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FIELD SURVEY OF INTERIOR COATINGS FOR WATER TANKS

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U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

FIELD SURVEY OF INTERIOR COATINGS FOR WATER TANKS

Y-R007-08-403

Type B

by

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OBJECT OF TASK

To find or develop the most effective materials and methods for coating and lining steel water tanks, 24 inches in diameter and larger, to protect the tanks from interior corrosion.

ABSTRACT

A field survey of the Naval Shore Establishment was conducted to assess the magnitude of coating deterioration and tank corrosion on the interior of steel tanks used to store water. Data collected from the survey were also analyzed to ascertain the factors contributing to such deterioration. Improper surface preparation and choice of paint systems were noted as important factors allowing corrosion in such tanks. Surface preparation by sandblasting before application of coatings was recommended for maximum coating life.

INTRODUCTION

The task of investigating interior coatings for steel water storage tanks was initiated at the request of the Bureau of Yards and Docks, Power and Utilities Branch. A number of field activities with related corrosion problems also proposed the task. It is co-sponsored by the Sanitary Engineering Branch, Code M-530, and the Preservation and Chemical Specification Section, Code E-236.

The Bureau furnished background information citing typical field problems of corrosion on the interior of medium and large warm or hot water storage tanks. Separate field activities reported corrosion and premature coating deterioration in (1) two submarine escape training tanks storing warm chlorinated water at about 90 F, (2) one large ground level tank storing hot demineralized water at about 150 F, and (3) numerous siliceous (portland cement base) lined tanks 24 inches in diameter and larger used to store hot water.

The Bureau requested the Laboratory to conduct a field survey of naval installations by questionnaire to determine the type of corrosion problems existing in the interior of water tanks and make recommendations as to further investigations.

PROCEDURE

The Laboratory conducted a field survey directed to all activities of the Naval Shore Establishment, to assess the magnitude of corrosion deterioration on the interior of steel water tanks and to ascertain the factors contributing to such deterioration. This survey was initiated in May 1960 using the two-page inquiry form, Appendix A. Data collected from the survey were analyzed, and the results are reported herein.

ANALYSIS OF SURVEY DATA

A total of 400 survey forms were received from twelve of the fourteen field activities contacted. All reporting activities furnished data for medium and large outdoor ground level and elevated tanks used to store water at ambient temperatures. Only one activity included data on tanks used to supply hot water.

From the 400 inquiry forms received, only 300 contained information suitable for analysis. The other forms were so incomplete that their data were not included in the survey. Because of the large number of variables, the limited data were considered too meager to be adaptable for rigid statistical analysis. Simple array counting techniques were, therefore, used to analyze the survey data.

1. Cold Water Tanks

Extent of coating deterioration was generally similar to extent of tank corrosion. There were a few tanks, however, in which serious coating deterioration had occurred, but tank corrosion had not proceeded to a significant extent. These were included in the category "significant deterioration." Although the extent of deterioration at different tank levels was requested, insufficient information in this area was received for presentation in this report.

The magnitude of coating deterioration and tank corrosion reported for tanks used to store water at prevailing ambient temperatures is related to storage capacity in Table 1. Serious or significant deterioration were reported in 50 percent (23 plus 27) of the tanks for which data was available, corresponding to 48 percent (23 plus 25) of the total storage capacity of the tanks represented. Extent of deterioration was not given for an additional 64 tanks that were reported. This represents a capacity of 12.2 out of a total storage capacity of 59.5 million gallons.

Table 1. Deterioration with Respect to Storage Capacity

Observed Deterioration	No. of Tanks	% of Tanks with Deterioration Data	Storage Capacity in Million Gallons	% of Capacity with Deterioration Data
Serious	54	23	10.8	23
Significant	64	27	11.8	25
Negligible	118	50	24.7	52
Total	236	100	47.3	100
Not Given	64	--	12.2	--

In Table 2, the extent of coating deterioration and tank corrosion is related to the type of surface preparation used prior to painting. Combined serious and significant deterioration was reported in 30 percent of the sandblasted tanks and 70 percent of the wirebrushed tanks for which data was available. Type of surface preparation was not given for 179 tanks reported.

Table 2. Deterioration with Respect to Surface Preparation

Observed Deterioration	Sandblasted Surfaces: No. of Tanks	Sandblasted Surfaces: % of Tanks with Deterioration Data	Wirebrushed Surfaces: No. of Tanks	Wirebrushed Surfaces: % of Tanks with Deterioration Data	No. of Tanks Surface Preparation Not Given	Total
Serious	4	9	16	22	34	54
Significant	9	21	35	48	20	64
Negligible	30	70	22	30	66	118
Not Given	5	--	0	--	59	64
Total	48	100	73	100	179	300

In Table 3, the extent of coating deterioration and tank corrosion is related to the type of paint or paint system, the age of the coating, and the age of the tank. Each of the five paint systems used on ten or more tanks is listed individually, and the remaining thirty-three paint systems reported on survey sheets are classified under the category "Miscellaneous." The miscellaneous coatings were frequently described incompletely and often comprised unorthodox combinations.

In Figure 1, individual tanks with paint systems A, B, C, D, and E are plotted in a manner that shows the relationship of paint system, coating age, and surface preparation to extent of deterioration.

Table 4 shows the magnitude of coating deterioration and corrosion in tanks with and without cathodic protection. Combined serious and significant deterioration was reported in 44 percent of the tanks with cathodic protection as compared to 55 percent in tanks without cathodic protection. An additional 64 tanks (10 with and 54 without cathodic protection) were reported, but no deterioration data was given.

Table 3. Deterioration with Respect to Paint Coating, Age of Coating, and Age of Tank

Observed Deterioration	Paint System*																
	A			B			C			D			E			Misc.	Not Given
	No. of Tanks	Median Coating Age	Median Tank Age	No. of Tanks	Median Coating Age	Median Tank Age	No. of Tanks	Median Coating Age	Median Tank Age	No. of Tanks	Median Coating Age	Median Tank Age	No. of Tanks	Median Coating Age	Median Tank Age	No. of Tanks	No. of Tanks
Serious	16	4	6	2	3	14	0	--	--	0	--	--	6	18	18	11	19
Significant	12	5	19	5	4	17	2	2	22	5	5	5	4	18	18	26	10
Negligible	11	7	16	10	4	16	12	2	16	5	5	17	0	--	--	27	53
Total	39	--	--	17	--	--	14	--	--	10	--	--	10	--	--	64	82
% of Tanks with Serious or Significant Deterioration	72			41			14			50			100			58	55
Deterioration Not Given	1	1	1	1	3	3	6	4	6	1	8	8	0	--	--	7	48

*Paint Systems: A, TT-V-51 Asphalt Varnish; B, 34Yc Coal Tar Enamel; C, MIL-P-15145 Zinc Dust/Zinc Oxide Paint; D, TT-P-86 Type IV Phenolic Red Lead; E, "TT-R-191."

Figure 1

Age of Coating in Years

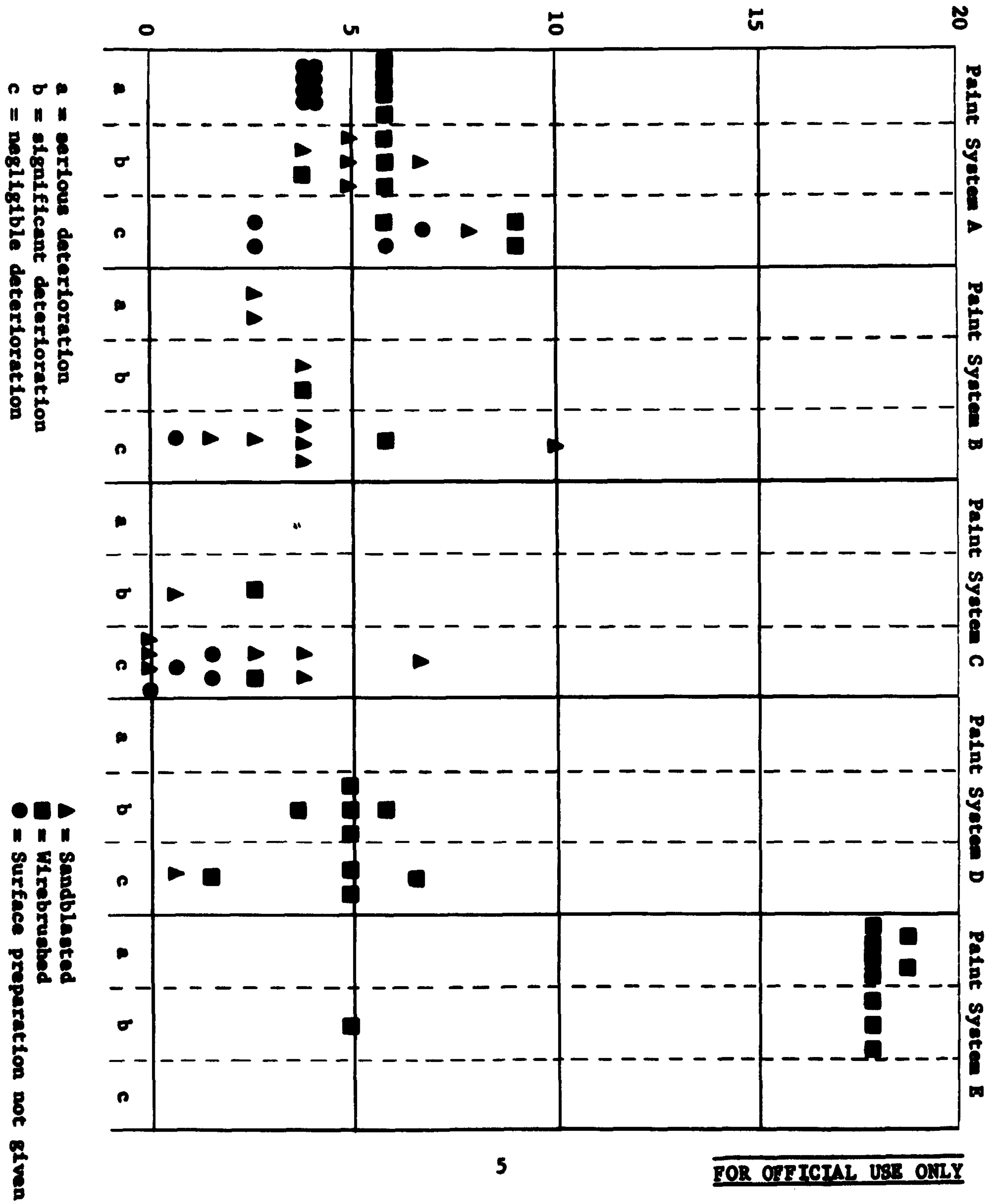

Table 4. Deterioration with Respect to Cathodic Protection

Observed Deterioration	Tanks with Cathodic Protection		Tanks without Cathodic Protection		Total No. of Tanks
	No. of Tanks	% of Tanks with Deterioration Data	No. of Tanks	% of Tanks with Deterioration Data	
Serious	19	18	35	27	54
Significant	28	26	36	28	64
Negligible	59	56	59	45	118
Not Given	10	--	54	--	64
Total	116	100	184	100	300

In Table 5 coating deterioration and tank corrosion is related to the normal ambient temperature range of the stored water. Serious or significant corrosion was reported in 65 percent of the tanks storing water with a normal ambient temperature range between 34 and 61 F as compared to 52 percent of tanks storing water with a range between 62 and 80 F. The normal ambient temperature range of the stored water was not given for 89 tanks for which deterioration data was reported, and deterioration data was not given for 64 additional tanks.

An attempt was made to relate the extent of coating deterioration and tank corrosion to type of water stored. No appreciable differences in condition of interior surfaces were found either when the tanks were classified according to whether the water was "potable" or "non-potable," or when classified according to water use as "domestic," "industrial," or "both."

Table 5. Deterioration with Respect to Normal Ambient Temperature of Stored Water

Observed Deterioration	Tanks Between 34 and 61 F		Tanks Between 62 and 80 F		Temperature Not Given		Total
	No. of Tanks	% of Tanks with Deterioration Data	No. of Tanks	% of Tanks with Deterioration Data	No. of Tanks	% of Tanks with Deterioration Data	
Serious	25	28	15	26	14	16	54
Significant	33	37	15	26	16	18	64
Negligible	32	35	27	48	59	66	118
Not Given	11	--	12	--	41	--	64
Total	101	100	69	100	130	100	300

2. Hot Water Tanks

All information to be presented concerning corrosion in hot water tanks was obtained from BuDocks Southwest Division. This was the only one of the twelve reporting activities that furnished corrosion data for such tanks. Laboratory personnel visited SOWESTDOCKS to obtain additional information on corrosion problems in hot water tanks that had occurred in the Eleventh Naval District.

SOWESTDOCKS sent a project proposal to the Bureau of Yards and Docks for the development of a formula and material specification for a siliceous (portland cement base) coating for the interior of hot water tanks. At the time of the proposal only one contractor was available for lining hot water tanks in 11ND, and this precluded competitive bidding. To minimize the cost of repairs it was usually necessary to wait until a large number of tanks necessitated repair before the services of the contractor were utilized. SOWESTDOCKS personnel felt that development of a formula type material specification for a suitable lining that could be applied by station personnel would alleviate this repair problem.

With increased need for repair and lining of hot water tanks in 11ND, other contractors became available for this work. Competitive bidding alleviated the urgency for developing a formula type material specification for a suitable siliceous lining, and effort in this development was discontinued. Because it is still necessary to wait until a number of tanks require repair, SOWESTDOCKS personnel feel that the availability of a standard effective protective coating that could be easily applied by station personnel in individual tanks would be better than the current practice of contracting for repair of groups of tanks.

Uncoated mild steel tanks requiring this maintenance were installed in 11ND as early as 1942. Serious leaks from internal corrosion which necessitated the installation of siliceous linings occurred about two to three years after installation. Corrosion was attributed to corrosive properties of the Colorado River water stored in the tanks. The corrosion of hot water tanks at other locations has similarly been attributed to the corrosive nature of the local water.

Many early failures occurred to the first siliceous linings used in 11ND. Failure of these first linings consisted of cracking or spalling of the lining to expose the metal substrate. Improved methods of application resulted in better performance of the linings. Hand tools which were originally permitted for surface preparation are now considered inadequate, and present contracts require sandblasting before lining. The cracking and spalling failures that still occasionally occur may be reduced in number by a more thorough inspection for proper surface preparation and lining application.

Siliceous linings are hand-troweled in one or two coats to a total thickness of about 5/8 inch. Some contractors use a steel mesh tack-welded at an appropriate distance from the tank shell to reinforce the cement lining and to keep it intact during application. Lining is a relatively inexpensive maintenance operation, usually costing between four and five cents per square foot.

Present siliceous linings are expected to increase the tank life by 10 to 20 years, if they are periodically inspected and patched as needed every three to five years. Original contractors provide tank inspection service and/or patching for about $50 per tank. This fee is fixed whether tanks need patching or not. If the patching required is nominal, it is usually included in the fee. If extensive patching is needed, the contractor submits an estimate of additional cost. SOWESTDOCKS personnel feel that siliceous lining is a "Stone Age" method of preservation and that more recently developed systems, such as polyurethane or epoxy resin coatings should receive laboratory investigation as serviceable replacements on a costwise basis.

SOWESTDOCKS has installed hot water tanks 24 inches in diameter and larger as new installations or as replacements for old field tanks deteriorated beyond repair. From their past experience with corrosion in hot water tanks, they now specify steel tanks lined with sheet copper at least 0.0647 inches thick (3 lb/sq ft), where the additional cost is justified. They feel that copper lined steel tanks should last indefinitely and never require field maintenance. Where the added cost of copper lined tanks cannot be justified, or where time does not permit, the replacement tanks are of uncoated mild steel construction.

The precise number of hot water tanks 24 inches in diameter or larger that have required repair in the past or may require repair in the future could not be determined from the survey data furnished by the reporting activity. A rough estimate of the total number of such tanks is believed to involve several thousand, based on incomplete survey data and information furnished Laboratory personnel by SOWESTDOCKS.

SOWESTDOCKS personnel felt that there was no corrosion problem in cold water tanks, except in desert areas of 11ND. Presently used coatings for cold water tanks were considered satisfactory with the exception of hot-applied coal tar base coatings which are difficult to apply.

DISCUSSION

The results of a survey based on partial or incomplete data are suggestive rather than definitely conclusive. Results of this kind are far more believable if corroborated with other supporting information consistent with reason or past experience.

Table 1 shows that the extent of deterioration is about the same whether related to the number or storage capacity of the tanks. The extent of the problem of corrosion in cold water storage tanks in the Naval Shore Establishment is indicated by the fact that approximately one-quarter of all such tanks had serious deterioration and another one-quarter had significant deterioration.

Table 2 indicates that the extent of deterioration was significantly less for cold water storage tanks that were sandblasted before coating than those that were wirebrushed. This conclusion is consistent with the universally accepted opinion that sandblasting of metal surfaces results in a better surface preparation than does wirebrushing. Many paint manufacturers specify that their product gives optimum service when applied to sandblasted metal surfaces.

Table 3 tabulates the extent of deterioration along with paint system, age of coating, and age of tank. The survey data indicates that the tank age does not appear to be an important factor. The five most frequently reported coatings occurred in 24%, 12%, 11%, 6%, and 6%, respectively, of the tanks for which coatings were reported. A total of 38 different paint systems were used. This indicates that no one paint system was considered to be significantly superior to the other systems used.

Paint system C, MIL-P-15145, had a lower percentage of serious and significant deterioration than did the other systems reported in Table 3, but the median coating age for this system was half or less that of the other systems. That MIL-P-15145 zinc dust/zinc oxide paint gives satisfactory service is indicated by its successful use for many years in potable water tanks of Navy Fleet vessels.*

Paint system B, 34Yc coal tar enamel, and paint system D, TT-P-86 Type IV red lead-phenolic, had a greater percentage of serious and significant deterioration than paint system C, but the median coating ages of each of these two systems were approximately twice as great as that of C. Coal tar enamel and TT-P86a Type IV red lead-phenolic are listed in specification D102-52** of the American Water Works Association among the types of paints which have given good service in the interior of elevated steel water storage tanks and which are believed to represent good practice.

Paint System A was the system most frequently reported, but corrosion data from the survey does not indicate that this system should be recommended for the interior of water tanks.

Paint system E, TT-R-191, is a specification for a red lead pigment. This specification also describes the compounding of a paint with this pigment for specification test purposes. In any event, because of the high median coating age of 18 years and the fact that this system was listed by only one reporting naval activity, it cannot validly be compared with the other four coating systems listed in Table 3.

Paint systems that contain leachable toxic materials should be prohibited in tanks storing drinking water. For this reason, the American Water Works Association Elevated Tank and Standpipe Committee voted not to include red lead-linseed oil paints in future AWWA standards.

*Bureau of Ships Manual, Chapter 19 (NAVSHIPS 250-000-19)
**Journal American Water Works Association, Vol. 44, pages 749-764 (1952).

Figure 1 shows the range of coating ages of paint systems A, B, C, D, and E. It also shows that paint systems D and E were applied to wirebrushed surfaces in almost all the tanks in which they were reported.

No inferences could be made from the survey data presented in Table 4 as to the effectiveness of cathodic protection in mitigating corrosion in the interior of steel water storage tanks. Many different cathodic protection systems were used in conjunction with a variety of coating systems. Quite frequently the cathodic protection system was installed a number of years after the coating was applied, and some deterioration of the coating may have occurred before the application of cathodic protection. Approximately 40% of the reported tanks are now using cathodic protection for corrosion mitigation. This entailed a considerable expenditure of funds, expecially when one considers that no evidence can be found from the field survey data that cathodic protection contributed significantly to the life of the tanks or tank coatings.

Because of the limited data and large number of variables present, no significance was given to the slight differences in magnitude of corrosion that occurred in cold water tanks at different temperatures, as presented in Table 5.

Tanks used to supply hot water present special corrosion problems. Many organic coatings normally suitable at ambient temperatures deteriorate badly at the higher temperature of the stored hot water (150 F on the average).

Reports of SOWESTDOCKS and discussions with their personnel indicate that numerous tanks of uncoated steel construction have required some measure of maintenance because of internal corrosion deterioration. Other similarly uncoated hot water tanks have required very little or no field maintenance. For example, uncoated steel tanks installed at the Naval Construction Battalion Center, Port Hueneme, as early as 1942 have never required more than nominal maintenance. All of these tanks are still giving satisfactory service after 19 years of continuous use. The low rate of corrosion at Port Hueneme has been attributed by personnel there to the high silica content of the local water.

Of the twelve reporting activities only SOWESTDOCKS indicated a corrosion problem in hot water tanks. While it is reasonable to assume that the other activities not reporting on hot water tanks have conditions somewhat similar to those in 11ND, it is quite possible that the existing corrosion deterioration may not be of sufficient magnitude to be considered a significant problem. If the omission of data on hot water tanks by the majority of activities is a criterion, corrosion in such tanks may not be a sufficiently general problem to warrant laboratory investigation.

Corrosion deterioration in escape training tanks at Pearl Harbor Naval Shipyard and the Naval Submarine Base, New London, also present special problems. A paint suitable for use on the interior of such tanks must be white in color and remain white to enhance visibility during training operations. It must mitigate corrosion under conditions of continuous immersion in chlorinated fresh water maintained at an average temperature of 90 F. All of the various specification and proprietary paints used in these tanks have shown early failure. Premature failure of paints is frequently attributed to improper surface preparation, poor application of coating, or a combination of both. Background information furnished was considered insufficient to determine if any of the above reasons was responsible for the premature paint failure in the escape training tanks. Because of the special requirements that must be met, the problem of maintaining a suitable coating in these tanks should be investigated separately.

CONCLUSIONS

1. Approximately one-quarter of all cold water storage tanks in the Naval Shore Establishment have serious corrosion and another one-quarter have significant corrosion.

2. The survey data indicates that less corrosion occurred in tanks that were sandblasted rather than wirebrushed before painting.

3. Because of differences in surface preparation, age of coating systems and the limited number of tanks for which data was available, it was not possible to definitely conclude that one coating system was superior to the others reported.

4. Because of the limited survey data and large number of variables, no definite conclusion could be made concerning the effects of cathodic protection, ambient temperature range, or type of water stored.

5. The survey does not indicate that corrosion deterioration in hot water tanks 24 inches in diameter or larger is a general field problem.

6. Insufficient information is available to determine the reasons for the premature failure of coatings in submarine escape training tanks.

RECOMMENDATIONS

1. Proper preparation of interior metal surfaces of cold water storage tanks by sandblasting should be made before application of paint coatings.

2. An effort should be made to determine the best coating system or systems for the interior metal surfaces of cold water tanks, and such system or systems should be standardized for use throughout the Naval Shore Establishment.

3. An effort should be made to determine if cathodic protection systems have a significant effect in mitigating tank deterioration and if they can be justified by reduced maintenance costs.

4. Laboratory investigation of coatings for lining hot water tanks is not recommended.

5. A separate investigation should be conducted on the problem of maintaining a suitable coating in submarine training tanks.

ACKNOWLEDGMENT

The author wishes to thank Dr. R. W. Drisko and Dr. W. S. Haynes of this Laboratory for their careful review of the material used and constructive suggestions regarding its presentation in this note.

EXPERIENCE INQUIRY OF INTERNAL CORROSION DETERIORATION IN STEEL WATER STORAGE TANKS

FROM:	NAME *(Person Responsible)*	TELEPHONE NO.	EXT. NO.

TO: U.S. NAVAL CIVIL ENGINEERING LABORATORY   PORT HUENEME, CALIFORNIA

PREPARE ONE QUESTIONNAIRE FOR EACH WATER STORAGE TANK LOCATED WITHIN THE ACTIVITY. COLOR PHOTOGRAPHS OF THE CONTAMINATED AREA IN THE WATER TANKS ARE INVITED, BUT NOT REQUIRED. ATTACH SHEETS WHEN ADDITIONAL SPACE FOR ANSWERS IS NEEDED.

TYPE OF TANK *(Ground level, Elevated, Diving, Etc.)*	TANK SHAPE *(Spheroid, Cylinder, Odd shaped tops & bottoms)*

TANK HEIGHT	TANK WIDTH	TANK DEPTH	TANK INTERNAL AREA	TANK VOLUME CAPACITY

YEAR CONSTRUCTED	CONTRACT NUMBER	STORED WATER SOURCE	STORED WATER USE

FREQUENCY OF INTERNAL INSPECTIONS	DATE LAST INSPECTED

CHEMICAL TREATMENT OF STORED WATER

SPECIFICATION	BRAND NAME	AMOUNT ADDED PER UNIT VOLUME	FREQUENCY OF TREATMENT

OPERATING TEMPERATURE OF STORED WATER

MAXIMUM	MINIMUM	NORMAL

IN-SERVICE WATER LEVEL FLUCTUATIONS IN FEET

MAXIMUM	MINIMUM	NORMAL

EXTENT OF CONTAMINATION OF STORED WATER

☐ SERIOUS   ☐ SIGNIFICANT   ☐ INSIGNIFICANT

DESCRIPTION OF CONTAMINATION

SERVICE LIFE OF ORIGINAL PROTECTIVE COATING

DETERIORATION

☐ SERIOUS   ☐ SIGNIFICANT   ☐ INSIGNIFICANT

SPECIFICATIONS	BRAND NAME	ORIGINAL COATING	SURFACE PREPARATION METHOD

AREA COVERED	LENGTH OF SERVICE	TOTAL COST OF APPLIC.	% OF FAILURE	METHOD OF APPLICATION

UNDERCOATS & NUMBER OF COATS APPLIED

EXTENT OF CORROSION IN AREA ABOVE HIGH WATER LEVELS

EXTENT OF CORROSION IN AREA OF HIGH TO LOW WATER LEVEL

EXTENT OF CORROSION IN AREA CONTINUALLY SUBMERGED

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EXTENT & COST OF INTERNAL STRUCTURAL REPAIRS RESULTING FROM CORROSION

SERVICE LIFE OF REPLACEMENT OF ORIGINAL PROTECTIVE COATING

DETERIORATION

☐ SERIOUS ☐ SIGNIFICANT ☐ INSIGNIFICANT

SPECIFICATION	BRAND NAME	REPLACEMENT COATING	SURFACE PREPARATION METHOD

AREA COVERED	LENGTH OF SERVICE	TOTAL COST OF APPLIC.	% OF FAILURE	METHOD OF APPLICATION

UNDERCOAT & NUMBER OF COATS OF PAINT APPLIED

EXTENT OF CORROSION IN AREA ABOVE HIGH WATER LEVEL

EXTENT OF CORROSION IN AREA OF HIGH TO LOW WATER LEVEL

EXTENT OF CORROSION IN AREA CONTINUALLY SUBMERGED

EXTENT & COST OF INTERNAL STRUCTURAL REPAIRS RESULTING FROM CORROSION

CATHODIC PROTECTION SYSTEMS

NAME OF CATHODIC SYSTEM	TYPE OF CATHODIC SYSTEM
INSTALLATION COST OF SYSTEM	MAINTENANCE COST OF SYSTEM

DESCRIPTION OF DIFFICULTIES ENCOUNTERED

EFFECTIVENESS OF CATHODIC CONTROL OF INTERNAL CORROSION *(Explain)*

REMARKS PERTINENT TO THE OBJECTIVES OF THIS INQUIRY

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