

AWS C2.14 74 0784265 0002234 2

C2.14-74

9-18V

CORROSION TESTS OF FLAME-SPRAYED COATED STEEL

19-YEAR REPORT



AMERICAN WELDING SOCIETY

AWS C2.14-74

CORROSION TESTS OF FLAME-SPRAYED COATED STEEL 19-YEAR REPORT

Prepared by
AWS Committee on Thermal Spraying

Under the Direction of
AWS Technical Activities Committee

Jay Bland
Technical Director

AMERICAN WELDING SOCIETY, INC.
2501 N.W. 7th Street, Miami, Florida 33125

Library of Congress Catalog Card Number: 73-91825
International Standard Book Number: 0-87171-111-7

American Welding Society, 2501 N.W. 7th Street, Miami, Florida 33125

© 1974 by American Welding Society. All rights reserved.

Note: By publication of this report, the American Welding Society does not insure anyone utilizing the report against liability arising from its use. A publication of a report or standard by the American Welding Society does not carry with it the right to make, use or sell any patented items. Each prospective user should make an independent investigation.

Printed in the United States of America

CONTENTS

<i>Personnel</i>	iv
------------------------	----

PART I

TEST PROGRAM, RESULTS, AND CONCLUSIONS

INTRODUCTION	1
TEST SITES	1
TEST PANELS	1
PANEL PREPARATION	2
INSPECTION	3
CONCLUSIONS	4
RESULTS	7
Sea Water Exposure: Total Immersion and Mean Tide	10
Wrightsville Beach, North Carolina—Mean Tide	10
Wrightsville Beach, North Carolina—Total Immersion	10
Freeport, Texas	10
Marine Atmosphere	11
Kure Beach, North Carolina 80 ft Lot—Severe Marine Environment	11
Kure Beach, North Carolina 800 ft Lot—Mild Marine Atmosphere	11
Brazos River, Texas	14
Point Reyes, California	14
Industrial Atmosphere	15
New York City Area	15
Columbus, Ohio	15
East Chicago, Indiana	15

PART II

TABULATED INSPECTION DATA

TABLES 7-11	20-27
<i>Acknowledgments</i>	29

PERSONNEL

AWS Committee on Thermal Spraying

<i>J. N. Childs, Jr., Chairman</i>	Metalweld Incorporated
<i>F. J. Hermanek, Vice Chairman</i>	General Electric Company
<i>T. J. Olivera, Secretary</i>	American Welding Society
<i>A. E. Bender</i>	Bender Machine Incorporated
<i>R. G. Brooks</i>	Brooks Flame-Spray Inc.
<i>S. K. Coburn</i>	Consultant
<i>L. W. Davis</i>	Netco
<i>F. W. Gartner, Jr.</i>	F. W. Gartner Company
<i>D. J. George</i>	Alcoa Process Development Labs
<i>R. D. Green</i>	Airco Welding Products
<i>E. S. Hamel</i>	Norton Company
<i>C. W. Hayden</i>	Hayden Corporation
<i>G. M. Herterick</i>	Bay State Abrasives
<i>R. J. Janowiecki</i>	Monsanto Research Corporation
<i>A. I. Kayser</i>	Naval Air Engineering Center
<i>A. E. Kuhar</i>	Kuhar Metallizing Company
<i>E. J. Lell</i>	Wall Colmonoy Corporation
<i>M. A. Levinstein</i>	General Electric Company
<i>M. Levy</i>	AMMRC, Watertown
<i>F. N. Longo</i>	Metco Incorporated
<i>C. R. McElroy</i>	Metal Cladding Inc.
<i>W. H. McMakin</i>	Metallizing Company of America
<i>D. R. Marantz</i>	Flame-Spray Industries Incorporated
<i>I. H. Marantz</i>	Columbia Cable & Electric Corporation
<i>W. B. Meyer</i>	St. Louis Metallizing Company
<i>H. S. Miller</i>	Nehfco Alloys & Equipment Incorporated
<i>W. T. Monagle</i>	Eastern Airlines Engineering Lab
<i>J. D. Peterson</i>	Sylvester and Company
<i>J. W. Rosenbery</i>	Consultant
<i>J. R. Ruff</i>	Naval Ship Systems Command
<i>R. Unger</i>	Consultant
<i>H. N. Watson</i>	Hard Face Welding & Machine Company
<i>L. J. Williamson</i>	Third Coast Guard District

Subcommittee III — Corrosion Applications

<i>F. W. Gartner, Jr., Chairman</i>	F. W. Gartner Company
<i>T. J. Olivera, Secretary</i>	American Welding Society
<i>J. N. Childs, Jr.</i>	Metalweld Incorporated
<i>S. K. Coburn</i>	Consultant
<i>D. J. George</i>	Alcoa Process Development Labs
<i>E. W. Horvick</i>	American Zinc Institute
<i>M. Levy</i>	AMMRC, Watertown
<i>F. N. Longo</i>	Metco Incorporated
<i>C. R. McElroy</i>	Metal Cladding Incorporated
<i>W. H. McMakin</i>	Metallizing Company of America
<i>I. H. Marantz</i>	Columbia Cable & Electric Corporation
<i>C. F. Schrieber</i>	Dow Chemical Company
<i>L. J. Williamson</i>	Third Coast Guard District

PART I

TEST PROGRAM, RESULTS, AND CONCLUSIONS

INTRODUCTION

This report presents the results of a 19-year study of the corrosion protection afforded by wire-flame-sprayed aluminum and zinc coatings applied to low-carbon steel. The program was initiated in July 1950 by the Committee on Metallizing (now the Committee on Thermal Spraying) of the American Welding Society. The first panels were exposed in January, 1953. This report presents the results of an inspection of the flame-sprayed coated steel panels made after all panels had been exposed for 19 years.

Originally, exposure periods of one, three, six, and twelve years were scheduled. At the end of each of the above periods, a complete set of panels, consisting of three identical panels of each type, was to be removed from the exposure racks for laboratory examination. At the same time, the panels of each type remaining on site were to be inspected and their condition recorded. However, the results of early inspections indicated that nearly all coatings would last for more than twelve years, at each site. Accordingly, the panels scheduled for removal at six years were exposed for twelve years, and the twelve-year set was exposed for nineteen years. Results of the six-year and twelve-year inspections are reported in AWS publications C2.8-62 and C2.11-67, respectively.

The initial program details discussed here, with minor deletions, were taken directly from the AWS 12-Year Report, C2.11-67.

TEST SITES

Test sites were selected to provide a wide variety of environmental conditions. These exposure sites and the exposure dates for the panels in this program are listed in Table 1. All locations were recognized ASTM test areas. No rural exposures were included; some degree of atmospheric contamination, either saline or industrial, exists at all sites. Sea water tests included full and half-tide immersion in quiet sea water, and full immersion in flowing sea water (approximately three knots).

Test panels for atmospheric exposure were mounted on racks inclined 30 deg from the horizontal.

Panels for sea water immersion were mounted in a vertical position.

TEST PANELS

Test panels were made of low-carbon steel sheet (carbon—0.08%; manganese—0.30%; phosphorous—0.08%; sulfur—0.03%; silicon—0.003%; copper—0.30%). The sizes of the steel panels for atmospheric and sea water exposure were 4 x 6 x 1/8 in. (102 x 152 x 3.2 mm) and 4 x 12 x 1/8 in. (102 x 305 x 3.2 mm), respectively.

The aluminum and zinc wire-flame-sprayed coating thicknesses for atmospheric exposure tests were 0.003, 0.006, 0.009, 0.012, and 0.015 in. (0.08, 0.15, 0.23, 0.30, and 0.38 mm). In addition to these, a coating thickness of 0.018 in. (0.46 mm) was included in sea water exposure tests.

2 / 19-YEAR CORROSION TEST REPORT

PANEL PREPARATION

The panels were hot-rolled steel which had been pickled to remove mill scale. Surfaces were inspected and panels showing gross defects were rejected.

The next operation was the marking of the panels using a suitable and enduring identification system, a primary requirement in any test program. Experience had shown that notching the edges of the test panels was the most suitable method of identification. All notching was done before blast cleaning and metallizing.

The panels were then thoroughly blast cleaned using a force-fed blast generator and minimum pressure of 90 psi (620 kPa) at the generator with the types and mesh sizes of abrasives shown in Table 2.

The flame-spraying operation was done with a

special automatic machine on which 36 panels were flame-sprayed at once. The speeds of rotation and traverse of both panels and wire flame-spray-gun across the surface were automatically controlled in order to obtain uniformity of coating thickness.

Coating thickness on all panels was checked with a magnetic thickness gage and by weight gain. Complete records were kept. The edges of the panels were then coated separately.

Three types of wire were used:

- (1) 1/8 in. (3.2 mm) diam aluminum—99.0% min purity.
- (2) 1/8 in. (3.2 mm) diam zinc—99.9% min purity.
- (3) 1/8 in. (3.2 mm) diam steel, SAE 1010 grade; carbon—0.08-0.12%; phosphorus—0.04% max; sulfur—0.05% max.

TABLE 1—TEST SITE DESCRIPTION

Test Site and Environment	No. of Panels		Date Exposed
Atmospheric Exposure	Aluminum	Zinc	
Brazos River, Texas (salt air)	156	156	March 1954
Columbus, Ohio (industrial)	120	120	November 1953
East Chicago, Indiana (industrial)	120	120	November 1953
Kure Beach, North Carolina			
*80-ft (24 m) lot (severe marine)	336	336	January 1953
**800-ft (244 m) lot (salt air)	156	156	January 1953
New York City Area (industrial)	120	120	November 1953
Point Reyes, California (salt air)	156	156	December 1953
4 x 6 in. (102 mm x 152 mm) panels reserved	156	156	
Sea Water Exposure			
Freeport, Texas	156	156	October 1953
Wrightsville Beach, North Carolina			
below-low-tide	156	156	October 1953
mean-tide	336	336	October 1953
4 x 12 in. (102 mm x 305 mm) panels reserved	156	156	
Total	2124	2124	

*80 ft (24 m) from shoreline

**800 ft (244 m) from shoreline

TABLE 2—TYPES OF ABRASIVE USED FOR BLAST CLEANING SPECIMENS IN THIS TEST PROGRAM*

Types of Abrasive	Mesh Distribution	Description
Coarse Silica Sand	<i>Tyler Screen Sieve Analysis</i>	Abrasive is washed angular silica sand, dry and free of feldspar, clay or other friable constituents.
	+14 mesh ≤ 5%	
	—14+20 " 48% ±10%	
	—20+28 " 40% ±10%	
	—28+35 " 10% ±10%	
Fine Silica Sand	—35 " ≤ 5%	Abrasive is washed angular silica sand, dry and free of feldspar, clay or other friable constituents.
	<i>U.S. Standard Screen Analysis</i>	
	+20 mesh ≥ 5%	
	—20+30 " 67% ±10%	
Chilled Iron Grit	—30+40 " 24% ±10%	Abrasive is angular chilled iron grit.
	—40 " ≥ 10%	
	Conforms to SAE specification for G-25 angular chilled iron grit.	

*The precise mesh distributions shown would probably not be obtainable in all areas, and they should not be used for specification purposes.

The steel wire was used for a flash-bonding coat on some specimens and was applied automatically to a thickness of 0.001 in. (0.03 mm). This bonding coat is not considered part of the coating thickness.

Sealing treatments, where used, were applied by spraying. Table 3 shows the composition of the sealing materials. These formulations were thinned sufficiently to ensure good penetration and were applied sparingly. The purpose was to fill the surface and subsurface pores of the sprayed metal, rather than to overcoat. By actual measurements, the sealers used added little to the coating thickness.

The types of aluminum- and zinc-sprayed panels exposed are listed in Tables 4 and 5; Types 14 through 28 were included in order to determine the effect of preparation of the steel on the life of the coating. All of these panels had a coating thickness of 0.009 in. (0.23 mm) and were located at only two of the test sites: Kure Beach, North Carolina (80 ft [24m] lot) for atmospheric exposure and Wrightsville Beach, North Carolina (mean tide) for sea water exposure.

INSPECTION

Standard practice in evaluating hot-dipped aluminum, zinc, or other metallic coatings on steel has been to report the percentage of rusted base metal area. When the present program was adopted, it was felt that the appearance and condition of the coating itself should be fully described to accurately assess the status of coating deterioration. In this connection, the inspectors reported separately on the condition of the seal coats, the flame-sprayed coatings, and the base metal, as well as on any other conditions. The panels were inspected visually, and therefore the results depended on the interpretation of the individual inspectors. To avoid this, the inspections for the 19-year report were made using a standardized inspection form (see Table 6). Where factors other than normal corrosion processes affected the panels, the results were noted. For example, at one site (Kure Beach 80 ft [24m] lot) some of the racks were damaged by a hurricane. A few panels were lost, but most were recovered;

TABLE 3 — COMPOSITION AND DESCRIPTION OF SEAL COATS

Seal Coat	Composition	Description
Wash Primer	Resin component: Pigment: insoluble type, inert, zinc chromate 8.2% Nonvolatile vehicle: polyvinyl butyral 9.5% Volatile vehicle: butyl and isopropyl alcohol 82.3% Acid component: Phosphoric acid 16.0% Ethyl (or isopropyl) alcohol plus water Balance	An air drying, two-part, acid-zinc chromate wash coat primer
Mix four parts of the resin component with one part of the acid component to obtain final primer composition.		
Aluminum Vinyl	Pigment: nonleafing aluminum flake 10% Nonvolatile vehicle: vinyl copolymer and plasticizer 20% Volatile vehicle: toluene and ketones 70%	A vinyl copolymer aluminum flakes, air-drying type of coating material
Clear Vinyl	Pigment: none Nonvolatile vehicle: vinyl chloride-acetate Resin 16 % Plasticizer 1.4% Volatile vehicle: ketones 37.6% aromatic hydrocarbons (toluene, benzol, xylol) 45.0%	A clear, vinyl copolymer, air-drying coating material
Chlorinated Rubber	Solids: chlorinated rubber—plus two types of chlorinated paraffins plus a stabilizer 34% Solvents: aromatic petroleum solvents 66%	A clear, air-drying, chlorinated rubber type coating material

4 / 19-YEAR CORROSION TEST REPORT

TABLE 4—PANEL TYPES FOR ATMOSPHERIC EXPOSURE¹

ALUMINUM FLAME-SPRAYED PANELS				ZINC FLAME-SPRAYED PANELS			
Panel Type	Panel Preparation ²	Coating Thickness, in. (mm)	Seal Coat ³	Panel Type	Panel Preparation ²	Coating Thickness, in. (mm)	Seal Coat ³
1	1	0.003 (0.08)		1	1	0.003 (0.08)	
2	1	" "	WP+AV—1	2	1	" "	WP+AV—1
3	1	" "	WP+AV—2	3	1	" "	CR—2
4	1	0.006 (0.15)		4	1	0.006 (0.15)	
5	1	" "	WP+AV—1	5	1	" "	WP+AV—1
6	1	" "	WP+AV—2	6	1	" "	CR—2
7	1	0.009 (0.23)		7	1	0.009 (0.23)	
8	1	" "	WP+AV—1	8	1	" "	WP+AV—1
9	1	" "	WP+AV—2	9	1	" "	CR—2
10	2	0.012 (0.30)		10	2	0.012 (0.30)	
11	2	" "	WP+AV—1	11	2	" "	WP+AV—1
12	2	" "	WP+AV—2	12	2	" "	CR—2
13	2	0.015 (0.38)		13	2	0.015 (0.38)	
14	2	0.009 (0.23)		14	2	0.009 (0.23)	
15	2	" "	WP+AV—1	15	2	" "	WP+AV—1
16	2	" "	WP+AV—2	16	2	" "	CR—2
17	4	" "		17	4	" "	
18	4	" "	WP+AV—1	18	4	" "	WP+AV—1
19	4	" "	WP+AV—2	19	4	" "	CR—2
20	6	" "		20	6	" "	
21	6	" "	WP+AV—1	21	6	" "	WP+AV—1
22	6	" "	WP+AV—2	22	6	" "	CR—2
23	3	" "		23	3	" "	
24	3	" "	WP+AV—1	24	3	" "	WP+AV—1
25	3	" "	WP+AV—2	25	3	" "	CR—2
26	5	" "		26	5	" "	
27	5	" "	WP+AV—1	27	5	" "	WP+AV—1
28	5	" "	WP+AV—2	28	5	" "	CR—2

¹If a comparison between the aluminum- and zinc-sprayed panels in a certain environment is desirable, it should only be made between panels where coating thickness, panel preparation, and seal coat are the same.

²Types of Surface Preparation

1. Coarse silica sand
2. Coarse silica sand and steel flash
3. Fine silica sand
4. Fine silica sand and steel flash
5. Chilled iron grit
6. Chilled iron grit and steel flash

³Types of Seal Coat

- WP — Wash primer
 AV — Aluminum vinyl
 CR — Chlorinated rubber
 —1 — One coat of specified seal coat
 —2 — Two coats of specified seal coat

some of these had sustained minor mechanical damage.

All panels were removed from the exposure sites, assembled in one location, and inspected by the committee that reviewed the observations of field inspectors.

CONCLUSIONS

(1) Aluminum-sprayed coatings 0.003 in. to 0.006 in. (0.08 mm to 0.15 mm) thick, both sealed and unsealed, gave complete base metal protection from corrosion in sea water and also in severe marine and industrial atmospheres.

(2) Unsealed zinc-sprayed coatings required 0.012 in. (0.30 mm) minimum thickness for complete protection in sea water for 19 years. In severe marine and industrial atmospheres, 0.009 in. (0.23 mm) of unsealed zinc or 0.003 in. to 0.006 in. (0.08

mm to 0.15 mm) of sealed zinc are needed for 19-year protection.

(3) In severe marine atmospheres, the application of one coat of wash primer plus one or two coats of aluminum vinyl enhanced the appearance and extended the life of zinc coatings at least 100%. With aluminum, the sealing system primarily enhanced appearance, because both systems showed no base metal rust after 19 years.

(4) Thin coats of aluminum perform better because they have less tendency to develop pits and blisters and therefore extended life is expected. Vinyl also seems to perform better because it must penetrate to the base metal.

(5) Where aluminum coatings showed damage such as chips or scrapes, corrosion did not progress, suggesting the occurrence of galvanic protection.

(6) The corrosion protection afforded by zinc and aluminum coatings is not affected by the

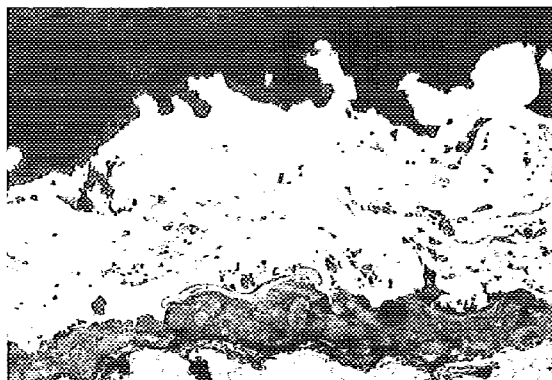


Fig. 1a—Flame-sprayed aluminum coating 0.006 in. (0.15 mm) thick, no sealer, over a flash coat of carbon steel. This photomicrograph illustrates the condition of the aluminum coating after exposure for 18 years at Wrightsville Beach, N.C. in sea water at mean tide level. 250X Nital etch. (Reduced 22% in reproduction.)

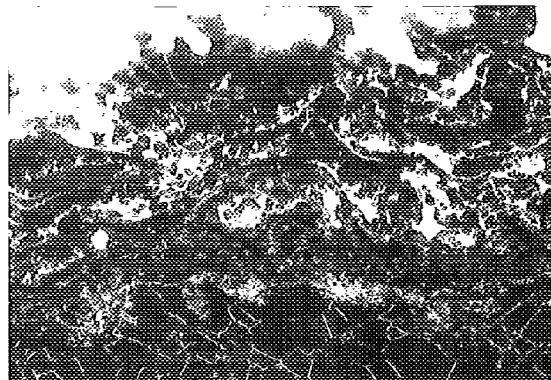


Fig. 1b—Same area, as shown in Fig. 1a, but under polarized light to show the amount of coating that has converted to aluminum corrosion product (white) and remaining aluminum (black). (Reduced 22% in reproduction.)

TABLE 5 — PANEL TYPES FOR SEA-WATER EXPOSURE¹

ALUMINUM FLAME-SPRAYED PANELS				ZINC FLAME-SPRAYED PANELS			
Panel Type	Panel Preparation ²	Coating Thickness, in. (mm)	Seal Coat ³	Panel Type	Panel Preparation ²	Coating Thickness, in. (mm)	Seal Coat ³
1	2	0.003 (0.08)	WP+CV-1	1	2	0.003 (0.08)	CR-1
2	2	" "	WP+CV-2	2	2	" "	CR-2
3	2	0.006 (0.15)	" "	3	2	0.006 (0.15)	" "
4	2	" "	WP+CV-1	4	2	" "	CR-1
5	2	" "	WP+CV-2	5	2	" "	CR-2
6	2	0.009 (0.23)	" "	6	2	0.009 (0.23)	" "
7	2	" "	WP+CV-1	7	2	" "	CR-1
8	2	" "	WP+CV-2	8	2	" "	CR-2
9	2	0.012 (0.30)	" "	9	2	0.012 (0.30)	" "
10	2	" "	WP+CV-1	10	2	" "	CR-1
11	2	" "	WP+CV-2	11	2	" "	CR-2
12	2	0.015 (0.38)	" "	12	2	0.015 (0.38)	" "
13	2	0.018 (0.46)	" "	13	2	0.018 (0.46)	" "
14	1	0.009 (0.23)	" "	14	1	0.009 (0.23)	" "
15	1	" "	WP+CV-1	15	1	" "	CR-1
16	1	" "	WP+CV-2	16	1	" "	CR-2
17	3	" "	" "	17	3	" "	" "
18	3	" "	WP+CV-1	18	3	" "	CR-1
19	3	" "	WP+CV-2	19	3	" "	CR-2
20	5	" "	" "	20	5	" "	" "
21	5	" "	WP+CV-1	21	5	" "	CR-1
22	5	" "	WP+CV-2	22	5	" "	CR-2
23	4	" "	" "	23	4	" "	" "
24	4	" "	WP+CV-1	24	4	" "	CR-1
25	4	" "	WP+CV-2	25	4	" "	CR-2
26	6	" "	" "	26	6	" "	" "
27	6	" "	WP+CV-1	27	6	" "	CR-1
28	6	" "	WP+CV-2	28	6	" "	CR-2

¹If a comparison between the aluminum- and zinc-sprayed panels in a certain environment is desirable, it should only be made between panels where coating thickness, panel preparation, and seal coat are the same.

²Types of Surface Preparation

1. Coarse silica sand
2. Coarse silica sand and steel flash
3. Fine silica sand
4. Fine silica sand and steel flash
5. Chilled iron grit
6. Chilled iron grit and steel flash

³Types of Seal Coat

- WP — Wash primer
 CV — Clear vinyl
 CR — Chlorinated rubber
 —1 — One coat of specified seal coat
 —2 — Two coats of specified seal coat

6 / 19-YEAR CORROSION TEST REPORT

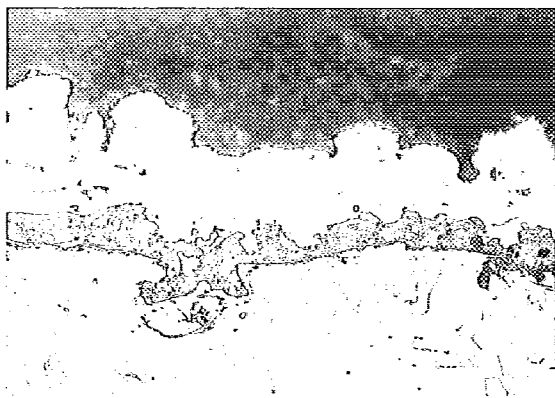


Fig. 2a—Flame-sprayed aluminum coating 0.003 in. (0.08 mm) thick plus one coat of primer and two coats of vinyl. This photomicrograph illustrates the overall condition of the aluminum coating after exposure for 18 years below low tide at Wrightsville Beach, N.C. 250X. Nital etch. (Reduced 22% in reproduction.)

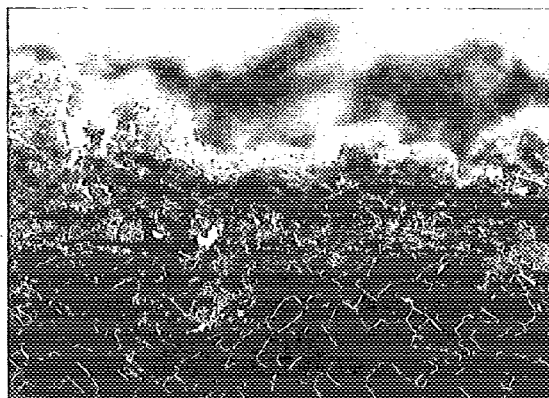


Fig. 2b—This photomicrograph shows the same area as in Fig. 2a, but under polarized light to illustrate the relatively small amount of aluminum corrosion. (Reduced 22% in reproduction.)

TABLE 6 — TERMINOLOGY USED TO DESCRIBE CONDITION OF TEST PANELS (BY INSPECTORS)

Appearance and Condition Terms

- R — *Red rust*, originating from the base metal. Usually well-defined and entirely different from red rust stain.
- W — *White rust*, the corrosion product of zinc or aluminum. Not necessarily white in color; may be stained by contamination.
- D — *Foreign deposit*, such as dirt, etc.
- S — *Stain*, any discoloration other than white rust or red rust stain.
- RS — *Red rust stain*, originating from the base metal with no evidence of blisters, coating failure, or loss of adhesion.
- DS — *Deposit stain*, originating from some source other than panel.
- B — *Blisters* in seal coats or sprayed metal.
- P — *Pits* in sprayed metal, resulting from corrosion.
- N — *Nodes*, well-defined growths or lumps of corrosion product.
- F — *Flakes*, loose segments of seal coat or sprayed metal.

Degree and Descriptive Terms

- b — **Large defect* over $\frac{3}{8}$ in. (9.5 mm) diam.
- me — **Medium defect* over $\frac{1}{8}$ to $\frac{3}{8}$ in. (3.2 - 9.5 mm) diam.
- s — **Small defect* less than $\frac{1}{8}$ in. (3.2 mm) diam.
- p — **Pinpoint defect*.
- f — *Few*—less than 6 per sq in. (6.45 sq cm) of surface.
- i — *Intermediate*—6 to 20 per sq in. (6.45 sq cm) of surface.
- m — *Many*—over 20 per sq in. (6.45 sq cm) of surface.
- g — *General*—covering all or most of the panel.
- bl — *Blotchy*—any irregular pattern.
- gr — *Gray* in color.
- d — *Dark* in color.

*These terms generally used to describe size of nodes, pits, blisters, or spots.



Fig. 2c—Same coating as in Fig. 2a, but Nital etched on a reserve panel which was never exposed. (Reduced 22% in reproduction.)



Fig. 2d—Unexposed aluminum. Compare with Fig. 2b. (Reduced 22% in reproduction.)

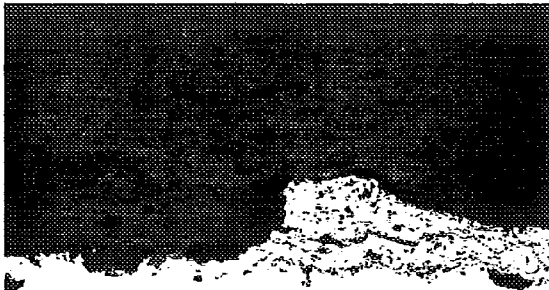


Fig. 3a—Flame-sprayed zinc 0.012 in. (0.30 mm) thick with no sealer after exposure for 18 years at Wrightsville Beach, N.C. in sea water at mean tide level. This photo illustrates the remaining zinc and zinc corrosion product. 60X. (Reduced 22% in reproduction.)

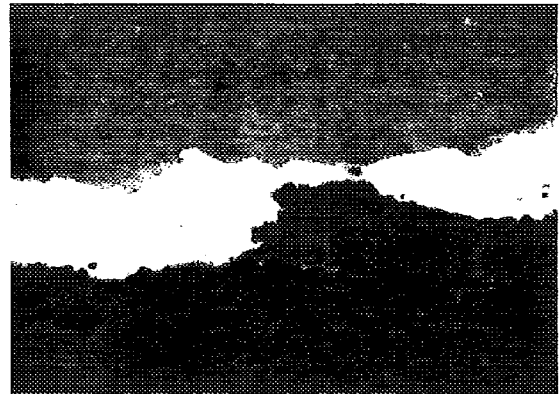


Fig. 3b—Same area as shown in Fig. 3a, but under polarized light. The zinc corrosion product appears white and the zinc, black.

method of surface preparation used for this test. Specifically, a steel-flash-bond coat is not essential. For large parts, or where coating thickness will exceed 0.006 in. (0.15 mm), a coarse abrasive is recommended. (See Table 2.)

(7) The use of flame-sprayed aluminum and zinc coatings is recommended as a means to extend the life of such iron and steel structures as bridges, highway or street light poles, marine piers or pilings, ship hulls, storage tanks, industrial structures, etc. Corrosion is thereby combated, and the natural resources needed in the manufacture of iron and steel are conserved.

(8) Chlorinated rubber is an unsatisfactory seal coat for both aluminum and zinc flame-sprayed coatings.

RESULTS

The following results are divided into three separate sections:

- (1) Sea Water Exposure—Total Immersion and Mean Tide
- (2) Marine Atmosphere
- (3) Industrial Atmosphere

It should be kept in mind that these are the results of the test panel inspections at each of the above three types of exposure sites.

The results of each panel inspection are presented in Part II of this report. Although not included in this report, an analysis of the corrosion products of the zinc- and aluminum-sprayed panels would be of interest.

SEA WATER EXPOSURE — TOTAL IMMERSION AND MEAN TIDE

Wrightsville Beach, North Carolina

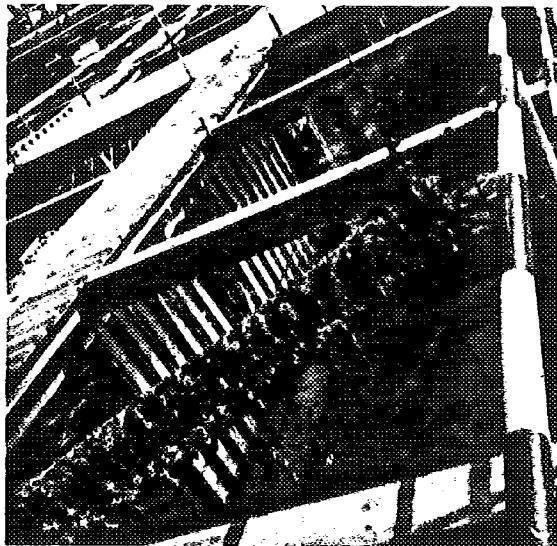


Fig. 4—Test rack of flame-sprayed aluminum-coated steel panels being removed from test site after 19 years in sea water.

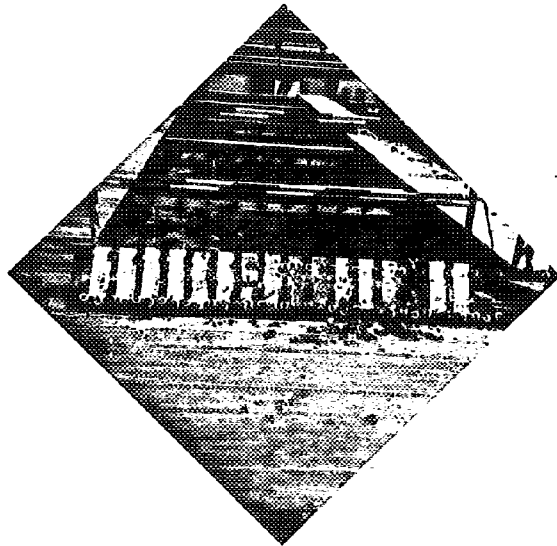


Fig. 5a—Flame-sprayed aluminum-coated steel panels, with foulants removed, after 19 years in sea water.



Fig. 5b—A closer view of one of the panels in Fig. 5a. This panel has 0.009 in. (0.23 mm) of flame-sprayed aluminum, wash primer, and one vinyl seal coat. The white markings are the remains of some of the tightly adherent foulants.



Fig. 6—Test rack of flame-sprayed zinc-coated panels immediately after removal from the mean tide site after 19 years exposure. Foulants have not been removed.

SEVERE MARINE ENVIRONMENT

Kure Beach, North Carolina 80 ft Lot

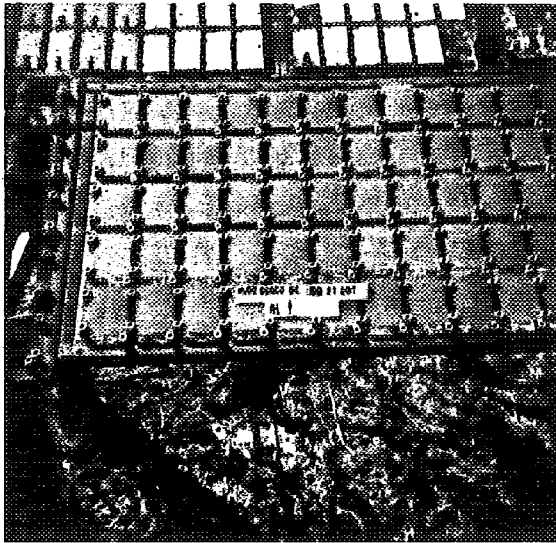


Fig. 7a—Flame-sprayed aluminum with and without sealers after exposure for 19 years, 80 ft (24 m) from the normal mean tide level, facing the surf.



Fig. 7b—Flame-sprayed zinc with and without sealers after exposure for 19 years, 80 ft (24 m) from the normal mean tide level, facing the surf.

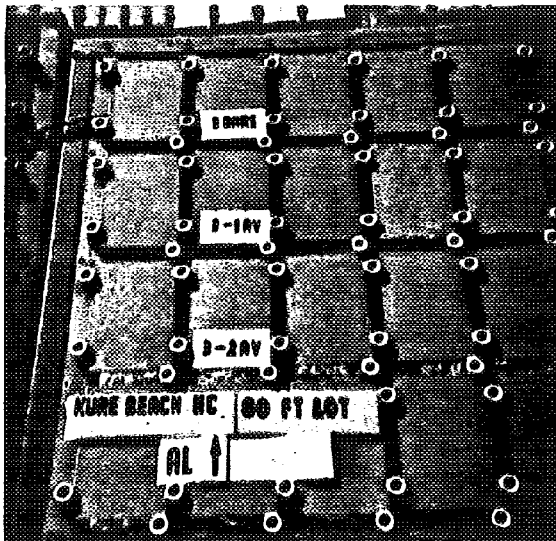


Fig. 7c—A closer view of some of the panels in Fig. 7a (above). The top row, left three panels have 0.003 in. (0.08 mm) aluminum without a sealer. The upper second row, left three panels have 0.003 in. (0.08 mm) aluminum, a wash primer, and one coat of aluminum vinyl. The third row (from the top), left three panels are the same except for two coats of aluminum vinyl. The remaining unidentified panels are 0.006 in. (0.15 mm) and 0.009 in. (0.23 mm) aluminum with and without sealers.

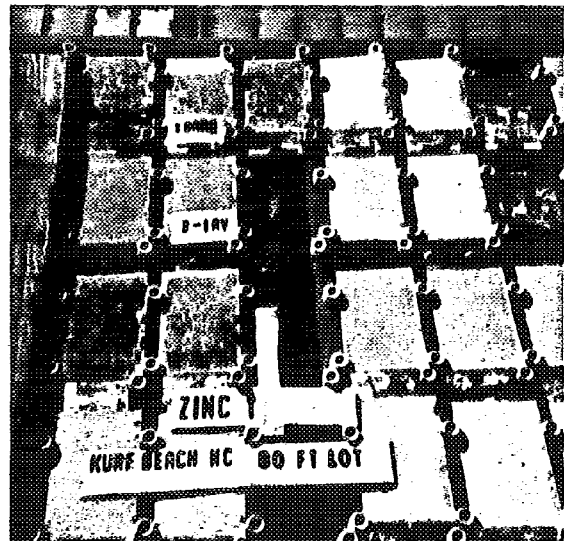


Fig. 7d—A closer view of some of the panels in Fig. 7b (above). The top row, left three panels show the condition of 0.003 in. zinc panels without a sealer. The upper second row, left two panels have 0.003 in. zinc, a wash primer, and one coat of aluminum vinyl. The third row (from the top), left two panels have 0.003 in. zinc with chlorinated rubber sealer. The top row, right two panels have 0.006 in. zinc with a chlorinated rubber sealer. The remaining panels are 0.009 in. zinc with and without sealers.

10 / 19-YEAR CORROSION TEST REPORT

SEA WATER EXPOSURE: TOTAL IMMERSION
AND MEAN TIDE

Wrightsville Beach, North Carolina—Mean Tide

Aluminum-Sprayed Panels (Figs. 1a, 1b, 2a-2d). Unsealed aluminum-sprayed panels at this site show a few blisters which originate at the coating-steel interface. The heavier the coating, the larger the blisters (as large as 5/16 in. [8.0 mm] diam, in some cases). In those cases where a blister had broken open, the exposed steel was relatively free of corrosion. A layer of iron oxide was present, but no measurable loss of steel was evident. While the aluminum surrounding these broken blisters probably contributed to the protection of the steel, there was no significant evidence of aluminum corrosion. See Figs. 2c and 2d for the typical structure of aluminum. Scraping the aluminum surface results in a bright, metallic lustre.

All vinyl-sealed panels were in excellent condition—including those which were coated with only 0.003 in. (0.08 mm) of aluminum. A few small blisters were present on some of the sealed panels but were considerably smaller than those on the unsealed aluminum panels. When opened, these blisters reveal typical voluminous aluminum corrosion products and a thin layer of rust on the steel. No measurable loss of steel was evident. This is also true where the coatings were mechanically damaged at the edges by the ceramic mountings insulators. Areas as large as 1/2 in. (12.7 mm) x 1/8 in. (3.2 mm) of exposed steel showed no significant loss of steel. No progressive corrosion of the aluminum surrounding these areas was evident.

There is no noticeable difference in coating performance as a function of the variations in surface preparation methods tested (see Table 2).

Zinc-Sprayed Panels (Figs. 3a, 3b). All unsealed zinc-sprayed panels of less than 0.012 in. (0.30 mm) in coating thickness have failed. The 0.012 in. (0.30 mm), 0.015 in. (0.38 mm), and 0.018 in. (0.46 mm) thick unsealed zinc coatings show little or no rust but, as shown in Figs. 3a and 3b, the coatings have been almost completely converted to a protective corrosion product.

Chlorinated rubber sealers on zinc did not perform satisfactorily. The steel was deeply pitted where the coatings had failed, and the appearance indicated that the residual zinc corrosion product had become cathodic to the exposed steel. There was no evidence of any difference in coating performance as a result of the surface preparation methods tested.

Wrightsville Beach, North Carolina—
Total Immersion

Aluminum-Sprayed Panels (Figs. 4, 5a, 5b). Unsealed aluminum coatings at this site appeared to blister slightly more than those at the mean-tide level. The steel was still being protected, even where the blisters had broken open, as in the case of the aluminum-sprayed panels exposed at the mean-tide level.

The vinyl-sealed panels were in excellent condition, showing only a few, small, unbroken blisters. The coatings on these panels were in a condition similar to aluminum-sealed panels exposed at the mean-tide level.

Zinc-Sprayed Panels (Fig. 6). Zinc coating performances in this exposure were very similar to those of the coatings exposed at the mean-tide level.

Sealed and unsealed zinc coatings of less than 0.012 in. (0.30 mm) thick had failed. Zinc coatings of 0.012 in. (0.30 mm), 0.015 in. (0.38 mm), and 0.018 in. (0.46 mm), sealed and unsealed, had protected the base metal, but the zinc had been converted to corrosion products. This tightly adherent mixture of white rust and foulants appeared to be providing corrosion protection to the base metal. All panels that failed were very deeply pitted.

Freeport, Texas

Panels at this site were lost in a hurricane. The only documented test information is that available from the AWS 12-year Report, AWS C2.11-67. The results are given below.

Aluminum-Sprayed Panels. At this site, panels were suspended in a large concrete flume where the sea water velocity was approximately three knots. All panels were removed here because the exposure racks were breaking up, and the panels could have been lost had they not been removed.

The aluminum-sprayed panels at this site showed extensive mechanical damage at the edges. This was due to the velocity of the water in the flume and the looseness of the insulated mountings which allowed the panels to shift about freely. Corrosion had not progressed in from the damaged edges, however.

The unsealed aluminum panels all showed blisters. Some of the larger blisters had broken open and showed rust stains, and in many cases, the base metal had apparently been exposed at this site for several years. There was no measurable loss of steel, and the original blast pattern could be seen after the superficial rust was removed.

The vinyl-sealed aluminum panels of 0.003 in.

(0.08 mm) thickness showed several areas where the sprayed aluminum and sealer were gone, leaving the aluminum corrosion product with red rust. The vinyl-sealed panels of heavier aluminum coating thickness were in good condition showing a light coating of white rust, and on some of these panels, a few small blisters. There was no evidence of base metal corrosion on these heavier-coated panels.

Zinc-Sprayed Panels. Zinc panels of Types 8-13 are not reported because that rack of panels was dropped and lost in July 1965 when all the panels were being shifted to another point in the flume.

Unsealed zinc panels were in better condition than sealed panels. On the unsealed panels, sprayed zinc was covered with heavy white rust. Only one panel showed corrosion pits in the base metal and red rust stains. This occurred on a panel of 0.003 in. (0.08 mm) thickness of zinc. Thicker zinc coatings showed no evidence of red rust staining.

All zinc-sprayed panels sealed with chlorinated rubber showed evidence of base-metal corrosion. The seal coat was completely gone on all panels. Panels coated with 0.003 in. (0.08 mm) of zinc showed deep corrosion pits on 20% of the surface. Panels with heavier zinc coatings showed corrosion pits on 5% of their surfaces. All the panels sealed with chlorinated rubber showed heavy white-rust and red-rust stains on the remaining portion of their surfaces.

MARINE ATMOSPHERE

Kure Beach, North Carolina 80 ft Lot— Severe Marine Environment

At this site the specimens faced the surf in a southeasterly direction at an average distance of 80 ft (24 m) from the normal mean-tide level, exposing them to the Atlantic Ocean's spray, salt air and the weather.

Aluminum-Sprayed Panels (Figs. 7a, 7b). All unsealed sprayed panels had a dull, gray-brown, blotchy appearance, with evidence of aluminum blistering in thicknesses greater than 0.003 in. (0.08 mm). Unsealed 0.006 in. (0.15 mm) thick panels had approximately 6-20 blisters per sq. in., less than 1/8 in. (3.2 mm) diameter. Unsealed aluminum panels 0.009 in. (0.23 mm) thick had over 20 blisters per sq. in., up to 1/8 in. (3.2 mm) diameter. Blisters did not appear to be as prevalent on the groundward surfaces.

One coat of aluminum vinyl sealer on 0.003 in. (0.08 mm) of aluminum appeared slightly duller

than two coats. Aluminum vinyl-sealed panels were in excellent condition, as shown in Fig. 7b. There was evidence of a few blisters in coatings thicker than 0.003 in. (0.08 mm) sealed with one and two coats of aluminum vinyl. The groundward side of these panels had a slightly blotchy appearance but no evidence of any blisters.

No differences in general appearance or tendency of the sprayed coating to blister as a function of surface preparation method could be observed.

Zinc-Sprayed Panels (Figs. 7c, 7d). Unsealed zinc coatings of 0.003 in. (0.08 mm) exhibited heavy rusting of the base metal, as shown in Fig. 7d.

Aluminum vinyl sealer had completely deteriorated on the 0.003 in. (0.08 mm) zinc, with rusting of the base at the edges encroaching on the faces. Both skyward and groundward surfaces were covered with white rust. Unsealed 0.006 in. (0.15 mm) zinc exhibited rusting of the base metal at the edges; the flat surfaces were covered with small nodes of heavy white rust.

Zinc coatings sealed with chlorinated rubber were similar in appearance to unsealed zinc.

Unsealed coatings of zinc 0.009 in. (0.23 mm) thick or greater were covered with small nodes of white rust with no evidence of the base metal rusting.

The aluminum vinyl sealer was gone from the skyward surface of most of the panels to which it was applied. Heavy white rust was evident. The groundward surfaces had very little evidence of aluminum vinyl sealer remaining.

The fact that the aluminum vinyl sealer had deteriorated completely on the zinc panels in this severe marine atmosphere appears to justify the decision not to use the vinyl-sealer on the sea water test panels. Early laboratory tests with vinyl-sealed, zinc-coated panels exposed in the sea waters off Long Island, N.Y., indicated failure of the vinyl as a sealer for zinc. This may be a function of the chloride ion because vinyl-sealed zinc has performed very well in the industrial atmospheres where lower chloride concentrations were present.

No difference in the condition of panels as a function of surface preparation method was apparent.

Kure Beach, North Carolina 800 ft Lot— Mild Marine Atmosphere

Aluminum-Sprayed Panels (Figs. 8a, 8b). As shown in Figs. 8a and 8b, all panels were in excellent condition at this site. Unsealed aluminum panels 0.003 in. (0.08 mm) thick were light gray in color on the skyward surface with a slightly darker

MILD MARINE ATMOSPHERE

Kure Beach, North Carolina 800 ft Lot

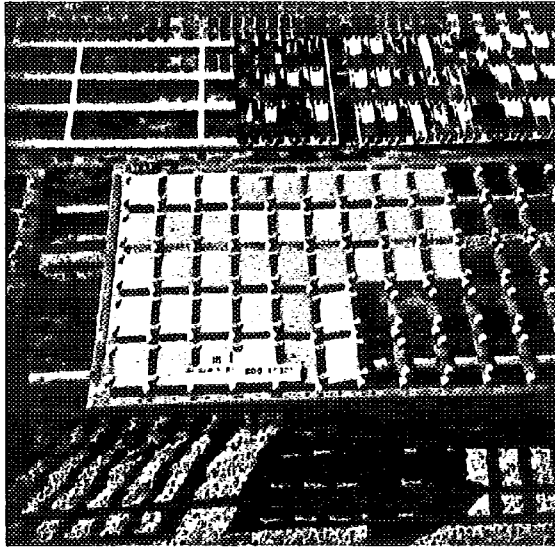


Fig. 8a—Flame-sprayed aluminum with and without sealers after exposure for 19 years, 800 ft (244 m) from the normal mean tide level.

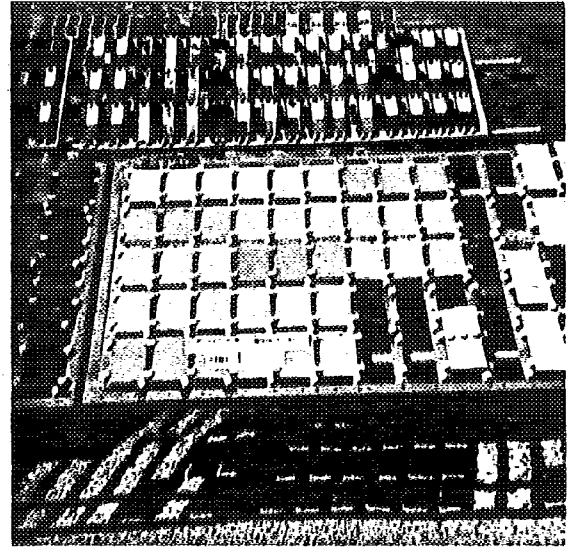


Fig. 8b—Flame-sprayed zinc, with and without sealers, after exposure for 19 years, 800 ft (244 m) from the normal mean tide level.

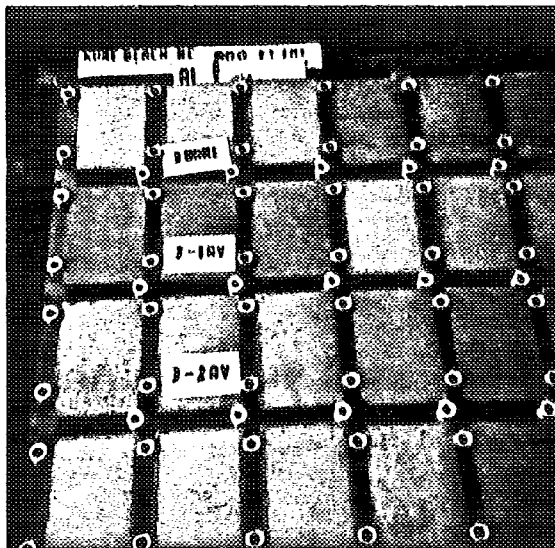


Fig. 8c—A closer view of some of the panels in Fig. 8a (above). The top row, left three panels have 0.003 in. (0.08 mm) aluminum without a sealer. The upper second row, left three panels have 0.003 in. (0.08 mm) aluminum, a wash primer, and one coat of aluminum vinyl. The third row (from the top), left three panels have 0.003 in. (0.08 mm) aluminum, a wash primer, and two coats of aluminum vinyl.

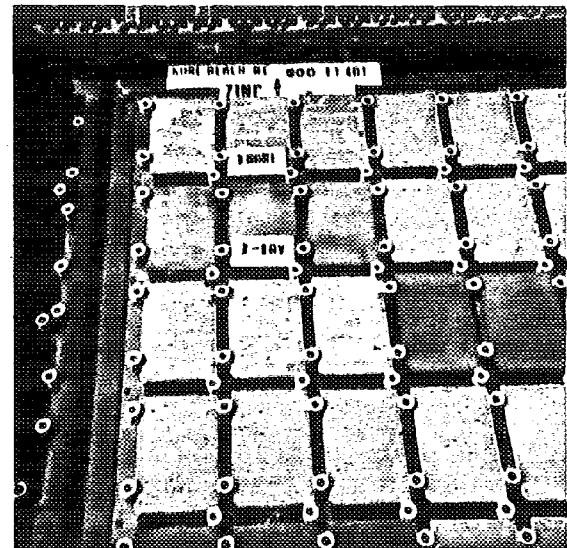


Fig. 8d—A closer view of some of the panels in Fig. 8b (above). The top row, left three panels have 0.003 in. (0.08 mm) zinc without a sealer. The upper second row, left three panels have 0.003 in. (0.08 mm) zinc, a wash primer, and one coat of aluminum vinyl. The bottom row, left three panels have 0.006 in. (0.15 mm) zinc, without a sealer.

INDUSTRIAL ATMOSPHERE

New York City Area

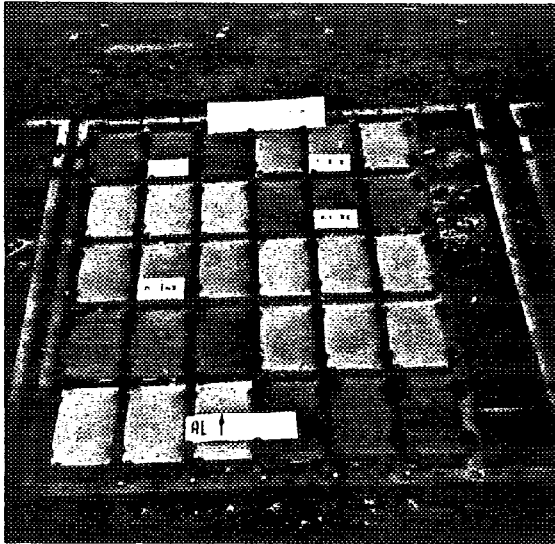


Fig. 9a—Flame-sprayed aluminum with and without sealers after exposure for 19 years.

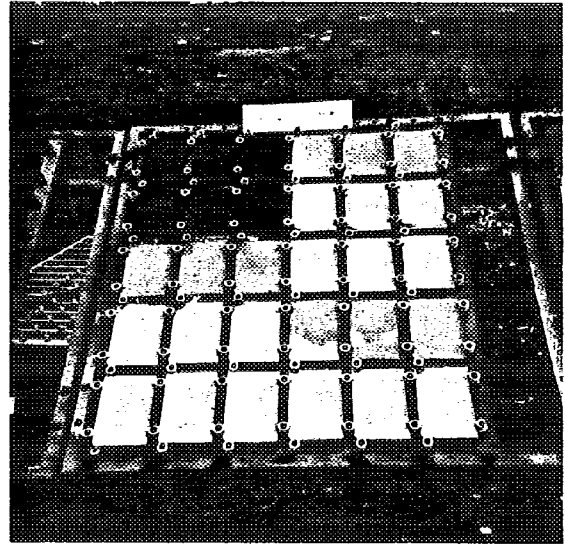


Fig. 9b—Flame-sprayed zinc with and without sealers after exposure for 19 years.

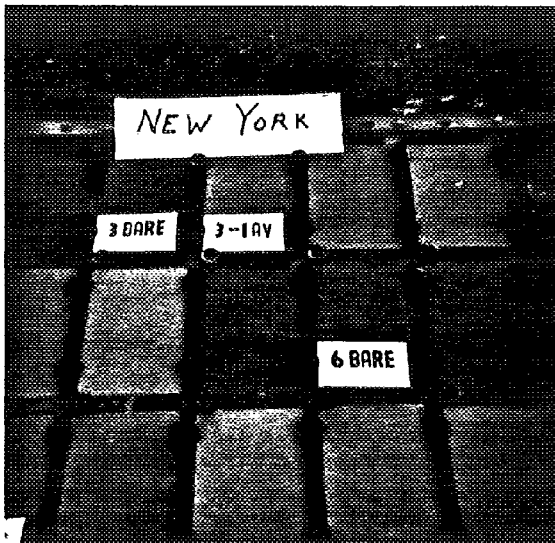


Fig. 9c—A closer view of some of the panels in Fig. 9a (above). The top row, left two panels have 0.003 in. (0.08 mm) aluminum, with no sealer. The top row, right three panels have 0.003 in. (0.08 mm) aluminum, wash primer, and one coat of aluminum vinyl. The center row, right three panels have 0.006 in. (0.15 mm) aluminum with no sealer.

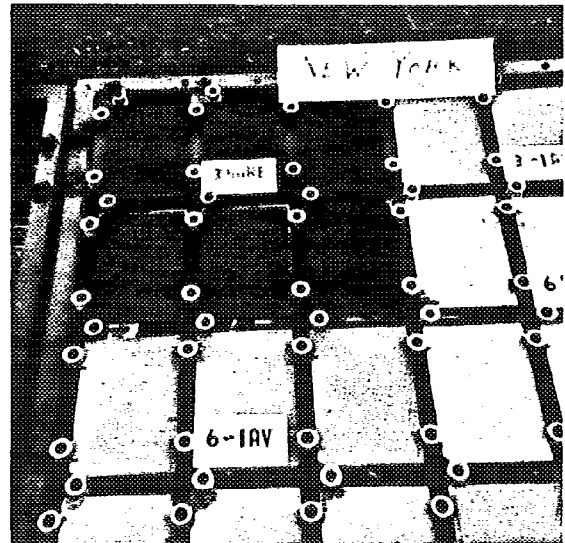


Fig. 9d—A closer view of some of the panels in Fig. 9b (above). The top row, left three panels show that the 0.003 in. zinc is gone and the steel is rusting. The upper second row, left three panels show that the 0.003 in. zinc and chlorinated rubber sealer are gone and the steel is rusting. The third row (from the top), left three panels have 0.006 in. zinc, wash primer, and one coat of aluminum vinyl.

14 / 19-YEAR CORROSION TEST REPORT

gray stain and some light rust staining on the groundward surface. No rust staining was evident on the heavier unsealed aluminum coatings.

All aluminum vinyl-sealed panels were in excellent condition. Those with one coat of sealer had a dark mottled appearance over 95% of the skyward surface while those with two coats had the mottled appearance on only 20-25% of the area. The groundward surfaces retained their original appearance.

Zinc-Sprayed Panels (Figs. 8c, 8d). The 0.003 in. (0.08 mm) thick unsealed zinc panels were dark blue with horizontal stripes of white rust that appeared to conform to the spray pattern (see Figs. 8c and 8d). This condition was apparent on both surfaces, with the groundward surface having a slightly darker blue color.

The one coat of aluminum vinyl sealer on the 0.003 in. (0.08 mm) thick zinc appeared mottled on 10-20% of the skyward surface, with a few pinpoint blisters of the aluminum vinyl. Groundward surfaces were in very good condition except for the sealer on one panel that had deteriorated approximately 5%. The chlorinated rubber-sealer had long since disintegrated leaving those panels very similar to the unsealed panels, with slightly less evidence of the horizontal striping (see panel types 3, 6, 9, and 12 in Table 8).

Panels with coating thicknesses greater than 0.003 in. (0.08 mm) had absorbed the aluminum vinyl sealer to a greater degree than the 0.003 in. (0.08 mm) thick coatings. The groundward surfaces were in very good condition. There was no evidence of base metal rusting on any of the panels in the 800 ft (244 m) lot.

Brazos River, Texas

Aluminum-Sprayed Panels. This test site is similar to the Kure Beach 800 ft (244 m) lot. All panels were in very good condition with no evidence of base metal corrosion. All panels had a light tan discoloration which was the color of the dust in the area. The groundward surfaces of unsealed aluminum-sprayed panels in the 0.006 in. to 0.015 in. (0.15 mm to 0.38 mm) thickness range show some evidence of blisters which were not apparent on the skyward surfaces. The 0.003 in. (0.08 mm) unsealed aluminum panels had no evidence of blistering on either side. The aluminum-vinyl sealer had developed a blotchy appearance on most of the panels. Vinyl-sealed 0.003 in. (0.08 mm) thick aluminum panels were in excellent condition with the groundward surface having a like-new appearance. Panels in the 0.009 in. to 0.012 in. (0.23 mm to 0.30 mm) thick

group with one coat of aluminum vinyl had developed a blotchy appearance on the groundward surface. Those with two coats of vinyl sealer were in excellent condition.

Zinc-Sprayed Panels. Zinc-sprayed panels at this site were in good condition. A tan discoloration on all panels was particularly evident at the edges. There was no evidence of base metal rusting. Unsealed zinc-sprayed panels developed a light blue color.

The aluminum-vinyl sealer showed some deterioration, as much as 25% of the skyward surface on some of the panels with zinc corrosion products evident. The groundward side of the panels sealed with aluminum vinyl were in good condition.

Panels sealed with chlorinated rubber were similar in appearance to the unsealed panels except that a horizontal striping effect was more evident. There was no evidence that any chlorinated rubber remained.

Point Reyes, California

Aluminum-Sprayed Panels. Unsealed aluminum-sprayed panels 0.003 in. (0.08 mm) thick had developed a black discoloration over 25-75% of the skyward surfaces, with no evidence of nodes or blisters. The groundward surfaces displayed a slight rust stain. Heavier coatings of unsealed aluminum were lighter and did not have as much discoloration.

All panels sealed with one coat of aluminum vinyl had a mottled appearance, while those sealed with two coats were in excellent condition.

There was no evidence of base metal rusting on any of the panels.

Zinc-Sprayed Panels. Unsealed zinc-sprayed panels had a blue color on the skyward surfaces, with the familiar horizontal stripes more evident on the 0.003 in. (0.08 mm) thick coatings than on heavier coatings. The groundward surfaces on all unsealed panels were dark blue.

The 0.003 in. (0.08 mm) thick zinc-sprayed panels, sealed with one coat of aluminum vinyl, showed blistering on 5-10% of the skyward surfaces. The remaining area was bright and in excellent condition. It was apparent that the aluminum vinyl sealer had deteriorated to a greater extent on the heavier coatings of zinc than on thinner coatings. This deterioration was accompanied by zinc corrosion. Because heavier coatings are more absorbent, two coats of vinyl sealer would be in order.

Panels sealed with chlorinated rubber had a tan discoloration, a combination of zinc corrosion product, and disintegrated sealer. This was true of both surfaces.

INDUSTRIAL ATMOSPHERE

New York City Area

Aluminum-Sprayed Panels (Figs. 9a, 9b). Unsealed 0.003 in. (0.08 mm) thick aluminum coatings showed, on the skyward surface, many black nodes of corrosion due to retained contamination. The groundward surface was gray to black in color with some indication of nodular corrosion. No rusting of the base metal was evident.

Unsealed 0.006 in. (0.15 mm), 0.009 in. (0.23 mm), and 0.012 in. (0.30 mm) thick aluminum coatings showed heavy blistering of aluminum on the skyward surface. The groundward surfaces exhibited nodular type corrosion.

Aluminum vinyl-sealed coatings showed a few scattered nodes of corrosion product on the skyward surface of the 0.003 in. (0.08 mm) panels. Heavier coatings had a few scattered blisters. Groundward surfaces were all excellent.

All coating thicknesses sealed with two coats of aluminum vinyl were in excellent condition on both surfaces.

Zinc-Sprayed Panels (Figs. 9c, 9d). Unsealed 0.003 in. (0.08 mm) thick zinc coatings failed completely on the skyward surface and on approximately 75% of the groundward surface. The 0.003 in. (0.08 mm) zinc coatings sealed with chlorinated rubber also failed completely on the skyward surface and about 10% on the groundward surface. Zinc coatings 0.003 in. (0.08 mm) thick sealed with aluminum vinyl were in excellent condition and were brighter and cleaner than aluminum with an equivalent amount of sealer. It is interesting to note that the vinyl sealer was in better condition on the 0.003 in. (0.08 mm) thick coatings than on the heavier zinc coatings where, in some cases, it had deteriorated 10-30%. This is probable because 0.003 in. (0.08 mm) thick coatings are smoother and do not absorb as much sealer as the heavier coatings.

Unsealed 0.006 in. (0.15 mm) thick coatings exhibited some rusting on the skyward surface, but less on the groundward surface. Unsealed 0.009 in. (0.23 mm) and 0.012 in. (0.30 mm) thick coatings were blue with some deposit staining. No base metal rusting was evident.

Columbus, Ohio

Aluminum-Sprayed Panels (Figs. 10a, 10b). All unsealed sprayed aluminum panels had a black,

nodular type of corrosion product, the size of the nodule increasing with the thickness of the coating. There was no evidence of base metal corrosion. Panels sealed with one coat of aluminum vinyl were beginning to show some indications of black node formation. Panels with two coats of aluminum vinyl sealer were in excellent condition.

Zinc-Sprayed Panels (Figs. 10c, 10d). Unsealed 0.003 in. (0.08 mm) thick zinc-coated panels lost approximately 90% of the zinc on the skyward surfaces with rusting at the base metal. Edges also showed rusting. The groundward side of the panels were covered with white rust that appeared stained with red rust. All zinc-sprayed, coated panels sealed with aluminum vinyl were in good condition. One panel in each of the 0.006 in. (0.15 mm) and 0.009 in. (0.23 mm) thick group, sealed with aluminum vinyl, exhibited a 5-10% sealer deterioration, with some of the white rust evident. Unsealed 0.006 in. (0.15 mm) thick panels showed some red rust at the edges of the identifying notches. Some black nodes of white rust with deposit stain were evident.

East Chicago, Indiana

Aluminum-Sprayed Panels (Figs. 11a, 11b). This was a heavy industrial environment with all panels showing a dark brown discoloration. All unsealed aluminum panels of 0.006 in. (0.15 mm) or more had evidence of aluminum blistering on the skyward surfaces. Unsealed aluminum 0.003 in. (0.08 mm) thick had a more nodular type of corrosion on the groundward surface. Aluminum-vinyl sealed panels had a very heavy deposit stain on both surfaces. Two coats of aluminum vinyl appeared slightly better than one coat. No corrosion of the sprayed aluminum was evident.

Zinc-Sprayed Panels (Figs. 11c, 11d). The unsealed zinc coatings of 0.003 in. (0.08 mm) thickness had completely disappeared from the skyward surface leaving the base metal exposed and rusted. The groundward surface was about 90% exposed and rusted. This was also true of the 0.003 in. (0.08 mm) thick-sprayed zinc sealed with chlorinated rubber except that approximately 20% of the groundward side was exposed and rusted. Unsealed coatings of zinc, 0.006 in. (0.15 mm) thick or more, were in good condition with no evidence of base metal rusting. Sprayed zinc sealed with aluminum vinyl was in very good condition with some deposit stains on the vinyl sealer.

INDUSTRIAL ATMOSPHERE

Columbus, Ohio

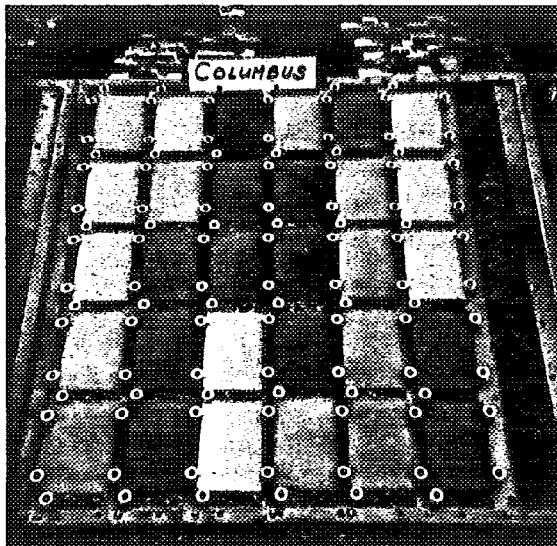


Fig. 10a—Flame-sprayed aluminum with and without sealers after exposure for 19 years.

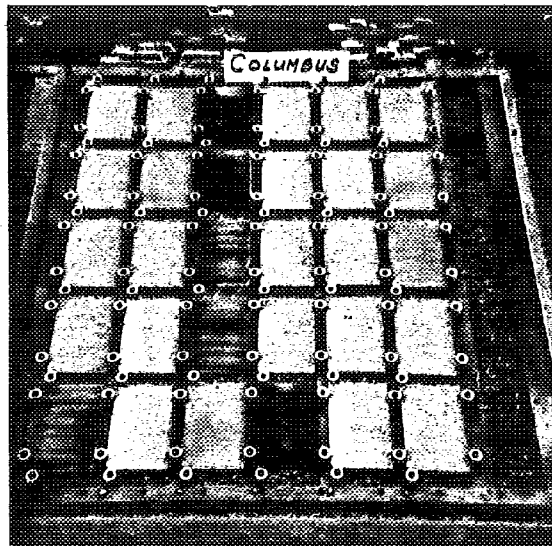


Fig. 10b—Flame-sprayed zinc with and without sealers after exposure for 19 years.

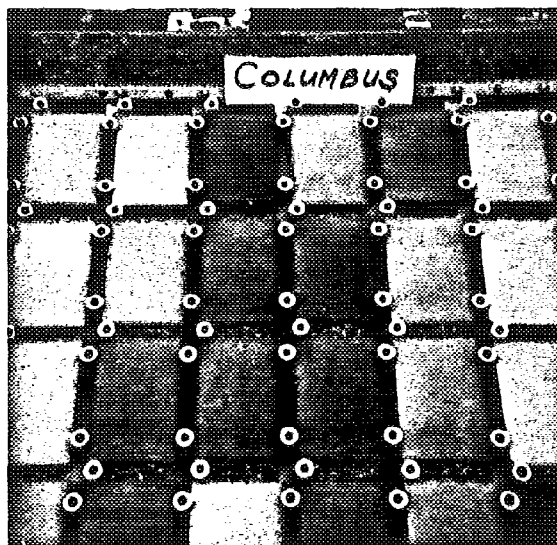


Fig. 10c—A closer view of some of the panels in Fig. 10a (above). The three dark panels in the third column from the left are 0.003 in. (0.08 mm) aluminum without a sealer. The second panel from the left in the top row is 0.003 in. (0.08 mm) aluminum with a wash primer and two coats of aluminum vinyl. The panel directly below that in the second row is the same except that it has only one coat of aluminum vinyl.

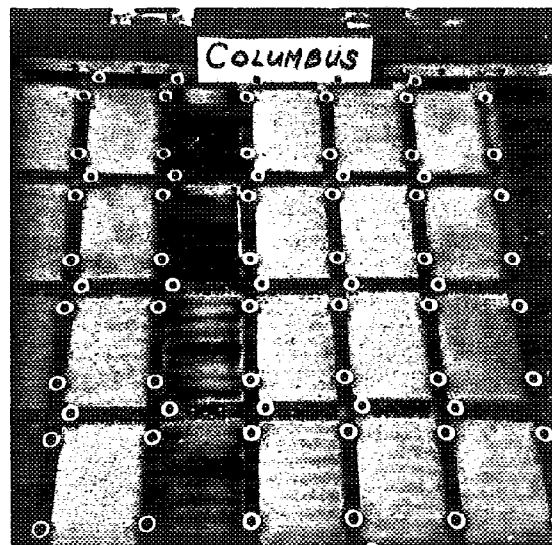


Fig. 10d—A closer view of some of the panels in Fig. 10b (above). The upper two panels in the third column from the left show the condition of 0.003 in. (0.08 mm) zinc without a sealer. The two panels below them were 0.003 in. (0.08 mm) zinc with chlorinated rubber sealer. The upper right column of three panels is 0.003 in. (0.08 mm) zinc, wash primer, and one coat of aluminum vinyl.

INDUSTRIAL ATMOSPHERE

East Chicago, Indiana

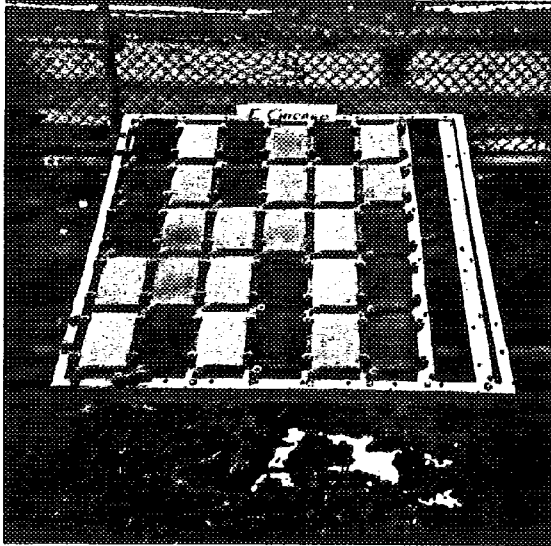


Fig. 11a—Flame-sprayed aluminum with and without sealers after exposure for 19 years.

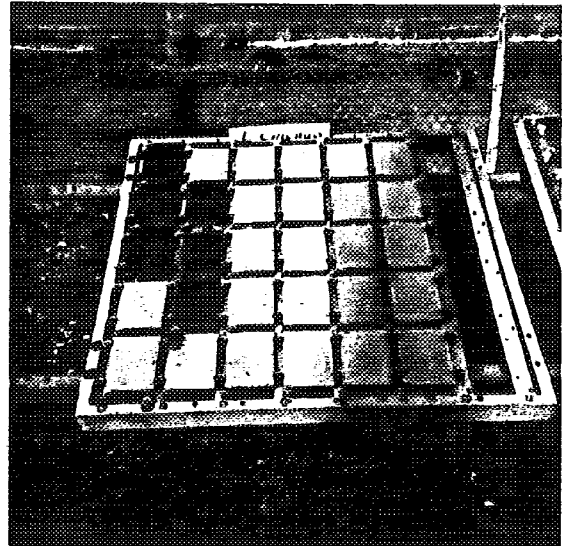


Fig. 11b—Flame-sprayed zinc with and without sealers after exposure for 19 years.

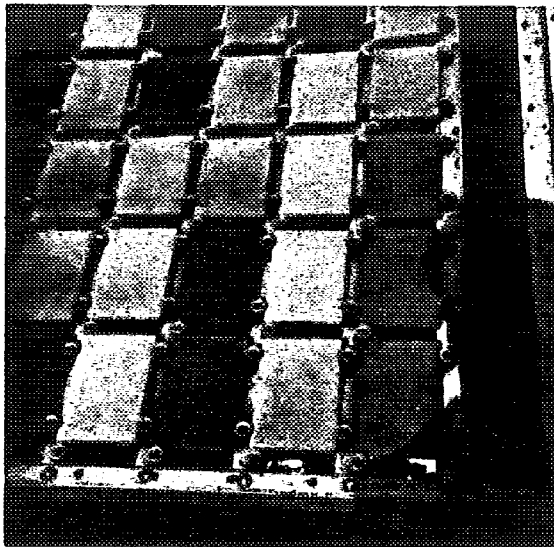


Fig. 11c—A closer view of some of the panels in Fig. 11a (above). The dark panels are unsealed flame-sprayed aluminum, of various thicknesses, discolored by pollutants in the atmosphere. The lighter panels are flame-sprayed aluminum of various thicknesses with a wash primer and one or two coats of aluminum vinyl.

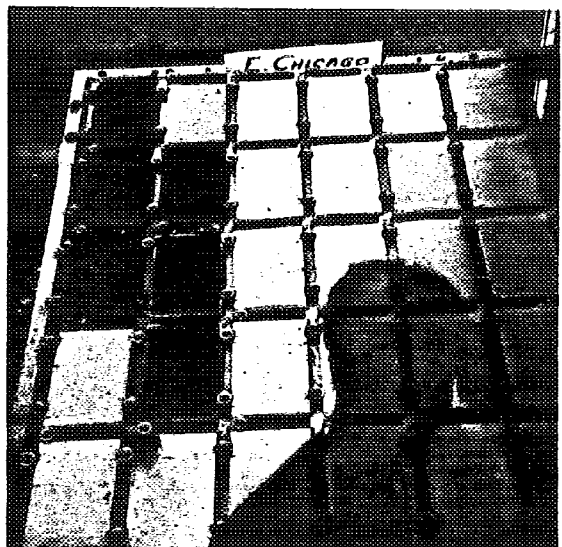


Fig. 11d—A closer view of the panels in Fig. 11b (above). The upper three panels in the first column show that the 0.003 in. (0.08 mm) zinc is gone and the steel is rusting. The three center panels in the second column were 0.003 in. (0.08 mm) zinc sealed with chlorinated rubber. The lower two panels in the first column have 0.003 in. (0.08 mm) of zinc, a wash primer, and one coat of aluminum vinyl.

PART II

TABULATED INSPECTION DATA

The following tables give a detailed account of the 19-year inspection results of all the test panels at each site. It should be kept in mind that there were three panels of each type at each test site for each exposure period. Accordingly, the inspection results for a certain type of test panel listed in Tables 7 through 11 apply to the general condition of all the panels of that type. Exception to this general condition was made, however, where there was a large variation in the condition of the individual test panels of the same type.

In describing the general condition of the test panels at each test site, the following items were taken into account:

- (1) Corrosion of base metal.
- (2) Corrosion of flame-sprayed coating.
- (3) Dissipation of seal coat.
- (4) Staining of the panel surface.

The inspection terminology used to describe the condition of the test panels is given in Table 6.

Any other condition existing on the panels was recorded in detail by the inspectors. The terminology used by the inspectors for describing the panel condition concurred with that given in Table 6; however, for the reader's benefit, the terminology used here is more self-descriptive.

As stated in the introduction to Part I of this report, one of the objectives of this program was to determine the effect of base metal preparation on the corrosion protective properties of the thermal sprayed coating. Test panels for this part of the program were located at only two test sites: Kure Beach, North Carolina (80 ft [24 m] lot) for atmospheric exposure; Wrightsville Beach, North Carolina (mean tide) for sea-water exposure.

The test panels used for determining the effect of base metal preparation are discussed under their respective test sites. The inspection results for this phase of the program are listed in Tables 11a and 11b for the atmospheric and sea-water test sites respectively.

20 / 19-YEAR CORROSION TEST REPORT

TABLE 7 — 19-YEAR INSPECTION RESULTS OF ATMOSPHERIC EXPOSURE TESTS

PANEL TYPE	1	2	3	4	5
BASE METAL PREPARATION *	1	1	1	1	1
ALUMINUM COATING THICKNESS, in. (mm)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.006 (0.15)	0.006 (0.15)
TYPE OF SEAL COAT **	None	WP+AV-1	WP+AV-2	None	WP+AV-1
TEST SITE	ENVIRONMENT				
BRAZOS RIVER, TEXAS	SALT-AIR	Base metal was not attacked. Sprayed aluminum was intact but showed a faint tan color on front of panels with a very light gray stain and white rust on back.	Base metal was not attacked. Sprayed aluminum was intact. Vinyl-seal coat on front of panels showed dull gray blotches. Vinyl-seal coat on back of panels was unaffected.	Same as Type 2, with more gloss of vinyl. Sealer retained.	Same as Type 1.
COLUMBUS, OHIO	URBAN	Base metal was not attacked. Sprayed aluminum on front of panels showed many pinpoint nodes and a general dark gray deposit stain. Backs of panels showed a general dark gray stain.	Base metal was not attacked. Sprayed metal was intact. The vinyl-seal coat showed a thin dark gray deposit stain on both the front and back of panels.	Base metal was not attacked. Sprayed aluminum and vinyl-seal coat was unaffected on both front and back of panels.	Base metal was not attacked. Sprayed aluminum on front and back of panels showed many pinpoint nodes and a general dark gray deposit stain.
EAST CHICAGO, INDIANA	INDUSTRIAL	Base metal was not attacked. Sprayed aluminum on front of panels showed many pinpoint nodes and a general dark brown deposit stain. Backs of panels showed a dark brown deposit stain.	Base metal was not attacked. Sprayed metal was intact. Vinyl-seal coat on front of panels showed a general dark deposit stain. Back showed a thin deposit stain.	Same as Type 2, with less deposit stain on front and back.	Base metal was not attacked. Sprayed aluminum on front and back of panels showed many small blisters and dark brown deposit stains.
KURE BEACH, NORTH CAROLINA 80-ft (24 m) lot	SEVERE MARINE	Base metal was not attacked. Sprayed aluminum on front of panels showed dull blotches with a few small nodes of white rust. There was general light rust staining on back. Edges had small nodes of aluminum corrosion.	Base metal was not attacked. Sprayed aluminum was intact. Vinyl-seal coat showed dull gray blotches on front and back of panels.	Base metal was not attacked. Sprayed aluminum was intact. Vinyl-seal coat showed dull gray blotches on front, but was unaffected on back of panels.	Base metal was not attacked. Sprayed aluminum showed many small nodes of corrosion on front, back, and edges of panels.
KURE BEACH, NORTH CAROLINA 800-ft (244 m) lot	SALT-AIR	Base metal was not attacked. Sprayed aluminum on front and back of panels was intact. There was generally very light rust staining on back of panels.	Base metal was not attacked. Sprayed aluminum was intact. Vinyl-seal coat showed dull gray blotches on front of panels. Vinyl-seal coat on back of panels was unaffected.	Same as Type 2 with more gloss of sealer retained.	Base metal was not attacked. Sprayed metal on front and back of panels was intact.
NEW YORK CITY AREA	INDUSTRIAL	Base metal was not attacked. Sprayed aluminum on front and back of panels showed many pinpoint nodes and a general gray deposit stain.	Base metal was not attacked. Sprayed metal was intact. Vinyl-seal coat had an intermediate number of small nodes visible. Seal coat on back was unaffected.	Base metal was not attacked. Sprayed metal was intact. Vinyl-seal coat was unaffected.	Base metal was not attacked. Sprayed aluminum on front of panel showed many small nodes and general gray deposit stain. Sprayed aluminum on back of panel showed many pinpoint nodes with gray deposit stains.
POINT REYES, CALIFORNIA	SALT-AIR	Base metal was not attacked. Sprayed aluminum on front and back of panels was intact. Black discoloration was on 25-75% of front of panels. There was slight rust staining on backs.	Base metal was not attacked. Sprayed aluminum was intact. Vinyl-seal coat showed a mottled appearance. Vinyl-seal coat on back was unaffected.	Base metal was not attacked. Sprayed aluminum and vinyl-seal coat was unaffected on both front and back of panels.	Same as Type 1, with lighter and less discoloration.

* Types of base metal preparation:

1. Coarse silica sand
2. Coarse silica sand and steel flash

** Types of seal coat:

- WP — Wash Primer
AV — Aluminum vinyl
— 1 — One coat of specified seal coat
— 2 — Two coats of specified seal coat

ON FLAME-SPRAYED ALUMINUM-COATED CARBON STEEL PANELS

6	7	8	9	10	11	12	13
1	1	1	1	2	2	2	2
0.006 (0.15)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.012 (0.30)	0.012 (0.30)	0.012 (0.30)	0.015 (0.38)
WP+AV—2	None	WP+AV—1	WP+AV—2	None	WP+AV—1	WP+AV—2	None
Same as Type 3.	Same as Type 1.	Same as Type 2.	Same as Type 3.	Same as Type 1.	Same as Type 2.	Same as Type 3.	Same as Type 1.
Same as Type 3.	Same as Type 4.	Same as Type 2.	Same as Type 5.	Same as Type 4.	Not Tested.	Not Tested.	Not Tested.
Same as Type 3.	Same as Type 4.	Same as Type 2.	Same as Type 3.	Same as Type 4.	Not Tested.	Not Tested.	Not Tested.
Base metal was not attacked. Sprayed metal showed a few small nodes of white rust. Vinyl-seal coat on front showed many gray blotches, but was unaffected on back.	Base metal was not attacked. Sprayed aluminum showed many medium size nodes of aluminum corrosion on front, back, and edges.	Same as Type 5.	Same as Type 6.	Same as Type 7.	Same as Type 5.	Same as Type 6.	Base metal was not attacked. There were many small-to-big blisters of sprayed aluminum filled with white rust on front and back of panels.
Same as Type 3.	Same as Type 4 with a slightly darker gray color on front of panels.	Same as Type 2.	Same as Type 3.	Same as Type 4 on the front, with a few small blisters of aluminum on back.	Same as Type 2.	Same as Type 3.	Base metal was not attacked. Sprayed aluminum on front and back showed an intermediate number of medium size blisters, with light white rust evident on a few.
Same as Type 5.	Same as Type 4.	Same as Type 5.	Same as Type 5.	Same as Type 4.	Not Tested.	Not Tested.	Not Tested.
Same as Type 3.	Same as Type 4.	Same as Type 2.	Same as Type 3.	Same as Type 4.	Same as Type 2.	Same as Type 3.	Same as Type 4.

22 / 19-YEAR CORROSION TEST REPORT

TABLE 8 — 19-YEAR INSPECTION RESULTS OF ATMOSPHERIC EXPOSURE TESTS

PANEL TYPE	1	2	3	4	5
BASE METAL PREPARATION*	1	1	1	1	1
ZINC COATING THICKNESS, in. (mm)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.006 (0.15)	0.006 (0.15)
TYPE OF SEAL COAT**	None	WP+AV-1	CR-2	None	WP+AV-1
TEST SITE ENVIRONMENT	1	2	3	4	5
BRAZOS RIVER, TEXAS SALT-AIR	Base metal, was not attacked. Sprayed zinc was intact, with many pinpoints of white rust on front. Back was similar, with thick white rust at bottom edge.	Base metal was not attacked. Sprayed zinc was also intact. Vinyl-seal coat showed many pinpoints of white rust on lower quarter of panel front. Seal coat on back was slightly dissipated at lower quarter of panel, with thick white rust at bottom edge.	Same as Type 1, with heavy layer of white rust on front quarter of panel. CR seal coat was completely dissipated.	Same as Type 1.	Base metal was not attacked. Sprayed zinc was intact. Bottom edges showed thick white rust. Vinyl sealer was 50% dissipated on front, 30% on back.
COLUMBUS, OHIO URBAN	Base metal was exposed and rusting on 95% of front. Base metal was exposed and rusting on 15% of back.	Base metal was not attacked. Sprayed zinc was intact. Vinyl-seal coat was unaffected.	Base metal was exposed and rusting on 60% of front. Some evidence of CR was still present. Base metal and sprayed metal were not attacked on back of panel.	Base metal was not attacked. Sprayed zinc was intact, but showed very thin white rust on front and back of panels.	5-10% of vinyl-seal coat was dissipated with light white rust evident on front. Base metal, sprayed zinc and vinyl sealer were unaffected on back.
EAST CHICAGO, INDIANA INDUSTRIAL	Base metal was 100% exposed and rusting on front. Base metal was 90% exposed and rusting on back and edges.	Base metal was not attacked. Sprayed metal was intact. Vinyl-seal coat on front of panels showed a general light gray deposit stain.	Back of panels showed a thin deposit stain. Base metal was 100% exposed and rusting on front. Base metal was 10-20% exposed and rusting on back. Very little shine was left on remaining CR seal coat on back.	Approximately 25% of base metal was exposed and rusting on front. Back of panels showed a thin white rust.	Same as Type 2.
KURE BEACH, NORTH CAROLINA 80-ft (24 m) lot SEVERE MARINE	Base metal was 75% exposed and rusting on front. Base metal was 10% exposed and rusting on back. Remaining zinc was covered with layer of white rust.	Base metal was exposed and rusting on one edge. Many small and medium size nodes of white rust on front of panels with vinyl-seal coat were completely dissipated. On back of panel, 80% of vinyl sealer was dissipated, with many small nodes of white rust.	Base metal was 90% exposed and rusting on front. Base metal was 10-20% exposed and rusting on back. Edges were mechanically damaged. Remaining zinc on back was covered with a layer of white rust.	Base metal was rusting at edges, with front and back of panels covered with small nodes of heavy white rust.	Base metal was not attacked. Sprayed zinc showed many small nodes of white rust on front, with vinyl-seal coat completely dissipated. Sprayed zinc on back showed many small nodes of white rust, with the vinyl sealer 80% dissipated.
KURE BEACH, NORTH CAROLINA 800-ft (244 m) lot SALT-AIR	Base metal was not attacked. Sprayed zinc on front of panels showed very thin white horizontal stripes of rust. Back of panels showed a very thin white rust.	Base metal was not attacked. Sprayed zinc was intact. Vinyl-seal coat showed dissipation in 25-30% of area on front and back of panels.	Base metal was not attacked. Sprayed zinc was intact on front and back with a thin layer of white rust. CR sealer was completely dissipated front and back.	Base metal was not attacked. Sprayed zinc showed a very thin layer of white rust on front of panels, with very many pinpoint nodes of white rust on back of panels.	Base metal was not attacked. Sprayed zinc was intact. Vinyl-seal coat was dissipated in 75% of area on front of panels, with very many pinpoints of white rust. Vinyl sealer was unaffected on back of panel except at lower 5% of panel, where sprayed zinc showed intermediate size nodes of white rust.
NEW YORK CITY AREA INDUSTRIAL	Base metal was 100% exposed and rusting on front. Base metal was 80-90% exposed and rusting on back and edges.	Base metal was not attacked. Sprayed zinc was intact. Vinyl-seal coat was unaffected.	Base metal was 100% exposed and rusting on front. Base metal was 10% exposed and rusting on back.	Base metal was 25% exposed and rusting on front. Back of panels had thin layer of white rust.	Base metal was not attacked. Sprayed zinc was intact. Vinyl sealer was 5-10% dissipated, with white rust evident.
POINT REYES, CALIFORNIA SALT-AIR	Base metal was not attacked. Sprayed zinc on front of panels showed horizontal stripes of very thin white rust. Backs of panels were a dark blue color.	Base metal was not attacked. Sprayed zinc was intact. Vinyl-seal coat showed dissipation in 5-10% of area on front of panels. Vinyl sealer was unaffected on back.	Base metal was not attacked. Sprayed zinc was intact on front and back, with a thin layer of white rust. CR was completely dissipated on front and back.	Base metal was not attacked. Sprayed zinc showed a thin layer of white rust on front, with very many pinpoint nodes of white rust on back of panels.	Base metal was not attacked. Sprayed zinc was intact. Vinyl-seal coat was dissipated in 50-75% of area on front of panels with very many pinpoints of white rust. Vinyl sealer was unaffected on back.

* Types of base metal preparation:

1. Coarse silica sand
2. Coarse silica sand and steel flash

** Types of seal coat:

- WP — Wash primer
CR — Chlorinated rubber
AV — Aluminum vinyl

- 1 — One coat of specified seal coat
— 2 — Two coats of specified seal coat

ON FLAME-SPRAYED ZINC-COATED CARBON STEEL PANELS

6	7	8	9	10	11	12	13
1	1	1	1	2	2	2	2
0.006 (0.15)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.012 (0.30)	0.012 (0.30)	0.012 (0.30)	0.015 (0.38)
CR—2	None	WP+AV—1	CR—2	None	WP+AV—1	CR—2	None
Same as Type 3.	Same as Type 1.	Same as Type 5.	Same as Type 3.	Same as Type 1.	Same as Type 5.	Same as Type 3.	Same as Type 1.
Base metal was not attacked. Sprayed zinc was intact. CR seal coat was dissipated on front of panels showing very thin white rust. Seal coat was 50% dissipated on back of panels.	Same as Type 4.	Same as Type 5.	Same as Type 6.	Same as Type 4.	Not Tested.	Not Tested.	Not Tested.
Base metal was not attacked. Many pinpoints of deposit stained white rust were on front of panel. Sprayed zinc was intact on back with 80% of CR seal coat intact.	Many pinpoints of deposit stained white rust were on front of panel. Base metal not attacked. There was a thin layer of white rust on back of panel.	Same as Type 2.	Same as Type 6.	Same as Type 7.	Not Tested.	Not Tested.	Not Tested.
Base metal was 5% exposed and rusting on front. Sprayed zinc on front showed a layer of white rust, with a thinner layer of white rust on back of panel. Base metal was exposed at corners due to mechanical damage.	Base metal was not attacked. Sprayed zinc was intact, with very many small nodes of white rust on front of panels. Sprayed zinc on back of panels was covered with a thin layer of white rust.	Same as Type 5.	Base metal was not attacked. Sprayed zinc showed thick white rust on front and back of panel. Corners were mechanically damaged.	Base metal was not attacked. Sprayed zinc showed very many small nodes of white rust on front of panel. Back of panel was covered with a thin layer of white rust.	Base metal was not attacked. Sprayed zinc showed very many small nodes of white rust on front and back with vinyl-seal coat 50% dissipated.	Same as Type 9.	Same as Type 10.
Same as Type 3.	Same as Type 4.	Same as Type 5.	Same as Type 3, except heavier layer of white rust.	Same as Type 4.	Base metal was not attacked. Sprayed zinc was intact. Vinyl seal coat was dissipated in 50% of area on front, with very many pinpoint nodes of white rust. Back of panels showed 25% dissipation of vinyl-seal coat, with many small nodes of white rust.	Same as Type 3.	Same as Type 4.
Base metal was 5-10% exposed and rusting. CR seal coat was 50% dissipated on back with white rust.	Base metal was not attacked. Sprayed zinc showed a thin layer of deposit stain on front, with a thin layer of white rust on back of panels.	Base metal was not attacked. Sprayed zinc was intact. Vinyl-seal coat was dissipated about 25% on front but not affected on back of panels.	Base metal was not attacked. Sprayed zinc on front showed a thin layer of white rust with deposit stain. Back of panel showed CR seal coat 50% dissipated, with white rust evident.	Same as Type 7.	Not Tested.	Not Tested.	Not Tested.
Same as Type 3.	Same as Type 4.	Same as Type 5.	Same as Type 3.	Same as Type 4.	Same as Type 5.	Same as Type 3.	Same as Type 4.

24 / 19-YEAR CORROSION TEST REPORT

TABLE 9 — 19-YEAR INSPECTION RESULTS OF SEAWATER EXPOSURE TESTS

PANEL TYPE		1	2	3	4	5
BASE METAL PREPARATION*		2	2	2	2	2
ALUMINUM COATING THICKNESS, in. (mm)		0.003 (0.08)	0.003 (0.08)	0.006 (0.15)	0.006 (0.15)	0.006 (0.15)
TYPE OF SEAL COAT**		WP+CV—1	WP+CV—2	None	WP+AV—1	WP+AV—2
TEST SITE	ENVIRONMENT					
WRIGHTSVILLE BEACH, NORTH CAROLINA (Below low tide)	TOTAL IMMERSION	Base metal was not attacked. Sprayed metal was intact on front and back of panels. Very small amount of red rust was along edges of panels. Vinyl-seal coat was dissipated.	Base metal was not attacked. Sprayed metal was intact on front and back of panels. There was less red rust on edges and less dissipation of vinyl sealer than on Type 1.	General white rusting of the sprayed aluminum on front and back of panels was present with red rust staining from base metal evident in 50% of area.	Base metal was not attacked. Sprayed metal on front and back showed a few small broken nodes with white corrosion products evident. Vinyl-seal coat was dissipated.	Same as Type 4.
WRIGHTSVILLE BEACH, NORTH CAROLINA	ALTERNATE EXPOSURE TO ATMOSPHERE AND SEA WATER	Base metal was not attacked. Sprayed aluminum was intact. Vinyl seal coat was dissipated.	Same as Type 1.	Sprayed aluminum showed a few small broken blisters of metal with corrosion of base metal under blisters only.	Same as Type 1.	Same as Type 1.
FREEPORT, TEXAS	TOTAL IMMERSION	Base metal showed red rust on 3-5% of the front and back of panels. Sprayed metal and vinyl-seal coat were dissipated in these same areas. Edges had been damaged mechanically.	Panels were missing.	Base metal was not attacked. Sprayed metal on front and back of panels showed a few small scattered blisters and red rust stains. Edges had been damaged mechanically.	Base metal was not attacked. Sprayed metal was intact on both sides. Vinyl-seal coat was unaffected on both sides. Edges had been damaged mechanically.	Same as Type 4.

* Type of base metal preparation:
2. Course silica sand and steel flash

** Types of seal coat:
WP—Wash primer
CV—Clear vinyl
—1—One coat of specified seal coat
—2—Two coats of specified seal coat

TABLE 10 — 19-YEAR INSPECTION RESULTS OF SEAWATER EXPOSURE TESTS

PANEL TYPE		1	2	3	4	5
BASE METAL PREPARATION *		2	2	2	2	2
ZINC COATING THICKNESS, in. (mm)		0.003 (0.08)	0.003 (0.08)	0.006 (0.15)	0.006 (0.15)	0.006 (0.15)
TYPE OF SEAL COAT**		CR—1	CR—2	None	CR—1	CR—2
TEST SITE	ENVIRONMENT					
WRIGHTSVILLE BEACH, NORTH CAROLINA	TOTAL IMMERSION	Panels were missing or corroded beyond recognition.	Panels were missing or corroded beyond recognition.	Panels were missing or corroded beyond recognition.	Panels were missing or corroded beyond recognition.	Panels were missing or corroded beyond recognition.
WRIGHTSVILLE BEACH, NORTH CAROLINA	ALTERNATE EXPOSURE TO ATMOSPHERE AND SEA WATER	Panels were missing or corroded beyond recognition.	Panels were missing or corroded beyond recognition.	Base metal showed heavy rust over 75% of panel surfaces, front and back; heavy loss of steel at edges.	One panel was identifiable. Same as Type 3.	One panel was identifiable. Same as Type 3.
FREEPORT, TEXAS	TOTAL IMMERSION	Base metal showed deep corrosion pits over 20% of the panel surface, front and back. Sprayed metal showed general red and white rust over the entire surface. CR seal coat was completely dissipated.	Base metal showed deep corrosion pits over 4-6% of the panel surface, front and back. Sprayed metal showed general red and white rust over the entire surface. CR seal coat was completely dissipated.	Base metal showed deep corrosion pits over 1% of the panel surface, front and back. Sprayed metal showed thin white rust and large red rust stains, front and back.	Same as Type 2.	Same as Type 2.

* Type of base metal preparation:
2. Course silica sand and steel flash

** Types of seal coat:
CR—Chlorinated rubber
—1—One coat of specified seal coat
—2—Two coats of specified seal coat

Seawater Exposure—Aluminum—and Zinc-Coated Panels / 25

ON FLAME-SPRAYED ALUMINUM-COATED CARBON STEEL PANELS

6	7	8	9	10	11	12	13
2	2	2	2	2	2	2	2
0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.012 (0.30)	0.012 (0.30)	0.012 (0.30)	0.015 (0.38)	0.018 (0.46)
None	WP+CV-1	WP+CV-2	None	WP+CV-1	WP+AV-2	None	None
Same as Type 3.	Base metal was not attacked. Sprayed metal on front and back showed an intermediate number of small broken nodes with white corrosion products, some of which showed red rust stains. Vinyl-seal coat was dissipated.	Same as Type 7.	Same as Type 3. Mechanical damage to edges.	Same as Type 7.	Same as Type 7.	Same as Type 3.	There was general white rusting of the sprayed aluminum on front and back of panels with red rust staining from base in 50% of area. An intermediate number of medium broken nodes was found on both front and back of panels.
Sprayed aluminum showed a few broken medium sized blisters of metal with corrosion of base metal under blisters only.	Same as Type 1.	Same as Type 1.	Sprayed aluminum showed a few big broken blisters of metal with corrosion of base metal under blisters only.	Base metal was not attacked. Sprayed aluminum showed a few small broken nodes with white rust.	Same as Type 10.	Same as Type 6.	Same as Type 9.
Base metal was not attacked. Sprayed metal showed a few blisters on both sides of the panels, with several broken open. Faint red rust stains appeared on both sides. Edges had been damaged mechanically.	Same as Type 4.	Base metal was not attacked. Sprayed metal showed a few small blisters on both sides of panels. Two spots showed white rust. Edges had been damaged mechanically.	Same as Type 6.	Same as Type 8.	Same as Type 4.	Same as Type 6.	Same as Type 6.

ON FLAME-SPRAYED ZINC-COATED CARBON STEEL PANELS

6	7	8	9	10	11	12	13
2	2	2	2	2	2	2	2
0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.012 (0.30)	0.012 (0.30)	0.012 (0.30)	0.015 (0.38)	0.018 (0.46)
None	CR-1	CR-2	None	CR-1	CR-2	None	None
Panels were missing or corroded beyond recognition.	Panels were missing or corroded beyond recognition.	One panel was lost. Base metal showed small-to-large, deep corrosion pits over 50% of area and loss of steel at edges. Remaining sprayed zinc was converted to white rust with heavy pitting.	Base metal was not attacked. Sprayed zinc showed heavy white rust over entire surface with heavy pitting.	One panel was identifiable. Sprayed zinc was converted to corrosion product with thick white rust and 25% of base metal showing red rust.	Sprayed zinc was converted to corrosion product with thick white rust and heavy, deep pitting and 50% of base metal showing red rust.	Same as Type 9.	Same as Type 9.
Base metal showed heavy rust over 50% of panel surface, front and back; heavy loss of steel at edges.	Same as Type 6.	Same as Type 6.	One panel was missing. Base metal was not attacked. Sprayed zinc showed thick white rust with heavy pitting.	One panel missing. Same as Type 9.	Same as Type 9.	Same as Type 9.	Same as Type 9 with very heavy pitting.
Base metal was not attacked. Sprayed metal showed general white rust over 90% of the panel surface, front and back.	Same as Type 2.	Test panels lost in 1965.	Test panels lost in 1965.	Test panels lost in 1965.	Test panels lost in 1965.	Test panels lost in 1965.	Test panels lost in 1965.

26 / 19-YEAR CORROSION TEST REPORT

TABLE 11A — EFFECTS OF VARIOUS BASE METAL PREPARATION METHODS AND BLASTING ABRASIVES

ALUMINUM-COATED PANELS							
PANEL TYPE	14	15	16	17	18	19	20
BASE METAL PREPARATION*	2	2	2	4	4	4	6
ALUMINUM COATING THICKNESS, in. (mm)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)
TYPE OF SEAL COAT**	None	WP+AV—1	WP+AV—2	None	WP+AV—1	WP+AV—2	None
KURE BEACH, NORTH CAROLINA 80-ft (24 m) lot	Base metal was not attacked. Sprayed aluminum showed many medium size nodes of aluminum corrosion on front, back, and edges.	Base metal was not attacked. Sprayed aluminum showed an intermediate number of small nodes of white rust on front of panels. Vinyl-seal coat showed a few dull gray spots on back of panels.	Same as Type 14.	Same as Type 14.	Same as Type 15.	Same as Type 14.	Same as Type 14.

ZINC-COATED PANELS							
PANEL TYPE	14	15	16	17	18	19	20
BASE METAL PREPARATION*	2	2	2	4	4	4	6
ZINC COATING THICKNESS, in. (mm)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)
TYPE OF SEAL COAT**	None	WP+AV—1	CR—2	None	WP+AV—1	CR—2	None
KURE BEACH, NORTH CAROLINA 80-ft (24 m) lot	Base metal was not attacked. Sprayed zinc showed very many small nodes of white rust on front of panels. Back of panel was covered with a thin layer of white rust.	Base metal was not attacked. Sprayed zinc showed very many small nodes of white rust on front and back with vinyl-seal coat 50% dissipated.	Base metal was not attacked. Sprayed zinc showed thick white rust on front and back of panels. Corners mechanically damaged.	Same as Type 14.	Same as Type 15.	Same as Type 16.	Same as Type 14.

TABLE 11B — EFFECTS OF VARIOUS BASE METAL PREPARATION METHODS AND BLASTING ABRASIVES

ALUMINUM-COATED PANELS							
PANEL TYPE	14	15	16	17	18	19	20
BASE METAL PREPARATION*	1	1	1	3	3	3	5
ALUMINUM COATING THICKNESS, in. (mm)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)
TYPE OF SEAL COAT**	None	WP+CV—1	WP+CV—2	None	WP+CV—1	WP+CV—2	None
WRIGHTSVILLE BEACH, NORTH CAROLINA	Sprayed aluminum showed a few big, broken blisters of metal with corrosion of base metal under blisters only.	Base metal was not attacked. Sprayed aluminum showed a few small broken nodes with white rust.	Same as Type 15.	Sprayed aluminum showed a few small broken blisters of metal with corrosion of base metal under blisters only.	Same as Type 15.	Same as Type 15. One panel had separation of aluminum at 3 mil level over area of one square in. with no attack of base metal.	Same as Type 15.

ZINC-COATED PANELS							
PANEL TYPE	14	15	16	17	18	19	20
BASE METAL PREPARATION*	1	1	1	3	3	3	5
ZINC COATING THICKNESS, in. (mm)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)
TYPE OF SEAL COAT**	None	CR—1	CR—2	None	CR—1	CR—2	None
WRIGHTSVILLE BEACH, NORTH CAROLINA	Base metal showed heavy rust over 50% of panel surface, front and back. There was heavy loss of steel at edges.	Same as Type 14.	Same as Type 14.	One panel was missing. Sprayed zinc showed thick white rust with heavy pitting, and base metal showing red rust in 25% of area.	One panel was missing. Base metal showed heavy rust over 75% of panel surface, front and back. There was heavy loss of steel at edges.	Same as Type 18.	Same as Type 14. One panel was missing.

* Types of base metal preparation:
 1. Coarse silica sand
 2. Coarse silica sand and steel flash
 3. Fine silica sand

4. Fine silica sand and steel flash
 5. Chilled iron grit
 6. Chilled iron grit and steel flash

** Types of seal coat:
 WP—Wash primer
 AV—Aluminum vinyl
 CV—Clear vinyl

CR—Chlorinated rubber
 —1—One coat of specified seal coat
 —2—Two coats of specified seal coat

ON FLAME-SPRAYED ALUMINUM- AND ZINC-COATED CARBON STEEL PANELS

21	22	23	24	25	26	27	28
6	6	3	3	3	5	5	5
0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)
WP+AV—1	WP+AV—2	None	WP+AV—1	WP+AV—2	None	WP+AV—1	WP+AV—2
Same as Type 15.	Base metal was not attacked. Sprayed aluminum was intact. Vinyl-seal coat showed dull gray blotches on front and back of panels.	Same as Type 14.	Same as Type 22.	Same as Type 22.	Base metal was not attacked. Sprayed aluminum showed an intermediate number of medium size nodes of corrosion product on front, back, and edges of panels.	Same as Type 22.	Same as Type 22.

21	22	23	24	25	26	27	28
6	6	3	3	3	5	5	5
0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)
WP+AV—1	CR—2	None	WP+AV—1	CR—2	None	WP+AV—1	CR—2
Same as Type 15.	Same as Type 16.	Same as Type 14.	Base metal was not attacked. Sprayed zinc showed very many small nodes of white rust on front with vinyl-seal coat completely dissipated. Sprayed zinc on back showed many small nodes of white rust with the vinyl sealer 80% dissipated.	Same as Type 16.	Same as Type 14.	Same as Type 24.	Same as Type 16.

ON FLAME-SPRAYED ALUMINUM- AND ZINC-COATED CARBON STEEL PANELS

21	22	23	24	25	26	27	28
5	5	4	4	4	6	6	6
0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)
WP+CV—1	WP+CV—2	None	WP+CV—1	WP+CV—2	None	WP+CV—1	WP+CV—2
Same as Type 15.	Same as Type 15.	Sprayed aluminum showed a few medium sized broken blisters of metal with corrosion of base metal under blisters only.	Same as Type 15.	Same as Type 15.	Same as Type 17.	Same as Type 15.	Same as Type 15.

21	22	23	24	25	26	27	28
5	5	4	4	4	6	6	6
0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)	0.009 (0.23)
CR—1	CR—2	None	CR—1	CR—2	None	CR—1	CR—2
Base metal showed heavy rust over 90% of panel surfaces, front and back. There was heavy loss of steel at edges.	Same as Type 18.	Same as Type 14.	Same as Type 18.	Same as Type 18. One panel was missing.	One panel was missing. Base metal was not attacked. Sprayed zinc showed thick white rust with heavy pitting.	Same as Type 18. One panel was missing.	Same as Type 18. One panel was missing.

ACKNOWLEDGMENTS

The AWS Committee on Thermal Spraying extends its thanks to the following individuals who served on the committee at various times since the inception of this test program. (The companies listed below represent the affiliations of these individuals at the time of their membership on the committee.)

<i>D. C. Boltz</i>	Metco, Inc.
<i>R. E. Booth</i>	General Electric Co.
<i>C. J. Breitenstein</i>	Metal-Cladding, Inc.
<i>J. L. Cahill</i>	New York Naval Shipyard
<i>W. P. Campbell</i>	Bureau of Mines, Dominion of Canada
<i>R. S. Capp</i>	U.S. Coast Guard
<i>M. W. Caskey</i>	U.S. Coast Guard
<i>V. A. Cook</i>	Metallizing Company of America
<i>A. Eisenlohr</i>	Arde-Portland Co.
<i>E. B. Gaines</i>	Gulf Engineering Co.
<i>H. C. Gifford</i>	U.S. Coast Guard
<i>S. A. Greenberg</i>	American Welding Society
<i>A. H. Griffin</i>	U.S. Coast Guard
<i>H. S. Hammond</i>	Metalweld, Inc.
<i>N. P. Harvey</i>	Arthur Tickle Engineering Works
<i>J. W. Heck</i>	American Bureau of Shipping
<i>G. Heitman</i>	Aerojet-General Corp.
<i>G. Jensen</i>	Avco Industrial Products Div.
<i>T. F. Kearns</i>	Department of the Navy
<i>F. Keller</i>	Aluminum Company of America
<i>H. V. Kojola</i>	Union Carbide Corp., Linde Division
<i>C. P. Larrabee</i>	United States Steel Corp.
<i>K. G. LeFevre</i>	Metalweld, Inc.
<i>H. H. Libby</i>	Libby Welding Co.
<i>W. E. McKenzie</i>	United States Naval Weapons Lab.
<i>R. C. Miller</i>	General Electric Co.
<i>T. W. Morgan</i>	Armco Steel Corp.
<i>R. Nelson</i>	General Electric Co.
<i>H. J. Nichols</i>	Bureau of Mines, Dominion of Canada
<i>J. H. Nill</i>	Metallizing Company of America
<i>P. C. Shepard</i>	American Welding Society
<i>J. F. Broland</i>	General Electric Co.
<i>P. G. Dennison</i>	Metal Spraying Corp.
<i>E. T. Englehart</i>	Aluminum Company of America
<i>S. J. Grisaffe</i>	National Aeronautics & Space Administration
<i>H. P. Godard</i>	Aluminum Labs., Ltd.
<i>R. J. McWaters</i>	Metco, Inc.

30 / 19-YEAR CORROSION TEST REPORT

T. P. May
R. L. Piehl
J. Royer
W. M. Wheildon
G. W. Oxley
E. T. Parkinson
T. Pascala
R. S. Pelton
E. L. Perry
E. A. Pigan
B. Ronay
K. B. Smith
H. B. Smith
H. S. Swan
F. H. Turbyville
S. Tour
R. Unger
H. Vanderpool
A. E. Vandersee
W. E. R. Watt
W. L. Webster
J. L. Wilson

International Nickel Co.
 Standard Oil of California
 Weldco, Inc.
 Norton Co.
 Standard Oil of New Jersey
 Eastern Metallizing Co.
 General Motors Corp.
 General Electric Co.
 U.S. Coast Guard
 Westinghouse Electric Corp.
 Consulting Engineer
 Dix Engineering Co.
 U.S. Coast Guard
 The H. S. Swan Co.
 Graver Tank Manufacturing Co.
 Sam Tour and Co.
 Plasmadyne
 Aerojet-General Corp.
 Vandee Manufacturing Co.
 Aluminum Company of America
 U.S. Coast Guard
 American Bureau of Shipping

The Committee also wishes to thank the following individuals, upon whom fell the burden of the yearly inspection of the panels at the various test sites:

E. T. Chiles
S. Dent
G. J. Durmann
E. T. Englehart
J. P. Fraser
H. P. Godard
K. Howie
R. M. Kolb
T. P. May
F. L. McGearry
G. A. Nelson
C. J. O'Boyle
R. Piehl
D. R. Power
C. F. Schrieber
A. P. Shepard
R. E. Taber
V. G. Taylor

Shell Development Co.
 Metco, Inc.
 Metco, Inc.
 Aluminum Company of America
 Shell Development Co.
 Aluminum Labs., Ltd.
 Dow Chemical Co.
 American Oil Co.
 International Nickel Co.
 Aluminum Company of America
 Shell Development Co.
 Metco, Inc.
 Standard Oil of California
 Dow Chemical Co.
 Dow Chemical Co.
 Metco, Inc.
 Shell Development Co.
 International Nickel Co.

The AWS Committee on Thermal Spraying wishes to express its deep appreciation to the American Society for Testing and Materials. The cooperation of this Society, in arranging for the use of portions of their own test sites and portions of private test sites for this corrosion test program, was invaluable.

Last, but far from least, the Committee wishes to thank the following organizations for their various contributions to this test program. Without their help, this project would never have been possible.

Akron Sand Blast Co.	Keystone Shipping Co.
Aluminum Company of America	Magnesium Company of America
Aluminum Labs., Ltd.	Metallizing Company of America
American Brass Co.	Metco, Inc.
American Petroleum Institute	Metal-Cladding, Inc.
American Zinc, Lead and Smelting Co.	Metalweld, Inc.
A. O. Smith Corp.	New England Hard Facing Co.
Armco Steel Corp.	New Jersey Zinc Co.
Atlantic Refining Co.	Pacific Telegraph and Telephone Co.
Battelle Memorial Institute	Philadelphia Electric Corp.
Bates Expanded Steel Plant	Port of New York Authority
Bell Telephone Labs.	Reynolds Metals Co.
Christiansen Corp.	R. P. C. Shipbuilders & Dry Dock Co.
Clark Metallizing	Ruemelin Manufacturing Co.
Dow Chemical Co.	St. Louis Metallizing Co.
Dowington Iron Works	Union Electric Co.
Fulton Foundry and Machine Works	United Engineers and Constructors
F. W. Gartner Co.	United States Steel Corp.
General Electric Co.	Warner Co.
Hayden Wire Works, Inc.	Welding and Supplies Company, Ltd.
Kaiser Aluminum and Chemical Corp.	Westinghouse Electric Corp.