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PERFORMANCE CHARACTERISTICS OF ZINC-RICH COATINGS APPLIED TO CARBON STEEL

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16. Abstract

A program was conducted at Kennedy Space Center to evaluate the performance of top-coated and untopcoated zinc-rich coatings. Sacrificial coatings of this type are required for protecting carbon steel structures from the aggressive KSC seacoast environment. A total of 59 commercially available zinc-rich coatings and 47 topcoated materials were exposed for an 18-month period. Test panels were placed in special racks placed approximately 30.5 m (100 feet) above the high tide line at the KSC Corrosion Test Site.

Laboratory tests to determine the temperature resistance, abrasion resistance, and adhesion of the untopcoated zinc-rich coatings were also performed.

It has been concluded that (1) The inorganic types of zinc-rich coatings are far superior to the organic types in the KSC environment, (2) Organic zinc-rich coatings applied at 0.1 - 0.15 mm (4-6 mils) film thickness provide better corrosion protection than when applied at the manufacturers' recommended nominal film thickness of .08 mm (3 mils), (3) Topcoats are not necessary, or even desirable, when used in conjunction with zinc-rich coatings in the KSC environment, (4) Some types of inorganic zinc-rich coatings require an extended outdoor weathering period in order to obtain adequate mechanical properties, and (5) A properly formulated inorganic zinc-rich coating is not affected by a 24-hour thermal exposure to 400°C (752°F).

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PERFORMANCE CHARACTERISTICS OF ZINC-RICH COATINGS APPLIED TO CARBON STEEL

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INTRODUCTION

This is an interim report of the work performed to date on a program to evaluate various zinc-rich coatings and topcoats for protecting carbon steel at Kennedy Space Center (KSC).

The overall objectives of this program were as follows:

1. To evaluate various commercially available zinc-rich coatings suitable for protecting carbon steel structures for the purpose of establishing a suggested source list.
2. To determine the relative merits of the various classes of zinc-rich coatings.
3. To determine the influences of various topcoating materials on the performance of zinc-rich coatings in the KSC environment and to identify suitable topcoating materials.

Zinc has a higher electromotive potential than iron or steel and in the presence of an electrolyte will be sacrificed to protect the steel. Zinc ions go into solution, liberating electrons which cause a current flow into the steel to prevent ferrous ions from going into solution and beginning the electrochemical corrosion process.

In order to function anodically, the zinc particles must be in intimate contact with one another so that the coating film is electrically conductive. This is achieved by very high zinc loading with a relatively small amount of binder. In order to protect the steel, the coating itself must be in electrical contact with the substrate and not insulated by any rust, scale, old paint, or pretreatment chemicals. Sandblasting to a near-white (Steel Structures Painting Council Surface Preparation Specification No. 10) surface is generally the preferred surface preparation.

Initially, a zinc-rich coating's mechanism is basically anodic. As the zinc is sacrificed, zinc corrosion products in the form of efflorescing salts -- commonly called "white rust" -- appear on the film, making the coating denser and reducing its conductivity. These products of corrosion then act as a barrier between the active zinc and the corrosive influences. However, if the coating is damaged, the fresh zinc metal that is exposed provides renewed anodic action. Essentially, then, a zinc-rich coating is a "self healing" film since any damage to the barrier reinitiates the anodic action.

For certain exposures involving chemical contamination, water immersion, and other aggressive atmospheres, where the zinc might be attacked or consumed through unnecessarily fast sacrificial action, a topcoat or topcoat system is used to protect the zinc from chemical attack and to slow down the sacrificial action. The effects of using topcoats in the aggressive KSC marine atmosphere have never been formally evaluated.

This report describes the results of an 18-month beach exposure test and various laboratory tests. Included are an overall evaluation of the performance characteristics of untopcoated zinc-rich coatings, the effects of coating thickness on performance, and the performance effects of topcoating the zinc-rich coatings. The laboratory tests performed on the zinc-rich coatings include heat resistance, abrasion resistance, and adhesion.

A previous report, "Application Characteristics of Zinc-Rich Coatings Applied to Carbon Steel," was published in March 1971.

Zinc-rich coatings may be composed of organic or inorganic vehicles. Some of the inorganic vehicles used are silicates, silicate esters, phosphates and modifications thereof. The organic vehicles used are chlorinated rubber, styrene, epoxies, phenoxies, urethanes, silicones, and other suitable vehicles. KSC-SPEC-0020

(Specification for Organic and Inorganic Zinc-Rich Coating) dated December 22, 1969 classifies self-curing zinc-rich coatings as follows:

Type I, Class 1: Inorganic zinc, organic solvent-reducible
Type I, Class 2: Inorganic zinc, water-reducible
Type II, Class 1: Organic zinc, single component
Type II, Class 2: Organic zinc, two or more components

MATERIALS

All known manufacturers of zinc-rich coatings were contacted to obtain a wide variety of commercially available zinc coatings. Information on these manufacturers was obtained from an Interim KSC Qualified Products List supplied by the Mechanical Design Division, from the Thomas Register, and from the Materials Testing Branch Visual Search Microfilm File (VSMF). Listings of the zinc-rich coatings applied as of this date are given in Tables 1 through 4. These coatings are listed alphabetically in their respective categories. A total of 59 candidate zinc-rich coatings were obtained from 22 manufacturers.

Topcoat system materials were obtained from the zinc-rich coating suppliers. Intermediate (tie) coats were also obtained, when recommended by the manufacturers. Forty-seven topcoat materials including epoxies, vinyls, coal tar epoxies, acrylic latexes, polyurethanes, chlorinated rubbers, and enamels were supplied. These topcoat systems are listed in Table 5.

TEST PROCEDURES

Application

All test panels were prepared in accordance with Steel Structures Painting Council (SSPC) Surface Preparation Specification No. 10 (Near-White Blast Cleaning) using the dry sandblast method. Silica sand, 20 to 30 mesh, conforming to MIL-S-17726, was used as the abrasive. The National Association of Corrosion Engineers (NACE) Standard TM-01-70 (Visual Standard for Surfaces of New Steel Airblast Cleaned with Sand Abrasive) was used as a guide to ensure that a near-white surface was produced. Application of the zinc-rich coatings was effected by conventional spray equipment, in accordance with the manufacturer's recommendations.

KSC-SPEC-F-0020 specifies that a dry film thickness of 0.1 to 0.15 mm (4 to 6 mils) shall be attainable with one coat which may consist of multiple passes. Most manufacturers suggest an optimum dry film thickness of 0.05 to 0.08 mm (2 to 3 mils). All coatings were applied at 0.1 to 0.15 mm (4 to 6 mils), and also at the manufacturer's recommended dry film thickness, to evaluate the effect of different coating thicknesses on performance. The types and quantities of carbon steel panels prepared for each zinc-rich coating are:

1. Four Tator panels for service test - two coated at 0.1 to 0.15 mm (4 to 6 mils) dry film thickness, and two at the manufacturer's recommended dry film thickness. These test panels were obtained from Ken Tator Associates and are widely used for coatings evaluations.

2. Two 0.32 cm (1/8-inch) by 10 cm (4-inch) by 15 cm (6-inch) coating thickness (film build) panels - one coated at 0.1 to 0.15 mm (4 to 6 mils) dry film thickness, and one at the manufacturer's recommended dry film thickness.

FOLDOUT FRAME FOLDOUT FRAME

Seacoast Exposure Test

KSC-SPEC-F-0020 zinc-rich coating exposure requirements are as follows: "After 18 months of field testing, without touchup to the coating, there shall be no general surface deterioration or pitting. Total localized film failures should not exceed 5 percent of the test area. Coatings should continue to provide excellent protection against corrosion without excessive touchup for a minimum of 5 years for Type I coatin(and 3 years for Type II coatings."

The exposure tests were performed at a site located approximately 2.4 kilome (1.5 miles) south of Launch Complex 39A. The test panels were placed in Type 304 stainless steel racks holding 25 panels each. Porcelain insulators were used as stand offs. The racks were installed on galvanized pipe frames at a 30° angle. The racks w placed approximately 30.5 meters (100 feet) from the mean high-tide line facing the ocean. An overall view of the test site, panels, racks, and frames is shown in Figure 1. An illustration of one test rack with panels installed is shown in Figure 2. A stainless steel cover was used as a means of preventing rain impingement on the rack of sheltered test panels.

Evaluation of the exposure test samples consisted of regular visual inspection. Periodically, color photographs were made for documentation.

Laboratory Tests on Zinc-Rich Coatings

All laboratory test panels were allowed to cure for several weeks in the coating laboratory. Abrasion resistance tests were performed in accordance with Federal Test Method Standard 141a, Method 6192, using a Taber Abrader equipped with CS 17 wheels and a 1000-gram load as shown in Figure 3. A combination of the wear index (rate of wear) and wear cycles techniques was used. The wear index is the loss in weight in milligrams per 1000 cycles of abrasion. The wear cycles technique is the number of cycles of abrasion required to wear a film of known thickness through to the test plate. The zinc coating test method used was the wear index technique, or until the coating was judged to be worn down to the test plate base metal if the plate was exposed in less than 1000 cycles of abrasion.

Adhesion tests were performed in accordance with ASTM D2197-68 using the balanced-beam scrape-adhesion tester shown in Figure 4. This machine tests the adhesion of a paint film by pushing it 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 kilograms. The term "scrape-adhesion" is employed to define the minimum load in kilograms which causes removal of the adhering film from the base. Failures may result from poor adhesion between the paint and its base, which causes them to separate; deformation of the film by the scraping tool to such an extent that the film flows away completely from around the loop, thus exposing the base; or poor cohesion of the film, which makes it disintegrate by powdering or crumbling under the loop. The value obtained with the instrument, therefore, may be the sum of all these effects, but in most cases, since the cohesion level is fairly high and plasticity is minimized, the results are considered as adhesional levels. Numerical values from 0.5 to 1 kg are usually interpreted as poor; 1.5 to 2.5 kg as fair; 3 to 4 kg as good; 4.5 to 5 kg as very good, and above 5 kg as excellent. Some excellent modern coatings may test as high as 10 kg or more.

While performing the adhesion and abrasion-resistance tests, it was observed that most of solvent-reducible inorganic and one of the water-reducible inorganic zinc-rich coatings displayed quite poor adhesion and cohesion. According to manufacturers' literature, moisture is required for curing some of these formulations. It was suspected that possibly the coatings displaying poor mechanical properties were not completely cured. Therefore, additional test panels were placed in an outdoor location where they were subject to night-time dew, thunderstorms, and occasional hose applications of fresh water. These panels remained under these conditions for 30 days. The adhesion and abrasion resistance tests were then repeated (see first paragraph under Laboratory Test Results).

KSC-SPEC-F-0020 requires that the inorganic zinc-rich coatings show no evidence of failure when exposed to a temperature of 400°C (752°F) for 24 hours. This specification has no heat resistance requirements for the organic coatings; however, these coatings were also tested. The organic zinc-rich coated panels were placed in a convection oven. Oven temperature was monitored using a precision potentiometer. Tests were begun at 79°C (175°F) and were increased in 13.9°C (25°F) increments at 2-hour intervals up to 260°C (500°F). Each panel was checked visually at the end of each incremental level by comparing the test panel appearance with reference test panels. The panels were also checked for softening by scraping the panels with a pointed spatula. The organic test panels were removed from the oven at the completion of the 260°C (500°F) level, allowed to cool, and checked for loss of adhesion per ASTM-D-2197-67T. Six organic zinc-rich coatings that showed no appreciable deterioration up to this point were then placed in a high-temperature oven and were exposed to 316°C (600°F) for a 24-hour period. The panels were then removed from the oven, allowed to cool, examined visually, and checked for loss of adhesion per ASTM-D-2197-67T. Two of these six coatings remained in satisfactory condition after this exposure. These two organic zinc-rich coatings and all the inorganic coatings were placed in the high-temperature oven and exposed to 400°C (752°F) for a 24-hour period. Visual and adhesion tests were then performed on these coatings.

TEST RESULTS

Seacoast Exposure Tests

Results of the 18-month seacoast exposure tests are given in Tables 6 through 13. 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.

Subjective evaluations of degree of rusting were made by taking an average value of the two test panels coated at each of the two thickness levels.

The topcoated test panels were also evaluated for general appearance and for degree of blistering as described in ASTM Standard D-714-56. This standard uses photographic references to describe blister size and frequency. Blister size is described by a numerical scale from 10 to 0, in which No. 10 represents no blistering and 0 represents a very large blister. Blister frequency standards used are:

Dense, D
Medium Dense, MD
Medium, M
Few, F

The general appearance of the test panels is shown in Figures 5 through 23. The condition of the Type 304 stainless steel racks is also of interest. In general, the inorganic zinc-rich coatings remain in excellent condition. The water-reducible inorganic coatings generally show somewhat heavier deposits of "white rust" than the solvent-reducible inorganic coatings. There is no discernible difference at this time between those panels with an inorganic zinc-rich coating applied at 0.1 to 0.15 mm (4 to 6 mils) dry film thickness and those coated at the manufacturers' recommended coating thickness.

Most of the organic zinc-rich coatings deteriorated rapidly, several failing co pletely in as little as 4 months. Extensive pin hole corrosion appeared on most of the org coatings during the final months of the exposure period. This was particularly true of tho: panels with a dry film coating thickness of the nominal 0.08 mm (3 mils). Overall, the two-or-more component organic zinc-rich coatings are in slightly better condition than the single-component zinc-rich coatings. The zinc-rich coated panels sheltered from rain impingement deteriorated at approximately the same rate as the unsheltered panels. The zinc-rich coatings used as primers in the topcoat portion of the program received a rating Of 10 when not topcoated.

The majority of topcoated zinc-rich coatings were not in as good condition as the untopcoated zinc-rich coatings. This was particularly true of the topcoated water-reducible inorganic and the single-component organic zinc-rich coatings. Generally, the vinyl, chlorinated rubber, epoxy, and epoxy coal-tar coatings gave the best performance. Several of the coatings maintained a clean, high-gloss appearance throughout the test per One of the polyurethane coatings also gave very good performance. Epoxy coatings, altho having good adhesion, chalked and yellowed badly. Most of the acrylic latex coatings we very dirty with little or no gloss at the end of the test period. The latex coatings were als subject to heavy concentrations of very small blisters.

Laboratory Test Results

The results of the abrasion resistance tests are presented in Tables 14 throug 17. Most of the solvent-reducible inorganic zinc-rich coatings that were cured under out-door weathering conditions substantially improved, as shown by the data. The water-reducible coating cured outdoors also substantially improved. However, the water-reducib inorganic type was superior to the other generic classes, even without an outdoor weatheri period. It is possible that further outdoor weathering could affect the results somewhat. Inorganic coatings applied at 0.1 to 0.15 mm (4 to 6 mils) had a slightly higher wear index than when applied at the nominal 0.08 mm (3 mils) thickness. Coating thickness had little effect on the wear index of the organic zinc-rich coatings.

The results of the adhesion tests are presented in Tables 18 through 21. The adhesion end point is defined as the point where the loop stylus removed the coating from the substrate for more than half the scrape distance. The organic coatings usually reached the load limit of the machine without penetration to the base metal. Outdoor weathering greatly improved the adhesion of most of the solvent-reducible inorganic coatings and the water-reducible inorganic coating. Coating thickness variations had very little effect on the adhesion characteristics of the zinc-rich coatings.

Results of the heat resistance tests are given in Tables 22 through 25. Several of the inorganic zinc-rich coatings showed a significant loss of adhesion after exposure to 400°C (752°F). This would indicate that these coatings may have significant organic content. One of the organic coatings tested showed no appreaciable loss of adhesion after thermal exposure at 400°C (752°F). One other organic coating withstood 316°C (600°F) satisfacorily.

CONCLUSIONS

The following tentative conclusions are drawn, based on the work performed to date.

The inorganic (Type I) classes of zinc-rich coatings are far superior to the organic (Type II) classes in the aggressive KSC seacoast atmosphere. Both inorganic classes performed equally well in the 18-month exposure test when not topcoated. The Type I coatings' performance with only a nominal 0.08 mm (3 mils) film thickness was excellent during this exposure period.

Most of the organic (Type II) coatings applied at a nominal 0.08 mm (3 mils) film thickness deteriorated badly after approximately 12 months of exposure. Type II coatings gave improved performance when applied at 0.1 to 0.15 mm (4 to 6 mils) under severe exposure conditions.

Two-or-more component (Type II, Class 2) zinc-rich coatings slightly outperformed the single-component (Type II, Class 1) zinc-rich coatings in exposure tests. However, the difference is so slight that selection of the coating to be used should be determined by ease of application of specific products.

Topcoat systems are not necessary, or even desirable, when used in conjunction with zinc-rich coatings in the KSC seacoast environment. Topcoats actually adversely affected the performance of the zinc-rich coatings. This effect is attributed to the enormous reduction in the exposed area of the zinc primer coating whose sacrificial capability is correspondingly reduced. Of the classes of zinc-rich coatings that were topcoated, Type I, Class 1 zinc-rich coatings gave the best performance. Purchasing topcoat systems from the same manufacturing source as the zinc-rich coatings does not necessarily guarantee good performance.

Of the generic types of topcoats tested, the vinyl, chlorinated rubber, epoxy, and epoxy coal-tar coatings gave the best performance.

The zinc-rich coated panels sheltered from the elements deteriorated at approximately the same rate as the unsheltered coated panels.

The water-reducible inorganic (Type I, Class 2) coatings had by far the best abrasion resistance. Most of the solvent-reducible inorganic (Type I, Class 1) coatings and one of the Type I, Class 2 coatings required outdoor weathering for up to 30 days in order to obtain adequate mechanical properties.

The organic (Type II) coatings had better adhesion and cohesion than the inorganic (Type I) coatings. This is probably due to the porous nature of the inorganic coatings.

A properly formulated inorganic zinc-rich coating is not affected by thermal exposure to 400°C (752°F) for a 24-hour period. One of the organic coatings subjected to these conditions showed no appreciable deterioration.

KSC-SPEC-F-0020 is considered to be too lenient in the exposure test requirements. The exposure period should be lengthened for the Type I coatings and the allowable degree of corrosion should be greatly decreased for both Type I and Type II coatings.

TABLE 1. TYPE I, CLASS 2, SOLVENT-BASE, INORGANIC, ZINC-RICH COATINGS

Ameron Corporation D-6 (Alkyl Silicate)
Carboline Company Carbo Zinc 11 (Silicate)
Carboline Company Carbo Zinc 13 (Silicate)
Cook Paint & Varnish Company Galva Pak 101 (Polymeric Alkoxy Silane)
DeVoe and Raynolds Company Catha Cote 302 (Modified Alkyl Silicate)
DeVoe and Raynolds Company Catha Cote 304 (Alkyl Silicate)
DuPont Ganicin 347-931 (N.A.)*
Grow Chemical Coatings, Prufcoat Division, Zinc Prime 500 (Silicate)
Mobile Chemical Company Mobile Zinc 7 (Ethyl Silicate)
Napko Corporation 5Z (Hydrolized Silicate)
Plas Chem Corporation Zincite G (Ethyl Silicate)
Seaguard 3 (Alkyl Silicate)
Southern Imperial Coatings Durazinc 525 (Silicate)
Subox Galvanox Type V (Ethyl Silicate)
Wisconsin Protective Coatings Corporation Plasite 1000 (Silicate)
Zinc Lock Company No. 351 (Silicone)

*Vehicle Description Not Available

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TABLE 2. TYPE I, CLASS 2, WATER-BASE, INORGANIC, ZINC-RICH COATINGS

Ameron Corporation D-4 (Silicate)
Ameron Corporation D-5 (Silicate)
Carboline Company Carbo Zinc 33 (Silicate)
DeVoe and Raynolds Company Catha Cote 300 (Post-Cured Silicate)
DeVoe and Raynolds Company Catha Cote 305 (Alkyl Silicate)
Enjay Chemical Company Rust Ban 191 (Silicate)
Grow Chemical Coatings, Prufcoat Division, Zinc Prime 200 (Silicate)
Koppers Company Inorganic Zinc #1 (Post-Cured Lead Silicate)
Mobil Chemical Company Mobil Zinc 1 (Metallic Silicate)
Napko Corporation 4Z (Silicate)
Seaguard 6 (Single Component)
Sherwin Williams Company Zinc Clad 8 (Silicate)
Southern Imperial Coatings Durazinc 500 (Silicate)
Subox Galvanox Type VI (Lithium Silicate)

TABLE 3. TYPE II, CLASS 1, SINGLE-COMPONENT, ORGANIC, ZINC-RICH COATINGS

Ameron Corporation #39 (Synthetic Resin)
Carboline Company #676 (Phenoxy)
Con Lux Paint Products Zinc Plate (Epoxy-Phenolic)
Cook Paint & Varnish Company One Package (N.A.)*
Enjay Chemical Company #5699 (Thermoplastic Epoxy)
Galvicon Corporation Galvicon (N.A.)*
Koppers Company Organic Zinc (N.A.)*
Napko Corporation 2Z (Modified Polyhydroxy Ether Resin)
Plas Chem Corporation Zincor #7 (N.A.)
Rustoleum Corporation 9634 (Chlorinated Rubber)
Rustoleum Corporation 7085 (Modified Rubber)
Rustoleum Corporation 92-8504 (Phenoxy)
Sherwin Williams Company Zinc Clad 5 (Polystyrene)
Southern Imperial Coatings Permazinc 520 (Chlorinated Rubber)
Subox Galvanox Type I (Chlorinated Rubber)

*Vehicle Description Not Available

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TABLE 4. TYPE II, CLASS 2, TWO-OR-MORE COMPONENT, ORGANIC ZINC-RICH COATINGS

American Abrasive Metals Company AAM ZINC 14A-2 (Epoxy)
Cook Paint & Varnish Company Epicon R (Epoxy)
DuPont Ganicin 347-937 (N.A.)*
Enjay Chemical Company #5662 (Epoxy)
Essex Chemical Corporation Beta-Cote 75-61 (N.A.)*
Grow Chemical Coatings, Prufcoat Division, Zinc Prime 100 (Three Component Epoxy)
Mobil Chemical Company Mobil Zinc #2 (Chlorinated Rubber)
Mobil Chemical Company Mobil Zinc #4 (Polyamide Catalyzed Epoxy)
Sherwin Williams Company Zinc Clad 7 (Polyamide Catalyzed Epoxy)
Sherwin Williams Company Zinc Clad 9 (Phenoxy)
Subox Galvanox Type II (Catalyzed Epoxy)
Wisconsin Protective Coatings Corporation Plasite 1704 (Thermoplastic Resin)
Wisconsin Protective Coatings Corporation Plasite 7140 (Polyamide-Cured Epoxy)
Wisconsin Protective Coatings Corporation Plasite 1636 (Polyamide-Cured Epoxy)

*Vehicle Description Not Available

TABLE 5. TOPCOAT MATERIALS

1. Ameron #99 Vinyl Chloride Copolymer (High Build)
2. Ameron #2024 Chlorinated Rubber
3. Ameron #1969 Vinyl Acrylic
4. Ameron #1756 Acrylic Latex
5. Carboline 3300 Acrylic Latex
6. Carboline Carbomastic 2256-140 Aluminum Epoxy Coal Tar
7. Carboline Carbomastic 14 Epoxy Coal Tar
8. Con Lux Trim Plex 53-71 Acrylic Latex
9. Con Lux Vinyloid Vinyl
10. Cook Coro Cryi Acrylic Latex
11. Cook E 346 High Build Polyamide-Cured Epoxy
12. DuPont DuLux Enamel #25-5203
13. DuPont Tufcoat Carylic Emulsion #310-404
14. DeVoe and Raynolds Devflex II Acrylic Emulsion
15. DeVoe and Raynolds Formula 209 Devran Epoxy
16. Enjay Rust-Ban CR 6893 Chlorinated Rubber
17. Enjay Rust-Ban EX 6670 Catalyzed Epoxy With EX 6666 Epoxy Intermediate Coat
18. Enjay Rust-Ban EM 6657 High Build Epoxy With EX 6666 Epoxy Intermediate Coat
19. Enjay Rust-Ban VY 6500 Vinyl
20. Enjay Rust-Ban VM 6510 High Build Vinyl
21. Essex Betacote 93 Series Vinyl
22. Essex Betacote 15-61-01 Acrylic Latex
23. Koppers #600 Acrylic Latex
24. Koppers #400 Vinyl With #25 Intermediate Coat
25. Napko Epoxycote PA 5697 Polyamide-Cured Epoxy
26. Napko 8-2484 Acrylic Latex

TABLE 5. TOPCOAT MATERIALS (Continued)

27.	Plas-Chem X-82B High Build Epoxy
28.	Plas-Chem X-72B Vinyl Medium Build
29.	Plas-Chem R35-9A Acrylic Latex With #2504 Wash Primer
30.	Prufcoat HSA 570-10-00 Vinyl
31.	Prufcoat Clad 233-00-00 Acrylic Latex
32.	Prufcoat MBX 559-10-00 Acrylic Enamel
33.	Sherwin Williams Polane Polyurethane
34.	Sherwin Williams Metalatex Acrylic Emulsion
35.	Southern Imperial Permachlor #890 Chlorinated Rubber
36.	Southern Imperial Duramet #550 Stainless Steel Filled Inorganic Silicate (High Temperature)
37.	Southern Imperial #1120 Acrylic Latex
38.	Subox VL 2000 Vinyl
39.	Subox Kintron 1800 Chlorinated Rubber
40.	Wisconsin Protective Coatings Plasite #2088 Aliphatic Polyurethane
41.	Wisconsin Protective Coatings Plasite #284 Acrylic Latex
42.	Wisconsin Protective Coatings Plasite #2050 Vinyl Acrylic
43.	Zinc Lock #400 Vinyl With #301 Wash Primer
44.	Zinc Lock #900 Acrylic Emulsion
45.	MIL-C-22750B, Amendment 2, Type I Polyamide-Cured Epoxy
46.	MIL-C-38427A, Type I (Carboline), Acrylic Latex
47.	FSN 8010-K02-6307 Acrylic Latex (Atlantic Paint Mfg. Co.)

TABLE 8. RESULTS OF 18-MONTH SEACOAST EXPOSURE

TYPE II, CLASS 1 COATINGS

Coating Material	Degree of Corrosion Rating at Manufacturer's Recommended Film Thickness	Degree of Corrosion Rating at 4-6 mils* Film Thickness
Ameron Corporation #39	1	5
Carboline Corporation #676	0	0
Con Lux Paint Products Zinc Plate	7	9
Cook Paint & Varnish Company One Package	7	9
Enjay Chemical Company #5699	5	5
Galvicon	0	**
Koppers Company Organic Zinc	10	10
Napko 2Z	8	10
Plas Chem Corporation Zincor #7	1	8
Rustoleum Corporation #9634	3	**
Rustoleum Corporation #7085	9	10
Rustoleum Corporation 92-8504	1	0
Sherwin Williams Company Zinc Clad 5	3	3
Southern Imperial Coatings Permazinc 520	1	1
Subox Galvanox Type I	3	9

*Metric equivalent: 0.1 to 0.15 mm
**Not applied at 4 to 6 mils

TABLE 10. RESULTS OF 18-MONTH SEACOAST EXPOSURE

SHELTERED TEST PANELS

Coating Material	Degree of Corrosion Rating at Manufacturer's Recommended Film Thickness	Degree of Corrosion Rating at 4-6 mils* Film Thickness
Ameron Corporation D-6	10	10
DeVoe & Raynolds Company Catho-Cote 304	**	10
Mobil Chemical Corporation Mobil Zinc 7	10	10
Wisconsin Protective Coatings Corporation Plasite 1000	**	10
Enjay Chemical Company Rust Ban 191	10	10
DeVoe & Raynolds Company Catho-Cote 305	**	10
Napko Corporation 2Z	7	9
Koppers Company Organic Zinc	10	10

*Metric equivalent: 0.1 to 0.15 mm
**Not applied at manufacturer's recommended thickness

TABLE 9. RESULTS OF 18-MONTH SEACOAST EXPOSURE

TYPE II, CLASS 2 COATINGS

Coating Material	Degree of Corrosion Rating at Manufacturer's Recommended Film Thickness	Degree of Corrosion Rating at 4-6 mils* Film Thickness
American Abrasive Metals Company AAM 14A-2	4	9
Cook Paint & Varnish Company Epicon R	10	10
DuPont Ganicin 347-937	1	1
Enjay Chemical Company #5662	4	7
Essex Chemical Corporation Beta-Cote 75-61	0	0
Grow Chemical Coatings Zinc Prime 100	10	10
Mobil Chemical Company Mobil Zinc 2	1	6
Mobil Chemical Company Mobil Zinc 4	7	10
Sherwin Williams Company Zinc Clad 7	6	9
Sherwin Williams Company Zinc Clad 9	6	8
Subox Galanox Type II	9	10
Wisconsin Protective Coatings Corporation Plasite 1704	2	2
Wisconsin Protective Coatings Corporation Plasite 7140	3	4
Wisconsin Protective Coatings Corporation Plasite 1636	10	10

*Metric equivalent: 0.1 to 0.15 mm

TABLE 11. RESULTS OF 18-MONTH SEACOAST EXPOSURE

TOPCOATED TYPE I, CLASS 1 COATINGS

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
1. Ameron #99 Vinyl Chloride Copolymer (high build)	10	0-F	Flat finish
2. Ameron #2024 Chlorinated Rubber	8	10	Semigloss
3. Ameron #1969 Vinyl Acrylic	10	10	Semigloss
4. Ameron #1756 Acrylic Latex	6	6-MD	Dirty, flat finish
5. Carboline 3300 Acrylic Latex	6	10	Flat finish
6. Carboline Carbomastic 2256-140 Aluminum Epoxy Coal Tar	10	10	Very good
7. Carboline Carbomastic 14 Epoxy Coal Tar	10	10	Very good
8. Con Lux Trim Plex 53-71 Acrylic Latex	10	8-MD	Dirty, flat finish
9. Con Lux Vinyloid Vinyl (2 coats)	9	10	High gloss, very good
10. Cook Coro Cryl Acrylic Latex	9	8-M	Semigloss
11. Cook E346 High Build Polyamide-Cured Epoxy	10	10	Yellow, chalky
12. DuPont DuLux Enamel #25-5203	10	8-M	Dirty, flat finish
13. DuPont Tufcoat Acrylic Emulsion #310-404	10	10	Dirty, flat finish
14. DeVoe and Raynolds Devflex II Acrylic Emulsion	4	8-M	Dirty, flat finish
15. DeVoe and Raynolds Formula 209 Devran Epoxy	7	6-F	Chalky
16. Enjay Rust-Ban CR 6893 Chlorinated Rubber (2 coats)	9	10	Semigloss

TABLE 11. RESULTS OF 18-MONTH SEACOAST EXPOSURE (Continued)

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
17. Enjay Rust-Ban EX 6670 Catalyzed Epoxy With EX 6666 Epoxy Intermediate Cost	8	10	Yellow, chalky
18. Enjay Rust-Ban EM 6657 High Build Epoxy With EX 6666 Epoxy Intermediate Coat	10	10	Yellow, chalky
19. Enjay Rust-Ban VY 6500 Vinyl	7	10	Low gloss
20. Enjay Rust-Ban VM 6510 High Build Vinyl	6	10	Flat finish
21. Essex Betacote 93 Series Vinyl	10	10	High gloss
22. Essex Betacote 15-61-01 Acrylic Latex	4	8-MD	Dirty, flat finish
23. Koppers #600 Acrylic Latex	10	8-MD	Dirty, flat finish
24. Koppers #400 Vinyl With #25 Intermediate Coat	8	10	Flat finish
25. Napko Epoxycote PA 5697 Polyamide-Cured Epoxy	10	10	Chalky
26. Napko 8-2484 Acrylic Latex	10	8-MD	Flat finish
27. Plas-Chem X-82B High Build Epoxy	10	10	Very good
28. Plas-Chem X-72B Vinyl Medium Build	10	10	Very good
29. Plas-Chem R35-9A Acrylic Latex With #2504 Wash Primer	10	10	Flat finish
30. Prufcoat HSA 570-10-00 Vinyl	5	10	Flat finish
31. Prufcoat Clad 233-00-00 Acrylic Latex	10	10	Dirty, flat finish
32. Prufcoat MBX 559-10-00 Acrylic Enamel	4	8-M	Semigloss
33. Sherwin Williams Polane Polyurethane	5	6-M	Semigloss, good

TABLE 11. RESULTS OF 18-MONTH SEACOAST EXPOSURE (Continued)

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
34. Sherwin Williams Metalatex Acrylic Emulsion (2 coats)	9	8-F	Dirty, flat finish
35. Southern Imperial Permachlor #890 Chlorinated Rubber	4	8-MD	Semigloss
36. Southern Imperial Duramet #550 Stainless Steel Filled Inorganic Silicate (High Temperature)	2	10	Low gloss
37. Southern Imperial #1120 Acrylic Latex	10	10	Dirty, flat finish
38. Subox VL 2000 Vinyl	10	10	High gloss, very good
39. Subox Kintron 1800 Chlorinated Rubber (2 coats)	9	10	Semigloss, very good
40. Wisconsin Protective Coatings Plasite #2088 Aliphatic Polyurethane	10	10	Semigloss, good
41. Wisconsin Protective Coatings Plasite #284 Acrylic Latex	10	8-MD	Dirty, flat finish
42. Wisconsin Protective Coatings Plasite #2050 Vinyl Acrylic	6	2-F	Dirty, flat finish
43. Zinc Lock #400 Vinyl With #301 Wash Primer	10	10	High gloss, very good
44. Zinc Lock #900 Acrylic Emulsion	8	8-F	Semigloss
45. MIL-C-22750B, Amendment 2, Type I Polyamide-Cured Epoxy	8	6-F	Chalky
46. MIL-C-38427A, Type I (Carboline), Acrylic Latex	10	8-M	Dirty, flat finish
47. FSN 8010-K02-6307 Acrylic Latex (Atlantic Paint Mfg. Co.)	10	8-M	Flat finish

TABLE 12. RESULTS OF 18-MONTH SEACOAST EXPOSURE

TOPCOATED TYPE I, CLASS 2 COATINGS

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
1. Ameron #99 Vinyl Chloride Copolymer (high build)	4	2-F	Flat finish
2. Ameron #2024 Chlorinated Rubber	4	8-F	Semigloss
3. Ameron #1969 Vinyl Acrylic	4	10	Semigloss
4. Ameron #1756 Acrylic Latex	5	8-M	Dirty, flat finish
5. Carboline 3300 Acrylic Latex	5	2-F	Flat finish
6. Carboline Carbomastic 2256-140 Aluminum Epoxy Coal Tar	10	10	Very good
7. Carboline Carbomastic 14 Epoxy Coal Tar	10	10	Very good
8. Con Lux Trim Plex 53-71 Acrylic Latex	7	8-D	Dirty, flat finish
9. Con Lux Vinyloid Vinyl	6	10	High gloss, good
10. Cook Coro Cryl Acrylic Latex	3	10	Semigloss
11. Cook E 346 High Build Polyamide-Cured Epoxy	9	10	Yellow, chalky
12. DuPont DuLux Enamel #25-5203	4	4-MD	Dirty, flat finish
13. DuPont Tufcoat Acrylic Emulsion #310-404	5	8-M	Dirty, flat finish
14. DeVoe and Raynolds Devflex II Acrylic Emulsion	5	8-M	Dirty, flat finish
15. DeVoe and Raynolds Formula 209 Devran Epoxy	1	6-M	Chalky
16. Enjay Rust-Ban CR 6893 Chlorinated Rubber	2	8-M	Semigloss

TABLE 12. RESULTS OF 18-MONTH SEACOAST EXPOSURE (Continued)

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
17. Enjay Rust-Ban EX 6670 Catalyzed Epoxy With EX 6666 Epoxy Intermediate Coat	9	10	Yellow, chalky
18. Enjay Rust-Ban EM 6657 High Build Epoxy With EX 6666 Epoxy Intermediate Coat	8	10	Yellow, chalky
19. Enjay Rust-Ban VY 6500 Vinyl	3	2-F	Low gloss
20. Enjay Rust-Ban VM 6510 High Build Vinyl	3	8-M	Flat finish
21. Essex Betacote 93 Series Vinyl	3	10	High gloss
22. Essex Betacote 15-61-01 Acrylic Latex	3	10	Dirty, flat finish
23. Koppers #600 Acrylic Latex	5	10	Dirty, flat finish
24. Koppers #400 Vinyl With #25 Intermediate Coat	6	10	Flat finish
25. Napko Epoxycote PA 5697 Polyamide-Cured Epoxy	9	10	Chalky
26. Napko 8-2484 Acrylic Latex	7	6-M	Flat finish
27. Plas-Chem X-82B High Build Epoxy	10	10	Very good
28. Plas-Chem X-72B Vinyl Medium Build	6	10	Very good
29. Plas-Chem R35-9A Acrylic Latex With #2504 Wash Primer	4	8-F	Flat finish
30. Prufcoat HSA 570-10-00 Vinyl	8	10	Flat finish
31. Prufcoat Clad 223-00-00 Acrylic Latex	4	10	Dirty, flat finish
32. Prufcoat MBX 559-10-00 Acrylic Enamel	4	6-F	Semigloss
33. Sherwin Williams Polane Polyurethane	2	4-F	Semigloss

TABLE 12. RESULTS OF 18-MONTH SEACOAST EXPOSURE (Continued)

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
34. Sherwin Williams Metalatex Acrylic Emulsion	4	10	Dirty, flat finish
35. Southern Imperial Permachlor #890 Chlorinated Rubber	1	8-MD	Semigloss
36. Southern Imperial Duramet #550 Stainless Steel Filled Inorganic Silicate (High Temperature)	10	10	Low gloss
37. Southern Imperial #1120 Acrylic Latex	2	8-M	Dirty, flat finish
38. Subox VL 2000 Vinyl	3	10	High gloss
39. Subox Kintron 1800 Chlorinated Rubber	3	10	Semigloss
40. Wisconsin Protective Coatings Plasite #2088 Aliphatic Polyurethane	8	10	Dirty, flat finish
41. Wisconsin Protective Coatings Plasite #284 Acrylic Latex	8	2-F	Dirty, flat finish
42. Wisconsin Protective Coatings Plasite #2050 Vinyl Acrylic	5	6-F	Dirty, flat finish
43. Zinc Lock #400 Vinyl With #301 Wash Primer	7	10	High gloss, good
44. Zinc Lock #900 Acrylic Emulsion	4	10	Semigloss
45. MIL-C-22750B, Amend. 2, Type I Polyamide-Cured Epoxy	5	6-F	Chalky
46. MIL-C-38427A, Type I (Carboline), Acrylic Latex	10	6-F	Dirty, flat finish
47. FSN 8010-K02-6307 Acrylic Latex (Atlantic Paint Mfg. Co.)	4	8-F	Flat finish

TABLE 13. RESULTS OF 18-MONTH SEACOAST EXPOSURE

TOPCOATED TYPE II, CLASS 1 COATINGS

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
1. Ameron #99 Vinyl Chloride Copolymer (high build)	5	8-M	Flat finish
2. Ameron #2024 Chlorinated Rubber	7	6-MD	Semigloss
3. Ameron #1969 Vinyl Acrylic	7	6-MD	Semigloss
4. Ameron #1756 Acrylic Latex	0	0-F	Large spalled area
5. Carboline 3300 Acrylic Latex	1	6-MD	Flat finish
6. Carboline Carbomastic 2256-140 Aluminum Epoxy Coal Tar	7	0-F	Very large blisters
7. Carboline Carbomastic 14 Epoxy Coal Tar	10	10	Very good
8. Con Lux Trim Plex 53-71 Acrylic Latex	2	6-M	Dirty, flat finish
9. Con Lux Vinyloid Vinyl	7	10	High gloss
10. Cook Coro Cryl Acrylic Latex	4	8-M	Semigloss
11. Cook E 346 High Build Polyamide-Cured Epoxy	2	2-F	Yellow, chalky
12. DuPont DuLux Enamel #25-5203	6	6-MD	Dirty, flat finish
13. DuPont Tufcoat Acrylic Emulsion #310-404	2	8-D	Dirty, flat finish
14. DeVoe and Raynolds Devflex II Acrylic Emulsion	5	8-D	Dirty, flat finish
15. DeVoe and Raynolds Formula 209 Devran Epoxy	9	8-D	Chalky
16. Enjay Rust-Ban CR 6893 Chlorinated Rubber	1	0-F	Large spalled area

TABLE 13. RESULTS OF 18-MONTH SEACOAST EXPOSURE (Continued)

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
17. Enjay Rust-Ban EX 6670 Catalyzed Epoxy With EX 6666 Epoxy Intermediate Coat	8	8-MD	Yellow, chalky
18. Enjay Rust-Ban EM 6657 High Build Epoxy With EX 6666 Epoxy Intermediate Coat	8	10	Yellow, chalky
19. Enjay Rust-Ban VY 6500 Vinyl	7	2-F	Low gloss
20. Enjay Rust-Ban VM 6510 High Build Vinyl	0	0-M	Flat finish
21. Essex Betacote 93 Series Vinyl	7	7-F	High gloss
22. Essex Betacote 15-61-01 Acrylic Latex	3	0-F	Very large blisters
23. Koppers #600 Acrylic Latex	5	8-D	Dirty, flat finish
24. Koppers #400 Vinyl With #25 Intermediate Coat	6	6-M	Flat finish
25. Napko Epoxycote PA 5697 Polyamide-Cured Epoxy	6	8-M	Chalky
26. Napko 8-2484 Acrylic Latex	4	6-M	Flat finish
27. Plas-Chem X-82B High Build Epoxy	6	2-F	Good
28. Plas-Chem X-72B Vinyl Medium Build	10	6-M	Very good
29. Plas-Chem R35-9A Acrylic Latex With #2504 Wash Primer	8	6-MD	Flat finish
30. Prufcoat HSA 570-10-00 Vinyl	9	10	Flat finish
31. Prufcoat Clad 233-00-00 Acrylic Latex	3	4-D	Dirty, flat finish
32. Prufcoat MBX 559-10-00 Acrylic Enamel	4	8-MD	Semigloss
33. Sherwin Williams Polane Polyurethane	8	8-MD	Semigloss, good

TABLE 13. RESULTS OF 18-MONTH SEACOAST EXPOSURE (Continued)

Topcoat Materials	Degree of Corrosion Rating	Degree of Blistering Rating	General Appearance
34. Sherwin Williams Metalatex Acrylic Emulsion	4	4-D	Dirty, flat finish
35. Southern Imperial Permachlor #890 Chlorinated Rubber	9	8-MD	Semigloss
36. Southern Imperial Duramet #550 Stainless Steel Filled Inorganic Silicate (High Temperature)	--	--	Failed during application
37. Southern Imperial #1120 Acrylic Latex	3	8-D	Dirty, flat finish
38. Subox VL 2000 Vinyl	6	6-M	High gloss, good
39. Subox Kintron 1800 Chlorinated Rubber	8	8-M	Semigloss, very good
40. Wisconsin Protective Coatings Plasite #2088 Alphatic Polyurethane	8	10	Semigloss, good
41. Wisconsin Protective Coatings Plasite #284 Acrylic Latex	0	8-D	Dirty, flat finish
42. Wisconsin Protective Coatings Plasite #2050 Vinyl Acrylic	6	2-M	Dirty, flat finish
43. Zinc Lock #400 Vinyl with #301 Wash Primer	7	6-M	High gloss, good
44. Zinc Lock #900 Acrylic Emulsion	3	6-D	Semigloss
45. MIL-C-22750B, Amend. 2, Type I Polyamide-Cured Epoxy	10	8-MD	Chalky
46. MIL-C-38427A, Type I (Carboline), Acrylic Latex	8	2-F	Dirty, flat finish
47. FSN 8010-K02-6307 Acrylic Latex (Atlantic Paint Mfg. Co.)	3	8-D	Flat finish

TABLE 14. ABRASION RESISTANCE DATA ON TYPE I, CLASS 1, INORGANIC ZINC COATINGS FEDERAL TEST METHOD STANDARD 141a, METHOD 6192 USING CS-17 WHEELS AND A 1000 GRAM LOAD (Continued)

Primer Identification	Coating Thickness (mils)**	Wear Index (Grams) Wear Cycles
Grow Pruf Coat 500	3.9	0.584/1000
	2.9	*0.786/917
	2.8	0.679/301
Mobil Zinc 7	6.0	1.895/1000
	3.0	*0.713/600
	3.0	1.150/1000
Napko 5Z	8.0	2.612/520
	3.8	*0.412/1000
	6.0	1.865/394
Plas Chem Zincite G	3.4	0.092/1000
	7.0	*0.236/1000
	6.3	0.324/1000
Sea Guard 3	5.0	*0.101/1000
	6.0	*0.129/1000
Southern Imperial Durazinc 525	6.0	0.068/1000
	5.4	*0.049/1000
	3.4	0.112/1000
Wisconsin Protective Coatings, Plasite No. 1000	2.4	0.045/1000
	4.1	0.066/1000

TABLE 14. ABRASION RESISTANCE DATA ON TYPE I, CLASS 1, INORGANIC ZINC COATINGS FEDERAL TEST METHOD STANDARD 141a, METHOD 6192 USING CS-17 WHEELS AND A 1000 GRAM LOAD (Continued)

Primer Identification	Coating Thickness (mils)**	Wear Index (Grams) / Wear Cycles
Subox Galvanox Type V	2.4	*0.035/1000
	5.2	*0.053/1000
Zinc Lock 351	2.0	*0.448/1000
	4.3	*0.296/1000

*30 Day Outdoor Exposure Panel
**Measurements were in mils. To convert to millimeters, multiply by 0.0254.

TABLE 15. ABRASION RESISTANCE DATA ON TYPE I, CLASS 2 ZINC COATINGS
FEDERAL TEST METHOD STANDARD 141a, METHOD 6192
USING CS-17 WHEELS AND A 1000 GRAM LOAD

Primer Identification	Coating Thickness (mils)**	Wear Index (Grams) / Wear Cycles
Ameron D-4	6.0	2.495/148
	5.0	*0.092/1000
	4.0	1.781/240
Ameron D-5	2.8	0.103/1000
	5.0	0.097/1000
Carboline Carbo Zinc 33	4.0	1.085/287
	4.4	1.707/418
Devoe and Raynolds Catha Cote 300 (post cured)	5.8	0.054/1000
	2.5	0.044/1000
Devoe and Raynolds Catha Cote 305	4.2	0.072/1000
	6.1	0.065/1000
Enjay 191	3.0	0.032/1000
	4.6	0.040/1000
Grow Pruf Coat 200	3.4	0.140/1000
	6.6	0.207/1000
Koppers Inorganic (post cured)	1.9	0.070/1000
	4.8	0.060/1000
Mobil Zinc 1	5.0	0.046/1000
	3.2	0.032/1000

TABLE 15. ABRASION RESISTANCE DATA ON TYPE I, CLASS 2 ZINC COATINGS
FEDERAL TEST METHOD STANDARD 141a, METHOD 6192
USING CS-17 WHEELS AND A 1000 GRAM LOAD (Continued)

Primer Identification	Coating Thickness (mils)**	Wear Index (Grams) / Wear Cycles
Napko 4Z	4.8	0.147/1000
	2.5	0.132/1000
Sea Guard 6	2.0	*0.027/1000
	6.0	*0.047/1000
Sherwin Williams Zinc Clad 8	3.8	0.035/1000
	4.0	0.038/1000
Southern Imperial Durazinc 500	3.9	0.147/1000
	5.2	0.107/1000
Subox Galvanox Type VI	2.0	0.214/212
	5.1	0.523/1000

*30 Day Outdoor Exposure Panel
**Measurements were in mils. To convert to millimeters, multiply by 0.0254.

TABLE 16. ABRASION RESISTANCE DATA ON TYPE II, CLASS 1, ZINC COATINGS FEDERAL TEST METHOD STANDARD 141a, METHOD 6192 USING CS-17 WHEELS AND A 1000 GRAM LOAD

Primer Identification	Coating Thickness (mils)*	Wear Index (Grams) / Wear Cycles
Ameron 39	5.3	0.745/1000
	2.9	0.735/955
Carboline 676	3.6	0.268/1000
	5.0	0.265/1000
Conlux Zinc Plate	2.6	0.224/1000
	5.8	0.161/1000
Cook One Package	2.2	0.381/1000
	2.4	0.436/1000
Enjay 5699	2.1	0.446/1000
	3.8	0.467/1000
Galvicon	2.5	0.903/1000
Koppers' Organic	5.0	0.157/1000
	3.4	0.101/1000
Napko 2Z	3.6	0.938/1000
	5.2	0.925/1000
Plas Chem Zincor No. 7	3.8	0.206/1000
	5.0	0.266/1000
Rustoleum 96-3404	2.6	0.923/1000

TABLE 16. ABRASION RESISTANCE DATA ON TYPE II, CLASS 1, ZINC COATINGS FEDERAL TEST METHOD STANDARD 141a, METHOD 6192 USING CS-17 WHEELS AND A 1000 GRAM LOAD (Continued)

Primer Identification	Coating Thickness (mils)*	Wear Index (Grams) / Wear Cycles
Rustoleum 7085	3.3	0.213/1000
	4.2	0.247/1000
Rustoleum 92-8504	3.3	0.315/1000
	4.2	0.357/1000
Sherwin Williams Zinc Clad 5	4.2	0.567/1000
	4.0	0.578/1000
Southern Imperial Permazine 520	2.4	0.756/1000
	5.4	1.183/1000
Subox Galvanox Type I	4.6	0.278/1000
	3.7	0.303/1000

*Measurements were in mils. To convert to millimeters, multiply by 0.0254.

TABLE 17. ABRASION RESISTANCE DATA ON TYPE II, CLASS 2, ZINC COATINGS
FEDERAL TEST METHOD STANDARD 141a, METHOD 6192
USING CS-17 WHEELS AND A 1000 GRAM LOAD

Primer Identification	Coating Thickness (mils)*	Wear Index (Grams) Wear Cycles
American Abrasive Metals AAMZINC 14A-2	2.5	0.683/1000
	6.0	0.696/1000
Cook Epicon R	4.3	0.149/1000
	3.7	0.107/1000
DuPont Ganacin 347-937	5.0	0.212/1000
	5.6	0.188/1000
Enjay 5662	5.0	0.165/1000
	3.0	0.143/1000
Essex 75-61	2.9	0.542/1000
	4.5	0.597/1000
Pruf Coat Zinc Prime 100	3.3	0.385/1000
	5.7	0.315/1000
Mobil Zinc 2	2.2	0.655/1000
	5.1	0.317/1000
Mobil Zinc 4	2.0	0.237/1000
	6.2	0.266/1000
Sherwin Williams Zinc Clad 7	3.8	0.690/1000
	6.2	0.504/1000

TABLE 6. RESULTS OF 18-MONTH SEACOAST EXPOSURE

TYPE I, CLASS 1 COATINGS

Coating Material	Degree of Corrosion Rating at Manufacturer's Recommended Film Thickness	Degree of Corrosion Rating at 4-6 mils* Film Thickness
Ameron Corporation D-6	10	10
Carboline Company Carbo-Zinc 11	10	10
Carboline Company Carbo-Zinc 13	8	9
Cook Paint & Varnish Company Galva Pak 101	10	10
DeVoe & Raynolds Company Catha Cote 302	4	8
DeVoe & Raynolds Company Catha Cote 304	10	10
DuPont Ganicin 347-931	10	10
Grow Chemical Coatings Zinc Prime 500	8	8
Mobil Chemical Company Mobil Zinc 7	10	10
Napko Corporation 5Z	10	10
Plas Chem Corporation Zincite G	10	10
Seaguard Corporation Seaguard 3	10	10
Southern Imperial Coatings Durazinc 525	10	10
Subox Galvanox Type V	10	10
Wisconsin Protective Coatings Corporation Plasite 1000	10	10
Zinc Lock Company 351	10	10

*Metric equivalent: 0.1 to 0.15 mm

TABLE 17. ABRASION RESISTANCE DATA ON TYPE II, CLASS 2 ZINC COATINGS FEDERAL TEST METHOD STANDARD 141a, METHOD 6192 USING CS-17 WHEELS AND A 1000 GRAM LOAD (Continued)

Primer Identification	Coating Thickness (mils)*	Wear Index (Grams) / Wear Cycles
Sherwin Williams Zinc Clad 9	2.8	0.277/1000
	6.0	0.214/1000
Subox Galvanox Type II	6.3	0.252/1000
	7.1	0.275/1000
Wisconsin Protective Coatings Plasite 1704	4.7	0.317/1000
	2.7	0.220/1000
Wisconsin Protective Coatings Plasite 7140	5.0	0.220/1000
	2.7	0.198/1000
Wisconsin Protective Coatings Plasite 1636	5.0	0.443/1000
	6.0	0.378/1000

*Measurements were in mils. To convert to millimeters, multiply by 0.0254.

TABLE 18. SCRAPE ADHESION DATA PERFORMED ON TYPE I, CLASS 1, INORGANIC ZINC PRIMERS ASTM D 2197-67T USING BALANCED BEAM TESTER

Primer Identification	Coating Thickness (mils)*	Load Required to Penetrate Through Coating (kg)	
		Before Outdoor Exposure	After 30 Day Outdoor Exposure
Ameron D-6	3.5	1	> 10
	6.2	1/2	9
Carbo Zinc 11	3.7	2	> 10
	2.7	1-1/2	> 10
Carbo Zinc 13	3.0	1-1/2	2
	3.4	1	2
Cook Galva Pak 101	2.4	2	7
	4.8	3	7
Devoe and Raynolds Catha Cote 304	5.6	2-1/2	3
	7.0	2	3
Devoe and Raynolds Catha Cote 302	4.0	> 10	> 10
	5.2	> 10	> 10
DuPont Ganacin Inorganic 347-931	2.2	1-1/2	> 10
	3.0	1-1/2	10
Grow Pruf Coat 500	2.7	2	2
	3.9	2	2
Mobil Zinc 7	6.0	1-1/2	4
	2.7	1-1/2	4

TABLE 18. SCRAPE ADHESION DATA PERFORMED ON TYPE I, CLASS 1, INORGANIC ZINC PRIMERS ASTM D 2197-67T USING BALANCED BEAM TESTER (Continued)

		Load Required to Penetrate Through Coating (kg)	
Primer Identification	Coating Thickness (mils)*	Before Outdoor Exposure	After 30 Day Outdoor Exposure
Napko 5Z	3.6	2-1/2	8
	6.2	2-1/2	5
Plas Chem Zincite G	3.0	2	10
	6.3	3	8
Sea Guard 3	4.0		4
	4.6		4
Southern Imperial Durazinc 525	6.0	5-1/2	8
	3.0	5	> 10
Subox Galvanox Type V	2.8	2	5
	5.0	3	6
Wisconsin Protective Coatings Plasite No. 1000	2.8	> 10	
	4.0	> 10	
Zinc Lock 351	2.3	10	
	4.3	9	

*Measurements were in mils. To convert to millimeters, multiply by 0.0254.

TABLE 19. SCRAPE ADHESION DATA PERFORMED ON TYPE I, CLASS 2, ZINC PRIMERS ASTM D 2197-67T USING BALANCED BEAM TESTER

Primer Identification	Coating Thickness (mils)*	Load Required to Penetrate Through Coating (kg): Before Outdoor Exposure	Load Required to Penetrate Through Coating (kg): After 30 Day Outdoor Exposure
Ameron D-6	3.6	1	> 10
	5.6	1/2	> 10
Amercoat D-5	2.2	> 10	
	3.7	> 10	
Carboline Carbozinc 33	6.0	1	
	4.2	1	
Devoe and Raynolds Catha Cote 300 Post-Cured	2.4	> 10	
	4.7	7	
Devoe and Raynolds Catha Cote 305	2.6	6	
	5.8	4	
Enjay 191	4.0	8	
	2.7	5	
Grow Pruf Coat 200	3.0	3	
	5.6	3	
Koppers' Inorganic Post-Cured	2.0	> 10	
	4.0	9	
Mobil Zinc 1	2.9	> 10	
	4.8	> 10	

TABLE 19. SCRAPE ADHESION DATA PERFORMED ON TYPE I, CLASS 2, ZINC PRIMERS ASTM D 2197-67T USING BALANCED BEAM TESTER (Continued)

Primer Identification	Coating Thickness (mils)*	Load Required to Penetrate Through Coating (kg)	
		Before Outdoor Exposure	After 30 Day Outdoor Exposure
Napko 4Z	3.9	9	
	2.7	9	
Sea Guard 6	5.0	10	
	5.5	7	
Sherwin Williams Zinc Clad 8	4.9	10	
	4.8	10	
Southern Imperial Durazinc 500	4.0	3	
	2.5	3	
Subox Galvanox Type VI	2.0	4	
	2.0	4	

*Measurements were in mils. To convert to millimeters, multiply by 0.0254.

TABLE 20. SCRAPE ADHESION DATA ON TYPE II, CLASS 1
ZINC-RICH PRIMERS ASTM D 2197-67T
USING BALANCED BEAM TESTER

Primer Identification	Coating Thickness (mils)*	Load Required to Penetrate Through Coating (kg)
Ameron 39	4.2	> 10
	5.7	> 10
Carboline 676	3.0	> 10
	5.0	> 10
Conlux Zinc Plate	4.0	> 10
	2.6	> 10
Cook One Package	2.3	> 10
	2.3	> 10
Enjay 5699	2.4	> 10
	4.0	> 10
Galvicon	2.3	10
Koppers' Organic	4.5	> 10
	3.2	> 10
Napko 2Z	3.8	> 10
	6.0	> 10
Plaschem Zincor No. 7	6.0	> 10
	3.3	> 10
Rustoleum 96-3404	3.5	7
Rustoleum 7085	4.4	8
	3.7	8

TABLE 20. SCRAPE ADHESION DATA ON TYPE II, CLASS 1 ZINC-RICH PRIMERS ASTM D 2197-67T USING BALANCED BEAM TESTER (Continued)

Primer Identification	Coating Thickness (mils)*	Load Required to Penetrate Through Coating (kg)
Rustoleum 92-8504	5.3	10
	3.2	10
Sherwin Williams Zinc Clad 5	4.2	10
	3.4	> 10
Southern Imperial Permazinc 520	2.5	9
	5.4	8
Subox Galvanox Type I	4.8	> 10
	4.6	> 10

*Measurements were in mils. To convert to millimeters, multiply by 0.0254.

TABLE 21. SCRAPE ADHESION DATA ON TYPE II, CLASS 2, ZINC-RICH PRIMERS ASTM D 2197-67T USING BALANCED BEAM TESTER (Continued)

Primer Identification	Coating Thickness (mils)*	Load Required to Penetrate Through Coating (kg)
Subox Type II	6.4	> 10
	4.8	> 10
Wisconsin Protective Coatings Plasite 1704	3.0	> 10
	4.5	> 10
Wisconsin Protective Coatings Plasite 7140	2.2	> 10
	5.2	> 10
Wisconsin Protective Coatings Plasite 1636	6.6	> 10
	4.0	> 10

*Measurements were in mils. To convert to millimeters, multiply by 0.0254.

TABLE 22. SOLVENT BASE, INORGANIC ZINC COATINGS
HEAT RESISTANCE TEST DATA

1.	Ameron Corporation D-6	Slightly darkening at 400°C (752°F), no loss of adhesion
2.	Carboline Company Carbo Zinc 11	Slight darkening at 260°C (500°F); no further change at 400°C, no loss of adhesion
3.	Carboline Company Carbo Zinc 13	Slight darkening at 400°C, no loss of adhesion
4.	Cook Paint and Varnish Co. Galva Pak 101	Slight darkening at 260°C; no further change at 400°C, no loss of adhesion
5.	DeVoe and Raynolds Co. Catha Cote 302	Softened at 163°C (325°F); hardened at 232°C (450°F); turned from bright green to brown at 260°C; turned yellowish-brown at 400°C, powdery, adhesion dropped from over 10 kg to less than 3-1/2 kg
6.	DeVoe and Raynolds Co. Catha Cote 304	No changes at 400°C
7.	DuPont Ganicin 347-931	Turned from green to pinkish-brown at 260°C; no further change at 400°C, no loss of adhesion
8.	Grow Chemical Coatings, Prufcoat Division Zinc Prime 500	Slight darkening at 400°C, very slight loss of adhesion (dropped from 2 kg to 1-1/2 kg)
9.	Mobil Chemical Co. Mobil Zinc 7	No changes at 400°C
10.	Napko Corporation 5Z	Darkened slightly at 260°C; turned from green to gray at 400°C, no loss of adhesion
11.	Plas Chem Corp. Zincite G	No changes at 400°C
12.	Sea Guard 3	No changes at 400°C
13.	Southern Imperial Coatings Durazinc 525	No changes at 400°C
14.	Subox Type V	Turned from green to light green at 316°C (600°F); turned gray at 400°C, no loss of adhesion

TABLE 22. SOLVENT BASE, INORGANIC ZINC COATINGS
HEAT RESISTANCE TEST DATA (Continued)

15.	Wisconsin Protective Coatings Plasite 1000	Turned from gray to blue-gray at 400°C, some loss of adhesion (dropped from over 10 kg to 5-1/2 kg)
16.	Zinc Lock Company No. 351	Turned from dark gray to lighter gray at 304°C; some loss of adhesion at 400°C (dropped from 10 kg to 5-1/2 kg)

TABLE 23. WATER REDUCIBLE, INORGANIC ZINC COATINGS
HEAT RESISTANCE TEST DATA

1.	Ameron Corporation D-4	Turned from dark brown to green at 260°C (500°F); turned blue-gray at 400°C (752°F), no loss of adhesion
2.	Ameron Corporation D-5	Turned from brown to darker brown at 400°C, no loss of adhesion
3.	Carboline Company Carbo Zinc 33	No changes at 400°C
4.	DeVoe and Raynolds Catha Cote 300 (post cured)	Turned lighter brown at 260°C; no further change at 400°C, no loss of adhesion
5.	DeVoe and Raynolds Catha Cote 305	No changes at 400°C
6.	Enjay Chemical Company Rust Ban 191	Slight darkening at 260°C; no further change at 400°C, no loss of adhesion
7.	Grow Chemical Coatings, Prufcoat Division, Zinc Prime 200	Some loss of adhesion at 400°C (dropped from 3 kg to 1 kg)
8.	Koppers Company Inorganic Zinc (post cured)	Turned lighter in color at 260°C; turned darker tan at 400°C, no loss of adhesion
9.	Mobil Chemical Co. Mobil Zinc 1	No changes at 400°C
10.	Napko Corporation 4Z	Turned from dark brown to lighter brown at 316°C (600°F); turned dark gray at 400°C, no loss of adhesion

TABLE 23. WATER REDUCIBLE, INORGANIC ZINC COATINGS HEAT RESISTANCE TEST DATA (Continued)

11.	Sherwin Williams Company Zinc Clad 8	Some loss of adhesion at 400°C (dropped from 10 kg to 5 kg)
12.	Sea Guard 6	No changes at 400°C
13.	Southern Imperial Coatings Durazinc 500	Turned lighter pink at 304°C; turned gray at 400°C, no loss of adhesion
14.	Subox Type VI	No changes at 400°C

TABLE 24. SINGLE COMPONENT, ORGANIC ZINC COATINGS HEAT RESISTANCE TEST DATA

1.	Ameron Corporation 39	Softened at 93°C (200°F); slight blistering at 177°C (350°F); turned lighter in color at 246°C (475°F); turned gray at 260°C (500°F), adhesion dropped from over 10 kg to less than 5 kg
2.	Carboline Company 676	Softened at 121°C (250°F); hardened at 218°C (425°F); darkened at 260°C, adhesion dropped from over 10 kg to less than 5 kg
3.	Con Lux Paint Products Zinc Plate	Softened at 121°C; hardened at 246°C (475°F); turned from gray to brownish green at 260°C, adhesion dropped from over 10 kg to less than 5 kg
4.	Cook Paint and Varnish Co. One Package	Softened at 121°C; hardened at 246°C; turned lighter in color at 260°C, adhesion dropped from over 10 kg to less than 5 kg
5.	Enjay Chemical Co. 5699	Softened at 121°C; hardened at 260°C and turned from gray to greenish gray, adhesion dropped from over 10 kg to less than 5 kg
6.	Galvicon Corporation Galvicon	Softened at 121°C, turned hard and powdery at 260°C, very low adhesion

TABLE 24. SINGLE COMPONENT, ORGANIC ZINC COATINGS
HEAT RESISTANCE TEST DATA (Continued)

7.	Koppers Company Organic Zinc	Softened at 163°C (325°F); turned from green to gray at 246°C; hardened at 260°C, adhesion dropped from over 10 kg to 7 kg
8.	Napko Corporation 2Z	Softened at 121°C; turned brownish green and hard at 260°C, adhesion dropped from over 10 kg to less than 5 kg
9.	Plas Chem Corporation Zincor #7	Softened at 135°C (275°F); turned hard at 177°C (350°F); turned from gray to greenish gray at 260°C, adhesion dropped from over 10 kg to less than 5 kg
10.	Rustoleum Corporation #96-3404	Softened at 93°C; hardened at 177°C; turned from green to gray at 260°C, adhesion dropped from 7 kg to less than 5 kg
11.	Rustoleum Corporation #7085	Softened at 93°C; hardened at 177°C; turned lighter gray at 260°C, adhesion dropped from 8 kg to less than 5 kg
12.	Rustoleum Corporation 92-8504	Softened at 121°C; hardened at 246°C; turned lighter gray at 260°C, adhesion dropped from over 10 kg to less than 5 kg
13.	Sherwin Williams Zinc Clad 5	Softened at 121°C; hardened and turned powdery at 246°C; turned lighter gray at 260°C, adhesion dropped from over 10 kg to less than 5 kg
14.	Southern Imperial Coatings Permazinc 520	Very soft at 93°C; hardened at 149°C (300°F) turned darker gray at 260°C but no loss of adhesion; tested at 316°C (600°F), some loss of adhesion (dropped from 9 kg to 7 kg)
15.	Subox Type I	Darkened at 191°C - 204°C (375°F - 400°F); tested at 316°C and 400°C (752°F) with no further changes or appreciable loss of adhesion (greater than 7 kg)

TABLE 25. MULTIPLE COMPONENT, ORGANIC ZINC-RICH COATINGS HEAT RESISTANCE TEST DATA

1.	American Abrasive Metals Co. AAMZINC 14A-2	Softened at 93°C (200°F); hardened at 177°C (350°F); turned greenish gray at 260°C (500°F), adhesion dropped from 10 kg to less than 5 kg
2.	Cook Paint and Varnish Co. Epicon R	Turned from reddish to brown at 260°C, adhesion dropped from over 10 kg to less than 7 kg
3.	DuPont Ganicin 347-937	Softened at 121°C (250°F); turned from green to gray-tan and hardened at 246°C (475°F), adhesion dropped from over 10 kg to less than 5 kg
4.	Enjay Chem Co. #5662	Softened at 135°C (275°F); hardened at 177°C; turned from reddish to brown at 260°C, but no loss of adhesion; no further changes at 316°C (600°F); tested at 400°C (752°F) but turned powdery and flaked off
5.	Essex Chemical Corp. 75-61	Softened at 121°C; hardened at 246°C; turned lighter gray at 260°C, adhesion dropped from over 10 kg to less than 5 kg
6.	Grow Chemical Coatings, Pruf-coat Division Zinc Prime 100	Softened at 121°C; hardened at 177°C; turned from reddish brown to brown at 260°C; adhesion dropped from over 10 kg to 7 kg
7.	Mobil Chem. Co. Mobil Zinc 2	Slight darkening at 246°C; turned from grayish-green to gray at 260°C but no loss of adhesion; tested at 316°C, adhesion dropped from 10 kg to less than 7 kg
8.	Mobil Chem. Co. Mobil Zinc 4	Softened at 163°C (325°F); hardened at 218°C (425°F); turned brown at 260°C, adhesion dropped from over 10 kg to 5 kg
9.	Sherwin Williams Zinc Clad 7	Softened at 93°C; hardened at 218°C; turned from gray to grayish green at 260°C, adhesion dropped from over 10 kg to less than 5 kg

TABLE 25. MULTIPLE COMPONENT, ORGANIC ZINC-RICH COATINGS
HEAT RESISTANCE TEST DATA (Continued)

10.	Sherwin Williams Zinc Clad 9	Softened at 93°C; hardened at 121°C; softened again at 163°C; slight darkening at 177°C; hardened at 260°C, no loss of adhesion; tested at 316°C with some loss of adhesion (dropped from over 10 kg to less than 7 kg)
11.	Subox Type II	Turned lighter gray at 260°C, adhesion dropped from over 10 kg to 7 kg
12.	Wisconsin Protective Coatings Plasite 1704	Softened at 135°C; hardened at 246°C; changed from grayish green to gray-brown at 260°C, adhesion dropped from over 10 kg to 7 kg
13.	Wisconsin Protective Coatings Plasite 7140	Slight discoloration at 163°C; changed from olive green to dark brown at 260°C but no loss of adhesion; tested at 316°C, adhesion dropped from over 10 kg to less than 7 kg
14.	Wisconsin Protective Coatings Plasite 1636	Softened at 135°C; hardened at 204°C (400°F); turned lighter gray at 260°C, adhesion dropped from over 10 kg to 7 kg

Figure 1 Overall View of Test Site

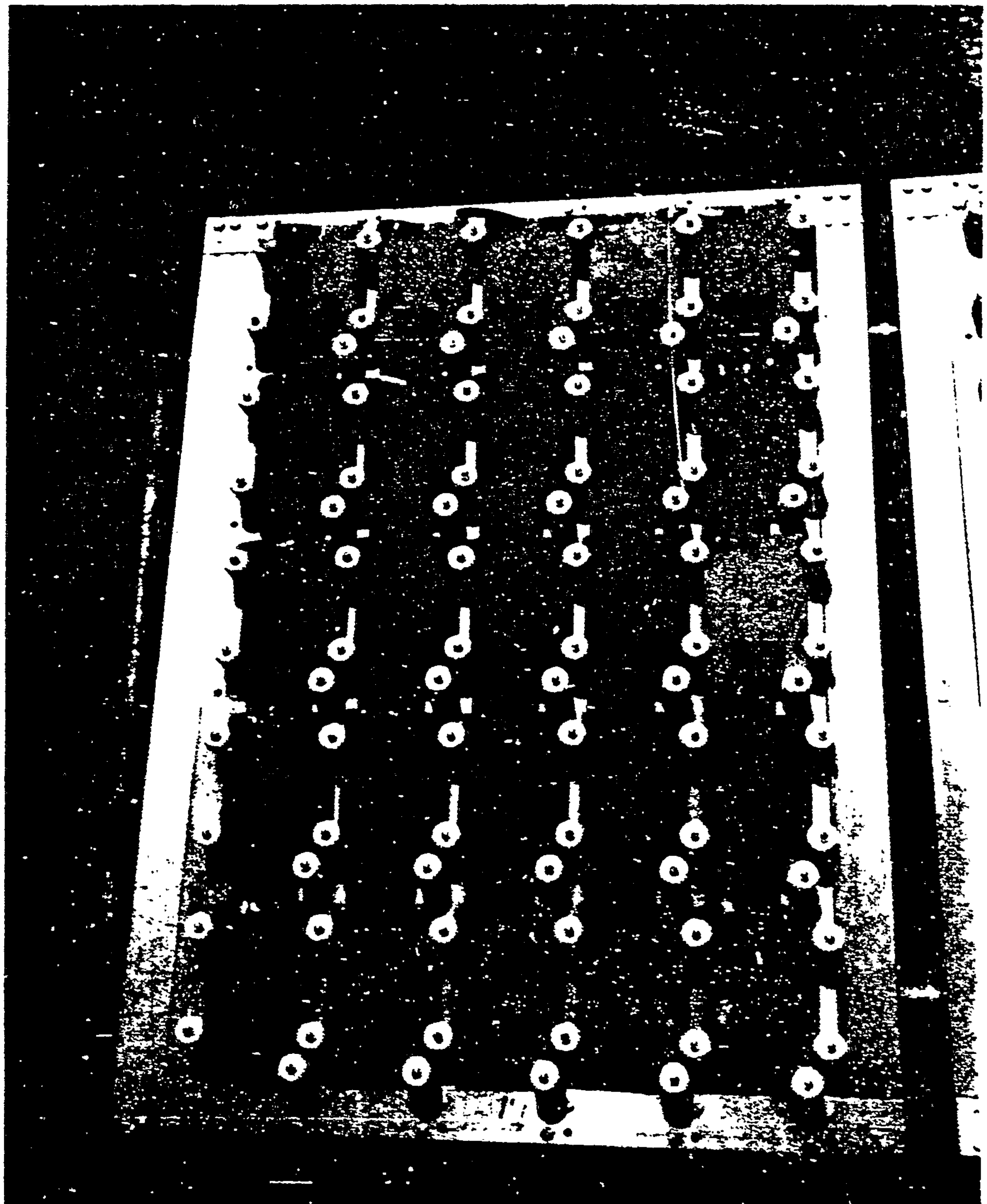

Figure 2. A Test Rack with Panels Installed

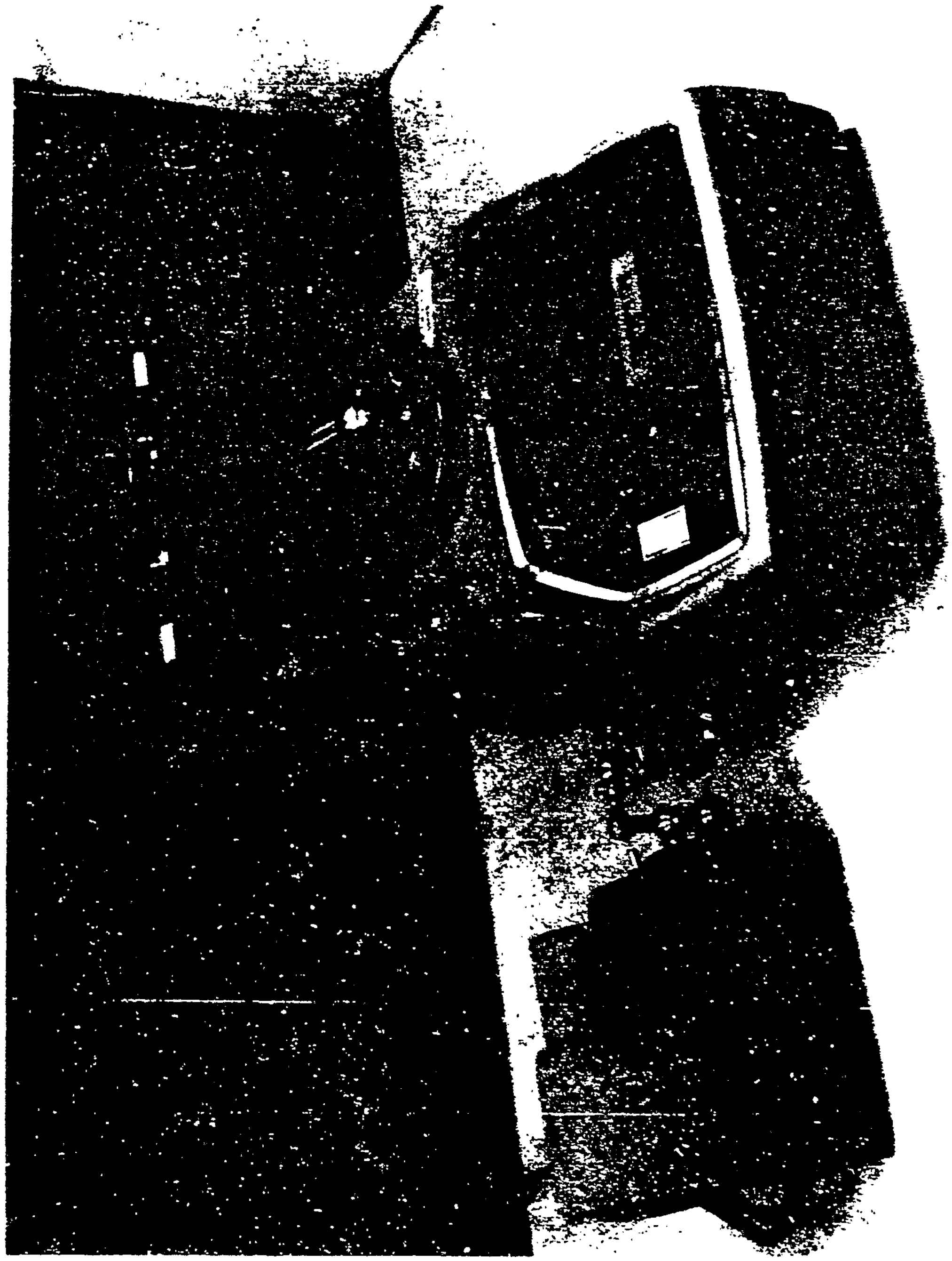

Figure 3. Taber Abraser

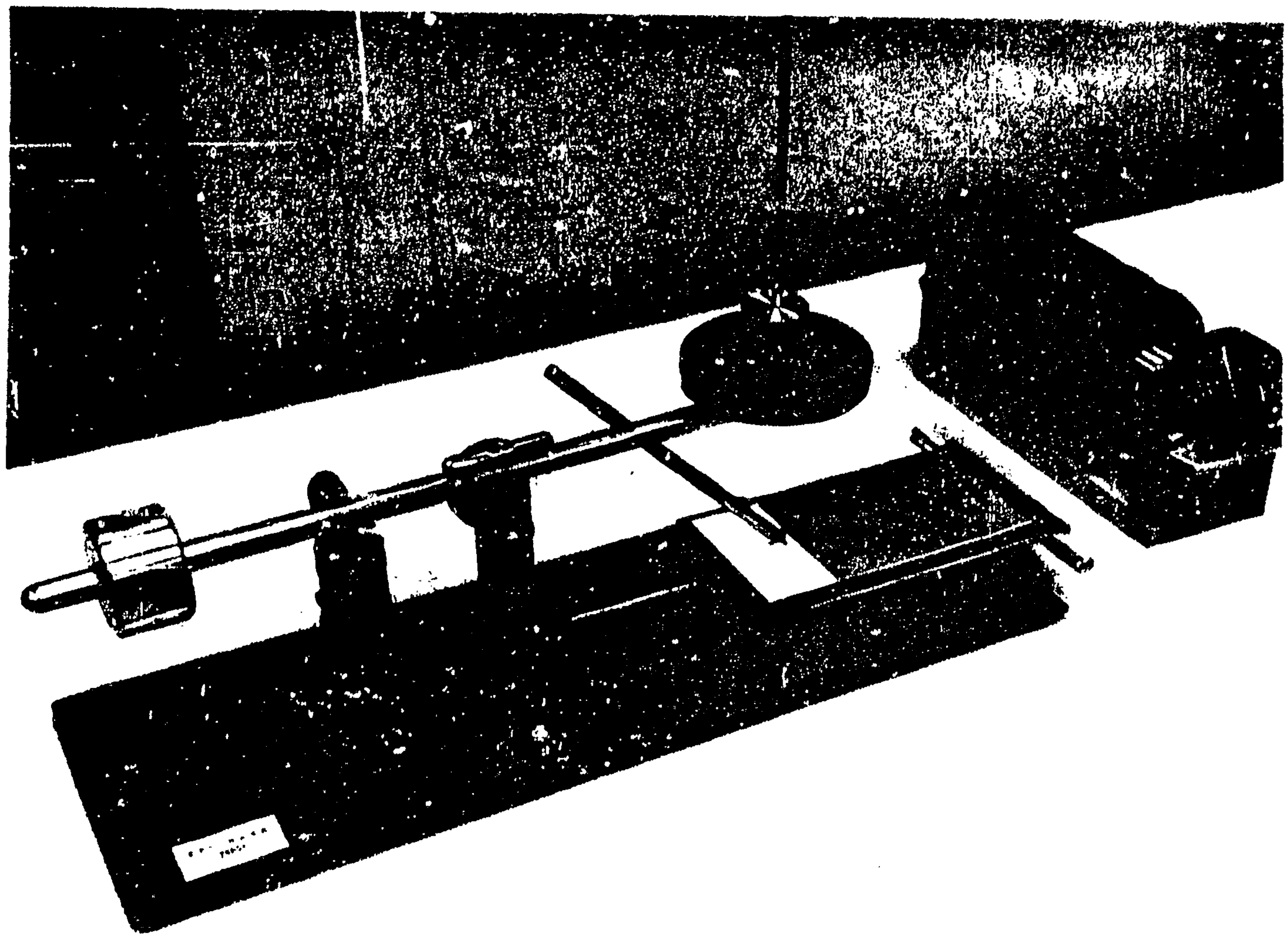

Figure 4. Balanced-Beam Scrape-Adhesion Tester

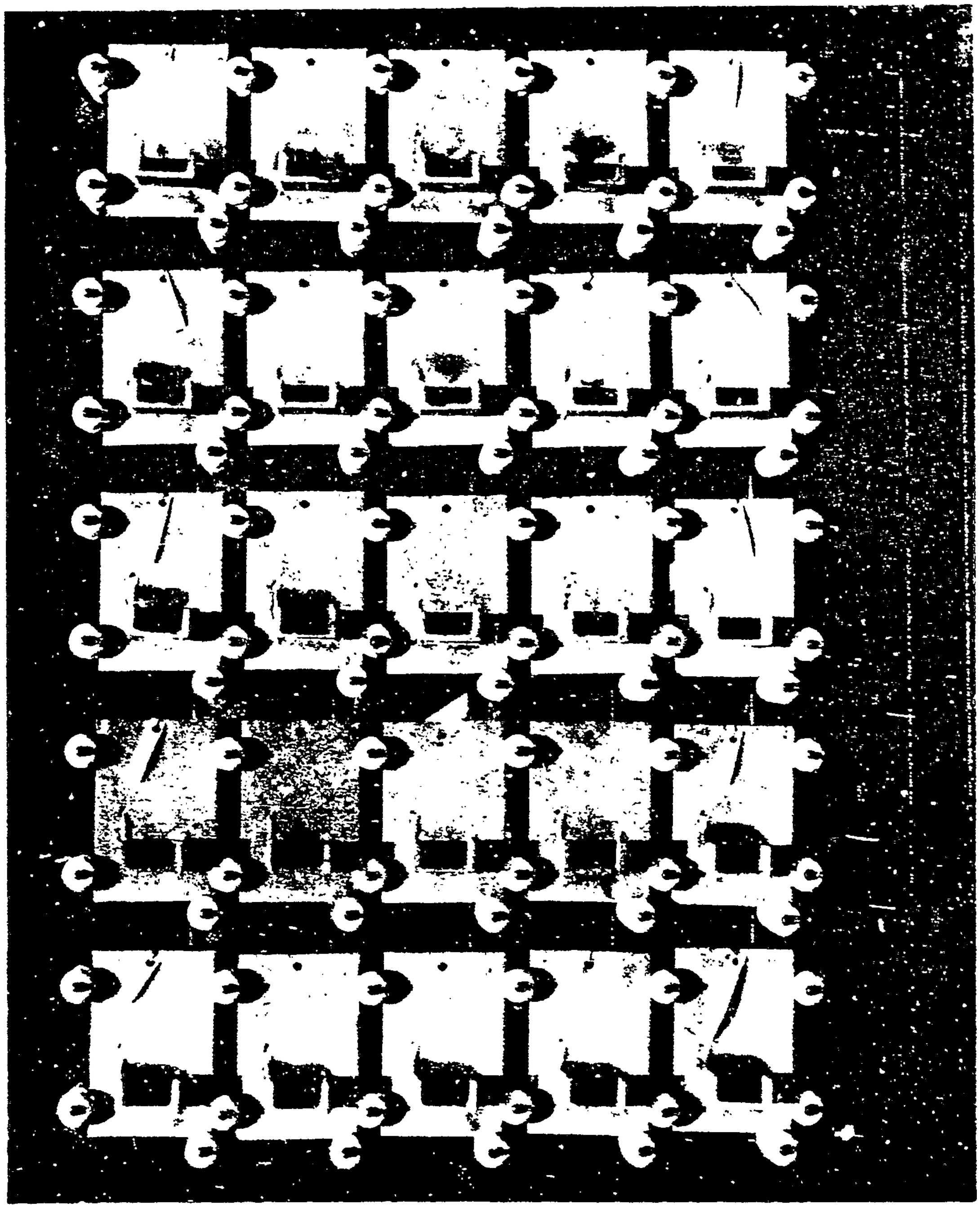

Figure 5. Type I Class 1 Inorganic Zinc Panels, Rack 1

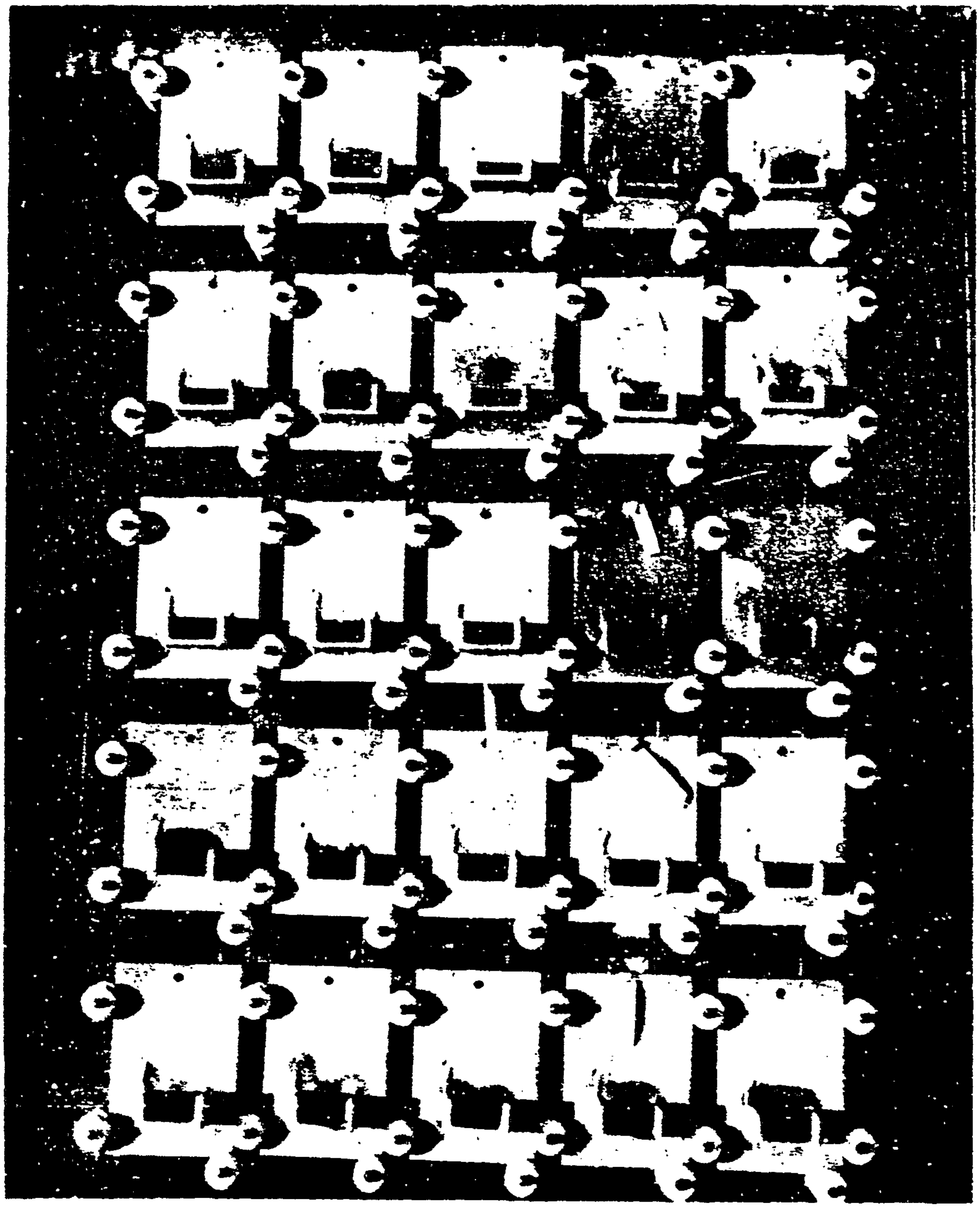

Figure 6. Type I Class 1 Inorganic Zinc Panels, Rack 2

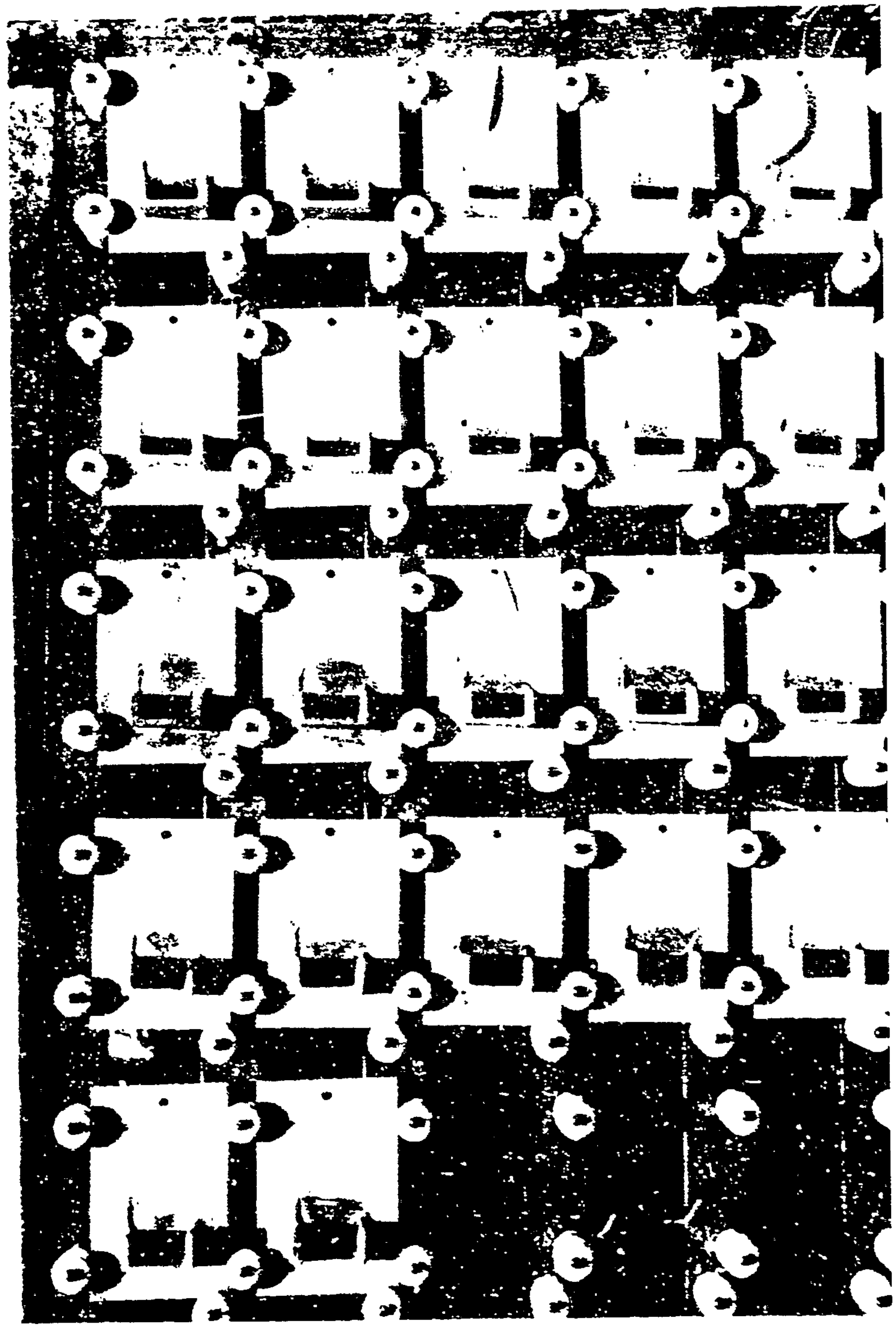

Figure 7. Type I Class 1 Inorganic Zinc Panels, Rac[illegible]

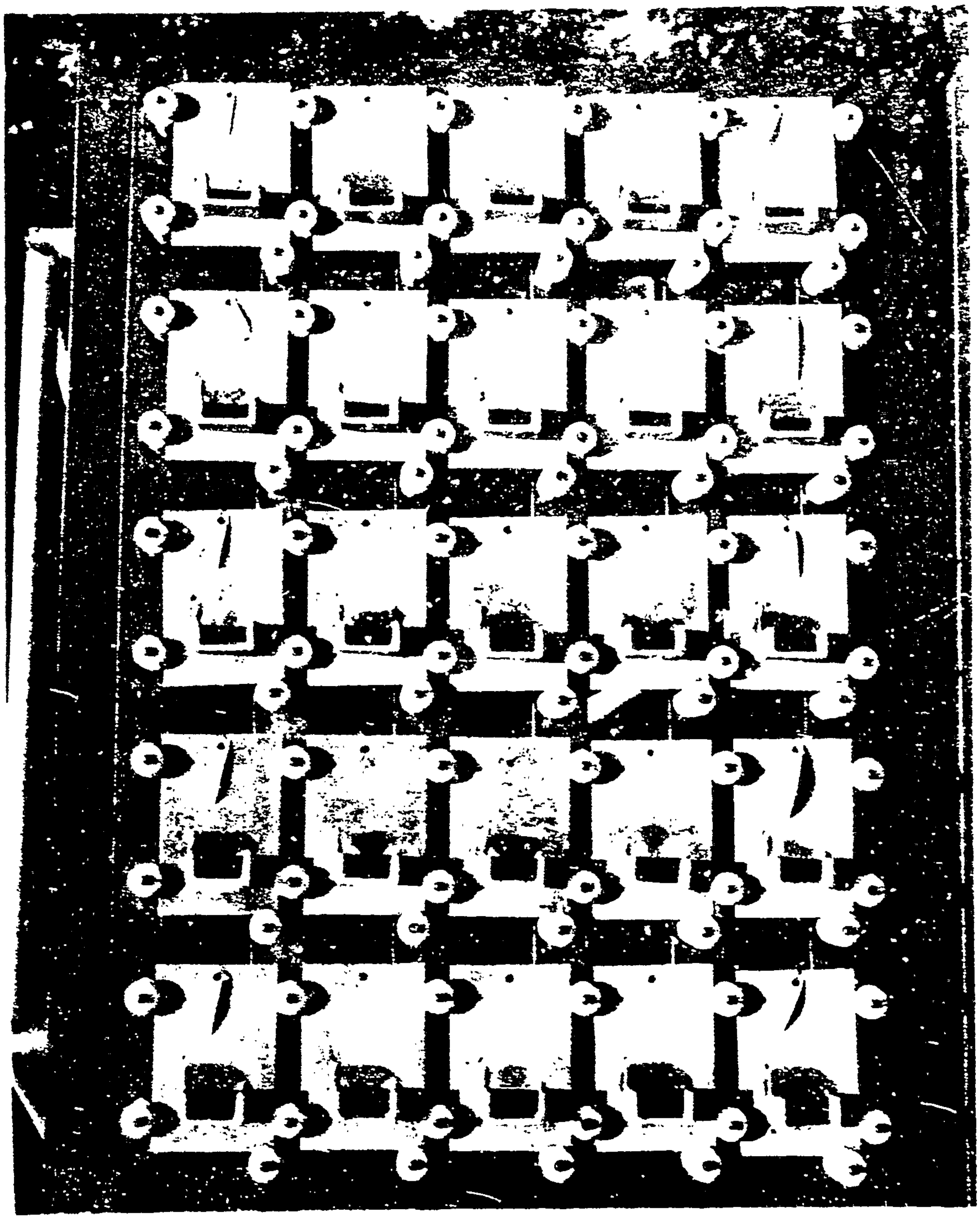

Figure 8. Type I Class 2 Inorganic Zinc Panels, Rack 1

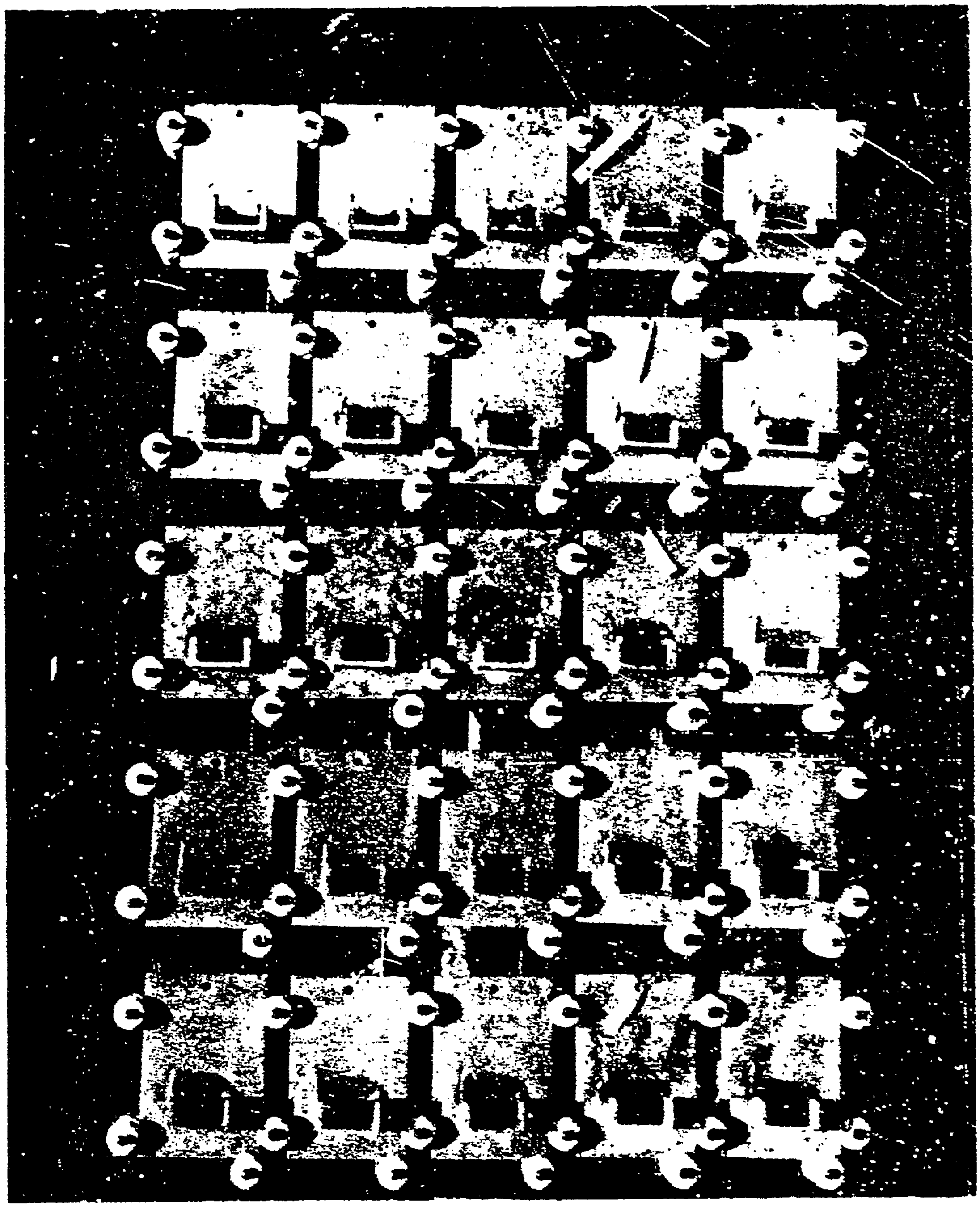

Figure 9. Type I Class 2 Inorganic Zinc Panels, Rack 2

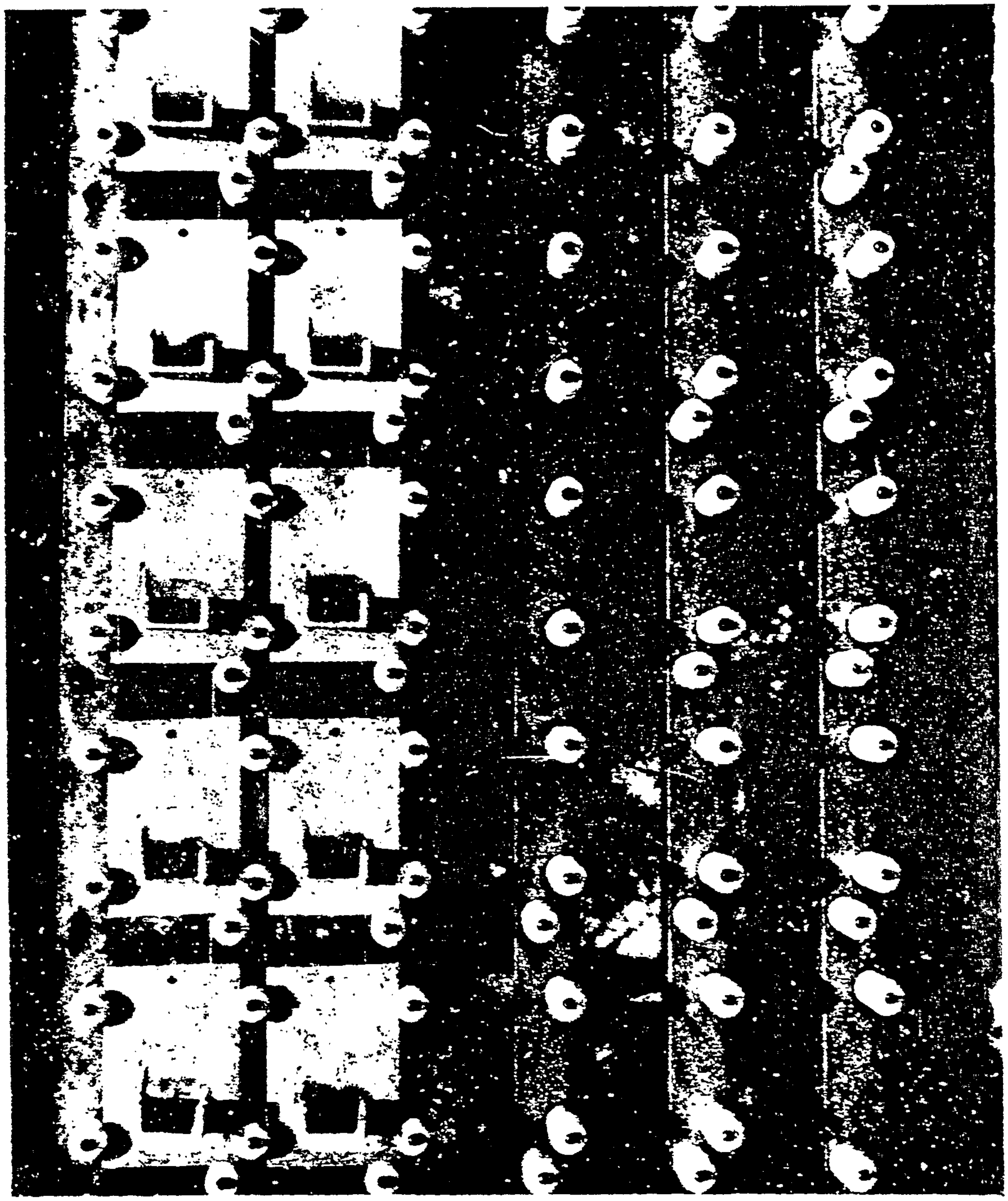

Figure 10. Type I Class 2 Inorganic Zinc Panels, Rack 3

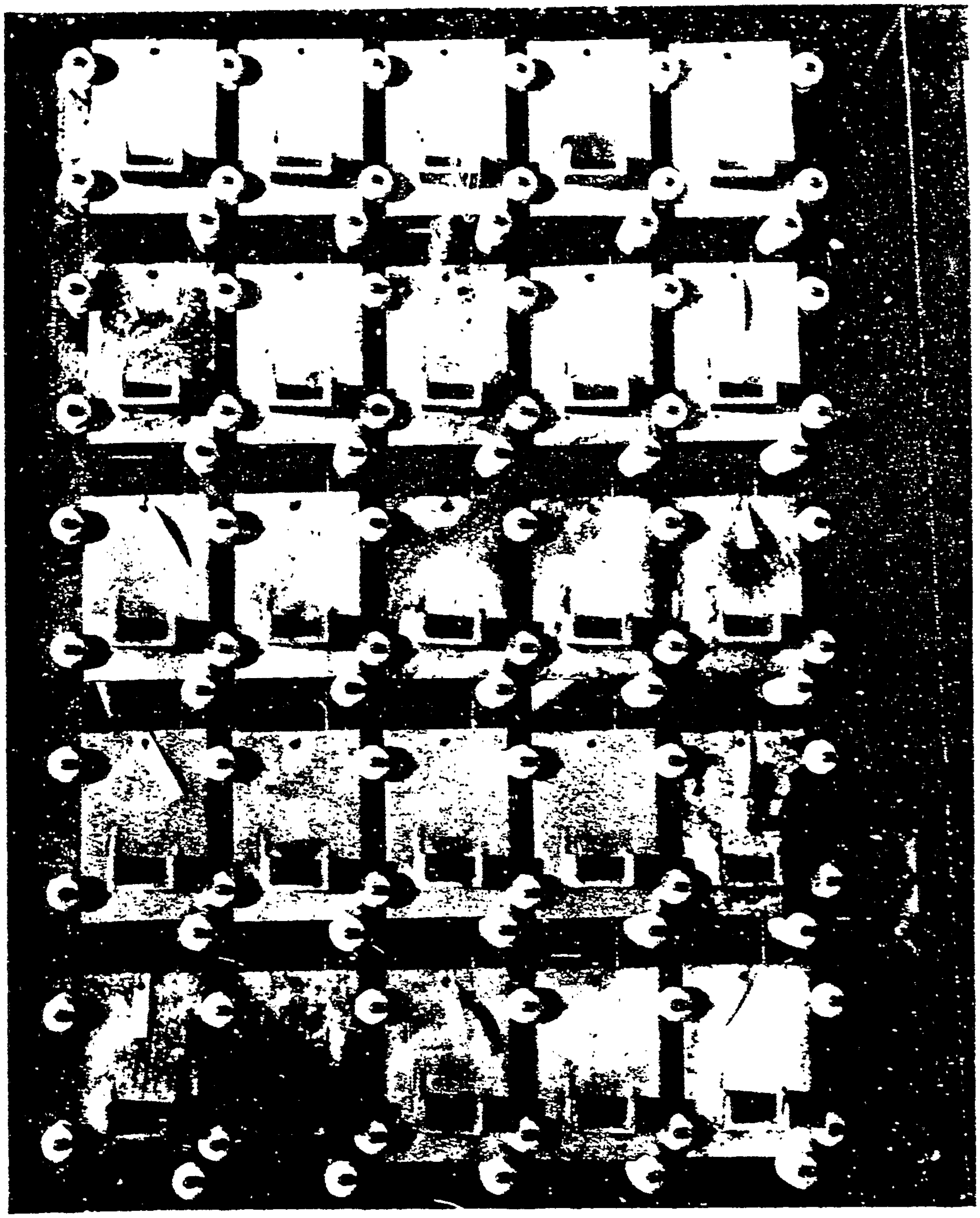

Figure 11. Type II Class 1 Organic Zinc Panels, Rack 1

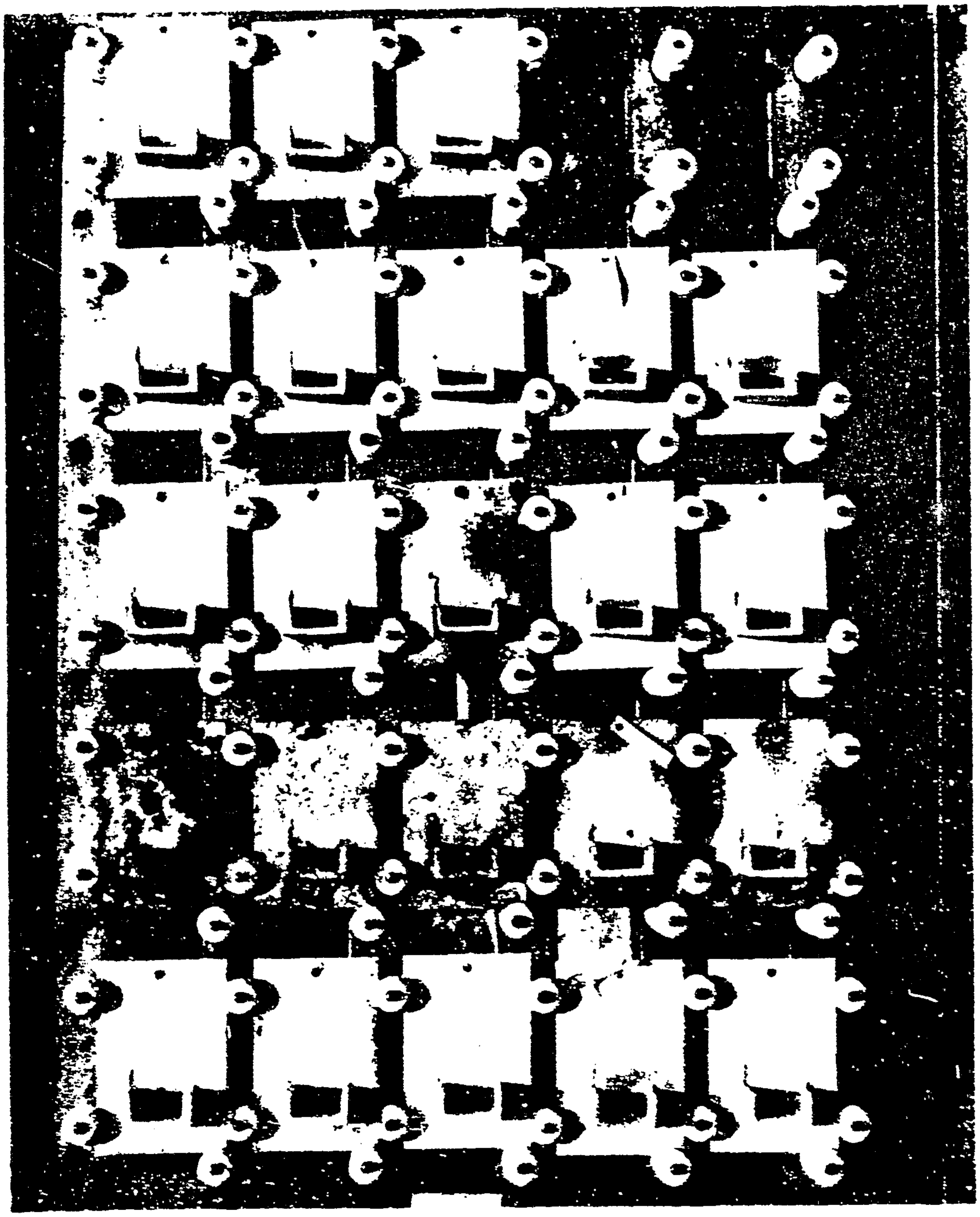

Figure 12. Type II Class 1 Organic Zinc Panels, Rack 2

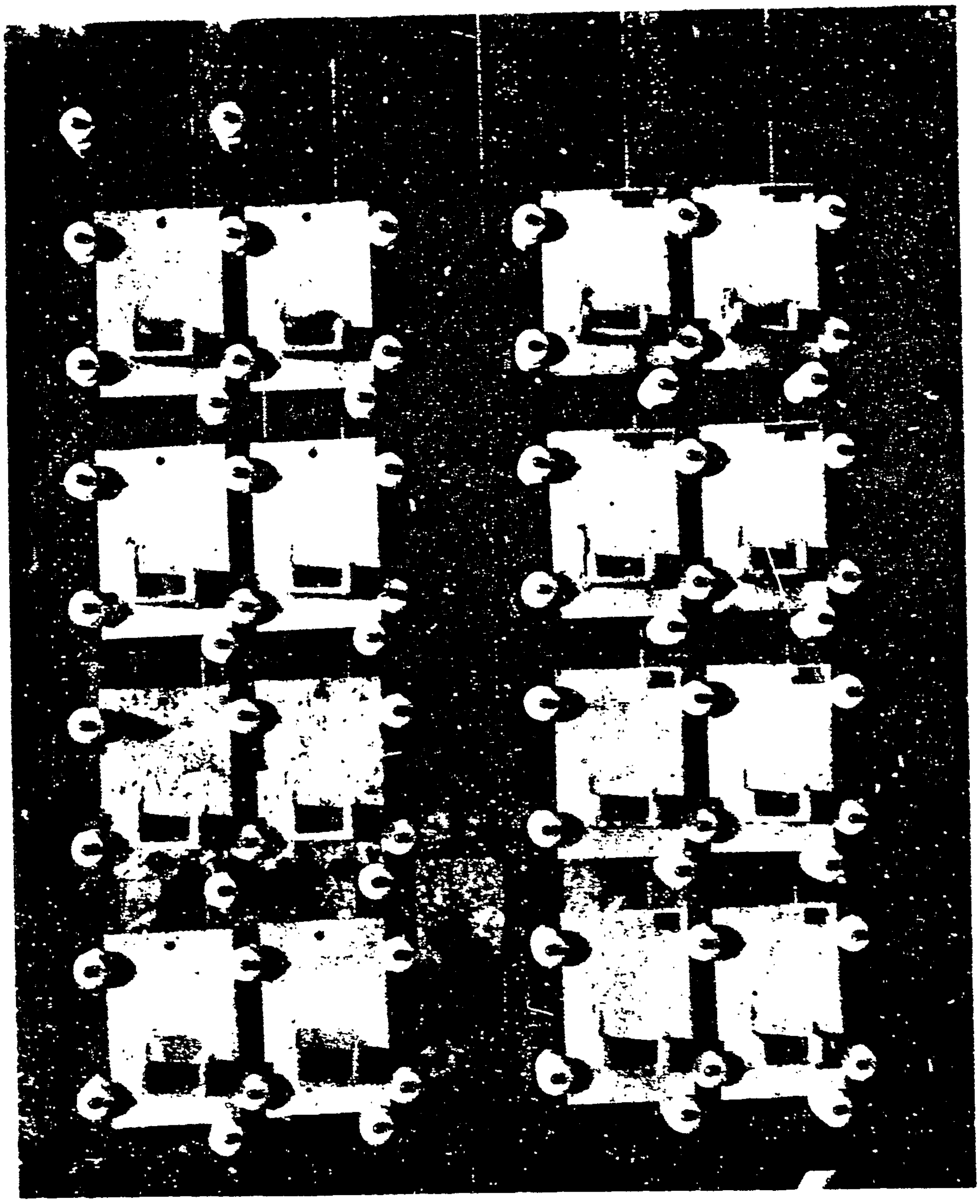

Figure 13. Type II Class 1 Organic Zinc Panels, Rack3

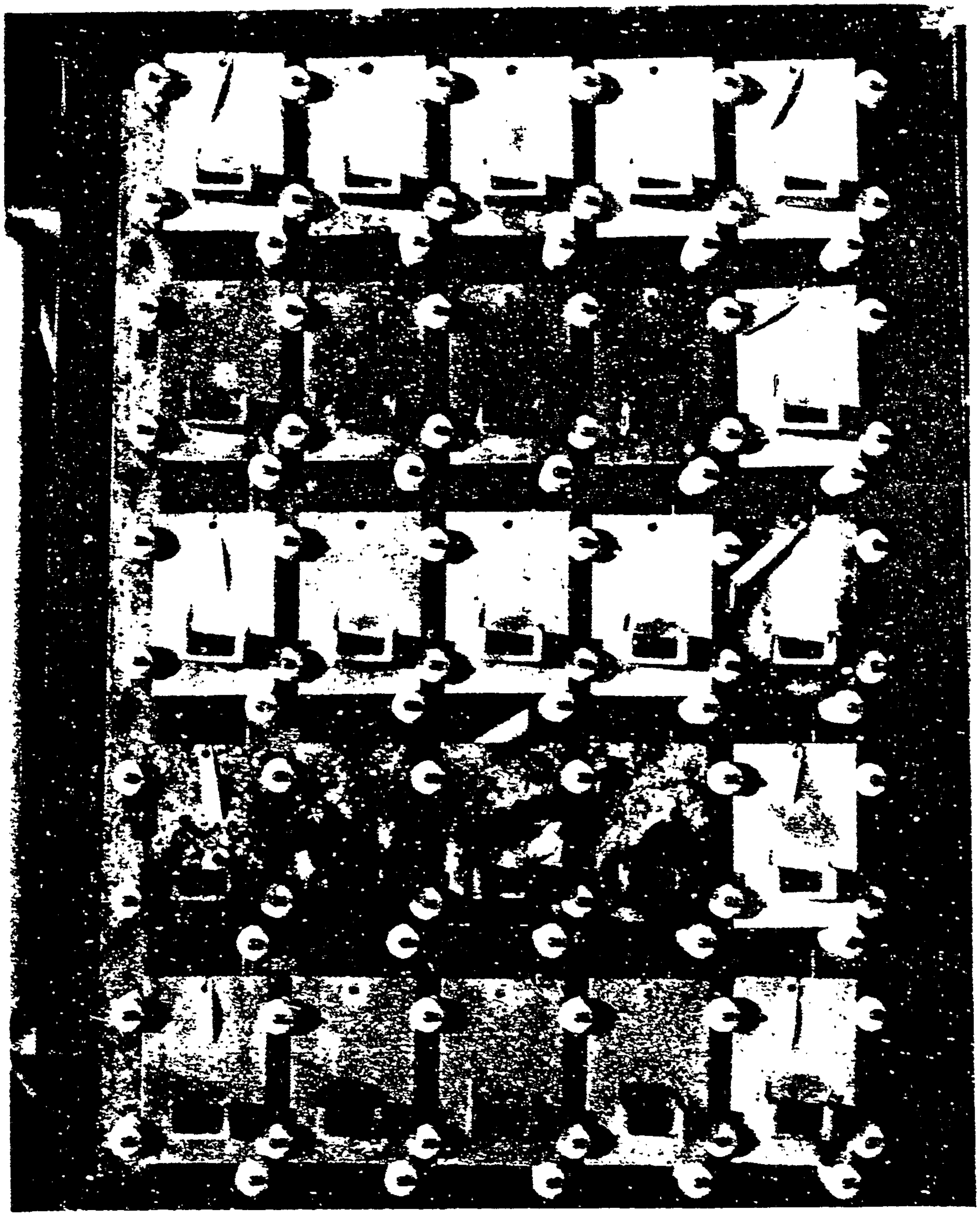

Figure 14. Type II Class 2 Organic Zinc Panels, Rack 1

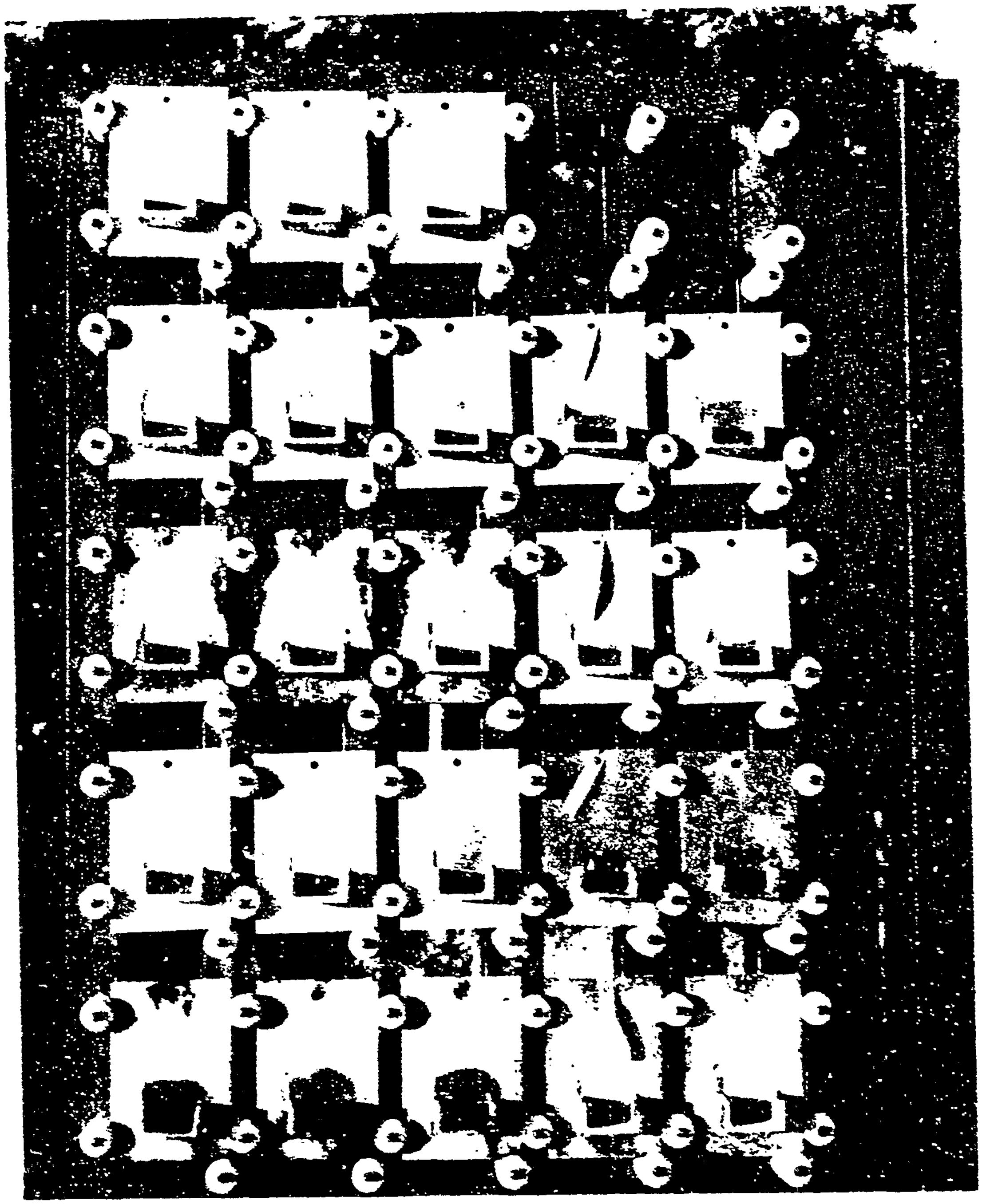

Figure 15. Type II Class 2 Organic Zinc Panels, Rack 2

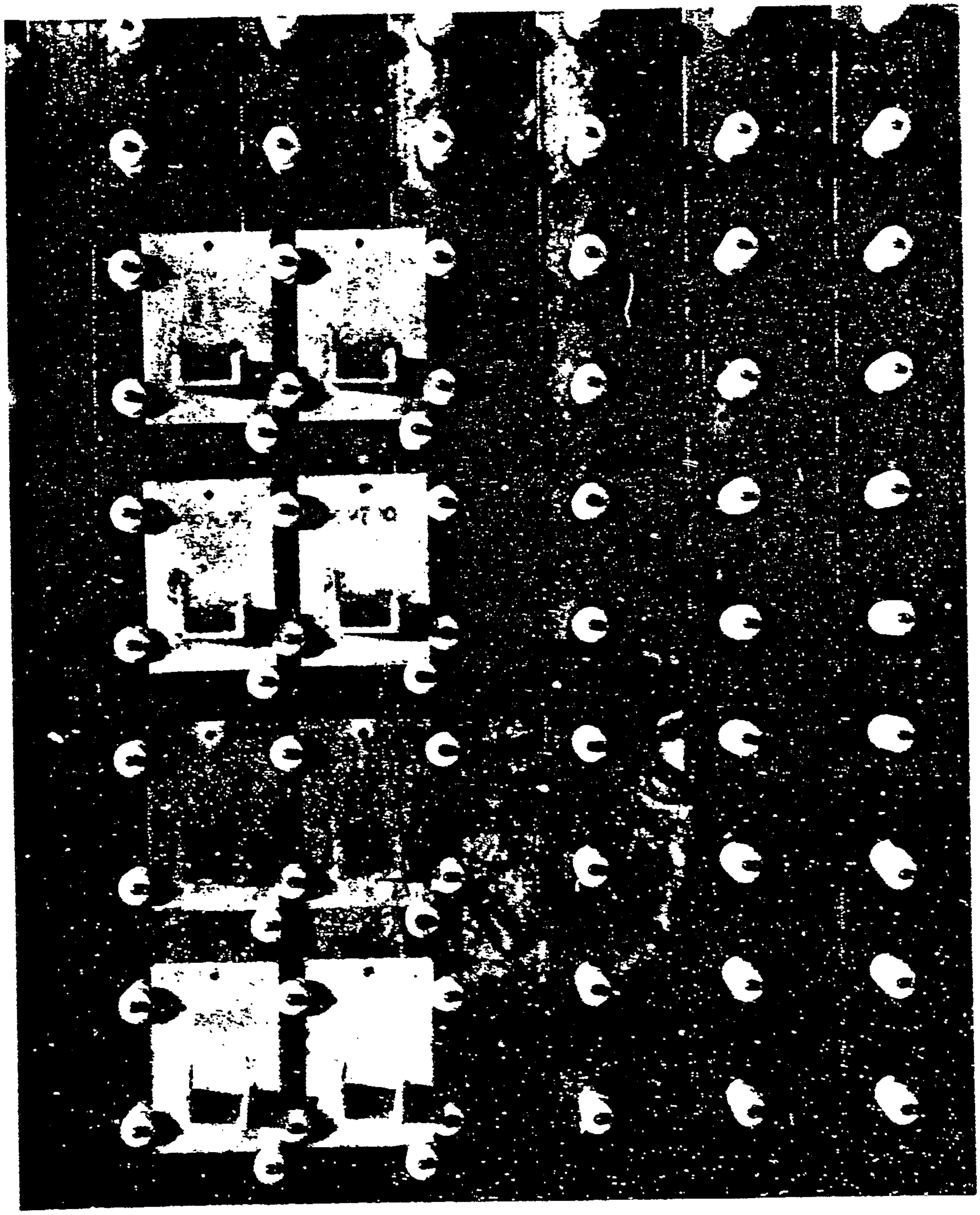

Figure 16. Type II Class 2 Organic Zinc Panels, Rack 3

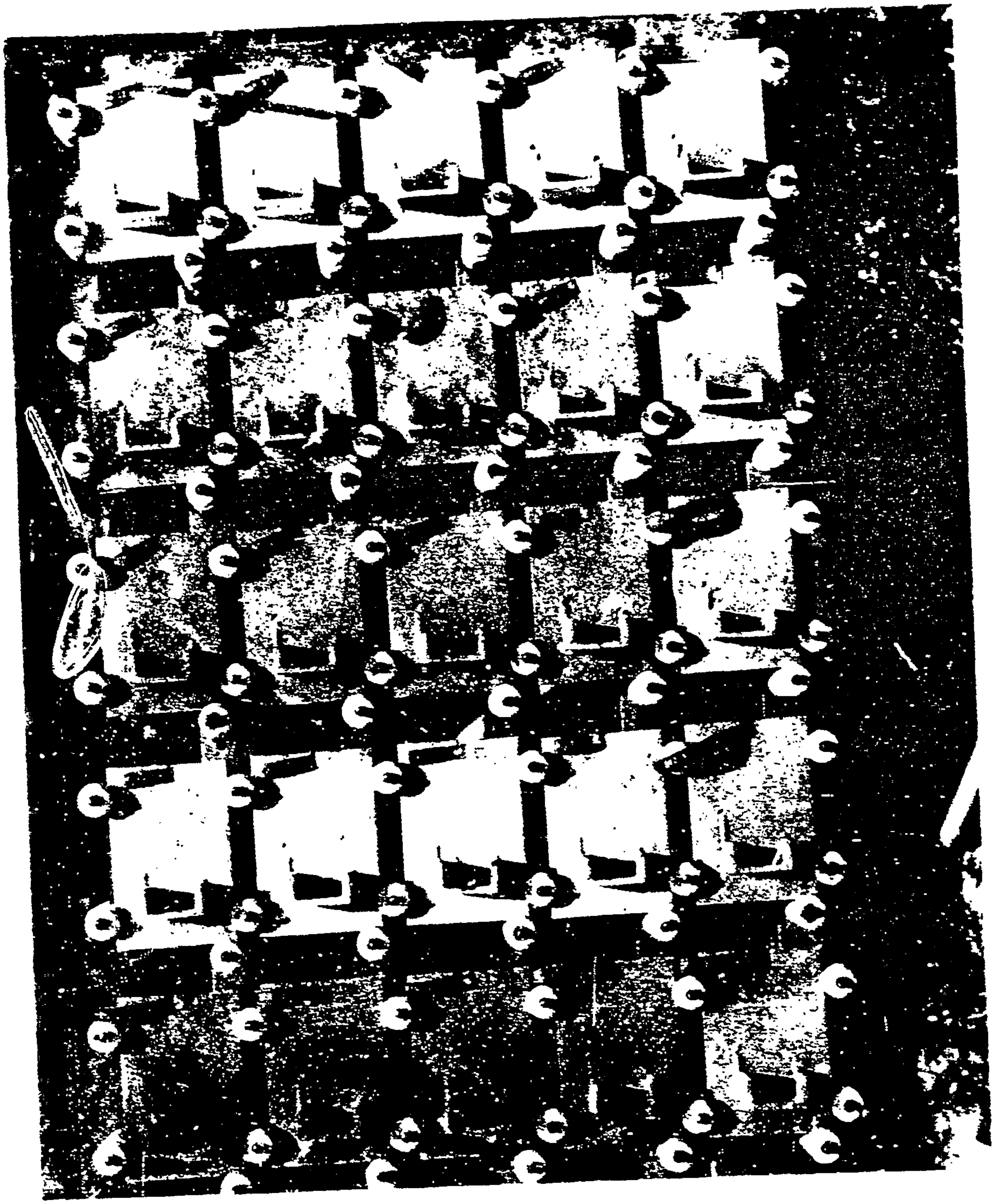

Figure 17. Sheltered Test Panels

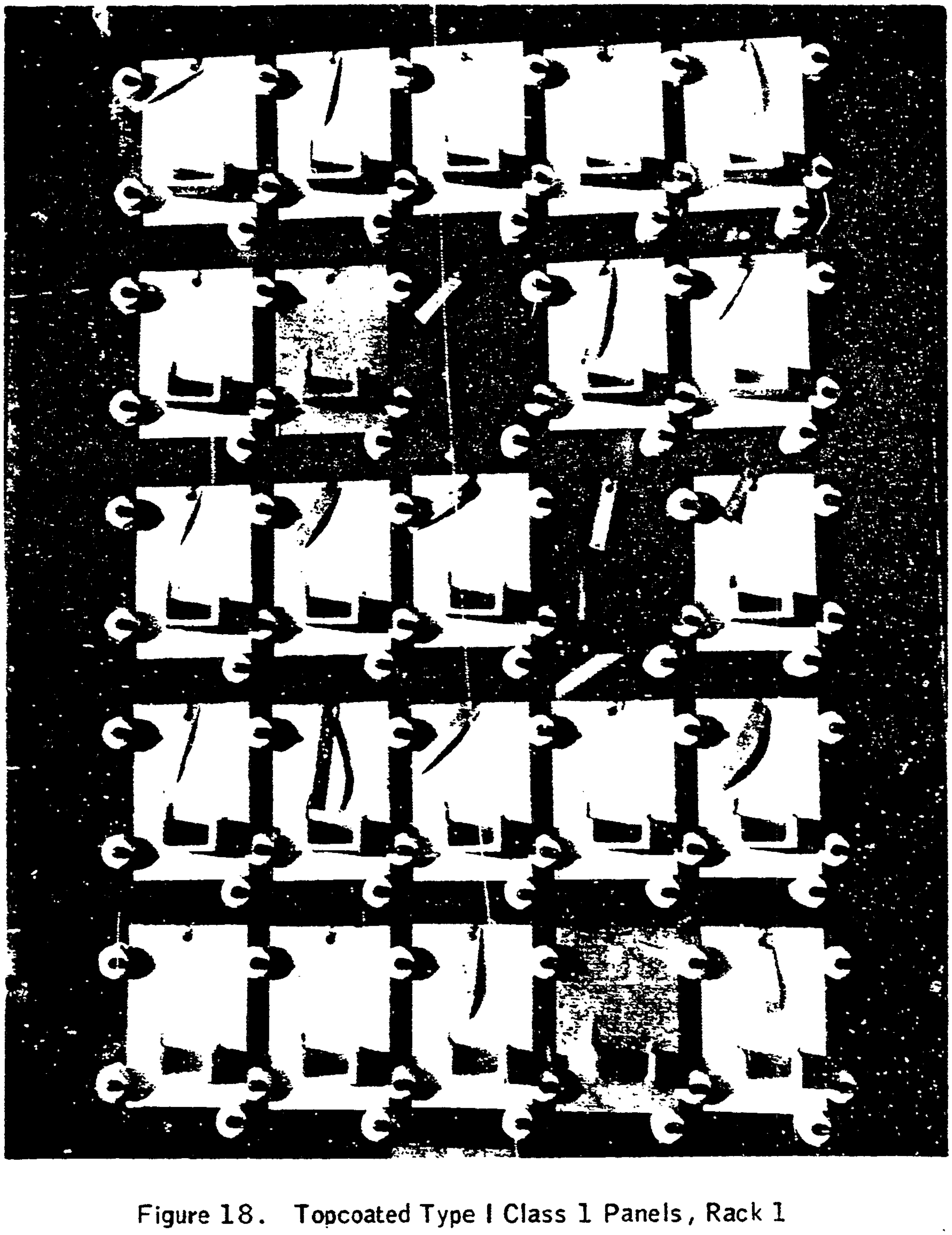

Figure 18. Topcoated Type I Class 1 Panels, Rack 1

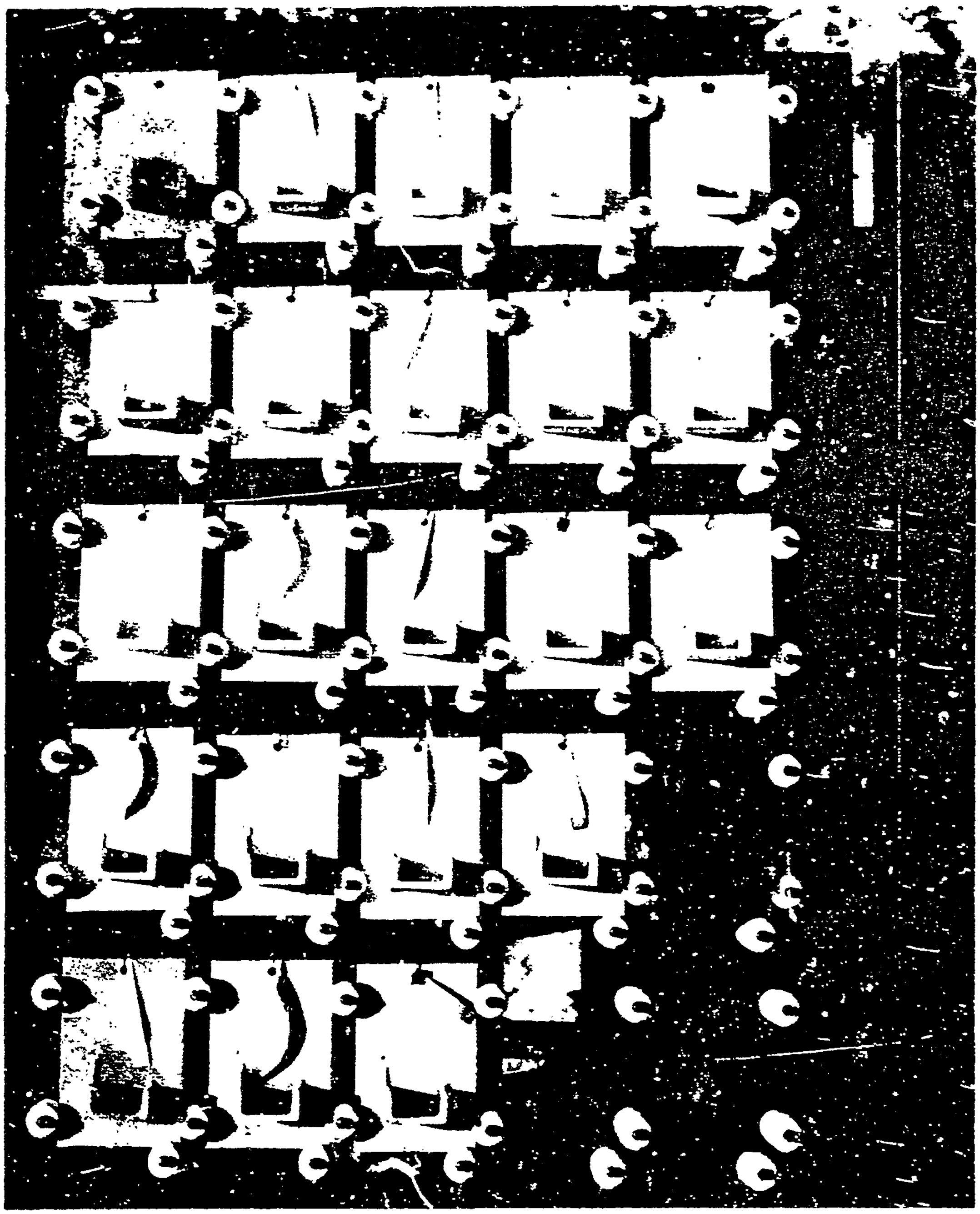

Figure 19. Topcoated Type I Class 1 Panels, Rack 2

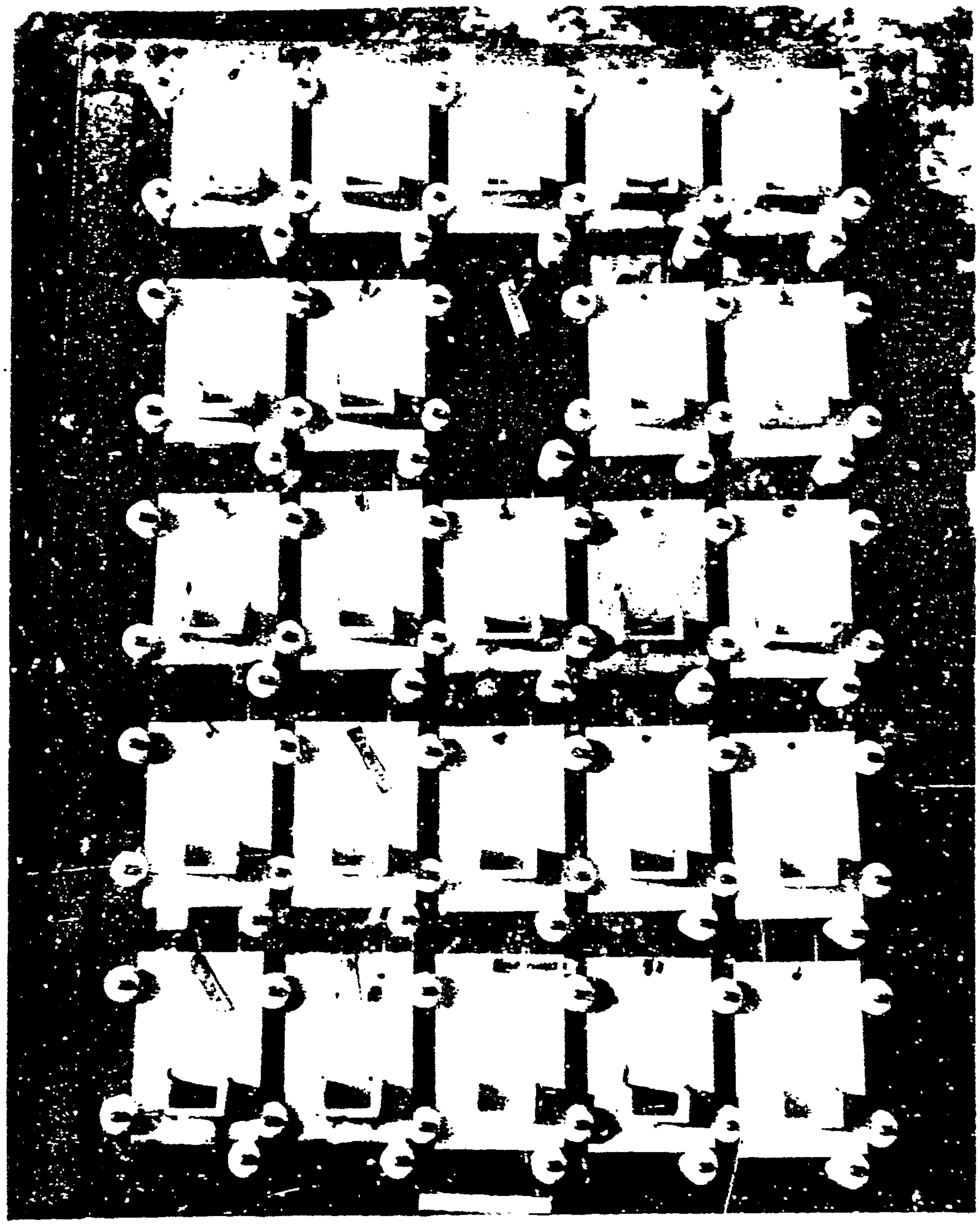

Figure 20. Topcoated Type I Class 2 Panels, Rack 1

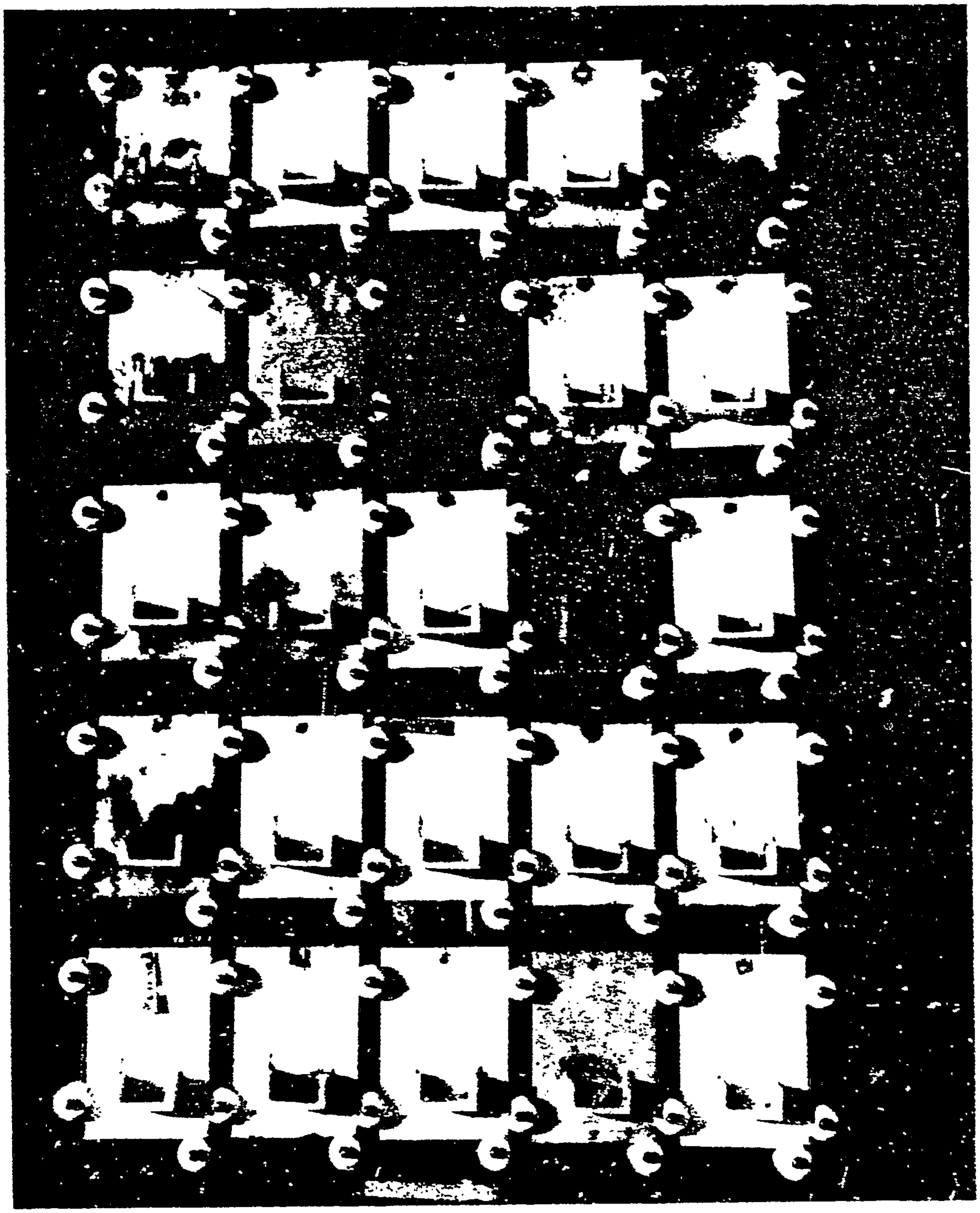

Figure 22. Topcoated Type II Class 1 Panels, Rack 1

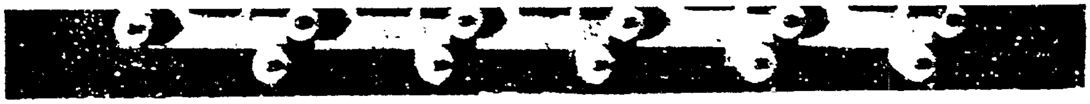

Figure 9. Type I Class 2 Inorganic Zinc Panels, Rack 2

FRAME FOLDOUT FRAME