NASA Technical Memorandum 103503

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SUBJECT: Evaluation of Carbon Steel, Aluminum Alloy and Stainless Steel Protective Coating Systems After 18-Months of Seacoast Exposure

RELATED DOCUMENTATION: MTS-341-82, Test Plan for Protective Coating Systems for Carbon Steel, Aluminum Alloy and Stainless Steel, TG-FLD-22, A. P. Rowe, October 19, 1982

MTS-341-82B, Application Characteristics and Laboratory Testing of Protective Coating System for Carbon Steel, Aluminum Alloys and Stainless Steel, TG-FLD-22, A. P. Rowe, March 18, 1983

MTS-341-82C, Evaluation of Carbon Steel, Aluminum Alloy and Stainless Steel Protective Coating Systems after 3 Months of Seacoast Exposure, TG-FLD-22, A. P. Rowe, March 23, 1983

MTS-341-82D, Evaluation of Carbon Steel, Aluminum Alloy and Stainless Steel Protective Coating Systems after 1 Year of Seacoast Exposure, DE-MAO-2, A. P. Rowe, August 25, 1983

KSC-STD-C-0001, Protective Coating of Carbon Steel, Stainless Steel and Aluminum on Launch Structures and Ground Support Equipment, Standard for Design Engineering Directorate, January 17, 1983.

1.0 FOREWORD

1.1 In 1970 a test program was undertaken by the Materials Testing Branch at KSC to evaluate organic and inorganic zinc-rich coatings for the protection of carbon steel. Test panels were coated and exposed at the beach corrosion test site, and evaluated after 18 months, 3 years, 5 years and 10 years. It was determined before the 18-month evaluation that the organic coatings performed poorly, whereas, the inorganic coatings exhibited excellent corrosion protection and many are still performing well today.

1.2 By 1981 advances in paint technology had produced new coating systems which may (1) be easier to apply effectively and/or (2) provide better corrosion protection. Also, by 1981, an additional hazard had been introduced into the environment of KSC launch structures and ground support equipment: the products of the SRM exhaust which include small particles of alumina (Al203) and hydrochloric acid (HCl) absorbed on the surface of those particles. Wherever this cloud settles the zinc-coated structures are being damaged even though a pressure washdown is carried out as soon as practical. It is evident that acid-resistant topcoats are needed in potential exposure areas. For this application most paint manufacturers recommend polyurethane formulations with an epoxy tie coat to a zinc primer. With that in mind, the present study was initiated to evaluate application characteristics, repair techniques, and field performance of a variety of new single-component inorganic zinc coatings, two-component inorganic zinc coatings, epoxy tie coat-polyurethane topcoat systems, alternative topcoat systems, and protective coating systems for stainless steel and aluminum.

2.0 MATERIALS AND EQUIPMENT

2.1 In order to accomplish this program, test panels were placed at the Beach Corrosion Site during the period between June 25 and September 8, 1982. They consisted of the following coatings and coating systems:

10 SINGLE-COMPONENT INORGANIC ZINC COATINGS ON CARBON STEEL (IZ-1)

MANUFACTURER	ZINC COATING
AMERON	DIMETCOTE EZ-II
CARBOLINE	CARBOZINC SP76
COOK	GALVA-PAC NO. 300
GLIDDEN	GLID-ZINC NO. 5535
INTERNATIONAL	INTERZINC QHA 0043
MATCOTE	MATCOTE 1-287
MOBIL	UNI-PAK 13-G-10
O'BRIEN	NAPKO 1-Z
PPG	METALHIDE 1000
SUBOX	GALVANOX IV

2 TWO-COMPONENT INORGANIZ ZINC COATINGS ON CARBON STEEL (IZ-2)

MANUFACTURER	ZINC COATING
AMERON	DIMETCOTE 6
MOBIL	MOBIL ZINC 7

17 EPOXY-POLYURETHANE TOPCOAT SYSTEMS ON CARBON STEEL (EU-TOPCOAT)

MANUFACTURER	ZINC PRIMER	EPOXY TIE COAT	POLYURETHANE TOPCOAT
AMERON	DIMETCOAT EZ-II	AMERCOAT 182	AMERCOAT 450
CARBOLINE	CARBO ZINC SP76	CARBOLINE 193	CARBOLINE 134
COOK	GALVA-PAC NO. 300	COPOXY 920-Y-134	ACROTHANE 975-W-426
GLIDDEN	GLID-ZINC NO. 5535	GLIDEGUARD 5461/ 5242	GLIDTHANE ONE
INTERNATIONAL	INTERZINC QHA 0043	INTERGUARD EPA006/ EBA744	INTERTHANE PCB000
MATCOTE	MATCOTE 1-287	MATCOTE 1-825	MATCOTE 2-500
MOBIL	UNI-PAK 13-G-10	VALCHEM 13-R-61	VALCHEM 40
O'BRIEN	NAPKO 1-Z	EPOXYCOAT PA 5616-00	NAPTHANE 5900-00
PPG	METALHIDE 1000	AQUAPON	PITTHANE
SUBOX	GALVANOX IV	CAPOX A-8051	SUBTHANE 3000
AMERON	DIMETCOTE 6	AMERCOAT 182	AMERCOAT 450
MOBIL	MOBIL ZINC 7	VALCHEM 13-R-61	VALCHEM 40
AMERON	NO ZINC PRIMER	AMERCOAT 182	AMERCOAT 450
PPG	NO ZINC PRIMER	AQUAPON	PITTHANE
AMERON/PPG	DIMETCOTE EZ-II	AQUAPON	PITTHANE
COOK/PPG	GALVA-PAC NO. 300	AQUAPON	PITTHANE
AMERON/PPG	DIMETCOTE EZ	AQUAPON	PITTHANE

6 ALTERNATIVE TOPCOAT SYSTEMS ON CARBON STEEL (ALT-TOPCOAT)

MANUFACTURER	ZINC PRIMER	TOPCOAT
AMERON	DIMETCOTE EZ-II	AMERCOAT 390 EPOXY ALUMINUM
CARBOLINE	CARBO ZINC SP76	CARBOMASTIC 15 EPOXY MASTIC
GLIDDEN	GLID-ZINC NO. 5535	5256/5257 EPOXY MASTIC
MOBIL	UNI-PAK 13-G-10	ALUMAPOXY 75-A-1
PPG	METALHIDE 1000	UC 50895 SILICONE ACRYLIC
AMERON	DIMETCOTE EZ-II	AMERCOAT 741 INORGANIC

4 GALVANIZED SYSTEMS ON CARBON STEEL (GALV)

MANUFACTURER	CONDITION
METALPLATE	UNBLASTED INDUSTRIAL GALVANIZED
METALPLATE	BLASTED INDUSTRIAL GALVANIZED
METALPLATE/PPG	AQUAPON/PITTHANE ON ACID-ETCHED GALVANIZED
METALPLATE/PPG	AQUAPON/PITTHANE ON GRIT-BLASTED GALVANIZED

3 MANUFACTURER-PREPARD SINGLE COMPONENT INORGANIC ZINC ON CARBON STEEL (MFR-IZ-1)

MANUFACTURER	ZINC COATING
MATCOTE	MATCOTE 1-287
MOBIL	UNIPAK 13-G-10 GREEN
DUPONT	DUPONT ZINC

3 MANUFACTURER-PREPARED EPOXY-POLYURETHANE TOPCOAT SYSTEMS ON CARBON STEEL (MFR-EU-TOPCOAT)

MANUFACTURER	ZINC PRIMER	EPOXY TIE COAT	POLYURETHANE TOPCOAT
MATCOTE	MATCOTE 1-287	MATCOTE 1-825	MATCOTE 2-500
MOBIL	UNI-PAK 13-G-10 GREEN	VALCHEM 13-R-61	VALCHEM 40
DUPONT	DUPONT ZINC	DUPONT EPOXY	DUPONT POLYURETHANE

7 COATING SYSTEMS ON ALUMINUM ALLOY 2024-T3

MANUFACTURER	COATING
GOODRICH	AR-7 NITRILE RUBBER WITH 35% ALUMINUM POWDER
GATES	GACOFLEX H-10 HYPALON AND ALUMINUM
AMERON	AMERCOAT 182/AMERCOAT 450 ON GRIT-BLASTED
AMERON	AMERCOAT 182/AMERCOAT 450 ON WASH-PRIMED
AMERON	AMERON EPOXY 66 ON WASH-PRIMED
ANODIZED	MIL-A-8625, TYPE 3, ANODIZED
IRIDITED	MIL-C-5541, CLASS 1A, IRIDITED

4 COATING SYSTEMS ON 304 STAINLESS STEEL (SS)

MANUFACTURER	COATING
GOODRICH	AR-7 NITRILE RUBBER WITH 35% ALUMINUM POWDER
GATES	GACOFLEX H-10 HYPALON AND ALUMINUM
AMERON	AMERCOAT 182 EPOXY/AMERCOAT 450 POLYURETHANE
AMERON	AMERCOAT 90 MODIFIED EPOXY

A REPAIR PROGRAM CONSISTED OF TWO APPLICATION TECHNIQUES (SPRAY AND BRUSHED) AND THE FOLLOWING FIVE SURFACE PREPARATION TECHNIQUES

NEEDLE GUN (NG)
COARSE GRINDER (CARBORUNDUM DISK) (CG)
SANDING DISC (SD)
OSPHO CORROSION REMOVAL COMPOUND (OS)
SOLVENT WIPE FOLLOWED BY WIRE BRUSH (SW)
NEEDLE GUN FOLLOWED BY ORGANIC ZINC (OZ)

THE REPAIR PROGRAM CONSISTED OF THE FOLLOWING COATINGS:

11 INORGANIC SINGLE COMPONENT ZINC COATINGS

MANUFACTURER	ZINC COATING
AMERON	DIMETCOTE EZ
AMERON	DIMETCOTE EZ-II
CARBOLINE	CARBO-ZINC SP76
COOK	GALVA-PAC NO. 300
GLIDDEN	GLID-ZINC NO. 5535
INTERNATIONAL	INTERZINC QHA 0043
MATCOTE	MATCOTE 1-287
MOBIL	UNI-PAK 13-G-10
O'BRIEN	NAPKO 1-Z
PPG	METALHIDE 1000
SUBOX	GALVANOX IV

1 ORGANIC ZINC COATING

MANUFACTURER	ZINC COATING
CONLUX	ZINC PLATE

2 TOPCOAT SYSTEMS

MANUFACTURER	ZINC PRIMER	TIECOAT	TOPCOAT
AMERON	DIMETCOTE EZ	AMERCOAT 182	AMERCOAT 450
AMERON	DIMETCOTE EZ	NONE	AMERCOAT 390 EPOXY ALUMINUM

2.2 The panels designated GALV and MFR have been included in the exposure tests for general information but cannot be compared directly with the panels prepared at KSC because coating thicknesses (DFT) varied widely. In some cases sanding had apparently been done between coats, and the galvanizer had rounded the fillets of the Tator panel troughs.

2.3 The paint shop was equipped with a Branson vapor degreaser and a Binks Model 18 spray gun with graphite packing, a 496 DEX needle, an AV-15-D nozzle, and a 33625-124 491 air cap with a 1-quart DeVilbiss pressure cup.

2.4 Dry film thickness was measured with a Mikrotest magnetic gauge which was calibrated by using plastic shims.

3.0 TEST PROCEDURES

3.1 Application

3.1.1 The coatings were applied in the Materials Testing Branch (MTB) paint shop by Mr. Edwin V. Tier, a journeyman painter on loan from Boeing Services International (BSI). Application data for the coating systems applied by Mr. Tier is found in the Appendix Section of this report. Mr. Tier was also responsible for the application of the coatings tested in the 1970 program. The anodized and iridited specimens were not prepared at KSC but were procured from a supplier through BSI.

3.1.2 The carbon steel panels, both the KTA (Tator) panels for exposure testing and the flat 4-inch x 6-inch x 1/8-inch panels for laboratory and scribe tests, were sandblasted with 20 to 30-micron silica sand at 100 psi at the nozzle to the near-white condition described as No. 2 in NACE STD TM-01-70, and stored with desiccants inside the paint shop until the coatings were applied.

3.1.3 The aluminum alloy specimens were 4-inch x 6-inch x 1/8-inch panels of 2024-T3. Those described as WP were solvent washed with methyl

ethyl ketone (MEK) in the vapor degreaser and then wash primed. Those described as GB were solvent washed and then blasted with fine silica abrasive.

3.1.4 The stainless steel specimens were 4-inch x 6-inch x 1/8-inch panels of Type 304 alloy. They were solvent cleaned before application of the coatings.

3.1.5 The various coatings were applied to a dry film thickness of 4 to 6 mils of the zinc-rich primers and thinner layers of the tie coats and topcoats. Insofar as the directions were complete, manufacturer's instructions were followed in mixing, thinning, and applying the coatings. After initial thorough mixing of the zinc primers it was generally not necessary to agitate them during the brief application periods.

3.1.6 Although protective coatings must often be applied outdoors at KSC due to size or site of the structure to be protected, the resultant variations in temperature, humidity and wind conditions constitute test variables which were eliminated by applying the coatings inside the paint shop, all under the same conditions by the same painter.

3.1.7 The repair test specimens were all carbon steel 4-inch x 6-inch x 1/8-inch flat panels. They were first sandblasted and the top half coated with single-component inorganic zinc coatings as described in 3.1.2 and 3.1.5 above.

The panels were then exposed at the beach corrosion site for approximately 3 weeks, which produced a fairly uniform coating of rust on the bottom half. A weld bead was then applied in the center of the panels so that it crossed the boundary between coated and rusted sections. Various surface preparation techniques were next used on these panels to clean off the rust and around the weld bead: a needle gun, a grinder with a carborundum disc or a sanding disc, a wire brush followed by application of MIL-C-10578C corrosion removing compound, or a solvent wipe followed by wire brush. Figures 1 through 6 show the various surface preparations. The coatings were then either sprayed on as described in 3.1.5 or applied with a brush. Brush application frequently showed brush marks where the paint had thickened too rapidly to even out.

3.1.8 Scribe panels were prepared by removing the coatings with a 1/16-inch or 3/32-inch 2-flute end mill on a milling machine. The depth of the cut was monitored to ensure that bare metal was exposed.

3.2 Laboratory Tests

3.2.1 Adhesion tests were performed in accordance with ASTM D2197-68 using a Gardner Laboratory balanced-beam scrape adhesion tester. In this test the paint film is pushed beneath a rounded loop stylus mounted in a pivoted beam which is loaded incrementally until the film is stripped from its base or resists 10 kg, which is the maximum load.

3.2.2 KSC-SPEC-F-0020, issued December 22, 1969, required that an inorganic zinc coating show no evidence of failure when exposed to a temperature of 400°C for 24 hours. Each of the zinc coatings were exposed at 350°C and 400°C for 24 hours and then tested for adhesion as described in 3.2.1. It should be noted that KSC-SPEC-F-0020 has been superseded by KSC-STD-C-0001. The new standard does not identify any temperature requirement for protective coatings.

3.2.3 The temperature limits of topcoats are not addressed in KSC-STD-C-0001. However, since topcoated systems in some locations are exposed to elevated temperatures for brief periods, an abbreviated testing program was undertaken to identify temperature limits of the topcoats being evaluated. Beginning at 100°C the temperature was increased at increments of 50°C until the coatings were judged to have failed.

3.3 Field Exposure

3.3.1 The exposure tests were performed at a site located approximately 1.5 miles south of LC-39A. The test panels were placed in type 304 stainless steel racks holding 75 panels each. Porcelain insulators were used as standoffs. The racks were installed on galvanized pipe frames at a 30° angle and placed approximately 100 feet from the mean high-tide line facing the ocean. An overall view of the test site and racks is shown in Figure 7. An illustration of a typical test rack with panels installed is shown in Figure 8.

3.3.2 Five different types of test panels were used for the exposure tests: (1) scribe panels, (2) repair panels, (3) panels exposed to normal conditions, (4) panels exposed to an Al203/HCl slurry, (5) panels exposed to Al203/HCl slurry and rinsed off 1 hour later. The slurry consisted of 0.3 micron AL203 particles in a 10% HCl solution and was applied periodically through three holes in a plexiglas template. Twenty-five such applications occurred during the 18 months of beach exposure.

4.0 TEST RESULTS

4.1 Laboratory Tests Results

4.1.1 The results of the adhesion tests are presented in Table I for two panels of each system.

4.1.2 The heat test results on zinc coatings are presented in Table II. Only one of the inorganic zinc coatings supplied for this program passed that standard. In fact, 7 of the 13 coatings were damaged by 24 hours at 350°C. Color changes were assumed to be due to dyes in the coating system and were judged not to impair performance of the zinc coatings. It is interesting that one of the coatings, Ameron D-6, met the 400°C standard when tested in 1971 with a slight darkening in color but no loss in adhesion. In 1982, the coating being marketed under that name lost adhesion after 24 hours at only 350°C.

4.1.3 The results of exposure of topcoat systems to elevated temperature are presented in Table III. The polyurethanes retained adherence at 150°C for 24 hours but all except PPG Metalhide turned cream or beige, which was judged to indicate a shortened polymer life. At 100°C for 24 hours the polyurethanes were undamaged. AR-7 and Hypalon were undamaged at 100°C for 2 hours but lost adhesion after 24 hours. The anodized aluminum and Amercoat 741 were undamaged at 400°C for 24 hours.

4.2 Field Exposure Results

4.2.1 For this "18-month" evaluation, all the test panels were examined on February 13, 1984. Thus the majority of the panels had actually been exposed for almost 19 1/2 months, having been placed at the beach corrosion site on June 29, 1982. Most of the remaining panels were placed on July 9, 1982, and a few were added as late as September 9, 1982. The consequent difference in exposure times from 18 months is considered negligible.

4.2.2 Results of the 18-month seacoast exposure tests are given in Tables IV and V. Degrees of corrosion are indicated by a graduated scale of 0 to 10, with 10 as the best rating. This rating system is described in ASTM D-610 as follows:

RATING	DESCRIPTION
10	no rusting or less than 0.01 percent of surface rusted.
9	minute rusting, less than 0.03 percent of surface rusted.
8	few isolated rust spots, less than 0.1 percent of surface rusted.
7	less than 0.3 percent of surface rusted.
6	extensive rust spots but less than 1 percent of surface rusted.

5 rusting to the extent of 3 percent of surface rusted.

4 rusting to the extent of 10 percent of surface rusted.

3 approximately one-sixth of the surface rusted.

2 approximately one-third of the surface rusted.

1 approximately one-half of the surface rusted.

0 approximately 100 percent of surface rusted.

4.2.3 A comment on the averaging of data from the panels is perhaps in order. Where ratings of individual panels differed, a simple arithmetic mean is reported to plus or minus one-half a rating point. Since the ratings themselves are numeric rather than arithmetic, approximating a geometric progression, a geometric mean might be more appropriate. However, the geometric progression breaks down at the lower end of the scale.

4.2.4 An alternate approach might be to consider the total areas of the four panels and report a rating based on total rusted area. The disadvantage of this would be to give undue weight to a single low rating, which might reflect a preparation defect rather than a system defect.

4.2.5 In Table VI these three data treatments are assessed for, (1) the variations commonly found (A and B), (2) a wider variation (C), (3) the case of a set where one panel had a much lower rating than the others (D), and (4) a very unusual case where one panel is doing much better than the other three (E).

4.2.6 The only significant difference in the results of averaging by the three systems is in case (D). Since the low rating of one panel probably reflects a preparation or handling defect rather than a system defect, the higher value of the arithmetic mean is probably a better evaluation of the coating system.

4.2.7 In the absence of a better system, the simple system has been used. However, it should be realized that a designation of, for example, "8.5" merely means that the performance lies somewhere between 8 and 9; the number does not have the arithmetic significance of a weight change or thickness change corrosion rating which would be used for a kinetic or mechanistic study.

4.2.8 In order for a coating to be accepted for the approved products list at KSC, it must receive a corrosion rating of 9 or better after 18 months of exposure. The coating must then continue to provide acceptable protection and performance for a period of 5 years. Therefore, all ratings below 8 are essentially for comparative purposes.

4.2.9 At the "18-month" evaluation, many of the coating systems have deteriorated. With the exception of O'Brian Napko 1Z and Subox Galvanox IV, all of the single-component inorganic zincs exposed to normal conditions have failed to meet KSC-STD-C-0001. The two-component inorganic zincs, Ameron D-6 and Mobil 7, exposed to normal conditions are still rated 10. Both the single-component and two-component inorganic zincs exposed to acid effluent have failed. This was expected since zinc dissolves in HCl.

4.2.10 The epoxy-polyurethane topcoat systems exposed to normal and acid conditions are not performing as expected. The majority of the epoxy-polyurethane topcoated inorganic zincs exposed to normal conditions are performing worse than the untopcoated inorganic zincs. However, the epoxy-polyurethane topcoated inorganic zincs have been shown to withstand the acid exposure better than the untopcoated inorganic zincs. The alternative topcoat systems have all failed with the exception of Amercoat 741. Amercoat 741 is an inorganic topcoat that has been applied over a single-component inorganic zinc. This coating system is still rated 10 under normal and acid conditions.

4.2.11 Figures 9 through 12 show single-component and two-component inorganic zinc, untopcoated and topcoated after 18 months of normal and acid exposure. Figure 13 shows Amercoat 741, an inorganic topcoat over a single-component inorganic zinc after 18 months of normal and acid exposure.

4.2.12 The aluminum coatings have all failed except for Goodrich AR-7, which is doing well under normal conditions but is not withstanding the acid treatment.

4.2.13 The stainless steel coatings are doing well. It should be noted that the epoxy-polyurethane coating on stainless steel is peeling off the bottom of the panel, but no corrosion has been observed.

4.2.14 Figures 14 through 22 show various coatings for aluminum and stainless steel after 18 months of normal and acid exposure.

4.2.15 It can be inferred from the data obtained in the 18-month evaluation that in regard to the inorganic zincs, there is little difference between acid exposed panels and acid exposed panels with a rinse 1 hour later. The large difference lies between normal exposure and acid exposure. The remaining panels in this program show little difference (on the average less than 1 rating point) between, acid exposure, acid exposure and rinse, and normal exposure.

4.2.16 There are a few discrepancies between the 1-year and 18-month evaluations which need to be discussed in detail. The Mobil 7 Valchem 13-R-61/40 normal exposure, acid treated, and acid treated and rinsed were rated 9, 6, 7.5 respectively at the 1-year evaluation and rated 9, 8, 9 at the 18-month evaluation. The panels exhibited delamination of the epoxy-polyurethane coating; however, only .03% to .1% corrosion was observed. Therefore, the ratings of 9, 8, 9, are believed to be correct. Another discrepancy involves Amercoat 90 modified epoxy normal exposure, which was rated a 5 at the 1-year evaluation and 10 at the 18-month evaluation. This panel has been rechecked and the rating of 10 is valid. There are a few other discrepancies between the 1-year and 18-month evaluations. A few of the ratings are higher at the 18-month evaluation than at the 1-year evaluation. These discrepancies are small and concern ratings well below 9.

4.2.17 The scribed panels were prepared to determine the ability of a coating to prevent the spread of corrosion. The extent of spread was evaluated as greater than 1/8 inch, less than 1/8 inch, or no appreciable spread. Since there were two scribed panels for each coating system, the possible gradations were:

5 no spread on either panel

4 no spread on one panel, less than 1/8 inch on other

3 less than 1/8 inch on each

2 less than 1/8 inch on one, more than 1/8 inch on other

1 more than 1/8 inch on both

4.2.18 All single-component inorganic zinc coatings on scribed carbon steel panels performed poorly after 18 months except for Carboline SP-76 and Subox Galvanox IV. The two-component inorganic zinc coatings, Ameron D-6 and Mobil-7, on scribed panels both performed well.

4.2.19 The Carboline epoxy-polyurethane and Amercoat 741 are the only two topcoat systems whose scribed panels are performing with a rating of 5. The majority of the other topcoat scribed panels are showing some spread of rust.

4.2.20 The coatings on scribed aluminum alloy panels are all showing signs of spreading corrosion. The epoxy-polyurethane and epoxy coatings are exhibiting the worst spread. On the other hand the stainless steel scribed panels are showing no signs of spread.

4.2.21 The results of the scribe tests are shown in Table IV. Figure 23 shows a rack of scribed panels in various stages of corrosion spread.

4.2.22 The results of the repair panel evaluation are presented in Table V. The surface preparation notations used in the table are as follows:

NG	Needle Gun
CG	Coarse Grinder (Carborundum Disk)
SD	Sanding Disc
OS	Ospho Corrosion Removal Compound
SW	Solvent Wipe followed by wire brush
OZ	Needle Gun followed by organic zinc

4.2.23 The repair program panels were all placed at the beach corrosion site at approximately the same time (July 9, 1982) and hence comparison of their performances is not subject to the differences discussed in 4.1.

4.2.24 At this 18-month evaluation period, the repair program has singled out the coarse grinder surface preparation as the most successful repair technique. Below is a list of the highest rated repair systems.

RATING	COATING SYSTEM	METHOD OF SURFACE PREPARATION	METHOD OF APPLICATION
8	Cook Galvapak 300	Coarse Grinder	Sprayed
8	Matcote 1-287	Coarse Grinder	Sprayed
7	Subox Galvanox IV	Coarse Grinder	Brushed
7	Carboline SP76	Coarse Grinder	Sprayed
7	Carboline SP76	Coarse Grinder	Brushed
7	Ameron EZ	Needle Gun	Sprayed

4.2.25 Figure 24 shows examples of repair systems for single-component inorganic zincs and single-component inorganic zincs with epoxy-polyurethane topcoats.

4.2.26 Progress of this testing program has been documented by color photographs at appropriate stages of exposure (initial, 3-4 months, 1-year, 18-months) which are available for examination in the Materials Testing Branch, O&C Building, Room 1219, Kennedy Space Center, Florida.

4.2.27 Photographs of test panels selected for inclusion in this report represent an average performance of a specific category of coatings. Actual ratings of each manufacturer's product are listed in Tables I through V. It should be recognized that black and white reproduction cannot convey the contrast of color photographs.

5.0 CONCLUSIONS

5.1 The laboratory test results show the majority of the coatings performing well under normal adhesion test and exhibiting a decrease in adhesion after exposure to temperatures of 350°C and 400°C. The topcoat systems exposed to elevated temperatures show the polyurethanes withstanding 100°C for 24 hours and the majority of the mastics withstanding 200°C for 24 hours before any signs of failure. It should be noted that these are general conclusions and do not represent values for all the coatings tested. Tables I, II, and III should be consulted for laboratory test results of specific coatings.

5.2 At this phase in the program, the results of the testing performed on protective coatings for aluminum have singled out Goodrich AR-7 as a successful coating for protection against the KSC marine environment. However, all of the protective coatings for aluminum have failed against the simulated SRB acid effluent.

5.3 The results of the stainless steel protective coatings have shown AR-7, Hypalon and Amercoat 90 modified epoxy to be successful. Amercoat 182/450 exhibited no corrosion; however, the coating is delaminating from the bottom of the test panel, indicating a possible adhesion problem. It should be noted that 18 months is a short period of time to evaluate protective coatings for stainless steel since stainless steel in itself is one of the more corrosion resistant materials. More significant data should be obtained at the 3-year and 5-year evaluation periods on these coatings.

5.4 The repair program results have clearly identified a few single-component inorganic zinc-rich coatings (Cook Galvapak 300, Carboline SP-76, Matcote 1-287, Subox Galvanox IV, Ameron E-Z), a surface preparation (coarse grinder-carborandum disc) and an application technique (sprayed, but brushed possible) as most likely to be successful.

5.5 At the 18-month evaluation period, the single-component inorganic zincs have performed poorly in the KSC marine environment with the exception of Napko 1Z and Subox Galvanox IV. The two-component inorganic zincs can be expected to perform excellently in the marine environment of KSC. However, both the single-component and two-component inorganic zincs appear to have a problem in handling the simulated SRB acid effluent.

5.6 The epoxy-polyurethane topcoating systems recommended by most paint manufacturers for acid resistance have been beneficial in protecting the zinc primer. However, in both the KSC marine environment and acid exposure, the epoxy-polyurethane topcoats failed to meet the qualifying specifications. The single success among topcoats at this time is the inorganic topcoat Amercoat 741. Although Amercoat 741 has shown no direct signs of corrosion, recently there has been an increased spread of a rust-colored stain for those test panels exposed to the acid environment. Amercoat 741 rated low in laboratory adhesion tests, and therefore may be susceptible to chipping. Amercoat 741 is also a porous material and difficult to clean, which may be of concern in some applications.

5.7 The results of the acid exposed panels and the acid exposed panels with a rinse have shown there is little difference between those washed one hour after exposure and those not washed. The difference on the average is less than one rating point which can be considered negligible due to the error involved at the low end of the rating scale. Recently, a water washdown system capable of washing the Al2O3/HCl effluent immediately after launch was installed at the Shuttle launch complex. Due to the results of this study and the installation of the new washdown system, future studies will evaluate acid exposed panels followed by a rinse immediately after application of the acid, instead of the one hour rinse previously applied.

5.8 Future studies will also encompass other recommendations from manufacturers along with the successful topcoats of the 1970 program which performed well in the KSC marine environment but have not been tested for acid resistance at KSC. The list of coatings to be tested will include epoxies, high build polyurethanes, acrylic latexes, vinyls, silicates and other inorganic topcoats.

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The acronyms used in Tables I through IV are identified as follows:

IZ-1	Single-component inorganic zinc coatings on carbon steel
IZ-2	Two-component inorganic zinc coatings on carbon steel
EU-Topcoat	Epoxy-polyurethane topcoat systems on carbon steel
ALT-Topcoat	Alternative topcoat systems on carbon steel
GALV	Galvanized systems on carbon steel
MFR-IZ-1	Manufacturer-prepared single component inorganic zinc on carbon steel
MFR-EU-Topcoat	Manufacturer-prepared epoxy-polyurethane topcoat systems on carbon steel
AL	Coating systems on aluminum alloy 2024-T3
SS	Coating systems on 304 stainless steel
NG	Needle gun
CG	Coarse grinder (carborundum disk)
SD	Sanding disc
OS	Ospho corrosion removal compound
SW	Solvent wipe followed by wire brush
OZ	Needle gun followed by organic zinc

TABLE I

ADHESION TEST RESULTS

		ADHESION LOAD, kg	
		PANEL 1	PANEL 2
IZ-1	AMERON EZ-II	10	10
	CARBOLINE SP-76	10	10
	COOK GALVAPAC 300	10	10
	GLIDDEN GLIDZINC 5535	10	10
	INTERNATIONAL INTERZINC QHA 0043	10	10
	MATCOTE 1-287	10	10
	MOBIL UNIPAK 13-G-10 GRAY	10	10
	MOBIL UNIPAK 13-G-10 GREEN	10	10
	O'BRIEN NAPKO 1Z	10	10
	PPG METALHIDE 1000	10	10
	SUBOX GALVANOX IV	10	10
IZ-2	AMERON D-6	6	6
	MOBIL 7	10	10
EU-TOPCOAT	AMERON EPOXY-POLYURETHANE	7	6
	CARBOLINE EPOXY-POLYURETHANE	7	9
	COOK EPOXY-POLYURETHANE	10	7
	GLIDDEN EPOXY-POLYURETHANE	10	10
	INTERNATIONAL EPOXY-POLYURETHANE	10	10
	MATCOTE EPOXY-POLYURETHANE	10	10
	MOBIL EPOXY-POLYURETHANE	9	8
	O'BRIEN EPOXY-POLYURETHANE	10	10
	PPG EPOXY-POLYURETHANE	10	10
	SUBOX EPOXY-POLYURETHANE	6	6

TABLE I (CONT'D)

ADHESION TEST RESULTS

		ADHESION LOAD, kg	
		PANEL 1	PANEL 2
	AMERON EPOXY-POLYURETHANE ON D-6	8	9
	MOBIL EPOXY-POLYURETHANE ON MOBIL 7	10	10
ALT-TOPCOAT	AMERON 390 EPOXY MASTIC	10	10
	CARBOLINE 15 EPOXY MASTIC	10	10
	GLIDDEN EPOXY MASTIC	10	10
	MOBIL ALUMAPOXY	10	10
	PPG SILICONE ACRYLIC	10	10
	AMERON AMERCOAT 741	5	5
GALV	PPG EPOXY-POLYURETHANE ON ACID-ETCHED	7	7
	PPG EPOXY-POLYURETHANE ON GB	10	10
AL	AR-7 ON GB	8	10
	HYPALON ON GB	10	10
	EPOXY-POLYURETHANE ON GB	10	10
	EPOXY-POLYURETHANE ON WP	10	6
	EPOXY-EPOXY ON WP	10	10
	ANODIZED	10	5
	IRIDITED	0.5	0.5
SS	AR-7	10	10
	HYPALON	8	7
	EPOXY-POLYURETHANE	10	10

TABLE II

ADHESION TEST RESULTS AFTER EXPOSURE TO ELEVATED TEMPERATURES

	ADHESION, KG, AFTER 24 HOURS	
	AT 400°C	AT 350°C
IZ-1		
AMERON EZ-II	2	*
CARBOLINE SP-76	3.5	2
COOK GALVAPAC	4	*
GLID ZINC 5535	10	7
INTERZINC QHA0043	6.5	5
MATCOTE 1-287	2	2
MOBIL UNIPAK GRAY	2.5	*
MOBIL UNIPAK GREEN	3	3
NAPKO 1Z	1.5	3
PPG METALHIDE 1-PAK	2	3
SUBOX GALVANOX IV	2.5	*
IZ-2		
AMERON D-6	4.5	3
MOBIL 7	4	*

* - NOT TESTED

TABLE III

HEAT TEST RESULTS ON TOPCOAT SYSTEMS

		MAXIMUM TEMPERATURE (C°) WITHOUT DAMAGE AT 24 HOURS
EU-TOPCOAT	AMERON POLYURETHANE	100
	AMERON POLYURETHANE	100
	CARBOLINE POLYURETHANE	100
	COOK POLYURETHANE	100
	GLIDDEN POLYURETHANE	100
	INTERNATIONAL POLYURETHANE	100
	MATCOTE POLYURETHANE	100
	MOBIL POLYURETHANE ON UNIPAK	100
	MOBIL POLYURETHANE ON MOBIL 7	100
	NAPKO POLYURETHANE	100
	PPG POLYURETHANE	150
	SUBOX POLYURETHANE	100
ALT-TOPCOAT	CARBOMASTIC 15	150
	AMERCOAT 390	200
	GLIDDEN 5256/5257	200
	MOBIL ALUMAPOXY	200
	PPG SILICONE ACRYLIC	100
	AMERCOAT 741	400
AL	GOODRICH AR-7	100
	HYPALON	<100
	AMERON 66 EPOXY	100
	AMERON POLYURETHANE	100
	ANODIZED	400
	IRIDITED	<250
SS	GOODRICH AR-7	<100
	HYPALON	<100
	AMERON POLYURETHANE	100
	AMERCOAT 90	100

TABLE IV

RUST GRADE EVALUATIONS AFTER 18-MONTH SEACOAST EXPOSURE FOR TATOR AND FLAT PANELS

COATING SYSTEM		SCRIBE RATING**	ASTM D-610-68(74) RUST GRADES* NORMAL EXPOSURE	ACID TREATED	ACID TREATED AND RINSED
IZ-1	AMERON EZ-II	2	4	3.5	2
	CARBOLINE SP-76	5	8	3	4
	COOK GALVAPAC 300	3	8	4	3
	GLIDZINC 5535	2	8.5	4	4
	INTERZINC QHA 0043	2	2.5	3.5	3
	MATCOTE 1-287	3	8	6	4
	MOBILZINC GRAY	1	6	2	2
	MOBILZINC GREEN	1	6	2.5	2
	O'BRIEN NAPKO 1Z	3	9	3.5	3.5
	PPG METALHIDE	3	5	3.5	3
	SUBOX GALVANOX IV	5	9	4	2.5
IZ-2	AMERON D-6	5	10	6	6.5
	MOBIL 7	5	10	7	8
EU-TOPCOAT	AMERON EZ-II/AMERCOAT 182/450	3	7	6.5	6
	CARBOLINE EPOXY/POLYURETHANE	5	6.5	5.5	6
	COOK COPOXY/ACROTHANE	3	7	6	4.5
	GLIDDEN GLIDGUARD/GLIDTHANE	1	6	6	7

*AVERAGE VALUE FOR FOUR PANELS OF EACH COATING SYSTEM, EXCEPT FOR THE GALV AND MFR SYSTEMS WHICH ARE REPRESENTED BY ONLY 2 PANELS PER SYSTEM.

**SEE SECTION 4.2.17

TABLE IV (CONT'D)

RUST GRADE EVALUATIONS AFTER 18-MONTHS SEACOAST EXPOSURE FOR TATOR AND FLAT PANELS

	COATING SYSTEM	SCRIBE RATING**	ASTM D-610-68(74) RUST GRADES* NORMAL EXPOSURE	ACID TREATED	ACID TREATED AND RINSED
	INTERGUARD/INTERTHANE	3	6	7.5	7
	MATCOTE 1-825/2-500	1	7	8	6.5
	MOBIL VALCHEM 13-R-61/40	3	6.5	6	6
	O'BRIEN EPOXYCOTE/NAPTHANE	3	7	6	6
	PPG AQUAPON/PITTHANE	1	5.5	6.5	5
	SUBOX CAPOX/SUBTHANE	3	6	7	6
	AMERON D-6/AMERCOAT 182/450	3	9	7.5	8
	MOBIL 7/VALCHEM 13-R-61/40	3	9***	8	9***
	PPG AQUAPON/PITTHANE ON AMERON EZ-II		6		
	PPG AQUAPON/PITTHANE ON COOK GALVAPAK		7		
	PPG AQUAPON/PITTHANE ON AMERON EZ		5.5		
ALT-	AMERON 390 EPOXY MASTIC	1	3	5	4
TOPCOAT	CARBOLINE CARBOMASTIC	1	3	4	4
	GLIDDEN EPOXY MASTIC	1	1	1	1
	MOBIL ALUMAPOXY	1	2.5	5	3
	PPG SILICONE ACRYLIC	3	7	6	5
	AMERCOAT 741	5	10	10	10

*AVERAGE VALUE FOR FOUR PANELS OF EACH COATING SYSTEM, EXCEPT FOR THE GALV AND MFR SYSTEMS WHICH ARE REPRESENTED BY ONLY TWO PANELS PER SYSTEM.

**SEE SECTION 4.2.17

***COATING IS DELAMINATING; HOWEVER, NO CORROSION WAS OBSERVED.

TABLE IV (CONT'D)

RUST GRADE EVALUATIONS AFTER 18-MONTHS SEACOAST EXPOSURE FOR TATOR AND FLAT PANELS

COATING SYSTEM		SCRIBE RATING**	ASTM D-610-68(74) RUST GRADES* NORMAL EXPOSURE	ACID TREATED	ACID TREATED AND RINSED
GALV	UNBLASTED INDUSTRIAL GALVANIZED	5	10		
	BLASTED INDUSTRIAL GALVANIZED	5	10		
	PPG AQUAPON/PITTHANE				
	ON ACID-ETCHED GALVANIZED		9***		
	ON GRIT-BLASTED GALVANIZED		10		
MFR-I-	MATCOTE 1-287		10		
IZ-1	MOBILZINC GREEN		10		
	MATCOTE 1-825/2-500		7		
MFR-EU-	MOBIL VALCHEM 13-R-61/40		7		
TOPCOAT	DU PONT ZINC		7.5		
	DU PONT EPOXY URETHANE		7.5		
Al	GOODRICH AR-7	3	9.5	7	7
	GATES HYPALON-Al	2	7	6	5
	AMERCOAT 182/450 ON GRIT-BLASTED	1	2	2	2
	AMERCOAT 182/450 ON WASH-PRIMED	1	6	2	2
	AMERON EPOXY 66 ON WASH-PRIMED	1	2	1.5	2
	ANODIZED		5	5	4
	IRIDITED		5	1	1

*AVERAGE VALUE FOR FOUR PANELS OF EACH COATING SYSTEM, EXCEPT FOR THE GALV AND MFR SYSTEMS WHICH ARE REPRESENTED BY ONLY TWO PANELS PER SYSTEM.

**SEE SECTION 4.2.17

***COATING IS DELAMINATING; HOWEVER, NO CORROSION WAS OBSERVED.

TABLE IV (CONT'D)

RUST GRADE EVALUATIONS AFTER 18-MONTHS SEACOAST EXPOSURE FOR TATOR AND FLAT PANELS

COATING SYSTEM		SCRIBE RATING**	ASTM D-610-68(74) RUST GRADES* NORMAL EXPOSURE	ACID TREATED	ACID TREATED AND RINSED
SS	GOODRICH AR-7	5	9.5	10	10
	GATES HYPALON-A1	5	10	10	10
	AMERCOAT 182/450	5	10	10***	10***
	AMERCOAT 90 MODIFIED EPOXY	5	10	10	10

*AVERAGE VALUE FOR FOUR PANELS OF EACH COATING SYSTEM, EXCEPT FOR THE GALV AND MFR SYSTEMS WHICH ARE REPRESENTED BY ONLY TWO PANELS PER SYSTEM.

**SEE SECTION 4.2.17

*** COATING IS DELAMINATING; HOWEVER, NO CORROSION WAS OBSERVED.

TABLE V

RUST GRADE EVALUATIONS AFTER 18-MONTHS SEACOAST EXPOSURE FOR REPAIR PANEL

	SPRAYED					BRUSHED					
	NG	CG	SD	OS	SW	NG	CG	SD	OS	SW	OZ*
REPAIR COATING ON SAME INORGANIC ZINC:											
AMERON EZ	7.0	5	3.5	4	3.5	1	2	3	2	2	-
AMERON EZ-II	4	5	1	5	1.5	1	1	1	2	1	3
CARBOLINE SP-76	4	7	2.5	4	4.5	5	7	4	4	4	5
COOK GALVAPAC 300	4	8	3.5	5	4.5	1.5	4	2	4	1	2
GLIDZINC 5535	3.5	5	1	5	3	4	6	1	3	1.5	3
INTERZINC QHA 0043	5.5	5	5	5	5.5	4	3	3.5	1	4	4
MATCOTE 1-287	6.5	8	3.5	2	5	6	4	3	3	4.5	5
MOBILZINC GREEN	3.5	2	2	3	1	3	1	2	3	1	3
O'BRIEN NAPKO IZ	3	3	2	1	1.5	1	1	1	1	1	1
PPG METALHIDE	4	6	3	2	3.5	4.5	4	4	4	2.5	3
SUBOX GALVANOX IV	4.5	7	1	5	4	4.5	7	1	4	3	5
REPAIR COATING ON AMERON EZ:											
CON LUX ZINC PLATE	3	2	1	**	1.5	2.5	2	1	1	1	**
AMERCOAT 182/450 EPOXY URETHANE	4.5	3	6	2	6.5	3	3	3	3	3	4
AMERCOAT 390 EPOXY	2	1	1	2	2	2	2	1	3	3	**

NOTE: MOST VALUES ARE AVERAGE OF TWO PANEL EVALUATIONS.

* - ORGANIC ZINC INSTEAD OF THE DESIGNATED INORGANIC ZINC WAS BRUSH APPLIED TO NEEDLE GUN CLEANED SURFACE.

** - NOT TESTED

TABLE VI

AVERAGING OF DIFFERENT PANEL RATINGS FOR SAMPLE SYSTEMS

CASE	PANEL RATINGS	ARITHMETIC MEAN	GEOMETRIC MEAN	TOTAL AREA RATING
A	6, 6, 5, 7	6	6.0	6
B	8, 8, 10, 10	9	8.9	8
C	4, 4, 7, 7	5.5	5.3	4
D	4, 9, 9, 9	8	7.4	5
E	9, 2, 2, 3	4	3.2	3

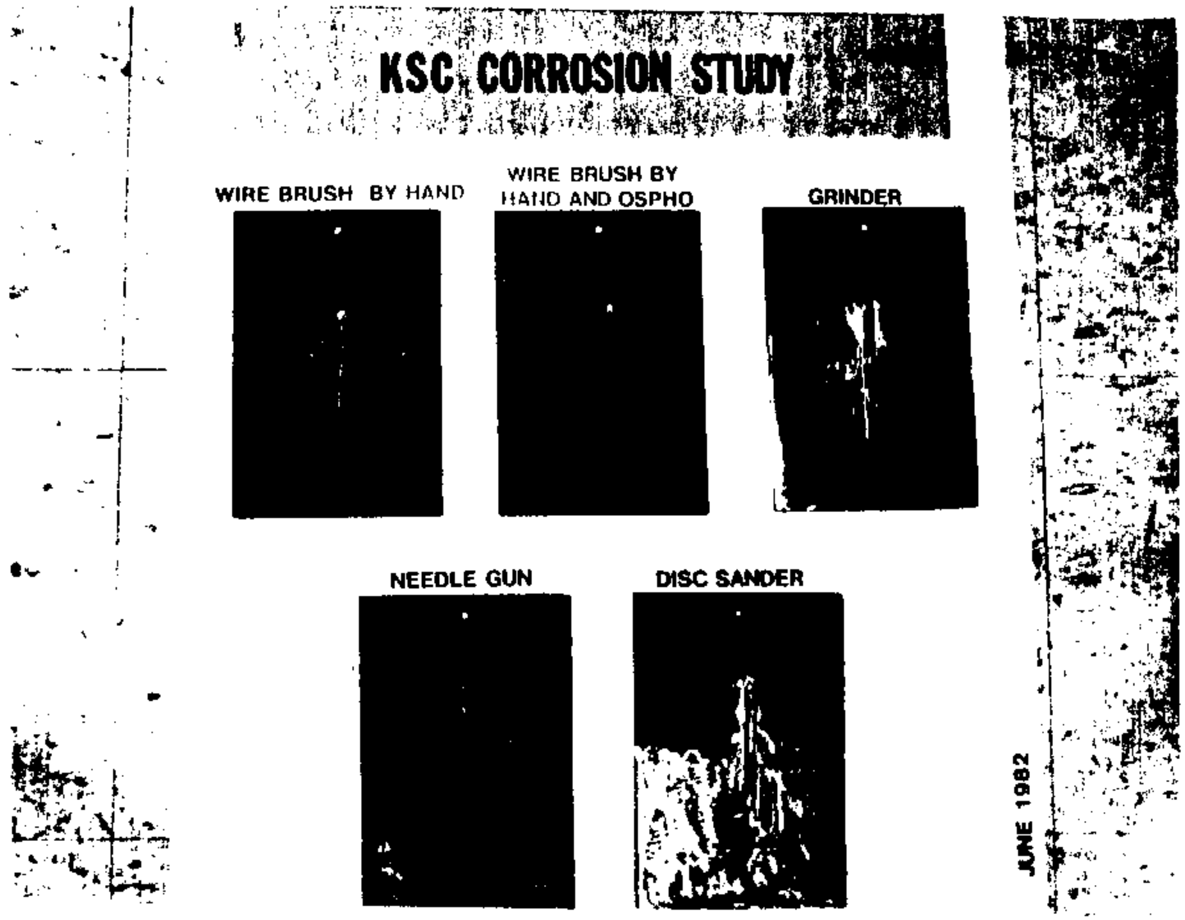

FIGURE 1
OVERALL VIEW OF SURFACE PREPARATION FOR REPAIR PANELS

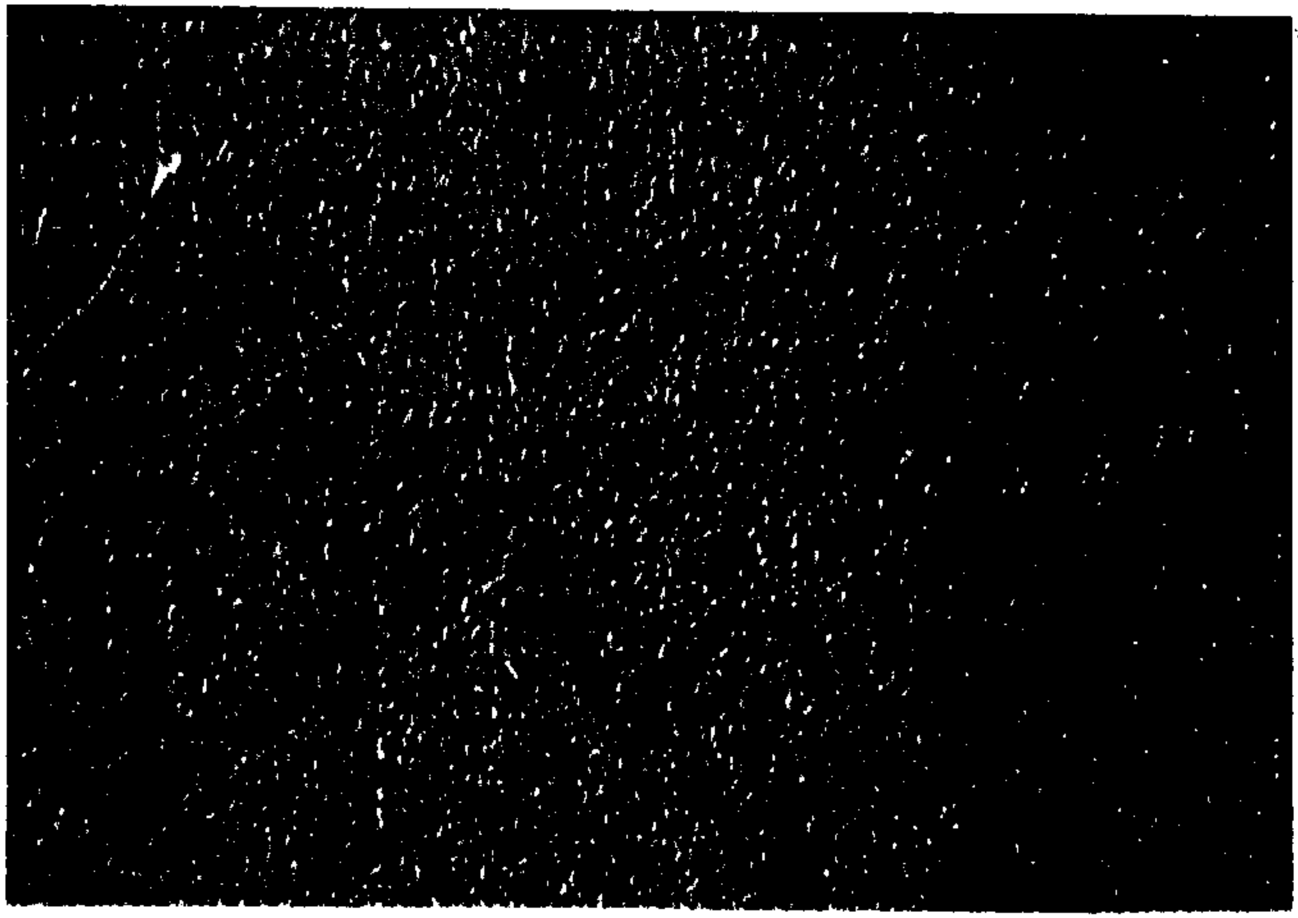

FIGURE 2
SURFACE PREPARED WITH WIRE BRUSH BY HAND

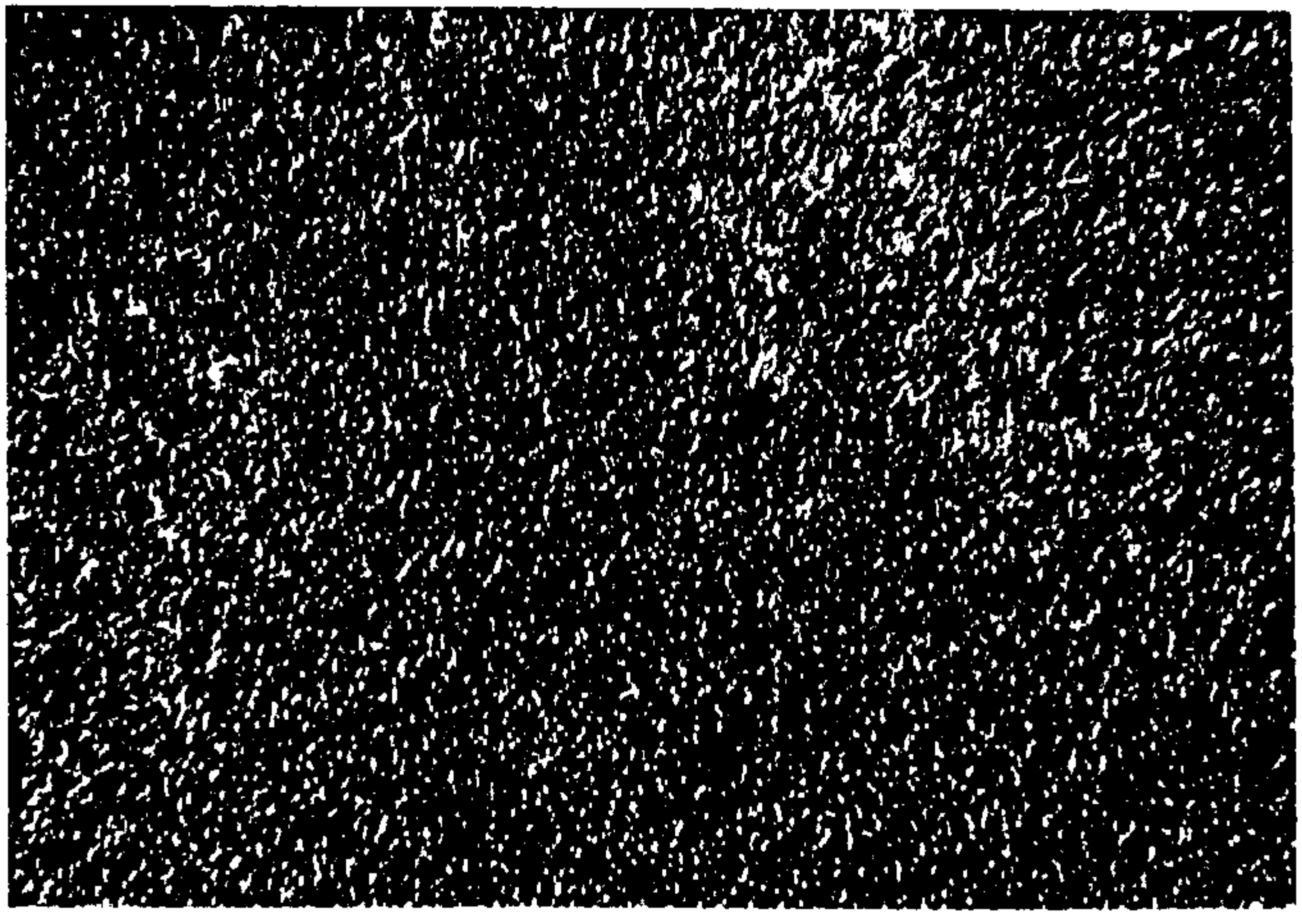

FIGURE 3
SURFACE PREPARED WITH WIRE BRUSH BY HAND THEN OSPHO APPLIED

FIGURE 4
SURFACE PREPARED WITH COARSE GRINDER

FIGURE 5
SURFACE PREPARED WITH NEEDLE GUN

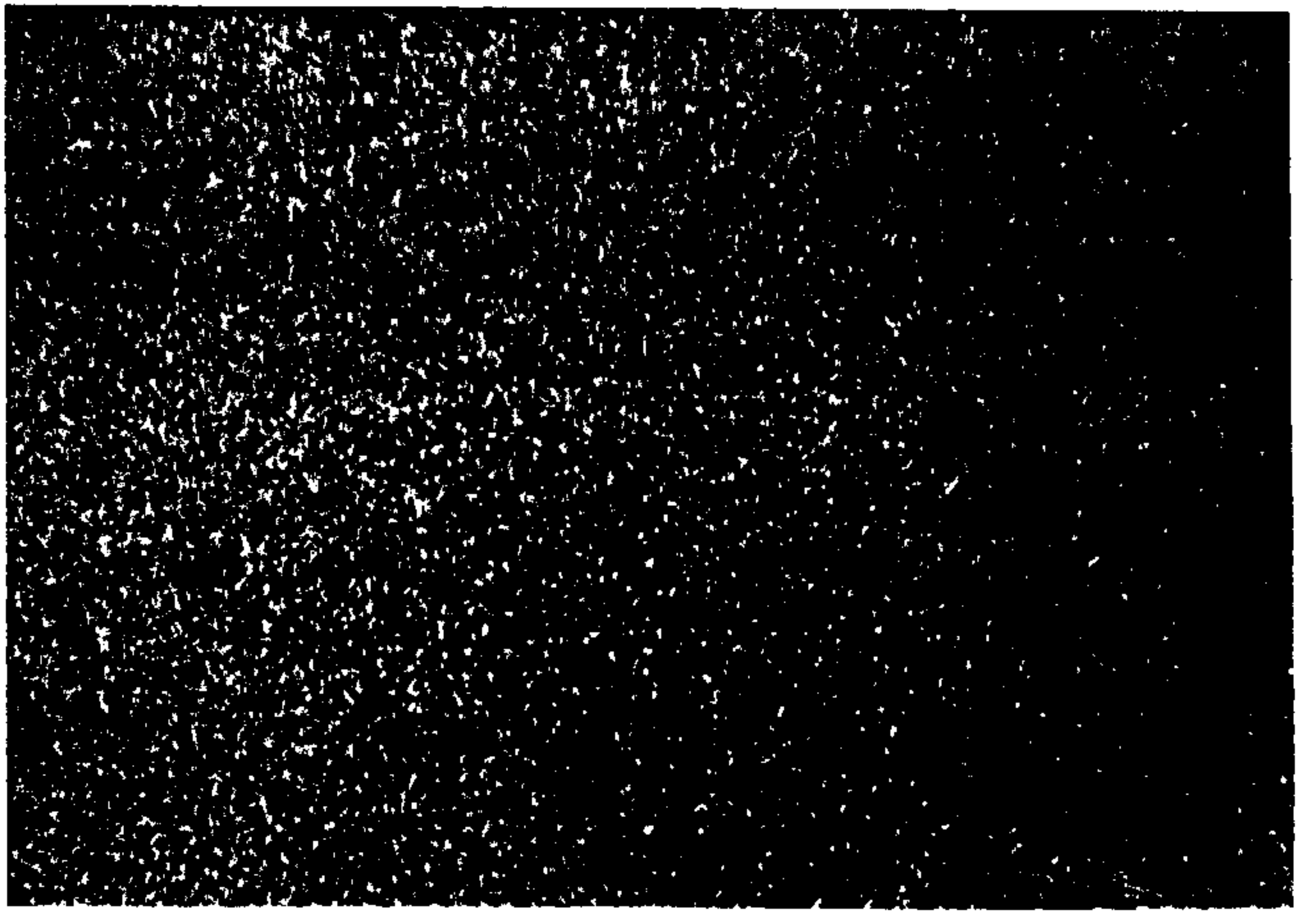

FIGURE 6
SURFACE PREPARED WITH DISC SANDER

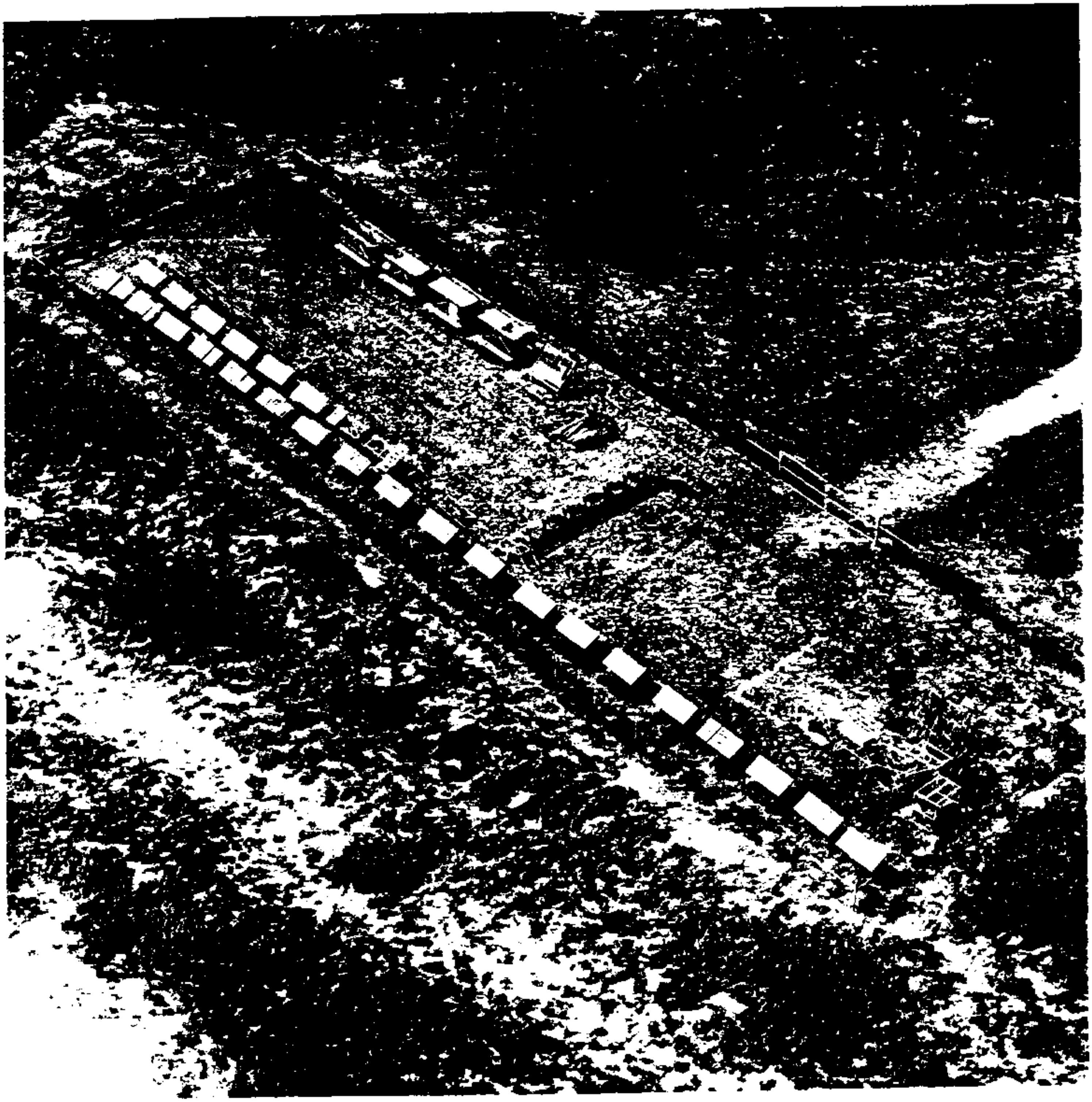

FIGURE 7
OVERALL VIEW OF KSC BEACH CORROSION TEST SITE

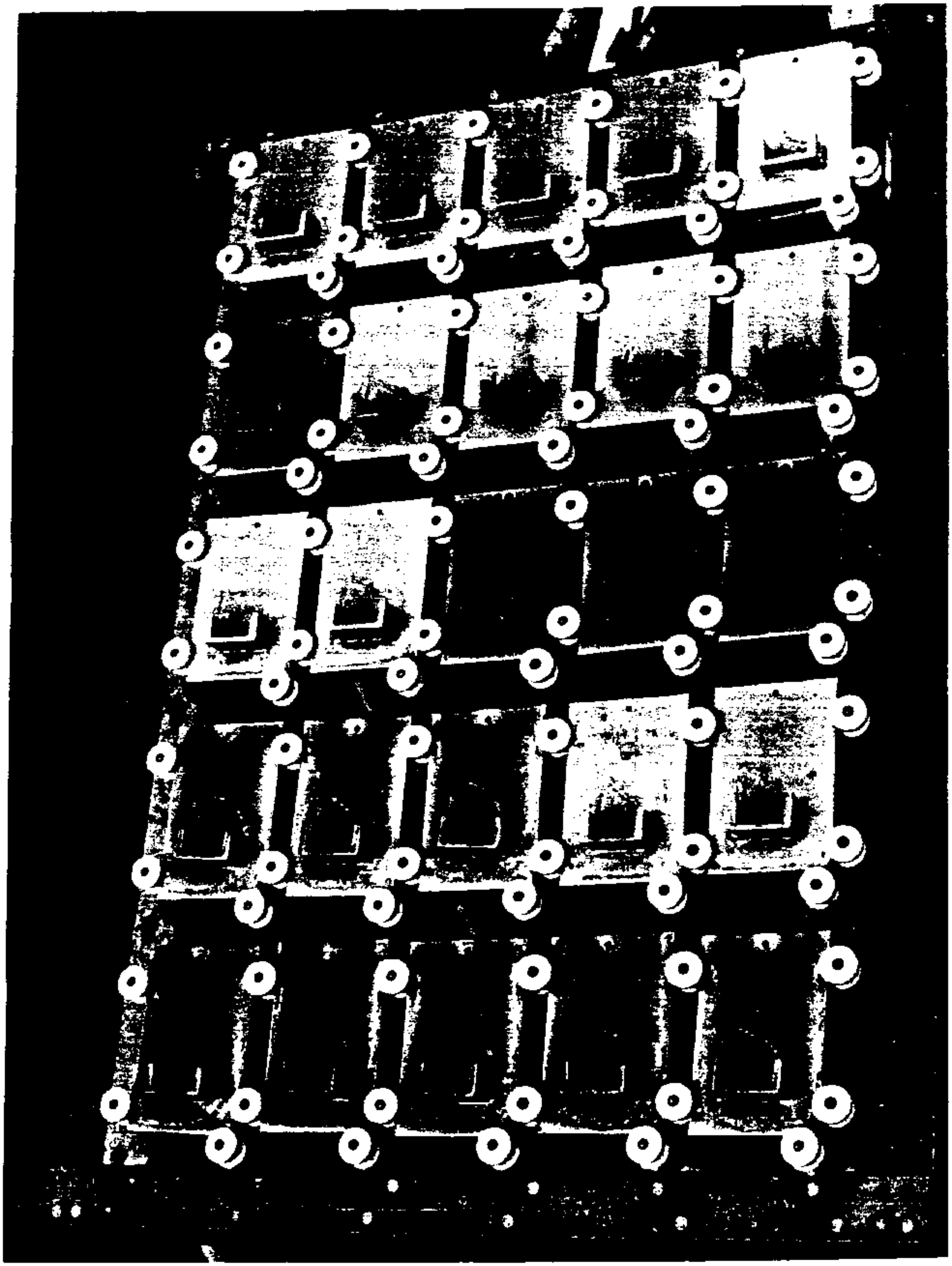

FIGURE 8
A TEST RACK WITH PANELS INSTALLED

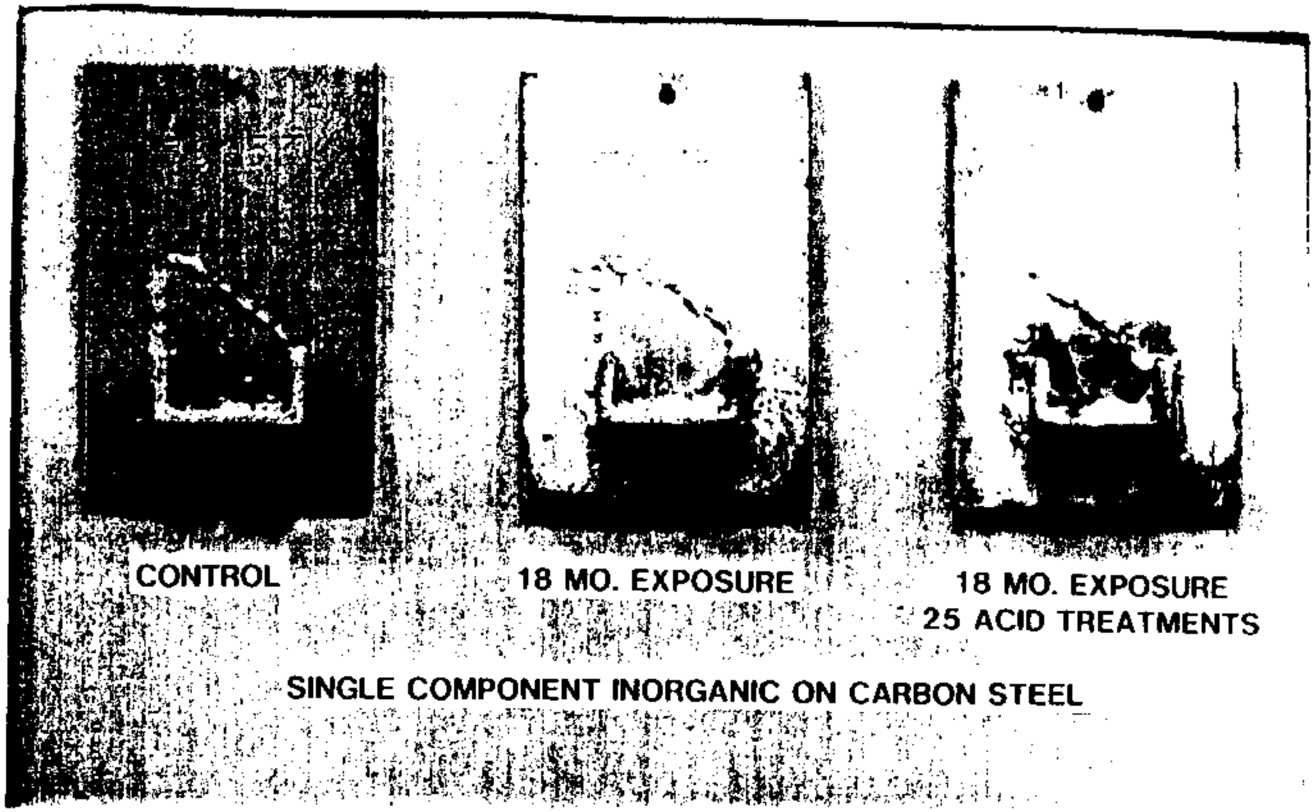

FIGURE 9
UNTOPCOATED SINGLE-COMPONENT INORGANIC ZINC, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

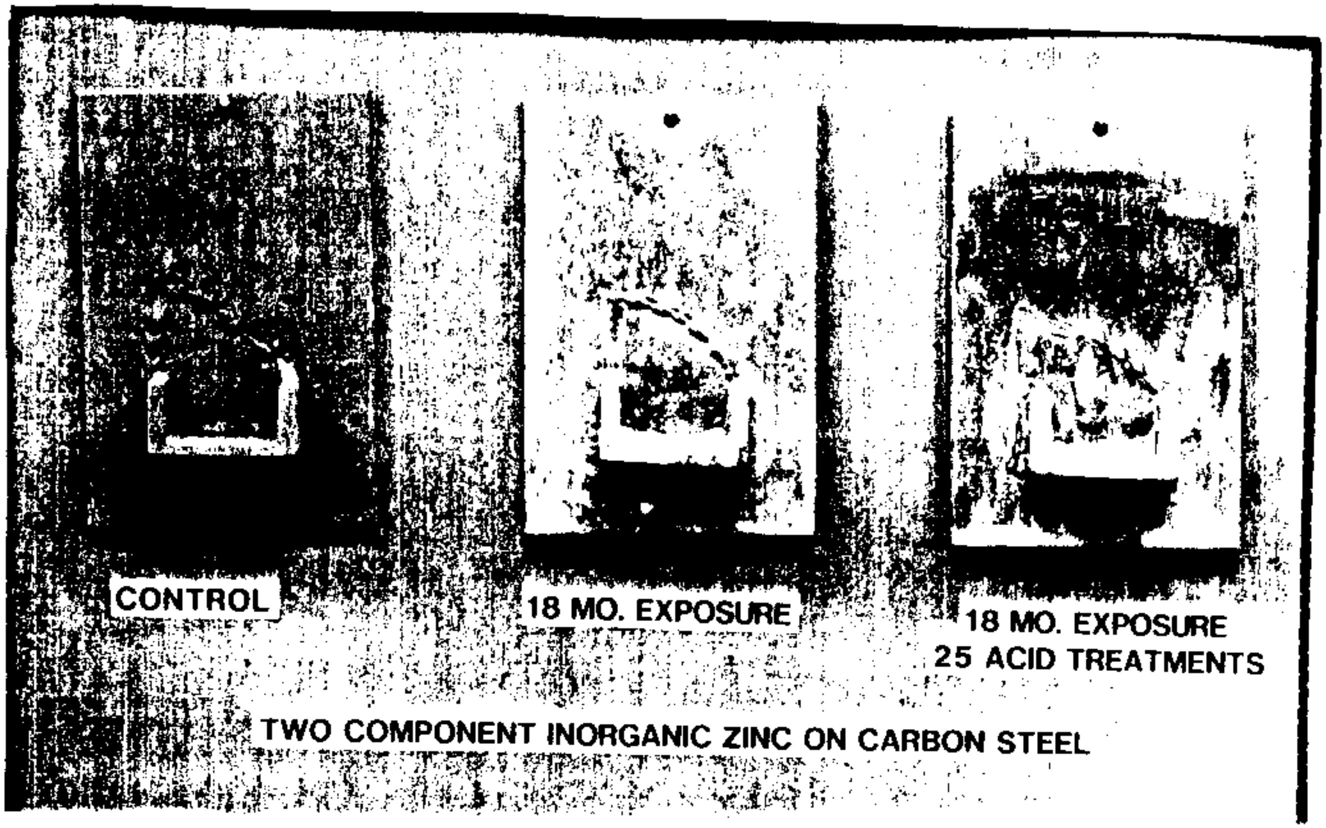

FIGURE 10
UNTOPCOATED TWO-COMPONENT INORGANIC ZINC, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

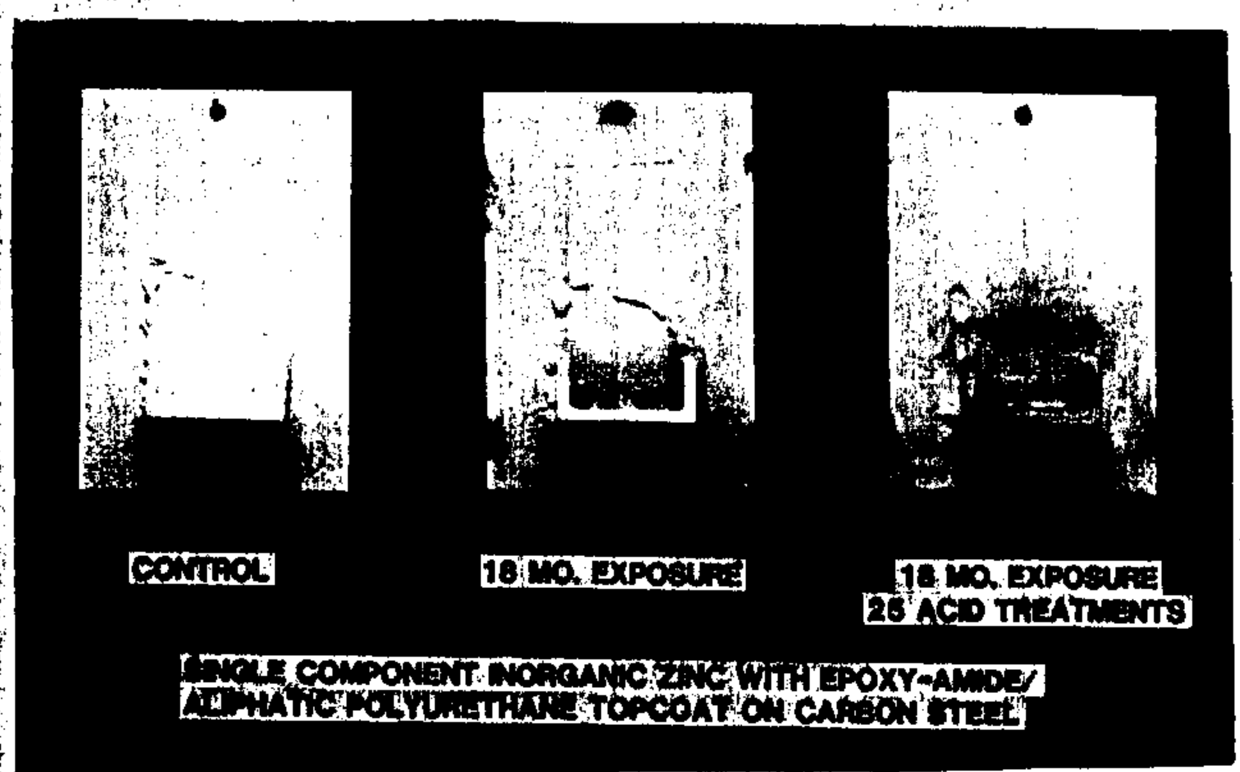

FIGURE 11
TOPCOATED SINGLE COMPONENT INORGANIC ZINC, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

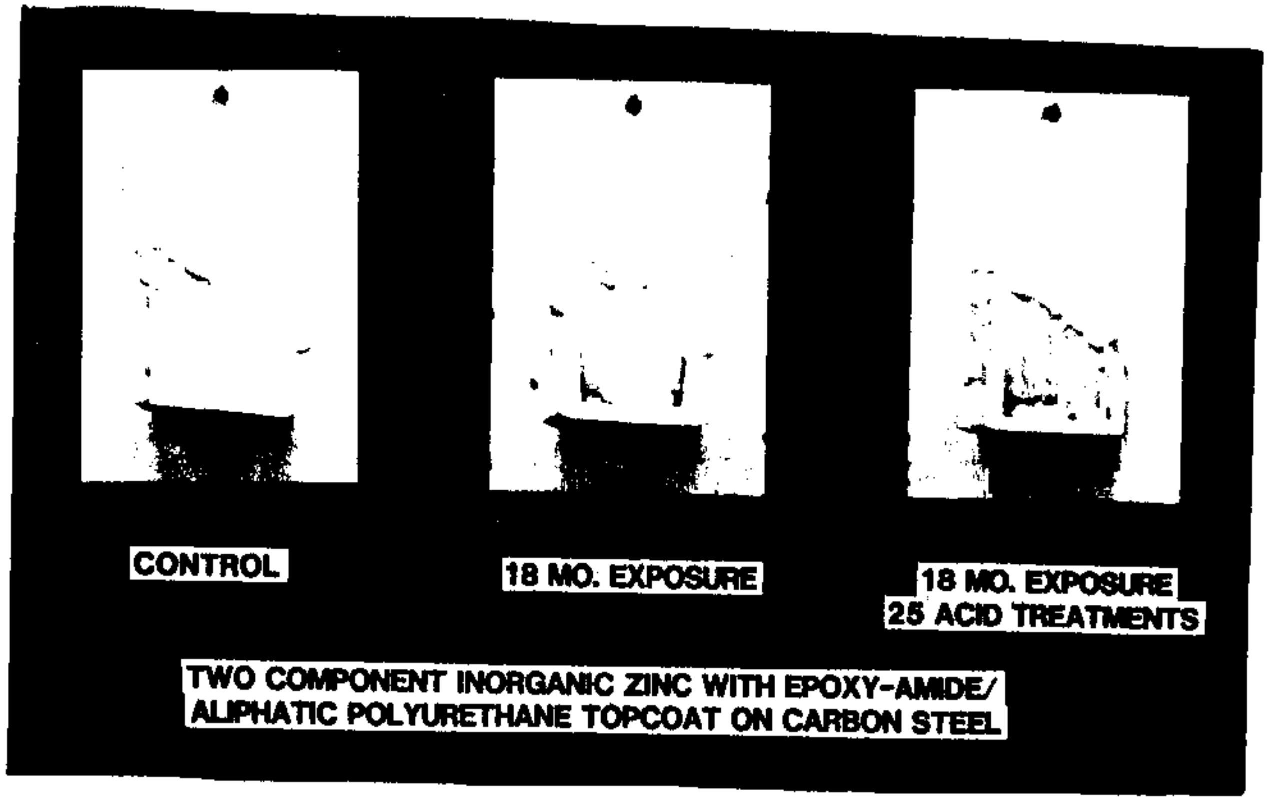

FIGURE 12
TOPCOATED TWO-COMPONENT INORGANIC ZINC, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

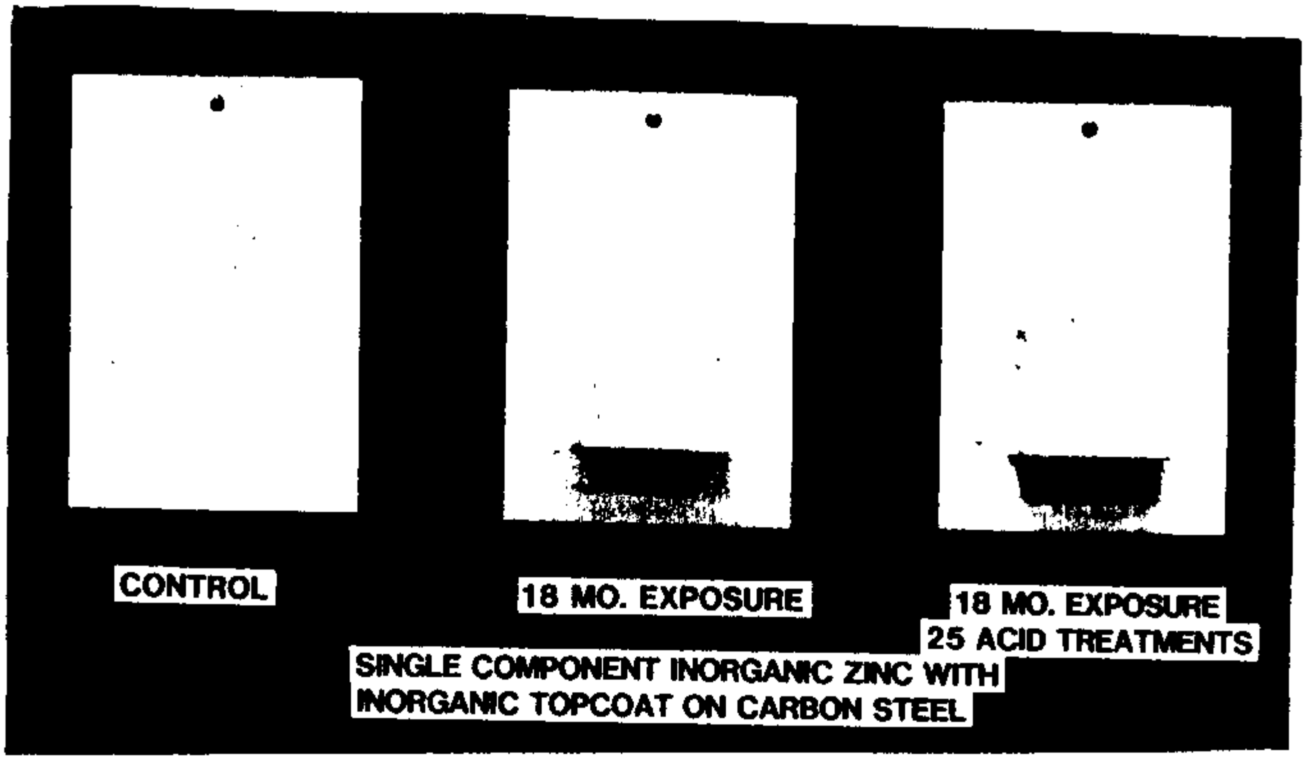

FIGURE 13
INORGANIC TOPCOAT AMERCOAT 741 OVER A SINGLE-COMPONENT INORGANIC ZINC AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

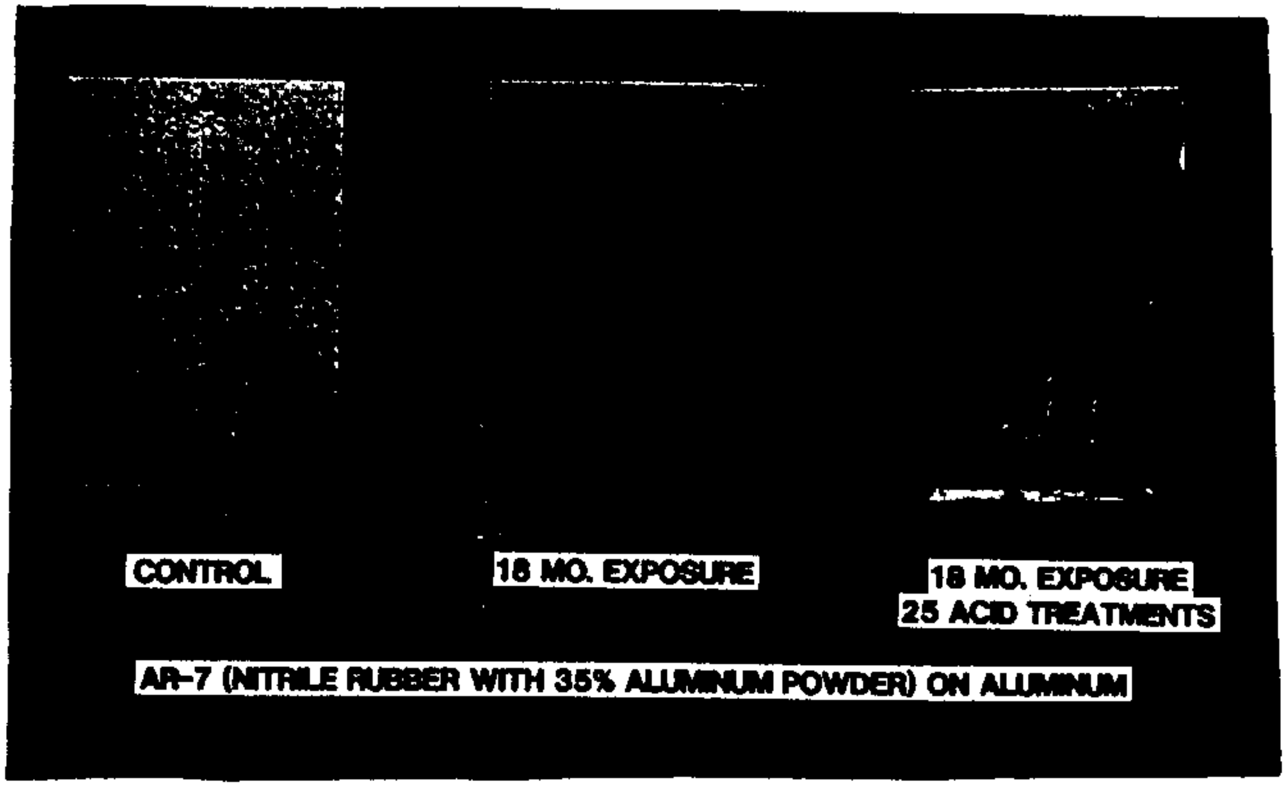

FIGURE 14
AR-7 ON ALUMINUM, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

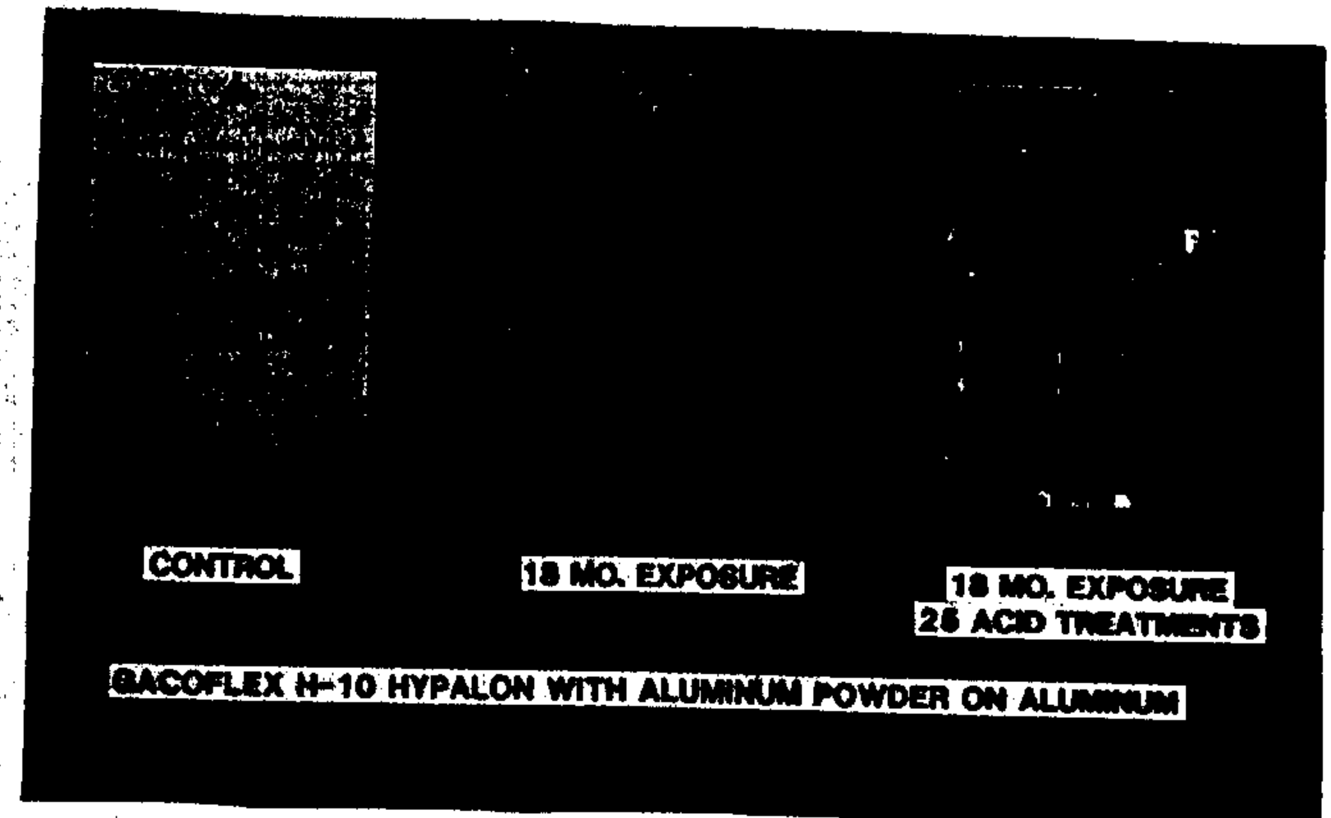

FIGURE 15
GACOFLEX H-10 HYPALON ON ALUMINUM, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

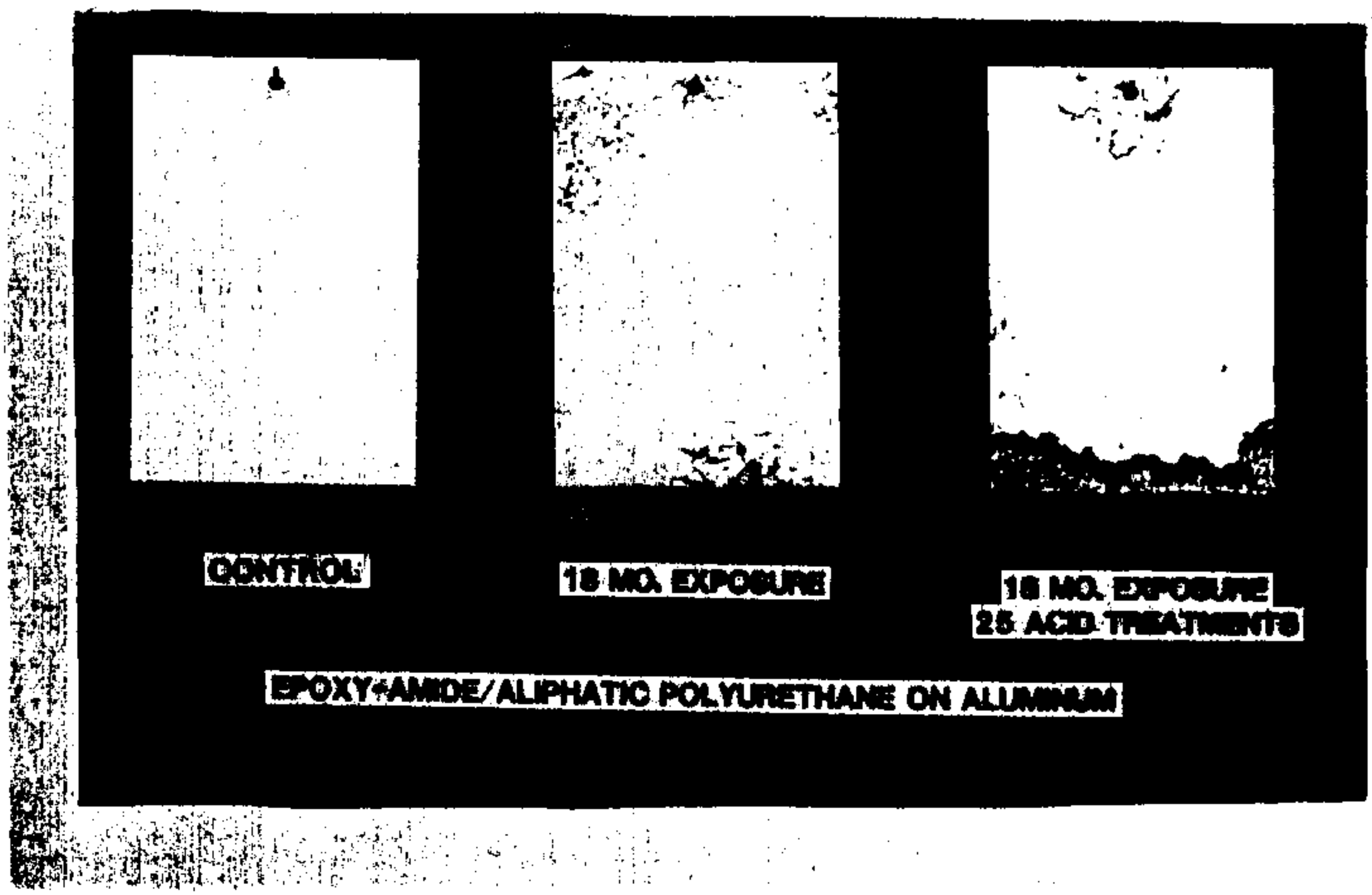

FIGURE 16
EPOXY/POLYURETHANE ON ALUMINUM, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

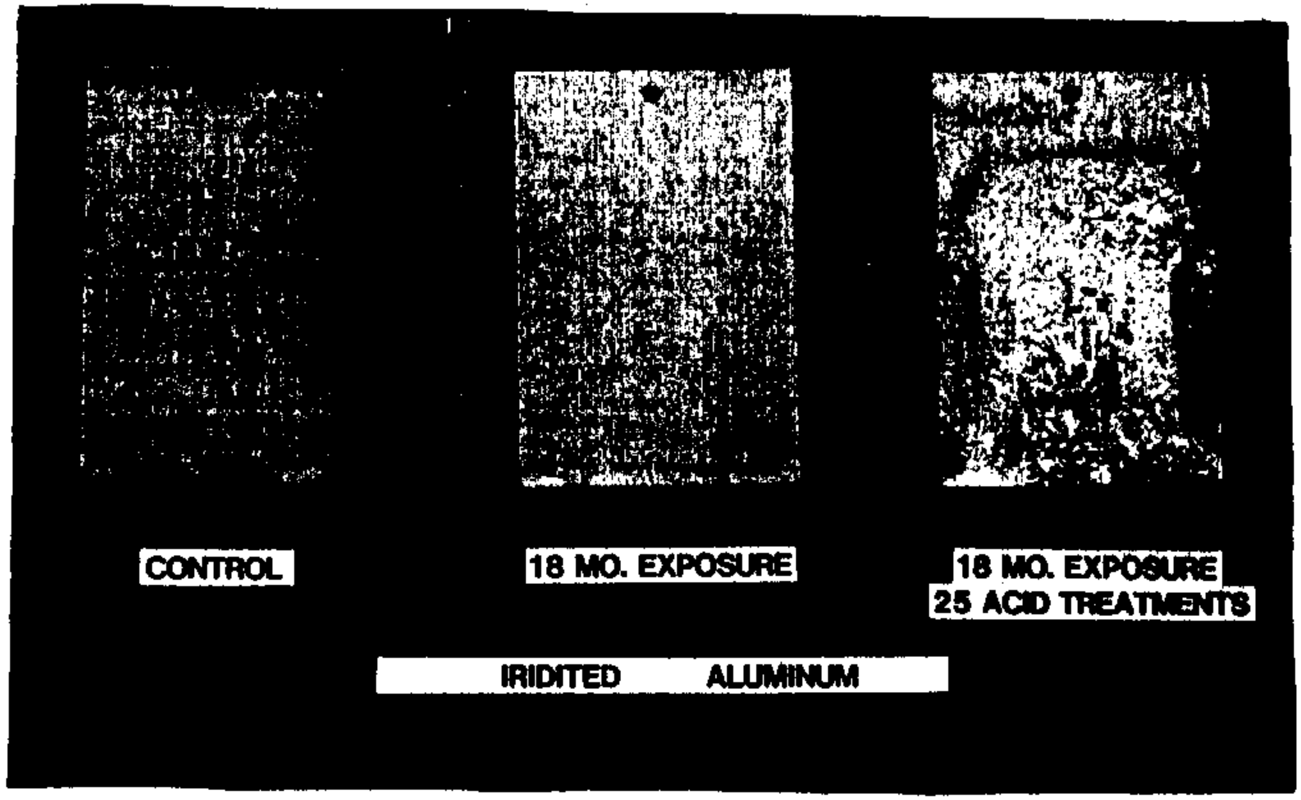

FIGURE 17
IRIDITED ALUMINUM, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

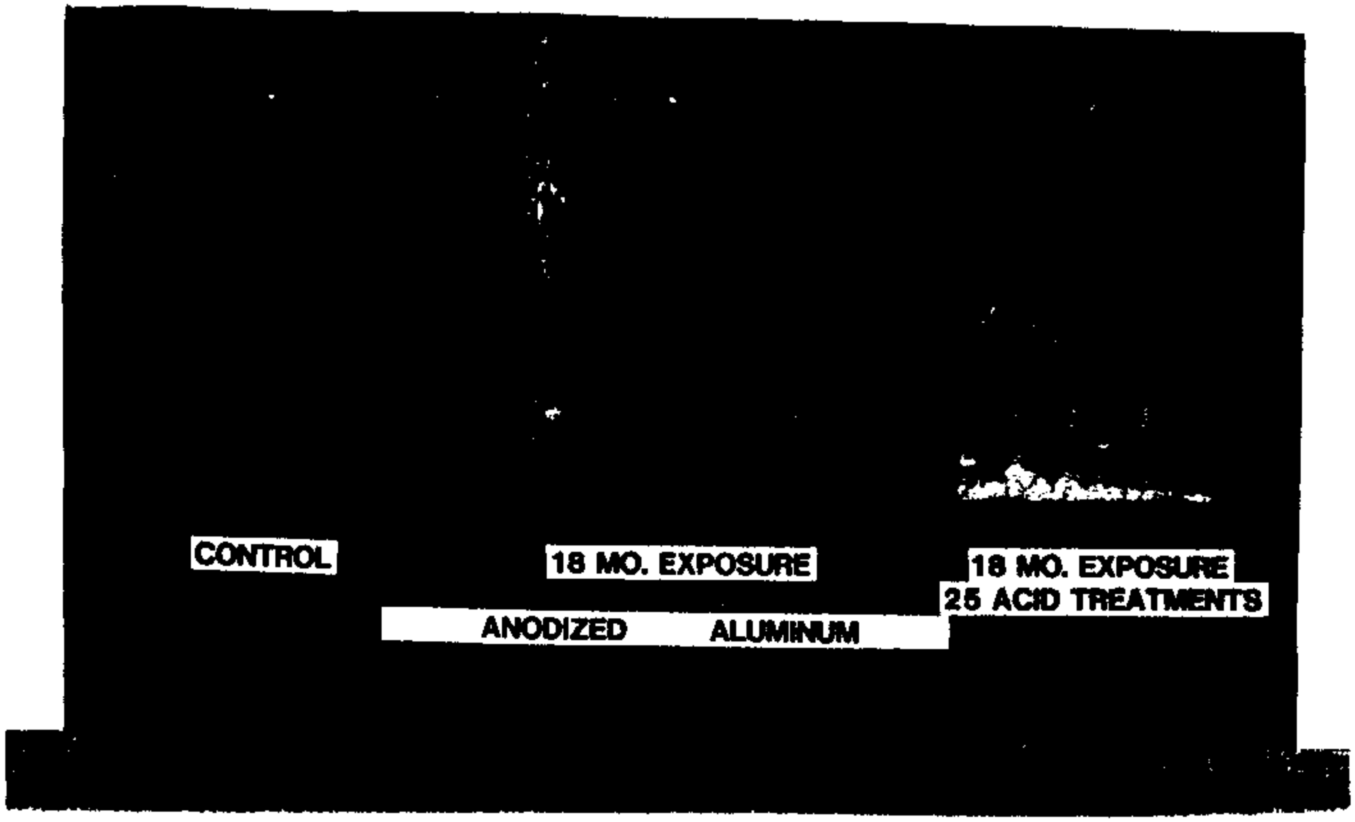

FIGURE 18
ANODIZED ALUMINUM, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

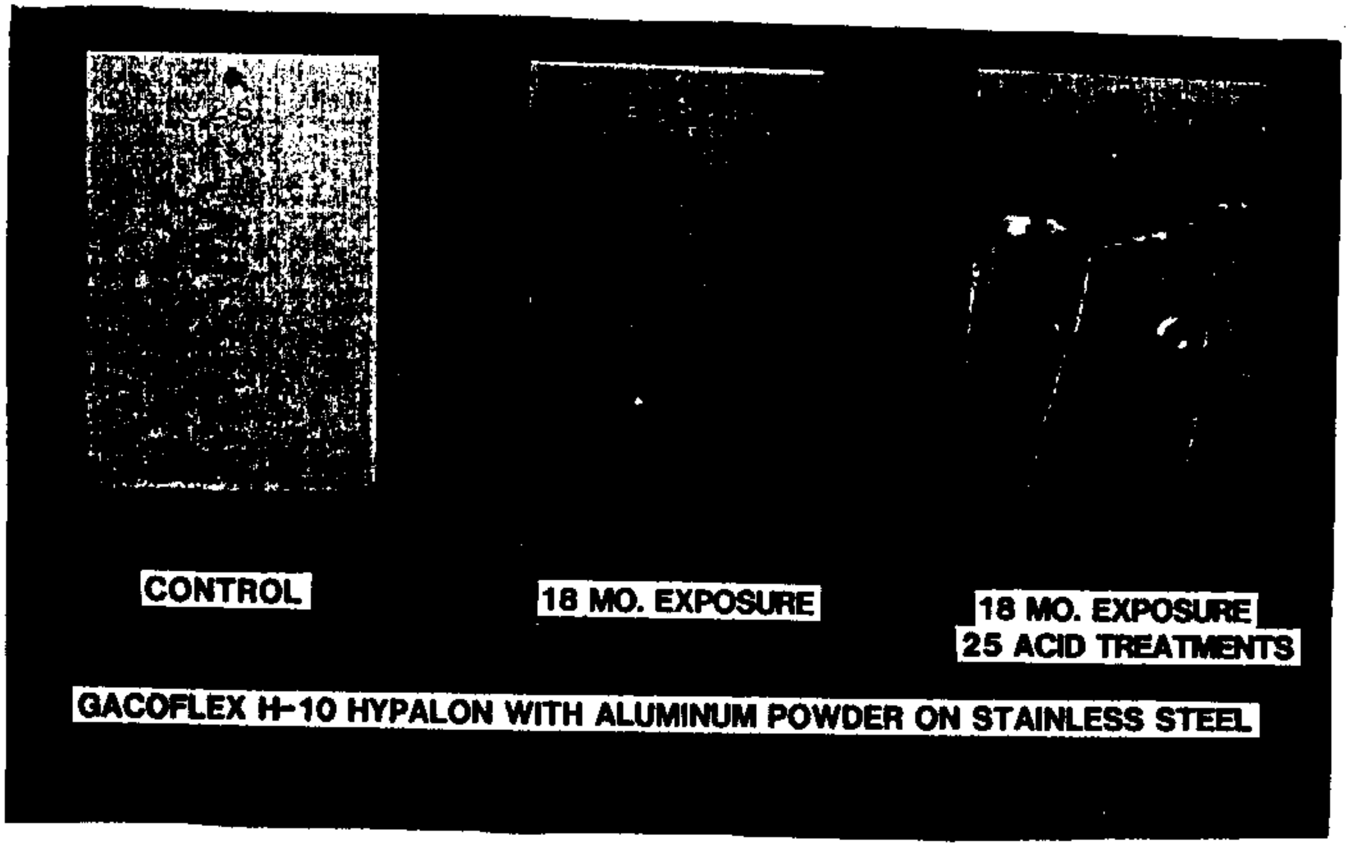

FIGURE 19
GACOFLEX H-10 HYPALON ON STAINLESS STEEL AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

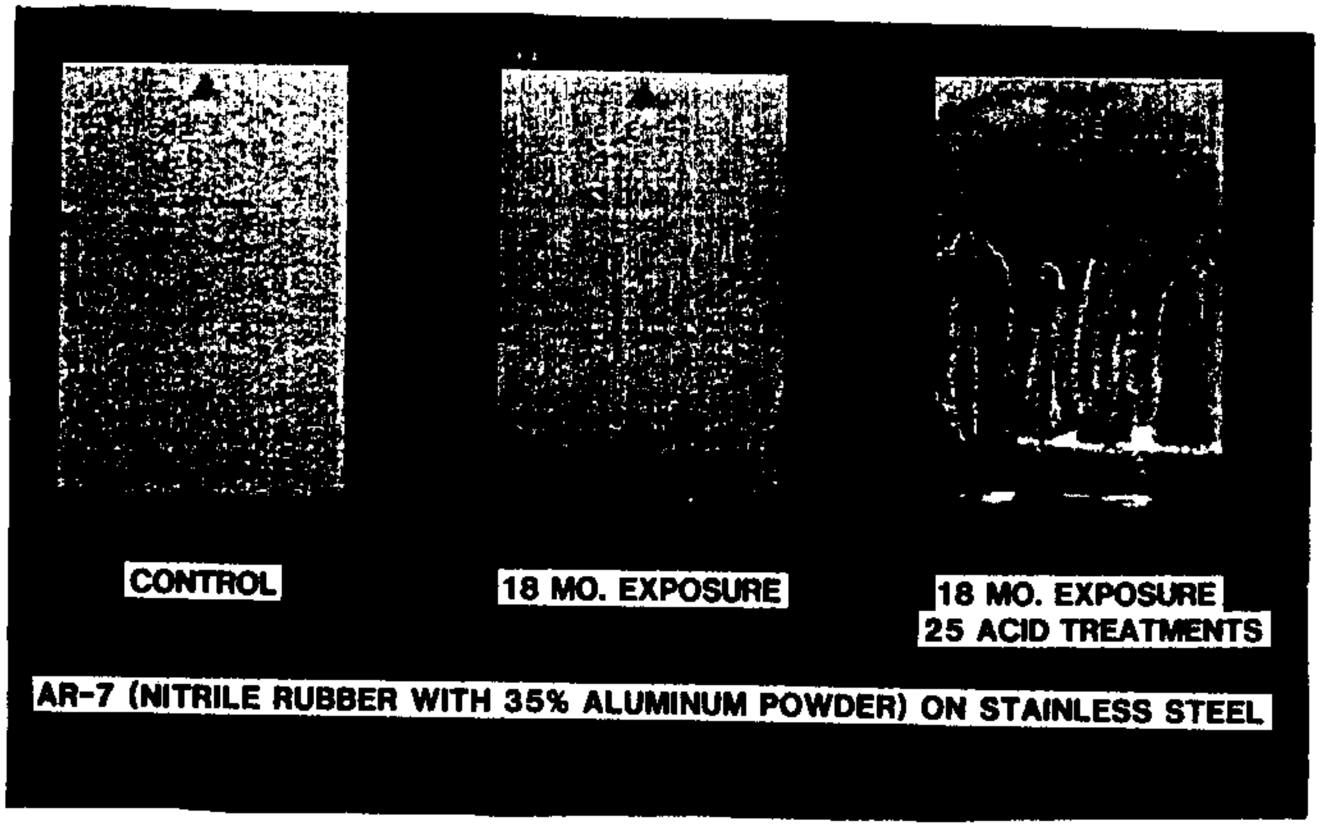

FIGURE 20
AR-7 ON STAINLESS STEEL, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

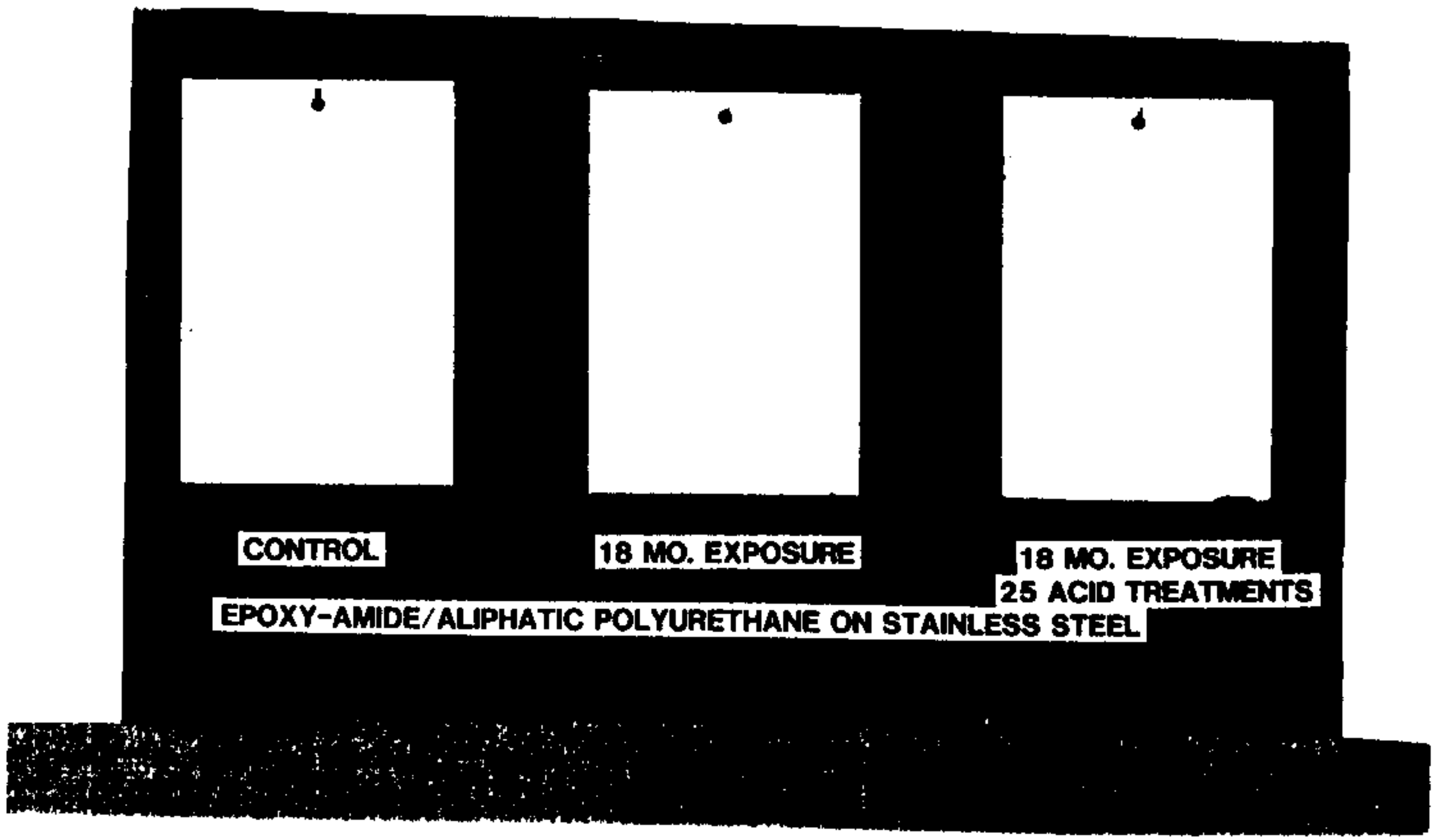

FIGURE 21
EPOXY/POLYURETHANE ON STAINLESS STEEL, AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

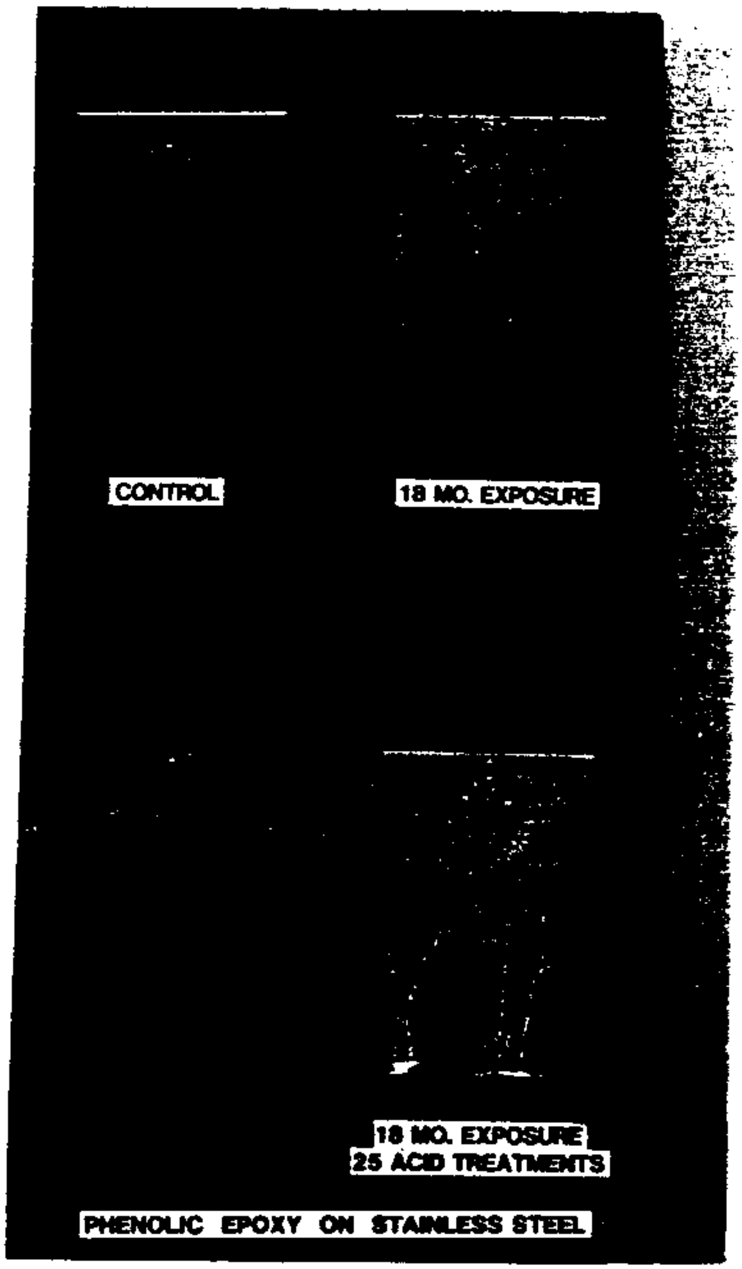

FIGURE 22
PHENOLIC EPOXY ON STAINLESS STEEL AFTER 18 MONTHS OF NORMAL AND ACID EXPOSURE

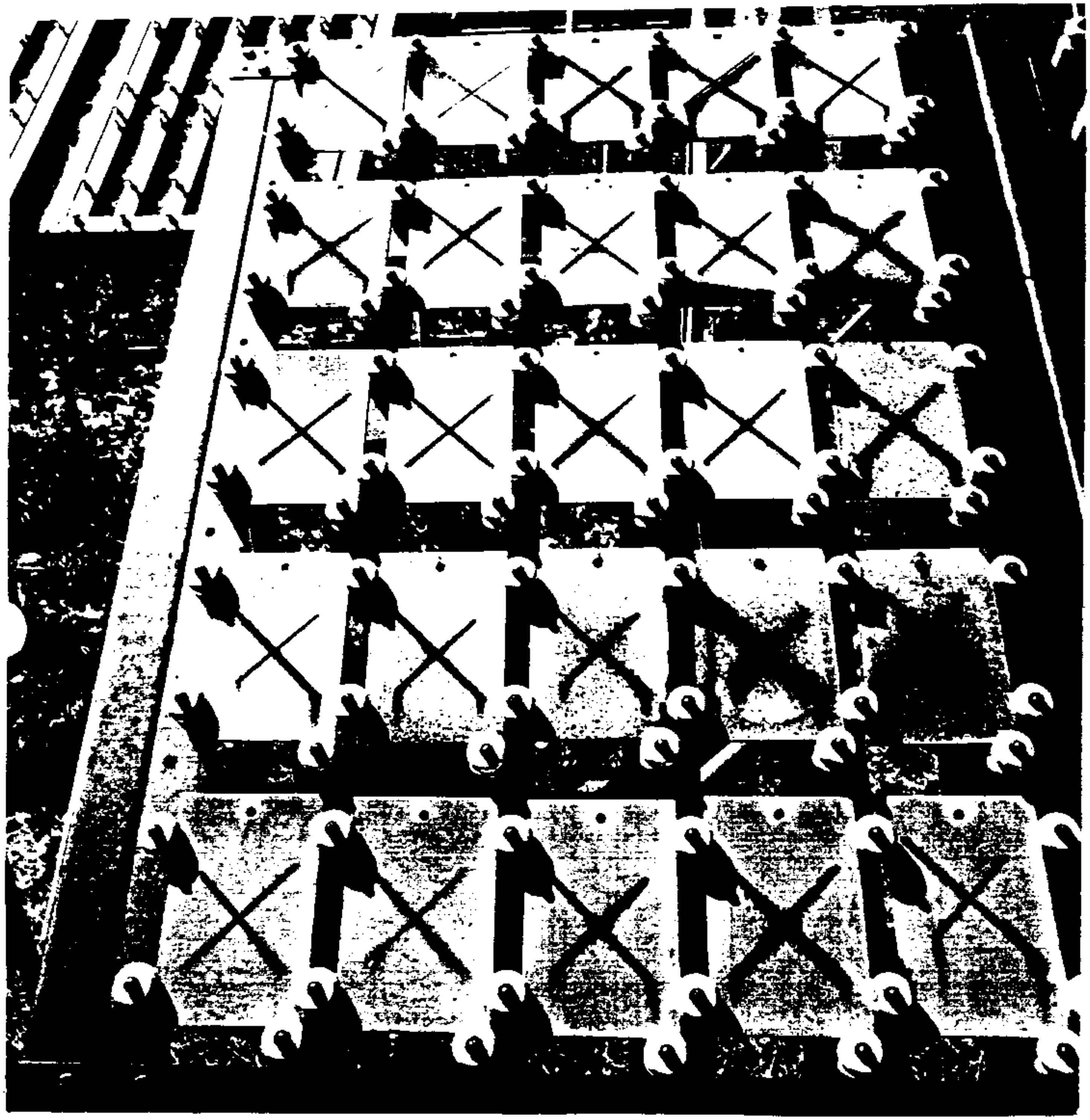

FIGURE 23
SCRIBED PANELS IN VARIOUS STAGES OF CORROSION SPREAD

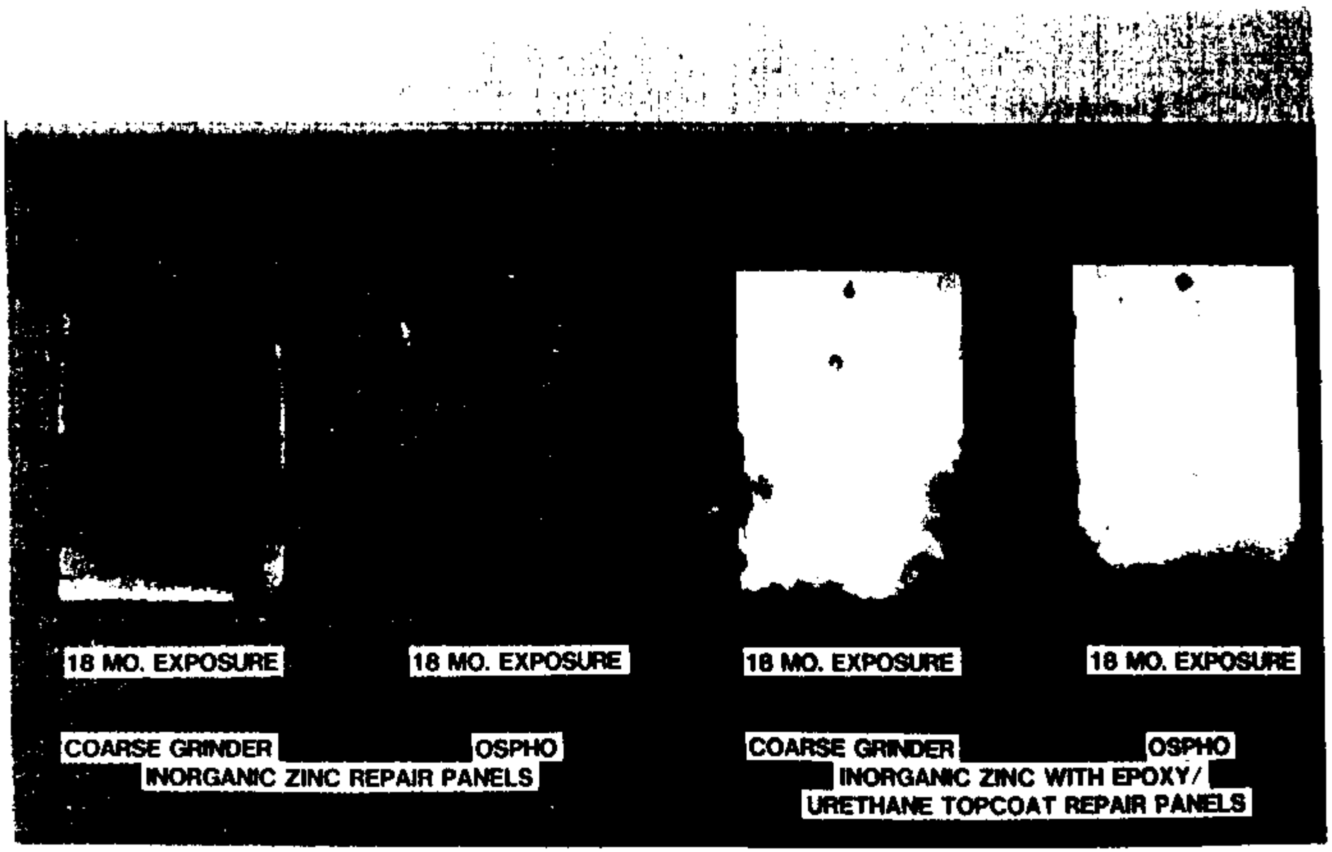

FIGURE 24
SAMPLES OF REPAIR SYSTEMS FOR SINGLE-COMPONENT INORGANIC ZINCS AND SINGLE-COMPONENT INORGANIC ZINCS WITH EPOXY POLYURETHANE TOPCOATS

APPENDIX

APPLICATION DATA

MANUFACTURER: AMERON PROTECTIVE COATINGS DIVISION
PRIMER: DIMETCOTE E-Z II INORGANIC ZINC
TIE COAT: AMERCOAT 182 EPOXY-POLYAMIDE
TOPCOAT: AMERCOAT 450 ALIPHATIC POLYURETHANE

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	YES	YES	NO
CONSISTENCY	SOFT	SOFT	SOFT
SEPARATION	YES	YES	NO
MIXING:			
MECHANICAL	EASY	EASY	
HAND	DIFFICULT	DIFFICULT	EASY
THINNING REQUIRED	NO	NO	NO
APPLICATION:			
FLUID PRESSURE, PSI	18	5	5
AIR PRESSURE, PSI	43	40	45
ATOMIZATION	GOOD	GOOD	GOOD
FLOW	GOOD	FAIR	GOOD
APPEARANCE	SMOOTH	SMOOTH	SMOOTH
DEFECTS			
COLOR	UNIFORM GREEN	UNIFORM RED	UNIFORM WHITE
THICKNESS, MILS:			
WET FILM	7	5	6
DRY FILM	4 1/2	3	3 1/2
MAXIMUM DFT WITHOUT SAGGING	30	30	4
MAXIMUM DFT WITHOUT CRACKING	40		
DRYING TIME, HOURS:			
TO TOUCH	1/6	1/4	1
THROUGH	1/2	1	OVERNIGHT
METALLIC POLISH	OVERNIGHT		

COMMENTS: PRIMER SPRAYED WELL WITH NO RUNNING OR CRACKING. TIE COAT BUILT HIGH MILS RAPIDLY, SOFT TO RECOAT AFTER 40 HOURS. TOPCOAT SPRAYED WELL AND BUILT HIGH MILS.

MANUFACTURER: AMERON PROTECTIVE COATINGS DIVISION
PRIMER: DIMETCOTE 6 INORGANIC ZINC
TIE COAT: AMERCOAT 182 EPOXY-POLYAMIDE
TOPCOAT: AMERCOAT 450 ALIPHATIC POLYURETHANE

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	NO	NO	NO
CONSISTENCY	SOFT	SOFT	SOFT
SEPARATION	NO	NO	NO
MIXING:			
MECHANICAL			
HAND	EASY	EASY	EASY
THINNING REQUIRED	NO	5% EPOXY	NO
APPLICATION:			
FLUID PRESSURE, PSI	5	10	5
AIR PRESSURE, PSI	30	40	45
ATOMIZATION	GOOD	GOOD	GOOD
FLOW	GOOD	FAIR	GOOD
APPEARANCE	FAIRLY SMOOTH	FAIRLY SMOOTH	FAIRLY SMOOTH
DEFECTS	SLIGHT ORANGE PEEL		BUBBLES, PINHOLES
COLOR			
THICKNESS, MILS:			
WET FILM	8	5	8
DRY FILM	4		4
MAXIMUM DFT WITHOUT SAGGING	4		
MAXIMUM DFT WITHOUT CRACKING	6		
DRYING TIME, HOURS:			
TO TOUCH	1/2	1/4	1
THROUGH	2	1	3
METALLIC POLISH	OVERNIGHT		

COMMENTS: PRIMER WORKS VERY WELL. TIE COAT WORKS WELL AND BUILDS RAPIDLY. TOPCOAT WORKS WELL WITH HIGH BUILD BUT BUBBLES ON BACK SIDES OF A FEW PANELS AND PINHOLES ALL OVER ON SOME.

MANUFACTURER: AMERON PROTECTIVE COATINGS DIVISION
PRIMER: AMERCOAT 182 EPOXY-POLYAMIDE
TIE COAT: NONE
TOPCOAT: AMERCOAT 450 ALIPHATIC POLYURETHANE

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	NO		NO
CONSISTENCY	SOFT		SOFT
SEPARATION	NO		NO
MIXING:			
MECHANICAL			
HAND	EASY		EASY
THINNING REQUIRED	5% EPOXY		NO
APPLICATION:			
FLUID PRESSURE, PSI	5		5
AIR PRESSURE, PSI	35		35
ATOMIZATION	GOOD		GOOD
FLOW	FAIR		FAIR
APPEARANCE	SMOOTH		SMOOTH
DEFECTS			
COLOR	UNIFORM RED		UNIFORM WHITE
THICKNESS, MILS:			
WET FILM	3		6
DRY FILM	[illegible]		4
MAXIMUM DFT WITHOUT SAGGING	10		
MAXIMUM DFT WITHOUT CRACKING			
DRYING TIME, HOURS:			
TO TOUCH	1/4		1/2
THROUGH	1		OVERNIGHT
METALLIC POLISH			

COMMENTS: BOTH COATINGS WORKED WELL. URETHANE REQUIRED TWO PASSES.

MANUFACTURER: AMERON PROTECTIVE COATINGS DIVISION
PRIMER: AMERCOAT 182 EPOXY POLYAMIDE
TIE COAT: NONE
TOPCOAT: AMERCOAT 66 EPOXY

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	NO		YES
CONSISTENCY	SOFT		SOFT
SEPARATION	NO		NO
MIXING:			
MECHANICAL			EASY
HAND	EASY		DIFFICULT
THINNING REQUIRED	5% EPOXY		10% EPOXY
APPLICATION:			
FLUID PRESSURE, PSI	5		6
AIR PRESSURE, PSI	35		40
ATOMIZATION	GOOD		GOOD
FLOW	FAIR		GOOD
APPEARANCE			
DEFECTS			
COLOR	UNIFORM RED		UNIFORM WHITE
THICKNESS, MILS:			
WET FILM	3		8 1/2
DRY FILM	1		4
MAXIMUM DFT WITHOUT SAGGING	20		15
MAXIMUM DFT WITHOUT CRACKING			
DRYING TIME, HOURS:			
TO TOUCH	1/4		2
THROUGH	1		OVERNIGHT
METALLIC POLISH			

COMMENTS: PRIMER WORKED WELL. TOPCOAT SPRAYED WELL WITH HIGH BUILD TO MATTE FINISH. METAL GRADE MARKING BLED THROUGH BOTH COATS

APPENDIX

APPLICATION DATA

MANUFACTURER: CARBOLINE
PRIMER: CARBO ZINC SP78 INORGANIC ZINC
TIE COAT: NONE
TOPCOAT: CARBOMASTIC 15 EPOXY MASTIC

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	YES		YES
CONSISTENCY	SOFT		SOFT
SEPARATION			NO
MIXING:			
MECHANICAL	EASY		EASY
HAND	DIFFICULT		DIFFICULT
THINNING REQUIRED			5% EPOXY
APPLICATION:			
FLUID PRESSURE, PSI	15		10
AIR PRESSURE, PSI	40		35
ATOMIZATION	GOOD		GOOD
FLOW			GOOD
APPEARANCE	FAIRLY SMOOTH		SMOOTH
DEFECTS			OVERSPRAY
COLOR	UNIFORM GREEN-GRAY		MOTTLED SILVER
THICKNESS, MILS:			
WET FILM	5		12
DRY FILM	4		10
MAXIMUM DFT			20
WITHOUT SAGGING	16-20		
MAXIMUM DFT			
WITHOUT CRACKING			
DRYING TIME, HOURS:			
TO TOUCH	2		4
THROUGH	8		OVERNIGHT
METALLIC POLISH	24		

COMMENTS: PRIMER HAD EXCEPTIONAL BUILD PROPERTIES AND CLEANED UP WELL WITH MEK. TOPCOAT SPRAYS WELL BUT REQUIRES HIGH THICKNESS TO PRODUCE SMOOTH FINISH

MANUFACTURER: COOK
PRIMER: GALVA-PAC NO. 300 INORGANIC ZINC
TIE COAT: COPOXY 970-T-134
TOPCOAT: ACROTHANE 979-W-420 ACRYLIC URETHANE

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	YES	NO	NO
CONSISTENCY	SOFT	SOFT	SOFT
SEPARATION	NO	NO	NO
MIXING:			
MECHANICAL	EASY		
HAND	DIFFICULT	EASY	EASY
THINNING REQUIRED	NO	NO	10%
APPLICATION:			
FLUID PRESSURE, PSI	20	10	5
AIR PRESSURE, PSI	30	40	35
ATOMIZATION	GOOD	GOOD	GOOD
FLOW	FAIR	GOOD	GOOD
APPEARANCE	FAIRLY SMOOTH	SMOOTH	SMOOTH
DEFECTS			
COLOR	UNIFORM GRAY-GREEN	UNIFORM YELLOW	UNIFORM WHITE
THICKNESS, MILS:			
WET FILM	7	5	4
DRY FILM	4 1/2	1 1/2	3
MAXIMUM DFT			
WITHOUT SAGGING	6		5
MAXIMUM DFT			
WITHOUT CRACKING	6		
DRYING TIME, HOURS:			
TO TOUCH	1/2	1	1/2
THROUGH	2	OVERNIGHT	OVERNIGHT
METALLIC POLISH	48		

COMMENTS: PRIMER REQUIRED 1/2 HOUR TO MIX AND TENDED TO PLUG SPRAY GUN. TIE COAT DID NOT BUBBLE AND WAS RATHER HEAVY. TOPCOAT NEEDS TO BE APPLIED IN THIN COATS

MANUFACTURER: GATES RUBBER COMPANY
PRIMER: NONE
TIE COAT: NONE
TOPCOAT: GACOFLEX N-10 HYPALON + ALUMINUM

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING			NO
CONSISTENCY			SOFT
SEPARATION			NO
MIXING:			
MECHANICAL			
HAND			EASY
THINNING REQUIRED			NO
APPLICATION:			
FLUID PRESSURE, PSI			10
AIR PRESSURE, PSI			45
ATOMIZATION			POOR
FLOW			
APPEARANCE			FAIRLY SMOOTH
DEFECTS			SOME OVERSPRAY
COLOR			MOTTLED GRAY
THICKNESS, MILS:			
WET FILM			4-6
DRY FILM			2
MAXIMUM DFT			
WITHOUT SAGGING			3
MAXIMUM DFT			
WITHOUT CRACKING			
DRYING TIME, HOURS:			
TO TOUCH			1/2
THROUGH			2
METALLIC POLISH			

COMMENTS: COATING BUILDS THIN COATS, RUNS IF OVER 3 MILS. DOES NOT SPRAY WELL. FULL BODY BUT LEVELS WELL AND CAN BE BRUSHED TO 8 MILS DRY ON FLATS

MANUFACTURER: GLIDDEN COATINGS AND RESINS, DIVISION OF SCM CORPORATION
PRIMER: GLID-GUARD GLID-ZINC NO. 5535 INORGANIC ZINC
TIE COAT: GLID-GUARD NO. 5461/5242 EPOXY POLYAMIDE
TOPCOAT: GLID-THANE ONE POLYURETHANE

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	YES	NO	YES
CONSISTENCY	SOFT	SOFT	SOFT
SEPARATION	NO	NO	NO
MIXING:			
MECHANICAL	EASY		
HAND	EASY	EASY	EASY
THINNING REQUIRED	NO	15% 5566	NO
APPLICATION:			
FLUID PRESSURE, PSI	15	18	57
AIR PRESSURE, PSI	40	45	40
ATOMIZATION	GOOD	GOOD	GOOD
FLOW		FAIR	FAIR
APPEARANCE	FAIRLY SMOOTH	SMOOTH	SMOOTH
DEFECTS		PINHOLES	
COLOR	UNIFORM GREEN	UNIFORM RED	UNIFORM WHITE
THICKNESS, MILS:			
WET FILM	7	8	
DRY FILM	4	5	
MAXIMUM DFT			
WITHOUT SAGGING	10	12	
MAXIMUM DFT			
WITHOUT CRACKING	8		
DRYING TIME, HOURS:			
TO TOUCH	2	2	
THROUGH	8	OVERNIGHT	
METALLIC POLISH	24		

COMMENTS: PRIMER CLEANS UP WELL WITH MEK, DID NOT SETTLE OUT IN 48 HOURS. TIE COAT BUBBLED IF APPLIED OVER 4 MILS WET, BUT MIST COAT COULD BE BUILT UP AFTER 3 MINUTE WAIT. TOPCOAT RAN AT 5 MILS WET, REQUIRED THREE PASSES TO COVER.

APPENDIX

APPLICATION DATA

MANUFACTURER: NAPKO INDUSTRIAL/MARINE DIVISION, THE O'BRIEN CORPORATION
PRIMER: NAPKO 1-Z INORGANIC ZINC
TIE COAT: NONE
TOPCOAT: NAPKO ALUMASTIC [illegible] MASTIC

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	NO		NO
CONSISTENCY	SOFT		SOFT
SEPARATION	NO		NO
MIXING:			
MECHANICAL	EASY AT HIGH SPEED		EASY
HAND	DIFFICULT		EASY
THINNING REQUIRED	NO		YES
APPLICATION:			
FLUID PRESSURE, PSI	15		20
AIR PRESSURE, PSI	40		40
ATOMIZATION	GOOD		POOR
FLOW			FAIR
APPEARANCE	FAIRLY SMOOTH		FAIRLY SMOOTH
DEFECTS	CRACKING		
COLOR	UNIFORM GRAY-GREEN		MOTTLED SILVER
THICKNESS, MILS:			
WET FILM	7		10
DRY FILM	4		
MAXIMUM DFT WITHOUT SAGGING	>40		
MAXIMUM DFT WITHOUT CRACKING	5		
DRYING TIME, HOURS:			
TO TOUCH	3/4		>4
THROUGH	2		
METALLIC POLISH	48		

COMMENTS: PRIMER TENDS TO CLOG THE GUN. TOPCOAT DOES NOT SPRAY WELL, RUNS AT REQUIRED THICKNESS, DID NOT DRY IN 10 DAYS. SPECIMENS NOT USED IN EXPOSURE TESTS

MANUFACTURER: PPG INDUSTRIES, INCORPORATED, PITTSBURGH PAINTS
PRIMER: PPG METALHIDE 1000 INORGANIC ZINC
TIE COAT: PPG AQUAPON EPOXY
TOPCOAT: PPG PITTHANE POLYURETHANE

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	NOT MUCH	NO	NO
CONSISTENCY	HARD ON PAIL SIDES	SOFT	SOFT
SEPARATION	NO	NO	NO
MIXING:			
MECHANICAL	EASY		
HAND	DIFFICULT	EASY	EASY
THINNING REQUIRED	NO	NO	
APPLICATION:			
FLUID PRESSURE, PSI	20	10	4
AIR PRESSURE, PSI	20	40	45
ATOMIZATION	GOOD	GOOD	GOOD
FLOW		GOOD	GOOD
APPEARANCE	FAIRLY SMOOTH	SMOOTH	SMOOTH
DEFECTS		BUBBLES	
COLOR	UNIFORM GRAY	UNIFORM GREEN	UNIFORM WHITE
THICKNESS, MILS:			
WET FILM	8	4	4
DRY FILM	5	6	2
MAXIMUM DFT WITHOUT SAGGING	12	4	3
MAXIMUM DFT WITHOUT CRACKING	4		
DRYING TIME, HOURS:			
TO TOUCH	1/2	1/2	1
THROUGH	2	OVERNIGHT	OVERNIGHT
METALLIC POLISH	18		

COMMENTS: PRIMER CLEANS UP WITH MEK. TIE COAT BUBBLES IF OVER 4 MIL, BUT CAN BE MISTED, SET TO TACKY AND THEN BUILT. TOPCOAT COVERS ON ONE PASS. WORKS WELL, BUT REQUIRED TWO PASSES TO GET THICKNESS.

MANUFACTURER: PPG INDUSTRIES, INCORPORATED
PRIMER: PPG METALHIDE 1000 INORGANIC ZINC
TIE COAT: NONE
TOPCOAT: PPG UC 50006 SILICONE ACRYLIC

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	NOT MUCH		NO
CONSISTENCY	HARD ON PAIL SIDES		SOFT
SEPARATION	NO		NO
MIXING:			
MECHANICAL	EASY		
HAND	DIFFICULT		EASY
THINNING REQUIRED	NO		10% XYLENE
APPLICATION:			
FLUID PRESSURE, PSI	20		10
AIR PRESSURE, PSI	35		35
ATOMIZATION	GOOD		FAIR
FLOW			FAIR
APPEARANCE	FAIRLY SMOOTH		SMOOTH
DEFECTS			
COLOR	UNIFORM GRAY		
THICKNESS, MILS:			
WET FILM	8		4 PER PASS
DRY FILM	5		
MAXIMUM DFT WITHOUT SAGGING	12		
MAXIMUM DFT WITHOUT CRACKING	8		
DRYING TIME, HOURS:			
TO TOUCH	1/2		1
THROUGH	2		OVERNIGHT
METALLIC POLISH	18		

COMMENTS: TOPCOAT DOES NOT COVER WELL IN ONE PASS, NEEDS TWO OR THREE

MANUFACTURER: SUBOX DIVISION, CARBOLINE COMPANY
PRIMER: GALVANOX IV INORGANIC ZINC
TIE COAT: CAPON A-8082 POLYAMIDE EPOXY
TOPCOAT: SUBTHANE 3000 ALIPHATIC POLYURETHANE

	PRIMER	TIE COAT	TOPCOAT
CONDITION IN CONTAINER			
SETTLING	SLIGHT	NO	NO
CONSISTENCY	SOFT	SOFT	SOFT
SEPARATION	NO	NO	NO
MIXING:			
MECHANICAL	EASY		
HAND	EASY	EASY	EASY
THINNING REQUIRED	NO	10% EPOXY	YES
APPLICATION:			
FLUID PRESSURE, PSI	10	8	5
AIR PRESSURE, PSI	30	45	45
ATOMIZATION	GOOD	GOOD	GOOD
FLOW		GOOD	GOOD
APPEARANCE	FAIRLY SMOOTH	SMOOTH	SMOOTH
DEFECTS			
COLOR	UNIFORM GREEN	UNIFORM RED	UNIFORM WHITE
THICKNESS, MILS:			
WET FILM	7	5	5
DRY FILM	4	2	1 3/5
MAXIMUM DFT WITHOUT SAGGING	8-10	3	3
MAXIMUM DFT WITHOUT CRACKING	>20		
DRYING TIME, HOURS:			
TO TOUCH	1	1	2
THROUGH	2	OVERNIGHT	24
METALLIC POLISH	24		

COMMENTS: PRIMER APPLIES WELL AND WASHES UP WITH MEK. TIE COAT COVERS WELL IN ONE PASS. TOPCOAT THINNER DID NOT WORK WELL BUT ANOTHER BRAND DID; PRODUCT COVERED WELL BUT CURED RATHER SLOWLY, PERHAPS DUE TO DIFFERENT THINNER.

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16. Abstract

A program was conducted at Kennedy Space Center to evaluate the performance of new, single package, zinc rich coatings versus the two package types. By 1981 advances in paint technology has produced new coating systems which may (1) be easier to apply effectively and/or (2) provide better corrosion protection. Also, by 1981, an additional hazard had been introduced into the environment of KSC launch structures and ground support equipment: the products of the solid rocket booster exhaust which include small particles of alumina (Al_2O_3) and hydrochloric acid (HCl) absorbed on the surface of those particles. It is evident that acid-resistant topcoats are needed in potential exposure areas. For this application polyurethane formulations with an epoxy tie coat to the zinc primer was recommended. With that in mind, this report evaluates the application characteristics, repair techniques, and field performance of a variety of new single component inorganic zinc coatings, two-component inorganic zinc coatings, epoxy tie coat-polyurethane topcoat systems, alternative topcoat systems, and protective coating systems for stainless steel and aluminum at the 18 month point.

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