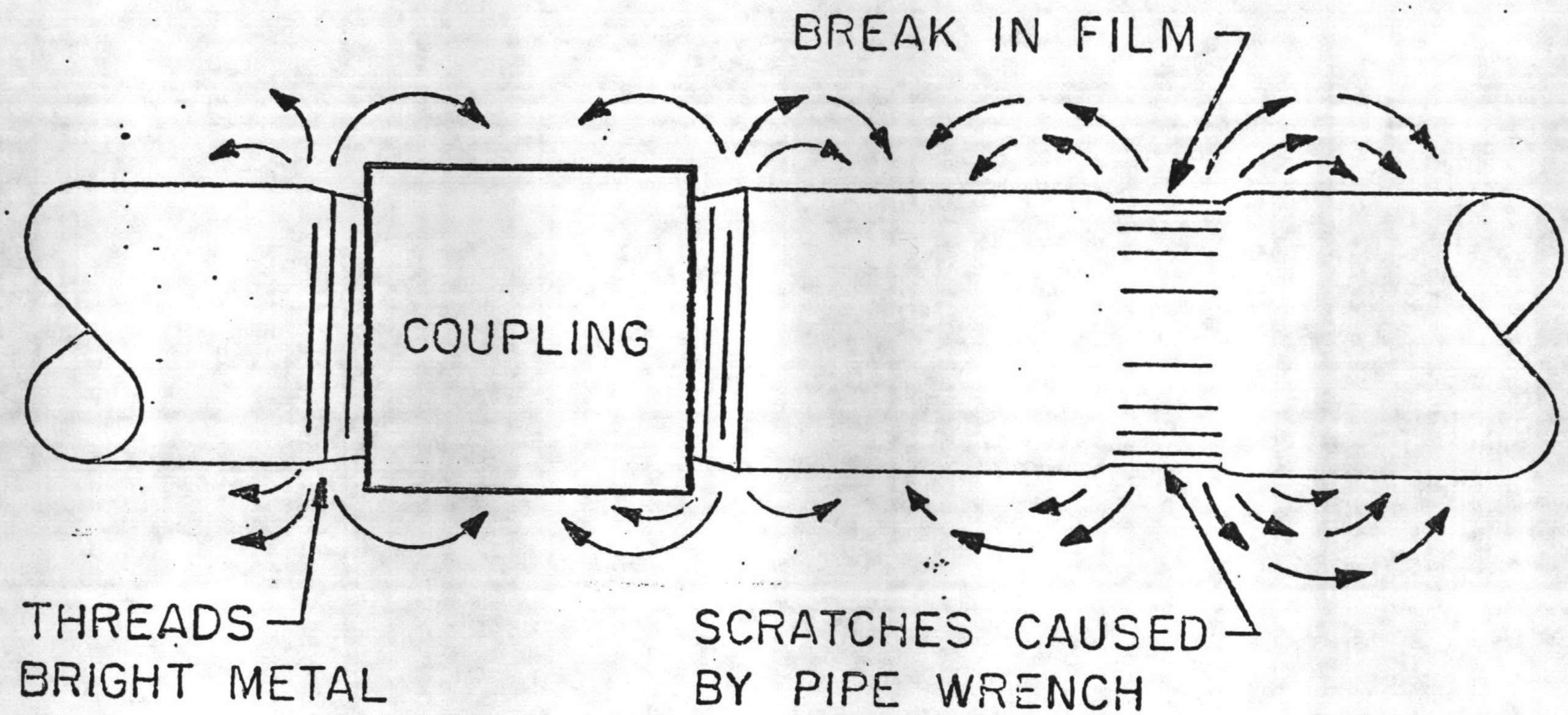
CORROSION CAUSED BY DISSIMILAR METALS

FIGURE 4



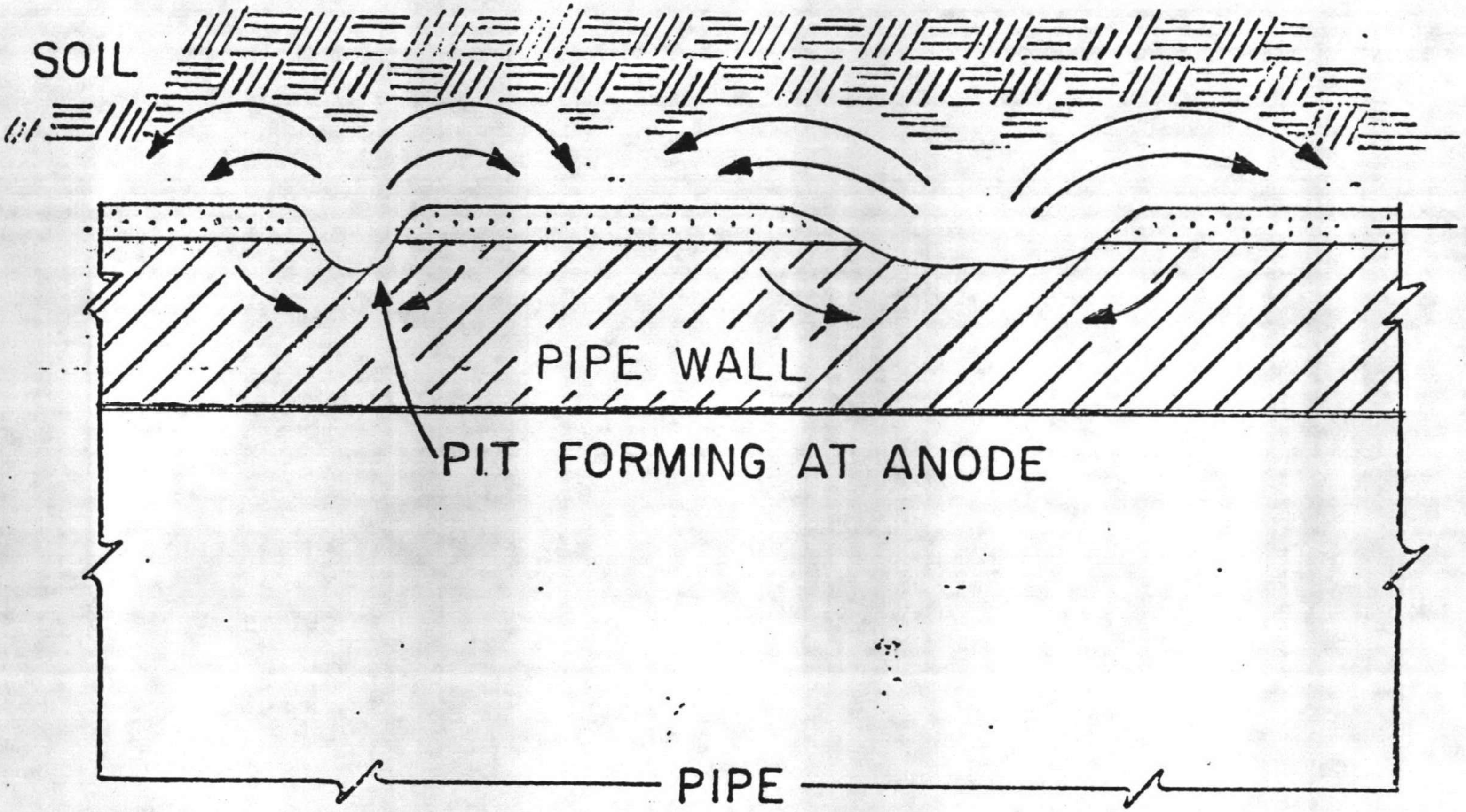
CORROSION DUE TO CINDERS

FIGURE 5



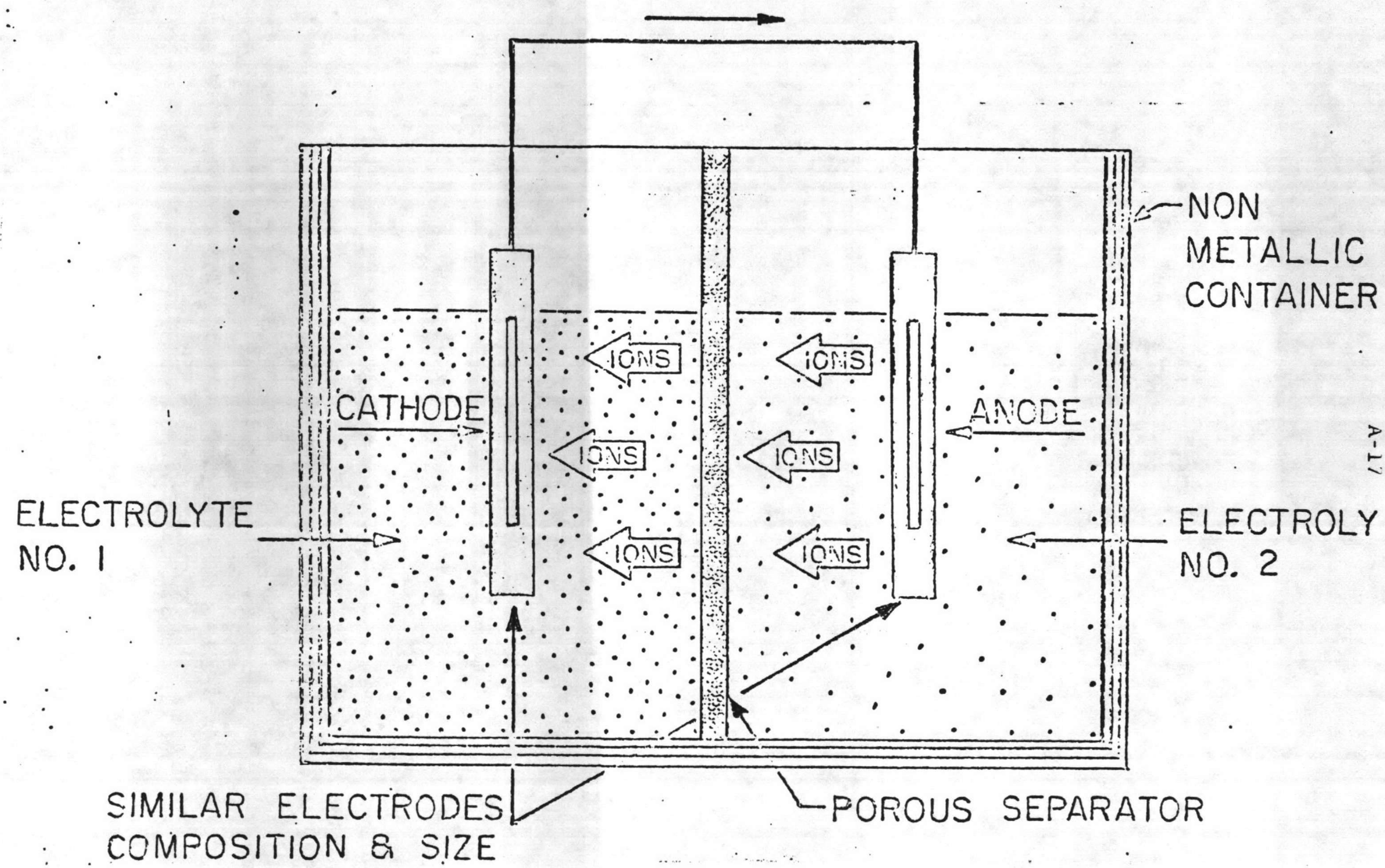
CORROSION CAUSED BY DISSIMILARITY OF SURFACE CONDITIONS

FIGURE 6



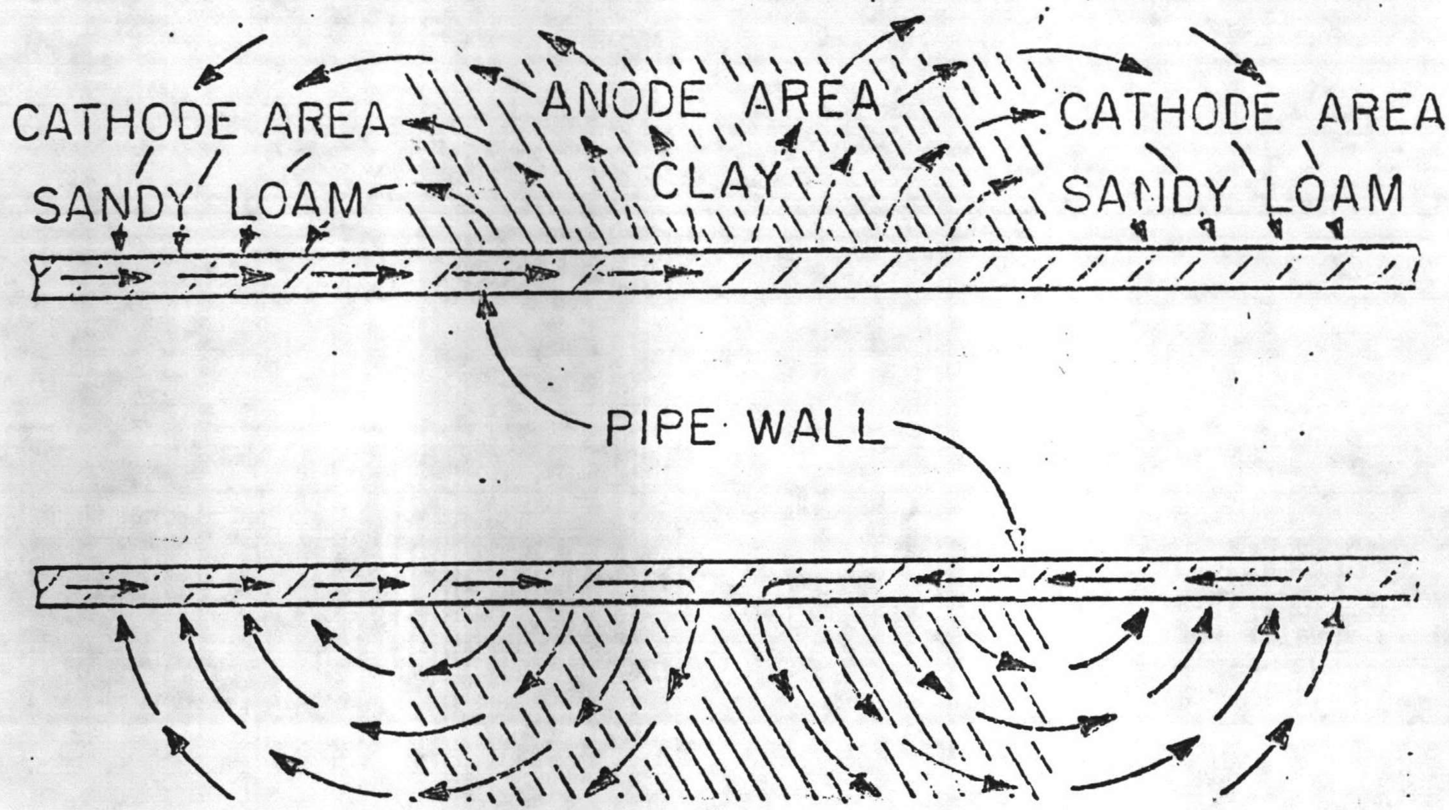
PITTING DUE TO MILL SCALE

FIGURE 7



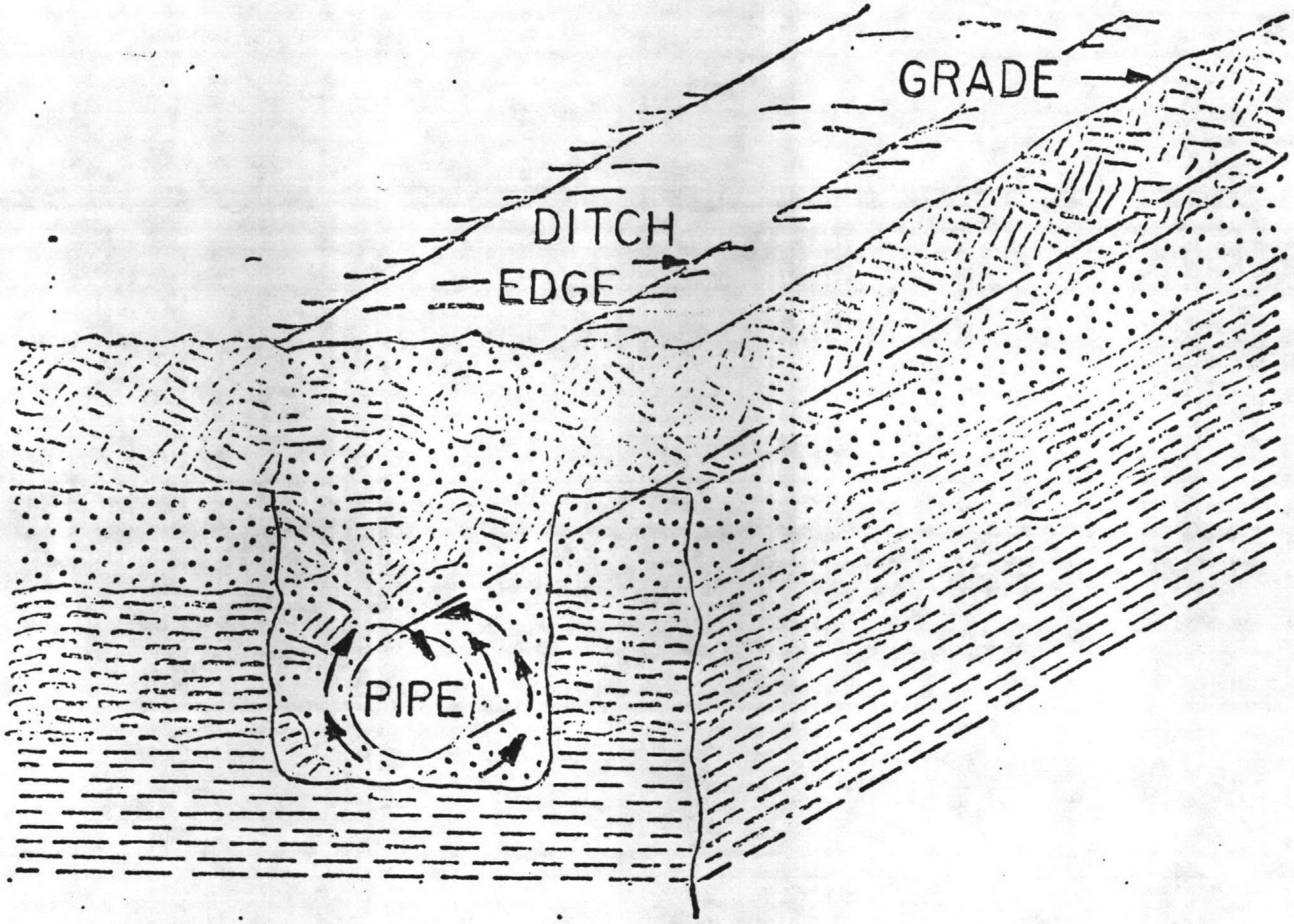
GALVANIC CELL - DISSIMILAR ELECTROLYTE

FIGURE 8



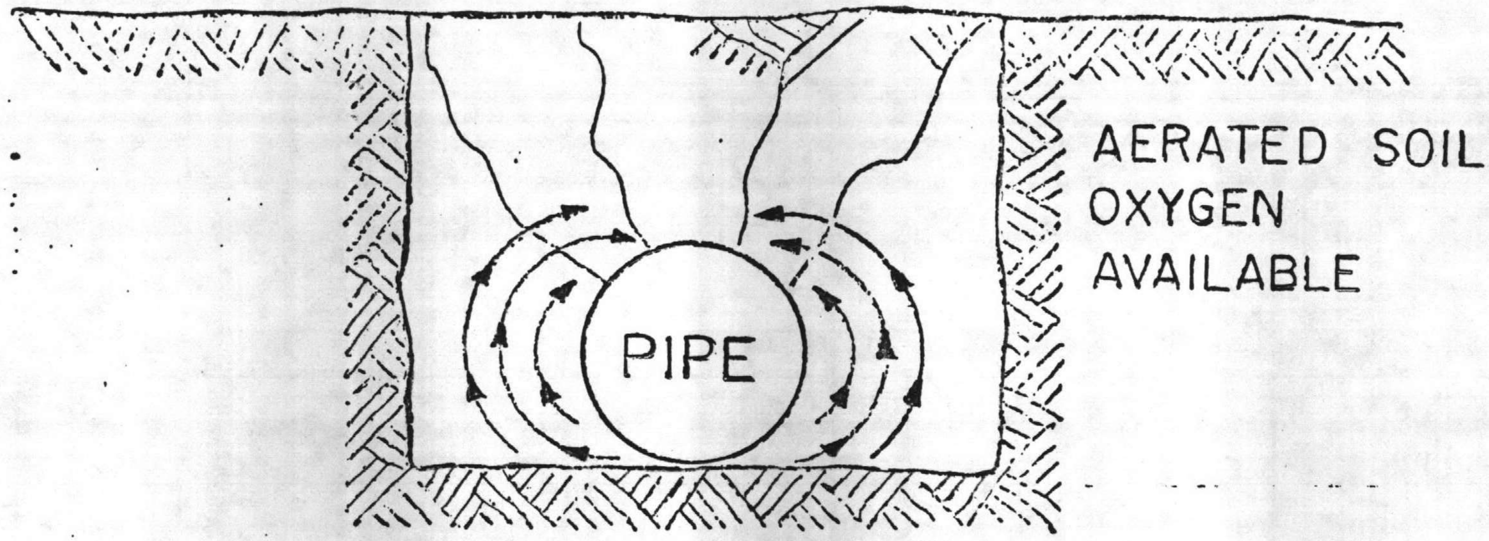
CORROSION CAUSED BY DISSIMILAR SOILS

FIGURE 9



CORROSION CAUSED BY MIXTURE OF DIFFERENT SOILS

FIGURE 10



CORROSION CAUSED BY DIFFERENTIAL AERATION OF SOIL

FIGURE 11

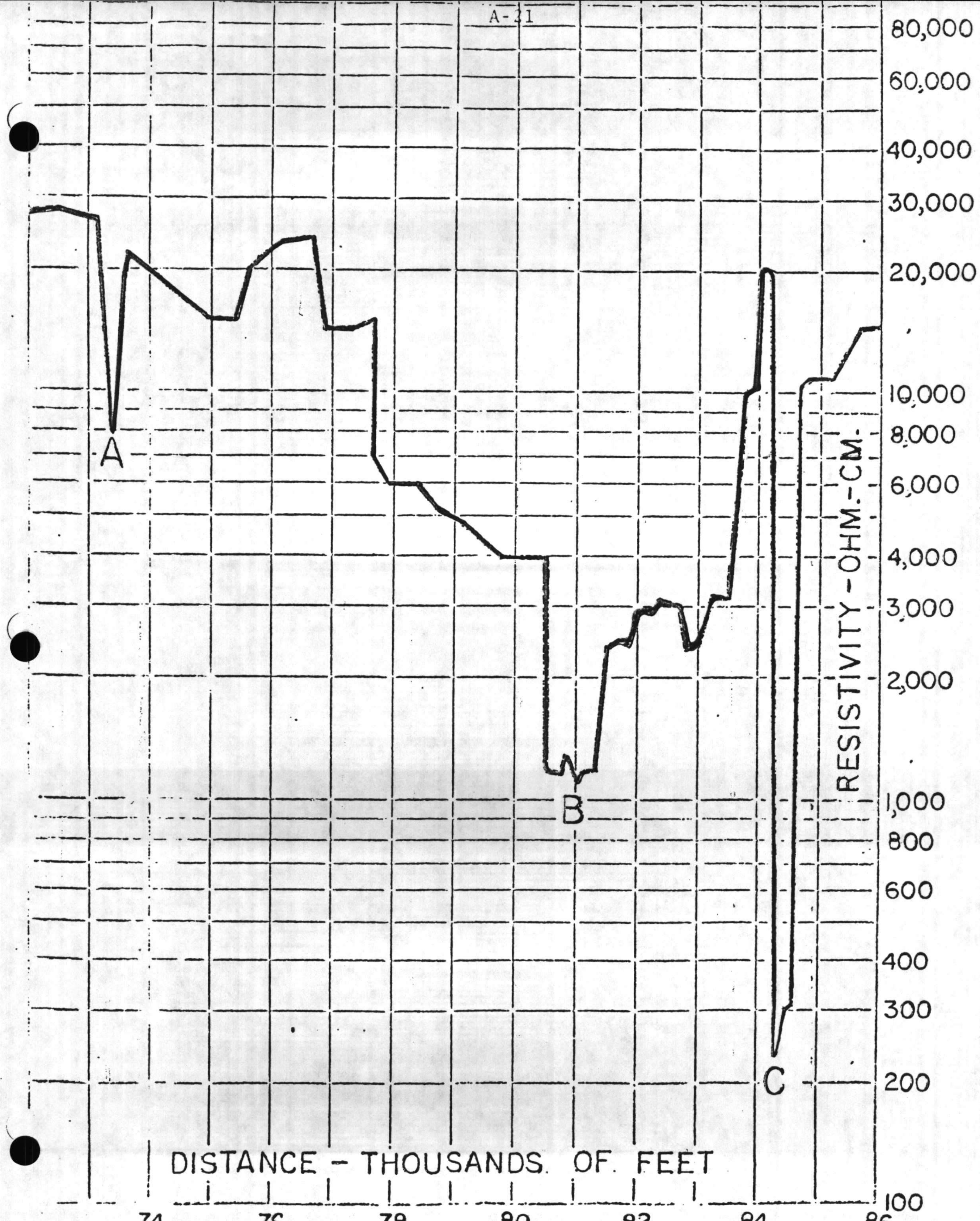
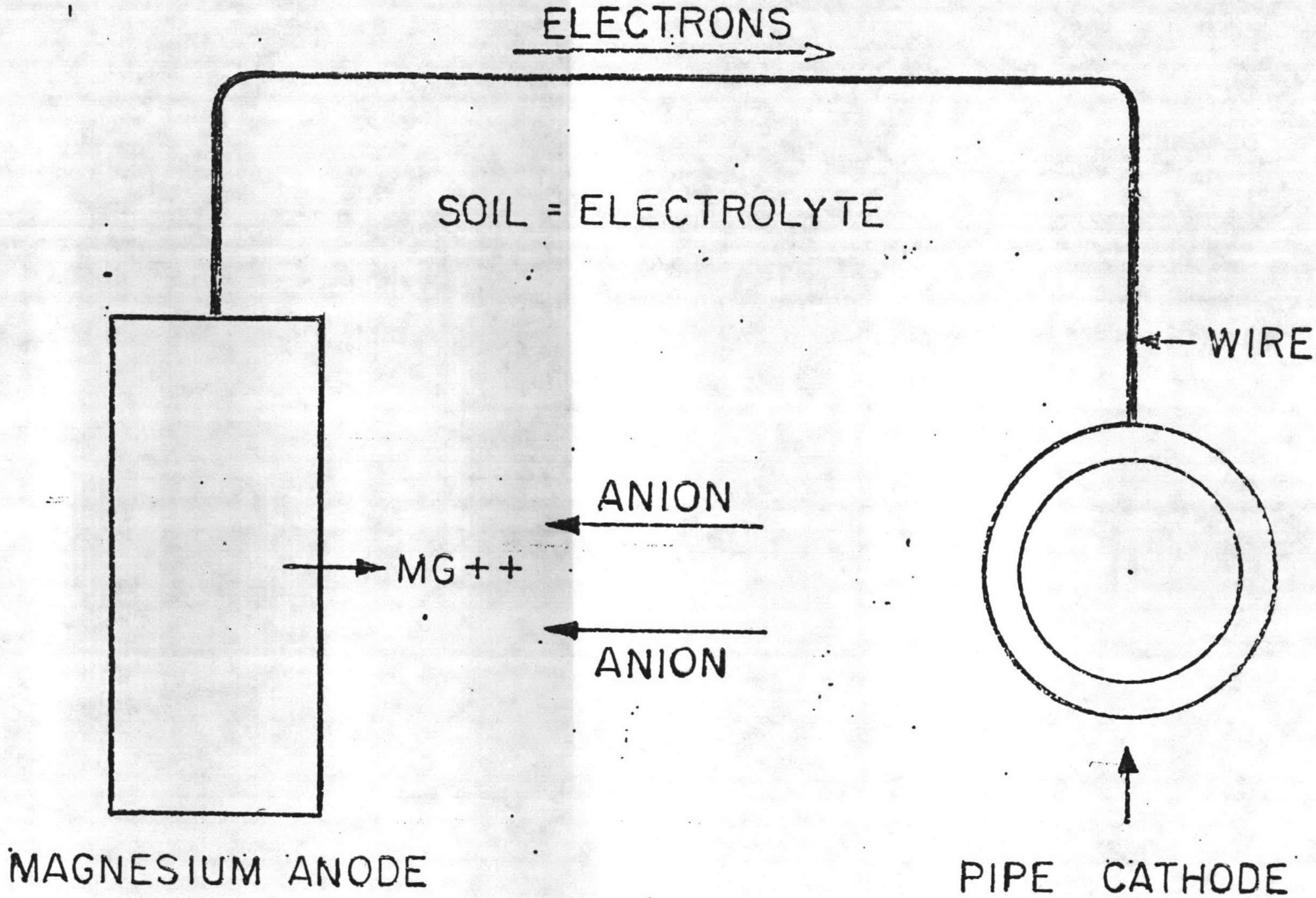
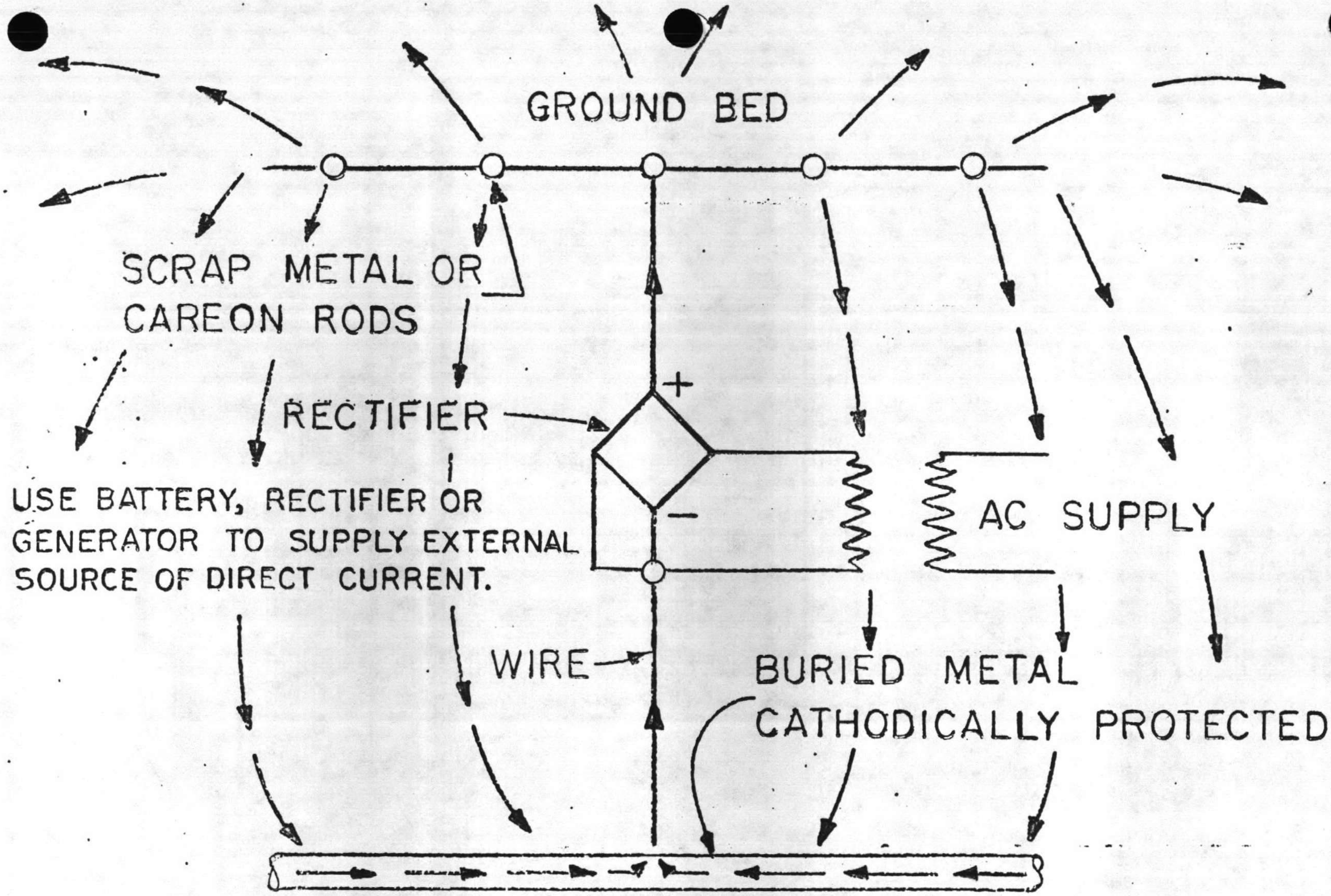

80,000
60,000
40,000
30,000
20,000
10,000
8,000
6,000
4,000
3,000
2,000
1,000
800
600
400
300
200
100
RESISTIVITY - OHM.-CM.
A
B
C
DISTANCE - THOUSANDS OF FEET
74
76
78
80
82
84
86

FIGURE 12



THE CATHODIC PROTECTION BATTERY

FIGURE 13



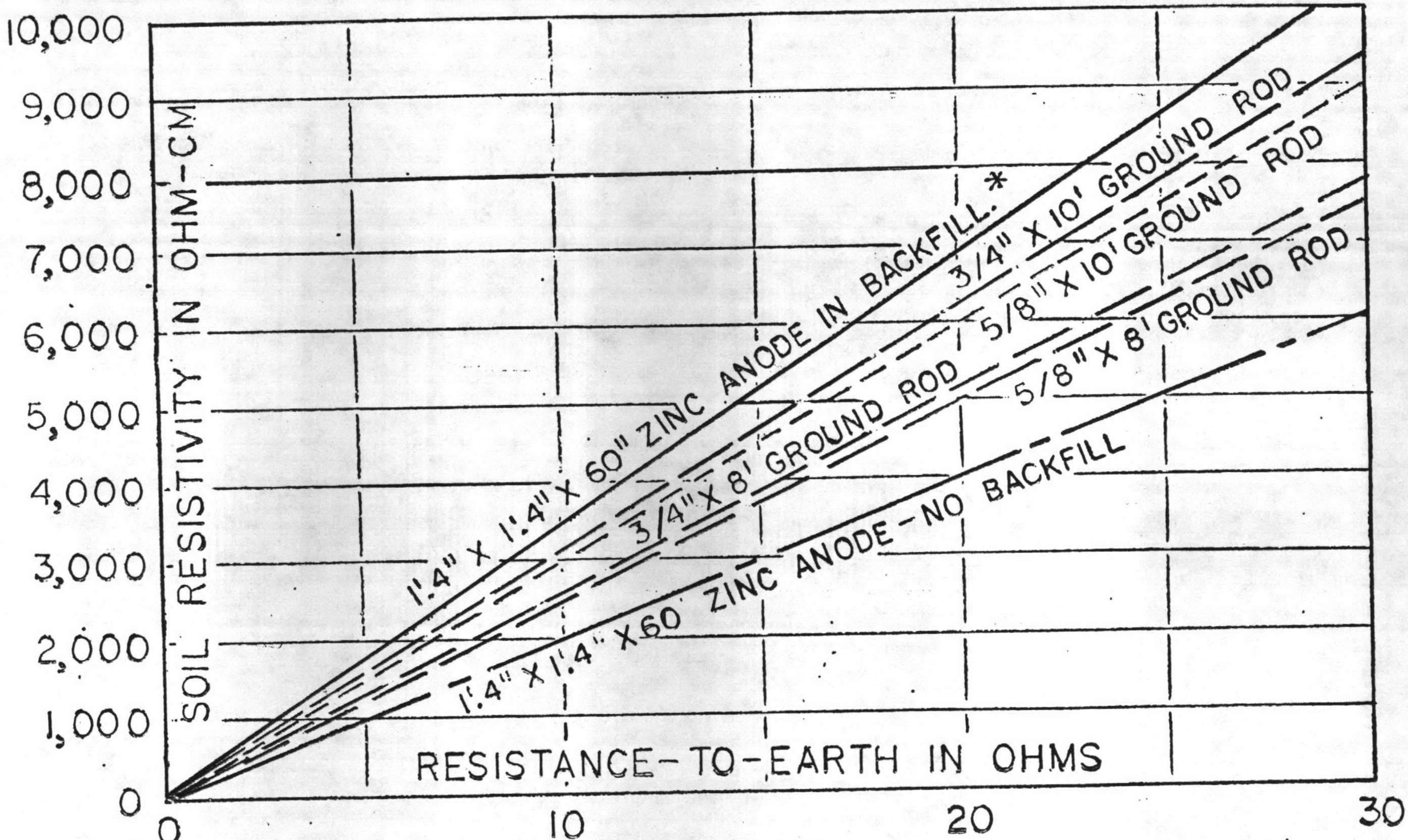
SCHEMATIC DIAGRAM OF CATHODIC PROTECTION OF BURIED METALS

FIGURE 14

GALVANIC COUPLE POTENTIALS

Galvanic Couple	Voltage Difference Volt
Iron-copper	0.55
Aluminum-copper	1.55
Lead-copper	0.45
Zinc (galvanizing)-copper	0.99

FIGURE 15



RESISTANCE OF ZINC ANODE VS COPPER CLAD GROUND RODS

FIGURE 16

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APPENDIX G

PHOTOGRAPHS

PHOTO NO. 1 EXISTING RECTIFIER AT TANK FARM (ABANDONED)

PHOTO NO. 2 TANK FARM AREA LOOKING NORTH-EAST

PHOTO NO. 3 ELEVATED WATER STORAGE TANK NO. 4130

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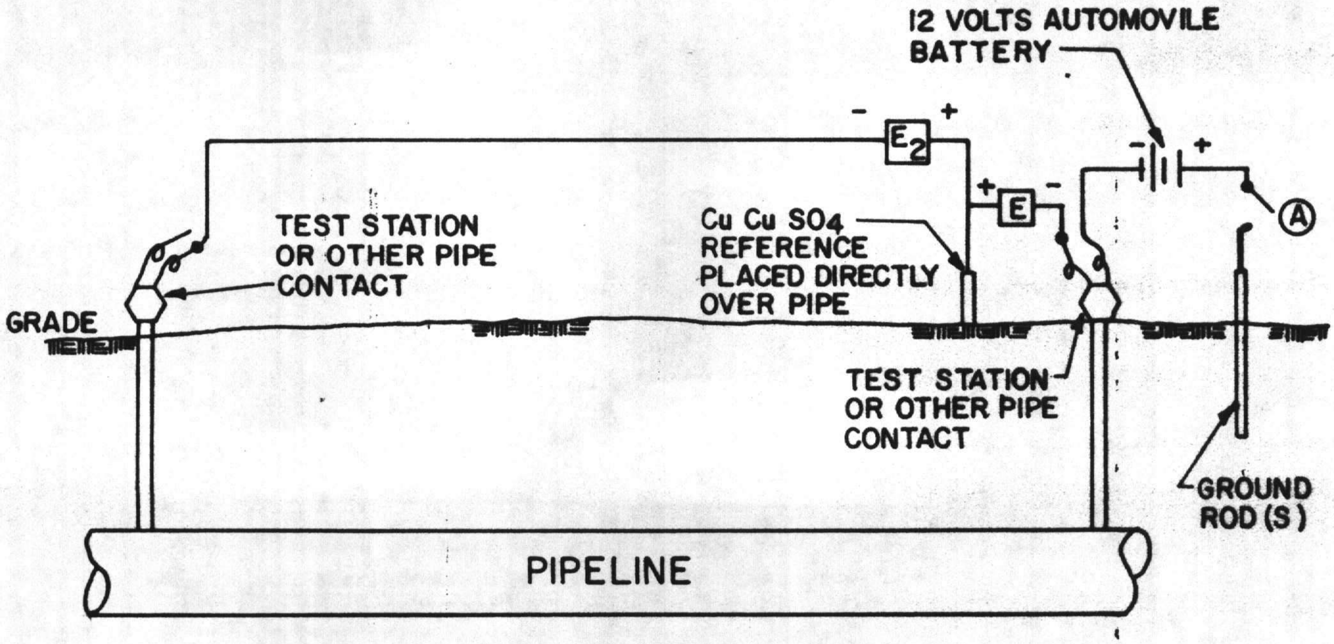
APPENDIX H

DRAWINGS



TEST PROCEDURE

1. ESTABLISH POSITIVE ELECTRICAL CONTACT TO THE PIPE AT EACH EXTREMITY OF SECTION TO BE TESTED.
2. WITH THE SWITCH AT (A) OPEN AND CLOSED, ELECTRICAL CONTINUITY FROM TEST STATION IS INDICATED WHEN E_1 AND E_2 ARE THE SAME MAGNITUDES.
3. WITH THE SWITCH AT (A) OPEN AND CLOSED, ELECTRICAL DISCONTINUITY FROM TEST STATION TO TEST STATION IS INDICATED WHEN E_1 AND E_2 ARE DIFFERENT MAGNITUDES.

MDA MENENDEZ - DONNELL & ASSOCIATES, INC.
GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELECTRICAL CONTINUITY TEST
UNDERGROUND PIPELINE

NO.	REVISION	DATE	DES DR H.D.V. SCALE NONE	CK APP DATE 10-15-84	DWG NO. SK-6148-A	REV

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ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA

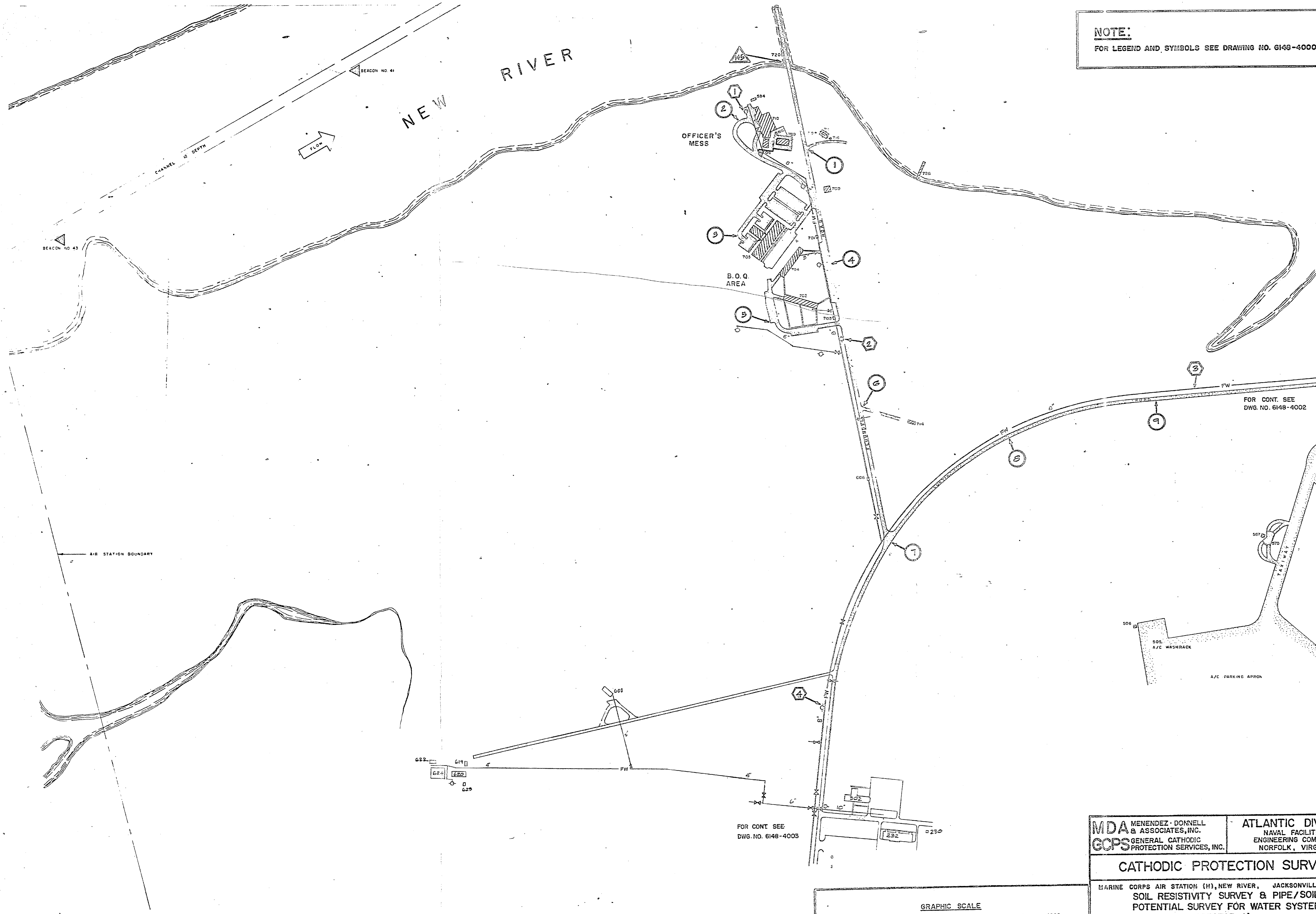
CATHODIC PROTECTION SURVEY

MARINE CORPS AIR STATION (H), NEW RIVER, JACKSONVILLE, N.C.

STATION MAP

DES.	CK. J. MESZAROS	DWG. NO.	REV.
DR. J. CRUZ	APP.	6148-4000	
SCALE GRAPHIC	DATE DEC. 14, 1984		

NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-4000



GRAPHIC SCALE
200 100 0 200 400 600 800 1000
SCALE 1" = 200'-0"

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CATHODIC PROTECTION SURVEY

MARINE CORPS AIR STATION (H), NEW RIVER, JACKSONVILLE, N.C.
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (SECTOR 1)

DES. DR. C. BEST SCALE GRAPHIC	CK. J. MESZAROS APP. DATE DEC. 14, 1984	DWG. NO. 6148-4001 REV.

NOTE:

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CATHODIC PROTECTION SURVEY

MARINE CORPS AIR STATION (H), NEW RIVER, JACKSONVILLE, N.C.

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (SECTOR 2)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE DEC. 14, 1984	DWG. NO. 6148-4002 REV.

NOTE:

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ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS AIR STATION (H), NEW RIVER, JACKSONVILLE, N.C.

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (SECTOR 3)

DES. DR. C. BEST SCALE GRAPHIC	CK. J. MESZAROS APP. DATE DEC. 14, 1984	DWG. NO. 6148-4003	REV.

NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-4000

GRAPHIC SCALE

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CATHODIC PROTECTION SURVEY

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SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (SECTOR 4)

DED DR. C. BEST SCALE GRAPHIC	CK. J. MESZAROS APP. DATE DEC. 14, 1984	DWG. NO. 6148-4004 REV.

NOTE:

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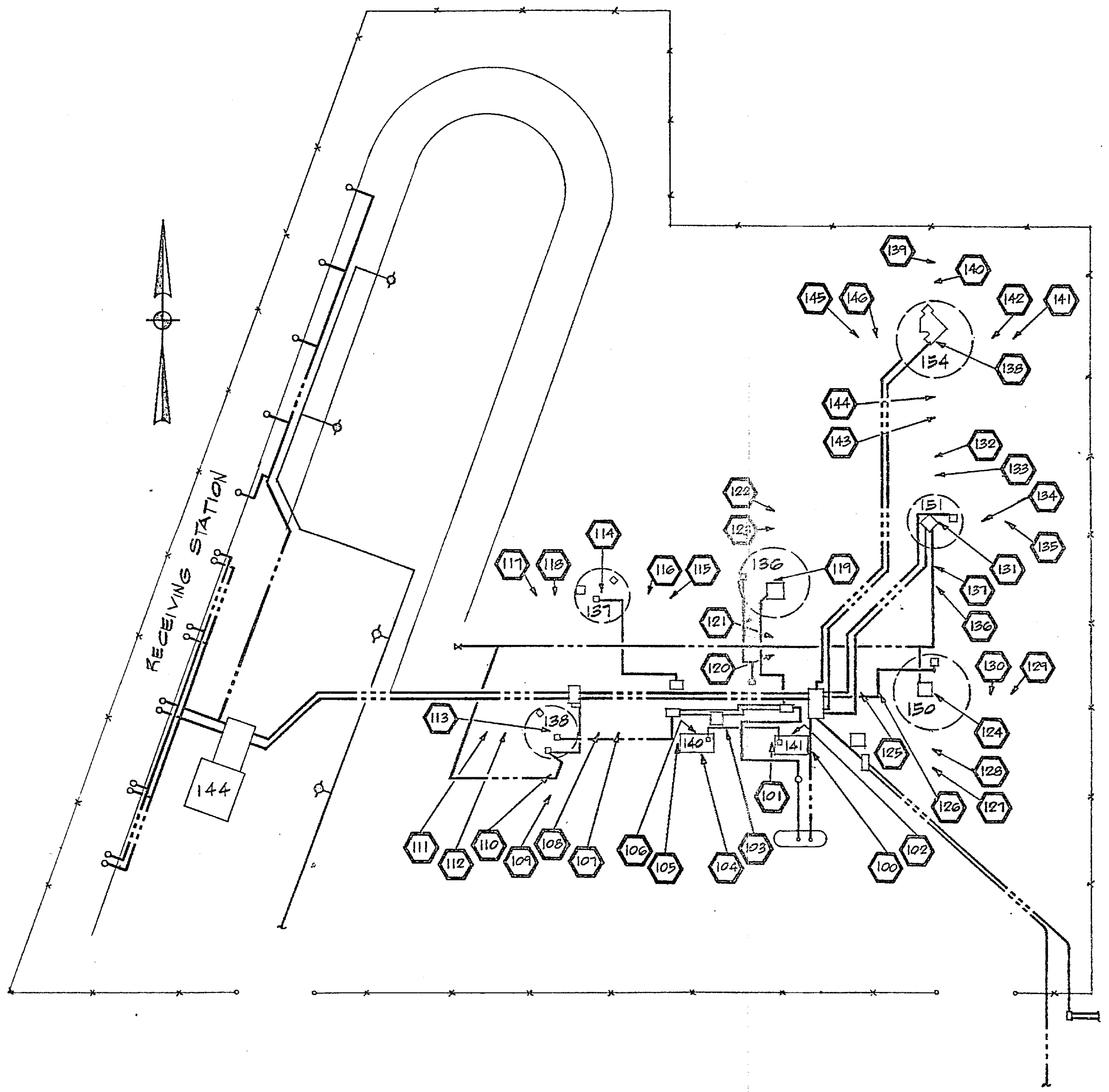
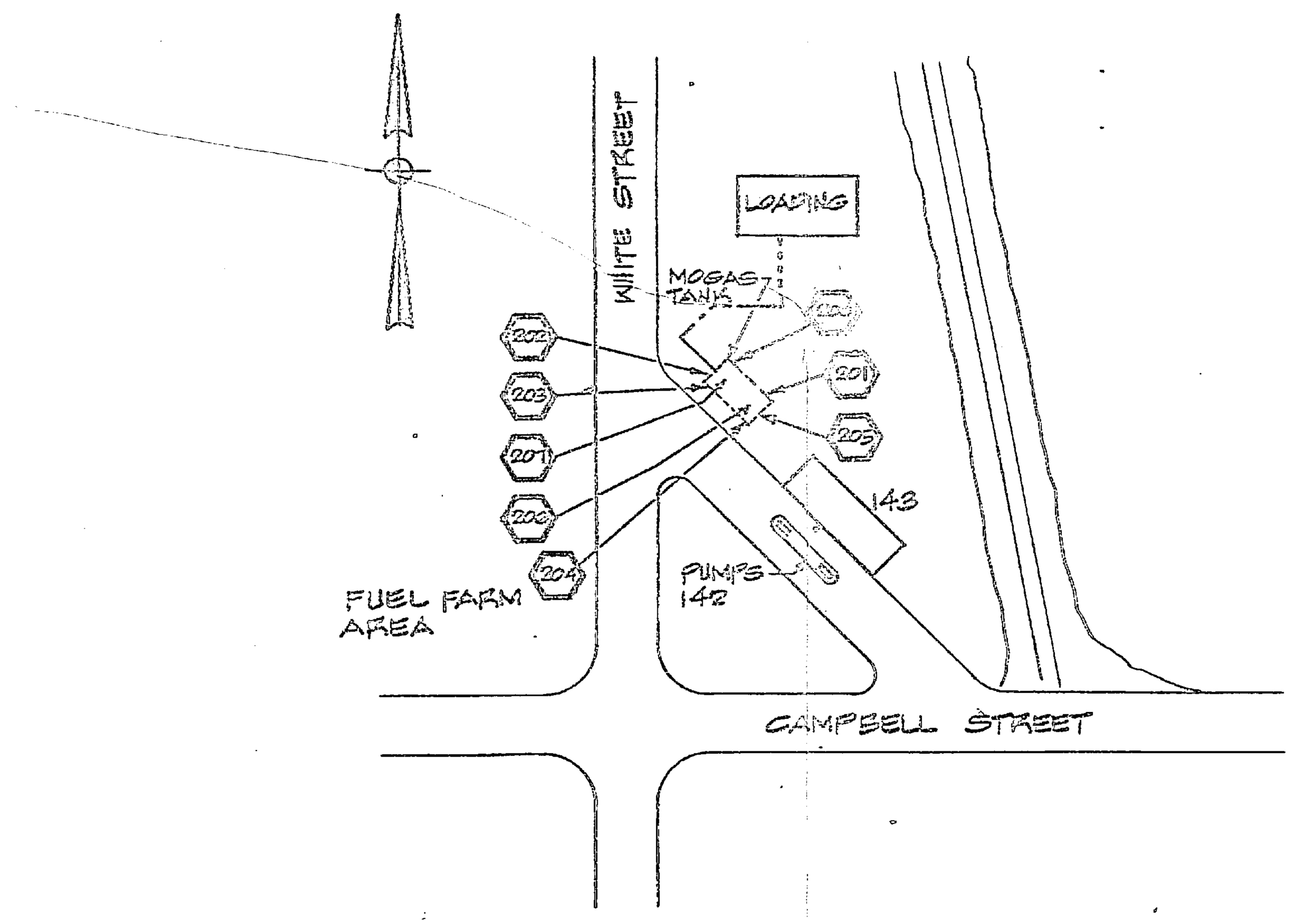


PIPING PLAN AT FUEL FARM AREA

SCALE 1"=40'-0"



UNDERGROUND MOGAS TANK AT BLDG. 143

NOT TO SCALE

GRAPHIC SCALE

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SCALE 1" = 40'-0"

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CATHODIC PROTECTION SURVEY

MARINE CORPS AIR STATION (H), NEW RIVER, JACKSONVILLE, N.C.

POTENTIAL SURVEY FOR POL SYSTEMS

DES DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE DEC. 14, 1984	DWG. NO. 6148-4005	REV.