NASA-TM-82402 TDL 83-0002

N81-19274

EVALUATION OF SEVERAL CORROSION PROTECTIVE COATING SYSTEMS ON ALUMINUM

R. H. Higgins

Marshall Space Flight Center, Alabama

February 1981

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

NTIS®

(NASA-TM-82402) EVALUATION OF SEVERAL CORROSION PROTECTIVE COATING SYSTEMS ON ALUMINUM (NASA) 20 p HC A02/MF A01 CSCL 11F

N81-19274

Unclas
G3/26 41652

NASA TECHNICAL MEMORANDUM

NASA TM-82402

EVALUATION OF SEVERAL CORROSION PROTECTIVE COATING SYSTEMS ON ALUMINUM

By R. H. Higgins
Materials and Processes Laboratory

February 1981

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA TM-82402	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO. N81-19274
4. TITLE AND SUBTITLE Evaluation of Several Corrosion Protective Coating Systems on Aluminum		5. REPORT DATE February 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) R. H. Higgins		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES Prepared by Materials and Processes Laboratory		

16. ABSTRACT

A study of several protective coating systems for use on aluminum in seawater/seacoast environments has been conducted. This study was conducted to review the developments that have been made on protective coatings since early in the Space Shuttle program and to perform comparative studies on these coatings to determine their effectiveness for providing corrosion protection during exposure to seawater/seacoast environments. Panels of 2219-T87 aluminum were coated with 21 different systems and exposed to a 5 percent salt spray for 4000 hr. Application properties, adhesion measurements, heat resistance and corrosion protection were evaluated. For comparative studies, the presently specified Bostik epoxy system used on the SRB structures was included. Results of these tests indicate four systems with outstanding performance and four additional systems with protection almost as good. These systems are based on a chromated pretreatment, a chromate epoxy primer, and a polyurethane topcoat. Consideration for one of these systems should be included for those applications where superior corrosion protection for aluminum surfaces is required.

17. KEY WORDS	18. DISTRIBUTION STATEMENT Unclassified—Unlimited	
19. SECURITY CLASSIF. (of this report) Unclassified	20. SECURITY CLASSIF. (of this page) Unclassified	21.

MSFC - Form 3292 (Rev. December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

Preceding page blank

LIST OF TABLES

LIST OF ILLUSTRATIONS

TECHNICAL MEMORANDUM

EVALUATION OF SEVERAL CORROSION PROTECTIVE COATING SYSTEMS ON ALUMINUM

INTRODUCTION

General corrosion presents a problem for many materials which are exposed to seawater/seacoast environments. Whenever design requirements necessitate the use of high strength materials which, in general, are more susceptible to corrosion degradation, serious attack can occur unless highly reliable protective coatings are utilized. In marine environments, several types of coatings are available which provide very good protection; however, in many instances, there are many other aspects of the coating which must be considered. Very early in the Space Shuttle program, the decision was made to recover the Solid Rocket Booster (SRB) stages from the ocean following each flight and to refurbish the SRBs for reuse on subsequent missions. Consequently, considerable literature research, personal contact, and extensive testing were conducted to determine what coatings were available which would provide outstanding corrosion protection for seawater exposure. In addition to the seawater corrosion protection, the coatings must also be weather resistant, resistant to the high temperatures expected during launch and re-entry (300-500°F), suitable as a base for the Thermal Protection System (TPS) adhesives, easily repaired, and be capable of fulfilling these requirements with relatively thin coatings (3 to 4 mils). As a result of these early efforts, an epoxy-amine chromate primer followed by an epoxy-amine topcoat was selected for providing corrosion protection to the aluminum structures of the SRB. Although numerous tests have been performed on the present coating system with excellent results, there was a need to evaluate new developments and other coatings to expand our knowledge in the area of corrosion protection. Therefore, a test program was conducted to review the developments made during the past few years and conduct comparative studies on several coatings to determine their effectiveness for providing corrosion protection during exposure to seawater/seacoast environments and, also, to evaluate their potential for application in other space related programs.

LITERATURE STUDY

A survey of recent literature was conducted and numerous contacts with personnel both in government and private industry were made in an effort to encompass the broad field of coatings used for severe environmental protection. The contacts included personnel with coatings experience in the areas of desalination, submarine, surface vessels and naval aircraft, weather buoys, drone targets, high speed aircraft and off-shore oil platforms. The survey included consideration for all types of coatings including primers, enamels, chlorinated rubbers, alkyds, epoxies, vinyls, polyurethanes, water-based paints, and anti-fouling paints. In analyzing the results of this survey, it was found that by reviewing comparative property and performance data for the many available coatings, many could be eliminated from consideration because of property constraints. While several of the coatings would probably provide satisfactory protection under specific conditions, they would not be expected to provide satisfactory protection under the severe type exposures that are usually associated with space launch vehicles, especially from a re-usable standpoint.

The results of this survey were similar to those obtained a few years ago with no major technology development being noted. The literature as well as personal recommendations did indicate that improved results might be expected with combinations of corrosion-inhibiting primers and highly resistant finish coats. The most often mentioned combination was a chromate inhibitive epoxy primer and a polyurethane topcoat. One recommendation included the use of a zinc-rich epoxy primer as a possibility since the zinc would be expected to preferentially corrode and protect the aluminum. Also, because of the increasing demands of OSHA and EPA to reduce the usage of toxic type materials, the survey gave consideration for non-chromated type inhibitors for use with aluminum alloys. In general, it was found that these type inhibitors are still in a development stage, and while several primers are available with inhibitors other than chromates, satisfactory corrosion protection has not been obtained in severe corrosive environments. Even so, it was decided to include some primers without chromates for comparative evaluation.

PROCEDURE

As a result of the information derived from the above study, a number of coatings were obtained for evaluation and comparison with the presently recommended coating system. Duplicate test panels (4 in. × 6 in. × 0.063 in.) for each coating system were fabricated from 2219-T87 aluminum alloy and a 3/16 in. hole drilled in each end to facilitate handling. All panels were wiped with acetone to remove the oil and grease film prior to subsequent treatments. Surface treatments, with the exception of one set of panels, were either by scrubbing with a Scotch-brite pad in running water or by applying a conversion coating (Iridite 14-2) in accordance with Mil-C-5541. All conversion coated panels were alkaline cleaned and deoxidized in a Turco Smut-go bath prior to coating. The one set of panels without further surface treatment was wash primed over a solvent wiped surface which would simulate a minimum effort of surface preparation for field application of a coating system.

In view of OSHA and EPA regulations regarding the use of chromates, surface preparation by Scotch-brite scrubbing in running water was employed on several of the panels. This method is used by some commercial aircraft manufacturers with a high degree of success.

Subsequent to the surface treatment, each set of panels was primed and topcoated in accordance with the manufacturer's instructions using a conventional air spray gun. Following cure, total coating thickness measurements were made using a Dermitron Thickness Gage. Table 1 gives the surface treatment, coating, and coating thicknesses utilized in this program. Table 2 provides information on specific materials used.

All panels were scribed with a 2-in. X on one side of the panel and exposed to a 5 percent salt spray in accordance with method 509.1 of Mil-STD-810C. Tape adhesion measurements were made following 2000 and 4000 hr salt spray exposure and repeated on one sample of each system following a 24 hr deionized water immersion (Fed. Test Method STD No. 141a, Method 6301.1). Following the salt spray test, a 1 in. × 3 in. section was cut from each sample and exposed to a forced air oven for resistance to high temperatures. The samples were placed in a cold oven and the temperature raised to 400°F within 20 min and allowed to remain for an additional 10 min. Visual examinations were made during all testing and the results recorded.

RESULTS AND DISCUSSION

Daily, and later, weekly observations were recorded throughout the test period. These observations (with the exception of the zinc-rich coatings) are summarized at 1008, 2016, 3024 and 4128 hr exposures in Table 3. All corrosion and blistering noted were along the scribe marks which were made prior to testing and for the tape adhesion tests after 2016 hr exposure. The portion without scribe marks remained in excellent condition throughout the test. Four of the systems showed outstanding protection to the 2219 aluminum substrate and four additional ones were almost as good. All of these samples had only very small blisters and light white corrosion products in the scribe marks after 4128 hr salt spray exposure (Fig. 1). There was no undercutting of the paint at the scribe marks. All of these eight systems had an epoxy primer and seven of the eight had a polyurethane topcoat. One of the systems which showed very good protection was used over a Scotch-brite prepared surface. The primer in this system was formulated especially for this type of surface treatment and is utilized on some aircraft built by the Boeing Company. This method is preferred when repainting is expected after 3 to 4 years since removal is much easier without a conversion coating. In these tests there was no discernable difference between the polyamide or amine cured epoxy primers; however, primer choice will be strongly influenced by compatibility of topcoats. Several instances of intercoat adhesion failure have been reported by industry between various primers and polyurethane topcoats. In what would be classified as the next best grouping, six coating systems had only small blisters and light corrosion in the scribe marks. The protection afforded by these systems would still be considered to be very good after a 4000 hr salt spray test (Fig. 2). The systems without chromates either in a conversion coating or the primer failed along the scribe marks by blistering, undercutting of the paint films and loss of adhesion (Fig. 3). Considerable improvement was noted however when a chromate conversion coating was used for surface preparation instead of Scotch-briting. The system that afforded the least protection (with the exception of the zinc-rich primers) utilized a wash primer pretreatment. Blistering and loss of paint adhesion at the scribe mark appeared early in the salt spray exposure; however, corrosion in this area was light for a considerable time after loss of adhesion (Fig. 4). Deterioration of the two zinc-rich systems began almost immediately with the phenoxy much worse than the epoxy polyamide. Small blisters appeared over the phenoxy coated panels after only one week exposure and approximately three weeks exposure on the epoxy-polyamide coated panels. After 2000 hr exposure, complete failure of the coatings had occurred with the coatings becoming soft, blistered, and almost total paint debond (Fig. 5).

Results of the tape adhesion tests after 2000 hr exposure showed adhesion loss on only the zinc-rich systems and a slight loss on systems 3, 5, 13, and 15. After 4000 hr exposure, results were similar except systems 5, 13, and 15 were embrittled and flaked at the mark upon scribing. The only effect noted with the additional 24 hr immersion test was an extension of the loss on system 3.

To further evaluate the potential of these coatings for aerospace use, resistance to changes resulting from exposure to an elevated temperature was evaluated. As stated above, the panels were placed in a cold oven and the temperature raised to 400°F within 20 min with an additional dwell time of 10 min at 400°F. The samples were visually examined following heating for any evidence of blistering and color changes. There was no evidence of blistering or lifting on any panel; however, the coatings (all white) did darken to various degrees. The least affected was system No. 9 (only slight change) while systems 1 and 1H turned a medium tan. Systems No. 17 and 18 were almost as dark and the remainder were ivory to light beige colored. For comparative purposes, Systems No. 1 and 1H were similar to Color Number 13531 of Fed. Std 595, Systems 17 and 18 were similar to color number 22563 and none of the remainder were darker than color number 27778. No other changes were visibly noted.

SUMMARY AND CONCLUSIONS

Examination of the results of these tests shows that outstanding protection can be afforded to 2219-T87 aluminum alloy in severe seacoast/seawater environments. Although the extensive evaluation of the presently used coating system utilized on the SRB has indicated very good protection for these environments, these tests indicate that some greater degree of protection would be expected by several of the coating systems evaluated. The most obvious being the substitution of a polyurethane topcoat instead of an epoxy topcoat. Four systems of this type were considered to provide the best protection of all systems evaluated. In reviewing the overall results, many of the systems provided similar results; however, this was expected since, in general, only the most promising candidate systems were evaluated. As expected, in all cases except one, a conversion coat provided the best surface treatment for subsequent coatings. Less corrosion and blistering occurred on panels with the conversion coating than were noted on panels with the wash primer or the

Scotch-brite scrubbing. The one system (No. 12) that showed very good protection with excellent adhesion has sufficient merit to warrant additional studies for some possible applications where a chemical treatment cannot be used. Although recommendations had been received on the potential of zinc-rich coatings for aluminum, the two types evaluated (phenoxy and epoxy-polyamide) performed rather poorly and could not be considered for any application in a seacoast atmosphere. In reviewing the overall performance of systems without chromates, the results indicated that good protection can be afforded to many aluminum alloys in atmospheres other than those that are chloride laden. The results would appear to be especially good if compared to other systems without chromates; however, when compared with systems incorporating chromates, equivalent protection is just not achieved in the more severe seacoast environment.

The results of this test program indicate that, in general, no dramatic developments have been made in the last few years relative to achieving major improvements in the corrosion protection of aluminum alloys. While some improvements can be obtained with various combinations of coatings, evaluation processes must continue to be utilized for obtaining the best protection under the expected use conditions. From this study, it also appears that chromates are essential for providing the outstanding protection desired in a seacoast/seawater environment. Present day technology has yet to develop an equivalent method of corrosion protection that does not incorporate the use of chromates. Four systems were found that provided outstanding protection and four additional systems were almost as good. These systems are based on a chromated pretreatment, a chromate epoxy primer and a polyurethane topcoat. Based on the results of this test program, one of these systems should be considered for those applications where superior corrosion protection for aluminum surfaces is required.

TABLE 1. COATING SYSTEMS EVALUATED

System Code	Product Code (Table II)	Coating System	Total Coating Thickness (Mils)
9333		Iridite 14-2	
	P1	Phenoxy Zinc-Rich Primer	
	T1	Epoxy-Polyamide Topcoat	3.4
9334		Iridite 14-2	
	P2	Epoxy-Polyamide Zinc-Rich Primer	
	T1	Epoxy-Polyamide Topcoat	4.0
1		Iridite 14-2	
	P3	Epoxy-Amine Calcium Chromated Primer	
	T2	Epoxy-Amine Topcoat	2.5
1H*		Iridite 14-2	
	P3	Epoxy-Amine Calcium Chromated Primer	
	T2	Epoxy-Amine Topcoat	2.4
2		Iridite 14-2	
	P3	Epoxy-Amine Calcium Chromated Primer	
	T3	Commercial Aliphatic Polyurethane Topcoat	3.0
3		Iridite 14-2	
	P3	Epoxy-Amine Calcium Chromated Primer	
	T4	Aliphatic Polyurethane Topcoat Per Mil-C-83286B (Air Force Spec)	3.5
4		Iridite 14-2	
	P4	Epoxy-Polyamide Strontium Chromate Primer per Mil-P-23377	
	T5	Epoxy-Polyamide Topcoat per Mil-C-22750	2.7
5		Wash Primer per Mil-P-15328C (GSA)	
	P4	Epoxy Primer per Mil-P-23377	
	T5	Epoxy-Polyamide Topcoat per Mil-C-22750	2.6
6		Iridite 14-2	
	P4	Epoxy Primer per Mil-P-23377	
	T6	Polyurethane Topcoat per Mil-C-83286B	2.7

TABLE 1. (Continued)

System Code	Product Code (Table II)	Coating System	Total Coating Thickness (Mils)
7		Iridite 14-2	
	P4	Epoxy Primer per Mil-P-23377	
	T7	Polyurethane Topcoat per Mil-C-81773B (Navy Spec)	2.1
8		Iridite 14-2	
	P5	Epoxy-Amine Chromated FR Primer	
	T6	Polyurethane Topcoat per Mil-C-83286B	2.5
9		Iridite 14-2	
	P6	Epoxy Modified Urethane Strontium Chromate Primer (COBOXY)	
	T8	Polyurethane Topcoat per Mil-C-81773B	2.6
10		Iridite 14-2	
	P7	Epoxy Primer per Mil-P-23377	
	T9	Polyurethane Topcoat per Mil-C-83286	2.9
11		Iridite 14-2	
	P8	High Performance Epoxy Primer per Mil-P-23377	
	T10	Commercial Aliphatic Polyurethane Topcoat — High Impact	2.2
12		Scotch-Brite Abrasive (Nylon)	
	P9	Epoxy-Amine Strontium Chromate Primer (Boeing Spec.)	
	T10	Polyurethane Topcoat (DAC Spec)	2.8
13		Scotch-Brite Abrasive	
	P10	Epoxy Molybdate Primer	
	T10	Polyurethane Topcoat	2.5
14		Iridite 14-2	
	P10	Epoxy Molybdate Primer	2.5
	T10	Polyurethane Topcoat	
15		Scotch-Brite Abrasive	
	P11	Epoxy Calcium Borosilicate Primer	
	T10	Polyurethane Topcoat	2.5

TABLE 1. (Concluded)

System Code	Product Code (Table II)	Coating System	Total Coating Thickness (Mils)
16		Iridite 14-2	
	P11	Epoxy Calcium Borosilicate Primer	
	T10	Polyurethane Topcoat	2.2
17		Scotch-Brite Abrasive	
	P12	Non-Chromated Titanium Dioxide Epoxy Primer	
	T11	Epoxy-Polyamide Topcoat	2.5
18		Iridite 14-2	
	P3	Epoxy-Amine Calcium Chromated Primer	
	T11	Epoxy-Polyamide Topcoat	2.5

* System 1H — Aluminum Alloy 2219 — Iridite coated in T37 condition and heat aged to T87 condition prior to priming.

TABLE 2. PRODUCT CODE IDENTIFICATION

Primers

P1	Rust-Oleum No. 9333
P2	Rust-Oleum No. 9334
P3	Bostik 463-6-3 (SRB Primer)
P4	Mil-P-23377 — Supplied by the Kopper's Co. through GSA
P5	Deft, Inc. FR Primer per Northrup Spec No. NAI-1269
P6	Sterling U-1482 Coboxy Primer
P7	DeSoto, Inc. 513-J102 (Mil-P-23377)
P8	DeSoto, Inc. 513-332 Mil-P-23377 (High Performance Fluid Resistant)
P9	DeSoto, Inc. 513-329 meets Boeing Spec. BMS 10-79B
P10	DeSoto, Inc. 517-300 Experimental Non-Chromated
P11	DeSoto, Inc. 511-301 Experimental Non-Chromated
P12	Woolsey Marine Ind. No. 648 Non-Chromated

Topcoats

T1	Rust-Oleum No. 9392
T2	Bostik 443-3-1 (SRB Topcoat)
T3	Bostik 643-3-41
T4	Bostik 643-18-1
T5	Mil-C-22750 Supplied by Advanced Coatings and Chemical through GSA
T6	Mil-C-83286B Supplied by Deft, Inc. (03-W-40) through GSA
T7	Mil-C-81773B Supplied by Advanced Coatings and Chemical through GSA
T8	Sterling 81-U-1001
T9	DeSoto, Inc. 821-330 (also meets DMS 2115)
T10	DeSoto, Inc. 821-T209 (meets DMS 2143)
T11	Woolsey Marine Ind. No. 450

TABLE 3. SUMMARY OF RESULTS AFTER VARIOUS SALT SPRAY EXPOSURES

1. 1008 Hours

Results	Systems
No noticeable change	6, 7, 8, 9, 11, 12
Very little white corrosion in scribe	4
Light corrosion in scribe	1H, 2, 3, 10, 18
Light corrosion in scribe and 1-5 tiny blisters at scribe	1, 14, 16
1-2 larger blisters at scribe	5
Light corrosion in scribe and largest blisters	13, 15, 17

2. 2016 Hours

Results	Systems
Essentially no change	8, 9
Very light corrosion in scribe	4, 6, 7, 10, 11, 12
Light corrosion in scribe	14, 16, 18
Light corrosion in scribe and few small blisters	1, 1H, 2, 3
Med blisters at scribe — Paint loss on tape test	5
Light corrosion at scribe, larger blisters	17
Light corrosion at scribe, larger blisters — Paint loss on tape test	13, 15

3. 3024 Hours

Results	Systems
Very small amount of light white corrosion in scribe	4, 6, 7, 8, 9
Very small blisters and light white corrosion in scribe	10, 11, 12, 14, 16, 18
Small blisters and light corrosion in scribe	1, 1H, 2, 3
Larger blisters and light corrosion in scribe	13, 15, 17
Larger blisters and light corrosion in scribe	5

TABLE 3. (Concluded)

4. 4128 Hours

Results	Systems
Few very tiny blisters and very light corrosion in scribe	6, 7, 8, 9
Few very small blisters and light corrosion in scribe	4, 10, 11, 12
Small blisters and light corrosion in scribe (more than above)	1, 1H, 2, 14, 16, 18
As above, but tape test removed some topcoat	3
Large blisters (1/4-1/2") light to med corrosion in scribe	15, 17
As above, loss of adhesion along scribe marks on tape test	13
As above, but more adhesion loss	5

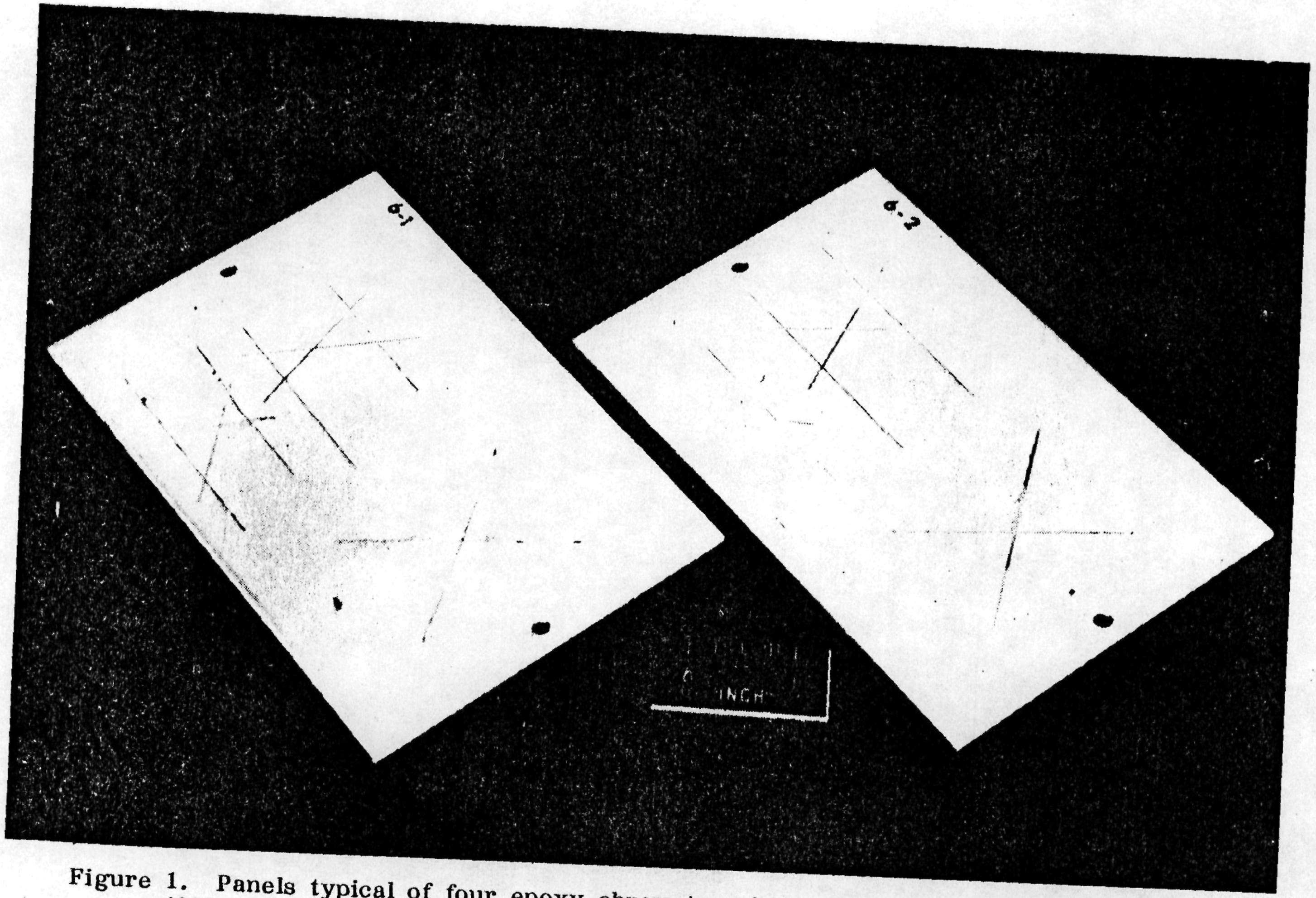

Figure 1. Panels typical of four epoxy chromate primer/polyurethane systems after 4000 hr salt spray exposure and tape adhesion tests (System No. 6).

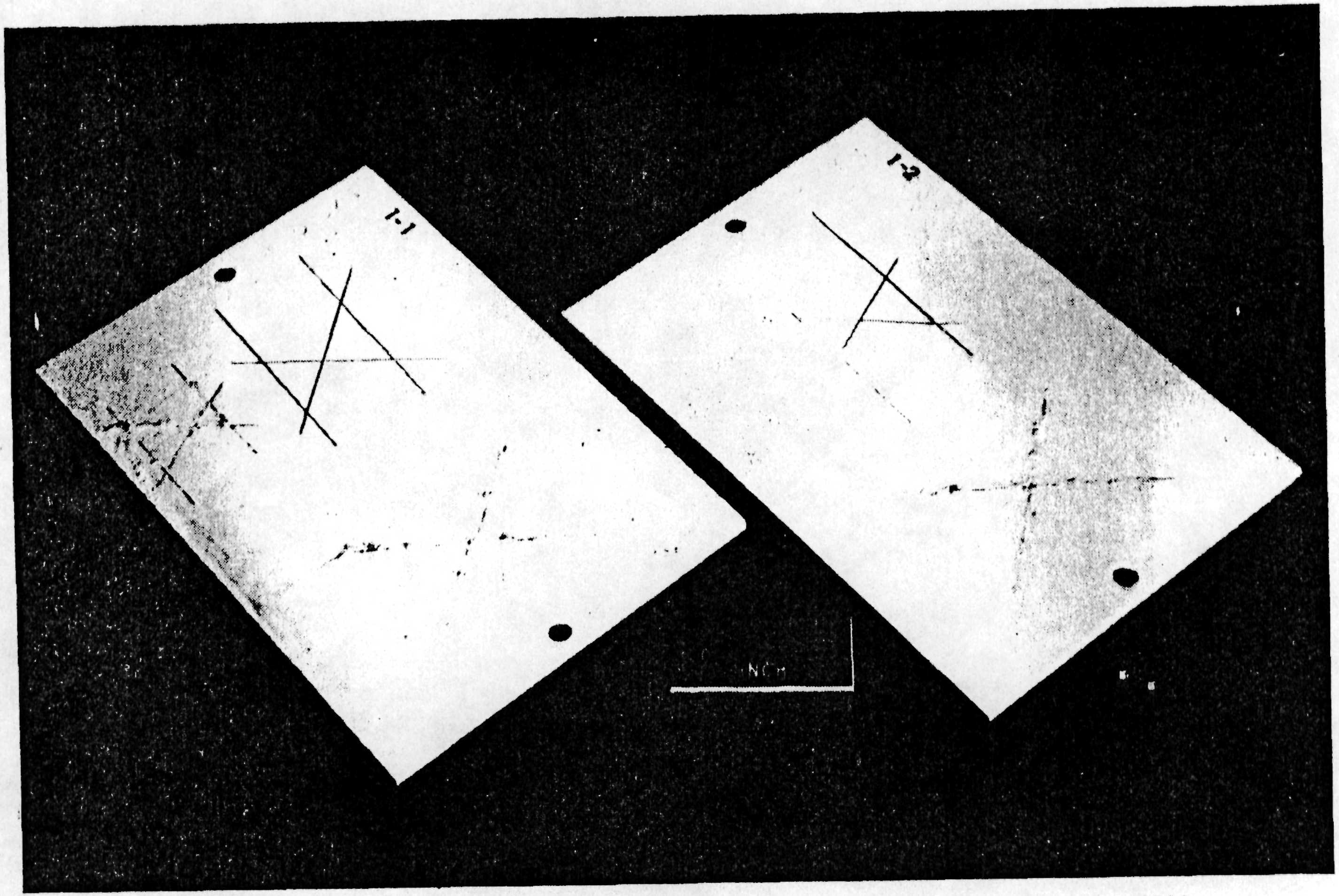

Figure 2. Panels with Bostik coating system (present SRB protection) after 4000 hr salt spray exposure and tape adhesion tests (System No. 1).

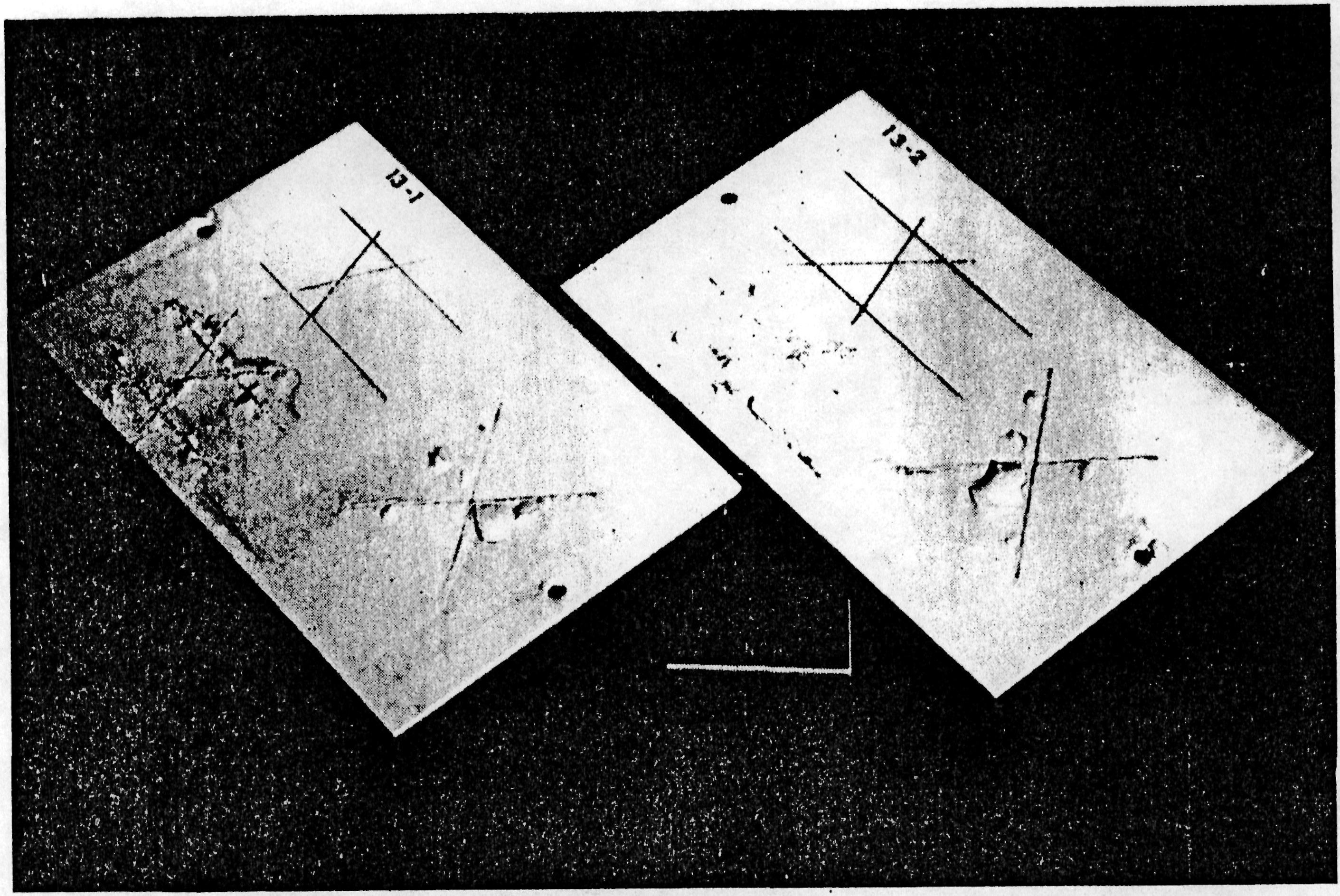

Figure 3. Typical of panels without chromates in the coating system after 4000 hr salt spray exposure and tape adhesion tests (System No. 13).

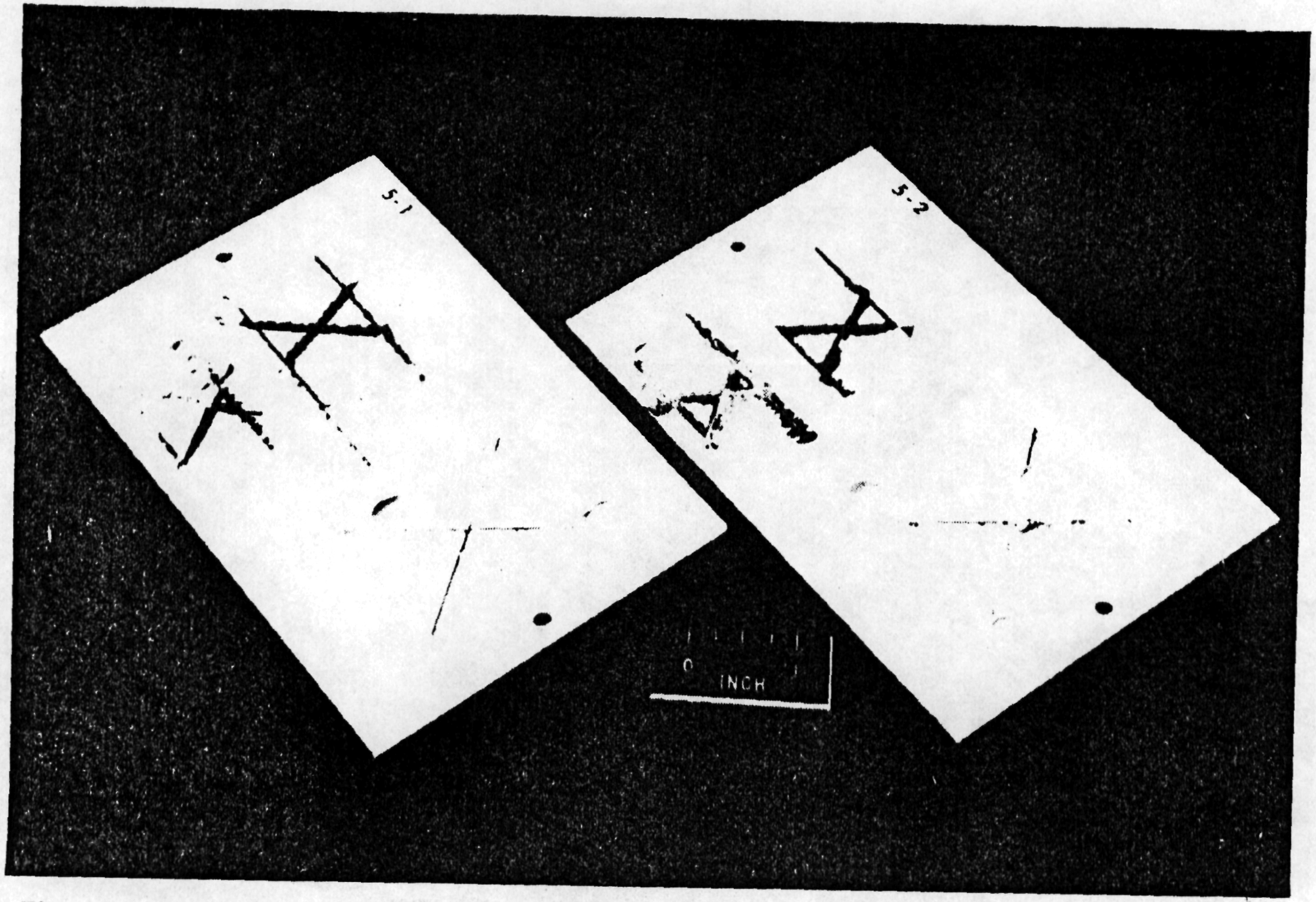

Figure 4. Panels with a wash primer pretreatment and an epoxy coating system after 4000 hr salt spray exposure and tape adhesion tests (System No. 5).

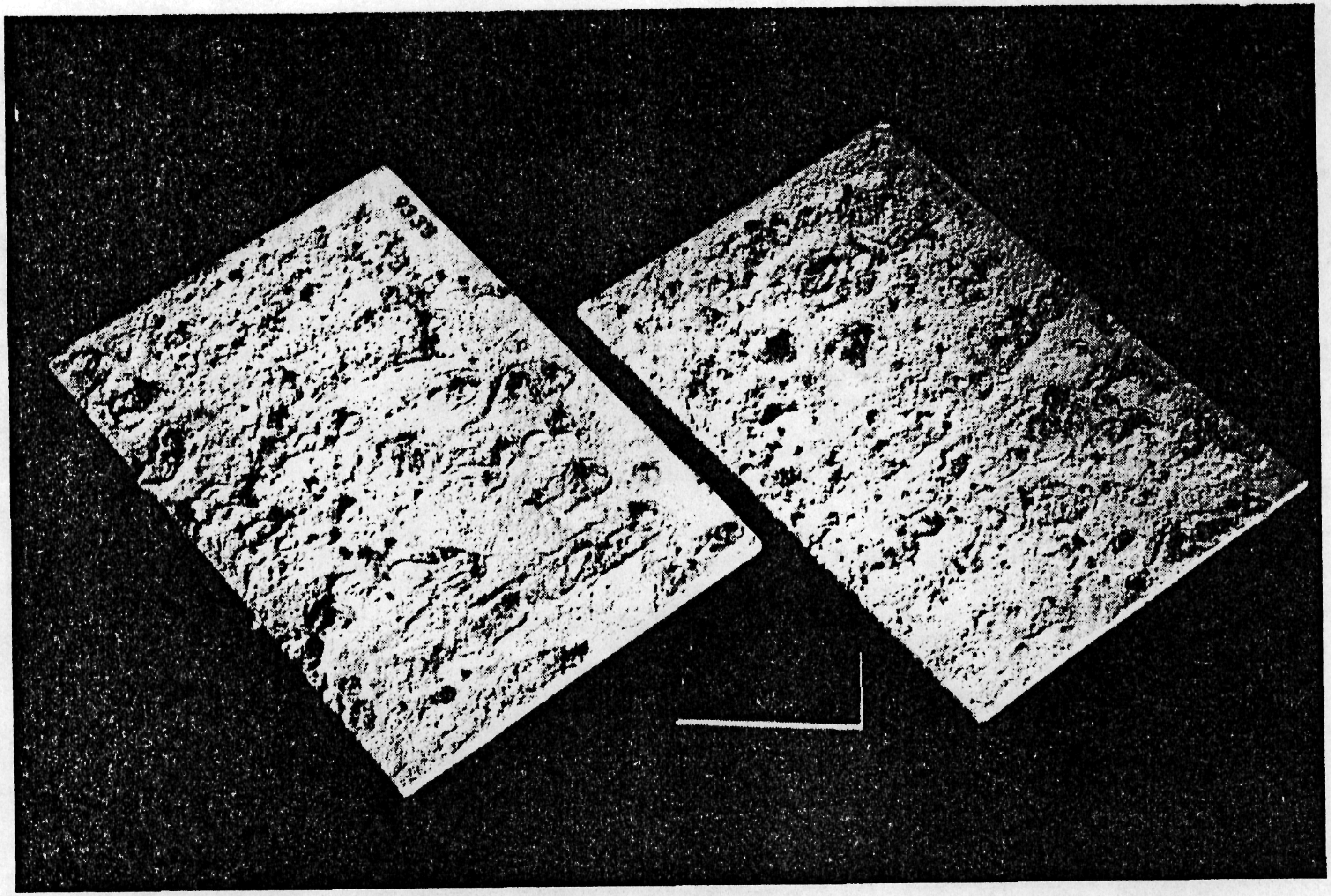

Figure 5. Panels with phenoxy zinc-rich primer/epoxy topcoat after 4000 hr salt spray exposure (System No. 9333).

APPROVAL

EVALUATION OF SEVERAL CORROSION PROTECTIVE COATING SYSTEMS ON ALUMINUM

By

R. H. Higgins

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

DB Franklin

D. B. Franklin
Chief, Corrosion Research Branch

Herman L. Gilmore

Herman L. Gilmore
Chief, Metallic Materials Division

R. J. Schwinghamer

R. J. Schwinghamer
Director, Materials & Processes Laboratory

☆U.S. GOVERNMENT PRINTING OFFICE 1981—740-066/336 REGION NO. 4

U. S. AIR FORCE