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GALVANIC CORROSION OF ALUMINUM ASSEMBLIES BY STAINLESS STEEL WIRE INSERTS

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ABSTRACT

Data on the galvanic corrosion which is associated with bare and plated stainless steel inserts in aluminum assemblies are presented. Bare, cadmium plated, and silver plated stainless steel inserts which had been installed in 5456 and 2219 aluminum alloy blocks were tested in several corrosive environments - salt, brackish, and tap water and salt spray. It was found that the cadmium plated stainless steel inserts resulted in minimum galvanic corrosion of 5456 aluminum and afforded cathodic protection to 2219 aluminum. Silver plated stainless steel inserts that were tested caused severe galvanic corrosion of the aluminum assemblies and, therefore, are not recommended for use with aluminum.

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

RESEARCH AND DEVELOPMENT OPERATIONS

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SUMMARY

A program was conducted to evaluate the galvanic corrosion of bare and plated thread inserts in aluminum assemblies because corrosion is an important factor in the selection of fasteners and inserts. Bare, cadmium-plated, and silver-plated stainless steel inserts which had been installed in 5456 and 2219 aluminum alloy blocks were tested in several corrosive environments - salt, brackish, and tap water and salt spray.

The results of this investigation indicate that cadmium plated stainless steel inserts cause minimum galvanic corrosion of 5456 aluminum and these inserts afford cathodic protection to 2219 aluminum. Tests on silver-plated stainless steel inserts showed severe galvanic corrosion of aluminum assemblies, particularly in saline solutions; therefore, silver-plated stainless steel inserts are not recommended for use with aluminum. From a corrosion compatibility standpoint, cadmium plated stainless steel inserts are recommended for threaded holes in aluminum components when aluminum or cadmium plated fasteners are used, and unplated stainless steel inserts are recommended when stainless steel fasteners are used.

INTRODUCTION

High strength aluminum alloys, used in space vehicle structures, are joined by welding and mechanical fasteners. For mechanical fasteners, however, the thread strengths of these alloys are not sufficient for very high loading requirements of primary structural applications. One of the most effective methods of obtaining higher thread strength is the use of thread inserts. For applications where weight control is a primary factor, wire inserts have a significant weight advantage over the heavier solid threaded bushings.

An extremely important factor to be considered by the designer in the selection of inserts is corrosion. Corrosion of the inserts per se and galvanic action between the threads and the inserts could be damaging to the integrity of the mechanical joint. Therefore, the inserts should be corrosion resistant and should be compatible with both the receiving threads and fasteners. This investigation was conducted to evaluate the effectiveness of cadmium plate in reducing corrosion of stainless steel wire inserts in aluminum components.

EXPERIMENTAL PROCEDURE

The test to evaluate the galvanic corrosion of wire inserts in aluminum was conducted by using aluminum alloys 5456-H343 and 2219-T87 as the test blocks for inserts and fasteners. Bare, cadmium plated (QQ-P-416, Type I, Class 1-.0005-inch thick without supplementary treatment), and silver plated (.0005-inch thick) stainless steel wire inserts were tested in 5456-H343 aluminum assemblies. Additional bare and cadmium plated (.0001-inch and .0002-inch thick with supplementary chromate treatment) stainless steel inserts, furnished by the Heli-Coil Corporation, were tested in both 5456 and 2219 aluminum test blocks. To simulate the environment that a space vehicle may encounter, salt water (3.5 percent sodium choride), brackish water (1000 ppm sodium chloride), and tap water were used as corrodents.

Three types of tests were conducted to simulate conditions that might be encountered in service. In one test, no bolts were used, and the blind holes which contained the inserts and corrodents were open to the atmosphere to simulate the removal of vehicle components which leave the fastener holes open to the elements until the components are replaced. The specific corrodents were added daily to maintain the level of the solution in the holes. In addition, fresh solution was added weekly after the holes had been thoroughly flushed with distilled water. All assemblies were removed and sectioned for examination after eight months of exposure.

The second type of test consisted of introducing the corrodents into the threaded holes which contained the various inserts prior to installing stainless steel or cadmium plated carbon steel bolts. Aluminum washers (alloy 2024) were used so that the dissimilar metal contact would be between the bolts and washers rather than between the bolts and the aluminum test blocks. This test simulated the entrapment of moisture in blind holes prior to installation of the fasteners or during the period between removal and replacement of the fasteners. The test assemblies were examined monthly, and fresh solution was added. After 15 months of exposure, the test was discontinued, and the assemblies were sectioned and examined.

The third type of test consisted of installing the various inserts, bolts, and washers in the test blocks. Part of the blocks contained through-holes, and the remainder contained blind holes with no solution in the blind holes. The assemblies were placed in the salt spray cabinet for a total exposure of 1-1/2 months for the through-hole assemblies and 15 months for the blind hole assemblies. This test simulated normal installation of fasteners into blind holes which contain no moisture or through holes which are exposed to salt laden atmospheres.

RESULTS AND DISCUSSION

Tables I and II list the various combinations of wire inserts, bolts, and test blocks comprising the assemblies, the exposure media, and a numerical rating of the corrosion that resulted from each test condition. The numerical corrosion rating was ascertained by assigning the number zero to no visible corrosion; the number ten to the most severely corroded hole; then rating the remaining corrosion between zero and ten, based on the severity. Galvanic corrosion of the 5456-H343 and 2219-T87 aluminum test blocks by bare and plated stainless steel inserts after eight months exposure to the three corrodents are shown in FIG 1 and 2. The test blocks have been sectioned through the blind holes, and the inserts have been removed.

As may be noted in Tables I and II and in FIG 1 and 2, the silver plated inserts caused more corrosion of the aluminum test blocks than the bare (unplated) stainless steel inserts, and the bare stainless steel inserts caused more corrosion than the cadmium plated inserts in all of the corrodents (salt, brackish, and tap water and salt spray). The cadmium plated inserts without supplementary treatment caused more corrosion of the 5456 test block than did the cadmium plated inserts with a supplementary chromate treatment. No significant difference in corrosion was observed in the holes containing 0.0001-inch and 0.0002-inch thick cadmium plated inserts with supplementary chromate treatment. It may be noted (Table II, FIG 2), however, that the cadmium plated inserts cause some acceleration of corrosion of the 5456 alloy blocks and reduced the corrosion (cathodic protection) in the holes of 2219 alloy blocks. This indicates that 5456 aluminum is more anodic than cadmium and that cadmium is more anodic than 2219 aluminum in the three corrodents.

As might be expected, corrosion was most severe in salt water and the least severe in tap water. Note that the corrosion was considerably more severe in the holes which were open to the atmosphere (Table I, Test No. 1) than in the holes that contained either stainless steel or cadmium plated steel bolts (Table I, Test No. 2). Regardless of the type (bare, cadmium plated, or silver plated) of stainless steel insert used, cadmium plated steel bolts caused less corrosion of the test blocks than did bare stainless steel bolts.

This does not dictate the indiscriminate use of cadmium plated steel bolts in aluminum components containing threaded inserts. A significant factor to consider is that the cadmium plated steel bolts, in all cases, suffered more corrosion than the stainless steel bolts, particularly when in contact with unplated or silver plated stainless steel inserts.

In the assemblies containing inserts and stainless steel or cadmium plated steel bolts which were exposed to salt spray, there was no evidence of corrosion in the holes except where salt spray seeped in around the bolts. This seepage probably resulted from the severe corrosion of the test blocks under and adjacent to the 2024 aluminum washers. The test results with the assemblies containing through-holes exposed to salt spray were similar to those in which the assemblies with blind holes were partially filled with the corrodents, in that the silver plated inserts caused the most corrosion, and the cadmium plated insert caused the least attack on the walls of the 5456 test blocks.

CONCLUSIONS

The results of this rather limited program indicate that:

1. Cadmium plated stainless steel wire inserts caused less corrosion of 5456 aluminum than either unplated or silver plated stainless steel inserts in all the test environments and these inserts cathodically protected 2219 aluminum.

2. Supplementary chromate treatment of cadmium plated stainless steel inserts is advantageous for additional corrosion protection.

3. There was little difference in the corrosion performance of 0.0001-inch and 0.0002-inch thick cadmium plated inserts (with supplementary chromate treatment); and, therefore, the selection of plating thickness should be based on factors other than corrosion.

4. Silver plated stainless steel inserts caused severe corrosion of the test blocks and, therefore, are not recommended for use in aluminum components.

5. Unplated stainless steel inserts caused more corrosion of the aluminum test blocks than the cadmium plated inserts and should be used only when conditions, such as elevated temperature, prohibit the use of cadmium plated fasteners.

6. From a corrosion compatability standpoint, cadmium plated stainless steel inserts are recommended for threaded holes in aluminum components

when aluminum or cadmium plated fasteners are used, and unplated stainless steel inserts are recommended when stainless steel fasteners are used.

TABLE I

CORROSION OF 5456-H343 TEST BLOCKS CONTAINING BARE AND PLATED STAINLESS STEEL INSERTS AND FASTENERS

TEST NO. 1 - HOLES OPEN TO ATMOSPHERE

Corrodent in Bolt Hole	Type of Stainless Steel Insert	Type of Bolt	Corrosion of Threaded Hole
Salt H_2O	Bare	None	7
Salt H_2O	Cadmium plated*	None	7
Salt H_2O	Silver plated	None	9
Brackish H_2O	Bare	None	5
Brackish H_2O	Cadmium plated*	None	3
Brackish H_2O	Silver plated	None	7
Tap H_2O	Bare	None	2
Tap H_2O	Cadmium plated*	None	1
Tap H_2O	Silver plated	None	4

TEST NO. 2 - BOLTS AND SOLUTION IN BLIND HOLES

Corrodent in Bolt Hole	Type of Stainless Steel Insert	Type of Bolt	Corrosion of Threaded Hole
Salt H_2O	Bare	Bare stainless steel	3
Salt H_2O	Cadmium plated*	Bare stainless steel	3
Salt H_2O	Silver plated	Bare stainless steel	6
Salt H_2O	Bare	Cadmium plated steel	2
Salt H_2O	Cadmium plated*	Cadmium plated steel	3
Salt H_2O	Silver plated	Cadmium plated steel	4
Brackish H_2O	Bare	Bare stainless steel	2
Brackish H_2O	Cadmium plated*	Bare stainless steel	2
Brackish H_2O	Silver plated	Bare stainless steel	4
Brackish H_2O	Bare	Cadmium plated steel	1
Brackish H_2O	Cadmium plated*	Cadmium plated steel	2
Brackish H_2O	Silver plated	Cadmium plated steel	3

*Cadmium plated with no supplementary treatment

(TABLE I CONTINUED)

Corrodent in Bolt Hole	Type of Stainless Steel Insert	Type of Bolt	Corrosion of Threaded Hole
Tap H_2O	Bare	Bare stainless steel	3
Tap H_2O	Cadmium plated*	Bare stainless steel	1
Tap H_2O	Silver plated	Bare stainless steel	2
Tap H_2O	Bare	Cadmium plated steel	2
Tap H_2O	Cadmium plated*	Cadmium plated steel	1
Tap H_2O	Silver plated	Cadmium plated steel	1
	TEST NO. 3 - ASSEMBLIES EXPOSED TO SALT SPRAY		
	Blind Holes-Bolts Installed		
None	Bare	Bare stainless steel	**
None	Cadmium plated*	Bare stainless steel	**
None	Silver plated	Bare stainless steel	**
None	Bare	Cadmium plated steel	**
None	Cadmium plated*	Cadmium plated steel	**
None	Silver plated	Cadmium plated steel	**
	Through Holes-No Bolts Used		
None	Bare	None	4
None	Cadmium plated*	None	2
None	Silver plated	None	10

*Cadmium plated with no supplementary treatment
**A numerical corrosion rating was not used because the only corrosion in the holes was caused by seepage of salt spray around the bolt.

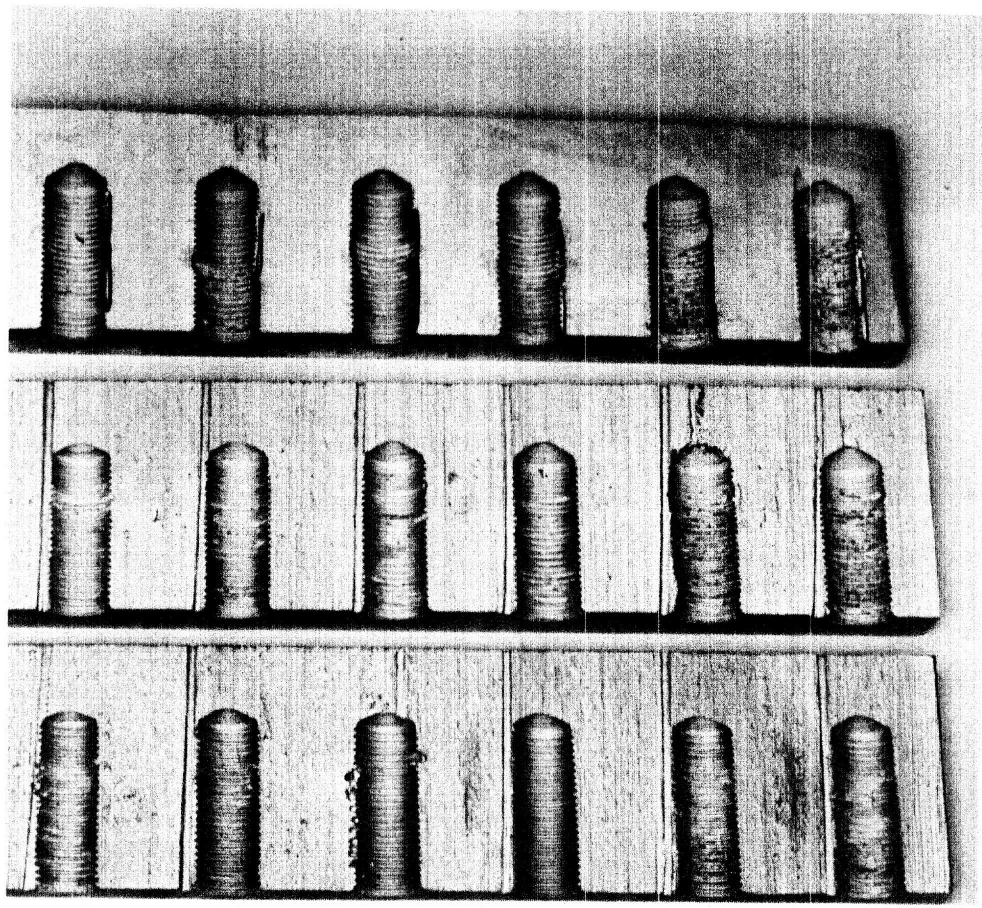
TABLE II

CORROSION OF 2219-T87 and 5456-H343 TEST BLOCKS CONTAINING BARE AND CADMIUM PLATED STAINLESS STEEL INSERTS

Corrodent in Bolt Hole	Assembly Material	Type of Stainless Steel Inserts	Corrosion of Threaded Holes* Category	Acceleration
Salt H_2O	2219-T87	Blank (no insert)	8	-
Salt H_2O	2219-T87	Bare	10	2
Salt H_2O	2219-T87	Cadmium plated .0001" **	7	-1
Salt H_2O	2219-T87	Cadmium plated .0002" **	6	-2
Brackish H_2O	2219-T87	Blank (no insert)	8	-
Brackish H_2O	2219-T87	Bare	9	1
Brackish H_2O	2219-T87	Cadmium plated .0001" **	5	-3
Brackish H_2O	2219-T87	Cadmium plated .0002" **	3	-5
Tap H_2O	2219-T87	Blank (no insert)	6	-
Tap H_2O	2219-T87	Bare	8	2
Tap H_2O	2219-T87	Cadmium plated .0001" **	4	-2
Tap H_2O	2219-T87	Cadmium plated .0002" **	3	-3
Salt H_2O	5456-H343	Blank (no insert)	0	-
Salt H_2O	5456-H343	Bare	6	6
Salt H_2O	5456-H343	Cadmium plated .0001" **	4	4
Salt H_2O	5456-H343	Cadmium plated .0002" **	3	3
Brackish H_2O	5456-H343	Blank (no insert)	0	-
Brackish H_2O	5456-H343	Bare	6	6
Brackish H_2O	5456-H343	Cadmium plated .0001" **	2	2
Brackish H_2O	5456-H343	Cadmium plated .0002" **	3	3
Tap H_2O	5456-H343	Blank (no insert)	0	-
Tap H_2O	5456-H343	Bare	3	3
Tap H_2O	5456-H343	Cadmium plated .0001" **	0	0
Tap H_2O	5456-H343	Cadmium plated .0002" **	1	1

*The acceleration was obtained by substracting the corrosion category number of the blank hole with no insert. A negative acceleration number indicates cathodic protection by the insert.

**Cadmium plated with supplementary chromate treatment.



3½% SALT WATER

BRACKISH WATER
(1000 PPM NACL)

TAP WATER

BARE

CADMIUM
PLATED

SILVER
PLATED

FIGURE 1 - GALVANIC CORROSION OF 5456 ALUMINUM BLOCKS BY STAINLESS STEEL WIRE INSERTS

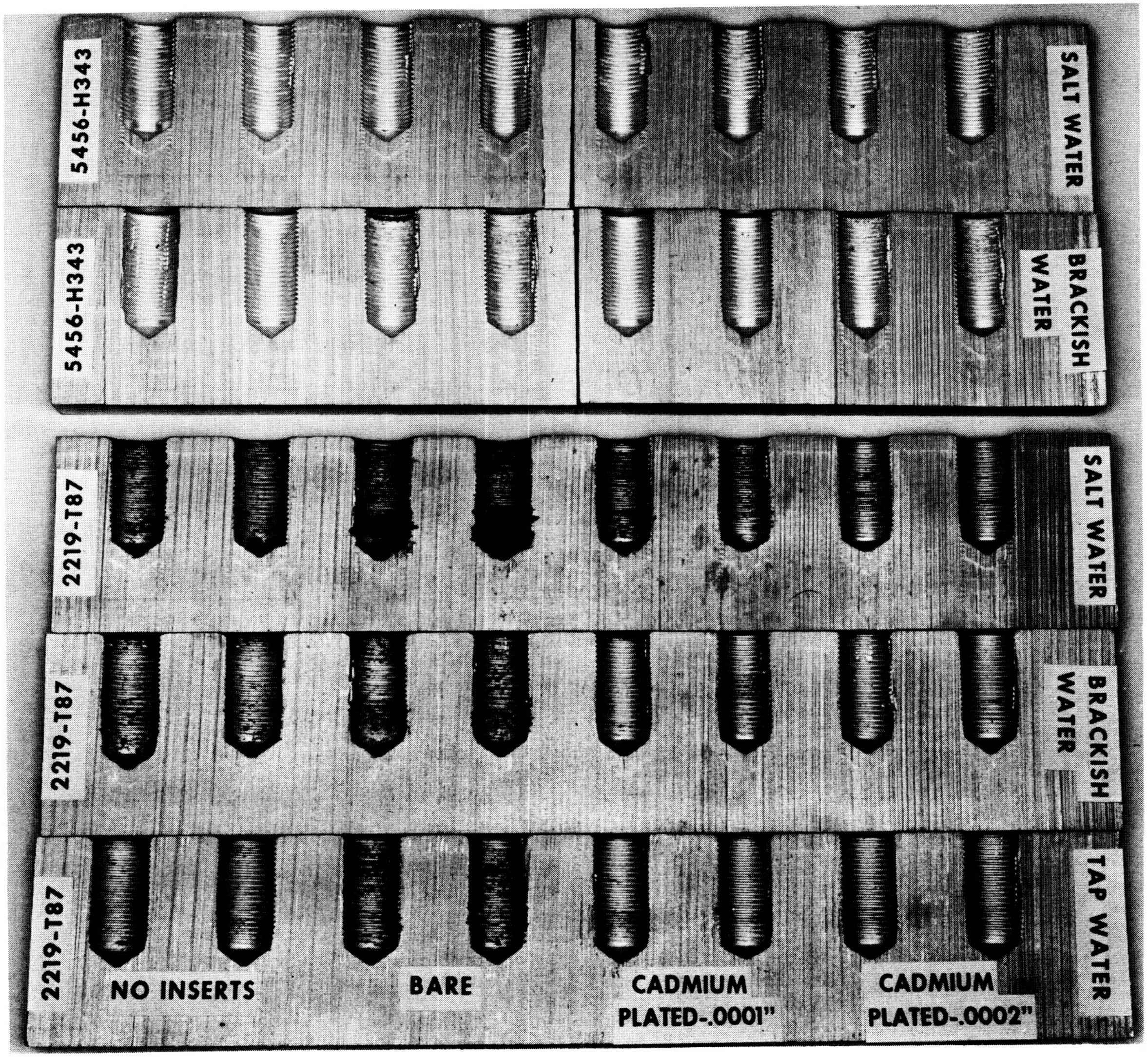


FIGURE 2 - GALVANIC CORROSION OF 2219 and 5456 ALUMINUM BLOCKS BY STAINLESS STEEL WIRE INSERTS

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This document has also been reviewed and approved for technical accuracy.

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