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CORROSION PROBLEMS ASSOCIATED WITH THE USE OF TITANIUM FASTENERS TO CONNECT ALUMINUM COMPONENTS

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ABSTRACT

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Corrosion studies, conducted to determine the extent of the corrosion problems that could arise from the use of titanium fasteners to connect aluminum components, have indicated that Ti-6Al-4V alloy fasteners can be used to connect aluminum components without significant corrosion on the aluminum component in a normal atmospheric environment. However, exacting installation procedures must be followed for adequate control of galvanic corrosion.

AUTHOR

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SUMMARY

Corrosion studies were conducted to determine the extent of the corrosion problems that could arise from the use of titanium fasteners to connect aluminum components and to evaluate methods for reducing these problems. The studies have indicated that Ti-6Al-4V alloy fasteners can be used to connect aluminum components without significant corrosion on the aluminum component in a normal atmospheric environment. However, the following installation procedures must be followed for adequate control of galvanic corrosion:

1. Extreme care must be taken during fastener installation to prevent damage to the protective coating of the components. Minimum protection for the aluminum components should consist of a conversion coating (MIL-C-5541) and one coat of zinc chromate primer (MIL-P-8585).

2. Fasteners must be dipped in zinc chromate primer and installed wet.

3. After installation, fasteners and adjacent area must be touched-up with zinc chromate primer. This would include any bare areas, such as broken collars or pins, that occur during installation.

INTRODUCTION

Because of the saving in weight that could be realized, titanium fasteners are being considered for use on future space and space launch vehicles. Many factors, however, must be considered before titanium fasteners can be used to a large extent for space launch vehicle applications. These include many metallurgical factors, the compatibility of the fasteners with various fuels and oxidizers, and the resistance of the joint to oxidation and corrosion. If titanium fasteners are used with aluminum alloys, the major material for construction of large space launch vehicles, the possibility of galvanic corrosion must be given serious consideration because of the high solution potential between these two alloys. The purpose of this work was to determine the extent of the corrosion problems that could arise from the use of titanium fasteners to connect aluminum components and to evaluate methods for reducing these problems.

EXPERIMENTAL PROCEDURE

Fasteners fabricated from titanium, aluminum, and cadmium plated steel alloys were used to connect two 4 x 4 inch 7075-T6 aluminum alloy panels with a two-inch overlap. Most panels were connected by using two fasteners. A few panels were connected with five fasteners to determine the effect of a larger ratio of titanium to aluminum and to more nearly simulate conditions that would exist in actual use.

"Hi-Lok" titanium fasteners, manufactured by the Hi-Shear Corporation, Torrance, California, were used primarily for this study. This fastener consists of a Ti-6Al-4V alloy pin with an anodized 2024 aluminum alloy collar. The collar is broken during the installation of this type fastener. The aluminum fasteners (2024-T6 aluminum alloy) and cadmium plated steel fasteners, normally used to connect aluminum alloy components, were used as controls and were the same type as the titanium fasteners. These fasteners also had aluminum collars which are broken during installation. Table I gives the combination of fasteners used, fastener material and surface finish, panel material and finish, and special installation procedures.

Prior to installation, the aluminum panels were cleaned in an alkaline cleaning solution and deoxidized in a nitric acid solution. Protective treatments for the panels, when required, were applied before assembly and consisted of a chemical conversion coating (MIL-C-5541) and one spray coat of zinc chromate primer (MIL-P-8585). Some of the fasteners were dipped in zinc chromate primer prior to installation and assembled wet. The broken collars of one group of fasteners were touched-up with zinc chromate primer after installation. All of the specimens were subjected to a five percent salt spray environment (5% NaCl solution) for 200 hours.

Tests also were made to determine the value of a proprietary coating developed by the Hi-Shear Corporation. This coating was applied by the manufacturer to the titanium pins for the purpose of reducing galvanic corrosion and galling. The coating was designated as Type II and was similar in appearance to a dry film lubricant. These coated fasteners, along with bare titanium fasteners, were installed on painted panels.

RESULTS AND DISCUSSION

Because of the high solution potential between titanium and aluminum alloys (Table II), considerable galvanic corrosion occurred on the bare aluminum panels adjacent to the titanium fasteners in this study. FIG 1 shows the concentration of corrosion products on the bare 7075-T6 aluminum panels adjacent to the titanium fasteners. As can be seen, some corrosion products were evident on the bare 7075 aluminum alloy panel as a result of normal surface corrosion. Considerable galvanic corrosion also occurred on the aluminum collars adjacent to the titanium pins, as shown in FIG 2. The corrosion at this location was more severe than the corrosion noted on the aluminum panel (FIG 1) adjacent to the head of the titanium fastener because of the larger ratio of titanium to bare aluminum at this location.

No galvanic corrosion was evident on the specimens with aluminum or cadmium plated steel fasteners. A slight amount of corrosion was evident on the unprotected part of the collars of these fasteners, as shown in FIG 3. These 2024 aluminum alloy collars were anodized. However, a bare area was exposed when the collar was broken during installation.

The second series of tests was conducted to evaluate the effects of titanium fasteners on protected aluminum panels. The panels were given a chemical conversion coating (MIL-C-5541) and one coat of zinc chromate primer (MIL-P-8585) before installation of the fasteners. The fasteners were dipped in the same primer and installed wet. Aluminum and cadmium plated fasteners were also used in this series of tests as controls. The corrosion which occurred as a result of these tests is shown in FIG 4, 5, and 6. The corrosion on the all aluminum specimens (FIG 4) was confined to the end of the broken collars, as discussed above. A little more corrosion was evident on the cadmium plated fastener, as shown in FIG 5. This fastener has an aluminum collar with a cadmium plated pin. The additional corrosion apparent on these collars, when compared with the all aluminum fasteners, was due to the slight difference in solution potential between cadmium and aluminum. Severe corrosion occurred on the aluminum collar of the titanium fastener in this series of tests, as shown in FIG 6. The amount and severity were about the same as in the first series of tests. However, this vulnerable area was the only place that any significant corrosion occurred on these specimens. The protective coatings had prevented corrosion in all other areas. Additional test specimens in which the end of the collar and titanium pin were painted with zinc chromate primer after installation were essentially free of corrosion products.

A third series of tests was made to evaluate a proprietary coating developed by the Hi-Shear Corporation. This coating was reported to reduce the effects of galvanic corrosion with aluminum as well as act as an anti-galling coating. Tests indicated that the coating did afford some limited additional protection over the uncoated fasteners but also showed that an additional coating system was necessary to reduce corrosion to a satisfactory level.

CONCLUSIONS

This study has indicated that Ti-6Al-4V alloy fasteners can be used to connect aluminum components without significant sacrifice to the structural integrity of the connection in a normal atmospheric environment. However, the following installation procedures must be followed for adequate control of galvanic corrosion:

1. Extreme care must be taken during fastener installation to prevent damage to the protective coating of the components. Minimum protection for the aluminum components should consist of a conversion coating (MIL-C-5541) and one coat of zinc chromate primer (MIL-P-8585).

2. Fasteners must be dipped in zinc chromate primer and installed wet.

3. After installation, fasteners and adjacent area must be touched-up with zinc chromate primer. This would include any bare areas, such as broken collars or pins, that occur during installation.

Titanium fasteners should not be used with aluminum components in any areas where the above procedures could not be used, unless the environment is extremely mild and can be closely controlled. Some slight additional corrosion protection can be realized by using the coated fasteners as supplied by the Hi-Shear Corporation. However, the same installation procedures specified for the bare fasteners must be used for the coated fasteners.

FIGURE 1 GALVANIC CORROSION ON 7075-T6 ALUMINUM PANEL ADJACENT TO TITANIUM FASTENERS AFTER 200 HOURS SALT SPRAY EXPOSURE

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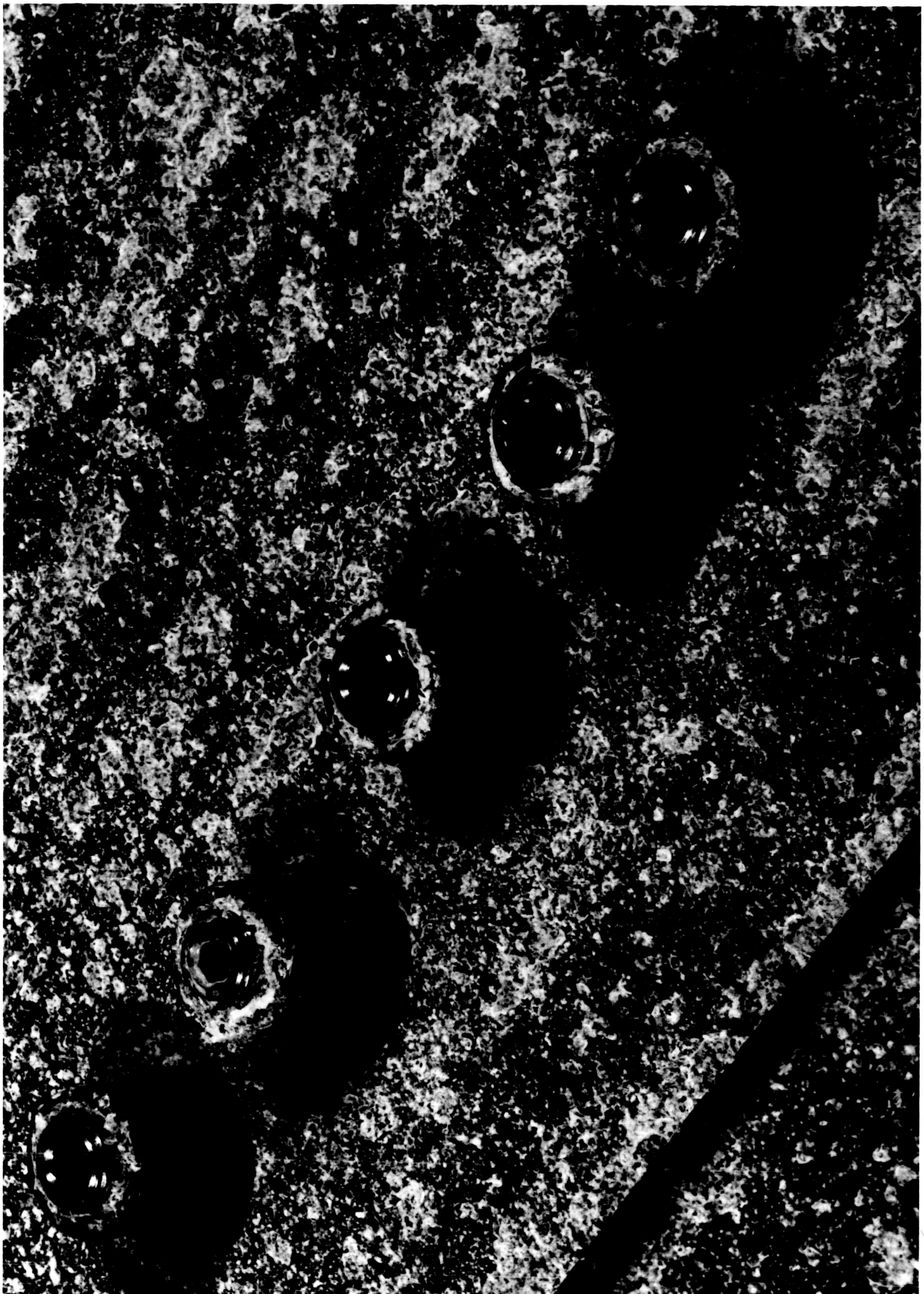

FIGURE 2 GALVANIC CORROSION ON 2024 ALUMINUM COLLARS ADJACENT TO TITANIUM PINS AFTER 200 HOURS SALT SPRAY EXPOSURE

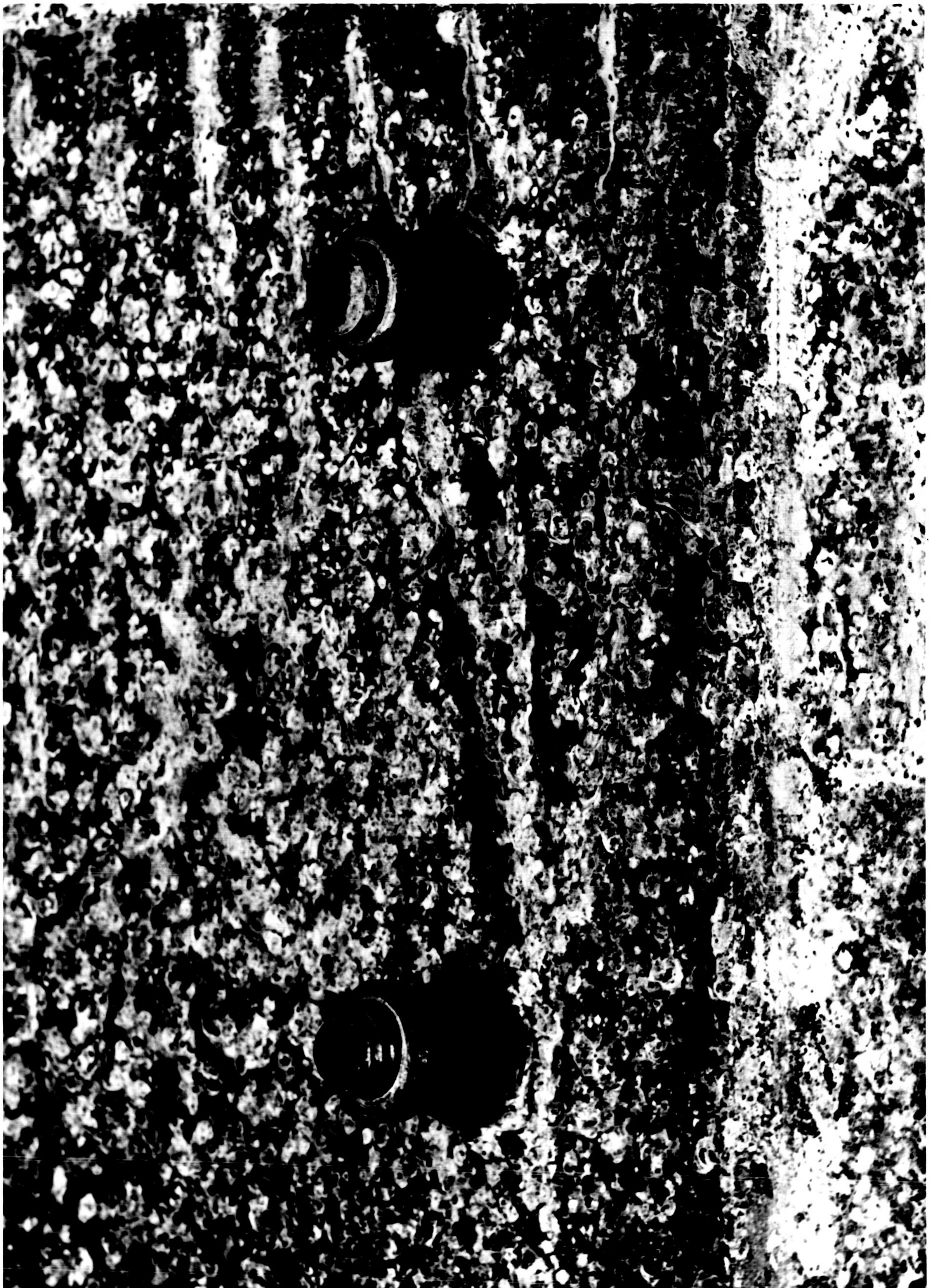

FIGURE 3 CORROSION ON 2024 ALUMINUM COLLARS AFTER 200 HOURS SALT SPRAY EXPOSURE

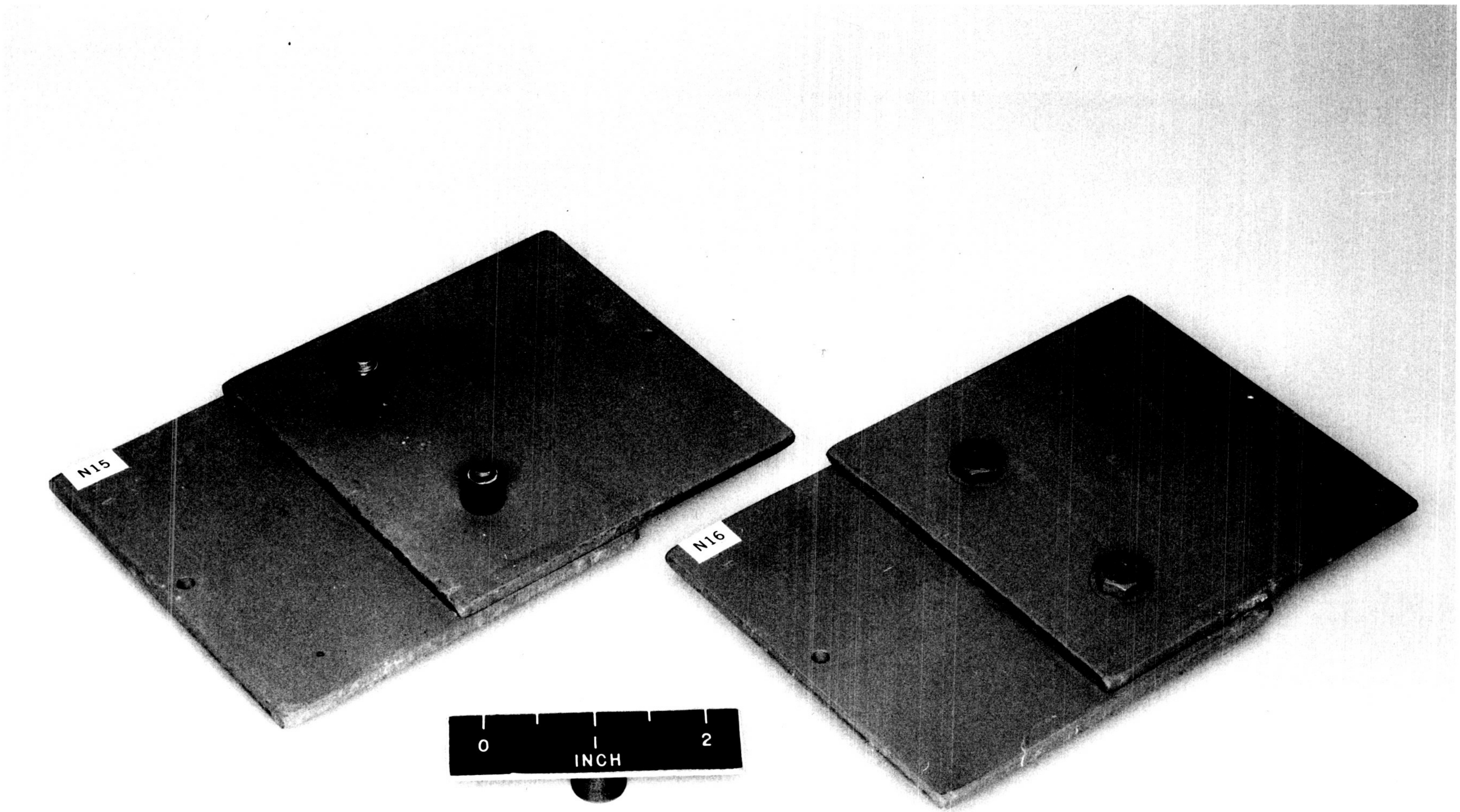

FIGURE 4 CORROSION ON ALUMINUM FASTENERS CONNECTING PAINTED 7075 ALUMINUM PANELS AFTER 200 HOURS SALT SPRAY EXPOSURE

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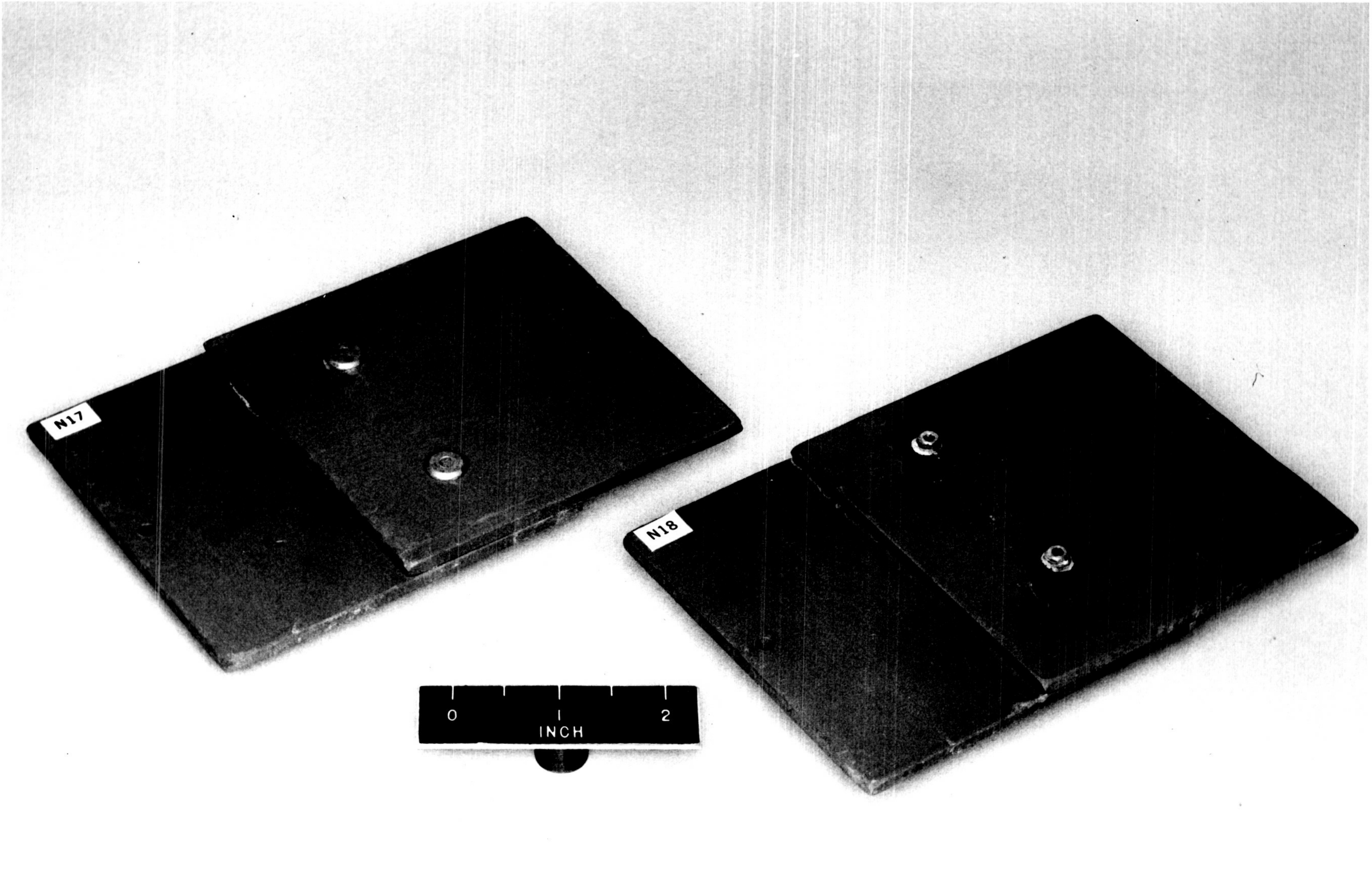

FIGURE 5 CORROSION ON CADMIUM PLATED FASTENERS CONNECTING PAINTED 7075 ALUMINUM PANELS AFTER 200 HOURS SALT SPRAY EXPOSURE

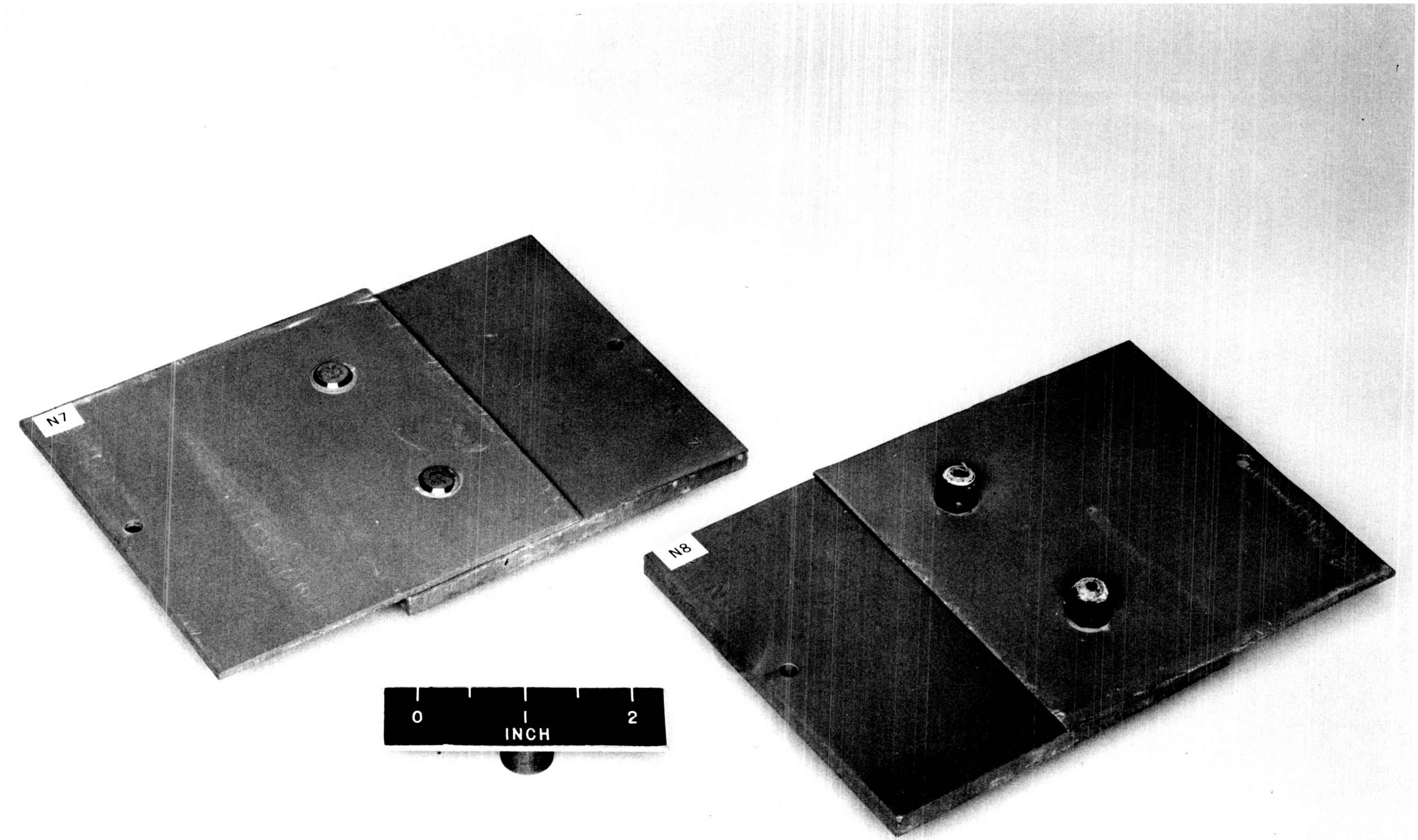

FIGURE 6 CORROSION ON TITANIUM FASTENERS CONNECTING PAINTED 7075 ALUMINUM PANELS AFTER 200 HOURS SALT SPRAY EXPOSURE

TABLE I

FASTENERS, FASTENER MATERIAL, AND SURFACE FINISHES

	Fastener	Panel Finish*
1.	HL 10 Pin, Ti-6Al-4V HL 70 Collar, 2024 Al., Anodized	Unprotected
2.	HL 10 Pin, Ti-6Al-4V HL 79 Collar, 2024 Al., Anodized	Conversion Coated (MIL-C-5541)
3.	HL 10 Pin, Ti-6Al-4V HL 70 Collar, 2024 Al., Anodized	Conversion Coated (MIL-C-5541) plus Zinc Chromate Primer (MIL-P-8585)
4.	HL 10 Pin, Ti-6Al-4V HL 70 Collar, 2024 Al., Anodized	Conversion Coated (MIL-C-5541) plus Zinc Chromate Primer (MIL-P-8585)**
5.	HL 10 Pin, Ti-6Al-4V HL 70 Collar, 2024 Al., Anodized	Conversion Coated (MIL-C-5541) plus Zinc Chromate Primer (MIL-P-8585)
6.	Pin 2024 Al., Anodized Collar, 2024 Al., Anodized	Unprotected
7.	Pin 2024 Al., Anodized HL 70 Collar, 2024 Al., Anodized	Conversion Coated (MIL-C-5541) plus Zinc Chromate Primer (MIL-P-8585)
8.	HL 20 Pin, Steel, Cadmium Plated HL 70 Collar, 2024 Al., Anodized	Conversion Coated (MIL-C-5541) plus Zinc Chromate Primer (MIL-P-8585)
9.	HL 10 Pin, Ti-6Al-4V (Coated) HL 79 Collar, 2024 Al., Anodized	Unprotected
10.	HL 10 Pin, Ti-6Al-4V (Coated) HL 79 Collar, 2024 Al., Anodized	Conversion Coated (MIL-C-5541) plus Zinc Chromate Primer (MIL-P-8585)
11.	HL 10 Pin, Ti-6Al-4V (Coated) HL 79 Collar, 2024 Al., Anodized	Conversion Coated (MIL-C-5541) plus Zinc Chromate Primer (MIL-P-8585)***

* All Panels 7075-T6 Aluminum

** Installed with wet zinc chromate primer.

*** Installed with wet zinc chromate primer plus touch-up with primer after installation.

TABLE II

GALVANIC SERIES OF METALS AND ALLOYS

Corroded End (Anodic or Least Noble)

Magnesium
Magnesium Alloys
Zinc
Aluminum

ALUMINUM ALLOYS ↑

Cadmium
Carbon Steel
Cast Iron
Stainless Steel Type 410 (active)
Stainless Steel Type 430 (active)
"Ni Resist"
Stainless Steel Type 304 (active)
Stainless Steel Type 316 (active)
"Hastelloy C" (active)
Lead
Nickel (active)
"Inconel" (active)
"Hastelloy B" (active)
Brasses
Copper
Bronzes
"Monel"
Nickel (passive)
"Inconel" (passive)
Stainless Steel Type 410 (passive)
Stainless Steel Type 430 (passive)
Stainless Steel Type 304 (passive)
Stainless Steel Type 316 (passive)

TITANIUM ↓

"Hastelloy B" (passive)
"Hastelloy C" (passive)
Silver
Graphite
Gold
Platinum

Protected End (Cathodic or Most Noble)

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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