MTB-268-86B
FEBRUARY 16, 1988

EVALUATION OF PROTECTIVE COATING SYSTEMS FOR CARBON STEEL EXPOSED TO SIMULATED SRB EFFLUENT AFTER 18 MONTHS OF SEACOAST EXPOSURE

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DOCUMENT NO. MTB-268-86B
DATE: FEBRUARY 16, 1988

TEST REPORT

Evaluation of Protective Coating Systems for Carbon Steel Exposed to Simulated SRB Effluent After Eiyhteen Months of Seacoast Exposure

ISSUED BY

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ACKNUWLEOGMENT: The author wishes to acknowledge Mr. E. V. Tier for the application of all coating systems and preparation that proved invaluable in the completion of this report.

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1.0 FOREWORD

1.1 The testing of protective coatings for carbon steel, stainless steel, and aluminum has been an ongoing process for many years at KSC. In 1970, a testing program was initiated by the Materials Testiny Branch to evaluate coatings for the long term protection of carbon steel exposed to a seacoast environment. Both oryanic and inorganic zinc-rich coatings were applied to test panels and exposed at the KSC Beach Corrosion Test Site. These panels were evaluated for corrosion after 18 months, 3 years, 5, years, and 10 years. The results of that study were that the oryanic zinc-rich formulations did not perform well, but that the inoryanic zinc-rich coatings displayed excellent corrosion protection and many are still performing well today. Also, as a result of that study, untopcoated inorganic zinc-rich coatinys were used for many years at KSC for the long-term protection of carbon steel.

1.2 By 1981, advances in paint technology had produced new coating systems that promised to be (1) easier to apply effectively and/or (2) provide better corrosion protection. Also, in 1981, the shuttle launch system introduced an additional hazard into the environment of KSC launch structures and ground support equipment: The products of the solid rocket booster (SRB) exhaust. This exhaust includes small particles of alumina (Al_2O_3) and hydrochloric acid (HCl) absorbed on the surface of these particles. Whenever this cloud settled, the unprotected zinc coatinys were being severely damaged even though a pressure washdown was carried out as soon as possible.

1.3 In 1982, a test program was undertaken by the Materials Testiny Branch (MTB) to evaluate protective coatiny systems applied to panels of carbon steel, aluminum alloys, and stainless steel. Test panels were coated with materials then available, exposed at the KSC Beach Corrosion Test Site, and evaluated after 18 months. Further testing was done to evaluate the coatiny system performance on repaired panels and panels exposed to simulated SKB effluent. The findinys of this study were that single component solvent based inorganic zinc primers were secondary in performance to the two component solvent based inoryanic zinc primers. Also noted was that repair procedures other than abrasive blasting were unacceptable when preparing corroded panels for recoatiny with inoryanic zinc primers. Further results showed that of all topcoat systems tested for inoryanic zinc, none passed the simulated SRB effluent test.

1.4 With that in mind, it was evident that topcoats for inoryanic zinc primers with increased acid resistance were needed in potential exposure areas due to the failure of the topcoat systems applied in the 1982 study. For this higher resistance, the present study will focus on the high build polyurethane formulations with a high build epoxy tie coat to the inoryanic zinc primer. The high build topcoat systems will be compared to thin film topcoat systems for increased resistance to the simulated SRB effluent.

2.0 MATERIALS AND EQUIPMENT

2.1 In preparation for the testing proyram, test panels were prepared in the MTB coatinys laboratory, installed in test racks, and placed at the KSC Beach Corrosion Test Site on May 14, 1986. The acronyms used for the materials are identified as follows.

KEY TO TEST MATERIALS

Carbon Steel Coatings:

IZ-1	One-component solvent based inorganic zinc.
IZ-2	Two-component solvent based inoryanic zinc
VEN-EU	Vendor's inorganic zinc + same vendor's epoxy/urethane.
VEN-HBEU	Vendor's inorganic zinc + same vendor's hiyh build epoxy/urethane.
VEN-REC	Vendor's inorganic zinc + same vendor's recommended alternate to epoxy/urethane.

2.2 The proposed testiny materials are listed in Table I.

2.3 The'one-component solvent based inoryanic zinc coatiny (IZ-1) was included in this study as a control material due to the performance displayed in MTB 341-82E. This was the only one-component inorganic zinc considered for use in this present test program.

2.4 The coatings application laboratory was equipped with a Binks Model 18 spray gun with graphite packings, various combinations of fluid needles, fluid nozzles, and air caps suited to spray materials of varying viscosities, A l-quart DeVilbiss pressure cup, and a E-quart Stewart-Warner agitated pressure cup.

2.5 Dry film thickness was measured with a calibrated Mikrotest magnetic pull-off yauge and a Positector 20UU diyital magnetic gauge calibrated with plastic shims.

3.0 TEST PROCEDURES

3.1 Application

3.1.1 The coatinys under consideration were supplied as wet samples to KSC by the Manufacturers and were applied in the MTB Coatinys Laboratory by Mr. Edwin V. Tier, a journeyman painter under contract to NASA. Application data for the 114 coatiny systems applied by Mr. Tier is presented in MTB-268-86A. Mr. Tier was also responsible for the coatiny applications in the 1982 and 1970 testing programs.

3.1.2 The carbon steel panels, both the KTA (Tator) Panels for exposure testiny and the flat 4-inch x 6-inch x 1/8-inch panels for laboratory tests, were abrasive blasted with 20 to 30-micron silica sand at 90 psi at the nozzle to the white metal condition described as No. 1 in NACE STD TM-01-70 or as SSPC-SPS by the Steel Structures Painting Council. The panels were blasted within several hours prior to the application of the primer coat to assure a clean,. non-contaminated surface for painting. The anchor profile created by the sandblasting ranyed from 1.0 - 2.0 mils.

3.1.3 The zinc-rich primers were applied to a dry film thickness (DFT) of 3 - 5 mils and varying dry film thickness for the tie coats and topcoats. Insofar as the directions were complete, manufacturer's instructions were followed in mixing, thinniny, and applying the coatings. After initial thorough mixing of the zinc primers, they were kept agitated in the

2-quart Stewart-Warner agitated pressure cup during application to prevent any settliny of the zinc powder.

3.1.4 Although protective coatings must often be applied outdoors at KSC, the resultant variations in temperature, humidity and wind conditions constitute test variables which were eliminated by applying the coatings inside the coatings laboratory. All under the same conditions by the same painter.

3.2 Laboratory Tests

3.2.1 Two methods of adhesion testiny were employed to judge adhesion of the inorganic zinc-rich primers. The first was performed in accordance with ASTM D2197-68 usiny a Gardner Laboratory balanced-beam scrape adhesion tester. In this test the paint film is pushed beneath a rounded loop stylus mounted on a pivoted beam which is loaded incrementally until the film is stripped from its base or resists 10kg, which is the maximum load. The second adhesion test was accomplished in accordance with ASTM D4541-85 using an Elcometer 106-l pull-off adhesion tester designed to measure the bond strength of applied coatings in pounds per square inch. The instrument uses the pull-off method to measure the lift-off force required to pull a small area of coatiny away from the base metal. In this test, a metal dolly is glued to the coating under examination, the glue is allowed to cure, the coatiny is cut through around the perimeter of the dolly using a special cutter, and then the instrument Claw is attached to the dolly. The lift force required to pull away the dolly is recorded by means of a dragying indicator on an engraved scale. The indicator retains the value when the dolly and coatiny Separate from the surface so it can be properly recorded. The indicator is then reset to zero prior to each test. The tests were done in triplicate and the values reported were a rounded averaye of the three pulls.

3.2.2 KSC-STD-C-0001, Rev. A, issued May 21, 1985, requires that an inoryanic zinc coating show no evidence of failure when exposed to a temperature of 400°C (750°F) for 24 hours. A loss of adhesion after heatiny constitutes a failure due to temperature effects on the coating film. Each of the zinc coatings were first tested for adhesion as described in 3.2.1 and then exposed to 400°C for 24 hours. The coating is then re-tested for adhesion to check for adhesion loss caused by heatiny. KSC-STD-C-0001, Rev B, issued July 1987, still requires this temperature resistance of inorganic zinc-rich coatinys due to their proximity to the hiyh heat effects of launch.

3.2.3 Due to the various levels of performance of polyurethane topcoats in recent years at KSC, topcoat gloss testing was considered to be in order during this round of testing. The desiynated panels were chosen at random during the initial installation on the test racks and were located on the edges of the racks so they could be easily removed and replaced for subsequent yloss measurement. The panels were then measured for initial gloss prior to exposure at the Beach Corrosion Test Site. The yloss readings were made on the topcoats as they were applied as a normal coating system on the panels. The gloss readinys were determined usiny a properly calibrated Gardner multi-angle gloss meter at the 60° anyle. Every 6 months, the desiynated panels were removed from the beach exposure and returned to the laboratory for yloss retention measurements. The panels were simply rinsed under tap water to remove any surface residues and allowed to dry prior to yloss testiny.

3.3 Field Exposure

3.3.1 The exposure testiny for this study was conducted at the KSC Beach Corrosion Test Site. This site is located approximately 1.5 miles south of Launch Complex 39A. The coated test panels were installed on a stainless steel rack that uses porcelain insulators as standoffs. Each rack can hold up to 25 panels; however, not all racks were completely filled. The racks were installed on yalvanized pipe test stands at a 30° angle facing the ocean. Each test stand held three test racks. The distance of the test stands from the mean high-tide line was approximately 100 feet. An overall view of the test site and racks is shown in Figure 1. A typical panel installation in a test rack is shown in Figures 2 and 3.

3.3.2 Seven different conditions were used in the field exposure testiny: (1) untopcoated inorganic zinc panels exposed to normal conditions, (2) thin film topcoats over zinc panels exposed to normal conditions, (3) high build topcoats over zinc panels exposed to normal conditions, (4) vendor recommended topcoats over zinc exposed to normal conditions, (5) thin film topcoats over zinc panels exposed to normal conditions plus Al_2O_3 slurry applications, (6) high build topcoats over zinc panels exposed to normal conditions plus Al_2O_3 slurry applications, and (7) vendor recommended topcoats over zinc panels exposed to normal conditions plus Al203 applications. The slurry was composed of 0.3 micron Al203 particles in a 10% (by volume) hydrochloric acid (HCl) solution. This slurry was periodically applied to the lower 2/3 of the panels using a polyethylene squeeze bottle. Thirty such applications were made to the panels during the 18 months of beach exposure.

4.0 TEST HESULTS

4.1 Laboratory Test Results

4.1.1 The results of the scrape adhesion tests of the inorganic zinc coatings are presented in Table II. One set of panels were tested after normal air curing and another set of panels were tested after further curing with four tap water wash and dry cycles. Several materials such as Ameron D-Y and Glidzinc 5530 displayed increased scrape adhesion resistance upon water washing. This could indicate these materials need more moisture than others to complete the curing process. One material, Devoe-Marine

Catha-Coat 304 showed decreased scrape adhesion resistance after water washing. The reasons for this result is unclear and could be due to improper application.

4.1.2 The results of scrape adhesion testing after heat testing are presented in Table III. As can be seen from the data, only 10 of 26 inoryanic zinc coatinys applied in this program passed the heat testiny (>8 KG on Panel 2). Color changes were assumed due to dyes and not judged to impair performance of the inorganic zinc coatings.

4.1.3 The results of the Elcometer adhesion testiny before and after heating are presented in Table IV. The numbers were the result of three readinys averaged and rounded to the nearest decade. As can be seen from the data, 22 of the 26 inoryanic zinc coatinys passed the heat testiny (>100 psi and no decrease from control panels). The relatively low adhesion numbers could have been influenced by the application thickness of the inorganic zinc primers. Dry film thickness readings for the adhesion panels ranged from 4 - 6 mils. This is higher than most manufacturers recommend and could have caused cohesive rather than adhesive failure of the primer film. However, the adhesive results still indicate the relative strength of the film before and after heat cycling.

4.1.4 The exact reasons for the discrepancies between the two tests are unclear; however, probable causes are as follows. The scrape adhesion test described by ASTM D2197-68 is a test related to organic coatings, applying results from this test to inorganic zinc primer coatings may be misleading. The scrape adhesion test appears to be more sensitive to coating hardness and brittleness thus less suitable for evaluatiny coatiny films rich in metallic zinc. Un the other hand, the Elcometer pull-off test is suited to test the adhesion of any type of applied thin film coating. From the results shown in the table, it is interesting to note that 22 of 26 coatings actually maintained or increased their adhesion levels upon heating. This result is to be expected of inorganic zinc coatinys due to the heat causing them to cure further thus increasiny adhesion. This increased tensile strength could also lead to increased film brittleness possibly causiny them to fail the scrape adhesion test. The four coatings that failed the Elcometer test also failed the scrape adhesion test indicating deterioration in the film due to exposure to high temperature. This could suggest that these coatings have significant organic content.

4.1.5 The results of the gloss retention testiny can be found in Tables V, VI, VII and VIII for initial exposure, 6, 12, and 18 months respectively. The data is presented in the format of percent loss of yloss. To find percent gloss retention subtract this value from 100 (i.e., 100 - % loss = % gloss retention). The time of year correspondiny to the different exposure times were 5/86 - 11/86 for the first 6 months, 11/86 - 5/87 for the second 6 months, and 5/87 - 11/87 for the final 6 months. As can be seen from the data, polyurethane topcoat formulations from different manufacturers can vary considerably in loss of gloss or gloss retention. The relative loss of gloss in the first 6 months (Florida summer) was not as dramatic as in the final 6 months. The loss of gloss during the second 6 months (Florida winter) was also not siynificant. However, after 12 months of weatheriny, the final 6 months of Florida summer seriously deteriorated topcoat gloss values. The best performers became apparent during this period and were clearly the aliphatic polyester formulations such as Rustoleum 9400 and Tnemec 70 included in the testiny. Several aliphatic acrylic resin formulations did well such as DuPont Imron 326, Glidden Glidthane II 6200, and Koppers 1122BRS, but most of the others had deteriorated to the point (>70% loss of gloss in 18 months) that no further yloss testing is warranted for these products.

4.2 Field Exposure Results

4.2.1 The test panels were examined on November 20, 1987, making the exposure duration just over 18 months. The results of the seacoast exposure are shown in Tables IX, X, XI, and XII. The deyree of corrosion is judged on a scale of 0 to 10, with 10 being the highest rating. This rating system is described in ASTM 0610 as follows:

RATING	DESCRIPTION
10	No rusting or less than 0.01% of surface rusted.
9	Minute rusting, less than 0.03% of surface rusted.
8	Few isolated rust spots, less than 0.1% of surface rusted.
7	Less than 0.3% of surface rusted.
6	Extensive rust spots, but less than 1% of surface rusted.
5	Rustiny to the extent of 3% of surface rusted.
4	Rusting to the extent of 10% of surface rusted.
3	Approximately 1/6 of the surface rusted.
2	Approximately 1/3 of the surface rusted.
1	Approximately 1/2 of the surface rusted.
0	Approximately 100% of the surface rusted.

4.2.2 All rating values presented in the tables are an average of four panels prepared and exposed at the same time. Where the ratings differed from panel to panel, a simple arithmetic mean is reported. In case one panel's rating was substantially below the other three, its rating was not included in the average due to the possibility of application or preparation defects.

4.2.3 The simple arithmetic averayiny system can be misleading. It should be noted that an evaluation of, for example, "8.25" merely means that the performance lies somewhere closer to 8 than 9. The numerical rating does not have arithmetic significance of a weight change or thickness change corrosion rating that could be used for kinetic or mechanistic study.

4.2.4 According to the regulations stated in KSC-STD-C-0001, an inorganic zinc coatiny must receive a corrosion rating of 9 or better after 18 months of beach exposure. This is the requirement a coating must meet to be accepted for the approved products list at KSC. Further, the coatiny must continue to perform to this level for a period of 5 years to remain on the approved list. If duriny this 5-year period a coating drops below the corrosion rating of 9, it is immediately removed from the approved products list.

4.2.5 At the "la-month" evaluation, most of the inorganic zinc-rich coating systems are performing well. With the exception of Coronado 935-152, Glidden 5536, and Subox Galvanox V, all of the two-component inorganic zincs exposed to normal conditions at the beach corrosion site have met the 18-month requirements of KSC-STD-C-0001. Interestingly, the single one-component inoryanic zinc included as a control, Subox Galvanox IV, performed better than the two-component Subox tialvanox V. Of the 25 two-component inoryanic zincs included in this study, only 5 have remained perfect with a rating of 10, Carboline

CZ-11, Devoe-Marine Catha-Coat 304, Enyard 519, Porter Zinc-Lock 311, and Sigma 7551.

4.2.6 The panels with the epoxy-polyurethane topcoat systems exposed to normal conditions are not performing as expected. However, the panels exposed to the acid slurry conditions are performing well. Overall, the panels exposed to acid are in better condition than the panels subject to normal exposure. A possible cause for this occurrence was that panels to be exposed to the acid conditions had hiyher film thicknesses than the panels chosen for normal exposure. Panels chosen for normal exposure for a given system were panels coated at or near the manufacturer's recommended film thickness while panels for acid exposure were all sliyhtly higher than the recommended film thickness.

4.2.7 One of the results found during this study confirmed earlier findings of other coating studies at KSC, that topcoating inoryanic zinc-rich primers in normal atmospheres deteriorates its long term protection potential. As can be seen from total panel averayes of the different systems, the untopcoated inorganic zinc panels exposed to normal conditions had an average rating of 9.43 whereas the average rating for topcoated panels (VEN-EU) was 8.08, (VEN-HBEU) was 8.22, and (VEN-REC) was 8.39. The mode of failure in the topcoated panels was rusting of the area under the channel of the Tator panel. This rusting then continues under the edge of the painted area creating failure of the adjacent coating. This indicates that the beneficial effects of the inorganic zincs "throwing power" to protect damaged or uncoated adjacent areas have been negatively affected by topcoating. This leads to increased localized failure of the coating system. By essentially "shutting off" the ability of surrounding zinc particles to protect a damaged area by "tying up" their anodic action with topcoats, the advantaye of using inorganic zinc primers in this situation has been compromised. However, this does not mean that topcoatiny inorganic zinc primers should be completely avoided. Certain conditions would still dictate the use of topcoats over inorganic zinc such as chemical exposures outside the accepted pH ranye of inorganic zinc primers (< pH 4 or > pH 10), immersion conditions in aqueous electrolytes, surfaces of machinery or equipment that must be kept clean for various reasons, color codiny, safety concerns, etc. In summary, to topcoat inorganic zinc primers in neutral atmospheric exposures purely for aesthetic reasons is unjustified.

4.2.8 One of the situations that directly affected the corrosion rating of individual panels of different systems was the fact that the manufacture of the Tator panels is not uniform. In some cases, the channel that is welded to the front of the panel had varying degrees of yapping between the bottom edge of the channel and the flat panel surface. On some panels this crevice was non-existent allowing the paint film to easily bridge and seal the channel; however, many panels had yaps varyiny from 1/32" to 1/16" that did not allow the topcoats to seal the channel yap. Therefore, moisture intrusion caused the rusting to start in the channel crevice. On the panels where the paint film successfully bridged the yap, especially in the higher build formulations, no rusting was observed. These circumstances could have biased results of one topcoat system compared to another, but the fact that the untopcoated inorganic zinc panels had the same yapping problem, but no rusting, just reinforces the fact that topcoatiny deteriorates the performance of an inorganic zinc-rich coating.

4.2.9 To address the problems associated with the testing of topcoats for inoryanic zinc-rich primers, possible remedies for failures caused by the yapping on the Tator panels would be (1) caulk the channel completely after application of primer and before application of topcoats, (2) seal weldiny around channel prior to abrasive blasting, or (3) consider the use of a flat plate panel, as described by ASTM, instead of the composite design of the Tator panel.

4.2.10 The purpose of this study was to determine if the higher build topcoat products would in fact give us superior resistance to the acid fallout and residues produced by the solid rocket boosters during an STS launch. From the exposure results to date, differences were measurable indicatiny increased performance by the high build products. Differences were kept small due to the general failure of topcoats as discussed in 4.2.8. Further, due to the short term of this first ratiny period (18 months), the yreat differences between the performance of the systems may take longer to manifest themselves. However, the results so far suggest that selection of the high build products will provide some increased chemical resistance in the STS launch environment. Since the gloss retention of the hiyh build polyurethane is not as yood as the thin film formulations, a decision must be made if this is important to the end use of the structure to be coated.

4.2.11 Proyress of this testing program has been documented by color photoyraphs at two stages of exposure (initial and 18 months). These photographs are available for examination in the Materials Testiny Branch, O&C Building, Room 1286, Kennedy Space Center, Florida.

5.0 CONCLUSIONS

5.1 The laboratory test results show that the majority of the inorganic zinc coatings performed well under adhesion testiny. The differences in the test procedures indicate that the scrape adhesion method may be unsuitable for the testiny of inorganic zinc-rich coatings. Tables II, III, and IV should be consulted for laboratory test results of specific coatings.

5.2 Laboratory findings indicate considerable variation in the gloss retention of the different polyurethane topcoat formulations tested. The polyester formulations performed the best with the high build, acrylic resin materials performing the poorest. Tables V, VI, VII, and VIII should be consulted for laboratory test results of specific coatinys.

5.3 At the 18-month evaluation period, the Z-component inoryanic zinc coatings have performed well in the KSC marine environment with the exception of Coronado 935-152, Glidden 5536, and Subox Galvanox V. Several of the other coatings are nearing failure and will be watched closely for possible removal from the approved products list. Table IX should be consulted for field test results of specific coatinys.

5.4 The epoxy-polyurethane topcoat systems used for acid resistance have been beneficial in protecting the inoryanic zinc primer. Both the thin film (VEN-EU) and the high build (VEN-HBEU) provided good resistance to the simulated SKB effluent with the high build products proving slightly superior. The two vinyl systems included in the VEN-KEC testing displayed good resistance also. Tables X, XI, and XII should be consulted for the field test results of specific coating systems.

5.5 Most of the failure of the topcoat panels was related to the crevice area associated with the composite Tator panels. In the future, topcoat testing will be performed in a way to minimize this failure mode.

5.6 As can be seen from the field exposure data, topcoatiny of inorganic zinc primers in neutral environments is detrimental to the long term protection potential of these type coatings.

Topcoatiny promotes the localized failure of the zinc primer and this leads to the premature failure of the coatiny system.

5.7 Future studies will continue to focus on other recommendations from manufacturers to enhance the performance of topcoats over inoryanic zinc primers. Other studies will also be performed to determine the correct materials and methods to protect carbon steel surfaces that can only be mechanically cleaned. The list of coatings to be tested will include hiyh build epoxies, aluminum epoxy mastics, moisture cured urethanes, hiyh build polyurethanes, and rust conversion coatings.

TABLE I

1 ONE-CUMPONENT INOKGANIC ZINC COATING (IZ-1)

MANUFACTUREK	ZINC-COATING
SUBUX	GALVANOX IV

25 TWO-COMPONENT INOKGANIC ZINC COATINGS (IZ-2)

MANUFACTURER	ZINC COATING
AMERON	D-6N
AMERON	D-9
BYCO	SP-101
CAKBOLINE	cz-11
CEILCOTE	200
CON-LUX	ZINC-PLATE 21
CORONADO	935-152
DEVOE-MARINE	CATHA-COAT 304
DEVOE-PKUFCOAT	ZINC-PRIME 500
DUPONT	GANICIN 347-Y-931
ENGARD	519
GLIDDEN	GLID-ZINC 5530
GLIDDEN	GLID-ZINC 5536
INTEKNATIUNAL	INTEKZINC 22
KOPPEKS	701
MOBIL/VALSPAR	13-F-12
NAPKU	5-z
PORTEK	ZINC-LOCK 311
PPG	METALHIDE 1001
RELIANCE	REL-ZINC 100
RUSTOLEUM	5686
SHERWIN WILLIAMS	ZINC-CLAD B69-V-1
SIGMA	7551
SUBOX	GALVANOX V
TNEMEC	90E-75

TABLE I (CONTINUED)

26 EPOXY/URETHANE TOPCOAT SYSTEMS (VEN-EU)

MANUFACTUKER	ZINC PRIMER	EPOXY TIE COAT	URETHANE
AMEKON	D-6N	182	450GL
AMERON	D-9	182	45UGL
BYCO	SP-101	300HB	450
CARBOL INE	cz-11	193LF	134
CEILCOTE	200	675	420
CON-LUX	ZP-21	20	200
CORONADO	935-l 52	101-147	827-1
DEVOE-MARINE	304	201	239
DEVOE-PRUFCOAT	ZP-500	545	369
DUPONT	GANICIN	COKLAK B.B.	IMRON
ENGARD	519	1447	428
GLIDDEN	5530	5461	6200
GLIDDEN	5536	5461	6200
INTEKNATIUNAL	IZ-22	INTERGARD	INTEKTHANE
KOPPERS	701	654	1122 BRS
MOBIL/BASPAR	13-F-12	13-R-60	40 SERIES
NAPKO	5-z	516	290
POKTEK	ZL-311	MCR-43	4610
PPG	1001	97-3	97-812
RELIANCE	RZ-100	59-ZP	300
RUSTOLEUM	5686	M9373	9400
SHEKWIN WILLIAMS	869-V-l	TILE CLAD	PULANE
SIGMA	7551	5434	7523
SUBOX	GALVANOX IV	A 8051	3000
SUBOX	GALVANOX V	A 8051	3000
TNEMEC	90E-75	66	70 SERIES

TABLE I (CONTINUED)

26 HIGH BUILD EPOXY/URETHANE SYSTEMS (VEN-HBEU)

MANUFACTURER	ZINC PRIMER	EPOXY TIE COAT	URETHANE
AMERON	D-6N	383HS	AMERSHIELD
AMEKON	D-9	383HS	AMEKSHIELD
BYCO	SP-101	300HB	451
CAKBOLINE	cz-11	190HB	133HB
CEILCOTE	200	690	470
CON-LUX	ZP-21	39D	200
CORONADO	935-152	111-111	827-l
DEVOE-MARINE	304	230	249
DEVOE-PRUFCOAT	ZP-500	547	359
DUPONT	GANICIN	CORLAR HB	IMRON HB
ENGARD	519	1447	449
GLIDDEN	5530	5555	G-THANE HB
GLIDDEN	5536	5555	G-THANE HB
INTERNATIONAL	IZ-22	I-GARD HB	I-THANE HB
KOPPERS	701	HIGARD	1122 BRS
MOBIL/VALSPAR	13-F-12	78-D-7	41 SERIES
NAPKO	5-z	520	295
PORTER	ZL-311	MCR-43	8610
PPG	1001	97-139	97-812
RELIANCE	HZ-100	HP-70	320
RUSTOLEUM	5686	9582 HB	9400
SHERWIN WILLIAMS	B69-V-1	E102	E106
SIGMA	7551	5434	7523
SUBOX	GALVANOX IV	850U	3100
SUBOX	GALVANOX V	8500	3100
TNEMEC	90E-75	66	73 SERIES

TABLE I (CONTINUED)

13 RECOMMENDED SYSTEMS (VEN-REC)

MANUFACTURER	ZINC PRIMER	EPOXY TIE COAT	URETHANE
AMERON	D-6N	400	AMERSHIELD
AMEKON	D-9	400	AMERSHIELD
CARBOLINE	cz-11	188HB	133HB
CON-LUX	ZP-21	MB47/V93	VINYL 98
DEVOE-MAKINE	304	201	249
DUPONT	GANICIN	CORLAR HB	IMRON
INTERNATIONAL	IZ-22	TAA-423	INTERTHANE
MOBIL/VALSPAR	13-F-12	VINYL 83	VINYL 22
PORTER	ZL-311	MG-77	4610
PPG	1001	97-148	97-812
RUSTOLEUM	5686	95-1501	9400
SUBOX	GALVANOX IV	A 4551	3100
SUBOX	GALVANOX V	A 4551	3100

TABLE II

ADHESION TEST RESULTS (SCRAPE ADHESION)

	ADHESION LOAD (KG)	
	PANEL 1	PANEL 2*
IZ-1		
SUBOX GALVANOX IV	10	10
IZ-2		
AMEKON D-6	10	10
AMERON D-9	7	10
BYCO SP 101	10	10
CARBOLINE CZ-11	10	10
CEILCOTE 2u0	10	10
CON-LUX ZINC PLATE 21	10	10
CORONADO 935-152	10	10
DEVOE MARINE CATHACOAT 304	10	8
OEVOE PRUFCOAT ZINC PRIME 500	10	10
OUPONT GANICIN	10	10
ENGARD 519	10	10
GLIDZINC 5530	6	10
GLIDZINC 5536	5	6
INTERZINC 22	10	10
KOPPERS 701	10	10
MOBIL/VALSPAR 13-F-12	10	10
NAPKO 5-Z	10	10
PORTER ZINC LOCK 311	10	10
PPG METALHIDE 1001	10	10
RELIANCE RELZINC 100	10	10
RUSTOLEUM 5686	10	10
SHERWIN WILLIAMS B69-V-1	10	10
SIGMA 7551	10	10
SUBOX GALVANOX V	7	8
TNEMEC 90E-75	10	10

*CURED WITH 4 WATER WASH AND DRY CYCLES

TABLE III

HEAT TEST RESULTS ON ZINC COATINGS (SCRAPE ADHESION)

	ADHESION, KG AFTER 24 HOURS AT 400°C	
	PANEL 1	PANEL 2*
IZ-1		
SUBOX GALVANOX IV	4	4
IZ-2		
AMEKON D-6	10	10
AMEKON D-9	5	7
BYCO SP 101	3	3
CAKBOLINE CZ-11	10	9
CEILGARD 200	4	5
CON-LUX ZINC PLATE 21	10	10
CORONADO 935-152	9	5
DEVOE MARINE CATHACOAT 304	6	2
DEVOE PRUFCOAT ZINC PRIME 500	3	2
DUPONT GANICIN	4	5
ENGARD 519	3	3
GLIDZINC 5530	3	3
GLIDZINC 5536	2	2
INTERZINC 22	3	8
KOPPERS 701	3	2
MOBIL/VALSPARD 3-F-12	5	8
NAPKO 5-Z	3	2
PORTER ZINC LOCK 311	4	3
PPG METALHIUE 1001	10	10
RELIANCE RELZINC 100	10	10
RUSTOLEUM 5686	10	10
SHERWIN WILLIAMS B69-V-1	2	2
SIGMA 7551	10	10
SUBOX GALVANOX V	3	3
TNEMEC 90E-75	10	10

*CURED WITH 4 WATER WASH AND DRY CYCLES

TABLE IV

ELCOMETER ADHESION RESULTS

	ADHESION (PSI)	
	BEFORE HEATING	AFTER 24 HRS AT 400°C
I z-1		
SUBOX GALVANOX IV	90	80
IZ-2		
AMERON D-6	120	210
AMERON D-9	100	160
BYCU SP 101	150	200
CARBULINE CZ-11	110	160
CEILCOTE 200	100	90
CON-LUX ZINC PLATE 21	110	210
CORONADO 935-152	60	90
DEVOE MARINE CATHACOAT 304	90	220
DEVOE PRUFCOAT ZINC PRIME 500	90	310
DUPONT GANICIN	120	170
ENGARD 519	150	200
GLIDZINC 5530	90	100
GLIDZINC 5536	100	100
INTERZINC 22	120	220
KUPPERS 701	150	130
MOBIL/VALSPAR 13-F-12	180	260
NAPKU 5-Z	90	100
PORTER ZINC LOCK 311	120	190
PPG METALHIUE 1001	200	290
RELIANCE RELZINC 100	160	210
RUSTOLEUM 5686	210	250
SHERWIN WILLIAMS B69-V-1	130	220
SIGMA 7551	210	380
SUBOX GALVANOX V	150	80
TNEMEC 90E-75	160	190

TABLE V

INTITIAL GLOSS DATA

MATERIAL NAME	GENERIC TYPE	INTITAL GLOSS
AMERUN AMEKSHIELD	POLYURETHANE	82%
AMERON 450GL	POLYURETHANE	74%
BYCO 450	POLYURETHANE	78%
BYCO 451	PULYUHETHANE	62%
CARBOLINE 133HB	PULYUHETHANE	35%
CARBOLINE 134	POLYURETHANE	85%
CEILCOTE 470-01	PULYUKETHANE	72%
CON-LUX A-2U0	POLYURETHANE	75%
CON-LUX V-98	VINYL ACKYLIC	29%
CORONADO 827-1	POLYUKETHANE	41%
DEVOE-MARINE 239	PULYUKETHANE	64%
DEVOE-MARINE 249	POLYUKETHANE	65%
DEVOE-PRUFCOAT 359	POLYUKETHANE	76%
DEVOE-PRUFCOAT 369	POLYURETHANE	89%
DUPONT 326BB	POLYURETHANE	79%
DUPONT 369HB	POLYURETHANE	40%
ENGARD 428	POLYURETHANE	51%
ENGARD 449	POLYURETHANE	60%
GLIDDEN 6200	POLYURETHANE	80%
GLIDDEN HBU	POLYURETHANE	63%
INTERNATIONAL PCBOUO	POLYUHETHANE	80%
INTERNATIONAL PHBOUO	POLYURETHANE	35%
KOPPERS 1122BRS	POLYURETHANE	80%
MOBIL/VALSPAR 22 SERIES	VINYL ACRYLIC	49%
MOBIL/VALSPAR 40 SERIES	POLYURETHANE	71%
MOBIL/VALSPAR 41 SERIES	POLYURETHANE	29%
NAPKO 290	POLYURETHANE	77%
NAPKU 295	POLYURETHANE	34%
PORTER 4610	POLYURETHANE	73%
PORTER 8610	POLYURETHANE	37%
PPG 97-812	POLYURETHANE	65%
RELIANCE 300	POLYURETHANE	92%
RELIANCE 320	POLYUHETHANE	50%
RUSTOLEUM 9400	POLYURETHANE	82%*
SHEKWIN-WILLIAMS HI-BILD	POLYURETHANE	71%
SHEKWIN-WILLIAMS POLANE	POLYURETHANE	60%
SIGMA 7523	POLYUKETHANE	81%
SUBOX 3000	POLYURETHANE	83%
SUBUX 3100	POLYURETHANE	46%
TNEMEC SERIES 70	POLYURETHANE	85%*
TNEMEC SERIES 73	POLYURETHANE	85%

*POLYESTER FUKMULATION

TABLE VI

6-MONTH GLOSS DATA

MATERIAL NAME	6-MONTH GLOSS	% LOSS (6 MO.)
AMEKON AMEKSHIELU	65%	21
AMERON 450GL	48%	35
BYCO 450	76%	3
BYCU 451	42%	32
CARBULINE 133HB	15%	57
CARBOLINE 134	55%	35
CEILCOTE 470-01	29%	60
CUN-LUX A-200	62%	17
CON-LUX V-98	21%	28
CORONADO 827-1	34%	17
DEVOE-MARINE 239	43%	33
DEVOE-MARINE 249	46%	29
DEVOE-PKUFCUAT 359	64%	16
DEVOE-PKUFCUAT 36Y	70%	21
DUPONT 326BB	73%	8
DUPONT 369HB	36%	10
ENGARD 428	41%	20
ENGARD 449	38%	37
GLIDDEN 6200	75%	6
GLIDDEN HBU	57%	10
INTERNATIONAL PCBOOO	47%	41
INTERNATIONAL PHBOOO	10%	71
KUPPERS 1122BRS	57%	29
MOBIL/VALSPAR 22 SEKIES	43%	12
MOBIL/VALSPAR 40 SEKIES	62%	13
MOBIL/VALSPAR 41 SERIES	20%	31
NAPKO 290	68%	12
NAPKO 295	24%	29
PUKTER 4610	58%	21
PORTEK 8610	15%	59
PPG 97-812	56%	14
KELIANCE 300	73%	21
RELIANCE 320	43%	14
RUSTOLEUM 9400	75%	9*
SHERWIN-WILLIAMS HI-BILD	27%	62
SHERWIN-WILLIAMS POLANE	14%	77
SIGMA 7523	47%	42
SUBOX 30UU	40%	52
SUBOX 3100	12%	74
TNEMEC SERIES 70	78%	8*
TNEMEC SEKIES 73	52%	39

*POLYESTER FORMULATION

TABLE VII

12-MONTH GLOSS DATA

MATERIAL NAME	12-MONTH GLOSS	% LOSS (12 MO.)
AMERON AMEKSHIELD	61%	26
AMEKUN 450GL	45%	39
BYCO 450	70%	10
BYCU 451	36%	42
CARBOLINE 133HB	14%	60
CARBOLINE 134	37%	56
CEILCOTE 470-01	16%	78
CUN-LUX A-2UU	52%	31
CON-LUX V-98	14%	52
CORONADO 827-1	30%	28
DEVOE-MARINE 239	32%	50
DEVOE-MARINE 249	41%	37
DEVOE-PRUFCOAT 359	55%	27
DEVOE-PRUFCOAT 369	57%	36
DUPONT 326BB	60%	24
DUPONT 369HB	34%	15
ENGARD 428	34%	33
ENGARD 449	37%	38
GLIDDEN 6200	68%	15
GLIDDEN HBU	56%	11
INTERNATIONAL PCB000	28%	65
INTERNATIONAL PHBOUU	6%	83
KOPPEKS 1122BKS	56%	30
MOBIL/VALSPAR 22 SEKIES	39%	20
MOBIL/VALSPAR 40 SERIES	54%	24
MOBIL/VALSPAR 41 SERIES	17%	41
NAPKU 290	58%	25
NAPKO 295	20%	41
PORTER 4610	57%	22
PORTER 8610	12%	68
PPG 97-812	49%	25
RELIANCE 300	67%	27
RELIANCE 320	39%	22
KUSTULEUM 9400	80%	2*
SHERWIN-WILLIAMS HI-BILD	16%	77
SHEKWIN-WILLIAMS POLANE	11%	82
SIGMA 7523	25%	69
SUBOX 3000	28%	66
SUBOX 3100	7%	85
TNEMEC SEKIES 70	71%	16*
TNEMEC SEKIES 73	51%	40

*POLYESTER FORMULATION

TABLE VIII

18-MONTH GLOSS DATA

MATEKIAL NAME	18-MONTH GLOSS	% LOSS (18 MU.)
AMERON AMEKSHIELD	18%	78
AMERUN 450GL	17%	77
BYCO 450	RESULTS NOT COMPLETE	
BYCO 351	KESULTS NUT COMPLETE	
CAKBULINE 133HB	4%	89
CAKBULINE 134	12%	86
CEILCOTE 470-01	7%	94
CON-LUX A-200	17%	77
CUN-LUX V-98	13%	5s
CORONADO 827-1	13%	68
DEVUE-MARINE 23Y	17%	73
DEVOE-MAKINE 249	23%	65
DEVUE-PRUFCOAT 35Y	35%	54
DEVUE-PRUFCOAT 369	37%	58
DUPONT 326BB	53%	33
DUPONT 369HB	29%	28
ENGARD 428	15%	71
ENGAKD 449	15%	75
GLIDDEN 6200	50%	38
GLIDDEN HBU	44%	30
INTEKNATIUNAL PCBOUO	10%	88
INTERNATIONAL PHBOUO	5%	86
KUPPERS 1122BKS	51%	36
MOBIL/VALSPAR 22 SEKIES	24%	51
MOBIL/VALSPAR 40 SEKIES	17%	76
MOBIL/VALSPAR 41 SEKIES	11%	62
NAPKO 290	28%	64
NAPKU 295	14%	59
PORTER 4610	33%	55
PUKTEK 8610	6%	84
PPG 97-812	15%	77
KELIANCE 300	RESULTS NOT COMPLETE	
RELIANCE 320	RESULTS NUT COMPLETE	
RUSTOLEUM 9400	61%	26*
SHEKWIN-WILLIAMS HI-BILD	17%	76
SHERWIN-WILLIAMS PULANE	15%	75
SIGMA 7523	15%	81
SUBUX 3000	5%	94
SUBOX 3100	4%	91
TNEMEC SERIES 70	65%	24*
TNEMEC SERIES 73	32%	62

*POLYESTER FORMULATION

TABLE IX

RUST GRADE EVALUATIONS AFTER 18-MONTH SEACOAST EXPOSURE

COATING SYSTEM		ASTM D-610-68(74) RUST GRADES* PANEL RATING
IZ-1	SUBOX GALVANOX IV	9.88
IZ-2	AMERON D-6	9.75
	AMEKUN D-Y	9.25
	BYCU SP-101	NUT COMPLETE
	CAKBOLINE CZ-11	10.00
	CEILCOTE 200	9.50
	CON-LUX ZINC PLATE 21	9.88
	COKUNAOO 935-152	8.63
	DEVOE-MARINE CATHA-COAT 304	10.00
	DEVOE-PRUFCOAT ZINC PRIME 500	9.00
	DUPONT GANICIN 347-Y-931	9.38
	ENGARD 519	10.00
	GLIDDEN GLIDZINC 5530	9.25
	GLIDDEN GLIDZINC 5536	7.88
	INTERNATIONAL INTERZINC 22	9.50
	KOPPERS 7U1	9.13
	MOBIL/VALSPAR 13-F-12	9.75
	NAPKO 5-Z	9.38
	PORTER ZINC LOCK 311	10.00
	PPG METALHIDE 1001	9.7s
	RELIANCE REL-ZINC 100	9.38
	RUSTOLEUM 5686	9.50
	SHERWIN WILLIAMS B69-V-1	9.63
	SIGMA 7551	10.00
	SUBOX GALVANOX V	8.63
	TNEMEC 90E-75	9.13

*AVERAGE VALUE FOK FOUR PANELS UF EACH COATING SYSTEM

TABLE X

RUST GRADE EVALUATIUNS AFTEH 18-MONTH SEACOAST EXPOSURE

	ASTM D-610-68(74) RUST GRADES*	
VEN-EU COATING SYSTEM	NOKMAL EXPOSURE	ACID TREATED
D-6/182/450GL	8.00	8.50
D-9/182/450GL	7.63	9.25
SP-101/300HB/450	RESULTS NOT COMPLETE	
CZ-11/193LF/134	7.75	8.50
200/675/470	8.13	8.00
ZP-21/20/200	7.63	8.25
935-152/101-147/827-1	7.75	8.38
304/201/239	9.38	9.0
ZP-500/545/369	9.75	8.63
GANICIN/CORLAR/IMRON	8.13	8.25
519/1447/428	8.25	8.88
5530/5461/6200	7.38	8.00
5536/5461/6200	7.63	8.25
IZ-22/INTERGARD/INTERTHANE	7.38	8.00
701/654/1122BRS	7.88	8.13
13-F-12/13-R-60/40	8.63	8.38
5-Z/516/290	8.75	8.50
311/MCR-43/4610	8.25	8.25
1001/97-3/97-812	8.33	8.83
RZ-100/59ZP/300	RESULTS NOT COMPLETE	
5686/M9373/9400	8.25	8.75
B69-V-1/TILE-CLAD/POLANE	7.88	7.63
7551/5434/7523	8.25	8.63
GALVANOX IV/8051/3000	7.00	7.63
GALVANOX V/8051/3000	8.13	8.38
90E-75/66/70	7.88	8.00

*AVERAGE VALUE FOR FOUR PANELS OF EACH COATING SYSTEM

TABLE XI

RUST GRADE EVALUATIONS AFTEK 18-MONTH SEACOAST EXPOSURE

VEN-HBEU COATING SYSTEM	ASTM U-610-68(74) RUST GRADES* NORMAL EXPOSUHE	ACID TREATED
D-6/383HS/AMERSHIELD	B.63	8.63
D-9/383HS/AMERSHIELD	7.88	8.00
SP-101/300HB/451	RESULTS NOT COMPLETE	
CZ-11/190HB/133HB	7.88	8.63
ZP-21/31/200	7.75	8.25
935-152/111-111/827-1	7.63	8.88
304/230/249	9.50	9.63
ZP-500/547/359	8.63	8.13
GANICIN/CORLAR HB/IMRON HB	8.38	8.50
519114471449	8.75	8.50
5530/5555/GLIDTHANE HB	7.88	8.50
5536/5555/GLIDTHANE HB	7.75	8.50
IZ-22/INTERGARD HB/INTERTHANE HB	7.75	8.13
701/HIGARD/1122BRS	8.63	8.50
13-F-12/78-D-7/41	8.63	Y.13
5-Z/520/295	8.00	8.38
311/MCR 43/8610	9.50	8.7s
1001/97-139/97-812	8.83	8.83
RZ-100/70/320	RESULTS NUT COMPLETE	
568619582 HB/9400	8.25	9.00
B69-V-1/E102/E106	7.63	8.13
75511543417523	7.88	8.25
GALVANUX IV/8500/3100	7.38	8.13
GALVANUX V/8500/3100	7.75	8.25
90E-75/66/73	8.25	8.25

*AVERAGE VALUE FOR FOUR PANELS OF EACH COATING SYSTEM

TABLE XII

RUST GRADE EVALUATIONS AFTER 18-MONTH SEACOAST EXPOSURE

VEN-REC COATING SYSTEM	NORMAL EXPOSURE	ACID TREATED
D-6/400/AMERSHIELD	8.75	8.50
D-9/400/AMERSHIELD	8.75	8.25
CZ-11/188HB/133HB	8.00	8.50
ZP-21/47/93/98	8.00	8.75
304/201/249	9.17	9.13
GANICIN/CORLAR HB/IMRON	7.63	8.38
IZ-22/TAA 423/INTERTHANE	7.63	B.25
13-F-12/83/22	7.88	8.38
311/MG-77/4610	10.00	9.63
1001/97-148/97-812	8.50	8.83
5686/95-1501/9400	8.88	9.13
GALVANOX IV/4551/3100	7.38	7.73
GALVANOX V/4551/3100	8.30	8.50
AVERAGE OF ALL PANELS (IZ-2)	9.43	---
AVERAGE OF ALL PANELS (VEN-EU)	8.08	B.311
AVERAGE OF ALL PANELS (VEN-HBEU)	8.22	8.50
AVERAGE OF ALL PANELS (VEN-REC)	8.39	8.61

*AVERAGE VALUE FOR FOUR PANELS OF EACH COATING SYSTEM

FIGURE 1 - KSC BEACH CORROSION TEST SITE

FIGURE 2 - TYPICAL TEST RACK PANEL INSTALLATION (BEFORE)

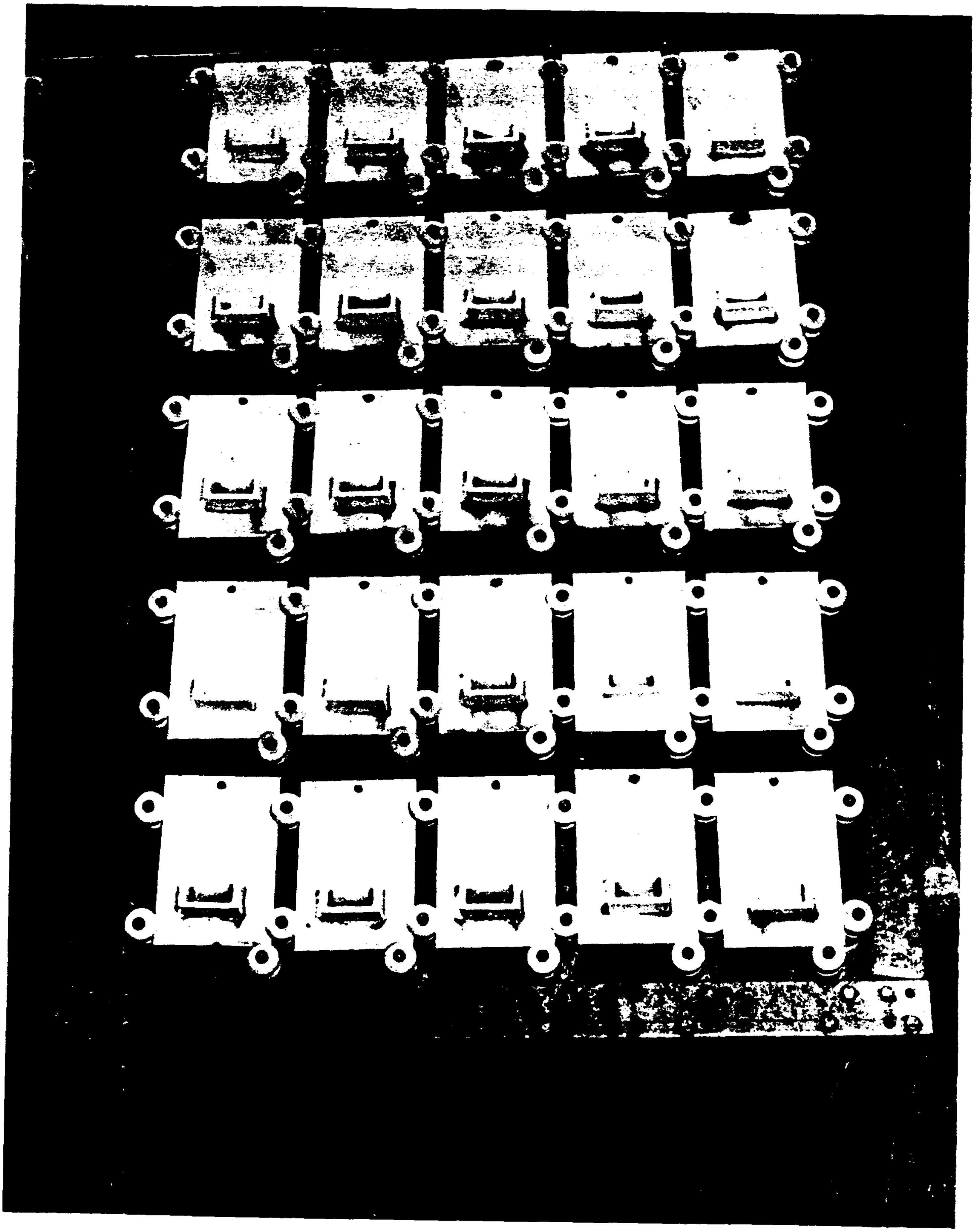

FIGURE 3 - TYPICAL TEST RACK PANEL INSTALLATION (AFTER)

RELATED DOCUMENTATION

1. MTB-268-86, Test Plan for Protective Coatiny Systems for Carbon Steel Exposed to Simulated SHB Effluent, DM-MSL-2, L. I;. MacDowell, May 23, 1986.

2. MTB-268-86A, Application Characteristics and Laboratory Testing of Protective Coating Systems for Carbon Steel Exposed to Simulated SKB Effluent, DM-MSL-2, L. G. MacDowell, August 25, 1986.

3. KSC-STD-C-UUUB, Protective Coatiny of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures and Ground Support Equipment, Standard for, Enyineeriny Development Directorate, July 1987.

4. MTS-341-82E, Evaluation of Carbon Steel, Aluminum Alloy and Stainless Steel Protective Coating Systems After 18 Months of Seacoast Exposure, DM-MSL-2, A. P. Howe.

5. Report II: Performance Characteristics of Zinc-rich Coatinys Applied to Carbon Steel, TN D-7336, W. J. Paton July, 1973.