Technical Memorandum PMR-TM-68-4

ANTICORROSION SEALING CAPS FOR MECHANICAL FASTENERS

By

W. L. MACKIE
Engineering Division

12 September 1968

PACIFIC MISSILE RANGE

Point Mugu, California

PMR-TM-68-4 (U)

PACIFIC MISSILE RANGE

POINT MUGU, CALIFORNIA

M. W. WHITE, RADM USN
Commander

Mr. C. C. Busenkell, Head, Aero-Mechanical Branch; Mr. B. C. Madden, Jr., Acting Head, Engineering Division; and Mr. J. N. Shellabarger, Head, Technical Support Department, have reviewed this report for publication.

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HEADQUARTERS
PACIFIC MISSILE RANGE
POINT MUGU, CALIFORNIA 93041

IN REPLY REFER TO:

232/jn
25 June 1968

Mr. N. Baldanza, Engineer
Plastec Building 3401
Picatinny Arsenal
Dover, New Jersey 07801

Dear Mr. Baldanza:

Your inquiry about Anti-Corrosion Sealing Caps has been received via Industrial Design Magazine.

Because of the large number of requests for this information, a technical report is being prepared describing the complete method developed here. When the report is complete, a copy will be mailed to you.

If you have further questions pending receipt of the report, please contact:

Materials Consultant
Code 3312-1
Pacific Missile Range
Point Mugu, California 93041

Sincerely,

Phil C. Russell

PHILIP C. RUSSELL
Head, Public Information Division
Public Affairs Office

HEADQUARTERS
PACIFIC MISSILE RANGE
Point Mugu, California 93041

16 December 1968

A copy of PMR Technical Report PMR-TM-68-4 titled "Anti-corrosion Sealing Caps for Mechanical Fasteners" is enclosed in response to your request, forwarded to the Pacific Missile Range by Industrial Research magazine.

The delay in getting this material to you was occasioned by security clearance and printing of the report.

Your interest in materials engineering projects of the Pacific Missile Range is appreciated. House organ or trade magazine articles dealing with your use of anti-corrosion sealing caps would be welcomed and clips of these pieces would be appreciated.

Please call or write Mr. William Mackie, Materials Consultant, Pacific Missile Range, Code 3312-1, Point Mugu, Calif., 93041, for further information on sealing caps.

Philip C. Russell

PHILIP C. RUSSELL
Head, Public Information Division
Code 232
Pacific Missile Range
Point Mugu, California 93041

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SUMMARY

This report describes the development and testing of a device that prevents or at least inhibits corrosion in fastened metal joints, and presents test results. The device consists of a cup-shaped receptacle, partially filled with a sealant, and is dimensioned to fit over bolt or screw heads. When applied over these fasteners, the device excludes moisture and effectively retards corrosion. It is called an Anticorrosion Sealing Cap for Mechanical Fasteners.

INTRODUCTION

Metal joints fastened with bolts, screws, and rivets are susceptible to several types of corrosion, in addition to the most common types--direct atmospheric or environmental. The configuration of the fastened joint leaves it especially susceptible to galvanic, stress, concentration cell, and exfoliation corrosion.

For naval facilities such as the Pacific Missile Range (PMR), the problem has become increasingly acute as more and more complex gear has been operated in harsh tropical or marine environments. In the case of the PMR, for example, deterioration of fastened metal joints in large radar installations has become a growing maintenance cost item.

This report describes a new approach to the problem. This consists of placing a plastic cap or receptacle partially filled with a flexible sealing material such as polysulfide or silicone rubber over a protruding fastener. The fastener is thus effectively sealed and protected against corrosion. For descriptive purposes, this device is called an Anticorrosion Sealing Cap for Mechanical Fasteners.

This report describes the development of the sealing cap (now in the primary stage), defines laboratory and field tests, and illustrates the results.

AUTHORITY FOR TESTS

The laboratory salt spray tests described in this report were accomplished under Job Order 9N35046 (Naval Missile Center support to Pacific Missile Range).

The field weathering tests at Kwajalein Atoll were performed by the Naval Civil Engineering Laboratory and authorized by Pacific Missile Range Request WR-7-0043/037-70001.

BACKGROUND

Various means have been employed for reducing the susceptibility of mechanical fasteners and adjacent structure to corrosion. Usually, the fasteners are protected against corrosive deterioration by the application of a thin coating of paint or sealant. However, the primary limitation of these or other preservatives is that they are applied by brush or spray gun. These methods usually result in a nonuniform protective coating, which invites penetration by moisture or other destructive media.

Research has led to better methods for preventing exfoliation and other types of corrosion, particularly in aluminum structure around steel fasteners. Systems tested have included wet and dry sealant or primer in the countersink prior to insertion of the fastener. Another system consists of precoating the fasteners with zinc chromate prior to assembly of parts.

There are numerous other methods for protecting the fastener and joint from corrosion. For example, corrosion-resisting material is selected for the fastener or the parts are electroplated with barrier-type materials such as chromium or nickel, which are more noble and therefore more corrosion resistant than the adjacent structure.

The methods described above and in the literature are, for the most part, employed in the manufacturing stage, and as such are not always feasible for use after assembly of equipment or for field maintenance.

Corrosion problems with fastened metal joints result when electrolytes such as salt spray or condensation penetrate the space between the fasteners and the surrounding structure. Corrosion starts at the exposed grain boundaries. The corrosion products exert pressures which cause expansion of the metal. This expansion results in exfoliation corrosion such as that illustrated in figure 1. The corrosion in this aluminum cover plate on a radar pedestal has followed a lamellar path parallel to the surface and destroyed the structural integrity of the metal. Figure 2 shows the result of destructive environmental corrosion of fasteners and adjacent structure on an electronic equipment van. The sealing caps were developed to prevent these types of corrosion as well as other kinds found detrimental to range equipment.

DESCRIPTION AND USE OF SEALING CAPS

The anticorrosion sealing cap is illustrated in figure 3. This thermoplastic cap is a commercially available, nonthreaded, tapered Caplug, a common type of closure used for temporary protection for products in process, storage, or transit (see appendix). The Caplug is partially filled with a sealant such as polysulfide or RTV (room temperature vulcanizing silicone rubber). The cap is used by inserting a measured amount of sealant into it and then pressing it over an exposed fastener such as a bolt, rivet, or screw. In a short time the sealing material cures to a flexible mass which seals the cap over the fastener head and thereby prevents admission of moisture. The cap may be readily pried off with a handtool such as a screwdriver.

SELECTION OF MATERIALS

Selection of materials for the anticorrosion sealing cap was based upon the following requirements: It should be a tough, flexible material that is impervious to most common chemical reagents such as solvents, caustics, and acids. It should be vermin- and fungus-proof and should not deteriorate under severe environmental conditions. It should retain form stability under stress and at temperatures ranging from -50°F to 250°F. Caplugs made from high density polyethylene appeared to meet these requirements and were selected for the sealing caps described in this report.

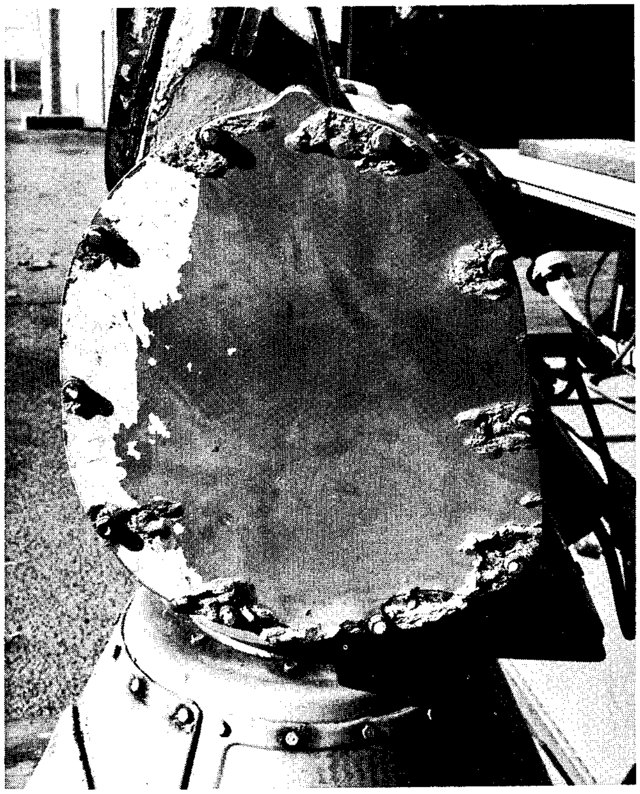


Figure 1. Exfoliation Corrosion of Aluminum Cover Plate on Radar Pedestal.

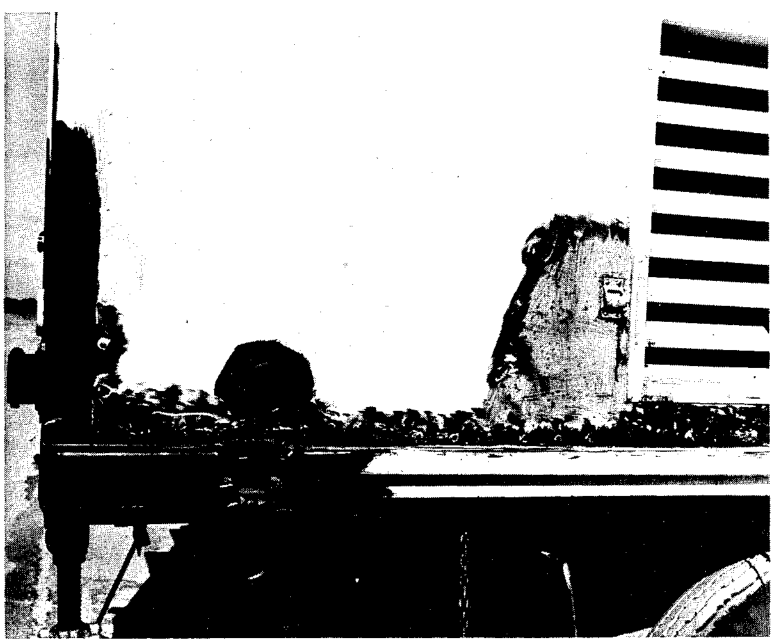
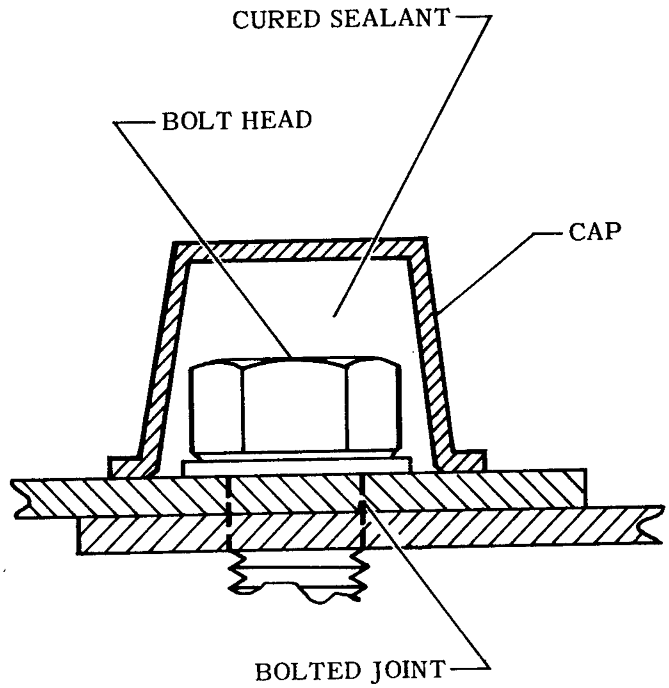


Figure 2. Environmental Corrosion of Steel Panel on Electronic Equipment Van.



CAP MATERIAL: POLYETHYLENE
SEALANT: POLYSULFIDE RUBBER BASE

Figure 3. Anticorrosion Sealing Cap for Mechanical Fastener.

A two-part, room-temperature curing, flexible, synthetic rubber material with a polysulfide base was selected for the sealant. The trade designation for this material is Pro-Seal No. 501. It is manufactured and distributed by the Coast Pro-Seal and Manufacturing Company. When mixed with a curing agent it cures to a resilient, low-shrinkage rubber sealant. The material is flexible at -65°F and is resistant to gasoline, oils, greases, and other petroleum products. It is exceedingly weather resistant and is suitable for use in water.

Detailed description and procurement sources for each of the materials used for the anticorrosion sealing cap test specimens are shown in the appendix.

TEST SPECIMENS

In order to evaluate the performance of the sealing caps, a quantity of double-bolted, lap-joint test specimens were prepared. These consisted of two 3.5 by 5 by 0.625-inch assembled panels of aluminum, magnesium, and steel in various combinations. The panels were prepared by a process described in paragraph 3.1.3 of Method 2011, Federal Test Method Standard (FTMS) No. 141A, and primed and painted in accordance with conventional coating systems described in table 1.

Table 1. Summary of Weathering Tests

Specimen	Combination of Metals in Lap Joint	ASTM Grade 5 Bolts* (3/8 Inch)	Primer Thickness** (Inches)	Total Coating Thickness** (Inches)	Torque on Bolts*** (Pounds)	Remarks
1	Aluminum to Aluminum	18-8 Stainless Steel	--	--	20	Specimen in good condition. Slight corrosion adjacent unprotected bolt. Bolts in good condition.
2	Aluminum to Aluminum	Medium Carbon Steel	--	--	31	Unprotected bolt and adjacent structure corroded. Protected bolt and adjacent structure in good condition.
3	Steel to Aluminum	Medium Carbon Steel	0.00035	0.00290	20	Steel portion of specimen badly rusted. Aluminum portion adjacent to unprotected steel bolt badly corroded. Bolt partially destroyed by heavy rust. Protected steel bolt in good condition.
4	Steel to Aluminum	18-8 Stainless Steel	0.00030	0.00300	20	Steel portion of specimen badly rusted. Aluminum portion corroded at joint. Bolts in good condition.
5	Steel to Aluminum	Medium Carbon Steel	0.00050	0.0033	20	Steel portion of specimen badly rusted. Aluminum portion corroded adjacent to steel bolt. Unprotected steel bolt partially destroyed by rust. Protected bolt in good condition.
6	Aluminum to Aluminum	Cadmium Plated Steel	--	--	31	Specimen in fair condition with moderate galvanic corrosion adjacent to unprotected bolt. Bolt badly rusted. Protected bolt and adjacent structure in good condition.
7	Magnesium to Magnesium	Cadmium Plated Steel	--	--	20	Structure adjacent to unprotected bolt perforated by corrosion. Unprotected bolt dropped out of joint. Protected bolt and adjacent structure in good condition.
8	Magnesium to Magnesium	18-8 Stainless Steel	--	--	20	Structure adjacent to unprotected bolt perforated by corrosion. Bolt dropped from joint. Structure adjacent to protected bolt in fair condition. Bolts in good condition.
9	Magnesium to Magnesium	Medium Carbon Steel	--	--	20	Specimen adjacent to unprotected bolt perforated by corrosion. Badly rusted bolt dropped from joint. Protected bolt in good condition. Adjacent structure in fair condition.
14	Mild Steel to Mild Steel	Medium Carbon Steel	0.00034	0.00260	31	Specimen badly rusted. Unprotected bolt badly rusted. Protected bolt in excellent condition with no rust evident.
15	Mild Steel to Mild Steel	18-8 Stainless Steel	0.00030	0.00320	20	Specimen badly rusted, particularly at joint. Bolts in good condition.
16	Mild Steel to Mild Steel	Cadmium Plated Steel	0.00040	0.00300	20	Specimen badly rusted. Unprotected bolt partially destroyed by heavy rust. Protected bolt in excellent condition.

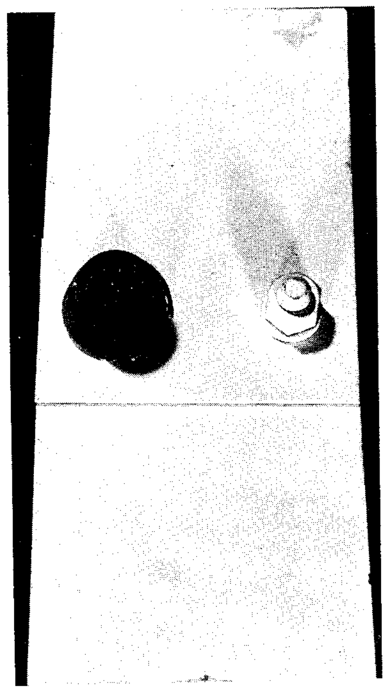
*American Society for Testing and Materials.
**Metal Surface Treatment and Appropriate Military Specifications:

1020 Steel	Primer-Cellulose-Nitrate Modified Alkyd Type MIL-P-7962B Top Coat - Alkyd Enamel MIL-E-7729A, Type 1
7075-T6 Aluminum Alloy	Chromate Conversion Coating, Iridite 14-2 (AL-coat) MIL-C-5541 Top Coat - Alkyd Enamel, MIL-E-7729A, Type 1
Magnesium	Dow 19 Pre-Treatment Top Coat - Alkyd Enamel, MIL-E-7729A, Type 1

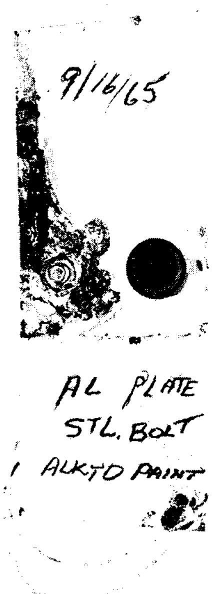
***From P. A. Sturtevant Co. "Torque Specification Chart for Steel Bolts."

Two panels were assembled in a lap-joint configuration illustrated in figure 4. American Society for Testing and Materials (ASTM) Grade 5 bolts of various materials were used to fasten the lap joint. Table 1 describes the combinations of dissimilar metals and fasteners employed in each test specimen and lists the torque values used to tighten the joints.

After completion of the panels, Proseal No. 501 sealant was prepared in accordance with the manufacturer's directions (described in the appendix). An adequate amount of sealant was injected into plastic Caplugs to seal and protect one bolt head and nut on each test specimen. Extrusion of a moderate amount of sealant around the lower periphery of the Caplugs was considered advantageous, since it prevented moisture from penetrating under the bolt head or nut and thus discouraged the inception of corrosion.



a. Before Exposure.



b. After Exposure.

Figure 4. Typical Salt Spray Test Specimens Before and After Exposure.

TEST PROCEDURES

Initially, several test specimens were tested for 5,000 hours by the Salt Spray (Fog) Test, Federal Standard Method No. 6061, with a 20 percent sodium chloride solution. The remaining test specimens were tested on the PMR paint exposure racks at Kwajalein Atoll in the South Pacific for 16 months.* The tests were made in accordance with Federal Standard Method No. 6061 of FTMS No. 141A, except for an essential deviation. The deviation from the test method consisted of mounting the specimens on the rack at an angle of 30 degrees from the vertical facing northwest, instead of 45 degrees from the vertical facing south. This change, which faced the specimens directly into the abundant salt spray from a coral reef surrounding the atoll, accelerated corrosion and appreciably reduced the time required to complete the tests.

TEST RESULTS

Salt Spray Tests

The results of the salt spray tests clearly indicated that the sealing caps adequately protected the structure adjacent to the 3/8-inch steel bolts from galvanic corrosion in the aluminum test specimens. Removal of the sealing caps from the steel bolts showed no rust on the bolt head and nut.

The steel test specimens were badly rusted after 5,000 hours exposure, but the protected steel bolts were in good condition. The unprotected steel bolts, on the other hand, were badly rusted and could not be removed from the joint by conventional methods.

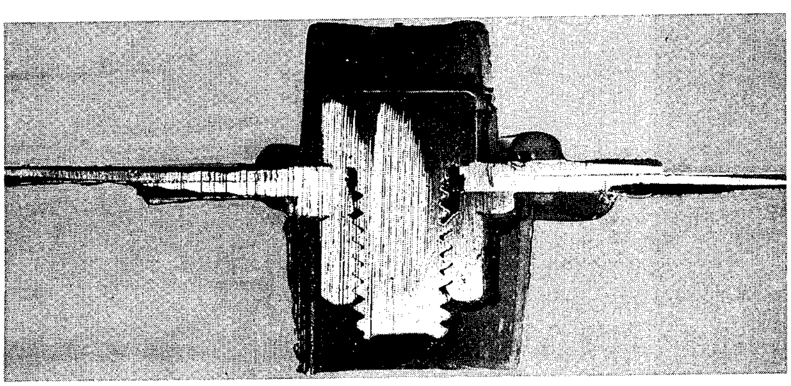
A typical aluminum test specimen before and after exposure for 5,000 hours is shown in figure 4.

*"Since it lies within 9 degrees of the equator, Kwajalein Atoll has a tropical marine environment characterized by moderately high temperature and humidity and high rainfall. The ever-present salt-laden moisture (for the air on the island contains an appreciable amount of salt which gets into the atmosphere from the surf) creates serious maintenance problems. Almost all metal surfaces corrode with amazing speed if not suitably protected. These conditions are among the world's worst from a corrosion standpoint and provide a rapid means of evaluating anticorrosion materials and methods." (Extracted from, "Kwajalein Atoll Geography and Facilities" by Dr. F. H. Bauer, Geographer Consultant, University of California.)

Weathering Tests

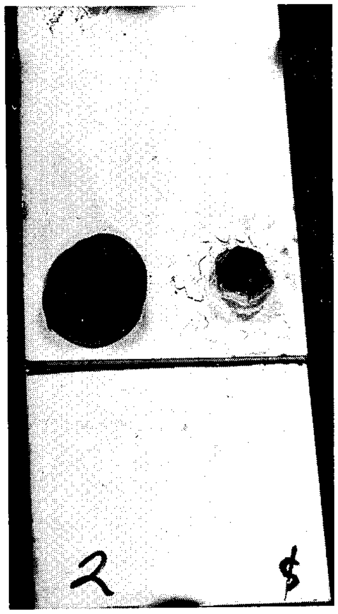
Results of the 16-month weathering tests at Kwajalein Atoll are summarized in table 1. The findings confirm the results of the salt spray tests. Several test specimens after 16 months exposure are shown in figures 5 through 7. The magnesium test specimens fastened with unprotected carbon steel bolts displayed the worst corrosive condition because of the rapid electrochemical reaction between magnesium and steel in the tropical-marine environment (figure 5a). The bolt in this specimen has dropped from the joint because of galvanic corrosion of the magnesium specimen. Figure 5b shows a section through the protected bolt on the same test specimen. The carbon steel bolt and adjacent magnesium structure are in good condition. Unprotected carbon steel bolts on all specimens were badly rusted and in some cases were partially destroyed (figure 6).

a. Test Specimen.

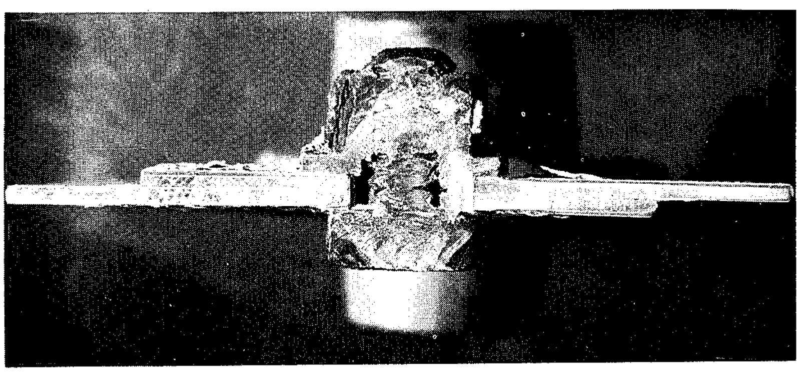


b. Cross Section of Protected Carbon Steel Bolt.

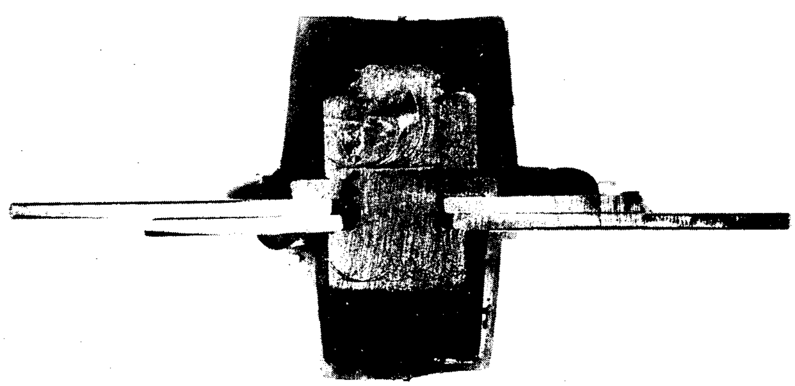
Figure 5. Magnesium Test Specimen With Carbon Steel Bolts After 16-Month Weathering Test.



a. Test Specimen. Unprotected Bolt and Adjacent Structure Corroded. No Corrosion on Protected Bolt.

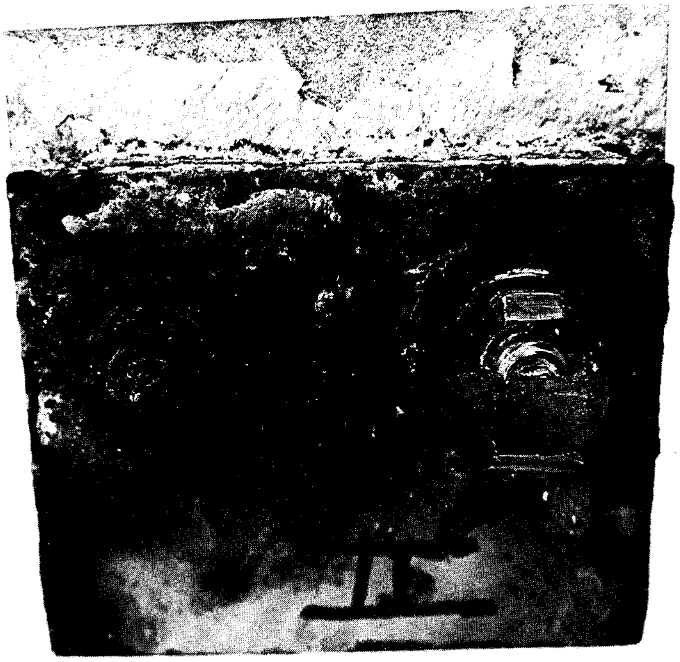


b. Cross Sections of Unprotected Carbon Steel Bolt, Showing Bolt and Adjacent Structure Badly Corroded.

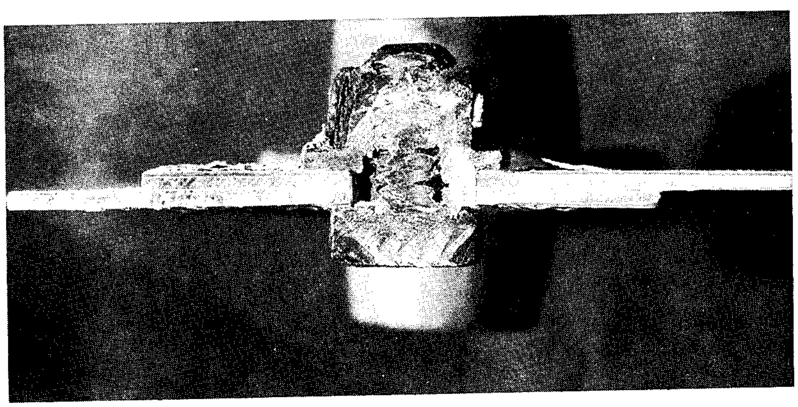


c. Cross Section of Protected Carbon Steel Bolt, Showing No Corrosion on Bolt and Adjacent Structure.

Figure 6. Aluminum Test Specimen With Carbon Steel Bolts After 16-Month Weathering Test.



a. Test Specimen. Sealing Cap Partly Removed From Protected (Right-Hand) Carbon Steel Bolt Shows No Corrosion. Unprotected Bolt Has Been Partly Destroyed by Rust.



b. Cross Section of Unprotected Carbon Steel Bolt, Showing Extensive Corrosion.

Figure 7. Steel and Aluminum Test Specimen With Carbon Steel Bolts After 16-Month Weathering Test.

Figure 7a shows protected and unprotected carbon steel bolts on an aluminum/steel specimen. The sealing cap on the left-hand bolt has been partially removed and shows the uncorroded condition of the bolt and nut. The right-hand, unprotected bolt has been partially destroyed by rust. Figure 7b shows section through the unprotected bolt.

No deterioration of the stainless steel bolts was observed in any of the specimens. However, the adjacent structure was badly corroded in most cases, particularly in the nonferrous test specimens.

All protected bolts on the test specimens were in good condition, and the structure adjacent to each bolt was less corroded than the structure adjacent to the unprotected bolt on the same specimen.

DISCUSSION

The results described in this report are evidence that the sealing caps will provide major protection against corrosion of fastened metal joints on equipment installed in a moist tropic or marine environment. The test results do not necessarily indicate that the sealing caps will protect mechanical fasteners under other environmental extremes such as arctic winter, hot desert, airborne, or underwater. Actually, there is little need for major corrosion protection in arctic winter or hot desert environments, because of the lack of essential moisture. However, it is felt that the sealing caps would be useful for conditions tending to cause fretting corrosion, corrosion fatigue, and stress corrosion cracking. Fretting corrosion occurs in fastened joints subjected to slight (vibratory) motion. In this case the sealing caps presumably would function as a vibration dampener and reduce susceptibility of the joint to fretting corrosion.

The basic configuration and material selection for the anticorrosion sealing caps developed at this writing are in the primary stage. Certainly, there are numerous suitable sealants other than the polysulfide base material discussed in this report. For example, silicone base sealants would be of use for environmental temperatures in the 300° to 600°F range. Similarly, the caps could be molded from thermoplastic materials suitable for operation in moderately high temperature environments. Also, the configuration could be adjusted to match the shape of the fastener. For example, hexagonal for hexagonal head bolts. This would conserve sealant and improve the appearance of a structure.

The answer to specific questions directed to use of the sealing caps in environments other than in the tests described herein would require additional tests with specimens made from various materials.

The test specimens prepared for the tests described in this report have one significant fault. Each specimen consisted of a lap joint with two bolts, one of which was protected by a sealing cap. In this type of specimen, corrosion of the unprotected fastener and adjacent structure could progress to the area adjacent to the protected fastener and cause an unreliable estimate of the beneficial aspects of the sealing caps. To prevent this condition, separate specimens should be provided for protected and unprotected fasteners.

CONCLUSION

It is concluded that the developed sealing caps are capable of protecting or at least inhibiting corrosion of mechanical fasteners and adjacent structure against common corrosive atmospheric environments.

APPENDIX

MATERIALS AND PROCUREMENT SOURCES

CAPLUGS*

Source	Caplugs Division Protective Closures Company, Inc. 2207 Elmwood Avenue Buffalo, New York 14216
Description.	Molded from linear (high density) polyethylene. Impervious to most common chemical reagents such as solvents, caustics, and acids, and are vermin- and fungus-proof. Will not chip, break, or shred under severe conditions, and retain form stability under stress at temperatures up to 250°F.

PRO-SEAL SEALANT NO. 501**

Source	Coast Pro-Seal and Manufacturing Company 2235 Beverly Boulevard Los Angeles, California
Type	Two-part, room-temperature curing, flexible, synthetic rubber sealant (polysulfide base).
Curing Agent	Pro-Seal No. 501-A.
Nonvolatile Content	96 percent.
Color	Translucent.
Consistency	A buttery paste.

*Descriptive matter extracted from Protective Closures Company Catalog Number 165 of 12 April 1965.

**Descriptive matter extracted from Coast Pro-Seal and Manufacturing Company Data Sheet of 3 January 1955.

Properties	When thoroughly mixed with the curing agent, Pro-Seal No. 501-A, the mixture cures to a strong, resilient, low-shrinkage sealant. The cured material is flexible at -65°F and is exceptionally resistant to gasoline, oils, greases, and other petroleum products. Pro-Seal No. 501 has good resistance to aging and weathering. Cured material has good resistance to water and has very high peel strength and elongation. The cured material is translucent to permit visual inspection of surface beneath for corrosion. Pro-Seal No. 501 will withstand service temperatures from -65°F to 250°F. Pro-Seal No. 501 has a normal work life of 1 1/2 hours at 60°F.
Application	Pro-Seal No. 501 may be applied by pressure flow gun or spatula.
Instructions for use	Stir the Pro-Seal No. 501 with a suitable spatula, breaking down the "false gel" structure. Add all the curing agent, Pro-Seal No. 501-A (30 parts by weight of Pro-Seal No. 501-A to 100 parts by weight of Pro-Seal No. 501) directly into the Pro-Seal No. 501 sealant and mix thoroughly for 5 minutes. The material can be used immediately.

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2. Seals (stoppers)
3. Metal joints
4. Corrosion prevention
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13. ABSTRACT

This report describes the development and testing of a device that prevents or at least inhibits corrosion in fastened metal joints, and presents test results. The device consists of a cup-shaped receptacle, partially filled with a sealant, and is dimensioned to fit over bolt or screw heads. When applied over these fasteners, the device excludes moisture and effectively retards corrosion. It is called an Anticorrosion Sealing Cap for Mechanical Fasteners.

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