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A Report on the Investigation of the Corrosion of the Underground Gas and Water System at the Stockton Fair Grounds, 2nd D.A.A.

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Stratfull, R.F. and W.L. Flaxa

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16. ABSTRACT

On May 11, 1959, Mr. Aldo Crestetto, Civil Engineering Supervisor, Division of Architecture, requested by letter that the Materials and Research Department perform a corrosion survey at the Stockton Fair Grounds, 2nd D.A.A., under the Inter-Agency Agreement S.A. 2094, and Work Order No. 4296SC. It was requested that the survey be made to determine the extent of damage to the existing gas line as well as recommendations for alleviation of the problem.

A second letter was received on August 19, 1959, from Mr. Crestetto requesting that the survey be made after the fair which ended August 29, 1959. In this letter it was requested that a survey also be run on all underground piping.

Historically, the underground piping system was installed in about 1955. By 1959 the leaks in the gas line had caused the gas bill to be approximately quadrupled. A leak was found and repaired. However, the total leakage was reduced only by one-third. After the fair ended the gas line was disconnected near the Agriculture Building, and 2,000 lineal feet of gas pipe service to the Jockey Building was put out of service. Another gas line leak was found and repaired in an old gas line that served the old golf club house. In addition to the perforations in the gas line, three water line leaks were found and repaired by the Fair Grounds Maintenance crew.

A corrosion study was made by the Materials and Research Department during the week of November 30, 1959, at the Stockton Fair Grounds, 2nd D.A.A., in Stockton. The results of this corrosion survey are included in this report.

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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

A REPORT ON THE INVESTIGATION OF THE CORROSION OF THE UNDERGROUND GAS AND WATER SYSTEM AT THE STOCKTON FAIR GROUNDS, 2nd D.A.A.

60-02

January 1960

MATERIALS & RESEARCH DEPARTMENT

State of California
Department of Public Works
Division of Highways
Materials and Research Department

January 1960

Lab. Project Auth. 72-S-6184

Mr. Anson Boyd
State Architect
Division of Architecture
1120 N Street
Sacramento, California

Attention: Mr. Aldo Crestetto, Civil Engineering Supervisor

Dear Sir:

Submitted for your consideration is:

A REPORT ON

THE INVESTIGATION OF THE CORROSION OF

THE UNDERGROUND GAS AND WATER SYSTEM AT THE

STOCKTON FAIR GROUNDS, 2nd D.A.A.

Study made by . . . . Structural Materials Section
Under general direction of . . . . J. L. Beaton
Work supervised by . . . . R. F. Stratfull
Report prepared by . . . . R. F. Stratfull and W. L. Flaxa

Very truly yours,

F. N. Hveem
Materials and Research Engineer

RFS:mw
cc: JWTrask
Richard Walker, Fair Mgr.
Donald Van Riper
OEAnderson
ISchultz
HGMyers
Dist. X (2)

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I. INTRODUCTION

On May 11, 1959, Mr. Aldo Crestetto, Civil Engineering Supervisor, Division of Architecture, requested by letter that the Materials and Research Department perform a corrosion survey at the Stockton Fair Grounds, 2nd D.A.A., under the Inter-Agency Agreement S.A. 2094, and Work Order No. 4296SC. It was requested that the survey be made to determine the extent of damage to the existing gas line as well as recommendations for alleviation of the problem.

A second letter was received on August 19, 1959, from Mr. Crestetto requesting that the survey be made after the fair which ended August 29, 1959. In this letter it was requested that a survey also be run on all underground piping.

Historically, the underground piping system was installed in about 1955. By 1959 the leaks in the gas line had caused the gas bill to be approximately quadrupled. A leak was found and repaired. However, the total leakage was reduced only by one-third. After the fair ended the gas line was disconnected near the Agriculture Building, and 2,000 lineal feet of gas pipe service to the Jockey Building was put out of service. Another gas line leak was found and repaired in an old gas line that served the old golf club house. In addition to the perforations in the gas line, three water line leaks were found and repaired by the Fair Grounds Maintenance crew.

A corrosion study was made by the Materials and Research Department during the week of November 30, 1959, and also the week of December 7, 1959, at the Stockton Fair Grounds, 2nd D.A.A., in Stockton. The results of this corrosion survey are included in this report.

II. SUMMARY AND CONCLUSIONS

The predominant cause of the corrosion is the electrical connection of piping buried in soil to steel embedded in concrete. A secondary cause of corrosion is the electrical interconnection of the new pipe to portions of the old golf course sprinkler system.

In the general area of the Administration and Agriculture Buildings, the fair grounds piping is receiving partial corrosion protection via the P. G. & E. gas line. The P. G. & E. gas line is not electrically disconnected from the fair grounds piping nor from the piping in adjacent properties.

As there will be a cost involved in locating the existing leaks in the now disconnected 2,000 feet of gas line servicing the Jockey Building, it is suggested that an economic analysis be made of the cost of placing about 500 feet of new gas pipe and abandoning the leaking 2,000 feet of pipe. Abandoning the existing pipe would eliminate a cathodic protection station and also eliminate the necessity of placing new pipe around the grandstand area.

It is recommended that the underground pipe be placed under low voltage and current cathodic protection for corrosion control. The cost of the cathodic protection system is estimated at approximately $4,000.00.

III. RECOMMENDATIONS

It is recommended that:

1. Six (6) impressed current cathodic protective stations be installed for corrosion alleviation by a competent contractor.

2. The cathodic protection anode beds be installed at the locations indicated on Exhibit II, Equi-Resistivity Contour Map.

3. The Division of Architecture prepare the final plans, specifications, and field inspection of the cathodic protection system.

4. The Division of Architecture make an economic analysis to determine the economics between (a) locating and repairing the leaks in the now disconnected gas line which runs between the Agriculture Building and the Jockey Building, and (b) installing a new gas line from the Jockey Building to a P. G. & E. main in the street south of the Jockey Building.

5. The P. G. & E. gas mains be electrically disconnected from the fair grounds gas lines at the meters.

6. The cathodic protection rectifiers be installed in locations protected from tampering by unauthorized personnel but accessible for convenient adjustment.

7. If any buried utility lines, such as telephone, gas, or water, traverse the general area of the fair grounds, officials of the interested parties be notified of the State's intentions.

8. Proper tests be performed in conjunction with the interested parties to determine if the cathodic protection system at the fair grounds will adversely affect such distribution systems, even if such systems are electrically isolated from the fair grounds.

9. The piping system be checked for electrical continuity prior to the application of cathodic protection.

10. All electrical discontinuities of the piping system or other underground metallic structures be electrically bonded to the piping system.

11. Any repair, connection, or dissimilar metal connected to the piping by this work be heavily coated with

"Pro-Seal" or some equally effective coating to prevent direct metallic contact to the soil.

12. The output of voltage and current of the rectifiers be recorded at weekly intervals for the first six weeks of operation and monthly thereafter.

13. The output of the rectifiers be regulated as required to maintain the piping system at least 0.85 volts negative to a copper sulfate half-cell.

14. The piping system not exceed 2.0 volts negative to a copper sulfate half-cell.

15. Any new piping installed be properly surveyed after installation to determine if protective voltages are within those specified.

16. The Materials and Research Department of the Division of Highways be immediately informed of any changes in rectifier output after the cathodic protection system is installed and accepted by the State.

17. The Materials and Research Department be immediately informed of any additional leaks in the piping system after the installation of the cathodic protection system.

18. At the conclusion of six weeks of operation of the cathodic protection system a equi-potential survey be made.

19. At semi-annual intervals a corrosion survey be made of the piping system to substantiate the effectiveness of such cathodic protection.

20. If the Materials and Research Department of the Division of Highways does not perform the maintenance and observation surveys, they should receive a copy of such survey reports.

IV. TESTS

A. Pipe to Soil Measurements

The flow of galvanic current from a corroding structure can be detected by measuring the electrical voltage drop in the soil around the structure.

The voltage drop, or pipe to soil potentials, of the underground structure was measured with a standard copper sulfate half-cell and a high impedance voltmeter.

The results of the pipe to soil measurements made at the Stockton Fair Grounds are shown on Exhibit I, Equi-Potential Contour Map.

As indicated by the pipe to soil measurements, there are several locations at which the gas and water pipes are now corroding. Anticipated future leaks are marked with the letter "F".

The stability and reproducibility of the pipe to soil potential measurements indicated that the corrosion problem is typically galvanic and is not caused by fluctuating stray electrical current.

As an additional check for stray currents, the pipe to soil potential was automatically recorded for 21 hours. The continuous recording showed there was no voltage variation in 21 hours. As shown by the pipe to soil potentials on Exhibit I, the principal cause of corrosion is the metals in the buildings. The electrical corrosion potentials measured in the vicinity of the buildings indicate that the concrete embedded steel is the predominant cause of the problem. The electrical potentials measured where there were no buildings show that a secondary cause of corrosion is the old golf course sprinkler piping system.

The main P. G. & E. gas distribution line is electrically connected to the piping in the fair grounds and other properties in the general Stockton area. In the area of the Agriculture and Commercial Buildings, corrosion protecting currents are flowing on the fair grounds piping. These protective electrical currents may emanate from or are carried by the P. G. & E. lines in the general Stockton vicinity. Tests were not made to find the exact origin of these protective currents. Because of the electrical interconnection of the P. G. & E. lines to the fair grounds piping and the adjacent Stockton properties, some of the piping in the fair grounds could be caused to corrode by adjacent pipe at locations that were not tested.

B. Electrical Resistivity of the Soil

Since the corrosion of the underground piping is electrochemical in nature, either the presence or the absence of certain chemicals contributes to the magnitude of the galvanic currents developed. Likewise the electrical resistivity of the soil, through which the electrical corrosion currents must flow, has a direct bearing on the rate of corrosion -- the lower the electrical resistivity of the soil, the greater the possible flow of current. In the final analysis a high current flow is directly related to a high rate of corrosion attack.

The electrical resistivity of the soil at the Stockton Fair Grounds is shown on Exhibit II, Equi-Resistivity Contour Map. The earth resistivity measurements in the field show that the soil varies from 600 to 1800 ohm cm. The field average is approximately 1000 ohm cm., which would be classified as a moderately corrosive soil. A laboratory analysis of the soil showed a minimum resistivity of 1200 ohm cm. and a pH of 7.9. These test results indicate that a bare 3/4" pipe placed in this soil could be perforated by corrosion in approximately 20 years.

As will be noted on Exhibit II, Equi-Resistivity Contour Map, the leaks are generally found in the areas where the electrical resistivity of the soils is at a lower value, which is to be expected under galvanic type of corrosion.

C. Miscellaneous Tests

1. Galvanic Current Flow

To determine the amount and the direction of galvanic current flow, measurements were made with a vacuum tube milli-voltmeter and a zero resistance milliameter.

The locations at which the measurements were made are shown on Exhibit III, Locations of Galvanic Current Tests, and results of these tests are shown in the tables below.

Location No. 1 - P. G. & E. gas meter west of the Commercial Building.

Location No. 2 - Gas line entrance at the Administration Building.

Location No. 3 - Gas line entrance at the Agriculture Building.

Location No. 4 - Excavation at the south edge of the paved area between the Commercial Building and the Agriculture Building where the gas line was disconnected.

At Location No. 4 there was a 16 mv open circuit between the pipes and a galvanic current flow of 24 ma in the direction of Location No. 1.

Locations Connected by Milli-Volt-meter	Reading with pipe electrically dis-connected at Location No. 4	Reading with pipe electrically con-nected at Location No. 4	Direction of Flow
Bet. Loc. 1 & 2	30 mv	28 mv	Towards Loc. 1
Bet. Loc. 1 & 3	20 mv	18 mv	Towards Loc. 1
Bet. Loc. 1 & 4	12 mv	14 mv	Towards Loc. 1

With a zero resistance milli-ameter inserted between a disconnected section of pipe, tests were made at the following locations and are shown on Exhibit III, Locations of Galvanic Current Tests:

Location No. 5 - Excavation where the gas pipe was disconnected. The excavation was at the fence that separated the grandstand from the Jockey Building.

Location No. 6 - Gas meter at the Jockey Building where the gas was disconnected in order to connect a butane tank for temporary gas service.

The reading that was made with the pipe temporarily electrically connected at Location No. 5 and dis-connected at Location No. 6 was 0.4 ma with negative toward the Jockey Building. With the pipe electrically connected at Location No. 6 and disconnected at Location No. 5, the current flow was 28 ma with negative towards the grandstand.

The voltage difference in the gas pipe at the gas meter on the Jockey Building was automatically recorded for 17 hours.

The continuous recording showed no voltage change in the 17 recorded hours.

2. Cathodic Protection Requirements

There are approximately 4,000 sq. ft. of pipe surface shown on the plans. The amount of additional piping contained in the old piping and golf course sprinkler system, etc. is not known since it could not be located and was not completely recorded on existing plans.

The piping was not tested to determine the actual amount of current required to protect the system because of the electrical connections of the P. G. & E. distribution line and the Fair Grounds piping.

The anode beds, as shown in Exhibit II, Equi-Resistivity Contour Map, were designed from theoretical calculations of current requirements. The current requirements for the anode beds were calculated by estimating 0.005 amperes per square foot of underground gas and water pipe.

V. CAUSE OF CORROSION

The fundamental cause of the corrosion as noted previously is galvanic. Galvanic corrosion is the result of dissimilar metals being electrically connected in a similar electrolyte, or similar metals being electrically connected in a dissimilar electrolyte. In the sense used here, an electrolyte is considered to be a soil or water that will allow or carry an electrical current flow.

At the Stockton Fair Grounds the following corrosion conditions were found:

1. The steel in concrete in the buildings is electrically connected to the piping system and is causing the pipe buried in soil to corrode.

2. The old piping and golf course sprinkler system is electrically connected to the new piping system and is causing the new piping to corrode.

3. The Fair Grounds piping was not electrically disconnected from the P. G. & E. gas distribution main at the three service locations.

VI. DISCUSSION

A. Electrical Interconnection of Underground Structures

Usually when a metallic pipe is buried in the earth, the possibility of corrosion will depend upon the differences in the environment of the system. For instance, when a network of different types of metallic pipes is placed in a corrosive soil and electrically inter-connected, conditions that create the corrosion voltage are built into the system. The rate of corrosion will usually be controlled either by the anode to cathode area ratio, depolarization, or the electrical resistance of the ground.

In the area of the grandstand and the Jockey Building, tests indicate that the gas line is electrically connected to the reinforcing in the buildings. Tests also indicate that this gas line is connected to the steel in the Agriculture and Administration Buildings. The electrical connection to the reinforcing steel is a cause of the accelerated corrosion.

In the area of the senior sheep and swine and also the senior cattle barns, tests indicate that the water lines are electrically connected to the steel in concrete and resulting in accelerated corrosion of the water line.

Tests also indicate that the old piping and golf course sprinkler system is electrically interconnected to the new piping system which is a cause of accelerated corrosion.

If it is found economical to eliminate the 2,000 feet of the now disconnected gas line which serves the Jockey Building and replace it with approximately 500' of new gas line, the number 3 rectifier can be eliminated.

Since the disconnected gas line passes beneath the grandstand and also beneath the pavement, it appears that it could be costly to find and repair the existing leaks. It is probable that the gas line is perforated close to the grandstand area as well as in other locations.

Therefore, if leaks are found to be under the grandstand, new piping will have to be installed as tunneling under the grandstand to repair a leak in a small gas pipe would be uneconomical. It is suggested that due consideration be given in the economic analysis of abandoning the existing gas line to (1) the cost involved in locating the existing leaks and (2) the fact that if there is leakage found under the grandstand new pipe will have to be installed. The placement of a new 500' gas line to serve the Jockey Building will also eliminate one cathodic protection rectifier.

B. Soil Corrosivity

One of the most widely used single criteria for anticipating or comparing the corrosivity of soils is the measurement of their electrical resistivity. The resistivity of the soil is described in ohm-cm., which is the electrical resistance, in ohms, of a cubic centimeter of soil. As an illustration, sea water has an electrical resistivity of about 50 ohm-cm., alkali soil is in the range of 10-200 ohm cm., and a clean sand is about 10,000 ohm cm.

The August 1931 issue of Western Gas presented the following classification of soil corrosivity as related to the specific electrical resistance of such soils:

Resistivity ohm cm	Corrosivity
0 - 400	Severely Corrosive
400 - 1200	Moderately Corrosive
1200 - 4000	Mildly Corrosive
4000 - 10000	Slightly Corrosive

Resistivity ohm cm	Probable life of bare steel pipe in years
0 - 1000	0 - 9
1000 - 2500	9 - 15
2500 - 10000	15 or more

As was shown by the field tests, the average resistivity of the soil at the Fair Grounds is approximately 1000 ohm cm which indicates a moderately corrosive soil and a probable pipe life of around 10 or more years.

C. Cathodic Protection

The use of cathodic protection for protecting underground metals is a common engineering practice. Such a method is quite practical, but cathodic protection requires that close attention be directed to the possibility of corroding adjacent piping systems not included in the piping network under consideration. It is therefore necessary that all underground metallic structures at the Fair Grounds be electrically interconnected.

There is a distinct possibility that a few leaks will appear in the piping soon after the application of cathodic protection. The reason for such leaks is that the pipe may already be so corroded that the corrosion products are acting as a temporary "plug". Movements of the soil resulting from variations in moisture content can loosen the "plug", and the resultant leak will be noticed.

If a leak is found in the piping system near a pipe joint, or other pipe, it is good field practice to electrically bond the pipe sections together as a standard repair procedure. Also, at the conclusion of the installation of the anodes and before the application of cathodic protection, the piping system should be checked for electrical continuity. The underground piping system should be electrically interconnected to prevent the possibility of damage by stray current.

The public utility companies which have service lines in the adjacent area should be notified of the State's intentions so that cooperative tests can be performed to determine if this cathodic protection system would adversely affect their underground lines.

VII. APPENDIX

A. Tentative Specifications

Rectifiers:

Good-all "Type N" Cathodic Protection Rectifier, D.C. output of 18 volts - 6 amps with an 11-step tap changing switch. Transformer and rectifier immersed in oil for maximum cooling. Input of 115 volts, 60 cycles, single phase A.C. or equal.

Impressed Current Anodes:

Duriron 1 1/2" x 60" Type C-LO high silicon cast iron anodes, or equal high silicon cast iron anodes.

Anodes shall have a five (5) foot watersealed length of A.W.G. #8 standard copper cable. The coating on the wire shall be Rome CPS OR-1 600 volts, or Anaconda Type CP Cathodic Protection cable, or equal.

Anode Backfill Materials:

"National" BF-3 backfill consisting of graphite particles and an alkalizer or equal.

Placement of Anodes:

Impressed current anodes shall be placed at the designated locations in the following manner:

1. Auger, or otherwise construct anode holes 10 inches in diameter at a depth of 9 feet below the grade of the original ground.
2. Backfill this hole with National BF-3, or equal, backfill material to a compacted depth of one foot (8 feet below grade).
3. Place and center anode in hole.
4. Continue to place and compact special backfill material in layers not exceeding one foot until the anode has a minimum of one foot of backfill cover.
5. Use a sand or otherwise non-clay porous material to completely backfill the anode installation. Top soil may be used within 6 inches of original ground level for the purpose of growing lawn, etc.

Wiring:

1. Standard copper anode lead wire shall be 600 volt, A.W.G. size 4/0 Rome cathodic protection cable, CPS OR-1 600 volt, or Anaconda Type CP cathodic protection cable suitable for direct burial or equal.

2. All splices of the anode lead wire to the main feeder lines shall be made by the split bolt connector or the Cadweld process, or equal.

3. All underground wire splices shall be adequately protected from current leakage through the soil by using a Scotchcast Splicing Kit containing No. 4 resin. The splicing kits shall be Scotchcast No. 82-A2 in line and No. 92-B1 "wye" or equal.

4. The main feeder wire from the rectifier to the anode beds shall be embedded at least two feet below the original ground grade or at a depth which will insure protection of the wire from accidental severance by cultivation or excavation.

5. The main feeder wire from the rectifier to the anode beds shall be encased in metallic conduit from the rectifier to the depth of burial of the wire. The length of the conduit shall be sufficient to protect the feeder wire from tampering or accidental severance.

SUGGESTED CATHODIC PROTECTION MATERIAL SUPPLIERS

Harco Corporation
P. O. Box 7026
16901 Broadway Avenue
Cleveland 28, Ohio

Electrical Facilities, Inc.
4224 Holden Street
Oakland, California

Sabina-Dohrmann Company
522 Catalina Boulevard
San Diego 6, California

Frost Engineers Service Co.
P. O. Box 767
Huntington Park, California

Brance Krachy Company
4411 Navigation Blvd.
Houston, Texas

Cathodic Protection Service
310 Thompson Building
Tulsa, Oklahoma

Pipe Line Anode Corporation
Box 996
Tulsa, Oklahoma

Pipeline Coating & Engrg. Co.
1566 East Slauson Avenue
Los Angeles, California

Vanode Corporation
880 East Colorado Street
Pasadena 1, California

B. <u>Cathodic Protection Cost Estimate</u>

No.	Unit	Item	Price per Unit	Price
6	each	Cathodic Protection Rectifiers	$ 110.50	$ 663.00
12	each	Duriron 1 1/2" x 60" Type C-LO high silicon cast iron anodes	9.65	115.80
1000	L.F.	AWG 4/0 Cathodic Protection cable, CPS OR-1 600 volt	674.00/M ft.	674.00
15.81	CY	Excavation	20.00	316.20
2760	lbs.	Special Backfill Material, "National" BF-3	5.10/100#	140.76
2.50	C.Y.	Sand or gravel backfill	7.00 L.S.	7.00
12.54	C.Y.	Backfill	20.00	250.80
6	each	Installation of rectifier	100.00	600.00
12	each	Installation of anodes	20.00	240.00
	L.S.	Installation of wiring	150.00	150.00
6	each	Scotchcast Splicing Kit containing No. 4 resin No. 82-A2	6.50	39.00
6	each	Scotchcast Splicing Kit containing No. 4 resin No. 92-B1	5.22	31.32
	L.S.	Miscellaneous Wire	50.00	50.00
12	each	KS28 Split bolt connectors	2.00	24.00
	L.S.	Engineering	1,000.00	1,000.00
		Sub Total		3,401.88
		Plus 15% Contingencies		510.28
		Total		$3,912.16
		Use		$4,000.00