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A Report on the Investigation of the Corrosion of the Underground Gas and Water System at the Porterville State Hospital

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7. AUTHOR(S)
R.F. Stratfull

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Porterville State Hospital
Corrosion Investigation

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Department of Public Works
Division of Highways
Materials and Research Department

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16. ABSTRACT

A. Request for Investigation

On April 24, 1957, Mr. O.E. Anderson, Supervising Mechanical and Electrical Engineer requested by letter that the Materials and Research Department perform a corrosion survey at the Porterville State Hospital under Work Order AR-1072. It was also requested that the results of the investigation, which were to include an appraisal of the cause of the corrosion problem as well as remedial recommendations, be forwarded to the Mechanical Section, Division of Architecture.

B. Corrosion History

A complete brief of the corrosion problem has been outlined in a letter dated March 13, 1957, to Walter Rapaport, M.D., Director of Mental Hygiene, Sacramento, California, from James T. Shelton, M.D., Superintendent and Medical Director, Porterville State Hospital.

As outlined by the referenced communication and substantiated by this investigation, the corrosion problem at the Porterville State Hospital is an economic burden as well as a potential hazard to the physical safety of the personnel and to the structures at the institution.

From December 1954 to the present, the institution has reported 17 leaks in the approximately 11,500 L.F. of gas lines. Several times the escaping gas has been reported to have collected in the sewer system and the steam tunnel which connect to all of the wards. Such a condition could result in the gas being accidentally ignited by a spark or flame.

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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 PORTERVILLE STATE HOSPITAL.

57-12
DND

May 31, 1957

MATERIALS & RESEARCH DEPARTMENT

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

May 31, 1957

Porterville State Hospital
Corrosion Investigation
Arch. File No. W.O. AR-1072
Lab. Project Auth. 100-S-6105

Division of Architecture
1120 N Street
Sacramento, California

Attention: Mr. C. Henderlong
Supervising Mechanical and Electrical Engineer

Gentlemen:

Submitted for your consideration is:

A REPORT ON

THE INVESTIGATION OF THE CORROSION

OF THE UNDERGROUND GAS AND WATER SYSTEM

AT THE PORTERVILLE STATE HOSPITAL.

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

Very truly yours,

F. N. Hveem
Materials and Research Engineer

RFS:mw
cc: LMullens
RVGoodman
ODGreenwood
JWTrask

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I. INTRODUCTION

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From December 1954 to the present, the institution has reported 17 leaks in the approximately 11,500 L.F. of gas lines. Several times the escaping gas has been reported to have collected in the sewer system and the steam tunnel which connect to all of the wards. Such a condition could result in the gas being accidentally ignited by a spark or flame.

Some of the leaks in the gas lines have occurred at locations where the field wrappings were faulty or had not been applied in accordance to the specifications.

II. SUMMARY

The gas lines are corroding as a result of their interconnection with (a) the reinforcing steel in the concrete wall of the steam tunnel, (b) the piping for the radiant heating system which is embedded in concrete, (c) the copper grounding rods, and (d) the cast iron water system. These latter are all cathodic to the gas line, with the highest potentials being developed by the metals embedded in the alkaline concrete matrix.

Unless protective measures are taken, leaks in the gas lines and the water system will continue to occur as a result of galvanic corrosion. The soil at the hospital site is of a corrosive nature. It also tends to deform with variations in moisture content, damaging the pipe coatings by its movement. As a result galvanic corrosion currents of significant intensity concentrate at new breaks or perforations in the pipe coating. The concentration of these galvanic currents at the small areas exposed by these breaks tends to accelerate the corrosion rate.

The plot of the recorded leaks at the hospital indicates that if corrective measures are not taken, the average number of yearly leaks will approximately double with each succeeding year. For instance, there may be an expected total of 15 leaks during 1957, and 29 leaks during 1958.

It is not economically practicable to electrically insulate or to isolate the existing galvanic couples which are causing the corrosion problem. However, cathodic protection would be economical, and it is recommended that such be installed to retard or prevent further galvanic or "Soil" corrosion of the presently deteriorating gas and water lines.

III. TESTS

A. Pipe to Soil Measurements

The flow of direct electrical current from a corroding metallic structure can be detected by measuring the electrical voltage drop about the structure.

The voltage drop or the pipe to soil potential about such a structure was measured with a standard copper sulfate half-cell and a high impedance voltmeter.

The results of the pipe to soil measurements are shown on Exhibit I, Equipotential Contours.

As indicated by the pipe to soil measurements, 34 locations are noted at which the gas and water lines are now corroding. There are undoubtedly a number of other locations where the piping system is corroding, but these points were not located by the initial measurements.

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

B. Electrical Resistivity of the Soil

Since the corrosion of wrapped gas and water piping is electrochemical in nature, either the presence or the absence of certain chemicals is contributory 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 -- And 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 Porterville State Hospital is shown on Exhibit II, Equi-Resistivity Contour Map. As shown by the earth resistivity measurements, the soil varies from 500 to 2000 ohm cm. The average is approximately 800 ohm cm., which indicates a corrosive soil.

IV. LEAK FREQUENCY

The frequency of leaks in a utility system follows a definite mathematical pattern, which is indicated by the plot of the accumulated leaks against time shown on Exhibit III, Accumulated Leaks Against Time.

As indicated by Exhibit III, the actual average leak frequency during 1955 was one leak every 8 weeks, and during 1956 one leak every 6 weeks. The projection of the plot of leak frequency indicates that there may be an estimated average of one new leak every 4 weeks during 1957, and one new leak every 2 weeks in 1958.

The estimated number of leaks is based upon the assumption that remedial measures such as cathodic protection would not be in place.

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.

At the Porterville Hospital the following corrosion conditions were found:

1. The reinforcing steel in the concrete steam tunnel, being cathodic in relation to the cast iron water line and the galvanized iron gas line, is causing their corrosion.

2. The concrete embedded radiant heating metal pipes in the floor of the wards are also cathodic in relation to the cast iron water lines and the galvanized iron gas lines and are contributing to their corrosion.

3. The concrete embedded electrical conduit and the copper electrical grounding rods are also causing the cast iron water lines and the galvanized iron gas lines to corrode.

4. The cast iron lines are causing the galvanized lines to corrode.

5. Pipe in high resistivity soil is causing pipe in low resistivity soil to corrode.

6. The electrical bonding of all of the buried metallic pipes is contributing to the corrosive action of dissimilar metals.

VI. DISCUSSION

A. Electrical Interconnection of Underground Structures

Usually if a metallic pipe is buried in the earth, the possibility of the corrosion of the pipe will depend upon the non-homogeneity of the system. Thus when a network of different types of metallic pipes is placed in a corrosive soil and electrically interconnected, conditions that create the corrosion voltage is 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.

At the Porterville Hospital several different types of metallic pipes are physically and electrically interconnected through common appliances, as well as being deliberately interconnected by means of a common electrical ground wire. Quite possibly, if the underground piping had been effectively electrically insulated at the time of construction, the present accelerating rate of corrosion would not exist. Under such a condition any corrosion leaks in a piping network free of bimetallic contacts could have been repaired in the normal manner, and, as a preventive measure, a galvo-pak magnesium anode could have been installed in the area of such a repair to prevent any further corrosion. Such failures could have been curbed for a total cost of approximately $20.00.

B. Coated Lines

The coating of underground piping is a common corrosion protection practice. Such coatings may at times appear to accelerate the holing through of a pipe. The coating does not increase the total corrosion current, but concentrates it at the locations of minor coating imperfections. There will invariably be a minute number of imperfections, or "holidays", which will expose the metal to the earth.

The cost of cathodic protection of a coated line is minor because of the small area of the exposed pipe to the soil. Conversely, the cost of cathodic protection of a bare pipe is high on account of the large surface area of the pipe exposed to the soil.

C. Field Tests and Investigations

Should a pipeline which is subject to corrosion be coated to prevent galvanic corrosion, the tendency for the coating to develop perforations will be greater than on a pipe which is not subject to corrosion currents.

As previously noted, the pipe to soil measurements on this project indicate that the main causes of corrosion to the gas lines are the electrical interconnection of the gas line to the concrete embedded radiant heating system, the reinforcing steel in the steam tunnel, the concrete embedded electrical conduit, and the copper grounding rods. The concrete embedded metals could cause future corrosive difficulty with the cast iron water lines. However, the electrical interconnection of the steel gas lines to the cast iron water lines is sufficient to cause the corrosion of the steel gas lines in lieu of the cast iron pipe.

D. Soil Corrosivity

The most acceptable and significant criterion for anticipating or comparing the corrosivity of soils is measurement of their electrical resistivity. The resistivity of a soil is described in ohm-cm., which is the electrical resistance, in ohms, of a cube of soil one centimeter cubed.

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

In a paper presented before the National Association of Corrosion Engineers on June 20, 1951, the following was outlined as the general practice of the Southern California Gas Company for coating pipeline installed in earth of different resistivities:

1. "Dry and well drained sand or fine gravel with resistivity of 5000 ohm-cm., and above is classed as good, and the pipelines buried in these soils are coated with a single layer coating of filled asphalt or coal tar and Kraft paper wrapper. If rocks are present or the installation is difficult, a mechanical shield is used.

2. "Damp, poorly drained loam silt with resistivities of 5000 to 2300 ohm-cm. is classed as intermediate. A single layer pipe coating of filled asphalt or coal tar and asbestos wrapper is used on the pipelines that are buried in this type of soil. Again if rocks are present or the installation is difficult, a mechanical shield is used.

3. "Wet, poorly drained clay or adobe with resistivities of 2300 ohm-cm. or less is classed as bad, and a heavy duty pipe coating is used. This type of coating consists of (1) Somastic, (2) double layer of filled

asphalt or coal tar with fiberglass reinforcement and an asbestos wrapper, or (3) double layer of filled asphalt with cellulose membrane and an asbestos wrapper. A mechanical shield is used if rocks are present or the installation is difficult. The coating on lines buried in this type of soil for any length of time shows evidence of severe soil stress."

Since the Porterville soils fall in the 500 - 2000 ohm cm. range, these can be considered moderately corrosive. Coatings such as noted under "3" above should be considered for future installations.

E. Cathodic Protection

The use of cathodic protection, or impressed electrical current method of protecting underground metals is a common engineering practice. Such a method is quite practical here, 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 necessary that all underground metallic structures at the hospital be electrically interconnected.

There is the 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 or variations in moisture content can loosen the "plug", and the resultant leak will be noticed.

If a leak appears in the piping system adjacent to a pipe joint, 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. Any electrical discontinuity of the underground 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 our cathodic protection system would adversely affect their underground lines.

VII. CONCLUSIONS

The corrosion of the gas lines and water system is the result of galvanic corrosion, which is induced by the electrical interconnection of dissimilar metallic structures and by soil conditions. Unless cathodic protection is installed, future leaks will occur in the gas and water system.

Because of the great mass of piping at the hospital, three cathodic protection stations are considered necessary. The three cathodic protection stations will counteract electrical shielding of the pipes by the buildings, etc., reduce the voltage gradient in the vicinity of reinforcing steel, and reduce the corrosion hazard to piping not electrically connected to the hospital system.

The suggested methods and tentative specifications for the cathodic protection installation are outlined in the following two sections.

VIII. RECOMMENDATIONS

1. That three (3) impressed current cathodic protection stations be installed for corrosion alleviation.

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

3. That the cathodic protection rectifiers be installed in a location free from tampering by unauthorized personnel but accessible for convenient adjustment.

4. That the cathodic protection rectifiers be installed within close proximity of the anode beds.

5. That the hospital's piping systems be electrically disconnected or isolated from the public utility lines which serve the hospital.

6. That if any buried utility lines, such as telephone, gas, or water, traverse the general area of the hospital, officials of the interested parties be notified of the State's intentions.

7. That proper tests be performed in conjunction with the inter-ested parties to determine if the cathodic protection system at the hospital will adversely affect such distribution systems.

8. That the piping system be checked for electrical continuity prior to the application of cathodic protection.

9. That all electrical discontinuities of the piping system or other underground metallic structures be electrically bonded to the piping system.

10. That all metallic objects located at an electrical discontinuity be electrically bonded to the system.

11. That any repair, connection, or dissimilar metal which is connected to the piping by this work be heavily coated with "Ozite" or some equally effective coating to prevent direct metallic contact to the soil.

12. That pipe to soil measurements be made and recorded at selected points at weekly intervals for the first 6 weeks of operation, and monthly thereafter.

13. That the output of voltage and current of the rectifiers be recorded at weekly intervals for the first 6 weeks of operation, and monthly thereafter.

14. That 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.

15. That the piping system not exceed 3.0 volts negative to a copper sulfate half-cell.

16. That 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.

17. That 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. That after the installation of the cathodic protection system an equi-potential survey be made to determine the current distribution and protection afforded by the installation.

19. That at the conclusion of the first month of operation of the cathodic protection station an equi-potential survey be made.

20. That at the conclusion of the first month of operation of the cathodic protection installation the output of the rectifier be altered, if necessary, to compensate for polarization of the piping.

21. That at yearly intervals a corrosion survey be made of the piping system to substantiate the effectiveness of such cathodic protection.

22. That if the Materials and Research Department of the Division of Highways does not perform the yearly surveys that the Materials and Research Department receive a copy of such surveys.

IX. APPENDIX

A. Tentative Specification

Rectifiers:

Input: 110 or 220 volt, single phase. (Specify input voltage according to available voltage at location of rectifier at hospital).

Minimum Output Requirements: Variable, to 30 volts D.C. at 50 amperes. Output regulation shall be available in a minimum of 10 steps of equal voltage.

Characteristics: Rectifier shall function satisfactorily at maximum output in ambient air temperature up to 130°F. (If rectifiers are to be installed in locations that are air conditioned or cooled, specifications could include some other maximum anticipated air temperature).

Rectifiers shall contain a D.C. ammeter and voltmeter to cover the output range of the rectifier. Rectifier shall contain a thermal protection device. Rectifier shall contain current overload protection. (Specification should also specify if the rectifiers are to be mounted on a utility pole or rack - pole or rack mounted).

Impressed Current Anodes: "National" 3" x 60" untreated graphite or 1½" x 60" Type C "Duriron" high-silicon cast iron anodes or equal.

Anodes shall have a five foot (5') watersealed length of A.W.G. #8 standard copper wire. Coating on wire shall be R.R. or Rome cathodic protection cable, CPS OR-1 600 volts, or Anaconda Type CP cathodic protection cable or equal.

Anode Backfill Material: "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 of 10 inches in diameter at a depth of 10 feet below the grade of the original ground.

2. Backfill this hole with BF-3, or equal backfill material, to a compacted depth of one foot (9 feet below grade).

3. Place and center anode in hole.

4. Continue to place and compact backfill material in layers not exceeding one foot each 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" of original ground level for the purpose of growing lawn, etc.

Wiring:

1. Stranded copper anode lead wire shall be 600 volt, R.R. A.W.G. size #2 or Rome cathodic protection cable, CPS OR-1 600 volt; or Anaconda Type CP cathodic protection cable or equal.

2. All splices of the anode lead wires to the main feeder lines shall be made by solder joints, or by the Cadweld process, or equal.

3. 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.

4. The main feeder wire from the rectifier to the anode beds shall be embedded at least one foot 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.

   If there is an anticipated problem of rodents severing the main feeder line or its insulation, this line shall be adequately protected by a suitable coverage of concrete or metallic sheath. In no case shall a metallic sheath be electrically or physically in contact with the anodes, piping, or the metallic portion of the main feeder wire.

SUGGESTED CATHODIC PROTECTION MATERIAL SUPPLIERS

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

Electrical Facilities, Inc.
4224 Holden Street
Oakland, California

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

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

Vanode Corporation
880 East Colorado Street
Pasadena 1, California

Brance Krachy Co.
4411 Navigation Boulevard
Houston, Texas

Cathodic Protection Service
310 Thompson Building
Tulsa, Oklahoma

Pipe Line Anode Corporation
Box 996
Tulsa, Oklahoma

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

CATHODIC PROTECTION COST ESTIMATE

3 - Cathodic Protection Rectifiers @ $500.00	$ 1,500.00
38 - impressed current anodes	360.00
Lime treated coke breeze, 8,800 lbs.	400.00
1500 L.F. A.W.G. No. 2·R.R. wire or equal	300.00
Miscellaneous wire, etc.	250.00
Installation of anodes	600.00
Installation of rectifiers	500.00
Installation of wire	1,500.00
Engineering	1,000.00
	$ 6,460.00
Plus 15%	969.00
	$ 7,429.00
Estimated cost	$ 7,500.00

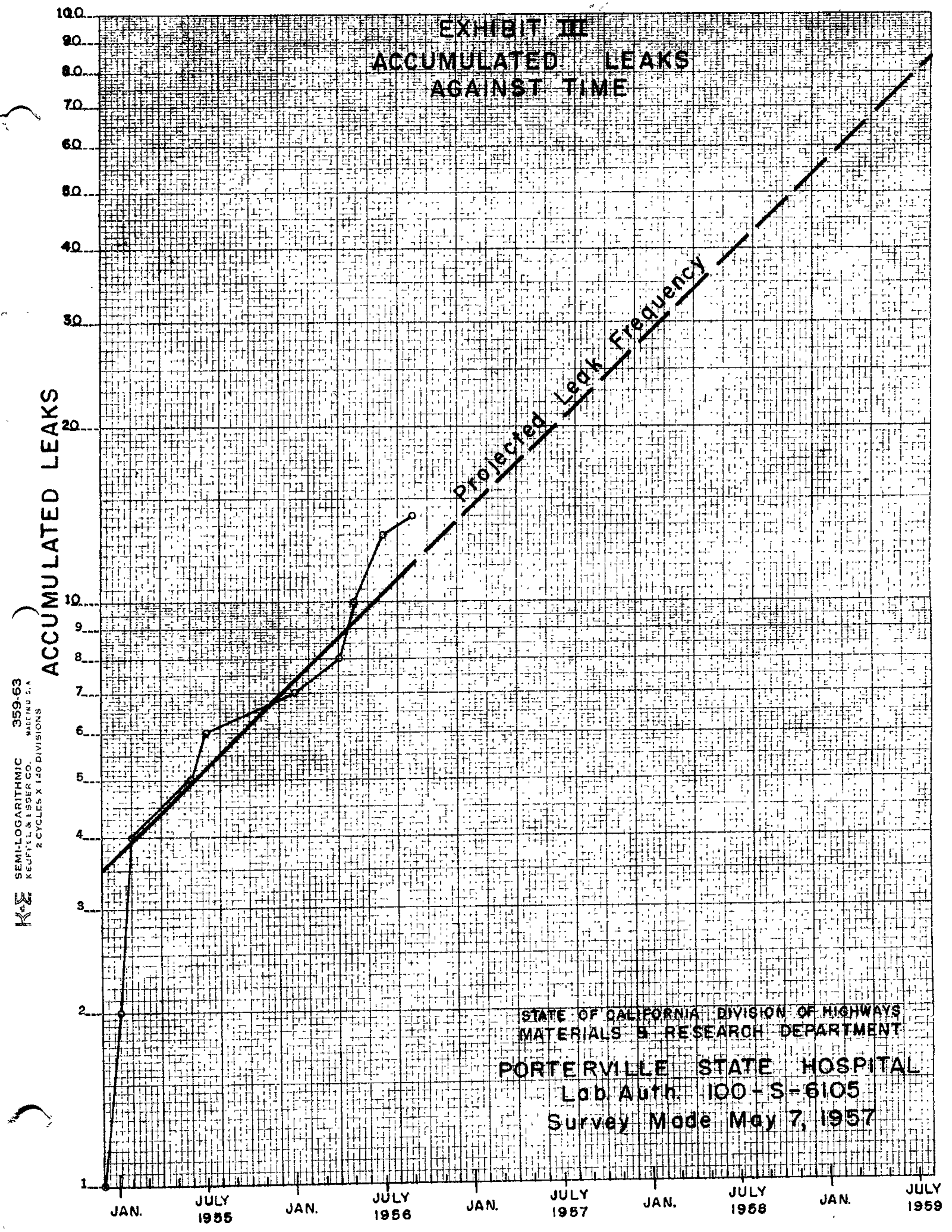
EXHIBIT III
ACCUMULATED LEAKS
AGAINST TIME
ACCUMULATED LEAKS
Projected Leak Frequency
STATE OF CALIFORNIA DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT
PORTERVILLE STATE HOSPITAL
Lab. Auth. 100-S-6105
Survey Made May 7, 1957
JAN.
JULY 1955
JAN.
JULY 1956
JAN.
JULY 1957
JAN.
JULY 1958
JAN.
JULY 1959
SEMI-LOGARITHMIC 359-63
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 140 DIVISIONS