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WEATHERING OF ADHESIVE-BONDED LAP JOINTS OF CLAD ALUMINUM ALLOY

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Carpenter Litho & Prtg. Co., Springfield, O.
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FOREWORD

This report was prepared by the Forest Products Laboratory under USAF Contract No. DO 33(616)56-9. The contract was initiated under Project No. 7340, "Rubber, Plastic and Composite Materials," Task No. 73401, "Structural Adhesives." The work was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. F. W. Kuhn acting as project engineer.

This report is the second of a series of reports to be made on the same subject, covering work performed from July 1952 to August 1956.

This report covers an evaluation of the performance of a number of products under specific conditions. The materials tested may not have been developed or intended by the manufacturer for the conditions to which they have been subjected. Any failure or poor performance of a material is therefore not necessarily indicative of the utility of that material under less stringent conditions or for other applications.

ABSTRACT

Lap-joint panels of clad 2024-T3 aluminum bonded with nine metal-bonding adhesives were weathered at Panama Canal Zone; Fairbanks, Alaska; Miami, Fla.; State College, N. Mex.; and Madison, Wis. Panels were exposed while stressed in bending and while unstressed. Test panels were also exposed to several laboratory conditions.

Three of the adhesives (2 epoxy resins and a phenolic-neoprene-nylon) were deteriorated seriously at the Canal Zone and Florida. Exposure at the other 3 sites was much milder, and only some stressed epoxy-bonded panels failed at these sites. Through 1 year, conditions at the Canal Zone caused greater bond deterioration than those in Florida. After 3 years, however, the deterioration was generally worse in Florida, and this exposure caused 2 other adhesives (nitrile-rubber type) to deteriorate. Stressing the bonded panels over bending frames generally accelerated the deterioration of those adhesive bonds that were subject to deterioration.

Laboratory exposure to salt-water spray or exposure to continuous or cyclic conditions of 120° F. and 97 percent relative humidity promoted deterioration in the same types of bonds that deteriorated from weather at the Canal Zone or Florida sites.

In general, the adhesives that performed well in these exposure tests were types that have qualified under the applicable Military specification, while those that showed appreciable deterioration have not.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

R. T. Schwartz

R. T. SCHWARTZ
Chief, Organic Materials Branch
Materials Laboratory
Directorate of Research

INTRODUCTION

Various laboratories have investigated the durability of metal-bonding adhesives used in aircraft fabrication by exposing bonded lap-joint specimens to salt water, tap water, and aircraft fluids, as described in Military Specification MIL-A-5090B "Adhesive, Airframe Structural, Metal to Metal," and to other laboratory exposures involving high humidities and high and low temperatures.

The purpose of this research[1] was to investigate further the durability of selected metal-bonding adhesives by exposing bonded lap-joint panels of clad 2024-T3 aluminum to weathering in various climates. Because weather resistance of adhesive bonds to metals may be affected by the character of the metal surface at the time of bonding, all of the panels were prepared for bonding with sulfuric acid-sodium dichromate etch treatments. This type of treatment had been found, in previous studies,[2,3] to result in bonds to aluminum that generally showed good resistance to corrosion during 30-day salt-water spray tests. Bonded lap-joint panels for this present study were exposed to weathering in both the unstressed and stressed conditions. Stresses were applied by bending the bonded panels.

Several continuous and cyclic exposures under controlled laboratory conditions were also included to determine if there might be a correlation between the results of the laboratory tests and the weathering tests.

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[1] Manuscript released by author November 1956 for publication as a WADC Technical Report.

[2] Eickner, H. W. A Study of Methods for Preparing Clad 24S-T3 Aluminum Alloy Sheet Surfaces for Adhesive Bonding, Forest Products Laboratory Report No. 1813-A, 1950.

[3] Eickner, H. W. Adhesive Bonding Properties of Various Metals as Affected by Chemical and Anodizing Treatments of the Surfaces, Forest Products Laboratory Report No. 1842, revised 1954.

PROCEDURE

Type and Number of Test Panels

Test panels (Fig. 1) of 0.064-inch 2024-T3 clad aluminum (formerly identified as 24S-T3) were prepared by bonding together, with a 1/2-inch overlap, two 4- by 8-inch pieces of the metal to result in a lap-joint panel 8 inches wide and 7-1/2 inches long. Five commercial metal-bonding adhesives were used in the first series of this study (Part I, February 1955), and 4 adhesives have since been added. One hundred and eight test panels were prepared with each adhesive, except where otherwise noted.

Adhesives

The adhesives used in the first series of test panels were, as described in Part I:

Metlbond MN3C Nylon Tape
Epon VI Adhesive
Scotchweld Bonding Film 585
Bloomingdale FM-47 Adhesive
Bloomingdale PA-101 (included only in exterior exposure tests).

The following additional adhesives have since been used in the second and third series in preparing test panels for the laboratory and exterior exposure tests.

Redux E, type R.--A high-temperature-setting two-component formulation of a phenol resin solution and a vinyl polymer powder. Ciba Co., Inc., Plastics Division, 627 Greenwich St., New York 14, N. Y.

Metlbond 4021.--A high-temperature-setting adhesive with a nitrile rubber-phenolic resin liquid primer and an unsupported nitrile rubber-phenolic resin film. Narmco Resins & Coatings Co., 600 Victoria St., Costa Mesa, Calif.

Epon VIII Adhesive.--A formulation of epoxy-type resins. Shell Chemical Corp., 380 Madison Ave., New York 17, N. Y.

Epon 422J, formulation 607.--A high-temperature-setting formulation of the phenol-epoxy type, supported on a woven glass-fiber fabric. Shell Chemical Corp., 380 Madison Ave., New York 17, N.Y.

Adhesive Bonding Conditions

Aluminum alloy sheets, sheared to the proper size with edges deburred by light hand filing, were prepared for bonding in the same manner as the previous panels. The surfaces were wiped with a clean cloth saturated in clean acetone, and then immersed for 10 minutes at 140 to 160° F. in a solution of 10 parts by weight concentrated sulfuric acid, 1 part sodium dichromate, and 30 parts water. The acid solution was rinsed from the metal pieces with warm water. A circulating fan was then used to quickly dry the water from the rinsed metal pieces.

The acid treatment for the test panels prepared with Epon VIII Adhesive was modified as recommended by the adhesive manufacturer to be 20 minutes at 140 to 160° F. in a solution of 12.5 parts by weight of concentrated sulfuric acid, 3.5 parts sodium dichromate, and 30 parts water.

The metal pieces of all panels were then bonded using conditions within the ranges recommended by each of the adhesive manufacturers. The particular conditions used with the first 5 adhesives are described in Part I (December 1955). The conditions used with the latter 4 adhesives were as follows:

Redux E, type R.--One brush coat of adhesive liquid was applied to each of the metal surfaces, and the powder component of the adhesive was immediately sprinkled into the wet spread. Excess powder was brushed from the surface. The adhesive film was air dried overnight. The joints were assembled and pressed for 15 minutes at 300° F. after a 10-minute heating-up period. A pressure of 100 pounds per square inch was applied during the heating and curing of the adhesive film.

Metlbond 4021.--One thin brush or spray coat of the liquid primer was applied to each of the metal surfaces. This primer was air dried for 1 hour and then precured for 15 minutes at 180° F. A layer of the adhesive film was placed between the coated faying surfaces. The adhesive film in the joint was then cured for 60 minutes at 350° F. after a 10-minute heating-up period. A pressure of 100 pounds per square inch was applied during the cure.

Epon VIII Adhesive. --One brush coat of liquid adhesive, catalyzed with 6 parts by weight of undyed curing agent A to 100 parts of the resin, was applied to both faying surfaces. The lap-joint panels were then assembled immediately and cured for 90 minutes at a temperature of 200° F. under a pressure of 10 pounds per square inch.

Epon 422J Tape. --One layer of the adhesive tape was placed between the faying surfaces of the metal panel. The adhesive joint was cured for 30 minutes at 330° F. after a 5-minute heating-up period. The pressure applied during the curing was 20 pounds per square inch.

Electrically heated or steam-heated platen presses were used to heat and apply curing pressure to all test panels. All panels were removed from the press while hot.

Exposure and Testing

A 1-inch-wide specimen (Fig. 1) was cut from each end of the 8-inch-wide test panels for tests as controls. Test panels, 5 inches wide, for exposure under the conditions described below were then randomly selected from the panels prepared with each adhesive.

Distribution of the test panels among the various exposure conditions is given in Table 1. The panels were exposed in unstressed or stressed conditions as indicated in Table 1. Stressed panels were mounted as shown in Figure 2 over steel bending frames (zinc-chromate primed) to give a 0.25-inch deflection at the center in a center-load, 6-inch-span flexure test. (Maximum computed tensile stress for 0.064-inch metal sheet for this span and deflection is 31,000 pounds per square inch. This is approximately 55 percent of the computed maximum tensile stress developed in the metal when the minimum required load of 150 pounds is applied in the standard bend test of Military Specification MIL-A-5090B.)

Tests on all of the 1-inch-wide specimens cut from the panels as controls or after exposure (Fig. 1) were made by applying tensile loads to the end of specimens until the bonded overlap failed. A rate of loading of 300 pounds per minute was used with all specimens from the original group of 5 adhesives, and this rate of loading was increased to 600 pounds per minute for the latter series of tests because of a change in the applicable military specification. The ends of the specimens were held in 1-inch-wide Templin-type grips that extended down from the ends of the specimens to within 1 inch of the edge of the lap. Testing was done at a temperature of 72° to 76° F.

A. Control tests.--A 1-inch-wide specimen was cut from each end of all panels prepared in this study tested as controls to determine the quality of bonds before exposure began.

B. Laboratory exposure tests - 120° F. and 97 percent relative humidity.--Nine unstressed panels with each adhesive(except Bloomingdale PA-101 adhesive) were exposed continuously at 120° F. and 97 percent relative humidity. Three panels with each adhesive were removed from exposure after each of the exposure periods, 3, 6, and 36 months. Each panel was then cut into four 1-inch-wide specimens and tested. The panels bonded with Redux E, Metlbond 4021, Epon VIII, and Epon 422J are still in exposure for the 36-month period.

C. Laboratory exposure tests - repeated cyclic exposure to 120° F. and 97 percent relative humidity; 158° F. and 20 percent relative humidity; and 0° F.--Twelve unstressed panels with each adhesive (excluding Bloomingdale PA-101 adhesive) were exposed to repeating cycles, each consisting of 2 weeks at 120° F. and 97 percent relative humidity, followed by 2 weeks at 158° F. and 20 percent relative humidity and then by 1 week at 0° F. ± 10° F. Three panels with each adhesive were removed from exposure after 2, 5, 7, and 10 cycles, and each was cut into four 1-inch-wide test specimens and tested.

D. Laboratory exposure tests - salt-water boil.--Nine unstressed panels with each adhesive (except Bloomingdale PA-101 adhesive) were exposed to boiling in a saturated sodium chloride solution for periods up to 6 hours. Three panels with each adhesive were removed after 1, 3, and 6 hours of exposure, and each was cut into four 1-inch-wide test specimens and tested.

E. Laboratory exposure tests - salt-water spray.--Five unstressed panels with each adhesive (except Bloomingdale PA-101 adhesive) were exposed by the Materials Laboratory, Wright Air Development Center, for 30 days to the salt-water spray as specified in Military Specification MIL-A-5090B. After exposure, each test panel was cut into four 1-inch-wide specimens for tests.

F. Laboratory exposure tests - 80° F. and 65 percent relative humidity.--Five stressed and five unstressed panels with each adhesive (except Bloomingdale PA-101 adhesive) have been or are being exposed continuously for 36 months at 80° F. and 65 percent relative humidity. Three stressed and three unstressed panels bonded with Epon VIII and Epon 422J have also been exposed for 3 and 12 months at this condition. All panels will be cut into four 1-inch-wide specimens after exposure.

G. Exterior exposure.--With each of the adhesives except Bloomingdale PA-101, 15 test panels (trimmed to a width of 5 inches after removal of control specimens), 9 unstressed and 6 stressed, were exposed on the roof of the Forest Products Laboratory at Madison, Wis.; on a ground-level, open site at the University of Alaska, Fairbanks, Alaska; and on a ground-level site shaded by trees at the Naval Research Laboratory Tropical Exposure Site in the Panama Canal Zone. Two sites were used at the Panama Canal Zone location because of a change in the location of the main station. The first set of panels was exposed near Fort Sherman on Limon Bay, and the second and third sets were exposed at Galeta Point. The conditions at both locations are considered to be similar, and are one-fourth to one-half mile from the seashore. Nine unstressed panels bonded with each adhesive were also exposed on a ground-level, open site at New Mexico College of Agriculture and Mechanical Arts, State College, N. Mex., and nine were exposed on a roof 50 yards from the seashore by the South Florida Testing Service, Miami, Fla. Panels bonded with Bloomingdale PA-101 adhesive were exposed at all sites except Madison, Wis.

Both the stressed and unstressed panels were mounted on preservative-treated wood frames (Figs. 3 and 4) with the edge of the overlap on the exposed face parallel to the ground and facing downward. The unstressed specimens were mounted on aluminum-painted wood spacer blocks attached to the frames. The panels were exposed to the south at a 45-degree angle. These metal bonds had no paint coating to protect the metal or adhesive joint.

Panels for the first set of tests were exposed in April 1953; the second set, including panels bonded with Redux E and Metlbond 4021, was exposed in September 1954; and the third set including panels bonded with Epon 422J and Epon VIII was exposed in May 1955. Climatic data reported for the 5 test locations during the exposure period are given in Table 2.

Three unstressed panels and two stressed panels for each adhesive were removed after 3, 12, and 36 months of exposure. The panels bonded with Redux E, Metlbond 4021, Epon VIII, and Epon 422J are still in exposure for the 36-month period. All panels were cut (Fig. 1) into four 1-inch-wide specimens after exposure and tested.

RESULTS

The results of the lap-joint tests made on the adhesive bonds to aluminum after laboratory-controlled exposure and after exterior exposures for periods up to 3 years in various climatic conditions are given in Tables 3, 4, 5, 6, and 7.

Control Tests

The results of the average control tests (Tables 3 and 6, exposure A) for all end specimens cut from each of the bonded panels before exposure indicated that all panels included in these tests met the requirements of Military Specification MIL-A-5090B for joint strength at 72° to 76° F. (2,500 pounds per square inch), and the joint strength values were within the range normally obtained in similar tests by the adhesive manufacturer. A few extra panels were prepared with each adhesive, so that any panels in which bond quality was indicated to be substandard by the control tests were immediately eliminated from the tests.

To determine if there had been any deterioration during exposure (Tables 3, 4, 5, 6, and 7), the values for percentage of control strength after exposure were computed by using the average control test values obtained from the same panels exposed and tested after each of the test periods at the particular exposure condition indicated, rather than the average control test value for all panels bonded with the particular adhesive.

Laboratory Exposure Tests

There was a decided decrease in the strength of some bonds in certain of the laboratory exposure conditions. This was particularly true of both conditions (exposures B and C) that involved the use of 120° F. and 97 percent relative humidity. The Metlbond MN3C bonds deteriorated to about 10 percent of their original control strength in 6 months at continuous exposure to 120° F. (exposure B) and in 5 to 7 cycles of the cyclic condition (exposure C). The Epon VI bonds deteriorated to about 40 percent, and Epon VIII bonds to about 50 percent, of their original strength in these conditions. There were also significant strength reductions in bonds made with these 3 adhesives and exposed to the 30-day salt-water spray exposure. With Metlbond MN3C and Epon VI bonds, the deterioration in the 30-day salt spray was decidedly less than in the 6-month exposure at 120° F. and 97 percent relative humidity, or 5 to 7 cycles of exposure C. The Epon VIII bonds, however, failed completely in the 30-day salt-water spray as compared to a loss of strength of about 50 percent in exposures B and C.

The Metlbond MN3C bonds also showed a loss of strength of about 40 percent in 3 years' exposure, either stressed or unstressed, in the mild condition (exposure F) of 80° F. and 65 percent relative humidity. The Epon VIII bonds failed in the stressed condition in 12 months at this exposure but the unstressed bonds retained essentially all their initial strength.

The bonds made with the other 5 adhesives, Scotchweld Film 585, Bloomingdale FM-47 Adhesive, Redux E, type R, Metlbond 4021, and Epon 422J, and exposed to the various laboratory conditions showed good durability without any appreciable losses of strength during the period covered by these tests.

The continuous salt-water boil exposure for periods up to 6 hours caused no significant bond deteriorations in any of the adhesive-bonded panels, including those types of bonds which deteriorated appreciably in other laboratory and exterior exposure conditions.

Climatic Exterior Exposure Tests

The results of the exterior exposure tests (Tables 4, 5, and 7) showed generally good correlation between these tests and the laboratory exposure tests. The 5 adhesives that showed good performance in the laboratory exposure tests generally showed good performance in the climatic exposures. Only the Scotchweld 585 bonds showed an erratic behavior after 3 years' exposure at Florida, with some of the bonds having no strength, and others having essentially all their original strength, the average being 57 percent of the original strength. In general, these 5 adhesives represent types that have qualified under Military Specification MIL-A-5090B or similar specifications, while the other 4 adhesives that show deterioration in certain of the laboratory and exterior exposure tests have not been so qualified.

The exposures in Wisconsin, Alaska, and New Mexico were much less severe than those in Florida or the Canal Zone, and only the stressed Epon VIII specimens showed appreciable deterioration in these milder exterior exposure conditions at Madison and Alaska.

In the Panama Canal Zone exposure, bonds made with Metlbond MN3C Tape (stressed and unstressed), Epon VI (stressed), and Epon VIII (stressed and unstressed) generally showed appreciable deterioration after 1 year of exposure, averaging less than 30 percent of their control strength. The unstressed Epon VI bonds also deteriorated to a strength of 40 percent when exposed for 3 years at the Canal Zone.

The Metlbond MN3C bonds deteriorated somewhat, and the Epon VIII bonds failed completely after 1 year in Florida. The Metlbond MN3C bonds deteriorated much less than during 1 year in the Canal Zone. By the end of 3 years, however, the deterioration of adhesive bonds was greater in Florida than in the Canal Zone. After 3 years in Florida, unstressed bonds made with Metlbond MN3C, Epon VI, and Bloomingdale PA-101 averaged 15 percent or less of their original control strength, and Scotchweld 585 film specimens averaged 57 percent of their original strength. Bloomingdale FM-47 bonds were not affected.

In most instances, as the bonds deteriorated in joint strength there was an increase in the percentage of adhesion-to-metal failure, and corrosion occurred on the surface of the metal in the bond line.

In general, it appeared that the method of stressing the joint panel over a bending frame accelerated the deterioration for those adhesive bonds which were subject to deterioration. In many of the tests, however, there was not a significant loss of strength in either the stressed or unstressed joint panels.

Table 1.--Distribution of adhesive-bonded lap-joint aluminum panels in interior and exterior exposure tests[1]

Exposure	Total number of panels[2]	Stressed: Number of panels	Stressed: Exposure time	Unstressed: Number of panels	Unstressed: Exposure time
Interior					
80° F., 65 percent relative humidity[4]	10	[3]3	3 months	[3]3	3 months
		[3]3	12 months	[3]3	12 months
		5	36 months	5	36 months
120° F., 97 percent relative humidity[4]	9			3	3 months
				3	6 months
				3	36 months
Repeated cycles, 120° F., 97 percent relative humidity; 158° F., 20 percent relative humidity; 0° F.[4]	12			3	2 cycles
				3	5 cycles
				3	7 cycles
				3	10 cycles
Boiling salt water[4]	9			3	1 hour
				3	3 hours
				3	6 hours
Salt-water spray[4]	5			5	30 days
Exterior					
Madison[4]	15	2	3 months	3	3 months
		2	12 months	3	12 months
		2	36 months	3	36 months
Panama	15	2	3 months	3	3 months
		2	12 months	3	12 months
		2	36 months	3	36 months
Alaska	15	[4]2	3 months	3	3 months
		2	12 months	3	12 months
		2	36 months	3	36 months
New Mexico	9			3	3 months
				3	12 months
				3	36 months
Florida	9			3	3 months
				3	12 months
				3	36 months

[1]Two specimens, one from each end of all panels prepared, were tested for quality of bond before exposure.

[2]Total number of panels bonded with each adhesive, except as noted by footnotes 3 and 4.

[3]Additional test panels for 3 and 12 months' exposure at this condition were prepared with only the Epon VIII and Epon 422J adhesives.

[4]Panels bonded with Bloomingdale PA-101 were not exposed at this condition.

Table 2.--Weather data at the test sites[1] for the years 1953 through 1956

Month	Temperature: Average daily maximum	Temperature: Average daily minimum	Relative humidity: Average daily maximum	Relative humidity: Average daily minimum	Total precipitation	Average daily solar radiation[2]
	°F.	°F.	Percent	Percent	Inches	Langleys
			Fairbanks, Alaska			
1953						
April	50	22	75	34	0.00	641
May	65	36	82	34	1.00	470
June	74	47	87	41	2.70	504
July	74	45	94	42	1.33	475
August	67	40	96	50	2.97	338
September	56	32	96	53	1.32	340
October	35	13	85	52	.25	212
November	10	6	76	55	.20	87
December	5	-9	77	62	.13	17
1954						
January	-5	-26	74	54	.55	58
February	-3	-30	75	48	.19	244
March	29	-2	78	48	.60	567
April	40	13	73	37	.00	848
May	65	34	78	25	.17	445
June	71	45	86	37	1.78	500
July	69	46	92	48	3.22	431
August	67	45	95	51	.84	423
September	54	30	94	49	1.82	308
October	41	21	90	55	.08	206
November	20	4	88	71	.42	75
December	-15	-31	79	59	.49	18
1955						
January	8	-10	86	69	.49	43
February	-23	-12	74	51	.60	161
March	29	-2	83	52	.52	395
April	37	10	81	43	.20	575
May	58	34	85	40	1.67	532
June	67	42	89	43	3.52	506
July	74	47	92	44	2.51	548
August	64	43	94	54	1.90	409
September	54	34	97	59	1.45	254
October	32	16	92	69	.94	107
November	-2	-16	81	64	.21	94
December	-1	-18	79	54	1.83	12
1956						
January	-13	-29	70	48	.43	53
February	1	-19	74	52	.99	128
March	25	-7	79	45	.15	428
April	46	19	78	41	.12	602
May	60	35	80	36	.61	516

Table 2.--Weather data at the test sites[1] for the years 1953 through 1956 (continued)

Month	Temperature		Relative humidity		Total precipitation	Average daily solar radiation[2]
	Average daily maximum	Average daily minimum	Average daily maximum	Average daily minimum		
	°F.	°F.	Percent	Percent	Inches	Langleys
Madison, Wisconsin						
1953						
April	52	34	86	45	3.12	351
May	70	46	86	45	1.02	482
June	83	58	88	45	5.15	586
July	85	61	90	42	4.28	523
August	86	59	90	43	3.49	504
September	76	49	87	36	2.11	442
October	69	42	87	40	1.81	291
November	50	31	84	50	.52	171
December	35	20	87	63	2.17	117
1954						
January	30	10	83	56	.76	152
February	41	24	86	53	.63	203
March	41	22	80	42	1.19	323
April	61	38	85	46	4.09	380
May	65	42	84	42	2.98	511
June	83	59	89	48	7.36	548
July	85	61	91	48	5.73	514
August	81	57	95	51	2.78	476
September	74	52	92	52	3.82	331
October	60	41	90	53	3.72	211
November	47	29	91	59	.81	123
December	32	16	89	69	1.20	107
1955						
January	27	11	82	60	.65	153
February	30	11	78	64	1.67	226
March	41	21	84	49	.96	384
April	65	41	83	43	3.65	432
May	73	48	87	40	2.10	542
June	77	54	85	49	2.78	523
July	91	65	91	44	3.93	567
August	89	63	88	39	1.55	512
September	77	49	87	36	.80	410
October	62	41	91	49	3.24	243
November	41	22	89	54	.57	151
December	28	12	84	57	.59	121
1956						
January	31	12	87	62	.43	159
February	33	12	86	55	1.00	259
March	39	21	89	54	2.53	340
April	55	32	86	38	3.54	403
May	68	46	89	46	5.11	439

Table 2.--Weather data at the test sites[1] for the years 1953 through 1956 (continued)

Month	Temperature: Average daily maximum	Temperature: Average daily minimum	Relative humidity: Average daily maximum	Relative humidity: Average daily minimum	Total precipitation	Average daily solar radiation[2]
	°F.	°F.	Percent	Percent	Inches	Langleys
			Panama Canal Zone[3]			
1953						
April	...	...	...	...	...	...
May	...	...	...	...	...	...
June	...	...	...	...	...	...
July	...	...	...	...	...	...
August	...	...	...	...	...	...
September	...	...	...	...	...	...
October	...	...	...	...	...	...
November	...	...	...	...	...	...
December	...	...	...	...	...	...
1954						
January	...	...	...	...	...	...
February	...	...	...	...	...	...
March	...	...	...	...	...	...
April	...	...	...	...	...	...
May	...	...	...	...	...	...
June	...	...	...	...	...	...
July	...	...	...	...	...	...
August	...	...	...	...	...	...
September	...	...	...	...	...	...
October	...	...	...	...	...	...
November	...	...	...	...	...	...
December	...	...	...	...	...	...
1955						
January	84	76	93	65	10.76	...
February	85	78	93	64	1.48	...
March	85	78	87	62	1.34	...
April	87	78	90	59	1.00	...
May	86	78	96	67	14.29	...
June	86	77	95	62	12.88	...
July	86	77	92	64	11.96	...
August	86	76	96	67	12.69	...
September	87	77	95	61	6.66	...
October	87	77	99	63	8.67	...
November	84	77	95	70	28.10	...
December	85	76	96	70	13.79	...
1956						
January	83	76	94	69	11.05	...
February	85	78	91	67	.91	...
March	86	79	89	61	3.78	...
April	87	80	91	63	2.60	...
May	...	...	...	...	...	...

Table 2.--Weather data at the test sites[1] for the years 1953 through 1956 (continued)

Month	Temperature		Relative humidity		Total precipitation	Average daily solar radiation[2]
	Average daily maximum	Average daily minimum	Average daily maximum	Average daily minimum		
	°F.	°F.	Percent	Percent	Inches	Langleys
			Miami, Florida			
1953						
April	84	68	96	61	5.51	486
May	88	74	95	64	3.83	474
June	89	76	98	67	5.93	361
July	90	76	98	68	8.20	412
August	91	78	97	66	6.22	404
September	90	77	98	72	12.30	390
October	83	70	99	67	12.33	398
November	80	66	98	68	2.97	402
December	78	63	97	67	2.34	462
1954						
January	78	61	96	61	.56	489
February	78	58	97	55	2.88	521
March	78	61	96	60	1.66	517
April	84	70	98	67	5.55	411
May	88	72	97	63	11.96	368
June	89	75	99	68	7.65	291
July	91	77	97	68	9.40	313
August	94	78	96	63	1.64	417
September	90	77	97	71	5.97	430
October	84	71	94	67	5.20	458
November	80	62	96	61	3.07	511
December	75	54	96	57	.08	539
1955						
January	77	54	95	55	.43	516
February	76	60	93	62	.41	406
March	81	64	95	63	.39	513
April	84	68	93	59	2.83	492
May	88	71	94	62	2.71	430
June	88	75	94	69	10.60	337
July	88	76	97	71	8.76	334
August	89	74	87	58	6.20	413
September	87	74	92	61	5.09	463
October	82	68	90	57	4.67	494
November	80	63	88	54	.83	517
December	76	61	89	56	2.09	410
1956						
January	71	52	89	49	1.50	551
February	77	64	88	58	.84	536
March	77	59	89	50	.00	575
April	79	64	86	50	3.37	486
May	83	70	87	58	3.21	422

Table 2.--Weather data at the test sites[1] for the years 1953 through 1956 (continued)

Month	Temperature		Relative humidity		Total precipitation	Average daily solar radiation[2]
	Average daily maximum	Average daily minimum	Average daily maximum	Average daily minimum		
	°F.	°F.	Percent	Percent	Inches	Langleys
State College, New Mexico						
1953						
April	78	44	56	19	0.03	635
May	86	47	59	27	.00	594
June	103	63	61	30	.34	591
July	101	67	83	32	1.24	556
August	100	65	77	30	.40	784
September	94	55	63	26	.00	681
October	78	43	76	39	.75	631
November	65	33	82	36	.00	643
December	47	20	90	43	.07	579
1954						
January	58	27	82	34	.19	562
February	65	30	64	27	.32	667
March	66	36	58	23	.17	590
April	84	48	52	21	.00	617
May	89	53	61	26	.88	594
June	98	61	50	19	.33	570
July	97	63	64	21	.83	541
August	98	64	76	30	1.14	614
September	92	61	61	33	1.26	685
October	78	48	61	24	1.24	689
November	66	19	46	30	.00	703
December	55	25	29	14	.00	613
1955						
January	48	25	48	27	.73	560
February	55	22	36	9	.00	717
March	67	35	32	13	.41	659
April	77	42	21	9	.00	....
May	85	50	37	11	.15	632
June	96	58	31	12	.08	619
July	93	64	61	26	3.42	506
August	95	61	64	25	.55	532
September	92	56	50	20	.01	638
October	81	48	53	32	.00	613
November	69	35	46	32	.00	600
December	64	32	51	35	.00	533
1956						
January	64	33	51	36	.20	489
February	55	24	42	18	1.04	....
March	71	32	14	5	.00	647
April	74	37	26	10	.02	628
May	90	50	25	12	.00	608

[1]Weather data for the test site as reported by the U. S. Weather Bureau or test-site personnel.

[2]Average daily radiation readings in Langleys or gram-calories per square centimeter on a 45-degree surface facing south.

[3]Weather data for this site were not obtained for the initial part of the exposures. Solar radiation data were not available. Exposure at this site, however, was in a shaded location.

Table 3.--Results of shear tests on 1/2-inch lap joints of 0.064-inch clad 2024-T3 aluminum alloy bonded with Metlbond MN3C Tape, Epon VI, Scotchweld Bonding Film 585, and Bloomingdale FM-47 before and after various laboratory exposure conditions

Exposure	Test results for -- [1]																			
	Metlbond MN3C Nylon Tape					Epon VI					Scotchweld Bonding Film 585					Bloomingdale FM-47				
	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure
	Average	Minimum	Maximum	Percent of control strength[2]		Average	Minimum	Maximum	Percent of control strength[2]		Average	Minimum	Maximum	Percent of control strength[2]		Average	Minimum	Maximum	Percent of control strength[2]	
	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent
A. Original control tests - 108 panels	2,820	2,500	3,457	....	76	3,976	3,218	4,715	....	99	3,405	2,910	3,880	....	68	4,976	4,320	5,600	....	57
B. 120° F. and 97 percent relative humidity																				
3 months	1,880	1,500	2,370	69	45	3,295	2,520	3,970	80	98	3,795	3,300	4,050	109	55	4,435	4,090	4,700	93	58
6 months	334	85	780	12	[3]16	1,685	310	3,117	41	[3]51	3,990	3,489	4,234	116	54	5,012	4,000	5,400	99	56
36 months	24	0	90	1	[3]0	50	0	310	1	[3]0	3,643	3,060	3,960	109	16	4,452	3,540	4,940	91	52
C. Cyclic - 120° F. and 97 percent relative humidity, 158° F. and 20 percent relative humidity, and 0° F.																				
2 cycles (10 weeks)	1,513	320	2,590	53	44	3,422	2,830	4,420	89	95	4,183	3,820	4,600	120	53	4,668	3,640	5,220	92	63
5 cycles (25 weeks)	364	98	754	13	[3]23	2,288	490	3,500	57	[3]66	4,502	4,260	4,770	130	56	4,826	4,205	5,191	100	72
7 cycles (35 weeks)	176	0	570	6	[3]0	1,443	540	2,788	36	[3]45	4,506	4,100	4,830	137	49	4,492	4,100	4,890	90	69
10 cycles (50 weeks)	0	0	0	0	[3]0	2,498	135	3,317	64	[3]60	4,744	4,600	4,960	135	56	4,295	3,840	4,740	87	51
D. Salt-water boil																				
1 hour	2,730	2,600	3,030	96	74	3,856	3,410	4,340	98	99	3,457	3,090	3,790	100	42	4,938	4,120	5,260	98	69
3 hours	2,698	2,340	2,990	94	72	3,848	3,650	4,120	97	98	3,490	3,030	3,750	103	49	5,081	4,840	5,280	99	70
6 hours	2,705	2,250	2,950	95	81	3,645	3,020	4,150	95	98	3,747	3,590	3,860	111	50	5,195	4,880	5,760	104	53
E. Salt-water spray 30 days	1,519	120	2,733	58	[3]33	2,704	766	3,961	68	[3]77	2,974	1,952	3,810	88	[3]48	[4]5,363	4,738	5,772	107	54
F. 80° F. and 65 percent relative humidity																				
36 months - stressed	1,658	677	2,770	58	[3]29	3,602	3,030	4,075	88	97	4,130	3,610	4,444	124	60	5,002	4,560	5,560	106	56
36 months - unstressed	1,721	470	2,500	61	[3]33	3,594	3,200	4,100	90	100	4,133	3,816	4,460	120	72	5,299	4,850	5,600	106	58

[1]The average test results given are based on 216 specimens (1 specimen from each end of 108 test panels) for the control tests; 12 specimens (4 specimens from each of 3 test panels) for tests B, C, and D; and 20 specimens (4 specimens from each of 5 test panels) for tests E and F.

[2]The values for percent of control strength were computed on the basis of the average original control test values obtained on the end specimens from the same panels exposed and tested at the particular exposure condition.

[3]Some evidence of corrosion of the metal was noted in the bond lines.

[4]An average value for only 15 test specimens, as the other test specimens in this group were tested before the machine was properly adjusted.

Table 4.--Results of shear tests on 1/2-inch lap joints of 0.064-inch clad 2024-T3 aluminum alloy bonded with Metlbond MN3C Tape, Epon VI, and Scotchweld Bonding Film 585, after weathering in various climates

Exterior exposure	Test results for -- [1]														
	Metlbond MN3C Nylon Tape					Epon VI					Scotchweld Bonding Film 585				
	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure
	Average	Minimum	Maximum	Percent of control strength[2]		Average	Minimum	Maximum	Percent of control strength[2]		Average	Minimum	Maximum	Percent of control strength[2]	
	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent
Madison, Wis.															
3 months - stressed	2,232	2,052	2,500	83	65	3,628	3,259	3,910	90	98	3,753	3,560	3,900	110	53
3 months - unstressed	2,581	2,320	3,110	89	71	3,522	3,125	4,038	93	99	3,681	3,150	4,060	110	34
12 months - stressed	2,542	2,360	2,740	91	92	3,510	2,808	4,232	83	100	2,742	2,376	3,176	81	52
12 months - unstressed	2,668	2,280	2,896	95	77	3,841	3,488	4,340	96	100	3,779	3,544	3,980	113	60
36 months - stressed	2,353	2,239	2,420	87	[2]78	1,258	0	2,980	32	[2]46	2,391	1,320	3,150	69	[3]48
36 months - unstressed	3,103	2,635	3,355	106	84	3,194	2,840	3,615	79	99	4,321	4,130	4,480	130	52
Panama Canal Zone															
3 months - stressed	1,457	882	1,800	57	[3]17	[4]3,630	3,550	3,730	91	96	3,068	2,916	3,322	92	64
3 months - unstressed	1,947	990	2,625	70	[3]49	3,148	2,682	3,520	79	92	3,431	3,140	3,875	100	64
12 months - stressed	0	0	0	0	[3]0	515	0	1,680	13	[3]16	3,476	3,232	3,616	97	49
12 months - unstressed	723	180	1,652	28	[3]13	3,248	2,528	3,640	78	86	3,340	2,024	3,888	100	53
36 months - stressed	815	0	1,860	28	[3]13	0	0	0	0	[3]0	2,991	2,750	3,448	89	47
36 months - unstressed	552	0	1,336	19	[3]3	1,621	0	2,615	40	55	3,905	3,390	4,160	114	43
Fairbanks, Alaska															
3 months - stressed	2,779	2,673	2,895	100	59	3,734	3,333	4,086	91	100	3,544	2,950	4,239	110	61
3 months - unstressed	2,882	2,520	3,177	103	69	3,641	3,317	3,894	94	100	3,883	3,680	4,170	110	63
12 months - stressed	2,797	2,530	2,980	101	78	3,529	2,240	4,040	90	93	3,172	2,970	3,460	93	55
12 months - unstressed	2,598	1,860	3,100	92	82	3,458	3,180	3,800	86	99	3,743	3,630	3,860	111	48
36 months - stressed	2,047	1,393	2,430	69	[3]63	3,206	1,740	3,836	81	99	2,966	2,900	3,030	86	54
36 months - unstressed	1,786	590	2,850	68	[3]62	3,527	3,270	3,910	89	99	3,656	3,380	3,980	107	67
New Mexico															
3 months - unstressed	2,588	2,330	2,958	92	77	4,008	3,622	4,460	100	100	3,610	3,230	4,030	105	67
12 months - unstressed	2,660	2,360	3,128	90	73	3,601	3,384	4,148	92	100	3,995	3,720	4,288	117	62
36 months - unstressed	3,004	2,750	3,531	100	85	3,384	3,250	3,580	86	100	4,470	4,187	4,645	133	58
Florida															
3 months - unstressed	2,621	2,197	3,063	89	59	3,292	3,105	3,500	87	100	3,540	3,187	3,900	105	76
12 months - unstressed	2,119	924	2,724	73	[3]54	3,007	1,324	3,580	76	[3]88	3,650	1,008	4,176	106	[3]55
36 months - unstressed	0	0	0	0	[3]0	591	0	3,360	15	[3]22	1,910	0	4,310	57	[3]27

[1] The average results given are for 8 specimens (4 specimens from each of 2 panels) for the stressed test conditions and for 12 specimens (4 specimens from each of 3 panels) for the unstressed test conditions, except where otherwise noted.

[2] The values for the percent of control strength were computed on the basis of the average original control test values obtained on the end specimens from the same panels exposed and tested at the particular exposure condition.

[3] Some evidence of corrosion of metal was noted in the bond lines.

[4] Test result for only 1 panel as other test panel for this group was damaged and failed before test.

Table 5.--Results of shear tests on 1/2-inch lap joints of 0.064-inch clad 2024-T3 aluminum alloy bonded with Bloomingdale FM-47 and Bloomingdale PA-101 adhesives, after weathering in various climates

Exterior exposure	Test results for -- [1]									
	Bloomingdale FM-47					Bloomingdale PA-101				
	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure
	Average	Minimum	Maximum	Percent of control strength[2]		Average	Minimum	Maximum	Percent of control strength[2]	
	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent
Madison, Wis.										
3 months - stressed	4,383	3,173	4,885	87	53	.....	.....	.....	.....	.....
3 months - unstressed	4,690	3,721	5,028	95	50	.....	.....	.....	.....	.....
12 months - stressed	4,325	3,860	4,720	88	59	.....	.....	.....	.....	.....
12 months - unstressed	4,934	4,720	5,200	103	43	.....	.....	.....	.....	.....
36 months - stressed	4,283	3,790	4,680	84	65	.....	.....	.....	.....	.....
36 months - unstressed	5,011	4,885	5,210	98	67	.....	.....	.....	.....	.....
Panama Canal Zone										
3 months - stressed	4,802	4,150	5,120	95	70	3,259	2,541	3,627	87	76
3 months - unstressed	5,677	5,019	5,980	114	57	3,843	3,395	4,208	98	93
12 months - stressed	4,291	3,120	4,730	89	69	3,122	2,572	3,928	86	70
12 months - unstressed	5,002	4,452	5,310	100	72	3,644	2,344	4,064	95	78
36 months - stressed	4,232	3,562	4,610	85	78	3,643	3,436	3,860	92	85
36 months - unstressed	4,552	3,700	4,970	94	70	3,807	3,550	4,062	102	85
Fairbanks, Alaska										
3 months - stressed	[4]4,987	4,680	5,320	97	61	.....	.....	.....	.....	.....
3 months - unstressed	5,406	5,093	5,660	102	66	3,724	3,416	4,180	102	89
12 months - stressed	4,633	4,150	5,050	96	58	3,602	3,260	4,030	96	85
12 months - unstressed	5,241	5,000	5,580	100	68	4,081	3,620	4,500	106	91
36 months - stressed	[4]4,910	4,840	4,950	97	70	3,386	3,240	3,540	89	87
36 months - unstressed	4,891	4,740	5,040	105	53	3,827	3,310	4,250	99	91
New Mexico										
3 months - unstressed	5,212	4,850	5,490	107	50	3,757	3,250	4,130	101	91
12 months - unstressed	4,967	4,650	5,380	100	56	3,620	2,990	4,072	94	77
36 months - unstressed	5,097	4,940	5,160	97	70	4,409	3,872	4,770	110	88
Florida										
3 months - unstressed	5,423	4,920	6,041	115	54	3,768	2,790	4,425	96	85
12 months - unstressed	5,480	5,260	5,680	102	60	3,880	2,820	4,216	95	[3]89
36 months - unstressed	5,151	4,970	5,330	100	71	247	0	2,500	6	[3]8

[1] The average results given are for 8 specimens (4 specimens from each of 2 panels) for the stressed test conditions and for 12 specimens (4 specimens from each of 3 panels) for the unstressed test conditions, except where otherwise noted.

[2] The values for the percent of control strength were computed on the basis of the average original control test values obtained on the end specimens from the same panels exposed and tested at the particular exposure condition.

[3] Some evidence of corrosion of the metal was noted in the bond lines.

[4] Test result for only 1 panel as other test panel for this group was damaged and failed before test.

Table 6.--Results of shear tests on 1/2-inch lap joints of 0.064-inch clad 2024-T3 aluminum alloy bonded with Redux E, type R, Metlbond 4021, Epon VIII, and Epon 422J adhesives, before and after various laboratory exposure conditions

Exposure	Test results for -- [1]																			
	Redux E, type R					Metlbond 4021					Epon VIII					Epon 422J				
	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure
	Average	Minimum	Maximum	Percent of control[2]		Average	Minimum	Maximum	Percent of control[2]		Average	Minimum	Maximum	Percent of control[2]		Average	Minimum	Maximum	Percent of control[2]	
	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent
A. Original control tests	3,384	2,940	3,773	....	33	4,103	3,560	4,630	....	46	3,444	3,052	3,934	....	96	2,913	2,534	3,230	....	97
B. 120° F. and 97 percent relative humidity																				
3 months	3,067	2,500	3,566	92	18	3,781	3,270	4,410	91	46	2,165	1,870	2,760	61	38	2,421	2,040	2,730	88	81
6 months	3,353	3,000	3,711	99	71	3,027	1,940	3,660	76	52	1,766	1,480	2,090	53	20	2,540	2,450	2,630	93	86
C. Cyclic--120° F. and 97 percent relative humidity; 158° F. and 20 percent relative humidity; and 0° F.																				
2 cycles (10 weeks)	2,965	2,604	3,191	95	29	4,695	4,421	5,117	111	75	2,366	2,070	2,710	71	72	2,670	2,420	2,870	91	97
5 cycles (15 weeks)	3,048	2,673	3,456	92	48	4,289	3,730	4,557	106	58	1,824	1,400	2,403	54	45	2,522	2,137	2,780	88	77
7 cycles (35 weeks)	3,210	2,980	3,411	94	68	4,382	3,290	4,880	108	70	1,647	380	2,320	48	29	2,515	2,310	2,770	84	92
10 cycles (50 weeks)	2,926	2,640	3,055	86	40	3,975	3,600	4,240	101	51	1,879	1,250	2,130	54	64	2,267	2,100	2,480	81	79
D. Salt-water boil																				
1 hour	3,271	2,936	3,542	96	24	3,715	3,018	4,355	95	42	3,183	2,872	3,510	92	99	2,729	2,539	2,938	94	100
3 hours	3,138	2,954	3,418	97	15	4,218	3,740	4,430	97	54	2,834	2,558	3,269	87	95	2,644	2,480	2,820	91	97
6 hours	3,385	2,833	3,611	99	24	3,920	3,196	4,520	95	50	3,128	2,777	3,500	89	100	2,734	2,530	2,921	90	100
E. Salt-water spray																				
30 days	3,180	2,680	3,402	94	53	3,615	1,608	4,269	89	44	0	0	0	0	[3]0	2,771	2,454	3,098	92	100
F. 80° F. and 65 percent relative humidity																				
3 months--stressed	......	......	......	......	......	......	......	......	......	......	3,381	2,900	3,840	100	96	2,870	2,680	3,120	102	100
--unstressed	......	......	......	......	......	......	......	......	......	......	[4]3,037	1,320	4,120	91	69	2,968	2,680	3,180	102	100
12 months--stressed	......	......	......	......	......	......	......	......	......	......	0	0	0	0	10	2,515	2,290	2,760	89	96
--unstressed	......	......	......	......	......	......	......	......	......	......	3,963	3,530	4,350	107	98	2,840	2,470	3,050	96	95

[1]The average test results given for the control tests (A) are for 216 to 240 specimens (1 specimen from each end of 108 to 120 test panels); results for B, C, D, and F are based on 12 specimens (4 specimens from each of 3 test panels); results for E are based on 20 specimens (4 specimens from each of 5 test panels).

[2]The values for the percent of control strength are based on the average original control test values obtained on the end specimens from the same panels exposed and tested at the particular exposure condition.

[3]Some evidence of corrosion of the metal was noted in the bond lines.

[4]One of the 3 test panels showed low strength, which lowered the overall average.

Table 7.--Results of shear tests on adhesive-bonded 1/2-inch lap joints of 0.064-inch clad 2024-T3 aluminum (second and third series) after weathering in various climates

Exterior exposure	Test results for -- [1]																			
	Redux E, type R					Metlbond 4021					Epon VIII					Epon 422J				
	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure	Shear strength				Average cohesion failure
	Average	Minimum	Maximum	Percent of control[2]		Average	Minimum	Maximum	Percent of control[2]		Average	Minimum	Maximum	Percent of control[2]		Average	Minimum	Maximum	Percent of control[2]	
	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent	P.s.i.	P.s.i.	P.s.i.		Percent
Madison, Wis.																				
3 months--stressed	3,257	3,041	3,396	104	62	3,590	3,056	4,060	92	42	[3]0	0	0	0	10	2,893	2,700	2,980	104	97
--unstressed	3,332	3,150	4,000	102	41	3,995	3,577	4,451	97	68	3,046	2,380	3,910	87	95	2,752	2,250	3,100	95	95
12 months--stressed	3,959	3,728	4,063	106	88	4,277	3,900	4,570	98	53	[4]1,362	0	3,290	42	38	2,867	2,760	3,020	96	100
--unstressed	3,715	2,925	4,333	105	61	4,553	4,400	4,690	106	82	2,475	1,960	3,380	67	79	2,930	2,580	3 140	99	95
Panama Canal Zone																				
3 months--stressed	3,015	2,560	3,311	94	32	4,076	3,630	4,360	96	47	0	0	0	0	10	2,583	2,360	2,803	97	92
--unstressed	2,841	2,270	3,382	85	38	4,472	4,160	4,700	104	75	495	0	2,000	14	13	2,910	2,711	3,080	101	98
12 months--stressed	3,395	2,966	3,888	96	58	4,108	3,560	4,519	95	71	[3]0	0	0	0	10	2,622	2,530	2,750	97	95
--unstressed	3,083	2,946	3,255	87	67	4,167	3,637	4,630	103	53	[5]0	0	0	0	10	2,665	2,470	2,960	90	84
Fairbanks, Alaska																				
3 months--stressed	3,361	3,193	3,572	105	47	3,868	3,288	4,259	94	73	[6]1,218	0	2,620	37	33	2,918	2,850	3,010	98	100
--unstressed	3,365	3,141	3,553	101	50	3,920	3,313	4,390	99	63	2,705	1,750	3,420	80	74	2,931	2,510	3,150	102	100
12 months--stressed	3,521	3,434	3,617	108	54	3,832	3,530	4,192	98	40	[4]1,496	0	3,160	43	54	2,645	2,460	2,690	93	95
--unstressed	3,236	2,946	3,576	96	23	4,229	3,673	4,570	104	63	2,925	2,080	3,690	83	92	2,733	2,260	2,980	93	93
New Mexico																				
3 months--unstressed	3,299	3,020	3,733	90	52	4,310	4,088	4,500	105	70	3,195	2,140	3,870	89	87	3,033	2,890	3,180	103	100
12 months--unstressed	3,119	2,480	3,583	93	41	4,466	4,182	4,781	106	72	[7]3,204	2,980	3,430	91	99	[8]2,870	2,120	3,100	98	99
Florida																				
3 months--unstressed	3,542	3,250	3,891	98	61	4,040	3,700	4,420	105	52	2,462	1,680	2,840	72	89	2,685	2,560	2,800	94	99
12 months--unstressed	2,495	[illegible]	3,372	74	29	3,835	1,060	4,710	96	68	[8]0	0	0	0	[9]10	2,830	2,560	2,990	94	98

[1] The average results given are for 8 specimens (4 specimens from each of 2 panels) for the stressed test conditions and for 12 specimens (4 specimens from each of 3 panels) for the unstressed test conditions.

[2] The values for the percent of control strength are based on the average original control test values obtained on end specimens from the same panels exposed and tested at the particular exposure condition.

[3] Both of the stressed test panels failed in less than 1 month of exposure.

[4] One of the stressed test panels failed in less than 3 months of exposure.

[5] The 3 unstressed panels failed in less than 3 months of exposure.

[6] One of the stressed test panels failed in less than 1 month of exposure.

[7] Panels tested by mistake after 3 months of exposure.

[8] Two of the unstressed panels failed in 8 months, and the third panel failed prior to 12-month inspection.

[9] Some evidence of corrosion of the metal was noted in the bond line.

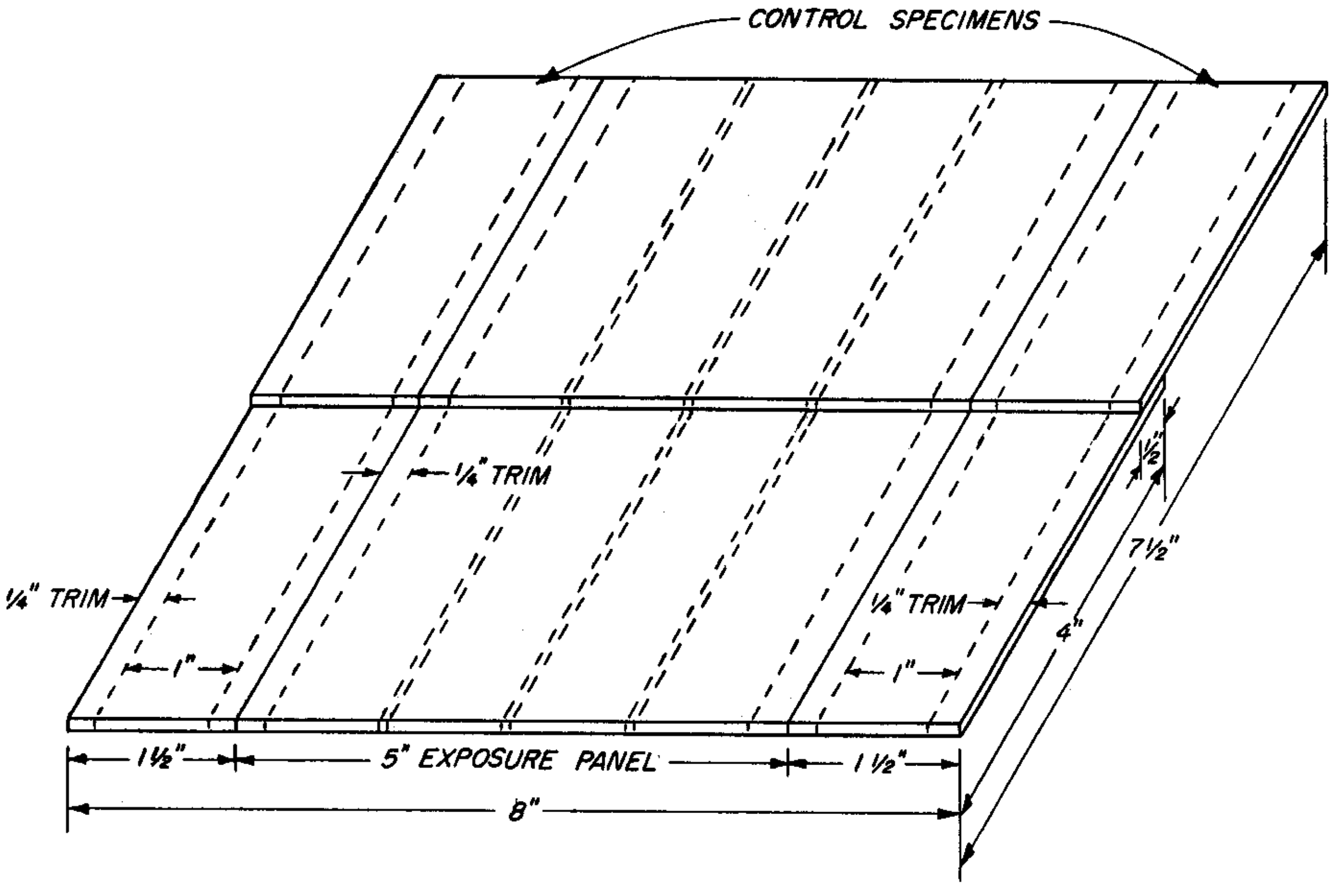

Figure 1. --Method of cutting lap-joint specimens of 0.064-inch clad 2024-T3 aluminum alloy for control testing and exposure.

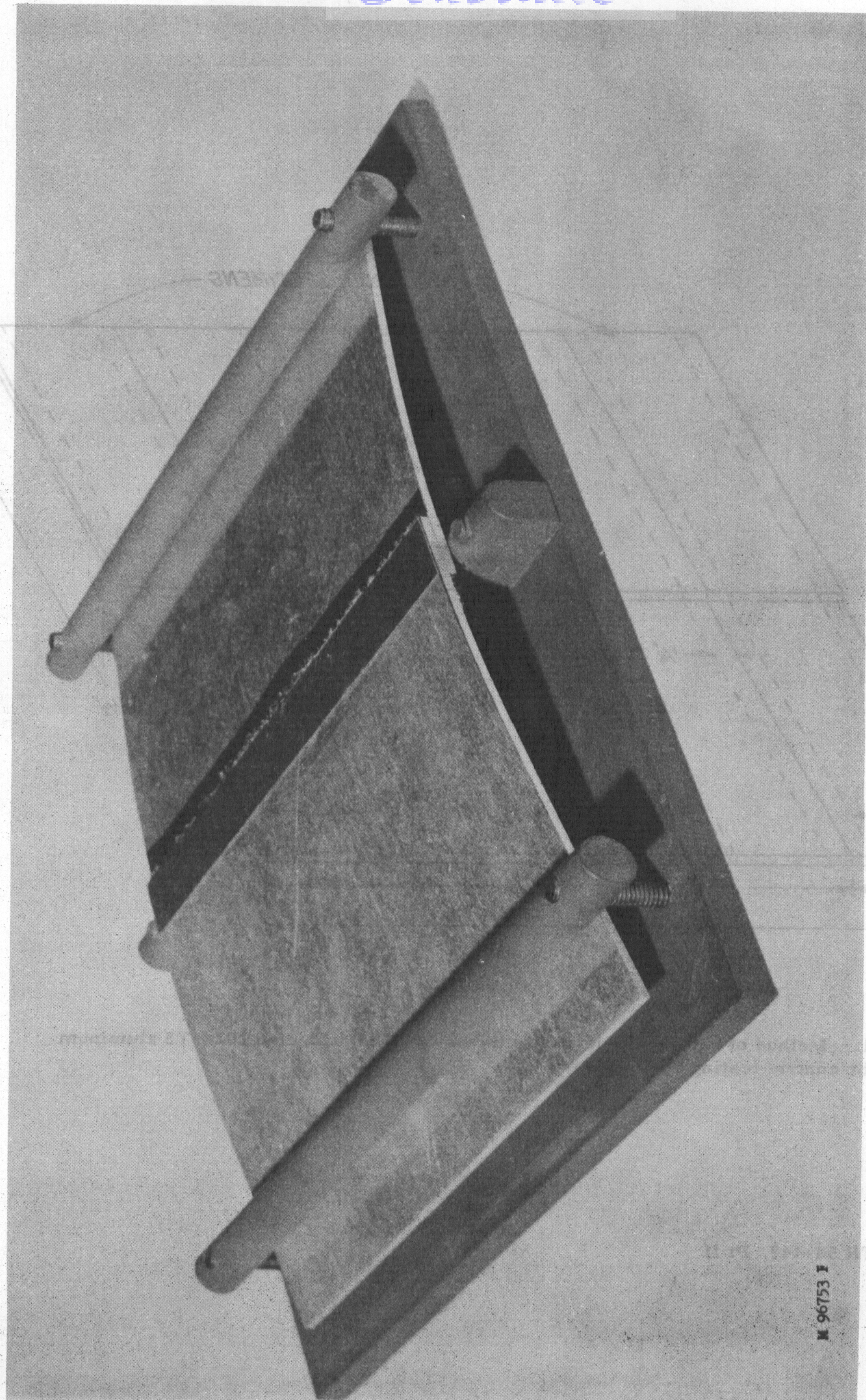

Figure 2. --Method of stressing aluminum lap-joint panels in bending to a 0.25-inch deflection over a 6-inch span by means of steel bending frames (zinc-chromate primed).

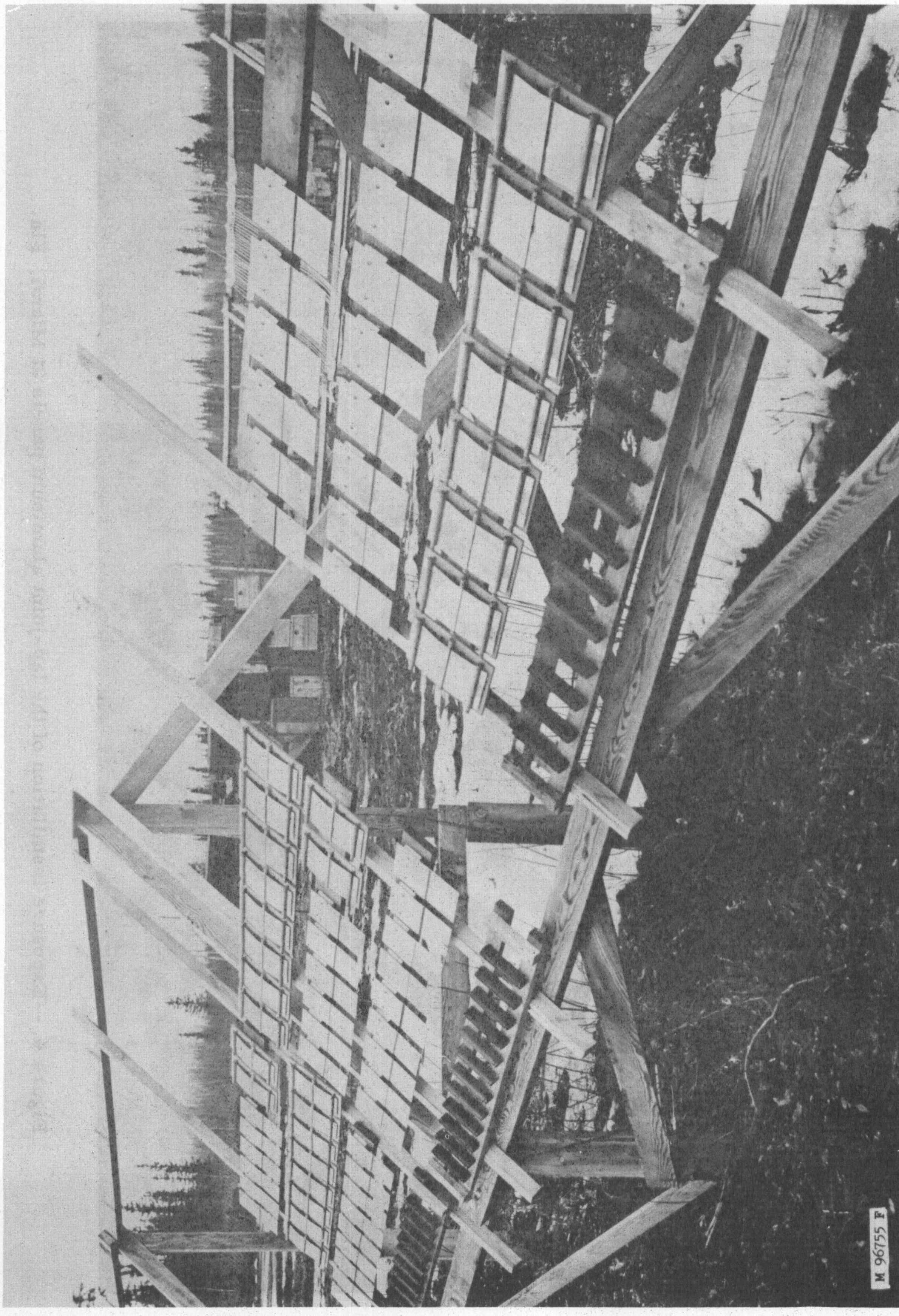

Figure 3. --Exposure installation of the lap-joint aluminum panels at Fairbanks, Alaska.

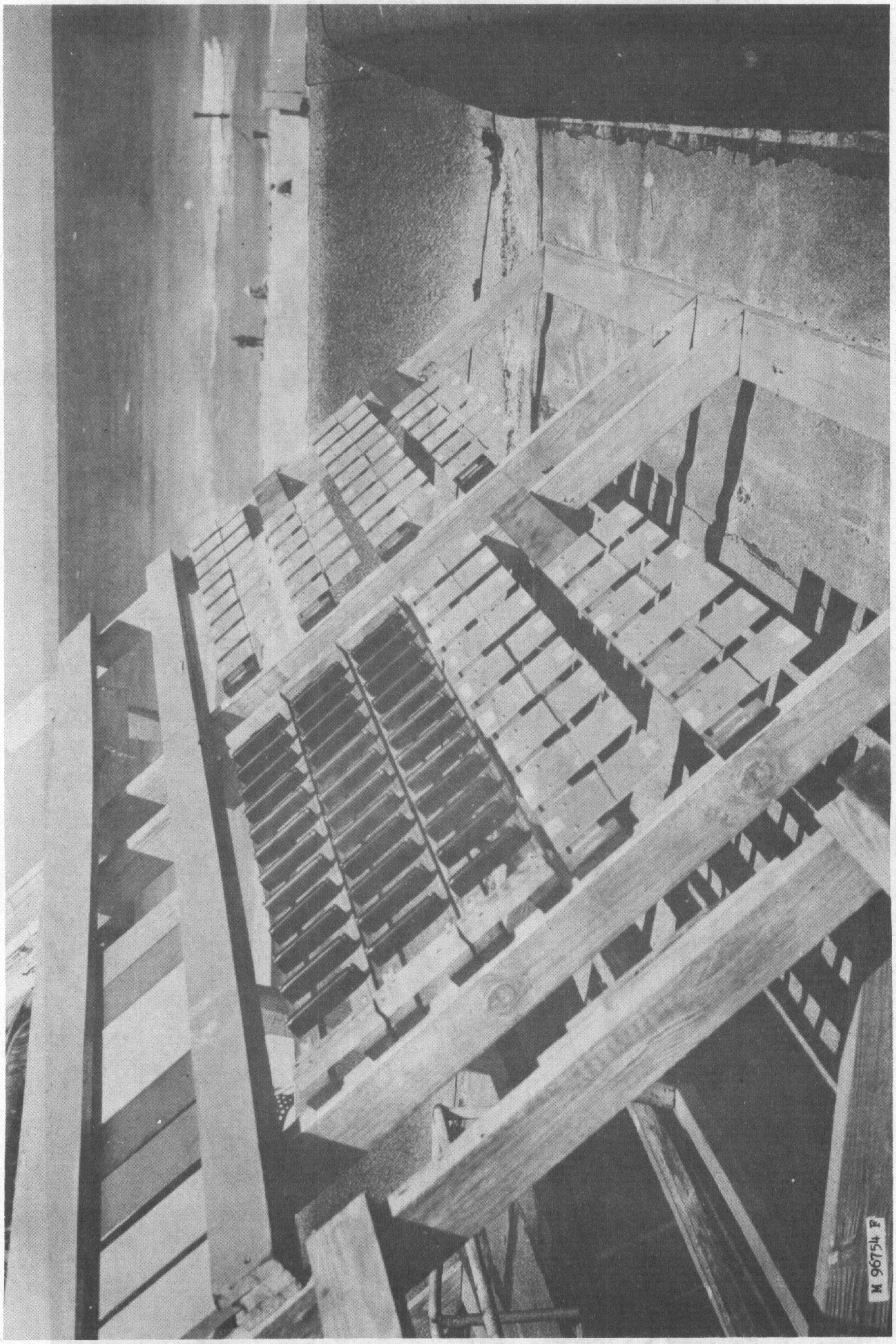

Figure 4. --Exposure installation of the lap-joint aluminum panels at Miami, Fla.