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ENVIRONMENTAL TESTING

by

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⑮

Submitted to
Navy Electronics Laboratory
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CHANGE SHEET

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ENVIRONMENTAL TESTING

Corrosion is a complex form of materials deterioration. This deterioration proceeds through chemical or electrochemical processes. Each environment in which materials are placed has associated with it various modes of corrosive attack which may or may not be consistent with each other. Operating in a sea water environment, materials can be subjected to several forms of corrosion; the more common forms being galvanic corrosion, cavitation corrosion, direct attack, stress corrosion, crevice corrosion, fatigue corrosion, caustic embrittlement, dezincification and corrosion due to marine fouling. The use of new systems or materials directly immersed or exposed to sea water, requires predicting the behavior of these systems or materials in this environment to insure a certain lifetime free from failure or drastic weakening and subsequent failure. Over the years much work both theoretical and experimental has gone into the study of the phenomenon of corrosion in its modes of attack and in its prevention. There are several laboratories in existence with facilities to expose and immerse various materials in sea water under various conditions, which monitor and examine these materials over long periods of time so that guides to useful lifetimes of these materials can be formulated. There are galvanic tables in existence which predict what potentials are generated when two dissimilar metals are electrically connected in sea water. Manufacturers supply test data as to hydrolytic stability and water absorption rates for their products. With these tools available it is reasonable to ask, why should new systems or materials associated with a developmental task be subjected to environmental testing? It is the hope of this memo to show why it is essential for this type of testing to be done in the light of today's knowledge.

The types of corrosion that will be discussed in this section are based upon the construction of a C/P sonar system of the sparse array type. The system as envisioned for this purpose uses transducers locked in sea chests which are flush mounted in the hull of the ship. The sea chests are welded in some manner to the hull plating. In the construction of the components of the sonar system (transducer and sea chest) several materials have been used in the past in the construction of test units. The transducer assembly has had the following materials associated with it: silicone rubber, aluminum or magnesium alloys, two types of brass, beryllium copper alloy, and piezoelectric elements. The sea chest has been made of stainless steel and the hull plate of a mild steel.

The first type of corrosion to be discussed is galvanic corrosion. Galvanic attack may proceed in areas where two dissimilar materials are in electrical contact, with the conductive path being completed by the sea water. Areas where galvanic coupling is likely to take place in this system are between sea chest and hull, sea chest and transducer, and between certain selected components of the transducer. The glavanic corrosion we are dealing with is that part of the corrosion of the anodic member of a couple directly related to the galvanic current by Faraday's Law. Simultaneous additional corrosion taking place on the anode is called local corrosion, and corrosion taking place where there is no contact between dissimilar metals is called normal or direct corrosion. When galvanic corrosion takes place the local corrosion of the anode may be equal to the normal corrosion or it may be altered by it. The change is called the difference effect and it may be either positive or negative. An important consideration in galvanic corrosion is the area relationship between anode and cathode. The galvanic corrosion is increased where there is a small anodic area and a large cathodic area. The fundamental relationships involved in galvanic corrosion are Kirchoff's Second Law and Faraday's Law. These have been described in an earlier report.[1] The work we have undertaken at TRG is this area involved firstly the measurement of the potentials of the materials used in the transducer, sea chest and hull. The potentials were measured potentiostatically in quiet and flowing sea water. This work was necessary because when a galvanic couple is formed, polarization of the electrodes takes place as current begins to

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[1] Report No. TRG-023-TM-65-10

flow. The potential then changes due to the new current condition and this continues until a steady state condition exists. Polarization of the electrodes is affected by several parameters which include water velocity, temperature, and water composition. Reliance alone on potentials which are given in data tables, in which the measurements are given for essentially static conditions will lead to erroneous values for current and voltage requirements. The current and voltage requirements are quite important in designing and impressed current cathodic protection system. It has been reported[2] that all Navy ships built after 1970 will have impressed current cathodic protection systems provided. Our measurements to date in this area have shown that our sonar system design would be compatible with a cathodic protection system without causing large current drains. Another problem area introduced with this sonar design is the effect of welding the stainless steel chest into mild steel hull plating (HY-80). This welding causes a polarization which cannot be determined except experimentally. Results of our work to date in this area have been reported previously.[3] To sum up this area, we feel it is necessary to gather data to supplement existing data so that galvanic corrosion can be minimized with the introduction of a C/P sonar array on naval vessels. Testing of an impressed current system model with the sonar system materials is a necessary step in insuring increased reliability and life of the system.

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[2] Private communication from I. Geld of NASL.

[3] TRG 023-TN-66-10

A second form of corrosion to be anticipated in the C/P sonar array design is cavitation corrosion. When the transducers are powered at high levels, cavitation will occur at the front mass. When the ships are in motion and this cavitation occurs, bubble collapse can take place on the coatings covering the hull plating adjacent to the transducers. It has been the experience with other sonar systems that this cavitation severely damages protective anti-corrosion and antifouling coatings which were applied near the sonar system. The use of coatings on Navy hulls will continue even with the use of impressed current protection systems. We have planned a test which is described in another communication[4] in which transducers in a simulated array will be powered to cavitation under flowing water conditions, and standard Navy coatings will be evaluated under these test conditions. Photographs of bubble formation and collapse will also be attempted to determine their position in those two states. This test is relatively inexpensive and is most important in determining whether a C/P sonar requires a dome or not.

The third type of corrosion which is important in this program is the direct or normal corrosion. Some data has already been gathered in our work on galvanic corrosion. Here we can use the single electrode potentials of the materials tested in determining

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[4] 94-1/9000 - 1

what the corrosion rate will be in a specified time. Again, it was most important to have the data available on conditions as close to actuality as possible and not under static or laboratory conditions which are quite different. This data is all valuable in assessing what precautions must be taken to protect susceptible parts where an alternate selection of material is not possible. In conjunction with direct corrosion we mention here the fact that the transducer has an elastomeric front (silicone rubber presently used)which is in constant contact with sea water. The manufacturer of the rubber gives average data for water absorption and water permeability rates for the general class of silicone rubbers and not the specific compound employed here. The values used by the manufacturer can be off by as much as a factor of 10. There are several important considerations which must also be taken into account. First, the end use of these materials are in applications which were probably never envisioned by the manufacturer and the test conditions used for accumulating the manufacturers data may not be valid for our application. Secondly, the test data as supplied by vendors is usually of short duration tests which again may be different than long exposure tests. We feel that it is quite important when evaluating a new material or an old material for a new use to check the test data on samples and, in the case of salt water immersion, to actually immerse the samples and evaluate effects of time. In the case of the silicone rubber, if higher absorption or permeability rates are found, this could be quite detrimental as the water would come in contact with the metallic front mass which is a reactive metal, resulting in hydrogen evolution, loss of bond strength of rubber to metal, and eventual loss of the elastomeric front. It has been our approach with respect to the elastomeric materials to run water absorption and water permeability tests on samples using sea water as the test medium. We hope to conduct experiments on individual units which can be taken apart for examination and weighing to see the effect of barrier layers (solid metallic front mass) on the absorption and permeability rate.

Another area of concern as far as corrosion goes is stress corrosion cracking. We are concerned with this phenomena in connection with the sea chest which is made of 316 stainless steel. 316 stainless steel was chosen for the sea chest because it is immune to most forms of corrosion, it has good machining and welding characteristics and would provide long service life. Stainless steels are known to be subject to stress corrosion cracking. The term stress corrosion cracking includes any combined action of static tensile stress and corrosion which leads to failure by cracking. The failure may involve an electrochemical mechanism, hydrogen embrittlement, or some other factor. The electrochemical mechanism often involves an intergranular failure, which may occur in the absence of stress. The function of the stress in this case seems to be one localizing, accelerating, and intensifying the attack. This type of attack may be experienced on the inner surface of the sea chest where stresses might be set up due to welding and where water can settle by seepage past the o-ring seal. By placing samples of the stainless steel under various tensile stresses in sea water we can simulate the condition that exists in the sea chest and determine whether these units will be affected by stress corrosion cracking. If the results indicate that it is a problem, corrective measures such as coating the inside of the sea chest, or the selection of a different material, may be necessary. Without the environmental test a reliable prediction cannot be made.

Crevice corrosion occurs where sea water enters a limited access area and attack proceeds via a differential aeration or concentration cell. In a crevice, pitting due to normal corrosion leads to small anodic areas deficient in oxygen. As more oxygen is removed, the cathodic area is polarized increasing the area of attack. The possibility exists of this type of corrosion occurring in the C/P sonar array. There is a small space between the transducer sleeve and sea chest where water can enter past the o-ring seals. Whether the existence of the crevice will lead to increased corrosion rates on the transducer and sea chest can not be accurately predicted. Again, a test can be devised to simulate the crevice, expose it to sea water and determine the precise effect that does occur.

Of great concern to anyone placing material in sea water is the question of marine fouling. Marine fouling is objectionable on two counts. Firstly, marine fouling is a direct cause of corrosion of many materials including plastics and stainless steels. Secondly, marine fouling generates noise and attenuates signals. In the C/P sonar array we have in contact with sea water a silicone rubber and an adjacent stainless steel chest. Normally, protection against marine growth is achieved by the application of coatings containing chemicals which inhibit marine growth on all exposed surfaces. These coatings are generally applied over the anticorrosive paints that are used and will provide protection to ships for anywhere from 1 to 2 years depending on several factors. Silicone rubbers do not easily bond to paints or adhesives and generally silicones find wide use as lubricants and mold release agents. This poses a problem with these transducers in that coatings will not adhere to the silicone rubber surface. The question then arises, "will silicone rubber promote, inhibit, or not exert an influence on marine growth in an uncoated condition?" In addition, what is the effect of the acoustic signal generated on the rate of marine growth? The literature in the field has provided no definitive answer. The answer is to be found in the sea with samples duplicating a working system under operating conditions. This test can be run in a facility used for measurements of efficiency and reliability as well. Our program, using the facilities at Ocean City Research Corp., Ocean City, New Jersey, will provide us with answers to these questions. Many materials can be placed in this environment and evaluated more properly than relying on laboratory data or experiments.

Environmental testing can be a great aid to the design engineer in providing data as to the service one can expect from a given material in a particular environment. Reliability and maintainability of a system are increased by knowing precisely what effects the operating environment has on the designed system. It is hoped that with the use of existing data and knowledge on corrosion and environmental testing, a C/P sonar system will be constructed subject to the minimum corrosive effects of the sea. We expect by a modest investment to insure against an expensive disaster.