NBSIR 73-133

Performance of Anodized and Chemically Surface Treated Aluminum Alloy Rivets in a Marine Environment

E. Escalante, W. F. Gerhold

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March 1973

Final Report
Bureau of Aeronautics (Naval Air Command)
Department of the Navy, Letter, Aer–AE–417/89
dated 19 March 1957

Prepared for
Materials Division
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

PERFORMANCE OF ANODIZED AND CHEMICALLY SURFACE TREATED ALUMINUM ALLOY RIVETS IN A MARINE ENVIRONMENT

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Reference: (a) Bureau of Aeronautics (Naval Air Systems Command), Department of the Navy, Letter, Aer-AE-417/89, dated 19 March 1957.

Introduction: Military Specification MIL-R-5674 permits the use of MIL-A-8625 anodic treatment or MIL-C-5541 chemical surface treatment on aluminum alloy rivets. Questions have arisen with respect to the protective ability of the surface treatments after the rivets have been driven or after having been heat treated and driven.

Reference (a) requested that an investigation be initiated to determine the relative protective ability of anodized and chemical surface treatments on aluminum alloy rivets after they have been driven. It was stipulated that painted and unpainted aluminum alloys be exposed in tidal immersion.

Materials and Specimen Preparation: Subassembly specimens fabricated from aluminum alloy sheet material were prepared. The alloys used were as follows:

Aluminum alloy 2219-T6

Clad aluminum alloy 2219-T6

Aluminum alloy 2024-T4

Clad aluminum alloy 2024-T4

Aluminum alloy 7075-T6

Clad aluminum alloy 7075-T6

Each of the subassembly specimens were prepared by drilling 16 holes through each at one end of the long dimension. The holes were spaced 1 inch from

each other and 1/2 inch from the edges. Two pieces of the same alloy were then overlapped at the drilled areas and riveted together to form an integral assembly 4 inches wide and 12 inches long. Figure 1 is a sketch illustrating a typical assembly. The rivet alloys and the surface treatments applied to each of the rivets are given in Table 1.

Five assemblies were fabricated from each of the alloys given above. Each alloy was divided into two lots, one lot consisting of three specimens to be exposed unpainted and the other lot consisting of two specimens to be exposed painted. The paint system on the latter was applied in accordance with Military Specification MIL-F-18264.

Exposures: All specimens were exposed to seawater in the tidal zone at Harbor Island, North Carolina. The specimens were totally immersed at high tide and totally out of the water at low tide. Periods of exposure were for approximately 15 months, 27 months, and 79 months.

Results: An on-site inspection of the specimens was made after 91 days' exposure. It was noted that two 2219-T4 aluminum alloy rivets had failed. One, an uncoated rivet, had been driven in an unpainted clad 2219-T6 aluminum alloy specimen; the other, with an Alumilite No. 205 treatment, had been driven in an unpainted 2024-T4 aluminum alloy specimen. Paint failures were observed on all 2219-T4 aluminum alloy rivets driven in 7075-T6 and clad 2024-T4 aluminum alloy specimens. Similarly, paint failures were noted on 2117-aluminum alloy rivets driven in clad 2024-T6 aluminum alloy specimens. Other scattered paint failures were also observed on other aluminum alloy rivets; however, no general trend was observed.

One complete set of aluminum alloy sheet specimens consisting of one of each of the unpainted specimens of each alloy system were removed from test after approximately 15 months' exposure. A second and third set of specimens, each set consisting of one unpainted and one painted specimen from each alloy system, were removed from test after exposure for approximately 27 months and 79 months.

All specimens were cleaned by scrubbing with a bristle brush to remove loosely adhering material. A wood scraper was used where necessary to remove fouling. Specimens were then rinsed in clear water and dried. The unpainted specimens were further cleaned in concentrated nitric acid to remove corrosion products.

All specimens were examined visually for estimations of deterioration from corrosion. The results obtained for each rivet alloy are given in Tables 2, 3, 4, and 5.

In general 2219 aluminum alloy rivets exhibit the same degree of corrosion whether anodized or chemically surface treated. Rivets fabricated from this alloy and driven in 2024-T4 or clad 2219-T6 aluminum alloy specimens failed at the rivet head areas, possibly as a result of tensile failure due to corrosion product build-up at the faying surfaces of the aluminum alloy sheet subassemblies. However, some of these rivets had failed prior to the inspection after exposure for approximately 3 months.

The 2017 aluminum alloy rivets which had been given the Iridite 14 treatment exhibited very good resistance to corrosion after approximately 27 months' exposure. After exposure for approximately 79 months all 2017 aluminum alloy rivets were equally corroded (Figure 2). However, in general, the 2017 aluminum alloy rivets showed good resistance to corrosion whether coated or not coated.

With some exceptions, bare or surface treated 2117 aluminum alloy rivets showed good resistance to corrosion. When driven in the 2024-T4 aluminum alloy sheet, these rivets were found to be pitted and badly corroded after exposure for approximately 27 months. This is shown in Figure 3. The rivets given the Alumilite 205 treatment exhibited the least attack while the bare, uncoated rivets had developed shallow pitting and all of the rivets which were given Alodine 1200 including those given the reheat treatment were deeply pitted.

Of the 2024 aluminum alloy rivets, those which had been given the special (stabilizing) heat treatment and were driven uncoated were found to be more susceptible to corrosion than either the non-stabilized uncoated rivet or the non-stabilized rivet given the Alumilite treatment 205 (Figure 4).

An evaluation of galvanic effects between the various aluminum alloy rivets and the aluminum alloy sheet specimens was made with considerations given only to short range effects (localized pitting). Table 6 contains the dissimilar metal couples evaluated. These are classified on the basis of what was corroded and what was protected.

In general, the effects of coupling were less obvious on the clad material as compared to the unclad material. With the exception of the clad 2219-T6 aluminum alloy sheet material where pitted areas were noted adjacent to the anodized 2017 and the 2219 aluminum alloy rivets, the cladding appeared to substantially reduce the crevice corrosion at the faying surfaces of the aluminum alloy sheet materials. This is shown in Figures 5 and 6.

Without exception, corrosion was substantially reduced on specimens that had been painted. In some cases there was no apparent corrosion.

Summary: Tests were conducted in the seawater in the tidal zone to determine the relative protective value of anodized and chemical surface treatments on aluminum alloy rivets after they have been driven. Rivet materials studied included 2219-T4, 2017-, 2117-, and 2024- aluminum alloys. Surface treatments studied were Alumilite No. 204 and No. 205, Alodine 1200, Irilac, and Iridite No. 14. Rivets were driven in 4-inch x 12-inch specimens fabricated from the following materials:

Clad and unclad 2219-T6 aluminum alloys

Clad and unclad 2024-T4 aluminum alloys

Clad and unclad 7075-T6 aluminum alloys

The results of visual examinations of specimens exposed for periods of up to approximately 79 months revealed the following:

(1) The Iridite 14 chemical surface treatment did provide good protection to the 2017 aluminum alloy rivets during the first 2 to 3 years. However, there was little difference between the protective ability of the anodized vs chemical surface treatments after 79 months exposure.

(2) For the Alodine 1200 surface treatments on the 2117 aluminum alloy rivet reheat treatment after surface treatment increased its susceptibility to corrosion.

(3) The stabilizing heat treatment given the 2024 aluminum alloy rivet increased its susceptibility to corrosion in many cases but not all.

(4) An evaluation was made of the galvanic effects between the various rivets and the aluminum alloy sheet (dissimilar metal couples).

It was noted that the effect was more pronounced between the following:

(a) Stabilized 2024 aluminum alloy rivets driven in bare 2219-T6 and 2024 T4 aluminum alloy sheet specimens;

(b) 2117 aluminum alloy rivets driven in bare 2024-T4 aluminum alloy sheet specimens.

There was little or no galvanic effect between aluminum alloy rivets driven in 7075-T6 aluminum alloy sheet specimens.

(5) Cladding reduced corrosion effects particularly at the faying surface.

(6) The painted specimens showed substantially reduced corrosion.

Table 1. Rivet Alloys and Surface Treatments Applied to Each of the Rivets.

Rivet Alloy	Surface Treatment
2219-T4	None
	Alumilite No. 205
	Alodine No. 1200
	Irilac
	Iridite No. 14
2017[(a)]	None
	Alumilite No. 205
	Alumilite No. 204
	Iridite N-. 14
2117[(a)]	None
	Alumilite No. 205
	Alodine No. 1200
	Alodine No. 1200[(b)(c)]
2024[(a)]	None
	Alumilite No. 205
	None, special heat treatment[(c)]

(a) Condition unknown
(b) Reheat treated after surface treatment
(c) Special stabilizing treatment which reportedly makes unnecessary the solution heat treatment normally used prior to being driven. Details of heat treatment unknown.

Table 2. Evaluation of Rivet Alloy 2219-T4 after Exposure in the Seawater for Number of Days Shown.

	Rivet Surface Treatment[1]								
Panel Alloy and Treatment	None (Uncoated)	Alumilite No. 205	Special Heat Treatment, Bare	Alodine No. 1200	Alumilite No. 204	Irilac	Iridite No. 14	Alodine 1200 (3)	Exposure Time (Days)
2219-T6, bare	d	a		a		a	a		455
" "	d	b		b		b	b		811
" "	b	b		b		b	b		2373
2219-T6, painted	ga	ga		ga		ga	ga		811
" "	ga	ga		d		d	gb		2373
Clad 2219-T6, bare	b	a		d		a	d		455
" " "	a	d		d		d	a		811
" " "	d	d		d		d	a		2373
Clad 2219-T6, painted	ga	ga		ga		ga	ga		811
" " "	ga	ga		ga		ga	ga		2373
2024-T4, bare	ad[4]	ad[4]		ad[4]		ad[4]	d		455
" "	d	d		d		d	b		811
" "	d	d		d		d	d		2373
2024-T4, painted	ga	ga		ga		ga	ga		811
" "	ga	ga		ga		ga	ga		2373
Clad 2024-T4, bare	a	a		a		a	a		455
" " "	a	a		a		a	a		811
" " "	a	a		a		a	a		2373
Clad 2024-T4, painted	ga	ga		ga		ga	ga		2373
" " "	-	-		-		-	-		Lost from racks
7075-T6, bare	b	d		d		a	a		455
" "	a	a		a		a	a		811
" "	a	a		a		a	a		2373
7075-T6, painted	ga	ga		ga		ga	ga		811
" "	ga	ga		ga		ga	ga		2373
Clad 7075-T6, bare	b	a		a		a	a		455
" " "	a	a		a		a	a		2373
" " "	-	-		-		-	-		Lost from racks
Clad 7075-T6, painted	-	-		-		-	-		Lost from racks
" " "	ga	ga		ga		ga	ga		2373

(1)
- (a) No corrosion
- (b) Scattered shallow corrosion pits
- (c) Scattered medium deep corrosion pits
- (d) Rivet head cracked
- (e) Driven head of rivet cracked
- (f) No paint failures at rivet heads
- (g) Paint failures at rivet heads
- (h) General shallow corrosion attack
- (i) General corrosion attack

(2) Heat treated, condition unknown

(3) Reseat treated after application of surface treatment

(4) Rivet cracked but still attached

Table 3. Evaluation of Rivet Alloy 2017[(2)] after Exposure in the Seawater for Number of Days Shown.

Panel Alloy and Treatment	Bare	Alumilite No. 205	Alumilite No. 204	Iridite No. 14	Days Exposed
2219-T6, bare	a	a	a	a	455
" "	b	b	b	b	811
" "	b	a	a	a	2373
2219-T6, painted	ga	ga	ga	ga	811
" "	ga	ga	ga	ga	2373
Clad 2219-T6, bare	b	a	b	a	455
" " "	a	a	a	a	811
" " "	a	ec	e	a	2373
Clad 2219-T6, painted	ga	ga	ga	ga	811
" " "	ga	ga	ga	ga	2373
2024-T4, bare	b	d	b	a	455
" "	b	b	b	b	811
" "	b	d	b	b	2373
2024-T4, painted	ga	ga	ga	ga	811
" "	ga	ga	gb	gb	2373
Clad 2024-T4, bare	a	b	a	a	455
" " "	a	a	a	a	811
" " "	a	a	a	a	2373
Clad 2024-T4, painted	ga	ga	ga	ga	2373
" " "	-	-	-	-	Lost from racks
7075-T6, bare	a	b	a	b	455
" "	a	a	a	a	811
" "	a	a	a	a	2373
7075-T6, painted	ga	ga	ga	ga	811
" "	ga	ga	ga	ga	2373
Clad 7075-T6, bare	a	b	a	a	455
" " "	a	a	a	a	2373
" " "	-	-	-	-	Lost from racks
Clad 7075-T6, painted	-	-	-	-	Lost from racks
" " "	ga	ga	ga	ga	2373

(1)
- (a) No corrosion
- (b) Scattered shallow corrosion pits
- (c) Scattered medium deep corrosion pits
- (d) Rivet head cracked
- (e) Driven head of rivet cracked
- (f) No paint failures at rivet heads
- (g) Paint failures at rivet heads
- (h) General shallow corrosion attack
- (i) General corrosion attack

(2) Heat treated, condition unknown

(3) Reheat treated after application of surface treatment

(4) Rivet cracked but still attached

Table 4. Evaluation of Rivet Alloy 2117[2] after Exposure in the Seawater for Number of Days Shown.

Panel Alloy and Treatment	Bare	Alumilite No. 205	Alodine No. 1200	Alodine No. 1200[3]	Days Exposed
2219-T6, bare	b	b	a	a	455
" "	b	b	b	b	811
" "	b	b	b	b	2373
2219-T6, painted	ga	ga	ga	ga	811
" "	ga	gb	ga	ga	2373
Clad 2219-T6, bare	a	a	a	a	455
" " "	a	a	b	a	811
" " "	a	a	a	a	2373
Clad 2219-T6, painted	ga	ga	ga	ga	811
" " "	ga	ga	ga	ga	2373
2024-T4, bare	b	c	b	b	455
" "	c	c	c	h	811
" "	c	ce	ie	ie	2373
2024-T4, painted	ga	ga	ga	ga	811
" "	gb	d	gb	gb	2373
Clad 2024-T4, bare	b	a	a	a	455
" " "	a	a	a	a	811
" " "	a	a	a	a	2373
Clad 2024-T4, painted	gb	ga	ga	ga	2373
" " "	-	-	-	-	Lost from racks
7075-T6, bare	b	b	b	b	455
" "	a	d	a	a	811
" "	a	a	d	a	2373
7075-T6, painted	ga	ga	ga	ga	811
" "	ga	ga	ga	ga	2373
Clad 7075-T6, bare	a	b	a	b	455
" " "	a	a	a	a	2373
" " "	-	-	-	-	Lost from racks
Clad 7075-T6, painted	-	-	-	-	Lost from racks
" " "	ga	gb	ga	ga	2373

(1)
- (a) No corrosion
- (b) Scattered shallow corrosion pits
- (c) Scattered medium deep corrosion pits
- (d) Rivet head cracked
- (e) Driven head of rivet cracked
- (f) No paint failures at rivet heads
- (g) Paint failures at rivet heads
- (h) General shallow corrosion attack
- (i) General corrosion attack

(2) Heat treated, condition unknown

(3) Reheat treated after application of surface treatment

(4) Rivet cracked but still attached

Table 5. Evaluation of Rivet Alloy 2024[2] after Exposure in the Seawater for Number of Days Shown.

Panel Alloy and Treatment	Bare	Alumilite No. 205	Special Heat Treatment, Bare	Days Exposed
2219-T6, bare	a	a	b	455
" "	b	b	h	811
" "	b	b	i	2373
2219-T6, painted	ga	ga	gb	811
" "	ga	ga	gc	2373
Clad 2219-T6, bare	a	b	b	455
" " "	a	a	b	811
" " "	a	a	b	2373
Clad 2219-T6, painted	ga	ga	ga	811
" " "	ga	ga	ga	2373
2024-T4, bare	d	ae[4]	i	455
" "	b	d	de	811
" "	b	b	de	2373
2024-T4, painted	ga	ga	ga	811
" "	ga	ga	gd	2373
Clad 2024-T4, bare	a	a	a	455
" " "	a	a	a	811
" " "	a	a	a	2373
Clad 2024-T4, painted	ga	ga	ga	2373
" " "	-	-	-	Lost from racks
7075-T6, bare	b	b	b	455
" "	a	a	ad[4]	811
" "	a	a	a	2373
7075-T6, painted	ga	ga	ga	811
" "	ga	ga	ga	2373
Clad 7075-T6, bare	a	a	a	455
" " "	a	a	a	2373
" " "	-	-	-	Lost from racks
Clad 7075-T6, painted	-	-	-	Lost from racks
" " "	ga	ga	ga	2373

(1)

(a) No corrosion
(b) Scattered shallow corrosion pits
(c) Scattered medium deep corrosion pits
(d) Rivet head cracked
(e) Driven head of rivet cracked
(f) No paint failures at rivet heads
(g) Paint failures at rivet heads
(h) General shallow corrosion attack
(i) General corrosion attack

(2) Heat treated, condition unknown

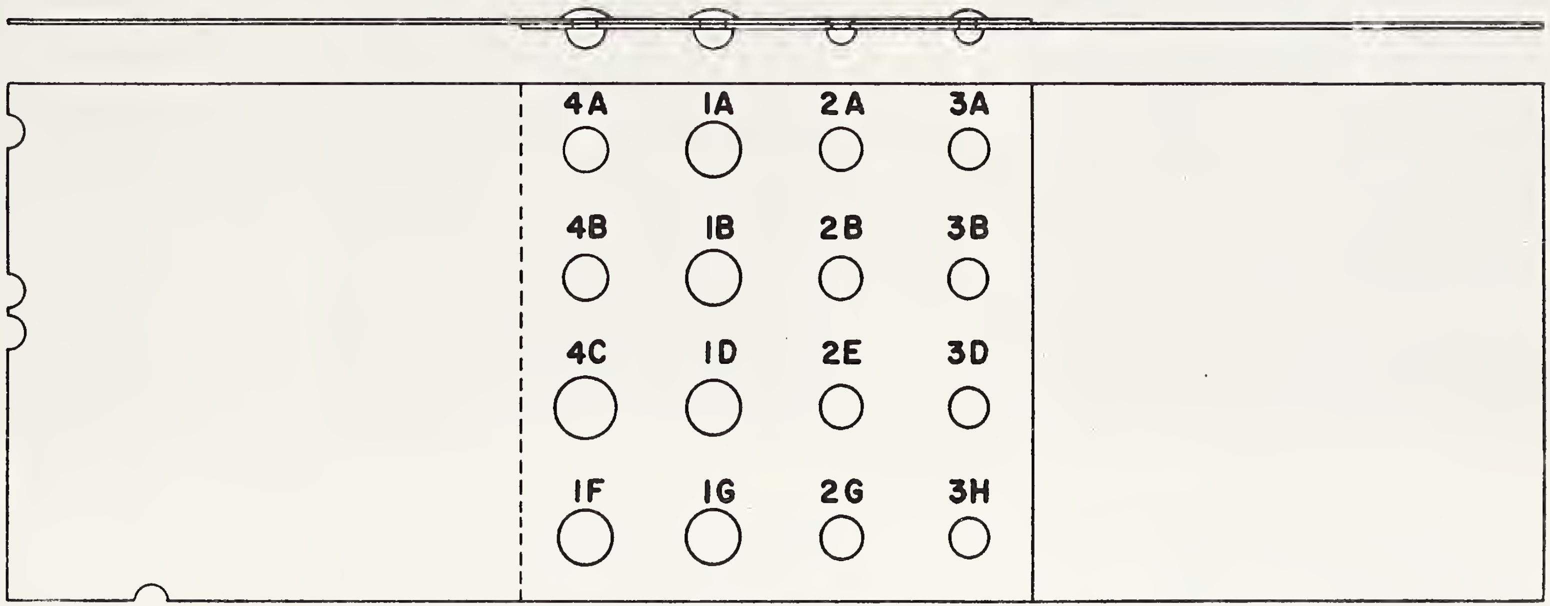
(3) Reheat treated after application of surface treatment

(4) Rivet cracked but still attached

Table 6. Dissimilar Metal Effects

Rivet Alloy	Coupled to	Sheet Alloy
2024 - slightly protected		2219-T6 - attacked
2024 - no effect		2024-T4 - no effect
2024 - slightly protected		7075-T6 - very slight attack
2024 (stabilized) - attacked		2219-T6 - protected
2024 (stabilized) - attacked		2024-T4 - protected
2024 (stabilized - protected		7075-T6 - slight attack
2219-T4 - slightly protected		2219-T6 - slight attack
2219-T4 - no effect		2024-T4 - no effect
2219-T4 - no effect		7075-T6 - no effect
2017 - protected		2219-T6 - attacked
2017 - no effect		2024-T4 - no effect
2017 - protected		7075-T6 - slight effect
2117 - slightly protected		2219-T6 - slight attack
2117 - attacked		2024-T4 - protected
2117 - no effect		7075-T6 - no effect

FIGURE 1. ALUMINUM ALLOY RIVET EXPOSURE PANEL



RIVET ALLOY

1-2219
2-2017
3-2117
4-2024

RIVET TREATMENT

A-BARE
B-ALUMILITE NO. 205
C-SPECIAL HEAT TREATMENT-BARE
D-ALODINE 1200
E-ALUMILITE NO. 204
F-IRILAC
G-IRIDITE NO. 14
H-ALODINE 1200 REHEAT TREATED

DIGIT PRECEDING LETTER REFERS TO RIVET ALLOY--LETTER REFERS TO RIVET TREATMENT, 2G-2017 ALUMINUM ALLOY RIVET WITH IRIDITE NO. 14 TREATMENT, 4F-2024 ALUMINUM ALLOY RIVET WITH IRILAC TREATMENT, ETC.

a

b

c

d

Figure 2. Appearance of 2017 Aluminum Alloy Rivets in Clad 2219-T6 Aluminum Alloy Sheet after Approximately 79 Months Exposure in Tidal Immersion at Harbor Island, North Carolina. X3.3

a) Bare
b) Coated, Alumilite 205
c) Coated, Alumilite 204
d) Coated, Iridite 14

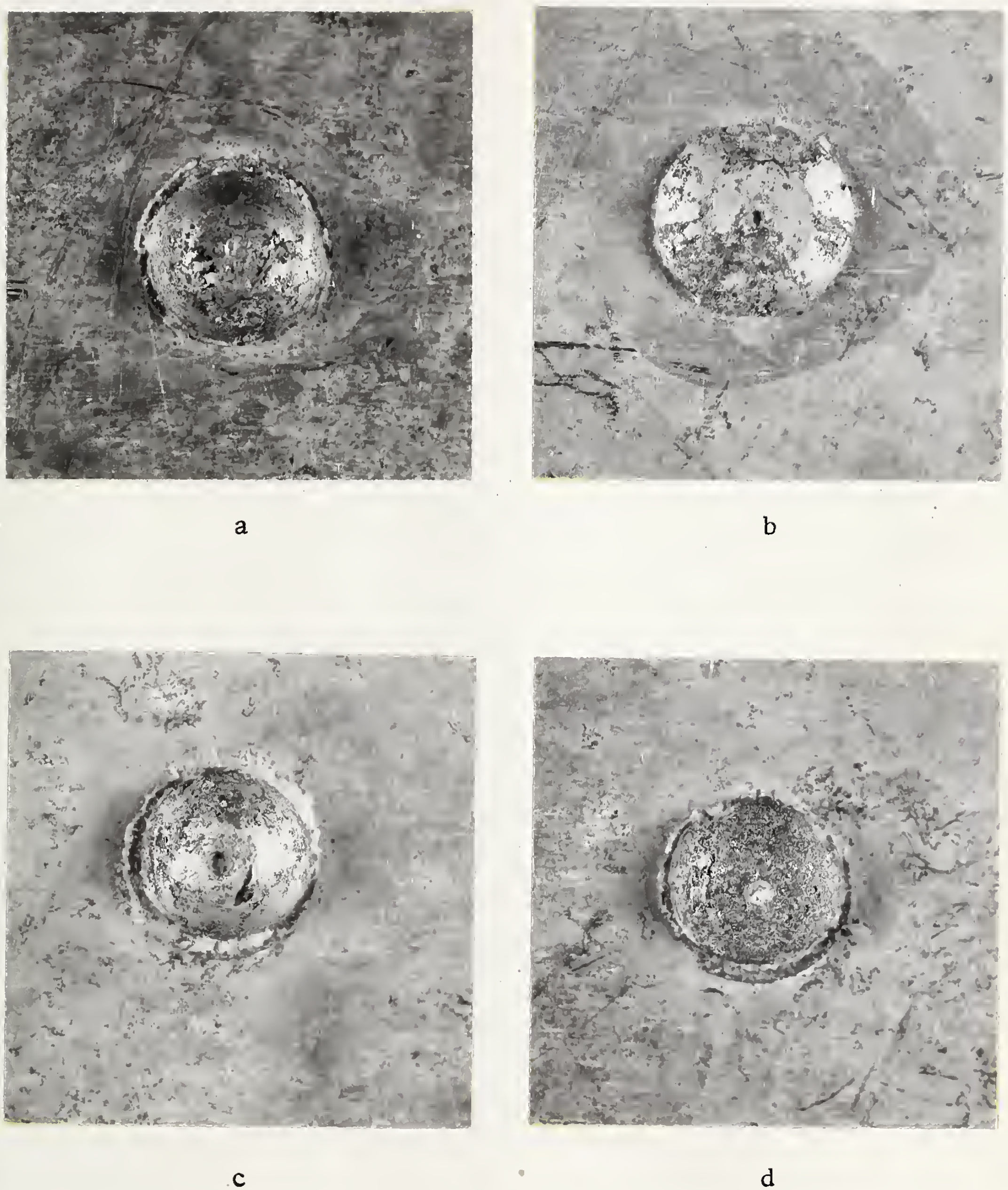
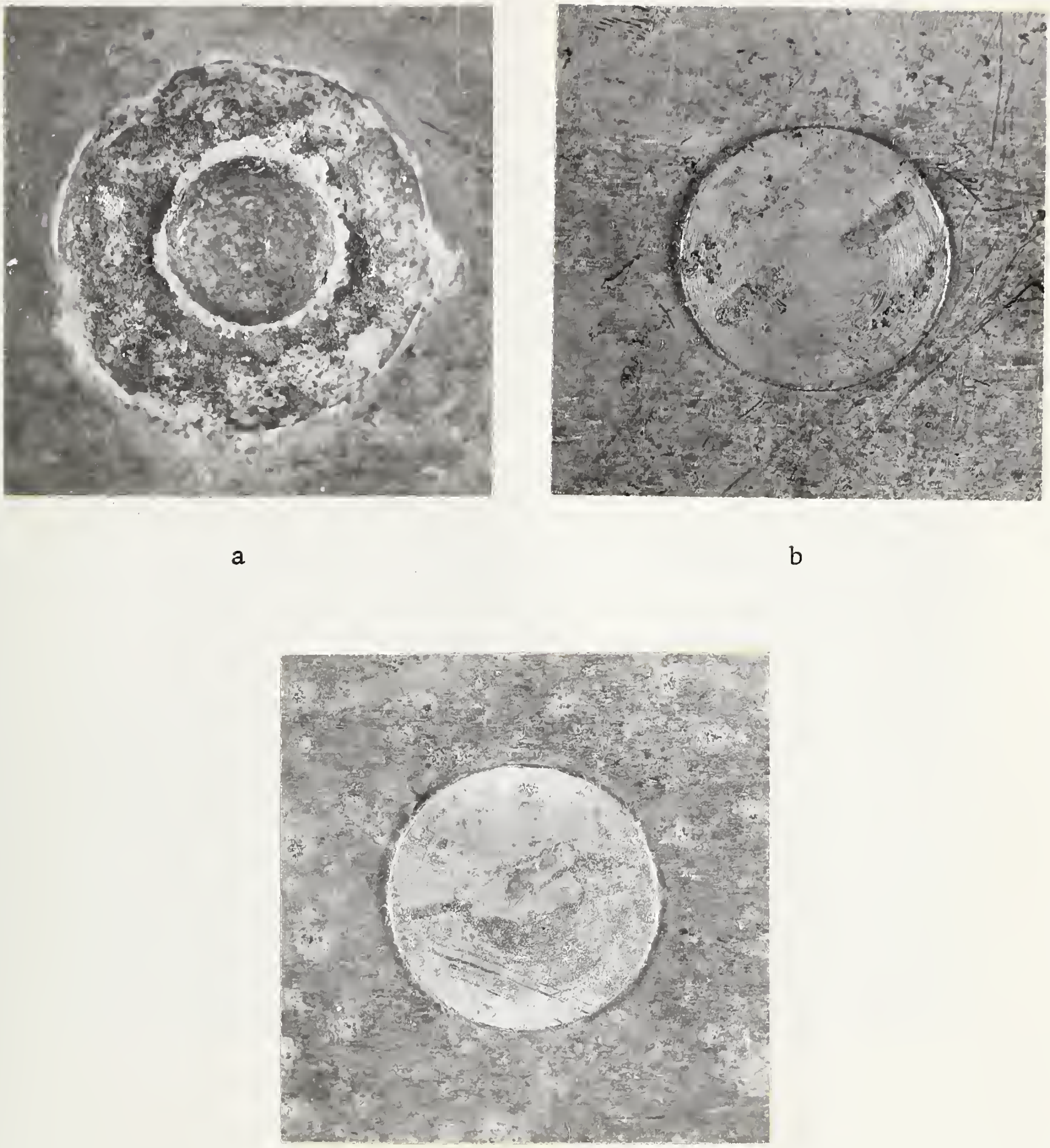


Figure 3. Appearance of 2117 Aluminum Alloy Rivets in Bare 2024 Aluminum Alloy Sheet after Approximately 27 Months Exposure in Tidal Immersion at Harbor Island, North Carolina. X3.3

a) Bare
b) Coated, Alumilite 205
c) Coated, Alodine 1200
d) Coated, Alodine 1200 Reheat Treated



a b

c

Figure 4. Appearance of 2024 Aluminum Alloy Rivets in Bare 2024-T4 Aluminum Alloy Sheet after Exposure Indicated in Tidal Immersion at Harbor Island, North Carolina. X3.3

a) Bare, 27 Months
b) Bare, Stabilizing Heat Treatment, 15 Months
c) Coated, Alumilite 205, 15 Months

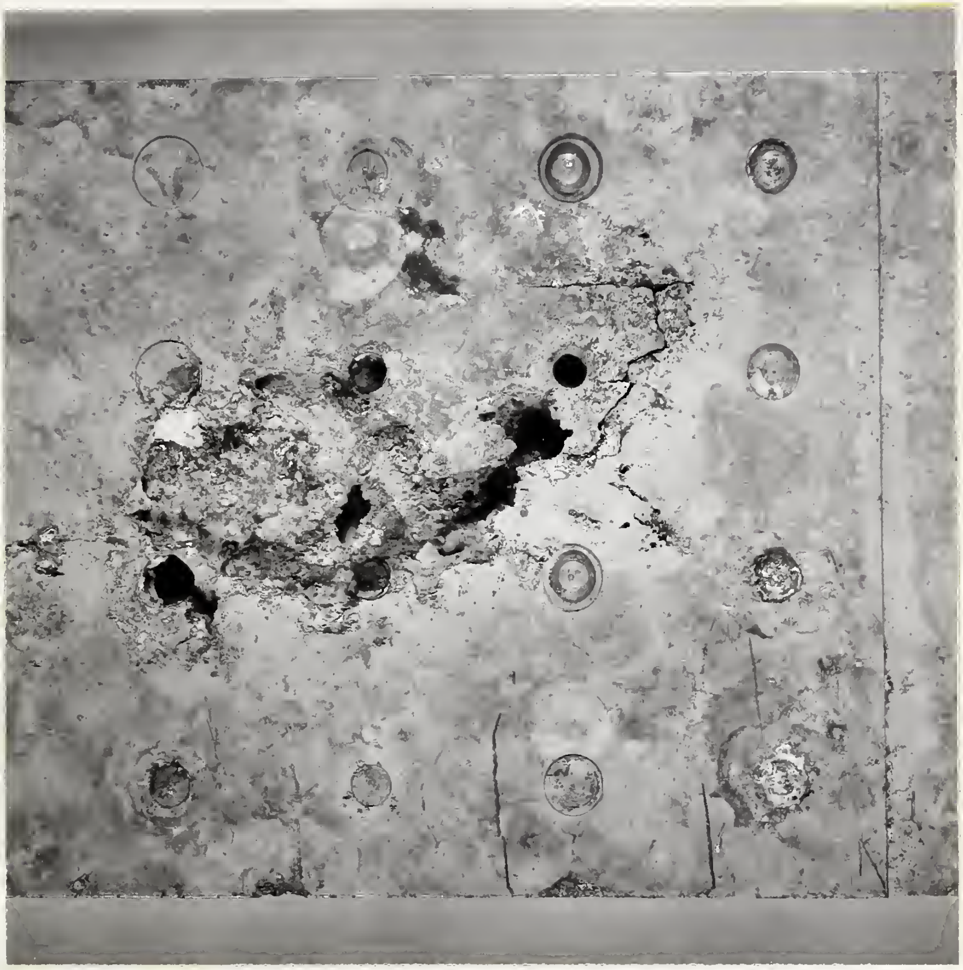


Figure 5. Appearance of Faying Surface of Bare 2024-T4 Aluminum Alloy Sheet after Exposure for 79 Months in Tidal Immersion at Harbor Island, North Carolina. X 1

Figure 6. Appearance of Faying Surface of Clad 2024-T4 Aluminum Alloy Sheet after Exposure for 79 Months in Tidal Immersion at Harbor Island, North Carolina. X 1

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

This is a report on the results of a corrosion study of surface treated aluminum alloy rivets on aluminum alloy sheet in a tidal zone environment. The rivet alloys investigated were 2024-, 2024- (stabilized), 2219-T4, 2017-, and 2117-. The sheet alloys investigated were 2219-T6, 2024-T4, and 7075-T6 in the clad and unclad condition. Various combinations of the rivet-sheet alloys were exposed bare or painted.

Results indicate little difference between chemical coatings or anodizing treatments of the rivets after three years exposure. The stabilizing heat treatment on 2024- increases its susceptibility to corrosion in most cases. Galvanic couples can lead to serious corrosion problems. However, cladding substantially reduces this effect. Paint coatings on the specimens did effectively reduce corrosion in all cases.

17. KEY WORDS (Alphabetical order, separated by semicolons) Aluminum alloys; anodized; chemically surface treated; corrosion; rivets.

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