RESEARCH AND DEVELOPMENT REPORT
REPORT 1026
17 MARCH 1961

NEL/Report 1026

Investigation of Sonar Diaphragm Coatings

J. C. Thompson, R. K. Logan, and R. B. Nehrich

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U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA
A BUREAU OF SHIPS LABORATORY

THE PROBLEM

Investigate commercially available coating materials for use on sonar equipment, particularly on sonar diaphragms which are constructed of 5 per cent chromium steel, Vasco-Jet 1000. Determine which material offers: optimum protection from corrosion; extreme fatigue strength; flexibility; abrasion resistance; and air-drying and adhesive properties.

RESULTS

1. Nineteen coatings were investigated, with tests applicable to the end use of the material. Elasticity, to withstand vibration of the sonar diaphragm; ability to withstand the natural environment of the equipment (sea water and salt almosphere); and air-drying and adhesive capabilities were the properties sought for.

2. One of the coatings, a polyurethane product available commercially as Laminar X-500, successfully passed the tests and was found to possess the required qualities. When properly applied this material is exceptionally effective in the protection of underwater equipments.

RECOMMENDATIONS

1. Investigate Laminar X-500 in future situations involving a search for suitable coating material.

2. Subject Laminar X-500 to tests on a variety of base materials to determine its suitability for use on other than the sonar equipments with which this study was concerned.

ADMINISTRATIVE INFORMATION

Work was performed by members of the Engineering Division under AS 02101, S-F001 03 02, Task 8016 (NEL E1-3). The report covers work from January 1959 to December 1960 and was approved for publication 17 March 1961.

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ILLUSTRATIONS

INTRODUCTION

The study reported here was undertaken after a decision was made to use 5 per cent chromium steel for sonar diaphragms. This steel possesses characteristics which make it particularly suitable for the purpose, as described in another report.[1] Its one objectionable property, however, is its extreme susceptibility to corrosion. Accordingly, it became necessary to find an effective coating for the steel. Such a coating, it was decided, should be commercially available; possess extreme fatigue strength, flexibility, and abrasion resistance; and should adhere effectively and dry in air.

TEST PROCEDURE

A literature search was made in an effort to find coatings that would meet these rigid requirements. Former tests of coating materials were reviewed, representatives of commercial coating manufacturers were interviewed, and other Naval installations were consulted for their recommendations. The investigation produced no concrete evidence that a satisfactory coating existed. The manufacturers agreed to coat samples for testing. Test panels of the 5 per cent chromium steel were distributed to those coating manufacturers that had proper facilities for the coating process. This not only assured application of the coating under optimum conditions by those most familar with the idiosyncrasies of the material involved, but also would provide a source of supply of whatever coating might be chosen. Other manufacturers, who did not have adequate facilities for production coating, sent supplies of their product to the Laboratory with precise instructions for proper application and treatment. These instructions were followed closely and the products were applied to steel specimens under strict supervision. Proper cleaning

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[1] Navy Electronics Laboratory Report 949, Evaluation of Steel Alloys Subjected to High-Frequency Flexural Motion, by J. C. Thompson, 17 December 1959

techniques were stressed and a pretreatment applied when required by the manufacturer's specifications. The coated specimens were carefully examined before undergoing test.

Nineteen coatings were investigated including metallic, plastic, ceramic and elastomeric materials. The metallic coatings included were chromizing, nickel plate, nickel-cad plate, 24-karat gold, and galvanizing. Plastic coatings investigated were trifluorochloroethylene, polyurethane, vinyl, phenolic, a copolymer resin, and several epoxy coatings. Also included were a neoprene rubber and ceramic material. As the manufacturers seemed to favor their epoxy resins for our proposed application, a variety of epoxies were tested as recommended. The specimens were designated by letter and number as follows:

A. Copolymer resin
B. Modified epoxy
C. Phenolic
E. Epoxy
F. Trifluorochloroethylene
G. Neoprene rubber
H. Polyurethane
J. Chromizing
K. Nickel
L. Nickel-cad plate
N. Epoxy
O. 24-karat gold
P. Galvanizing
Q. Ceramic
R. Epoxy
S. Epoxy
1. Phenolic
5. Vinyl
7. Epoxy

Tests were limited to those considered applicable to the end use of the coating. The properties important to the sonar diaphragm application included elasticity to withstand vibrating of the diaphragm and ability to undergo sea-water submersion, which will be the natural environment of the equipment, and severe salt atmospheric exposure when it is in port. The standard salt-spray test was included as a standard specification test according to American Society of Testing Materials (ASTM) Specification B117.

WEATHERING TEST

One set of specimens was mounted on a weathering rack located upon the roof of the main Laboratory building (fig. 1). This building is on Point Loma, a peninsula about one-half mile wide, projecting southward between

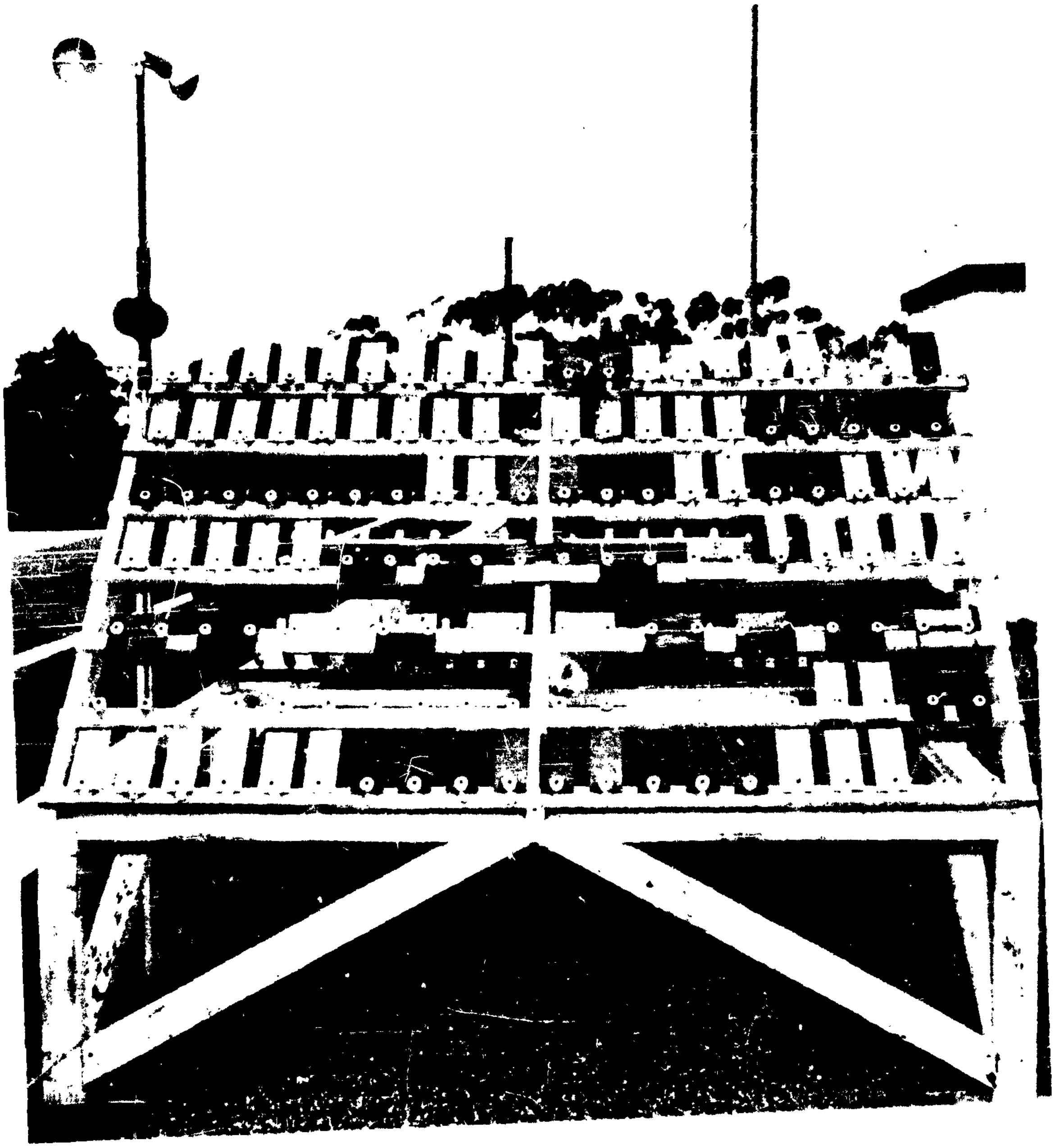

Figure 1. Roof weathering rack.

the Pacific Ocean and San Diego Bay. The test rack is approximately 450 feet above sea level and about equidistant from either body of water. This position subjected the specimens to a salt-laden atmosphere and fog, both morning and evening, during the fall and winter seasons; rain in relatively small quantities; and highly actinic sunlight. The specimen rack is constructed according to ASTM D-1014 and is mounted so that the exposure surfaces face north and south.

The samples were mounted on the southern exposure with ceramic stand-offs (fig. 2). This subjected the coatings to the most severe weathering conditions not only from the corrosion aspect but also from the quality and amount of sunlight which caused certain chemical changes evidenced by some extreme color changes. Tables 1 and 2 indicate the varying capabilities of the materials to withstand weathering in this location.

BAY IMMERSION TEST

A wooden rack approximately 50 inches wide and 40 inches high was constructed of 1 x 2-1/2-inch stock. Two pieces were added to divide the vertical dimension into three equal open panels. This permitted the mounting of three sets of samples, one under the other, approximately one foot apart (fig. 3). Eye bolts were provided at the bottom for attaching lead weights to the bottom of the frame and at the top for hanging the rack in the water. The test panels were hung using vinyl-covered copper wires. Separate wires were attached to the ends of the specimens and passed through equally spaced holes in the horizontal frame members. Thus the specimens were held equidistant in a fixed position against the action of the tides and were prevented from striking together and undergoing mechanical damage.

The completed rack assembly was transported to the piers at the NEL waterfront area and lowered on the north side of the main docking facility to a water depth of approximately 15 feet. This position was chosen because the area is seldom used for docking the larger boats and also to negate the possible effects of sunlight. The area chosen is on the bay side of the peninsula where contamination and the rapid action of the water during tide runs are believed to have

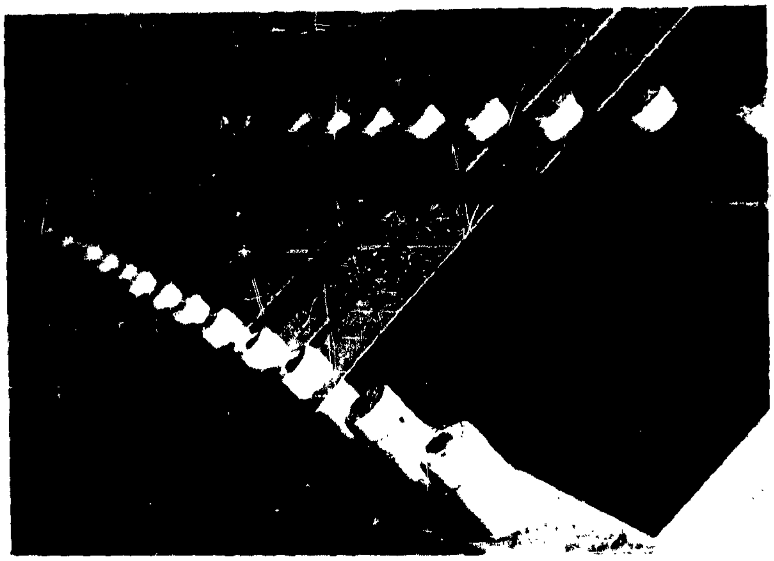

Figure 2. Ceramic stand-offs.

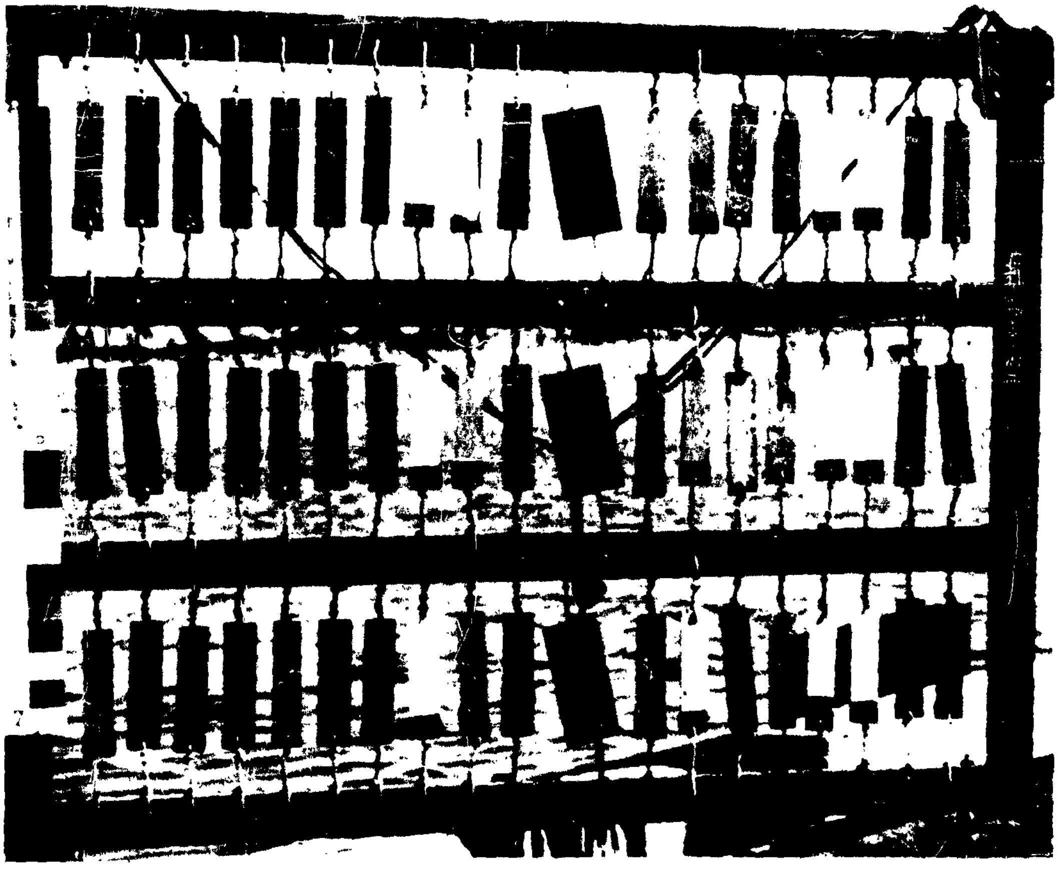

Figure 3. Samples mounted on wooden rack for bay immersion test.

TABLE 1. RESULTS OF 90-DAY WEATHERING TESTS.
(X, present; 0, not present)

Coating Type	Corrosion	Pitting	Porosity	Breakdown		Finish	Condition	Comments
				Edge	Face			
(A) Copolymer resin	0	0	0	X	X	0	Poor	Unsatisfactory
(B) Modified epoxy	Edge	0	0	X	X	0	Poor	Unsatisfactory
(D) Phenolic	X	0	0	X	X	0	Poor	Unsatifactory
(E) Epoxy	0	0	0	0	0	Flat	V. Good	Satisfactory
(F) Trifluoro-chloroethylene	X	0	0	X	X	0	Poor	Unsatisfactory
(G) Rubber	X	0	0	X	0	Darkened	Good	Doubtful
(H) Polyurethane	0	0	0	0	0	0	V. Good	Satisfactory
(J) Chromizing	X	X	X	X	X	0	V. Poor	Unsatisfactory
(K) Nickel (electrolytic)	0	0	0	0	0	0	Good	Satisfactory
(L) Ni-cad plate	X	0	0	0	X	Color Change	Poor	Unsatisfactory
(N) Epoxy	0	0	0	0	0	0	Good	Satisfactory
(O) 24-kt. gold								No test
(P) Galvanizing	X	0	0	X	0	0	Fair	Doubtful
(Q) Ceramic	0	0	0	0	0	Light Bleach	Good	Satisfactory
(R) Epoxy	X	0	0	X	0	Flat	Fair	Doubtful
(S) Epoxy	X	0	0	X	0	0	Fair	Doubtful
(1) Phenolic	0	0	0	Mottled	0	Comments	Good	Dark red to light yellow green. Acceptable
(5) Vinyl	0	0	0	0	0	Flat	Good	Satisfactory
(7) Epoxy	X	0	0	X	0	0	Fair	Doubtful

TABLE 2. RESULTS OF 18-MONTH WEATHERING TEST

Specimen	Result of Test
A	Complete failure
B	Edge corrosion; failure; surface oxide (chalking)
D	Failure
E	Satisfactory
F	Failure
G	Failure; edge and face panel corrosion
H	Satisfactory (chalking)
J	Failure
K	Satisfactory; one small corrosion pit
L	Failure
N	Failure at edges; surface oxide (chalking)
O	No test
P	Satisfactory
Q	Satisfactory
R	Failure; edge corrosion; surface oxide (chalking)
S	Failure
1	Color of coating changed from dark reddish brown to orange red (chalking)
5	Edge coloring and darkening
7	Failure; corrosion and pitting

accelerated corrosion action on the specimens.

The total immersion period was 50 days (1200 hours). The frame was brought up and inspected for coating breakdown and marine and grass growth every seven days. Records were kept of observations made at these times and colored photographs taken for the record.

After a period of 1200 hours of bay immersion the specimens were brought in and scrubbed with a fibre brush and hot water, to loosen and remove all grass and marine growth. They were then examined carefully to evaluate the effects of the complete immersion test period of 1200 hours. Figure 4 shows severe corrosion at the ends of the specimens. These areas had been left uncoated to determine the amount of creep protection afforded by the various coatings. The specimen designated as "J" shows considerably more oxidation of the material than the other panels. As this panel had been coated using a chromizing technique that made it impossible to mask off the end, it was necessary to grind this area of the sample to remove the coating. The grinding procedure also removed the passivation that was a common treatment for all the specimens before coating. This promoted a more active reaction and caused almost complete disintegration of the end of the specimen.

Discounting the factor of barnacle growth, most coatings proved to be acceptable (table 3). Specimens A, F, G, L, and R were the only ones either unacceptable or rejected. No appreciable corrosion creeping under the edge of the coating was observed in any of the samples. Specimen L was badly discolored, probably from the different colors of the nickel and cadmium corrosion. In "P" the coating was badly corroded but this is a function of the galvanizing. This preferential corroding had not penetrated through the galvanize, so the base material was not affected.

The following are the film-forming marine organisms that could reasonably be expected to be encountered in the test area:

1. Enteromorpha
2. Bryozoa
3. Annelida
4. Barnacles
5. Mud Tubes
6. Tunicates
7. Coelenterates
8. Algae
9. Hydroids
10. Oysters
11. Calcarea

SALT-SPRAY TEST

Three sets of specimens were suspended in a standard salt-spray chamber by means of vinyl-covered copper wire. Their position was normal to the movement of the salt fog and, of course, vertical. Controls were set for those parameters indicated as standard in specification

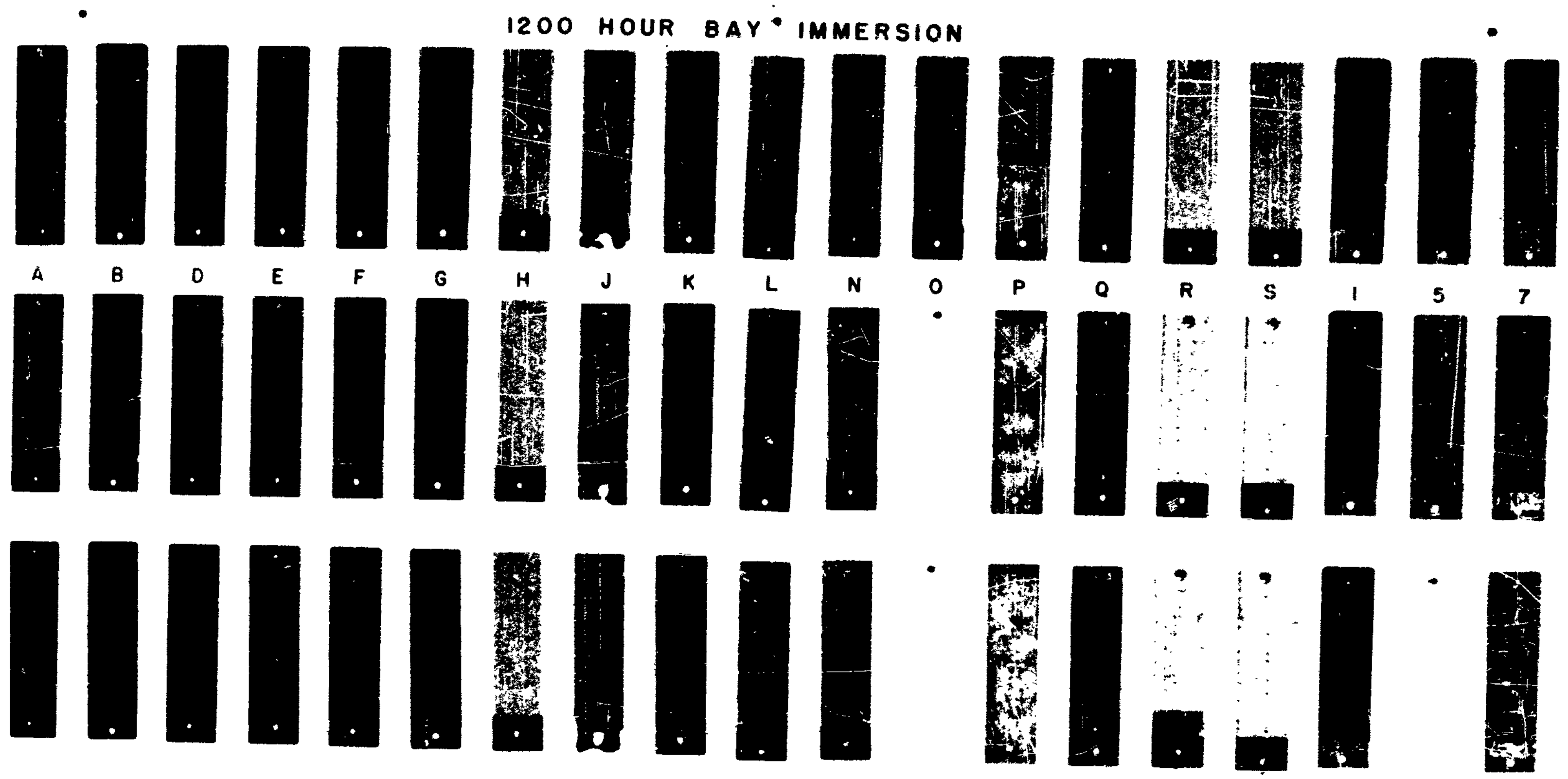

Figure 4. Specimens after bay immersion test.

TABLE 3. EFFECTS OF 1200-HOUR IMMERSION TEST.
(X, present; 0, not present)

Coating Type	Corrosion	Pitting	Porosity	Finish	Growth Barnacle	Growth Marine	Condition	Comments
(A) Copolymer resin	X	X	X	0	Few	X	V. Poor	Unsatisfactory
(B) Modified epoxy	Several spots	0	0	0	Few	0	Good	Satisfactory
(D) Phenolic	0	0	0	Flat	Few	0	Good	Satisfactory
(E) Epoxy	0	0	0	Flat	Moderate	0	Good	Satisfactory
(F) Trifluoro-chloroethylene	0	0	X	Flat	Few	X	Poor	Unsatisfactory
(G) Rubber	0	0	0	Flat	Moderate	0	Poor	Irregularities on surface - Unsatisfactory
(H) Polyurethane	0	0	0	Gloss	V. Few	0	V. Good	Exceptional
(J) Chromizing	X	X	0	0	V. Few	X	Fair	Unacceptable
(K) Nickel	0	0	0	0	V. Few	0	V. Good	Satisfactory
(L) Ni-cad plate	X (coating)	0	0	0	Few	X	Fair	Satisfactory
(N) Epoxy	0	0	0	Flat	Few	0	Good	Satisfactory
(O) 24-kt. gold	0	0	0	0	None	None	V. Good	Satisfactory
(P) Galvanizing	X (coating)	0	0	Darkened	None	0	Good	Satisfactory
(Q) Ceramic	0	0	0	Lighter	Moderate	0	Good	Satisfactory
(R) Epoxy	0	Blister (6-8 M ASTM D714-56)	X	0	V. Few	0	Poor	Unsatisfactory
(S) Epoxy	X	0	0	0	V. Few	0	Good	Satisfactory
(1) Phenolic	0	0	0	0	Few	0	Good	Satisfactory
(5) Vinyl	X	0	0	0	Many	X	Good	Satisfactory
(7) Epoxy	0	0	0	0	Many	0	Good	Satisfactory

ASTM B117-57T. The samples were checked periodically for a period of 500 hours. After this length of time the specimens were removed from the chamber and one set washed in warm water and scrubbed lightly with a fibre brush. Figure 5 shows all three sets, the top group being those that have been washed. Table 4 summarizes the final observations after the completion of the 500 hours in the chamber.

BEND TEST

One set of specimens was subjected to a bend test similar to that described in ASTM standard D522-41 Appendix. Each specimen was bent over a 3/8-inch-diameter mandrel using a standard sheet-metal power brake. The total bend was 145° ± 1°. The samples, being 1/16 inch thick, would elongate approximately 14.3 per cent if bent a full 180°; therefore their elongation is approximated at 11.5 per cent. Most coatings failed in this test. Such failures ranged from extremely brittle, non-adhesive cracking to very fine, short cracks extending generally over the surface of the bend. Figures 6-10 are examples of the results of this test. Table 5 summarizes the bend test results for all specimens.

DISCUSSION

The copolymer resin (A), according to the manufacturer's literature, is of a polyurethane family of resins. Of particular interest is a comparison between this material and the polyurethane sample (H). The difference in the properties between these two coatings may indicate a weakness in the formulation of (A); however, this Laboratory had no control over the application specifications involved in the preparation of these specimens.

Generally the coating A had satisfactory elasticity as shown by the bend test and had a certain resistance to marine growth and barnacles. The other parameters made it necessary to exclude this coating from further consideration.

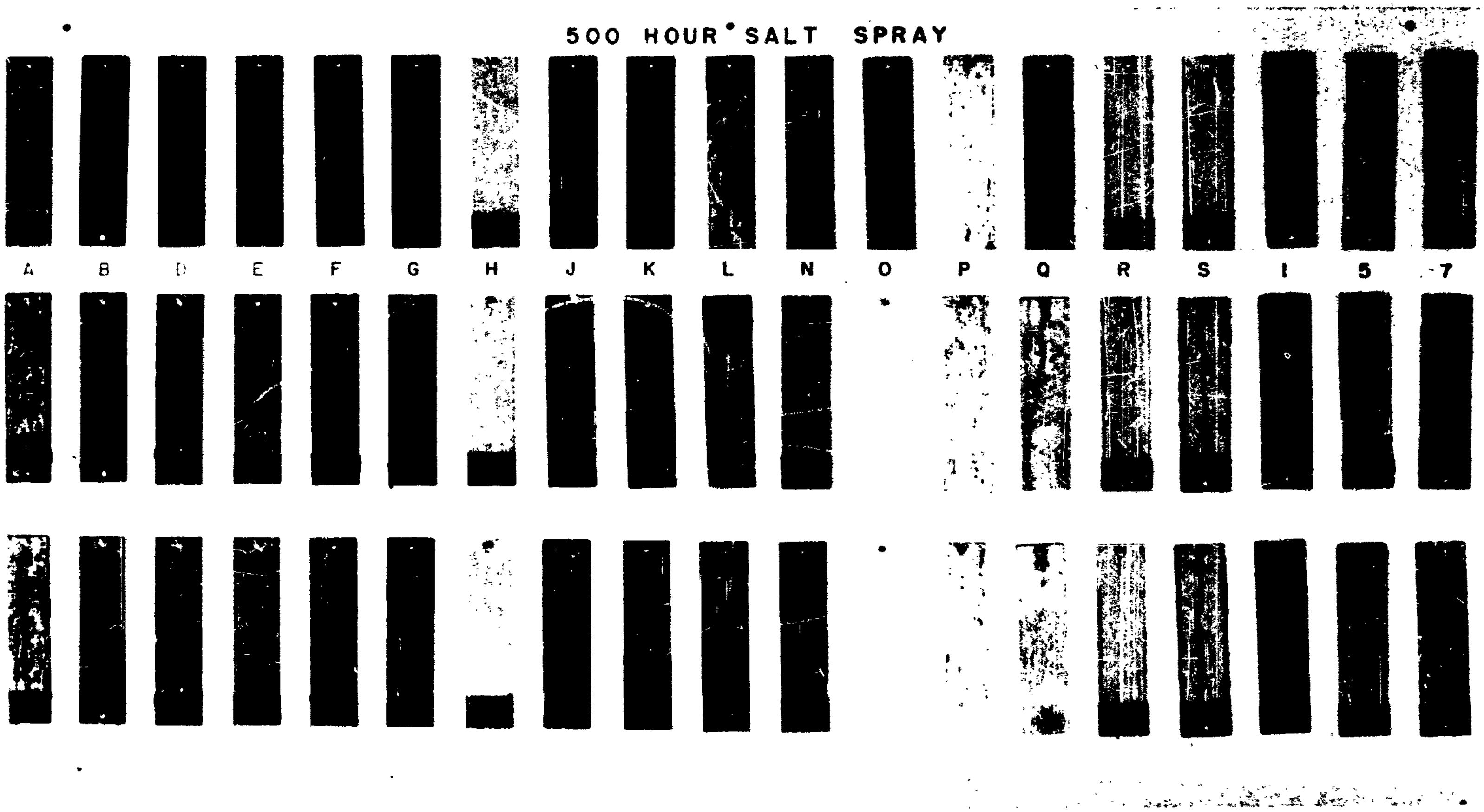

Figure 5. Specimens after salt-spray test. Top group have been washed.

TABLE 4. RESULTS OF 500-HOUR SALT SPRAY TEST.
(X, present; 0, not present)

Coating Type	Corrosion	Pitting	Blisters	Finish	Condition	Comments
(A) Copolymer resin	X (severe)	0	0	0	V. Poor	Unsatisfactory
(B) Modified epoxy	0	0	0	Glossy	Good	Exceptional
(D) Phenolic	X	0	Mottled	Dull	Poor	Unsatisfactory
(E) Epoxy	0	0	0	Dull	Good	Satisfactory
(F) Trifluoro-chloroethylene	X	0	X	0	V. Poor	Unsatisfactory
(G) Rubber	X	0	0	Dull	Poor	Unsatisfactory
(H) Polyurethane	0	0	0	Glossy	V. Good	Exceptional
(J) Chromizing	X (severe)	X	0	0	V. Poor	Unsatisfactory
(K) Nickel	X	X	0	0	Fair	Doubtful
(L) Ni-cad plate	X	X	0	0	Poor	Unsatisfactory
(N) Epoxy	0	0	0	Dull	Good	Satisfactory
(O) 24-kt. gold	X	X	X	0	Poor	Unsatisfactory
(P) Galvanizing	X	X	0	0	Poor	Unsatisfactory
(Q) Ceramic	0	0	0	0	Good	Satisfactory
(R) Epoxy	X	0	0	Dull	Fair	Doubtful
(S) Epoxy	X	0	X	Dull	Poor	Unsatisfactory
(1) Phenolic	0	0	0	0	Good	Satisfactory
(5) Vinyl	0	0	X	Rough	Fair	Doubtful
(7) Epoxy	0	0	0	Dull	Good	Satisfactory

TABLE 5. RESULTS OF BEND TEST OVER 3/8-IN. MANDREL, 145° BEND)
(X, present; 0, not present)

Coating Type	Adhesion	Finish	Breakdown Edge	Breakdown Face	Elasticity	Condition	Comments
(A) Copolymer resin	Good	Good	0	0	Good	Good	Satisfactory
(B) Modified epoxy	None	Broken	X	Complete	V. Poor	V. Poor	Unsatisfactory
(D) Phenolic	Fair	Sm. Cracks	X	Slight	Fair	Fair	Unsatisfactory
(E) Epoxy	Poor	Sm. Cracks	X	X	Fair	Poor	Unsatisfactory
(F) Trifluoro-chloroethylene	Poor	Strained	X	X	Fair	Poor	Unsatisfactory
(G) Rubber	Good	Good	0	0	Good	Good	Satisfactory
(H) Polyurethane	Good	V. Good	0	0	V. Good	V. Good	Exceptional
(J) Chromizing	Specimen broke; brittleness due to chromizing treatment.						
(K) Nickel							No tests
(L) Ni-cad plate	Poor	Sm. Cracks	X	X	Fair	Poor	Unsatisfactory
(N) Epoxy	Good	Good	0	0	Good	Good	Satisfactory
(O) 24-kt. gold							No tests
(P) Galvanizing	Good	Good	X	0	Fair	Fair	Unacceptable
(Q) Ceramic	Poor	Sm. Cracks	X	X	Poor	Poor	Unsatisfactory
(R) Epoxy	Fair	Sm. Cracks	X	X	Poor	Poor	Unsatisfactory
(S) Epoxy	Fair	Sm. Cracks	X	X	Poor	Poor	Unsatisfactory
(1) Phenolic	None	Broken	X	X	V. Poor	V. Poor	Unsatisfactory
(5) Vinyl	Good	Good	0	0	Good	Good	Satisfactory
(7) Epoxy	None	Broken	X	X	V. Poor	V. Poor	Unsatisfactory

Figure 6. Broken finish after bend test.

Figure 7. Small cracks and edge flaking after bend test.

Figure 8. Small cracks after bend test.

Figure 9. Strained finish after bend test.

Figure 10. Good result after bend test.

The modified epoxy (B) performed very well in the salt-spray and bay immersion tests; however, in the weathering test the surface oxidized such that a light brushing produced a fine black powder. The edges corroded completely and a small amount of creep was noticed extending into the face area. When subjected to the bend test it proved to be very brittle and so lacking in adhesion that relatively large sections broke away completely.

The phenolic sample (D) withstood the bay immersion satisfactorily. However, its color changed from a semi-glossy dark green to a darker green, approaching black. The salt-spray test produced severe edge corrosion and dulling of the surface while the color change was similar to that produced by the immersion test. The resistance to weathering, in this location, was very poor. The coating was completely oxidized, exposing the surface to complete corrosion. The bend test indicated a lack of sufficient elasticity.

The epoxy coating (E) completed four of the five tests satisfactorily but the bend test revealed a lack of sufficient elasticity for the proposed application. The weathering test sample showed evidence of minor breakdown along one edge in the form of a change in color, medium brown to yellow. Barnacle growth was moderate but sufficient to cause doubt as to the advisability of using this coating for underwater instrumentation.

Trifluorochloroethylene (F) failed the tests completely. On the weathering rack the coating lifted from the base in a sheet, permitting exposure of the face to corrosion. In the salt-spray cabinet, edge corrosion and creep were in evidence and considerable blistering of the surface indicated porosity. The bay immersion test results were comparable to those of the salt-spray test and in the bend test the material was pulled from the metallic surface and although not broken showed severe strain.

The rubber coating (G) broke down during the weathering test, showing edge and face corrosion and heavy chalking. Edge corrosion was severe enough to warrant rejection of the specimens after the salt-spray test. The bay immersion test produced moderate barnacle growth and small bubbles over a considerable portion of the sample. The elasticity and adhesion during the bend test were satisfactory.

Polyurethane (H) chalked slightly during weathering and bleached about two shades lighter gray. Its resistance to corrosion in both salt spray and bay immersion was exceptional. This feature, coupled with the very slight barnacle growth and the adhesion and elasticity proved in the bend test, rated this material as superior.

The chromized specimen (J) showed full surface corrosion during weathering and severe corrosion in the salt spray, and the bay immersion test yielded corrosive pitting. The embrittlement caused by the chromizing process caused the sample to break into several pieces when an attempt was made to bend it.

Electrolytic nickel (K) passed all the tests satisfactorily except the salt-spray. The result of the salt-spray test is listed as doubtful because of some scattered, small corrosive pitting over the face of the samples. No bend test was made.

Ni-cad (L) failed by corrosion and severe edge failure in the weathering test and general pitting in the salt spray. In all exposure tests the surface discolored. This was attributed to the oxidation of the coating constituents and the different colors of their oxides. The bend test produced small cracks throughout and edge flaking.

The epoxy coating (N) performed satisfactorily in all instances except the 18-month weathering. Final examination of the specimen at this time revealed moderate edge corrosion and surface chalking.

Electroplated gold (O) was only tested for corrosion in the bay immersion and salt-spray tests. The results of these tests were opposite extremes. The sample withstood the action of the bay immersion test admirably but the specimen tested in salt spray broke down completely.

The galvanized specimen (P) functioned in a normal fashion in nearly all the tests. Its failure in the salt-spray testing was attributed to the relatively thin coating of the edges of the sample which corroded away and permitted the base metal to oxidize. The bend test failure was due to cracking at the edges of the specimen. In the other tests, severe corrosion of the zinc was noted but the plate was sufficiently heavy to withstand testing for the period of time involved. The excessive corrosion of the plating material would make it unusable for application to sonar diaphragms.

The ceramic specimen (Q) passed all corrosion tests satisfactorily and, as would be expected because of the nature of the material, failed in bending. The bend test produced fine cracks throughout the bend area and severe flaking at the edges.

Another epoxy coating (R) was rated as doubtful in two tests and rejected in the other three. At the end of 90 days on the weathering test there were indications of breakdown that were proved as the test progressed to eighteen months. In the salt-spray test the specimen corrosion was concentrated along the edges in areas where the edge characteristics could have had undue influence.

Epoxy specimen (S) was very similar to R but withstood the bay immersion with minor edge corrosion. This too could have been due to edge characteristics.

The phenolic specimen (1) survived the corrosion testing reasonably well, although the weathering test produced a color change from dark reddish brown to orange-red and severe chalking of the entire surface. The bend test caused severe breaking of the coating, indicating brittleness and lack of adhesion.

The vinyl coating (5) withstood weathering from a corrosion standpoint but the color changed from a gray to a mottled olive green. The effect of salt spray is listed as doubtful because of the appearance of blisters and surface roughness. Barnacle growth was excessive.

The epoxy specimen (7) successfully passed the water tests except for being susceptible to barnacle growth. Weathering caused corrosion pitting and surface chalking. The bend test indicates lack of flexibility and adhesion.

Table 6 gives a qualitative analysis of all the test results.

The findings reported here are directed specifically toward suitability of the materials for protection of sonar diaphragms and do not preclude their use in other, less severe, applications. However it is important that the coatings show good adhesion in the bend test if they are to be used in applications where vibration or impact may be applied to the coated surface.

Barnacles and other marine growths could prove very damaging to sonar equipments. On many of the test specimens, such growths had accumulated in the indentations made where identifying marks had been stamped into the

TABLE 6. SUMMARY OF TOTAL TEST PROGRAM.

Coating Type	90 Days Weathering	18 Months Weathering	1200 Hours Bay Immersion	500 Hours Salt-Spray Fog	Bend Test
(A) Copolymer resin	Unsatisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory	Satisfactory
(B) Modified epoxy	Unsatisfactory	Unsatisfactory	Satisfactory	Exceptional	Unsatisfactory
(D) Phenolic	Unsatisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Unsatisfactory
(E) Epoxy	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Unsatisfactory
(F) Trifluoro-chloroethylene	Unsatisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory
(G) Rubber	Doubtful	Unsatisfactory	Unsatisfactory	Unsatisfactory	Satisfactory
(H) Polyurethane	Satisfactory	Satisfactory	Exceptional	Exceptional	Exceptional
(J) Chromizing	Unsatisfactory	Unsatisfactory	Unacceptable	Unsatisfactory	Complete break
(K) Nickel	Satisfactory	Satisfactory	Satisfactory	Doubtful	-----
(L) Ni-cad plate	Unsatisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Unsatisfactory
(N) Epoxy	Satisfactory	Unsatisfactory	Satisfactory	Satisfactory	Satisfactory
(O) 24-kt. gold	-----	-----	Satisfactory	Unsatisfactory	-----
(P) Galvanizing	Doubtful	Satisfactory	Satisfactory	Unsatisfactory	Unacceptable
(Q) Ceramic	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Unsatisfactory
(R) Epoxy	Doubtful	Unsatisfactory	Unsatisfactory	Doubtful	Unsatisfactory
(S) Epoxy	Doubtful	Unsatisfactory	Satisfactory	Unsatisfactory	Unsatisfactory
(1) Phenolic	Satisfactory	Doubtful	Satisfactory	Satisfactory	Unsatisfactory
(5) Vinyl	Satisfactory	Doubtful	Satisfactory	Doubtful	Satisfactory
(7) Epoxy	Doubtful	Unsatisfactory	Satisfactory	Satisfactory	Unsatisfactory

steel before application of the coatings. This occurred despite the fact that the coatings had thoroughly covered the stamped area, leaving only a rolling, nearly smooth marking. Apparently even slight irregularities in any surface exposed to marine environment would foster the accumulation of various organisms.

Generally plastic coatings are formulated in varying compositions even though they are of the same general category. Note the six epoxy-type coatings tested with varying results.

It would be improper to assume that, on the strength of the findings in this report, any general field of plastic coatings should be accepted as being superior to any other.

Proper surface preparation of the base material is of the utmost importance in order to bring out the optimum characteristics of the coating material. The application of proper pre-coats and primers is essential.

This series of tests was exceptionally severe and was planned to be so because of the severity of the environmental and operational conditions that the equipments would be subjected to.

CONCLUSIONS

1. Nineteen coatings were investigated, with tests applicable to the end use of the material. Elasticity, to withstand vibration of the sonar diaphragm; ability to withstand the natural environment of the equipment (sea water and salt atmosphere); and air-drying and adhesive capabilities were the properties sought for.

2. One of the coatings, a polyurethane product available commercially as Laminar X-500, successfully passed the tests and was found to possess the required qualities. When properly applied this material is exceptionally effective in the protection of underwater equipments.

RECOMMENDATIONS

1. Investigate Laminar X-500 in future situations involving a search for suitable coating material.

2. Subject Laminar X-500 to tests on a variety of base materials to determine its suitability for use on other than the sonar equipments with which this study was concerned.

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UNCLASSIFIED

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1. Laminar X-500
2. Sonar equipment - Coatings
I. Thompson, J. C.
II. Logan, R. K.
III. Nehrich, R. B.

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INVESTIGATION OF SONAR DIAPHRAGM COATINGS, by J. C. Thompson, R. K. Logan and R. B. Nehrich. 23 p., 17 March 1961.

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1. Laminar X-500
2. Sonar equipment - Coatings
I. Thompson, J. C.
II. Logan, R. K.
III. Nehrich, R. B.

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