Technical Report Documentation Page

1. REPORT No.

Lab. Project Authorization No.

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE

A Report on the Investigation of the Causes of Corrosion of Water Pipe at the District VIII Maintenance Station and Shop in San Bernardino, with Recommendations for Corrosion

5. REPORT DATE

October 1955

6. PERFORMING ORGANIZATION

7. AUTHOR(S)

R.F. Stratfull

8. PERFORMING ORGANIZATION REPORT No.

Lab. Project Authorization No. 6060

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Division of Highways

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT & PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

I. Introduction

The District VIII Maintenance and Shop Plant at San Bernardino was completed in June 1954. Subsequently a serious corrosion problem developed in the underground utility lines. By September 1955 there were 12 leaks in the water lines. The hose bib water service line at Building 3 was disconnected and is not at present in service because of the corrosion of the line.

After numerous repairs of the water lines, preliminary corrosion tests were made by the Division of Architecture. These tests indicated that the corrosion of the water lines was not "normal" soil corrosion.

On August 31, 1955, Mr. F.M. Reynolds, Principal Highway Engineer, requested by letter that the Materials and Research Department perform a corrosion investigation at the site and forward the findings and recommendations to him.

During the week of September 12, 1955, representatives of the Materials and Research Department carried out the requested corrosion survey of the utility piping, the purpose being to determine the probable cause of the corrosion, and to determine an effective and economical method of dealing with the problem.

This report covers the findings of the survey and includes recommendations for inhibiting the corrosion.

17. KEYWORDS

District VIII Maintenance Yard and Shop Water Pipe Installations
Lab. Project Authorization No. 6060

18. No. OF PAGES:

13

19. DRI WEBSITE LINK

http://www.dot.ca.gov/hq/research/researchreports/1930-1955/55-15.pdf

20. FILE NAME

55-15.pdf

55-15

4161

DEPARTMENT [illegible]

DIVISION OF HIGHWAYS

October 4, 1955

District VIII Maintenance
Yard and Shop Water Pipe
Installations
Lab. Project Authorization
No. 6060

Mr. F. M. Reynolds
Principal Highway Engineer
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A REPORT ON
THE INVESTIGATION OF THE CAUSES OF CORROSION OF WATER
PIPE AT THE DISTRICT VIII MAINTENANCE STATION AND SHOP
IN SAN BERNARDINO, WITH RECOMMENDATIONS FOR CORROSION
PROTECTION.

Study made by	Structural Materials Section
Under General Direction of	J. L. Beaton
Report Prepared by	R. F. Stratfull

Very truly yours,

F. N. Hveem

F. N. HVEEM
Materials and Research Engineer

cc: Division of Highways
E. Withycombe
District VIII (2)
G. Hellesoe
Division of Architecture
C. A. Henderlong
G. B. Vehn
J. A. Gillem
C. W. Rhodes
Earle S. Marsh
C. T. Troop
C. D. Greenwood

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I. INTRODUCTION

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On August 31, 1955, Mr. F. M. Reynolds, Principal Highway Engineer, requested by letter that the Materials and Research Department perform a corrosion investigation at the site and forward the findings and recommendations to him.

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This report covers the findings of the survey and includes recommendations for inhibiting the corrosion.

II. SUMMARY

The field corrosion survey of the underground pipe network in the San Bernardino Maintenance and Equipment Yard which included visual examination and measurements of pipe to soil potential and resistivity, led to the following conclusions:

The corrosion of the water lines is probably caused by galvanic corrosion. This type of corrosion is the result of pipes of dissimilar metals being connected in a similar electrolyte or similar metals in a dissimilar electrolyte.

The rapid failure in this case apparently has been caused by the concentration of galvanic current at slight imperfections in the field wrapped joints. Out of 12 leaks, only one leak occurred in a factory wrapped section of pipe.

Generally, it is recommended to insulate the contact points of pipes of dissimilar metals and coatings, and place a magnesium anode to partially protect each insulated section of pipe. Detailed recommendations are on page 8.

III. OBSERVATIONS

A. It was found that one out of twelve leaks occurred in the factory wrapped pipe. The remaining leaks occurred in field wrapped joints. It is obvious that the field wrapping was not of the same quality as the factory wrapping.

B. From the amount of metal lost due to pipe perforation, it is estimated that the corrosion current was approximately 10 to 50 milliamperes. If the pipe had not been wrapped, this would mean a general yearly corrosion loss of approximately 0.2 to 1.0 pounds of steel. Since the pipe was wrapped, this corrosion attack was focused at pin holes in the pipe wrapping. This resulted in rapid perforation of the pipe at these pin hole areas.

C. The exact cause of the corrosion of the water lines was not determined. However, the possibility that the cause of the corrosion was stray currents, or "electrolysis", was eliminated when making pipe to soil potential measurements.

D. The electrical resistance of the original ground in the area ranges from 600 to 1200 ohm centimeters and averages 1000 ohm centimeters. Soils in this range are generally classed as being moderately corrosive.

E. The potential measurements indicated, in one case, that corrosion was being caused by the electrical link of an old existing and a newly placed pipe. The measurements indicated that the new pipe was corroding. As the presence of stray currents was not indicated by potential measurements, the apparent cause of corrosion is galvanic corrosion.

F. The galvanic cells causing the corrosion are apparently caused by the following, or a combination of the following factors:

1. Electrical connection of steel pipe to cast iron pipe.
2. Electrical connection of steel pipe to copper pipe.
3. Electrical connection of galvanized pipe to black pipe.
4. Electrical connection of new pipe to old pipe.
5. Pipe placed in a soil of variable aeration, moisture, electrical resistivity or type.

From the foregoing, it is obvious that many factors can affect the probability of corrosion. The exact cause of the corrosion of the water system can be determined. However, the cost of such an investigation would probably exceed the cost of replacing the system. The general method used for corrosion alleviation in all cases would generally be the same.

IV. TESTS

A. Pipe to Soil

Potential measurements were made of the water lines with reference to a copper sulfate half cell.

The stability of the readings at each point of measurement indicated that stray electrical currents were not affecting the pipe system.

The measurements indicated that the corrosion currents were a result of a corrosion system set up within the pipe network itself.

The measurements are shown on Exhibit #1, Equipotential Contours.

B. Electrical Resistivity

Electrical resistivity measurements were made with a single probe vibroground. These measurements required the breaking of the pavement and pushing the "resistance probe" by hand from one to 2 1/2 feet below ground.

The electrical resistivity measurements indicated that the soil should be generally classed as "moderately corrosive".

It may be of interest to note that during the resistivity tests the steel resistivity probe, at places, could be pushed through the soil with such ease that the physical resistance of the soil indicated that it is swamp land. Often the probe was covered with free moisture.

V. DISCUSSION

The electrical resistance of the soil in the ground area indicates that the soil should be classed as "moderately corrosive".

From the August 1931 issue of Western Gas, the following are soil corrosion classifications based upon its specific electrical resistance:

Resistivity-ohm-centimeter	Corrosivity
0 - 400	Severely corrosive
400 - 1200	Moderately corrosive
1200 - 4000	Mildly corrosive
4000 - 10000	Slightly corrosive

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

The specific electrical resistance of the soil at the San Bernardino Maintenance and Shop Plant varied between 600 and 2000 ohm centimeters, and averaged 1000 ohm centimeters. In soils of this electrical resistance range it is good practice to electrically insulate pipes of different materials and old pipes from new pipes to prevent galvanic corrosion.

There are two basic methods to alleviate the corrosion problem.

1. Insulate all lines on State property from private lines and apply complete cathodic protection.
2. Insulate all lines on State property from private lines and electrically insulate all galvanic pipe couples. Place galvanic anodes at all insulated lines to supply partial protection of the lines.

The cost comparisons in the Appendix indicate that Method number 2 would be the most economical method for corrosion alleviation. This method insures protection of the lines from soil corrosion. Soil tests were not made beyond State property to indicate if the soil is similar throughout the area. If the soil is similar in the general area, then this method of protection should be practical. The maintenance forces stated that the utility lines to adjacent homes have lasted 20 years without perforation.

No matter which method of correction is used, a few leaks in the water lines should show up in the near future. This is because there are areas of pipe which have suffered from corrosion and are probably being stopped from leaking by the presence of corrosion products. When cathodic protection is applied, these corrosion products will be lifted from the pipe surface, and the remaining thin metal wall may be fractured by water pressure.

The potential measurements made at the site indicate that the lines in the vicinity of Building 5-A (Shop Gas Station) and Office #1 (Shop Office) are corroding. The hose bib lines at Building #11 (Warehouse) and the lines in the vicinity of Building 5-B (Maintenance Gas Station) are corroding.

As a matter of general interest, there is approximately 10,500 lineal feet of assorted pipe buried at this Maintenance and Shop Plant.

VI. CONCLUSIONS

The corrosion of the water lines apparently is the result of galvanic couples of pipes of different metals or environments. No stray electrical currents were discovered.

Complete protection of the piping system could be made economically by the use of impressed currents. However, there is a danger that stray electrical current from the protection system may adversely affect the underground pipes of adjacent properties.

As other utility lines in this same general and adjacent locations have been reported to last at least 20 years without perforation, it is recommended that the use of minimum protective measures would be the most practical to use. This method may not completely stop the corrosion, but it should inhibit the corrosion of the lines sufficiently to obtain satisfactory service. This minimum method of correction is outlined in the recommendations.

The following minimum corrective measures are recommended:

1. That all pipe lines be electrically insulated at the meters or at the State property line.

2. All lines of dissimilar metal be electrically disconnected and insulated.

3. All connections of coated and uncoated lines be electrically insulated.

4. All connections of original and new pipe be electrically insulated.

5. All outside lines that electrically connect within buildings are to be electrically insulated outside the building.

6. That type 32-D galvo-pak magnesium anodes be placed in the following manner:

Pipe Size	Anode distance from pipe	Length of pipe protected. Max.
6" bare	5'	150'
6" coated	10'	150'
4" coated	10'	175'
4" bare	5'	150'
3" coated	10'	200'
3" bare	5'	100'
2 1/2" coated	10'	200'
2 1/2" or less	10'	200'

7. That each storage tank have one Type 32-D magnesium anode placed 10' beyond each end of the tank. This will be a total of two anodes per tank.

The estimated cost of the above work is $2049.60. A detailed estimate is included in the appendix under "Minimum Protective Measures."

VIII. APPENDIX

Exhibit I

Exhibit II

EXHIBIT II

COST ANALYSIS

IMPRESSED CURRENTS - COMPLETE PROTECTION

3 rectifiers at $95.00 ea.	$285.00	
3 current regulators at $80.00 ea.	240.00	
14 - 3" x 60" graphite anodes at $15.00 ea.	210.00	
Cost of placing anodes at $10,00 ea.	140.00	
Wiring 1000 L.F. L.S.	750.00	
Insulating existing pipes	200.00	
Engineering	300.00	
Total	2125.00	
Prorated yearly cost for 25 years	85.00	
Yearly power consumption	180.00	
Approximate yearly cost		$265.00

GALVANIC ANODES - COMPLETE PROTECTION

160 Type 32-D magnesium galvopak anodes at $16.05 ea.	$ 2568.00	
Cost of placing ea. at $7.00 ea.	1120.00	
Insulating existing pipes L. S.	400.00	
Engineering L. S.	400.00	
Total	$ 4488.00	
Yearly cost for 12 years	$ 374.00	
Approximate yearly cost		$374.00

MINIMUM PROTECTIVE MEASURES

Galvanic Anodes

65 Type 32-D magnezium galvopak anodes at $16.84 ea.	$ 1094.60	
Cost of placing 65 anodes at $7.00 ea.	455.00	
Insulate existing pipe L. S.	400.00	
Engineering	100.00	
Total	$ 2049.60	
Estimated yearly cost at 9 years	$ 227.73	
Approximate yearly cost		$228.00