OCEANOGRAPHIC EFFECTS ON PLASTIC ENGINEERING MATERIALS

ASSIGNMENT 12 - (ID) UNDER
AIRTASK A32 523 001/200 1/ROO7 01 01

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OCEANOGRAPHIC EFFECTS ON PLASTIC ENGINEERING MATERIALS

ASSIGNMENT 12-72(ID) UNDER
AIRTASK A32 523 001/200 1/RO07 01 01

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ABSTRACT

The continuing effort to evaluate oceanographic environment effects on a wide spectrum of plastic engineering materials, reinforced laminates and other plastics, has been in progress. Submersible Test Unit I-2 test panel array, which is discussed, represents one segment of this continuing effort. This panel array was submerged October 1963 for 751 days at a depth of approximately 5,640 feet in the Port Hueneme Pacific Ocean area.

Laboratory studies, after exposure, indicated that, in general, deep sea immersion adversely affected the mechanical properties of most of the materials.
I. INTRODUCTION

A. The study described herein represents one segment of the continuing effort of the Aeronautical Materials Laboratory's endeavor in evaluating deep oceanographic effects on a wide spectrum of polymeric materials. This particular effort is directed principally toward exposures at various depths of the ocean which have been in progress.

B. The principal objective of this portion of the studies is to gather long term engineering data on the relative performance of plastic materials in various ocean environments so that designers of weapon system components will have reliable information on which to base their design of equipment for service under these environments.

II. GENERAL DISCUSSIONS

A. In recent years interest in the ocean depths and the study of new engineering materials that may be utilized at these depths have been increasing. Among these new materials being considered, for such applications as weapon systems, are organic polymers with which this report is concerned.

B. Through the cooperation of the U. S. Naval Civil Engineering Laboratory, Port Hueneme, California, a series of Naval Air Engineering Center - Aeronautical Materials Laboratory specimens are being deep sea exposed at contrasting depths and for various time durations.

C. This report discusses the test panel array (Submersible Test Unit I-2) of commercial plastic reinforced laminates and other plastics, in the relaxed and stressed conditions, which was submerged in October 1963 at a depth of approximately 5,640 feet for 751 days in the Port Hueneme Pacific Ocean area.

D. The selection of material for exposure was based on their presently intended application and the performance data previously submitted by the manufacturer or determined by the Naval Air Engineering Center, Aeronautical Materials Laboratory, Plastics Branch. Appendix A, Table 3, describes these materials.

E. The study of the effects of oceanographic exposure on materials is a problem complicated by the enormously complex environmental variables in the properties of the sea. Among the more important variables are such properties as salinity, temperature, pressure, hydrogen ion concentration, dissolved oxygen, flow currents and types of marine organisms, all of which vary with the depth, site and duration of exposure.

F. However, it is hoped that for any one particular depth and site, the continuous changes in ocean conditions are not so severe as to preclude reproducibility of tests within certain reasonable limits.
III. METHOD OF TESTS

A. Two groups of commercial plastic specimens, low pressure laminates and cured resins, size 5 1/2 inches x 12 inches x 1/8 inch, were mounted in a test jig such that a condition of flexural load of 40-55 pounds total constantly prevailed and below each was mounted a duplicate specimen in the relaxed state (see appendix B, Figures 1 and 2).

B. Each set was held together by phenolic pegs at both ends of the specimens, and all edges in the total assembly were sealed with an epoxy resin, Chrysler Cyclweld C-14, to prevent or hinder deterioration through any weaknesses that may have been incurred during the cutting of each specimen and jig component.

C. For the acrylic specimen, a flexural load of only 12 pounds total was impressed because of the limiting nature of the jig construction.

D. Specimens were submerged to a depth of 5,640 feet for 751 days duration at the Port Hueneme Pacific Ocean area on 2 October 1963 under the following environmental conditions:

<table>
<thead>
<tr>
<th>Location</th>
<th>33° 44'N, 120° 45'W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>2482 psi</td>
</tr>
<tr>
<td>Salinity</td>
<td>34.59 parts per thousand</td>
</tr>
<tr>
<td>Oxygen</td>
<td>2.14 parts per million</td>
</tr>
<tr>
<td>Temperature</td>
<td>36.3°F</td>
</tr>
<tr>
<td>pH</td>
<td>7.48</td>
</tr>
<tr>
<td>Current</td>
<td>less than 0.5 knots</td>
</tr>
<tr>
<td>Sediment</td>
<td>green mud to rocks</td>
</tr>
</tbody>
</table>

Specimens were retrieved 22 October 1965.

E. Upon retrieval, the entire assembly was forwarded to the Naval Air Engineering Center in the "as is" condition enclosed in plastic bags. Drying out of the specimens occurred during transit and the interval between disassembly and mechanical testing was such that the curvatures in the stressed specimens were difficultly discernible.

F. Specimen sizes, as cut from the exposed panels, and test procedures for mechanical testing are as detailed in MIL-STD-401A. Values obtained were based on the average of 3 to 6 specimens.

IV. TEST RESULTS

The results of mechanical testing are tabulated in Appendix A, Tables 1 and 2.
V. OBSERVATIONS

A. Specimens on receipt had no apparent surface effects except for a light deposit of what appeared to be marine plant life adhering to the surface of all the specimens and jig in a dendritic pattern. (See Appendix B, Figures 1, 2, 3 and 4.

B. Room temperature mechanical properties tested after exposure indicated the following characteristics:

1. In general, flexural strengths decreased after exposure except for the acrylic and phenolic #3 relaxed specimens which exhibited a slight increase in strength over the control. The values for these specimens demonstrating the increase were based on the average of four specimens. In either case, the fact that the flexural values of three of the four specimens were greater than the average for the respective control, reflects the degree of reliability of the observation.

The values noted for all the stressed specimens indicated that the oceanographic exposure effected loss in flexural strength ranging from 1.5% for phenolic #3 to 12.4% for phenolic #2.

2. Except for phenolic #3 which showed an increase for relaxed and stressed specimens, modulus of elasticity values dropped for all the specimens, relaxed as well as stressed.

3. Tensile strength increases occurred for the polyester and epoxy, both in the relaxed and stressed condition; and for the acrylic in only the stressed state.

4. All specimens incurred loss in compressive strength with those under stress, excepting phenolic #2, exhibiting a lesser degree of loss than those relaxed.

VI. CONCLUSIONS

A. Since this is a continuing effort in evaluating deep sea submergence effects at various depths and for different time durations, note will be made of the oceanographic effects on each individual type of material versus exposure. However, except for the results discussed in each respective report, it is premature at this stage of the effort to justifiably compare the various exposures since there has not been a significant number of them as yet and, additionally, not all of the exposures involve the same types of materials.

B. For this array of specimens deep sea immersion for 751 days adversely affected the mechanical properties of most of the materials.
The supposed enhancement of mechanical properties observed after exposure may be explained by the fact that control values were determined much in advance of values for the exposed specimens. During this interval it is possible that gradual postcuring may have occurred before, during, or after exposure to yield the higher strength values and any loss in strength incurred during exposure may be overshadowed by the increase due to this postcure.

VII. RECOMMENDATIONS

A. It is recommended that control specimens be tested, if possible, concurrently with the exposed specimens so as to prevent differences in test data due to any time interval effects such as postcuring.

B. It is also recommended that a significant number of exposures be made testing the same types of materials, providing sufficient coupons of these materials are available.

C. Also recommended is that the time interval between retrieval and laboratory tests be reduced as much as possible to prevent unreliability of results due to recovery or deterioration of mechanical properties during the time interval.

D. Retrieved specimens should be kept immersed in sea water until mechanical tests are initiated.

VIII. FUTURE PLANS

A. The same types of plastic materials as in previous exposures, if available, will be submitted for immersion until a significant number of exposures is obtained.

B. New types of plastic engineering materials will also be studied either concurrently with previous types or separately.

C. Specimens of the same types of materials as in STU 1-4 for shallow water immersion have been prepared and at present await consignment to the appropriate facility.

D. A type of test has been devised and will be applied to determine quantitatively the degree of sea water absorption of exposed specimens. This method of test should not be affected by the drying out of the specimens during the period between retrieval and laboratory testing.
IX. APPENDIX A
### Mechanical Tests of OceanoGraphic Specimens

<table>
<thead>
<tr>
<th></th>
<th>1/4&quot; Acrylic</th>
<th>Polyester</th>
<th>Phenolic 1</th>
<th>Phenolic 2</th>
<th>Spray</th>
<th>Phenolic 3</th>
<th>Phenolic Plates on Jig</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Exposed</td>
<td>Control</td>
<td>Exposed</td>
<td>Control</td>
<td>Exposed</td>
<td>Control</td>
</tr>
<tr>
<td>Norm Temperature Flexural Strength (psi)</td>
<td>17,050</td>
<td>17,320</td>
<td>16,645</td>
<td>67,690</td>
<td>64,575</td>
<td>63,535</td>
<td>66,845</td>
</tr>
<tr>
<td></td>
<td>64,575</td>
<td>63,535</td>
<td>66,845</td>
<td>61,170</td>
<td>62,085</td>
<td>61,220</td>
<td>72,010</td>
</tr>
<tr>
<td></td>
<td>61,170</td>
<td>62,085</td>
<td>61,220</td>
<td>72,010</td>
<td>71,170</td>
<td>83,000</td>
<td>72,430</td>
</tr>
<tr>
<td></td>
<td>83,000</td>
<td>72,430</td>
<td>74,490</td>
<td>76,130</td>
<td>78,590</td>
<td>75,000</td>
<td>19,150</td>
</tr>
<tr>
<td></td>
<td>76,130</td>
<td>78,590</td>
<td>75,000</td>
<td>19,150</td>
<td>19,510</td>
<td>20,215</td>
<td></td>
</tr>
<tr>
<td>Modulus of Elasticity (psi)</td>
<td>0.49 x 10^6</td>
<td>0.67 x 10^6</td>
<td>0.44 x 10^6</td>
<td>2.88 x 10^6</td>
<td>7.78 x 10^6</td>
<td>3.77 x 10^6</td>
<td>3.62 x 10^6</td>
</tr>
<tr>
<td></td>
<td>3.62 x 10^6</td>
<td>2.73 x 10^6</td>
<td>3.37 x 10^6</td>
<td>3.50 x 10^6</td>
<td>3.90 x 10^6</td>
<td>3.25 x 10^6</td>
<td>3.09 x 10^6</td>
</tr>
<tr>
<td></td>
<td>3.09 x 10^6</td>
<td>3.21 x 10^6</td>
<td>3.29 x 10^6</td>
<td>3.55 x 10^6</td>
<td>3.78 x 10^6</td>
<td>0.58 x 10^6</td>
<td>0.39 x 10^6</td>
</tr>
<tr>
<td></td>
<td>0.39 x 10^6</td>
<td>0.84 x 10^6</td>
<td>0.44 x 10^6</td>
<td>0.58 x 10^6</td>
<td>0.39 x 10^6</td>
<td>0.44 x 10^6</td>
<td>0.44 x 10^6</td>
</tr>
<tr>
<td>Tensile Strength (psi)</td>
<td>9,915</td>
<td>8,305</td>
<td>10,375</td>
<td>55,520</td>
<td>55,730</td>
<td>57,615</td>
<td>41,405</td>
</tr>
<tr>
<td></td>
<td>55,520</td>
<td>55,730</td>
<td>57,615</td>
<td>39,025</td>
<td>38,670</td>
<td>40,003</td>
<td>40,743</td>
</tr>
<tr>
<td></td>
<td>39,025</td>
<td>38,670</td>
<td>40,003</td>
<td>40,743</td>
<td>42,580</td>
<td>48,910</td>
<td>39,840</td>
</tr>
<tr>
<td></td>
<td>48,910</td>
<td>39,840</td>
<td>81,000</td>
<td>51,930</td>
<td>44,770</td>
<td>49,630</td>
<td></td>
</tr>
<tr>
<td>Compression Strength (psi)</td>
<td>21,320</td>
<td>16,795</td>
<td>17,165</td>
<td>43,705</td>
<td>33,230</td>
<td>24,085</td>
<td>35,860</td>
</tr>
<tr>
<td></td>
<td>43,705</td>
<td>33,230</td>
<td>24,085</td>
<td>45,475</td>
<td>48,605</td>
<td>62,930</td>
<td>50,410</td>
</tr>
<tr>
<td></td>
<td>45,475</td>
<td>48,605</td>
<td>62,930</td>
<td>47,210</td>
<td>72,000</td>
<td>60,350</td>
<td>51,795</td>
</tr>
<tr>
<td></td>
<td>60,350</td>
<td>51,795</td>
<td>60,015</td>
<td>48,535</td>
<td>44,640</td>
<td>21,185</td>
<td>26,590</td>
</tr>
<tr>
<td></td>
<td>48,535</td>
<td>44,640</td>
<td>48,535</td>
<td>44,640</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>44,640</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes: (1) Tested in accordance with MIL-STD-401A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) &quot;A&quot; denotes specimens in the relaxed condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;B&quot; denotes specimens under flexural stress</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## COMPARISON OF ROOM TEMPERATURE MECHANICAL PROPERTIES - CONTROL AND EXPOSED SPECIMENS

<table>
<thead>
<tr>
<th>Oceanographic</th>
<th>Flexural Strength</th>
<th>Modulus of Elasticity</th>
<th>Tensile Strength</th>
<th>Compressive Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimens</td>
<td>Relaxed vs Control</td>
<td>Stressed vs Control</td>
<td>Relaxed vs Control</td>
<td>Stressed vs Control</td>
</tr>
<tr>
<td>1/8&quot; Acrylic</td>
<td>1.6 Gain 2.4 Loss 3.9 Loss</td>
<td>4.4 Loss 11.1 Loss 7.0 Loss</td>
<td>17.3 Loss 17.6 Gain 26.3 Gain</td>
<td>21.3 Loss 19.6 Loss 2.3 Gain</td>
</tr>
<tr>
<td>Polyester</td>
<td>4.6 Loss 6.1 Loss 1.6 Loss</td>
<td>1.7 Loss 4.2 Loss 2.5 Loss</td>
<td>0.4 Gain 3.8 Gain 3.4 Gain</td>
<td>23.8 Loss 22.0 Loss 2.3 Gain</td>
</tr>
<tr>
<td>Phenolic (1)</td>
<td>8.2 Loss 8.8 Loss 1.0 Gain</td>
<td>3.2 Loss 4.0 Loss 0.4 Loss</td>
<td>4.3 Loss 6.6 Loss 2.4 Loss</td>
<td>34.0 Loss 28.9 Loss 7.7 Gain</td>
</tr>
<tr>
<td>Phenolic (2)</td>
<td>11.3 Loss 12.4 Loss 1.2 Loss</td>
<td>8.4 Loss 4.9 Loss 3.9 Gain</td>
<td>16.9 Loss 13.1 Loss 4.3 Gain</td>
<td>19.9 Loss 25.0 Loss 6.4 Loss</td>
</tr>
<tr>
<td>Epoxy</td>
<td>13.4 Loss 10.9 Loss 2.9 Gain</td>
<td>4.9 Loss 1.2 Loss 3.9 Gain</td>
<td>22.4 Gain 55.6 Gain 35.4 Gain</td>
<td>39.5 Loss 28.1 Loss 18.9 Gain</td>
</tr>
<tr>
<td>Phenolic (3)</td>
<td>2.9 Gain 1.5 Loss 1.8 Loss</td>
<td>7.9 Gain 2.7 Gain 4.8 Loss</td>
<td>4.2 Loss 3.8 Loss 0.4 Gain</td>
<td>19.9 Loss 26.3 Loss 8.0 Loss</td>
</tr>
</tbody>
</table>

Table 2
**DESCRIPTION OF MATERIALS TESTED**

1. 1/8" Acrylic
   - EVR-KLEER Type II UVA UVA Cast Optics Corp.

2. Polyester
   - Polyester Glass Reinforced Laminate Pleogen 1321
   - American Petro Chemical Corp.

3. Phenolic 1
   - Phenolic Glass Reinforced Laminate Plyophen 98-573
   - Reichold Chemical Inc.

4. Phenolic 2
   - Phenolic Glass Reinforced Laminate Plyophen 98-583
   - Reichold Chemical Inc.

5. Phenolic 3
   - Phenolic Glass Reinforced Laminate EC-200
   - Evercoat, Chemicals, Inc.

6. Epoxy
   - Epoxy Glass Reinforced Laminate Trevarno 161
   - Coast Manufacturing and Supply Co.

7. Phenolic Plate

---

*Table 3*
X. APPENDIX B
TOTAL ASSEMBLY - JIG AND TWELVE TEST SPECIMENS
PRIOR TO DISASSEMBLY FOR TESTING

PHOTO NO: CAN-374566(L)-3-66
JIG DISASSEMBLED WITH SPECIMENS REMOVED

PHOTO NO: CAN-374567(L)-3-66

Figure 2
SPECIMENS REMOVED FROM JIG SHOWING EPOXY, PHENOLIC #3, AND PHENOLIC #2 SPECIMENS RESPECTIVELY

PHOTO NO: CAN-374568(L)-3-56

Figure 3
SPECIMENS REMOVED FROM JIG SHOWING
PHENOLIC #1, ACRYLIC, AND POLYESTER SPECIMENS RESPECTIVELY

PHOTO NO: CAN-374565(L)-3-66

Figure 4
The continuing effort to evaluate oceanographic environment effects on a wide spectrum of plastic engineering materials, reinforced laminates and other plastics, has been in progress. Submersible Test Craft I-2 test panel array, which is discussed, represents one segment of this continuing effort. This panel array was submerged October 1963 for 751 days at a depth of approximately 5,640 feet in the Port Hueneme Pacific Ocean area.

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oceanographic
deep sea
plastic engineering materials
reinforced laminates