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MOST Project -4

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# SELECTION OF MATERIALS FOR TRANSDUCERS AND OTHER STRUCTURES IN MARINE ENVIRONMENTS

Written by Peter J. Cohn

Checked by__________





**PRELIMINARY**

ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE

EDO CORPORATION
COLLEGE POINT, NEW YORK

Introduction

In making a selection of material for a marine environment, Edo draws heavily on its experience with previous installations as well as the experience of other companies and government facilities Actual service conditions provide a wider spectrum of conditions than is likely to be incorporated into most environmental tests. Consequently, every material failure encountered is evaluated by the Edo Engineering Department. Where possible, the specific service conditions are evaluated, such as the presence of adjacent materials and conditions of grounding. In certain cases, tests are then made to try to simulate the conditions, or to provide an accelerated life test.

In the contemplated use of new materials, main reliance must of course, be placed on carefully set up tests. The main problem consists of having sufficient time available for long term evaluations and covering all possible corrosion and fouling conditions.

Several factors further complicate the selection of materials. In general, it is desirable to use one material throughout on all exposed areas. The transducer manufacturer, however, has no control and, often no knowledge, of the material on which the transducer will be mounted. Even within the transducer, casting or welding requirements can bring variations from materials available or suitable for hardware. The use of slightly differing materials, however, need not be feared if careful attention is paid to the electrolytic action as detailed in MIL-E-16400 and similar literature.

For any manufacturer, or for anybody else working within an economic framework the selection of materials cannot be divorced from a cost consideration. It is not feasible to upgrade even relatively uncritical members to monel, titanium or similar noble materials. The large scale use of these materials also provide an electrolytic bias against surrounding less noble steel ship structures. (When the Bureau upgraded an Edo periscope fairing from aluminum to monel it contrbuted to the rapid corrosion of stainless steel periscopes). In general, the selection of the material should be based on the requirements and criticalness of the component and on compatibility with all neighboring parts.

## Aluminum

Aluminum can find use as a transducer material only in special applications. Where there are no neighboring structures of other material, aluminum stands up quite well in the marine environment. Edo has built aluminum hydrophones for the Artemis project, and is currently building UQN-type aluminum transducers for E.G & G. These UQN transducers, however, get only limited and intermittent sea water exposure in their use with deep sea photography. In the Edo seaplane floats, where weight is a prime consideration, aluminum, or alclad with only paint finishing, has been used since these parts were first made, more than 30 years ago. Experience in the field with these floats has been excellent. Where the need exists, and conditions are suitable, Edo would not hesitate to use aluminum in a sea environment.

## Mild Steel

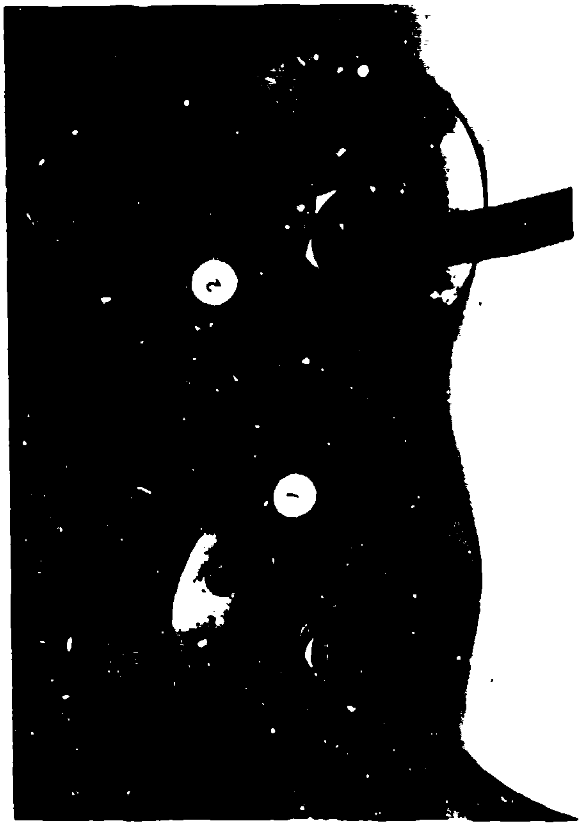
Mild steel has been used by Edo for a large number of transducers. In all cases, however, the steel has had some protective coating. Heavy transducers with thick sections such as the UQN, SQS-1, SQS-17, SQS-5 and SQS-503 have been built out of mild steel, cadmium plated and painted. Hardware has generally been stainless steel or monel. Experience in as far as known to Edo has generally been good with these units when directly mounted to galvanically protected steel ship structures. Edo has, however, seen a few UQN units, from uncertain installations, where strong currents or galvanic action has destroyed hardware or cut into the steel structure. Since the UQN transducers are used on mine sweepers, wooden hulls, and a large variety of commercial vessels, the few failures that do exist are believed to be caused by improper use or installation of the material. There have been no known corrosion failures with the mild steel cadmium plated SQS-1, SQS-17, SQS-5 or SQS-503 transducers.

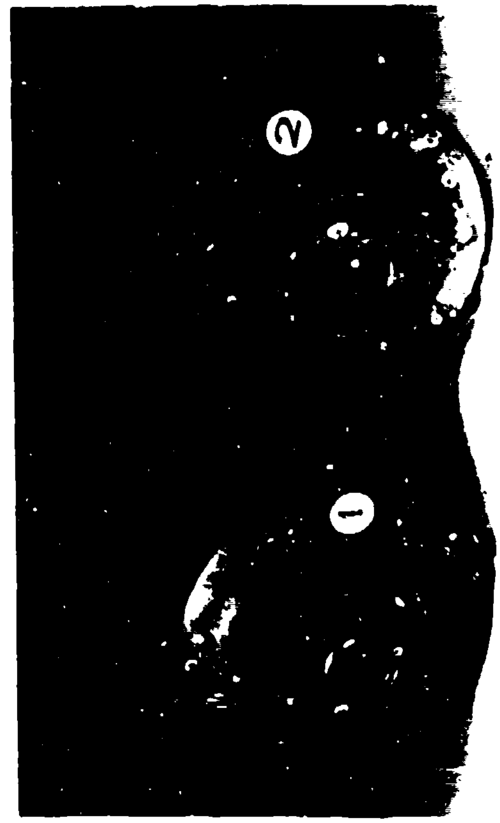
For transducers with thinner sections, Edo has used mild steel hot dipped, galvanized and sometimes painted over galvanizing when painting was required by the Bureau. The BQS-3 transducer and the SQS-26 (XN-1) transducer housing and frame have been built in this manner. Fully exposed fittings and hardware have been stainless steel, and care has been taken to install an adequate supply of sacrificial zincs. The SQS-26 (XN-1) transducer has stood up well with no element known to have failed due to corrosion. There were however, problems associated with the fabrication, lumps and zinc drip lines had to be removed in certain areas. Irriditing and a complex paint scheme had to be used to give proper paint adhesion. Furthermore, during testing and other sea water exposure where there was no other sacrificial element available, rapid removal of zinc through pin holes in the paint would occur. This would slow down as more zinc areas became exposed. However, the resulting blistering needed touch up or rework.

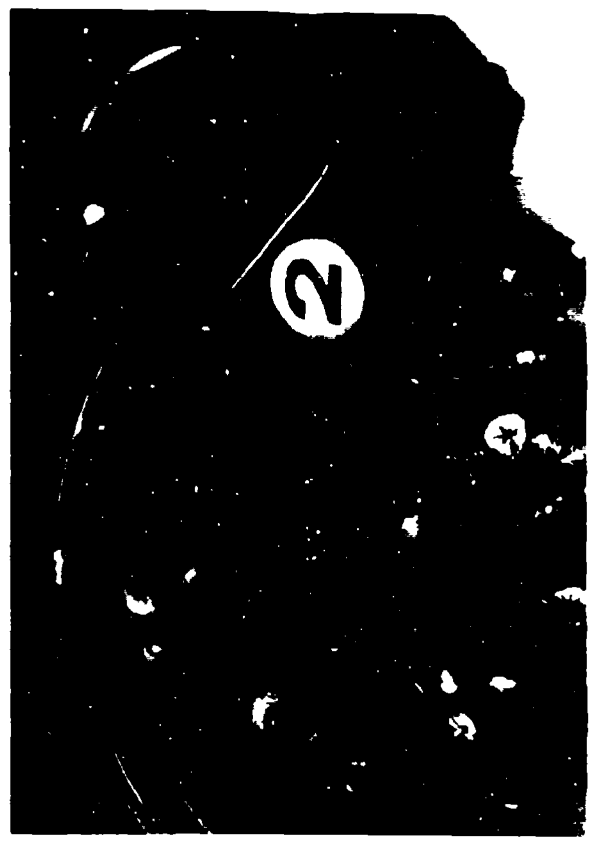
At the present time other covering methods such as fluidized bed processes employing epoxy or vinyl, and molding and encapsulation methods are available. These are somewhat independant of the skeleton material and are covered in a later section.

## Stainless Steel

In recent years, the Bureau has tended to favor the use of stainless steel and has made its use a requirement of various test specs. Consequently, Edo has built a very large number of stainless steel transducers and hydrophones. UQN, SQS-1, BQS-4 and SQS-35 transducers and most BQR-2, BQR-4, and BQQ-1 hydrophones have been built in stainless steel. There has been no major corrosion problem with any of the larger CRES transducer. On the BQR-7 hydrophone, however, Edo had its most serious corrosion failure. In relatively short periods after installation, severe crevice and stress corrosion occured at and around the sealing pipe plugs and at the cable packing nut, and destroyed the watertight integrity of the hydrophones. 302 stainless steel had been used throughout on the affected exposed surfaces, and the hydrophones had not been grounded in their installation. Edo tests on its barge duplicated the failure in an attempt to provide corrective measures. Several production hydrophones were tested for long term submersion. Hydrophones were immersed, some ungrounded as in the ship installation and others grounded to the hull of the test barge. Failure of the ungrounded hydrophone occurred in little more than 3 months in the same manner as occurred in service. There was only minor and superficial corrosion on the grounded stainless steel hydrophone. The attached photographs show the 3 month results, hydrophone (1) being the grounded unit and hydrophone (2) the ungrounded unit.







The shipboard hydrophone failures set off a flurry of activities to cover all exposed stainless steel surfaces with neoprene and to upgrade all exposed surfaces to 316 stainless, monel, and even titanium. Edo has not made extensive tests to discriminate between the various grades of 300 series stainless steel. However, from observation of various stainless steel transducers it is doubted that any one grade will be sufficiently superior under all conditions to warrant its selection for all purposes. There is also no evidence at Edo to suggest that mixing of 302, 303 and 304 materials as in AN hardware represents any special problem, since these materials are so closely related in the electrolytic series and since variations in one grade may equal variations between grades. It would, however, be interesting to repeat the photographed experiments for grounded and ungrounded 316 stainless steel hydrophones.

Edo has had substantial porousity problems with castings for transducer housings. Especially in the case of stainless steel these have required repeated impregnations in order to eliminate all leakage through the material. The same problem can also exist in bronzes and other casting materials and therefore Edo tries to avoid castings for transducers when other equally feasable production methods are available.

Monel and Bronze

Edo did repeat the above experiments with monel hydrophones that are being built on another contract. These hydrophones are made of monel which in turn is fully covered by neoprene caps cemented on with polysulfide cement. For the purpose of the test the neoprene caps were deleted leaving the monel exposed. Unit (3) was grounded and hydrophone (4) was left ungrounded. There has been no failure after 6 months of immersion. However, there is a substantial difference, with the ungrounded unit showing more corrosion than the grounded unit, and possibly even more corrosion than the grounded stainless steel hydrophone.

Edo has had only limited experience with bronze as a transducer material. However, because of requirements for large complicated castings, Edo is utilizing this material for 2 types of transducers that are presently being built for NAVOCEANO survey ship bathymetric systems. One additional type with bronze is being built for use by the Norwegian Navy.

With respect to these materials, it is pertinent to mention the corrosion - adhesion failure on Raytheon BQS-6 transducer elements. Accidental grounding of the bronze housing set up an electrolytic action with the housing as the cathode. The current caused failure of the water exposed neoprene-bronze band and eventually flooded out the elements.

Thus, the use of high quality bronzes or titanium does not guarantee freedom from corrosion failures.


## Additional Grounding Tests

The work done at the Canal Zone Corrosion Laboratory on mooring lines is interesting because it shows that under idealized conditions, with no overwhelming disproportion of surface areas, the sacrificial zinc need not be physically close to the member it protects. The work is reported in the July 1964 issue of "Report of NRL Progress". We quote from the report.

"PROGRESS: On 10 December 1963 four wire ropes (bright improved plow steel, galvanized improved plow steel, Monel, and Type 304 stainless steel) approximately 450 feet long were suspended well off the ocean bottom at Rodman in the Pacific entrance to the Panama Canal. A zinc anode was coupled to one end of each rope. Short unprotected lengths of each rope material were also exposed as controls.

"The experiment with the bright wire rope was terminated on 20 February 1964. Additional inspections of the three remaining ropes were made on 1 June 1964 (after 24 weeks).

"The following is a condensed summary of observations to date: Partial cathodic protection extended to the end of the bright wire rope, 427 feet from the anode, but some loss in load-bearing ability appeared to be underway beginning at roughly 200 feet from the anode and increasing toward the unprotected end; however the most corroded area was in strikingly better condition than the unprotected control. The zinc anode greatly extended the period for the beginning of corrosion of the galvanized rope. The first 250 feet of the Monel rope from the anode end did not show corrosion. The cathodically protected stainless steel rope did not show evidence of corrosion throughout its length after 29 weeks; this is in marked contrast to the unprotected stainless steel which exhibited considerable corrosion in crevices after only 10 weeks".

Covering Materials

Because of the corrosion problems encountered with all of the metals, the recent trend has been to fully encapsulate or cover all metallic transducer surfaces.

Polyurethane appeared to be highly useful for this purpose because of the ease of handling and the low curing temperatures required. Its general properties, its Rho-C qualities, and its adhesion appeared good. Unfortunately, some of the compounds are not completely impervious to moisture on long term submersion and these compounds caused a large number of hydrophone failures for various vendors and gave loss of adhesion on G. E. SQS-26 transducer faces. Edo, through its test program, became aware of some of the problems with this material at an early date, and no production units were built employing polyurethane in any critical application. It is, however, quite possible that the problems with polyurethane will be resolved and that it will have a large place in sonar transducers.

Neoprene encapsulation can be done by several methods. Neoprene caps or boots can be molded and these can then be cemented or clamped to the unit. The monel hydrophones mentioned before and the neoprene boot cemented to the front face of SQS-26 (XN-1) elements represent this approach. The use of a proper cement and cementing techniques is important especially for acoustic surfaces and on exposed edges.

A better method consists of molding neoprene over critical areas or over the complete unit. This method was used in molding the boot over the Edo SQS-26BX transducer head, and molding the SQS-26 element rear closure. The new BQR-7 zirconate hydrophone is completely molded in neoprene. Relatively low molding temperatures and pressures had to be used to avoid depoling the ceramic. This method with absolutely no exposed metals, seams, or cable entrances gives almost ideal corrosion protection although at the expense of serviceability and repair.

A third method of neoprene covering consisting of latex dipping, was used on the brackets for the abovementioned BQR-7 hydrophones and on the Edo SQS-26 BX element housing. The success of this method depends on quality preparation of the metal surfaces and care in the coating process to minimize pinholing and blistering.

The Edo neoprene-covered units have stood up well under salt spray and environmental submersion tests, and there has been no serious corrosion failure with any of these units.

There are presently available fluidized bed methods of fusion coating epoxies, vinyls, and other materials, over metallic surfaces. These provide tough, pinhole-free coverings of excellent corrosion resistance. They are very well suited to complete covering of relatively large surfaces, and should find increasing use for transducer frames and for some housings. Attachment points present some problems, as they do in all covering methods. Both fluidized bed vinyl and epoxy coverings were tested for salt spray and long term immersion with virtually no effect on the surface and on their adhesion. There was very little undercutting of exposed edges. The materials did, however, support some fouling as also did neoprene.

The frame for the Edo SQS-26 BX transducer is made from mild steel covered with a fluidized bed epoxy coating. Hardware is corrosion resistant steel. The structure and the mounting hardware of the transducer elements are further protected by zinc bars attached to bare spots counterbored into the frame.

In all cases where incompletely covered metals are used, care must be taken to avoid lifting of coatings or paints and primers due to possible electrolytic action. Raytheon, in its technical report of June 1962 entitled, "Transducer Failure Investigation", gives a cathodic action test to determine the resistance of elastometer to metal bands in the presence of cathodic action. It is believed there that bands (including organic coatings, primers, paints, etc.) resistant to cathodic action in salt water are very resistant to deterioration in salt water without cathodic action.

The fluidized bed epoxy coating mentioned above and used on the Edo SQS-26 transducer frame is excellent in this test. The bond to the steel surface is vastly superior even to that of neoprene molded directly on steel.

Environment

Additional environmental factors enter into the corrosion problem. Water may be fresh, or of different degrees of salinity. During World War II many sonar domes were filled with castor oil, which provided a comfortable environment for the transducer. Similarly, it is possible to use Sodium Dichromate solution in a dome in lieu of sea water to reduce corrosion.

Furthermore, the water may be stagnant or moving. An entirely different set of conditions is encountered with rapidly flowing water which requires wear resistant properties of the basic material or the covering. For these types of applications, Edo has had some experience through its floats, skis and hydrofoils.. On the aluminum floats, where quick serviceability is a prime requirement, Edo uses a lacquer finish. For the more severe application of hydrofoils and skis, Edo has had very good experiences with the ceramic filled, cross-linked polyurethane paint "Metalox Laminar X-500 Coating" made by Magna Coating and Chemical Corporation. Information received here also points to the possible use of Laminar X-500 materials with or without ceramic fillers for external use of critical Sonar domes and transducers.

## Fouling

Fouling represents another factor closely linked with the corrosion problem. It is extremely complex, being dependent on such factors as light or darkness, temperature and salinity, depth of immersion, stagnation or rates of water flow, and geographic location, as well as the properties of the exterior surface and the presence or absence of fouling inhibitors, such as copper or lead paints. The subject is outside the scope of this report and is mentioned only to avoid its being overlooked in the selection of materials.

## Conclusion

It is believed that the following points can be used as guidelines in transducer material selection.

1. No metal will provide a guarantee against corrosion failure. Selection must be made on the function and criticalness of the part and compatibility to all neighboring parts. Cost to the customer can be a major consideration.

2. One metal is better than two. Avoid dissimilar metals if possible; reduce joints and fittings to a minimum.

3. Cover metallic surfaces where possible, especially when using the lower grade materials. Full covering is greatly to be preferred over partial or broken covering.

4. Mounting and environmental conditions are equally as important as the selection of materials. Specifically watch adjoining materials, electrolytic action, and the question of grounding.

5. Wherever possible, make tests simulating the actual conditions. Accelerated life tests are helpful, but usually do not evaluate all conditions likely to be encountered.