FOR OFFICIAL USE ONLY

R 259

Technical Report

CORROSION OF BURIED PIPES

9 December 1963

U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

CORROSION OF BURIED PIPES

Y-F015-99-012

Type B Final Report

by

H. R. Joerding

ABSTRACT

The objective of this task was to determine the relative merit and economy of various types of external protective coverings for underground metal, cold pipes in the highly corrosive soil at the Naval Ordnance Test Station, China Lake, California.

A highly corrosive area of the station was selected as a test site. A network of a number of test pipes with different commercial protective coverings was connected to an existing cold water line and tested for 49 months. Included in the test as control were bare pipes of galvanized steel, black steel, and copper. Visual inspections through test holes were made periodically to determine the progress of corrosion. At the end of the test, all pipes were removed and brought to NCEL for close examination.

Final results showed no corrosion on galvanized steel pipe that was factory-wrapped with resin-impregnated glass cloth. This covering is very difficult to damage and imposes no special handling or installation requirements. Black steel pipe that was wrapped with black polyvinylchloride plastic tape was in excellent condition. Extreme care was necessary during installation to prevent cuts or nicks in the tape. The black steel pipes protected by bituminous coating, cured gilsonite, and uncured gilsonite had deteriorated badly.

INTRODUCTION

The desert soil at the Naval Ordnance Test Station, China Lake, California, has a heavy concentration of minerals in some areas, particularly the dry lake beds, causing serious corrosion problems for underground pipes. In these areas of the station, metal pipes have had very short lives. For example, an uncoated cast-iron water pipe failed after about 3 years of service. In another case, a 2-inch standard-weight black steel pipe, asphalt-coated and wrapped, failed in approximately 1 year. Because of the failure of these and other piping systems and the trend toward expansion of facilities in highly corrosive areas, an investigation was undertaken to determine the most suitable method of protecting cold water pipes against the corrosive elements of this soil.

The task objective was pursued by connecting underground test pipes to an existing cold water line in a corrosive area and observing the progress of corrosion by periodic visual inspection. Results of these inspections have been published.* After 49 months of tests, the pipes were removed and given a thorough and final inspection. The task is complete with this final report.

DESCRIPTIONS

Test Installation

The initial test installation was made in June 1958. At that time, six 60-foot lengths of 2-inch test pipe were laid in parallel trenches 3 feet deep and spaced 4 feet apart. The pipes were joined by a 10-inch asbestos-cement pipe header at each end, and the entire network was connected to an existing 10-inch asbestos-cement pipe that carried cold water. The network included one 60-foot length, made of 20-foot sections of galvanized steel, black steel, and copper, connected

---

* Technical Note N-373, Evaluation of External Corrosion Protection Methods for Cold Pipes in a Desert Soil, by K. B. Edwards, 1 June 1959. Technical Note N-404, Evaluation of External Corrosion Protection Methods for Buried Cold Pipes at China Lake, California, by H. R. Joerding, 1 March 1961. Ibid, N-441, 25 June 1962.

together by dielectric couplings and four 60-foot lengths of black steel pipe protected by a bituminous coating, a black plastic tape, uncured gilsonite, and cured gilsonite, respectively. The sixth length was galvanized steel and protected by a polyester-resin-impregnared glass cloth wrap. It was purchased from Temploc, Incorporated, Baldwin Park, California.*

As the test progressed, there was concern that the length with the 20-foot sections might not give reliable test data because the length of each pipe was shortened to 1/3 of full length, and because of the close proximity of dissimilar metals in soil of high electrical conductivity. As a result, three additional 60-foot lengths of pipe were installed in July 1960, with one length each of galvanized steel, black steel, and copper pipe, making a total of nine 60-foot lengths in the test. The complete network is shown schematically in Figure 1 and described as follows:

Pipe No. 1. Galvanized steel pipe: Type 1, standard-weight. The hot-dipped zinc-coated pipe conforms to Federal Specification WW-P-406b.

Pipe No. 2. Black steel pipe: Type 1, standard-weight. Conforms to Federal Specification WW-P-406b.

Pipe No. 3. Copper pipe: Type K, straight drawn tube. Conforms to Federal Specification WW-T-799a.

Pipe No. 4. Galvanized steel — black steel — copper pipe. Each length conformed to the weights and specifications for the corresponding type above. The dielectric couplings used between each length had a metallic cover with a threaded dielectric insert.

Pipe No. 5. Black steel pipe coated with bituminous coating. The black steel was the same as Pipe No. 2. The coating consisted of one coat of coal-tar primer, covered by a coat of coal-tar enamel. Application of the coating was according to Specification 34Yc for Type 1 protective system and was purchased under Mil-P-15147.

---

* This company is no longer in business, but the Durant Insulated Pipe Company, 325 Demeter Street, East Palo Alto, California, makes a similar product.

Pipe No. 6. Black steel pipe wrapped with plastic tape. The black steel was the same as Pipe No. 2. The tape was 3 inches wide, 10 mils thick, and made of polyvinylchloride. The adhesive used on the tape was a rubber-base cement. It was spirally wrapped with a 1/2-inch overlap. (The tape did not necessarily conform to any military specification.)

Pipe No. 7. Galvanized steel pipe factory-wrapped with resin-impregnated glass cloth. The galvanized steel was the same as Pipe No. 1. The cloth was 3 inches wide and about 40 mils thick. It was spirally wrapped with a 1/2-inch overlap at the factory. The glass cloth conforms to Mil-C-19663 and the resin to Mil-R-7575B, Grade A, Class O.

Pipe No. 8. Black steel pipe with uncured gilsonite. The black steel was the same as Pipe No. 2. The gilsonite, an asphaltic resinous material in granular form, surrounded the pipe and extended radially 5 inches; no heat was applied to the pipe to melt and consolidate the gilsonite into a coating.

Pipe No. 9. Black steel pipe with cured gilsonite. The black steel was the same as Pipe No. 2. The gilsonite, an asphaltic resinous material in granular form, surrounded the steel pipe and extended radially 5 inches. To melt this material and consolidate it around the pipe, the pipe was heated for 72 hours at 250 F as recommended by the supplier.

Inspection Procedure

The pipes were inspected periodically during the test through three test holes at each pipe. On each inspection, a set of new holes was dug so the condition of the pipes could be determined in soil not recently disturbed. The amount of rust and corrosion was observed and recorded; representative areas were photographed. There were five inspections; the first two at approximately 12-month intervals and the last three at 6-month intervals. The intervals were shortened as the test progressed because the rate of corrosion appeared to be accelerating.

In July 1962 the pipes were removed from the test and brought to NCEL. After a visual inspection of their general overall condition, they were thoroughly cleaned of rust and dirt by wire brushing so that micrometer measurements could be taken to determine the loss of metal from corrosion.

Determination of Metal Loss

Rough and uneven exterior surfaces on the pipe made it difficult to measure loss of metal; therefore, a statistical method was developed to obtain this information.

At 3-foot intervals on each pipe, one micrometer measurement of the outside diameter was made, at a random location on the circumference. These measurements were checked against the original specifications of the pipe diameters, and the percentage of loss was calculated (Appendix A). Then each pipe was cut lengthwise, and the thickness of the wall was measured at several places where extreme corrosion was evident. From this data the maximum percentage of loss in wall thickness was determined (Appendix A). The calculations for each pipe are summarized in Table I.

Soil Conditions

The corrosive character of the soil was determined by analyzing soil and ground water, and by measuring the ground-water level. Samples of soil and of ground water were taken from test holes at each periodic inspection and analyzed. These analyses are tabulated in Appendix B. Both soil and water were slightly alkaline and had a high concentration of dissolved solids, particularly chlorides, sulfates, and sodium. The results of pH determinations showed a variation from 7.8 to 9.4 for soil, and from 7.4 to 8.2 for ground water. The alkalinity of the ground water was produced by the presence of bicarbonates. The pH along with the chlorinity of the ground water showed it to be about equivalent to ocean water in corrosivity. The chlorinity of the ground water varied from 9000 to 38,000 ppm (parts per million); ocean water has a chlorinity of 19,000 ppm.

A thermocouple tree was located near the center of the test site to obtain temperatures of the air at ground level, and of the ground and ground water. Seven thermocouples were spaced at 9-inch intervals from 1 inch above ground level to 53 inches below the surface. Temperature curves from 6 April 1962 to 17 July 1962 (Figure 2) show that ground-water temperature was usually about 5 F below that of the ground. When this difference was noted between adjacent thermocouples, it was assumed that the ground-water level was between them. Figure 3 shows curves of the approximate level of the ground water for the same period. This level varied from 21 to 47 inches below the soil surface; thus the pipes were submerged much of the time.

RESULTS

Each length of pipe is described as it appeared at the final inspection at NOTS:

Pipe No. 1. Galvanized steel pipe; exposed 24 months. There was very little evidence of the zinc coating. Medium rust with tight scale covered 80% of the surface (Figure 4).

Pipe No. 2. Black steel pipe: exposed 24 months. There was medium to heavy rust with tight scale and pitting over the entire surface (Figure 5). Some of the pits penetrated over 50% through the wall. The surrounding soil was discolored by the rust.

Pipe No. 3. Copper pipe: exposed 24 months. The pipe was covered with a white powder that could be brushed off, leaving the surface clean like a mill finish although there were small marks, like those of a ball peen, over the entire surface. The surrounding soil was discolored dark green.

Pipe No. 4. Galvanized steel — black steel — copper pipe: exposed 49 months.

a. Galvanized steel pipe: nearly all of the zinc coating was gone and the remaining portions could be easily removed by rubbing. The pipe had blackened, but there was very little rust and only 5% loss of metal.

b. Black steel pipe: there was light to medium rust with loose scale over the entire surface. No deep pitting was observed.

c. Copper pipe: this pipe was clean and uncorroded although there were small marks, like those of a ball peen, over the entire surface.

Pipe No. 5. Black steel pipe with bituminous coating: exposed 49 months. Only about 50% of the pipe was still coated at the end of the test. The bitumin that came off seemed to disperse into the earth, discoloring the surrounding soil. The coating that remained on the pipe apparently did not offer much protection as there was medium rust with loose scale and pitting over the entire surface. Some of the pits penetrated over 40% through the wall.

Pipe No. 6. Black steel pipe wrapped with plastic tape: exposed 49 months. In general, the tape was intact, in good condition, and gave excellent protection. The only corrosion occurred where the tape had been nicked by shovels when the inspection holes were dug (Figure 6); however, at these places the pits penetrated over 40% through the wall.

Pipe No. 7. Galvanized steel pipe wrapped with resin-impregnated glass cloth: exposed 49 months. This pipe was in excellent condition. There was no sign of rust nor deterioration of the zinc coating (Figure 7). The glass cloth was also in excellent condition with no evidence of deterioration (Figure 8).

Pipe No. 8. Black steel pipe with uncured gilsonite: exposed 49 months. Medium to heavy rust, tight scale, and deep pits covered the pipe. The gilsonite did not deteriorate, but it apparently permitted gradual seepage of the corrosive soil elements. It offered good protection for the first 24 months of the test. However, when rusting began, it progressed very fast. Many deep pits penetrated the wall as deep as 85% (Figure 9).

Pipe No. 9. Black steel pipe with cured gilsonite: exposed 49 months. The gilsonite consolidated well and did not deteriorate, but it permitted overall light to medium rust with loose scale and pitting that penetrated as much as 84% into the wall (Figure 10).

The plastic tape and glass cloth provided the most protection, and gilsonite, cured and uncured, provided the least. However, uncured gilsonite gave good protection for the first 2 years. It is interesting to note that the individual pipes Nos. 2 and 3, suffered more metal loss than their coupled counterparts 4b and 4c despite the fact that the former were in the ground about half as long.

COST

Current prices (1963) of the pipes and protective coverings (Table II) are f.o.b. the vendor and do not include any costs for joints or connections. The rental cost of a steam generator for curing the gilsonite is also not included. For the test, a steam generator was used for 2 days at a cost of $100 per day. Because the zinc plating was unaffected, it is unnecessary to use galvanized pipe when the glass cloth is applied. Black steel pipe would lower the cost.

CONCLUSIONS

1. Resin-impregnated glass cloth was the most satisfactory covering tested in this environment. There was no rust or discoloration of the zinc plating or the steel pipe itself; there was no evidence of deterioration of the covering; and no special handling was required because the covering is hard and not easily damaged.

2. Plastic tape was also satisfactory where carefully installed. It was rust-free except where the tape had been damaged by shovels. There was no evidence of deterioration of the tape; however, the tape is soft, easily cut or damaged, and special care is required to prevent nicks or cuts during installation. Even a sharp rock in the backfill could cause damage.

3. The other three coatings (cured and uncured gilsonite and bitumin) permitted extensive rusting and are not satisfactory for use in this type of soil.

Table 1. Summary of Statistics for Corrosion of Buried Pipes at China Lake, California

Pipe No.	Type	External Covering	Exposure Time (mo)	Uniform External Metal Loss (%)			Maximum External Loss in Wall Thickness Due to Pitting (%)		
				Lower Limit[1]	Average	Upper Limit[1]	Lower Limit[1]	Average	Upper Limit[1]
1	Galvanized Steel	none	24	0	0^+	4	0	3	13
2	Black Steel	none	24	12	16	20	30	41	52
3	Copper	none	24	7	13	18	0	3	20
4a	Galvanized Steel	none	49	0	5	12	0	2	11
4b	Black Steel	none	49	0	2	6	0	5	14
4c	Copper	none	49	0	5	11	0	2	19
5	Black Steel	bituminous coating	49	11	15	18	26	38	47
6	Black Steel	plastic tape	49	0	0	1	0 23[2]	0 33[2]	0 43[2]
7	Galvanized Steel	glass cloth	49	0	0	0	0	0	0
8	Black Steel	uncured gilsonite	49	5	10	15	12	49	85
9	Black Steel	cured gilsonite	49	6	11	15	17	29	84

1/ 95% confidence limits.
2/ At places where the covering was nicked by shovels during inspections.

Table II. Costs of 2-Inch Pipes and Coverings (1963)

Pipe	Cost of Pipe[1] ($)	Covering	Cost of Covering[1] ($)	Total ($)
Galvanized Steel	0.55	none	—	0.55
Black Steel	0.45	none	—	0.45
Copper	1.20	none	—	1.20
Black Steel	0.45	bituminous coating	0.45	0.90
Black Steel	0.45	plastic tape	0.45	0.90
Galvanized Steel	0.55	glass cloth	0.87	1.42
Black Steel	0.45	uncured gilsonite	2.45	2.90
Black Steel	0.45	cured gilsonite	2.45	2.90

[1]per foot of pipe

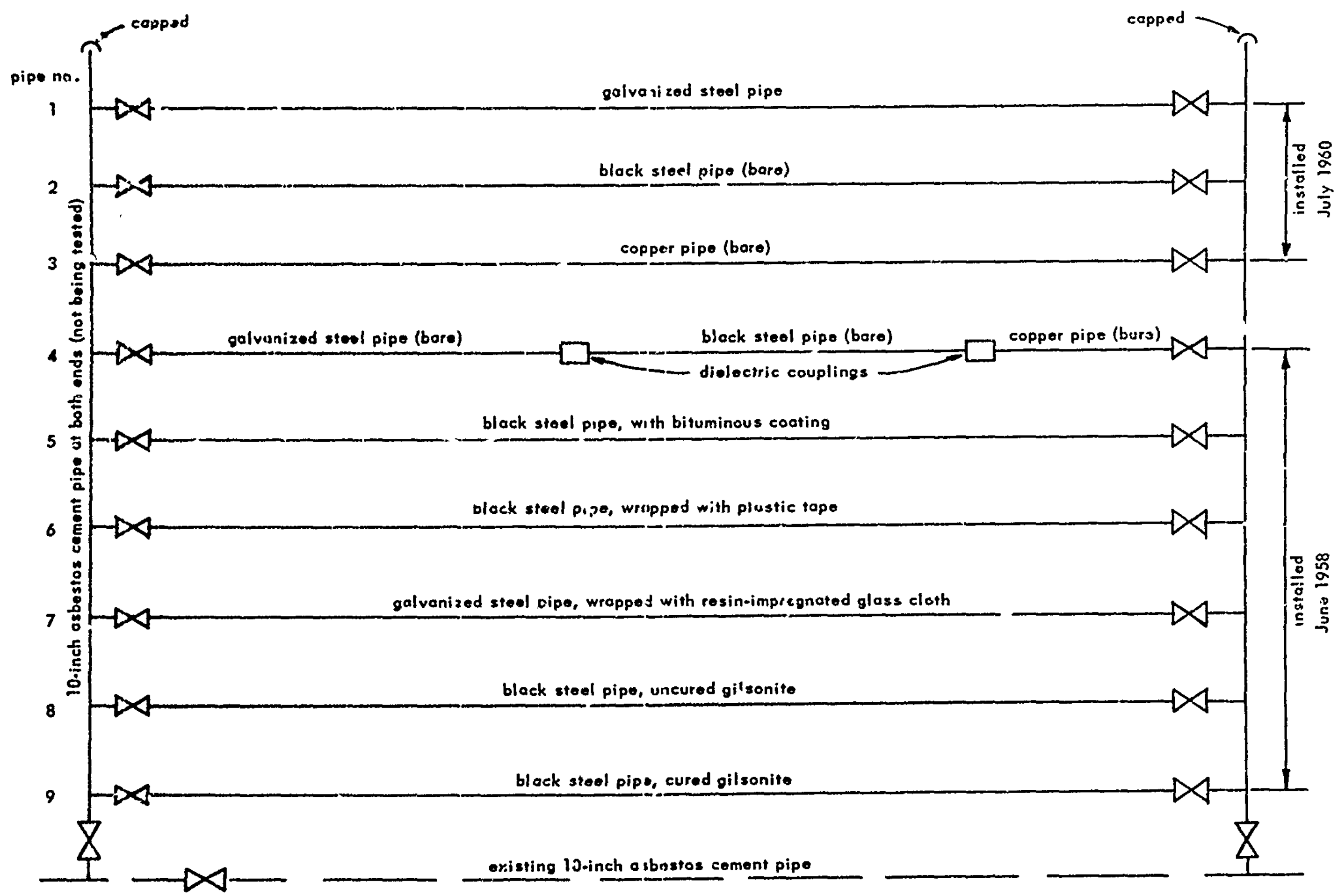

Figure 1. Diagram of underground pipe installation. Pipes spaced 4 feet apart and buried 3 feet.

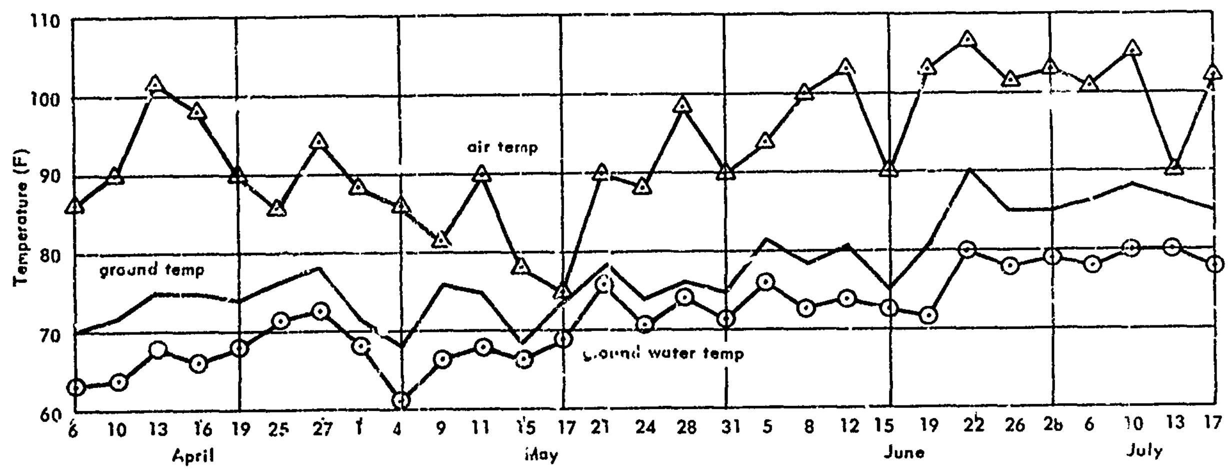

Figure 2. Temperature of air, soil, and ground water from 4 April to 17 July 1962.

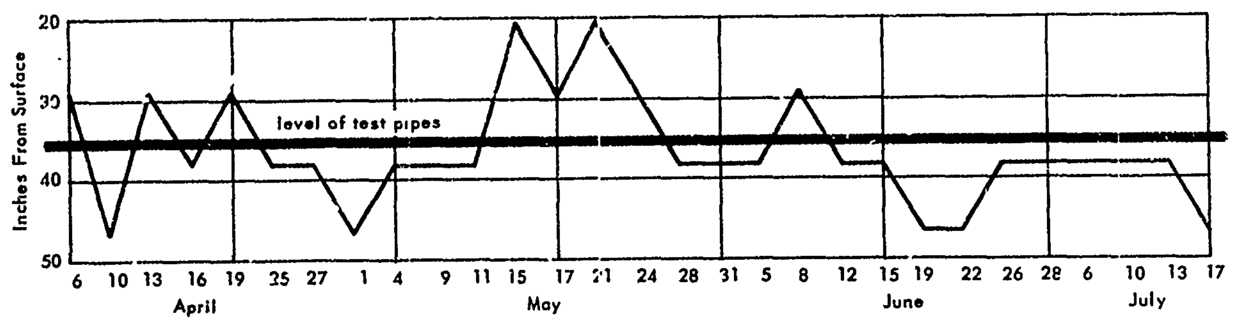

Figure 3. Approximate level of ground water from 4 April to 17 July 1962.

Figure 4. Galvanized steel pipe after 24 months exposure; galvanized coating nearly gone and 80% coverage of medium rust with tight scale.

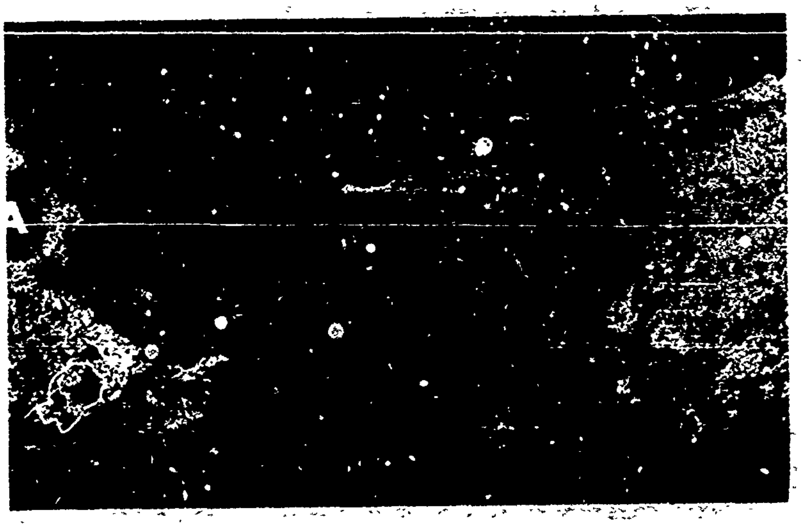

Figure 5. Bare black steel pipe after 24 months exposure; 100% coverage of medium to heavy rust with tight scale and pits.

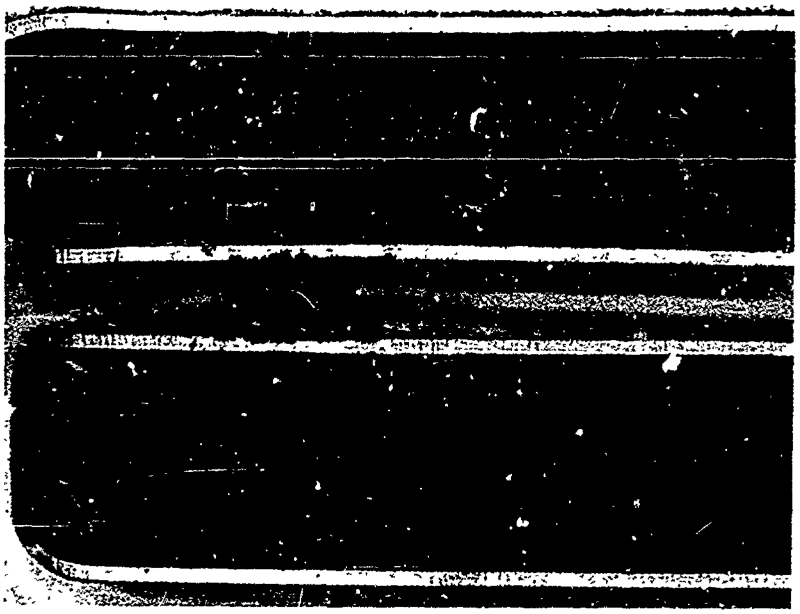

Figure 6. Black steel pipe wrapped with plastic tape; the pipe was rust-free except where the tape had been nicked by a shovel (see arrow).

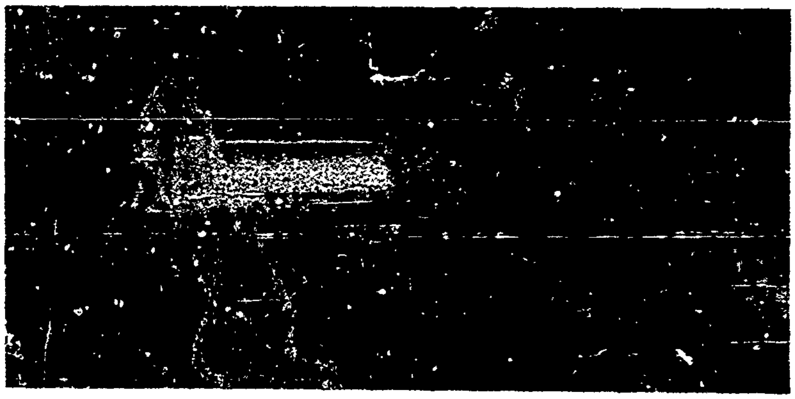

Figure 7. Galvanized steel pipe with a section of the resin-impregnated glass cloth removed; after 49 months exposure the pipe was bright and clean.

Figure 10. Black steel pipe with cured gilsonite; 100% coverage of light to medium rust with loose scale and light pitting.

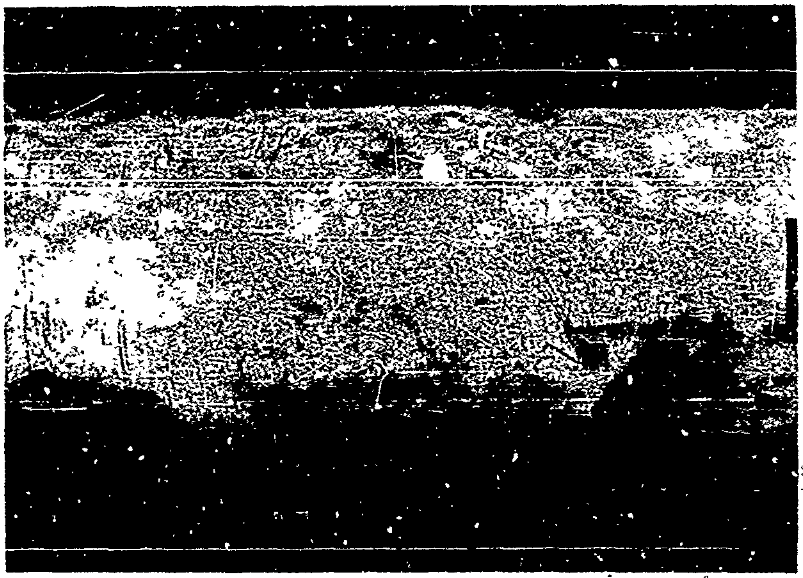

Figure 8. Resin-impregnated glass cloth wrapping on a galvanized steel pipe; no signs of deterioration after 49 months exposure.

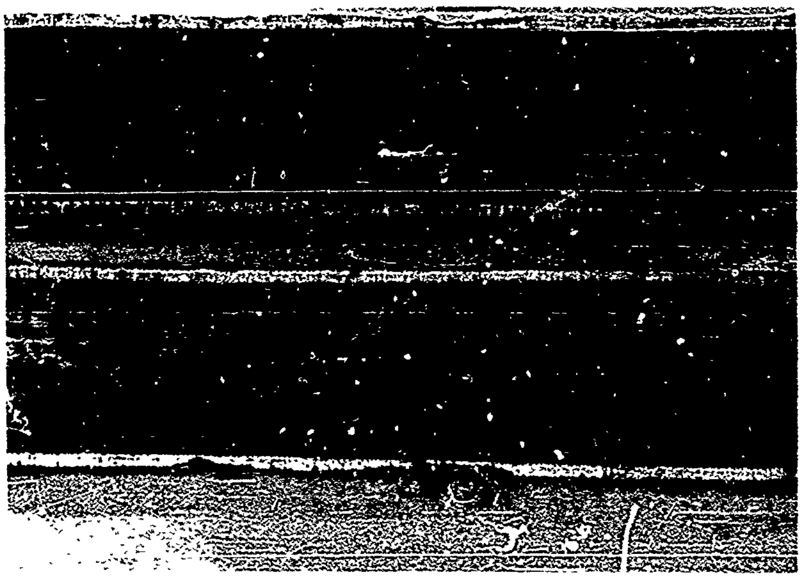

Figure 9. Black steel pipe coated with uncured gilsonite; 100% coverage of medium to heavy rust with tight scale and deep pits (see arrow).

Appendix A

CALCULATIONS OF LOSS OF METAL AND WALL THICKNESS

by

W. Wilcoxson

The statistics of importance to this investigation are the quantity of metal lost, per unit length, due to external corrosion, and the degree of pitting due to external corrosion. Let

L = length of pipe

$\bar{R}_o, \bar{r}_o$ = original mean outer and inner radii, respectively

$\bar{R}_t, \bar{r}_t$ = mean outer and inner radii after time t, respectively

Then an estimate of the percent of metal lost per unit length after a time t due to external corrosion is

$$m_t = \frac{100\left[\frac{2\pi L(\bar{R}_o - \bar{R}_t)}{L}\right]}{\frac{2\pi L(\bar{R}_o - \bar{r}_o)}{L}}$$

$$= \frac{100(\bar{R}_o - \bar{R}_t)}{\bar{R}_o - \bar{r}_o}$$

To determine the degree of pitting, let

$\bar{T}_o = \bar{R}_o - \bar{r}_o$

= original mean wall thickness

$\bar{T}_t$ = minimum wall thickness after time t (an average from several places showing extreme external pitting and corrosion).

The average loss in wall thickness, $\bar{\ell}_i$, due to internal corrosion and erosion is

$$\bar{\ell}_i = \bar{r}_t - \bar{r}_o$$

Therefore, the maximum percentage loss in wall thickness due to pitting, p_t, after a time t due to external corrosion is

$$p_t = \frac{100\,(\bar{T}_o - \bar{T}_t + \bar{\ell}_i)}{\bar{T}_o + \bar{\ell}_i}$$

An estimate of the 95% confidence limits* on m are

$$M_t = m_t \pm 1.96\left[\left(\Delta\bar{R}_o \frac{\partial m_t}{\partial \bar{R}_o}\right)^2 + \left(\Delta\bar{T}_o \frac{\partial m_t}{\partial \bar{T}_o}\right)^2 + \left(\Delta\bar{R}_t \frac{\partial m_t}{\partial \bar{R}_t}\right)^2\right]^{\frac{1}{2}}$$

$$= m_t \pm \frac{1.96}{\bar{T}_o}\left[\Delta\bar{R}_o^{\,2}\,(100 - m_t)^2 + \Delta\bar{T}_o^{\,2}\, m_t + \Delta\bar{R}_t^{\,2}\, 100^2\right]^{\frac{1}{2}}$$

An estimate of the limits on p_t are

---

* On the average one out of twenty samples would be expected to exceed these limits.

$$P_t = p_t \pm 1.96\left[\left(\Delta\bar{T}_o \frac{\partial p_t}{\partial \bar{T}_o}\right)^2 + \left(\Delta\bar{T}_t \frac{\partial p_t}{\partial \bar{T}_r}\right)^2 + \left(\Delta\bar{r}_t \frac{\partial p_t}{\partial \bar{r}_t}\right)^2 + \left(\Delta\bar{r}_o \frac{\partial p_t}{\partial \bar{r}_o}\right)^2\right]^{\frac{1}{2}}$$

$$= p_t \pm \frac{1.96}{\bar{T}_o + \bar{\ell}_i}\left[\Delta\bar{T}_o^{\,2}(100 - p_t)^2 + \Delta\bar{T}_t^{\,2}\, 100^2 + \Delta\bar{r}_t^{\,2}(100 - p_t)^2\right.$$

$$\left. + \Delta\bar{r}_o^{\,2}(100 - p_t)^2\right]^{\frac{1}{2}}$$

$$= p_t \pm \frac{1.96}{\bar{T}_o + \bar{\ell}_i}\left[(100 - p_t)^2(\Delta\bar{T}_o^{\,2} + \Delta\bar{r}_t^{\,2} + \Delta\bar{r}_o^{\,2}) + 100^2\,\Delta\bar{T}_t^{\,2}\right]^{\frac{1}{2}}$$

The manufacturer's tolerance on the original thickness is 0.007; i.e., $\Delta\bar{T}_o = 0.007$. According to standard shop practice, the tolerance on the original radii are

$$\Delta\bar{r}_o = 0.005/2 = 0.0025$$

$$\Delta\bar{R}_o = 0.005/2 = 0.0025$$

$\Delta\bar{R}_t$ is the standard error of the mean, $\bar{R}_t$, and $\Delta\bar{T}_t$ is the standard error of the mean, $\bar{T}_t$. They are estimated by

$$\Delta\bar{R}_t^{\,2} = \frac{1}{n(n-1)}\sum_{j=1}^{n}(R_{tj} - \bar{R}_t)^2$$

$$\Delta\bar{T}_t^{\,2} = \frac{1}{k(k-1)}\sum_{j=1}^{k}(T_{tk} - \bar{T}_t)^2$$

Where n is the number of measurements on the radius and k is the number of measurements on the thickness. R_{tj} and T_{tj} are the j^{th} measurements. $\overline{R}_t$ and $\overline{T}_t$ are the mean values of these measurements; i.e.,

$$\overline{R}_t = \frac{1}{n} \sum_{j=1}^{n} R_{tj}$$

$$\overline{T}_t = \frac{1}{k} \sum_{j=1}^{k} T_{tj}$$

Since the measurements were made on the pipe diameter, D, it can be shown that

$$\overline{R}_t = \frac{1}{2}\overline{D}_t$$

$$\Delta\overline{R}_t^2 = \frac{1}{4}\Delta\overline{D}_t^2$$

where $$\overline{D}_t = \frac{1}{n} \sum_{j=1}^{n} D_{tj}$$

$$\Delta\overline{D}_t^2 = \frac{1}{n(n-1)} \sum_{j=1}^{n} (D_{tj} - \overline{D}_t)^2$$

Sample Calculation

For black steel pipe coated with cured gilsonite (all measurements in inches)

Outside Diameter

i	D
1	2.314
2	2.334
3	2.347
4	2.362
5	2.340
6	2.367
7	2.370
8	2.327
9	2.330
10	2.330
11	2.342
12	2.363
13	2.342
14	2.352
15	2.365
16	2.297
17	2.333

Inside Diameter

1	2.075
2	2.074
3	2.074
4	2.074
5	2.073
6	2.073

Minimum Wall Thickness

1	0.095
2	0.103
3	0.120
4	0.130

$\bar{R}_o = 1.1875$ $\Delta\bar{R}_o = 0.0025$

$\bar{r}_o = 1.0335$ $\Delta\bar{r}_o = 0.0025$

$\bar{T}_o = 0.154$ $\Delta\bar{T}_o = 0.007$

Results of computations:

$\bar{R}_t = 1.171$ $\Delta \bar{R}_t^2 = 5.853 \times 10^{-6}$

$\bar{r}_t = 1.037$ $\Delta \bar{r}_t^2 = 6.333 \times 10^{-8}$

$\bar{T}_t = 0.112$ $\Delta \bar{T}_t^2 = 6.317 \times 10^{-7}$

$\bar{\ell}_i = 3.417 \times 10^{-3}$

$m_t = 10.695$

$M_t = 10.695 \pm 4.296$

$p_t = 28.851$

$P_t = 28.851 \pm 11.888$

Rounding the results, for external corrosion only:

	Metal Loss (%)	Maximum Loss in Wall Thickness (%)
Lower limit	6	17
Average	11	28
Upper limit	15	41

Appendix B

SOIL AND WATER ANALYSES

Table B-1. Soil Electrolyte Analysis (parts per million)

Date of Sample	Sample No.	Hydroxides (OH)	Carbonates (CO_3)	Bicarbonates (HCO_3)	Chlorides (Cl)	Sulphates (SO_4)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Oxides (Fe_2O_3) (Al_2O_3)	Hydrogen Ion Concentration (pH)
Oct 59	1 1/	0	384	329	9067	2941	64	5	8921	—	8.9
	2	0	552	305	895	1336	240	15	3934	—	9.1
	3	54	1812	0	9577	2602	280	29	8542	—	9.4
Oct 60	1	0	20	85	1700	222	537	267	897	138	9.2
Jul 61	1	0	0	49	4884	754	44	29	1660	128	8.6
	2	0	0	58	6648	1525	107	21	3380	112	8.3
Feb 62	1 2/	0	trace	[illegible]	1038	138	26	trace	764	0	8.2
	2	0	0	159	1475	203	18	2	1096	0	7.8
	3	0	0	171	1100	147	18	5	820	0	8.1
	4	0	trace	183	488	50	18	4	385	0	8.0
Jul 62	1 2/	0	0	122	3300	379	50	1	2310	0	8.1
	2	0	0	128	2200	264	40	2	1540	0	8.0
	3	0	trace	122	1438	250	24	1	1060	0	8.3
	4	0	0	114	940	125	13	0	700	0	8.5

1/ Analysis by Hornkohl Laboratories, Bakersfield, California
2/ Analysis by Fruit Growers Laboratory, Santa Paula, California

Table B-II. Ground Water Analysis (parts per million)

Date of Sample	Hydroxides (OH)	Carbonates (CO_3)	Bicarbonates (HCO_3)	Chlorides (Cl)	Sulphates (SO_4)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Silica (SiO_2)	Oxides (Fe_2O_3) (Al_2O_3)	Total Dissolved Solids	Hardness	Hydrogen Ion Concentration (pH)
Mar 59	0	36	74	8980	843	131	30	5006	52	37	15189	450	7.9
Oct 60	0	0	117	18500	1762	492	80	11320	177	458	32906	1551	8.0
Jul 61	0	142	65	38624	1972	291	68	30500	15	116	71793	1005	7.4
Feb 62 1/	0	0	189	23750	2764	290	47	16380	35	0	43422	920	7.7
Jul 62 1/	0	0	293	35000	4526	300	54	24600	52	0	65333	968	8.2

1/ Analysis by Fruit Growers Laboratory, Santa Paula, California

DISTRIBUTION LIST

SNDL Code	No. of Activities	Total Copies	
	1	10	Chief, Bureau of Yards and Docks (Code 42)
23A	1	1	Naval Forces Commanders (Taiwan only)
39B	2	4	Construction Battalions
39D	10	10	Mobile Construction Battalions
39E	3	3	Amphibious Construction Battalions
39F	1	2	Construction Battalion Base Units
A2A	1	1	Chief of Naval Research - Only
A3	2	2	Chief of Naval Operation (OP-07, OP-04)
A5	5	5	Bureaus
B3	2	2	Colleges
E4	1	2	Laboratory ONR (Washington, D. C. only)
E5	1	1	Research Office ONR (Pasadena only)
E16	1	1	Training Device Center
F9	7	7	Station - CNO (Boston; Key West; San Juan, Long Beach; San Diego; Treasure Island, and Rodman, C. Z. only)
F17	6	6	Communication Station (San Juan; San Francisco; Pearl Harbor; Adak, Alaska; and Guam only)
F41	1	1	Security Station
F42	1	1	Radio Station (Oso and Cheltenham only)
F48	1	1	Security Group Activities (Winter Harbor only)
H3	7	7	Hospital (Chelsea; St. Albans, Portsmouth, Va; Beaufort; Great Lakes; San Diego; and Camp Pendleton only)
H6	1	1	Medical Center
J1	2	2	Administration Command and Unit - BuPers (Great Lakes and San Diego only)
J3	1	1	U. S. Fleet Anti-Air Warfare Training Center (Virginia Beach only)
J4	2	2	Amphibious Bases
J19	1	1	Receiving Station (Brooklyn only)
J34	1	1	Station - BuPers (Washington, D. C. only)
J46	1	1	Personnel Center
J48	1	1	Construction Training Unit
J60	1	1	School Academy
J65	1	1	School CEC Officers
J84	1	1	School Postgraduate
J90	1	1	School Supply Corps

DISTRIBUTION LIST (Cont'd)

SNDL Code	No. of Activities	Total Copies	
J95	1	1	School War College
J99	1	1	Communication Training Center
L1	11	11	Shipyards
L7	4	4	Laboratory - BuShips (New London; Panama City; Carderock; and Annapolis only)
L26	5	5	Naval Facilities - BuShips (Antigua; Turks Island; Barbados; San Salvador; and Eleuthera only)
L30	1	1	Submarine Base (Groton, Conn. only)
L32	2	2	Naval Support Activities (London and Naples only)
L42	2	2	Fleet Activities - BuShips
M27	4	4	Supply Center
M28	6	6	Supply Depot (except Guantanamo Bay; Subic Bay; and Yokosuka)
M61	2	2	Aviation Supply Office
N1	6	18	BuDocks Director, Overseas Division
N2	9	27	Public Works Offices
N5	3	9	Construction Battalion Center
N6	5	5	Construction Officer-in-Charge
N7	1	1	Construction Resident-Officer-in-Charge
N9	6	12	Public Works Center
N14	1	1	Housing Activity
R9	2	2	Recruit Depots
R10	2	2	Supply Installations (Albany and Barstow only)
R20	1	1	Marine Corps Schools (Quantico)
R64	3	3	Marine Corps Base
R66	1	1	Marine Corps Camp Detachment (Tengan only)
W1A1	6	6	Air Station
W1A2	35	35	Air Station
W1B	8	8	Air Station Auxiliary
W1C	4	4	Air Facility (Phoenix; Monterey; Oppama; Naha; and Naples only)
W1E	6	6	Marine Corps Air Station (except Quantico)
W1H	9	9	Station - BuWeps (except Rota)
	1	1	Deputy Chief of Staff, Research and Development, Headquarters, U. S. Marine Corps, Washington, D. C.
	1	1	President, Marine Corps Equipment Board, Marine Corps School, Quantico, Va.

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	Chief of Staff, U. S. Army, Chief of Research and Development, Department of the Army, Washington, D. C.
1	1	Office of the Chief of Engineers, Assistant Chief of Engineering for Civil Works, Department of the Army, Washington, D. C.
1	1	Chief of Engineers, Department of the Army, Washington, D. C., Attn: Engineering Research and Development Division
1	1	Chief of Engineers, Department of the Army, Washington, D. C., Attn: ENGCW-OE
1	1	Director, U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Va., Attn: Information Resources Branch
1	1	ASD (ASNXRR), Wright-Patterson Air Force Base, Ohio
1	3	Headquarters, U. S. Air Force, Directorate of Civil Engineering, Washington, D. C., Attn: AFOCE-ES
1	1	Commanding Officer, U. S. Naval Construction Battalion Center, Port Hueneme, Calif., Attn: Materiel Dept., Code 140
1	1	Deputy Chief of Staff, Development, Director of Research and Development, Department of the Air Force, Washington, D. C.
1	1	Director, National Bureau of Standards, Department of Commerce, Connecticut Avenue, Washington, D. C
1	2	Office of the Director, U. S. Coast and Geodetic Survey, Washington, D. C.
1	20	Defense Documentation Center, Building 5, Cameron Station, Alexandria, Va.
1	2	Director of Defense Research and Engineering, Department of Defense, Washington, D. C
1	1	Commander, Pacific Missile Range, Technical Documentation Section, P. O. Box 10, Point Mugu, Calif., Attn: 4332
1	2	Director, Bureau of Reclamation, Washington, D. C.
1	1	Facilities Officer, Code 108, Office of Naval Research, Washington, D. C.
1	1	Federal Aviation Agency, Office of Management Services, Administrative Services Division, Washington, D. C., Attn: Library Branch
1	2	Commander Naval Beach Group TWO, U. S. Naval Amphibious Base, Little Creek, Norfolk, Va
1	1	Office of Naval Research Branch Office, Navy No. 100, Box 39, FPO, New York
1	1	Commanding Officer, U. S. Naval Unit, U. S. Army Chemical Corps School, Fort McClellan, Ala.
1	1	U. S. Naval Research Laboratory, Chemistry Division, Washington, D. C.
1	1	Deputy Chief of Staff, Research & Development Headquarters, U. S. Marine Corps, Washington, D. C.
1	1	Paint Laboratory, U. S. Engineers Office, Clock Tower Building, Rock Island, Ill.
1	4	U. S. Army Material Command, Washington, D. C.
1	1	Commanding Officer, Signal Corps Engineering Labs, Fort Monmouth, N. J.

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	Chief, Bureau of Ships, Navy Department, Washington, D. C., Attn: Chief of Research and Development Division
1	1	Officer in Charge, U. S. Naval Supply Research and Development Facility, Naval Supply Center, Bayonne, N. J., Attn: Library
1	1	Commander, Pacific Missile Range, Point Mugu, Calif., Attn: Technical Director
1	1	Commander, Amphibious Force, U. S. Pacific Fleet, San Diego, Calif.
1	1	Commander, Amphibious Force, U. S. Atlantic Fleet, U. S. Naval Base, Norfolk, Va.
1	1	Officer in Charge, U. S. Naval Supply Research and Development Facility, Naval Supply Center, Bayonne, N. J.
1	1	Commander, Norfolk Naval Shipyard, Portsmouth, Va., Attn: Metallurgical Laboratory
1	1	Commander, Norfolk Naval Shipyard, Portsmouth, Va., Attn: Chemical Laboratory
1	1	Commanding Officer, Fleet Training Center, Navy No. 128, FPO, San Francisco
1	1	Commander, U. S. Naval Shipyard, Boston, Mass., Attn: Materials and Chemical Laboratory
1	1	Commander, U. S. Naval Shipyard, Brooklyn, Attn: Material Laboratory
1	1	Navy Liaison Officer, Detroit Arsenal, Centerline, Mich.
1	1	U. S. Army Corps of Engineers, Office of the District Engineer, St. Paul District, 1217 U.S.P.O. and Customs House, St. Paul, Minn.
1	1	U. S. Army Cold Regions Research and Engineering Laboratory, Corps of Engineers, P.O. Box 282, Hanover, N. H.
1	1	Chief, Physical Research Branch, Research Division, U. S. Department of Commerce, Bureau of Public Roads, Washington, D. C.
1	1	Mr. J. R. Moses, Director (C-400), Materials Testing and Evaluation Division, District Public Works Office, 14ND, Navy No. 128, FPO, San Francisco
1	1	Mr. W. E. Edwards (Code M-220:WEE), Materials Division, District Public Works Office, 14ND, Navy No. 128, FPO, San Francisco, Calif.
1	1	Mr. William Crozer, (Code D-230), DPWO, 12th Naval District, San Bruno, Calif.
1	1	Mr. Gordon Ho[illegible]n, (Code 7036), Public Works Department, U. S. Naval Ordnance Station, China Lake, Calif.
1	1	Mr. E. W. Watkins, (Code B-330), DPWO, 11th Naval District, San Diego
1	1	Director, National Bureau of Standards, Department of Commerce, Connecticut Avenue, Washington, D. C., Attn: Mr. Melvin Romanoff
1	1	Director, Fort Monmouth Office, Communications-Electronics Combat Developments Agency, Building 410, Fort Monmouth, N. J.

U. S. Naval Civil Engineering Laboratory
Technical Report R-259
CORROSION OF BURIED PIPES, by H. R. Joerding
26 p. illus 9 Nov 63 OFFICIAL USE ONLY

The results of a 49-month test to evaluate methods of protecting external surfaces of underground, metal, cold pipes in the highly corrosive soil at NOTS, China Lake, California.

Key Words: Corrosion; Pipe Exteriors; Soil; Steel; Glass Cloth; Coatings.

1. Corrosion — Buried pipes
I. Joerding, H. R.
II. Y-F015-99-012

U. S. Naval Civil Engineering Laboratory
Technical Report R-259
CORROSION OF BURIED PIPES, by H. R. Joerding
26 p. illus 9 Nov 63 OFFICIAL USE ONLY

The results of a 49-month test to evaluate methods of protecting external surfaces of underground, metal, cold pipes in the highly corrosive soil at NOTS, China Lake, California.

Key Words: Corrosion; Pipe Exteriors; Soil; Steel; Glass Cloth; Coatings.

1. Corrosion — Buried pipes
I. Joerding, H. R.
II. Y-F015-99-012

U. S. Naval Civil Engineering Laboratory
Technical Report R-259
CORROSION OF BURIED PIPES, by H. R. Joerding
26 p. illus 9 Nov 63 OFFICIAL USE ONLY

... of a 49-month test to evaluate methods of protecting ... metal.

Key Words: Corrosion; Pipe Exteriors; S... Glass Cloth; Coatings.

1. Corrosion — Buried pipes
I. Joerding, H. R.
II. Y-F015-99-012

U. S. Naval Civil Engineering Laboratory
Technical Report R-259
CORROSION OF BURIED PIPES, by H. R. Joerding
26 p. illus 9 Nov 63 OFFICIAL USE ONLY

The results of a 49-month test to evaluate methods of protecting external surfaces of underground, metal, cold pipes in the highly corrosive soil at NOTS,

... Cloth; Coatings.

1. Corrosion — Buried pipes
I. Joerding, H. R.
II. Y-F015-99-012