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R.F. Stratfull

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16. ABSTRACT

I. Introduction and History

On July 21, 1960, Mr. Aldo Crestetto, Civil Engineer Supervisor, requested by letter that the Materials and Research Department check the operation of the cathodic protection system which was installed in 1958 at the subject facility.

A previous investigation on the causes of corrosion at the Paso Robles School for Boys by the Materials and Research Department was reported to the Division of Architecture on May 24, 1957.

Essentially, the corrosion problem at the school had been directed at the water lines, which had 43 leaks from 1954 to 1957. In order to combat this corrosion of the water lines, it was recommended that the present cathodic protection system be installed.

From 1958 to 1960 it has been reported that approximately 6 major water leaks have occurred in the 8" water pipe. These additional leaks in the water system and a request from the school to replace the pipe resulted in the request to determine the reason for the continuing corrosion of these lines.

This work was performed under inter-agency agreement S.A. 2337 and W.O. No. Mi 4300GC-45.

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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

A REPORT ON THE PERFORMANCE OF EXISTING CATHODIC PROTECTION SYSTEM AT THE PASO ROBLES SCHOOL FOR BOYS

60-27

November 1960

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

November 1960

Lab. Proj. Auth. 72-S-6222

Mr. Aldo Crestetto
Civil Engineer Supervisor
Division of Architecture
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A REPORT ON
THE PERFORMANCE OF EXISTING CATHODIC PROTECTION SYSTEM
AT THE PASO ROBLES SCHOOL FOR BOYS

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

Very truly yours,

F. N. Hveem
Materials and Research Engineer

By
J. L. Beaton
Supervising Highway Engineer

RFS:mw
cc: CJSchultz
CBrown
Div. of Arch. (10)

I. INTRODUCTION AND HISTORY

On July 21, 1960, Mr. Aldo Crestetto, Civil Engineer Supervisor, requested by letter that the Materials and Research Department check the operation of the cathodic protection system which was installed in 1958 at the subject facility.

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Essentially, the corrosion problem at the school had been directed at the water lines, which had 43 leaks from 1954 to 1957. In order to combat this corrosion of the water lines, it was recommended that the present cathodic protection system be installed.

From 1958 to 1960 it has been reported that approximately 6 major water leaks have occurred in the 8" water pipe. These additional leaks in the water system and a request from the school to replace the pipe resulted in the request to determine the reason for the continuing corrosion of these lines.

This work was performed under inter-agency agreement S. A. 2337 and W. O. No. Mi 4300GC-45.

II. SUMMARY AND CONCLUSIONS

The existing cathodic protection system does not completely control the corrosion of the underground pipe. This is evidenced by the fact that there were 31 recorded leaks between 1955 and 1957 prior to the installation of cathodic protection, and only 6 leaks have been reported from 1958 through 1960.

The cathodic protection system was installed in 1958 and has apparently reduced the frequency of perforations. Complete corrosion control has not been accomplished as evidenced by the minor number of leaks and also the results of potential measurements. The pipe can be brought under complete corrosion control for approximately $9000.

The installation of the existing cathodic protection system has never been entirely adequate to completely protect the underground pipe. In addition, the cathodic protection unit has become less effective because:

1. The plastic sprinkler pipe is being replaced with galvanized pipe.

2. Additional pipe in the farm area has been electrically connected to the cathodic protection system.

The addition of these pipes to the system has apparently reduced the area of effective corrosion protection to about 1/3 of the entire system.

Up to the present time periodic operational checks have not been performed on this system as previously recommended. It cannot be emphasized too greatly that a cathodic protection system of this nature should be periodically checked. The reasons are that it will not control the corrosion of the pipe if not properly adjusted, and there is a possibility that the electrical cathodic protection currents could corrode underground pipe both on and beyond the limits of the school. This could occur because of an electrical discontinuity in the pipe or the installation of new pipe that was not electrically bonded to the cathodic protection system.

III. RECOMMENDATIONS

It is recommended that:

1. If the cathodic protection system is not to be checked periodically, that the corrosion control measures be abandoned.

2. When new metallic pipe is to be installed, the influence of this pipe on the cathodic protection system be determined, and, if necessary, the rectifier output be adjusted.

3. The rectifier output be adjusted, so that all of the piping is at least -0.85 volts to a standard copper sulfate half-cell.

4. The existing 25 ampere rectifier be removed and replaced with a Y36-24 witn 4 stacks rectifier.

5. The existing anode ground beds be enlarged as shown on Exhibit II.

6. All underground pipe shall be made electrically continuous. (These are shown on Exhibit I.)

7. The existing rectifier ground cable connections to the pipe be replaced with a #2/0 wire, CPS-OR-1 or equal.

8. An additional 20 anode ground bed be installed in the vicinity of the well area as shown on Exhibit I.

9. Electrically connect all of the pipe in the well area to the pipe in school area.

10. Install jumper wires across all pipe couplings above the ground at the well.

11. Take monthly pipe to soil potentials at locations indicated on Exhibit II. (The method for obtaining pipe to soil potentials are noted in the Appendix.)

12. A standard copper sulfate half cell and a voltmeter be purchased by the school so that the maintenance personnel (who have been trained) may make the necessary monthly checks of the operation of the system. (These monthly operational checks were recommended in the original report of the causes of corrosion.)

13. That a complete pipe to soil potential survey be made six weeks after the installation of the new cathodic protection system and yearly thereafter.

14. An electrical continuity survey be made six weeks after the installation of the new cathodic protection system and yearly thereafter.

15. It is recommended that the Division of Architecture prepare the final plans and specifications for any approved construction.

16. All new metal pipe that is installed should be coated with an AWWA specification coal tar enamel or with a 10 mil thickness of polyethelyene or polyvinyl chloride tape coating.

17. Where new pipe is installed in expansive clay, the pipe be backfilled with a sand or non-expansive soil for a minimum distance of 3 inches all around.

IV. TESTS

A. Electrical Continuity

The effective application of a cathodic protection system requires that the pipe be electrically continuous. Otherwise, at points where electrical continuity is lacking, electricity may discharge into the soil at these points and cause corrosion of the pipe.

On the 8" line which is in the vicinity of the well, it was found that there is one location where the pipe was not electrically continuous. This location of high electrical resistance should be corrected at the earliest possible date. The 3" pipe in the well area not yet under protection was also found to be discontinuous. The locations of electrical discontinuity are noted on Exhibit II.

B. Pipe to Soil Potentials

In very general terms, a pipe to soil potential represents the inherent voltage of a steel pipe in a soil. In different soils the voltage of the metal will vary. Likewise, when corrosion is occurring, the inherent voltage or the "electrical charge" of the metal will vary. If a steel pipe has a voltage of -0.85 volts to a copper sulfate half cell, then the metal will not corrode. It is electrically "stable".

The limits of the effectiveness of the existing cathodic protection system is shown on Exhibit II. As it will be noted, only about 1/3 of the pipe is currently being protected from corrosion.

The existing rectifier is not adequate to protect the entire piping system. The reason that the rectifier is inadequate is that it is too small and in addition the concrete embedded steel in the buildings being connected to the underground pipe is draining an excessive amount of current. This latter condition can be corrected by the use of a larger rectifier.

C. Current Required for Cathodic Protection

The existing rectifier was disconnected and a welding generator was used to determine the current required for corrosion control. It was found that 100 amperes would protect all of the pipe except the pipe in the farm area and adjacent to the well.

Because of the high electrical resistance of the soil in the well area, it is not possible to protect this piping with the existing anode bed. This was determined by a current distribution test. An additional anode bed and rectifier is required in the vicinity of the well to protect the remainder of the pipe from corrosion.

Also, the existing anode beds will have to be enlarged to take care of the additional current required to control the corrosion of the water system under present protection.

V. DISCUSSION

In the original report dated May 1957 it was recommended that the cathodic protection system be periodically checked. This has not been done.

If this system had been checked at periodic intervals, it would have been found that it was inadequate to control the corrosion. As a result leaks are beginning to reoccur in the system. Also, at the time of the original survey, the pipe was found to be in relatively poor condition; that is, there were many locations where corrosion was active. It is possible that as a result of added corrosion of the pipe that severely corroded sections of the pipe may require replacement. The locations of severely corroded pipe can only be determined by exposing the pipe.

It is recommended that the school purchase test equipment and at least one of its personnel be trained to check the pipe at monthly intervals. The degree of training is nominal and would not require more than one day. If the monthly check by the school personnel indicates that there is erratic performance of the system, then a corrosion engineer can be called in to correct the trouble. If the school does not maintain and check this system with its own personnel or by others, it is recommended that the cathodic protection be abandoned.

The size of rectifier in the well area cannot be predetermined except by an actual test of the complete cathodic protection system. However, for estimating purposes the cost of a Y36-24 rectifier could be used for pricing the system.

It is possible that the existing 25 ampere rectifier may be adequate to protect the pipe in the well area, and, if so, it will be necessary to purchase only one rectifier.

A list of equipment for use by the school personnel to check performances of the cathodic protection system has been listed in Chapter VIII of this report. The voltmeter is a multipurpose meter which can be utilized for numerous types of electrical measurements, and is therefore not considered as an instrument which is primarily used for cathodic protection. However, it is of adequate sensitivity for control or checking purposes of an existing cathodic protection system.

The fundamental method for obtaining the potential measurements of the cathodic protection system has been included in Chapter VIII. However, it is recommended that the personnel performing the cathodic protection checks be trained by a corrosion engineer.

For the present the cathodic protection test stations indicated on Exhibit II are adequate. After the additional rectifier has been installed it may be necessary to alter the locations of the test stations.

A suggested form has been included in this report to aid the personnel of the school in recording their monthly measurements of the operation of the system. Copies of completed forms are requested to be submitted each month to the Division of Architecture and also to the Materials and Research Department for evaluation.

It is suggested that the corrosion engineering which would be required during the installation of the cathodic protection system be under the supervision of a corrosion engineer.

It is recommended that the final design and inspection of the cathodic protection system be performed by the Division of Architecture.

V. FEASIBILITY OF ELECTRICALLY INSULATING PIPING FROM BUILDINGS

The concrete embedded steel in the buildings is connected to the underground pipe. As a result, the steel in these buildings will absorb electrical current. This increase in the required electrical current for cathodic protection can be eliminated by installing electrical insulating couplings in the pipe where it enters a building.

The following cost analysis of the economics of electrically insulating the pipe from the buildings indicates that on a twenty year basis the cost of electrically insulating the buildings will cost about $24.00 more per year than the cost of the extra electricity. Therefore, it is recommended that the buildings not be electrically insulated from the underground pipe.

1. Estimated Cost of Insulating Buildings

    a. Excavation and backfill — $ 50.00

    b. Cost of and installing each coupling — 25.00

    c. Cost per connection — 75.00

    d. 30 couplings @ $75.00 per coupling — 2250.00

2. Estimated Cost of Increased Power

    a. Buildings are estimated to drain 1.5 KW @ 0.65¢ per KWH

    b. 30 volts @ 96 amps or (2.88 KW) will provide adequate protection

    c. Cost of power (1.5 KW) absorbed by building @ 0.65¢ KWH for 20 years — 1756.80

3. Comparison of Estimated Costs per Year Based on a 20 year Period

    a. Insulation

        1. Total cost — 2250.00

        2. Cost per year — 112.00

    b. Increased Power

        1. Total cost — 1756.80

        2. Cost per year — 87.84

VI. TENTATIVE SPECIFICATIONS (METHOD A)

Rectifier:

Good-All "Add-A-Stack" Model Y36-24 selenium rectifier or equal with four selenium stacks. The output shall be variable from 0 to the maximum voltage in a minimum of 10 equal steps.

The rectifier shall perform satisfactorily at maximum output at an ambient temperature of 130° F. The unit shall have built-in thermal and input and output overload protection.

A DC ammeter with suitable range switching shall be installed. The scale ranges of such an ammeter will not exceed 140% of the rated output of each selenium stack. A DC voltmeter with suitable range switching shall be installed. The scale ranges of such a voltmeter will not exceed 140% of the rated output reading of each selenium stack.

The entire installation shall be mounted in a vandal-proof enameled steel box of code gauge thickness. The box shall have a locking cover and padlock, and it shall be suitable for wall or bench mounting.

Anodes:

The impressed current anode shall be 3" x 60" National Graphite Anodes with five feet of A.W.G. #8 Oil Resistant Waterproof Cable or equal.

The anode backfill material shall be "National" BF-3 Backfill, a prepared mixture made of graphite particles and an alkalizer or equal.

Installations of Anodes:

Impressed current anodes shall be placed at the designated locations as follows:

1. Auger or otherwise construct an anode hole of 10" in diameter 10' below grade.
2. Fill bottom of hole with special backfill material to a compacted depth of 1', which is 9' below grade.
3. Center anode carefully in hole and add backfill material in one foot compacted layers until the backfill is approximately one foot above anode.

4. After making electrical connection, back-fill the remainder of the hole with sand. Top soil may be used in the top six inches.

Wiring:

Standard copper anode lead wire shall be C.P.S. OR-1 600 volt A.W.G. #2/0 or Anaconda type CP cathodic protection cable or equal.

All "in line" splices and all splices of the anode lead wires to the feeder lines shall be made with the Cadweld process or equal.

All underground wire splices shall be adequately protected from current leakage through the soil by using a Scotch-Cast Splicing Kit containing No. 4 resin or equal.

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

The main feeder wire from the rectifier to the anode beds and pipe shall be encased in conduit to the depth of burial of the wire. The length of conduit shall be sufficient to protect the feeder wire from tampering or accidental severance and will traverse the distance between the rectifier and that point where the wire is buried at specification depth.

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

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

The Pipeline Protection Co.
420 Market Street
San Francisco 11, Calif.

Brance Kracky Co.
4411 Navigation Blvd.
Houston, Texas

Cathodic Protection Service
310 Thompson Building
Tulsa, Oklahoma

Pipe Line Anode Corp.
Box 996
Tulsa, Oklahoma

Pipeline Coating & Engineering Co.
1566 East Slauson Avenue
Los Angeles 11, California

Vanode Corporation
880 East Colorado St.
Pasadena 1, California

VII. CATHODIC PROTECTION COST ESTIMATE

Quantity	Description	Cost per Unit	Total Cost
2 each	Good-All "Add-A-Stack" Rectifiers Y36-24 with 4 stacks	$ 756.00	$ 1512.00
31 each	3" x 60" National Graphite Anodes (Cat. No. 53100)	9.90	306.90
7130 lbs.	National BF-3 Backfill Material	$5.10/100 lbs.	367.20
LS	Excavation and Backfill	LS	1471.68
1000 LF	CPS OR-1 600 volt A.W.G. 2/0 Cable	4.4250/MFT	442.50
11 hrs.	Install Cable	3.15/hr.	34.65
40 hrs.	Install Rectifiers	3.15/hr.	126.00
124 hrs.	Install Anodes	3.15/hr.	390.60
33 each Connections	Cadweld Wire Connections	10.00	330.00
7 each	Scotch Cast Splicing Kits 82-A2 with #4 Resin (in line)	6.50	45.50
28 each	Scotch Cast Splicing Kits 90-B1 with #4 Resin (wye)	5.22	146.16
70 hrs.	Install Splicing Kits	3.15/hr.	220.50
9 LF	1¼" Conduit and Install	0.50	18.68
10 each	Jumper Wire Connectors and Install	1.50	78.00
LS	Jumper Wire Lugs and Clamp and Install	LS	30.90
LS	Misc. Wire and Install	LS	75.20
12 each	Misc. Fittings	1.00	12.00
6 hrs.	Install Misc. Fittings	3.15/hr.	18.90
LS	Testing	LS	600.00
	Sub-Total		6227.37
	15% Contingencies		934.11
	Sub-Total		7161.37
	25% Profit and Overhead		1790.34
	Total		8951.71
	Use		$ 9000.00

VIII. METHOD FOR MEASURING PIPE TO SOIL POTENTIALS

Monthly cathodic protection potential readings must be obtained and recorded so that any erratic changes noted in the system can be investigated and, if necessary, corrected.

Readings are obtained by conducting a pipe to soil potential survey using a high resistance voltmeter and a standard copper sulfate half-cell.

All pipe under a cathodic protection system has a certain electrical charge. The pipe to soil potential survey measures the amount or quantity of the electrical charge.

A high resistance voltmeter is used to obtain adequate sensitivity. The copper sulfate half cell is used as a stable reference point as it has a constant unchanging electrical charge. The voltmeter measures the difference between the electrical charge on the pipe and the copper sulfate half-cell.

Use the following procedure for conducting a pipe to soil survey:

1. Attach positive (+) lead from voltmeter to copper sulfate half-cell.
2. Attach negative (-) lead from voltmeter to pipe being checked.
3. Wet ground at check point.
4. Place copper sulfate half-cell on wet ground at check point.
5. Read and record voltage.

A record of all readings should be kept and any discrepancies in the system be brought to the attention of the corrosion engineer. Readings can be recorded as shown on Exhibit I.

EQUIPMENT FOR PIPE TO SOIL POTENTIAL SURVEY:

Simpson Model 269 AC-DC Volt-Ohm-Microammeter 100,000 ohms/volt DC, 5,000 ohms/volt AC, w/carrying case	$ 99.50
8" Copper Sulfate Electrode (Cathodic Protection Service, 310 Thompson Bldg., Tulsa 3, Oklahoma)	11.00
Cupric Sulfate-Fine Crystal Reagent (1 pound)	1.25
Total Cost Estimate	$ 111.75

EXHIBIT I

CATHODIC PROTECTION RECORD FOR ____________ 19 _____

		Volts	Amps
I. Rectifier No.	________	______	______
	________	______	______

		*P/S at Present Rectifier Setting	*P/S After Rectifier Adjustment
Check Point No.	________	______	______
	________	______	______
	________	______	______
	________	______	______
	________	______	______
	________	______	______
	________	______	______
	________	______	______
	________	______	______

Rectifier No. ________ Readjusted to ________ Volts ______ Amps

________ ________ ______

(This to be done only if a particular check point shows the pipe in that area is less than 0.85 volts.)

II. Leak Record:

Date Leak Detected	Location and Remarks
1. ____________	
2. ____________	
3. ____________	
4. ____________	
5. ____________	

NOTE: Forward monthly copy to Corrosion Engineer, Materials and Research Department, Sacramento, California

* P/S Pipe to soil potentials