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The Increase In Fire-Resistance Provided By Fire-Retardant Coating On Aluminum And Magnesium Sheet

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by

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THE INCREASE IN FIRE-RESISTANCE PROVIDED BY FIRE-RETARDANT COATINGS ON ALUMINUM AND MAGNESIUM SHEET

SUMMARY

Equipment and a test procedure were developed for determining the increase in fire-resistance provided to aluminum and magnesium alloy sheet materials by fire-retardant coatings. The equipment and procedure were used for conducting tests of Albi 99 and Albi 107 fire-retardant coatings and of Midland 7X2039 heat-resistant paint. The effectiveness of Albi Top Koter and Albi Top Koter M when applied to Albi 99 and Albi 107 also was evaluated. Aluminum and magnesium panels, 12 inches square, were found to be of a convenient size for application and evaluation of the coatings; however, several 24-inch-square aluminum panels coated with Albi fire-retardant coatings also were fire-tested in order to determine the effect of larger panels. The coated panels were tested by exposure to a 2,000° F. flame produced by a torch used previously for conducting fire-resistance tests of firewall and other materials. The time required for the test panels to reach temperatures of 500° and 600° F. was used as a measure of the increase in fire-resistance provided by the protective coatings, since the strength of aluminum and magnesium sheets is reduced at temperatures in that range. However, the tests were continued beyond that time, and until the metal softened to the extent that one of the thermocouple probes pushed through the panel, thus breaking contact.

The results indicate that the Albi fire-retardant coatings increased the fire-resistance of the test panels to some degree, although all of the coated tests panels, with the exception of two, reached a temperature of 600° F. in less than one minute. Accordingly, it is recommended that materials such as aluminum and magnesium protected by the coatings tested should not be used to replace stainless steel or other materials in the engine compartment structure of aircraft where the use of fireproof materials is recommended.

INTRODUCTION

Fire-retardant coatings are being used presently to increase the fire-resistance of engine compartment structures in helicopters. The use of such coatings is based on the results of fire tests in which coated panels were subjected to moderately severe fires. A need existed for information on the degree of increase in fire-resistance that can be provided by such coatings when the coated panels are exposed to a fire similar in severity to those which occur in aircraft engine compartments during flight. Such a fire was supplied by a fire testing torch developed and used at the CAA Technical Development Center for several years. Other equipment was developed and test procedures were established in order that laboratory tests could be conducted on presently available coatings as well as coatings which may be developed in the future. This report describes the equipment and test procedure, and presents the results of tests on three coatings; namely, Albi 99, Albi 107, and Midland 7X2039.

DESCRIPTION OF TEST EQUIPMENT

The fire testing torch positioned for a test is shown in Fig. 1. The torch consists of a gun-type conversion oil burner with a No. 2, 80° spray nozzle. The return relief valve was set at the pressure required to deliver two gallons of kerosene per hour through the nozzle. The air consumed by the burner was adjusted to produce a differential pressure of 0.35-inch of water across the inlet. Two deflector strips, each 3/4-inch wide, were fastened to the end of the barrel so that the ends of the strips were 1 1/2 inches apart and 1 1/2 inches beyond the oil nozzle. An extension was added to the burner, reaching 10 inches beyond the end of the barrel and having an elliptical opening with a major axis of 11 inches and a minor axis of 6 inches. The coated test panel was located four inches beyond the end of the barrel extension. This modified conversion oil burner produces a fuel-rich oil fire at a temperature of 2,000° F.

The temperature on the "cold" side of the test panels was measured by 9 pairs of chromel-alumel thermocouple probes of 1/16-inch-diameter wire grouped in rows of 3 to cover an area where the highest temperature occurred. The probes were supported in a fixture to facilitate positioning against the test panel. Details of this fixture are shown in Fig. 2. A spacing of 1/4-inch was maintained between contact points on the test panel for each pair of probes to complete the thermocouple circuit. The probes were kept in continuous contact with the test panel by means of air pressure at 40 psi applied to a steel ball in a cylinder, behind a small plunger attached to each probe. The load applied to each plunger was approximately one pound. The construction of the air cylinder, steel ball, plunger, and the thermocouple probes is shown in Fig. 2. Figure 3 shows the back of the test fixture and a portion of the angle iron frame to which the fixture was attached. Figure 4 shows the details of the transite frame used for holding the 12- by 12-inch test panels and the stainless steel shield. The frame for supporting the 24- by 24-inch test panels is shown in Fig. 5. Each thermocouple temperature was recorded on a single-point, high-speed, Minneapolis-Honeywell Brown potentiometer temperature recorder. Figure 6 shows the bank of temperature recorders.

TEST PROCEDURE

The coatings were applied to 12- by 12-inch and 24- by 24-inch panels of 0.040-inch 2024-T_3 clad aluminum and 12- by 12-inch AZ31B-H24 magnesium. The panels were prepared for coating by washing in solvent and wire brushing, followed by a second wash in solvent to remove all traces of oil which might have been present. Immediately following the second cleaning operation, the panels were primed with either vinyl wash primer or zinc chromate primer. Albi 99 and Albi 107 fire-retardant coatings, manufactured by Albi Manufacturing Company, Rockville, Connecticut, and Midland 7X2039 heat-resistant aluminum paint, manufactured by Midland Industrial Finishes, Waukegan, Illinois, were applied to the 12- by 12-inch panels of aluminum and magnesium by multiple spray coats or multiple brush coats to produce a film thickness of from 0.015- to 0.020-inch. A minimum of 24 hours' drying time between coats was allowed for most applications; however, in some cases the panels were coated by quick application with a minimum of 1 hour's drying time between coats. Each coating was applied to a group of four test panels. Four panels were left uncoated for use as controls in obtaining basic fire-resistance data. Also evaluated was the increase in fire-resistance provided by single brush coats of Albi Top Koter and Albi Top Koter M when applied to Albi 99 and Albi 107 coatings.

The test fire was applied to the panel on the coated side, and the average times for the uncoated side to reach 500° and 600° F., based on the 5 highest temperatures, were recorded. Also, the failure time of the panels was recorded as the time at which the panels were weakened to the extent that a thermocouple probe penetrated the metal.

RESULTS AND DISCUSSION

The data obtained from the fire tests conducted on several fire-retardant coatings when applied to aluminum and magnesium test panels are shown in Table I. The average time required for each test panel to reach the temperatures of 500° and 600° F., respectively, and the total time required for failure are shown. The allowable drying time between coats and the type primer used with the various coatings also are shown. Uncoated panels used as controls were tested in conjunction with coated panels to determine the degree of protection provided by the fire-retardant coating systems. Figure 7 shows a typical fire test on a coated aluminum panel. Figure 8 shows the protection provided by several coating systems applied to aluminum and magnesium test panels. For comparison, time-temperature curves for uncoated panels also are shown in the figure.

The Albi coatings intumesced, or swelled up to an average thickness of 3/8-inch when contacted by the test fire. Albi 99 fire-retardant coating, when applied to aluminum test panels following application of either type primer, gave the greatest protection to the panels. In a number of tests the coated panels lasted twice as long as plain uncoated panels. Magnesium panels primed with vinyl wash primer and coated with either Albi 99 or Albi 107 lasted over twice as long as uncoated panels. The Albi 107 fire-retardant coating for this application gave somewhat better results. Albi 107 coating, however, did not provide as much protection to the aluminum panels as it did to the magnesium panels. Albi Top Koter applied over Albi 99 coating did not give additional protection to aluminum panels by comparison with panels coated with Albi 99 alone. The results indicate that Albi Top Koter M, when applied over aluminum panels coated with Albi 107, gave better protection than similar panels coated with Albi 107 but without Top Koter. The results indicate also that 24 hours' drying time between coats, as recommended by the manufacturer, offered only a slight advantage over 1 hour's drying time between coats. Brushing as a method of applying the fire-retardant coatings produced test panels which were inferior to similar panels coated by the multiple spray method. Only slightly better results were obtained with the 24- by 24-inch test panels by comparison with 12- by 12-inch aluminum panels when tested with similar applied coatings. This slight difference is due to the larger area of panel which is not exposed to the flame, resulting in greater dissipation of heat. Midland 7X2039 heat-resistant paint offered only a small amount of protection to the magnesium panels but did not offer any protection as a coating when applied to aluminum. In this case, an increase in the rate of heat transfer to the cold side of the panel was noted by comparison with uncoated panels. Figures 9, 10, and 11 show the appearance of a typical panel from each group after being fire-tested to destruction.

CONCLUSIONS

From the results of the tests conducted, it is concluded that the equipment and test procedure described in this report comprise a suitable means of determining the increase in fire-resistance provided by intumescent and other fire-retardant coatings.

Further, it is concluded that·

1. Of the paints tested, Albi 99 fire-retardant coating applied to aluminum test panels provided the best protection to the panels

2. Magnesium panels coated with Albi 107 lasted longer than similar panels coated with Albi 99 fire-retardant coating

3. The effect of panel size had little significance on the test results. The 12- by 12-inch panel proved to be more acceptable specimen size from the standpoint of convenience and economy.

4. Midland 7X2039 heat-resistant paint increased the fire-resistance of magnesium to a small degree only and offered no increase in fire-resistance to the aluminum test panels.

5. From the standpoint of fire-resistance, brush-coated test panels were inferior to similar panels coated by the multiple spray method.

6. Although the Albi fire-retardant coatings increased the fire-resistance of the test panels to some degree, the increased protection provided was not sufficient to render the aluminum and magnesium materials suitable for replacing fireproof firewall materials, such as stainless steel.

RECOMMENDATIONS

It is recommended that:

1. The equipment and test procedure described in this report be used in determining the increase in fire-resistance provided by fire-retardant coatings.

2. Stainless steel and other fireproof materials in the engine compartment structure of helicopters or other aircraft not be replaced by aluminum and magnesium protected by the coatings tested where the use of fireproof materials is required.

TABLE I

RESULTS OF FIRE TESTS OF PANELS

Panel No.	Primer	Coating	Drying Time Between Coats (hrs.)	Average Time Required to Reach Following Temp. 500° F. (sec.)	600° F. (sec.)	Failure Time* (sec.)
12- by 12-Inch, 0.040-Inch-Thick 2024-T_3 Clad Aluminum						
1	None	Uncoated	None	21.4	34.8	69
2	None	Uncoated	None	25.6	30.8	52
3	None	Uncoated	None	24.0	29.2	49
4	None	Uncoated	None	21.6	25.4	56
13	Vinyl Wash	Albi 99	24	44.0	56.0	124
14	Vinyl Wash	Albi 99	24	39.8	52.4	111
15	Vinyl Wash	Albi 99	24	35.0	45.0	94
16	Vinyl Wash	Albi 99	24	39.6	49.8	98
17	Zinc Chromate	Albi 99	24	40.0	50.2	103
18	Zinc Chromate	Albi 99	24	50.4	64.0	129
19	Zinc Chromate	Albi 99	24	44.0	57.8	113
20	Zinc Chromate	Albi 99	24	40.6	52.0	121
21	Zinc Chromate	Albi 99	1	45.0	56.2	148
22	Zinc Chromate	Albi 99	1	35.0	44.7	90
23	Zinc Chromate	Albi 99	1	38.2	44.4	91
24	Zinc Chromate	Albi 99	1	36.8	45.0	83
26	Vinyl Wash	Albi 99	1	43.6	54.0	97
28	Vinyl Wash	Albi 99	1	42.0	52.4	101
29	Vinyl Wash	Albi 99	1	40.5	51.5	105
31	Vinyl Wash	Albi 99	1	48.0	59.0	99
33	Vinyl Wash	Albi 99 + Albi Top Koter	1	39.6	49.0	73
34	Vinyl Wash	Albi 99 + Albi Top Koter	1	45.0	56.6	100
36	Vinyl Wash	Albi 107	24	30.2	36.4	74
37	Vinyl Wash	Albi 107	24	23.2	30.0	65
38	Vinyl Wash	Albi 107	24	29.5	37.3	70
40	Vinyl Wash	Albi 107	24	32.0	39.4	73
41	Vinyl Wash	Albi 107 + Albi Top Koter M	24	34.6	44.2	90
42	Vinyl Wash	Albi 107 + Albi Top Koter M	24	38.4	45.2	105

TABLE I (continued)

RESULTS OF FIRE TESTS OF PANELS

Panel No.	Primer	Coating	Drying Time Between Coats (hrs.)	Average Time Required to Reach Following Temp. 500° F. (sec.)	600° F. (sec.)	Failure Time* (sec.)
43	Vinyl Wash	Albi 107 + Albi Top Koter M	24	31.4	40.8	108
44	Vinyl Wash	Albi 107 + Albi Top Koter M	24	32.8	44.2	112
53	Vinyl Wash	Midland 7X2039 4 Brush Coats	24	22.4	26.2	50
54	Vinyl Wash	Midland 7X2039 4 Brush Coats	24	20.0	23.5	51
55	Vinyl Wash	Midland 7X2039 4 Brush Coats	24	21.8	25.5	52
56	Vinyl Wash	Midland 7X2039 4 Brush Coats	24	22.0	25.5	49
57	Vinyl Wash	Albi 99 4 Brush Coats	24	36.8	46.8	92
58	Vinyl Wash	Albi 99 4 Brush Coats	24	36.2	42.8	88
59	Vinyl Wash	Albi 99 4 Brush Coats	24	30.2	39.0	78
60	Vinyl Wash	Albi 99 4 Brush Coats	24	35.0	43.8	96
61	Vinyl Wash	Albi 107 4 Brush Coats	24	28.0	35.8	73
62	Vinyl Wash	Albi 107 4 Brush Coats	24	29.2	35.8	62
63	Vinyl Wash	Albi 107 4 Brush Coats	24	29.6	36.8	58
64	Vinyl Wash	Albi 107 4 Brush Coats	24	26.0	33.6	79
		12- by 12-Inch, 0.040-Inch-Thick AZ31B-H24 Magnesium				
101	None	Uncoated	None	13.7	18.0	40
102	None	Uncoated	None	14.6	18.8	40
103	None	Uncoated	None	13.6	20.2	40

TABLE I (continued)

RESULTS OF FIRE TESTS OF PANELS

Panel No.	Primer	Coating	Drying Time Between Coats (hrs.)	Average Time Required to Reach Following Temp. 500° F. (sec.)	600° F. (sec.)	Failure Time* (sec.)
104	None	Uncoated	None	12.2	16.2	31
105	Vinyl Wash	Albi 99	24	26.0	34.6	65
106	Vinyl Wash	Albi 99	24	28.7	39.0	40
107	Vinyl Wash	Albi 99	24	21.6	31.2	60
108	Vinyl Wash	Albi 99	24	27.4	34.8	62
109	Vinyl Wash	Albi 107	24	30.7	40.7	108
110	Vinyl Wash	Albi 107	24	31.2	40.6	58
111	Vinyl Wash	Albi 107	24	30.4	38.4	63
112	Vinyl Wash	Albi 107	24	32.2	42.0	72
118	Vinyl Wash	Midland 7X2039 4 Brush Coats	24	20.2	24.6	28
119	Vinyl Wash	Midland 7X2039 4 Brush Coats	24	16.8	21.8	32
120	Vinyl Wash	Midland 7X2039 4 Brush Coats	24	16.4	19.6	31
		24- by 24-Inch, 0.040-Inch-Thick 2024-T_3 Clad Aluminum				
A	None	Uncoated	None	20.4	23.8	50
B	Vinyl Wash	Albi 99	24	48.6	63.4	114
C	Vinyl Wash	Albi 107	24	34.0	41.8	91
D	Vinyl Wash	Albi 107 + Albi Top Koter M	24	35.8	47.0	80

*The time at which the panels were weakened to the extent that a thermocouple probe penetrated the metal.

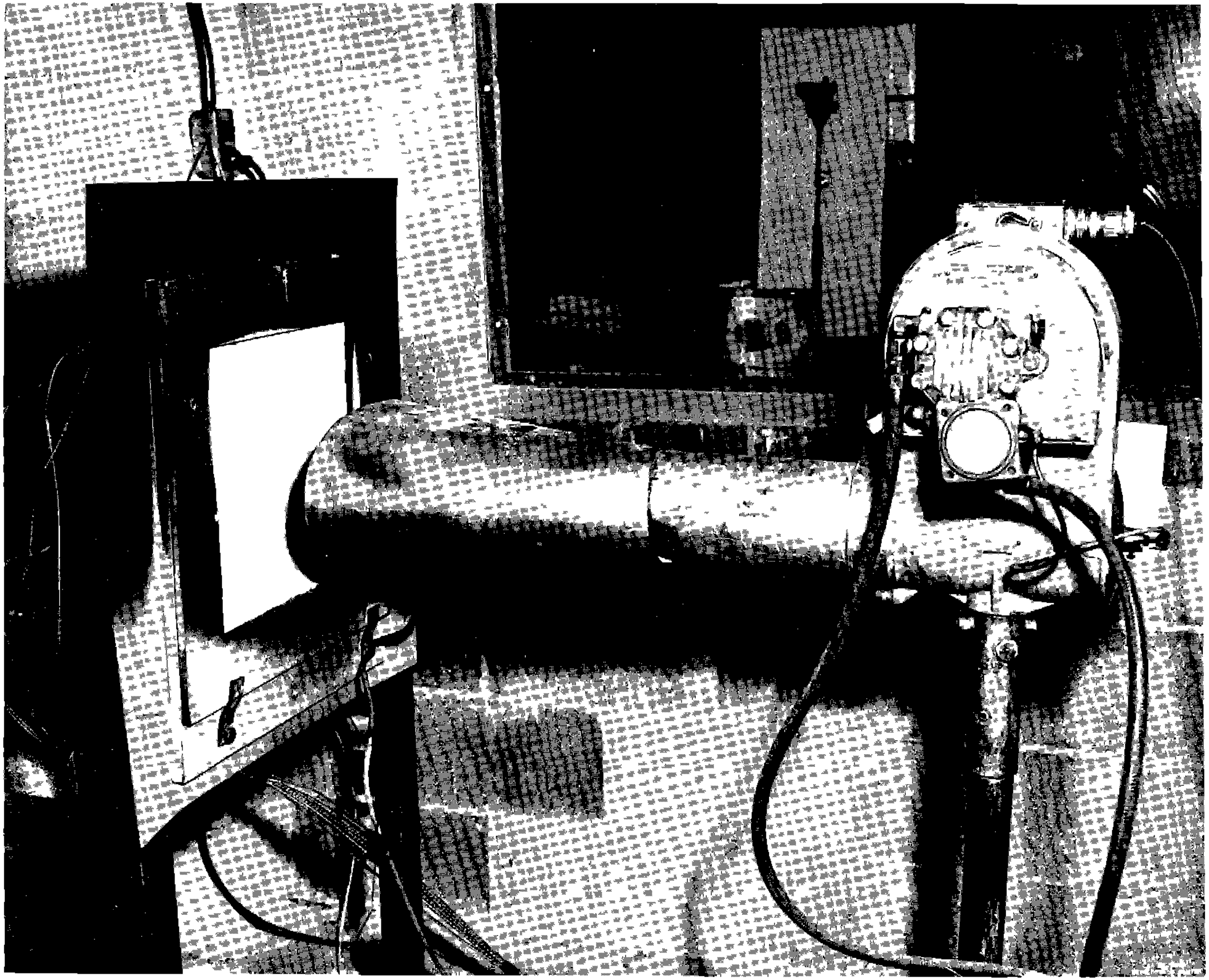


FIG. 1 FIRE TORCH IN POSITION FOR TESTS

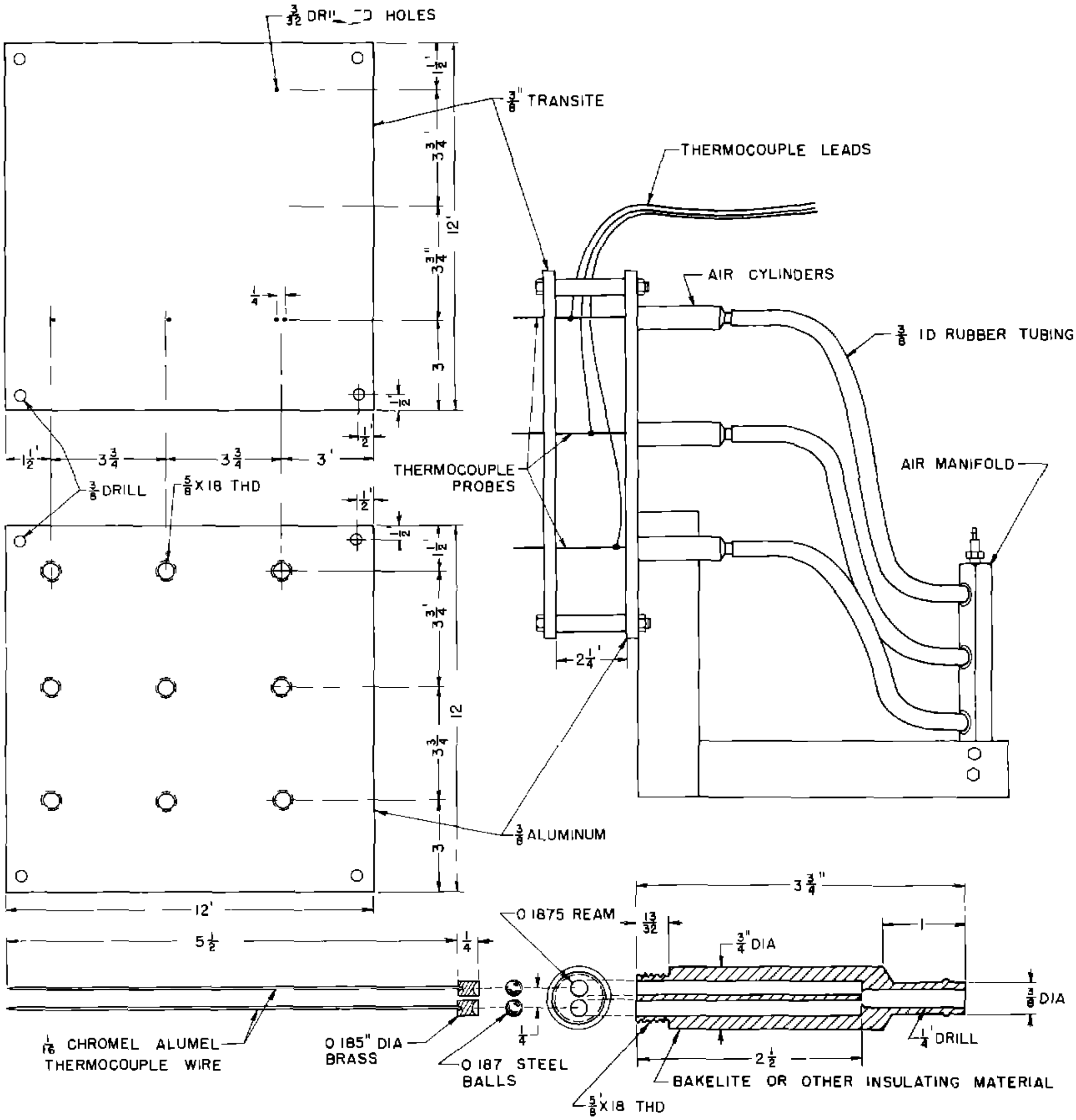


FIG. 2 DETAILS OF THERMOCOUPLES AND SUPPORTING FIXTURE

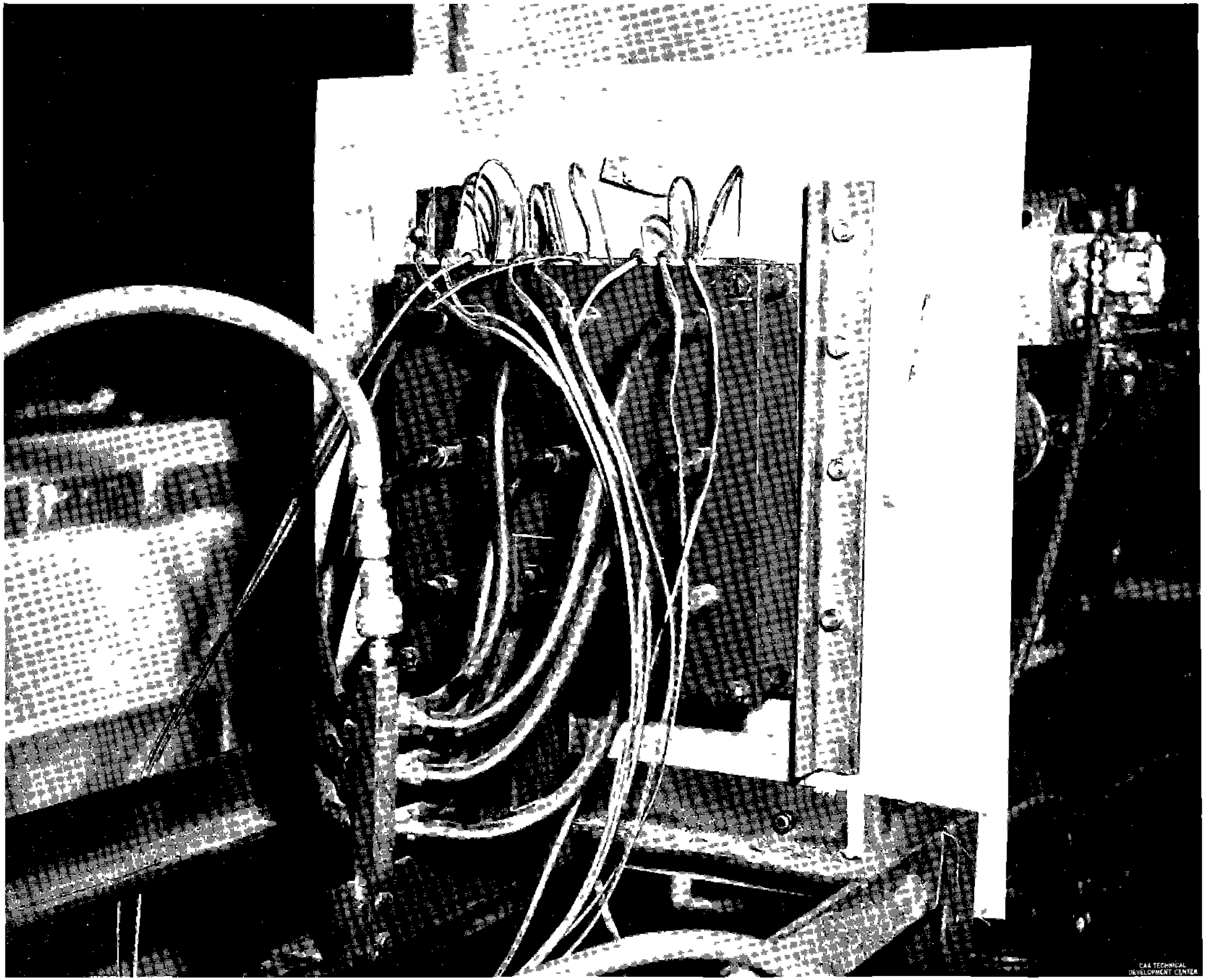


FIG. 3 REAR VIEW OF TEST FIXTURE AND MOUNTING SUPPORT

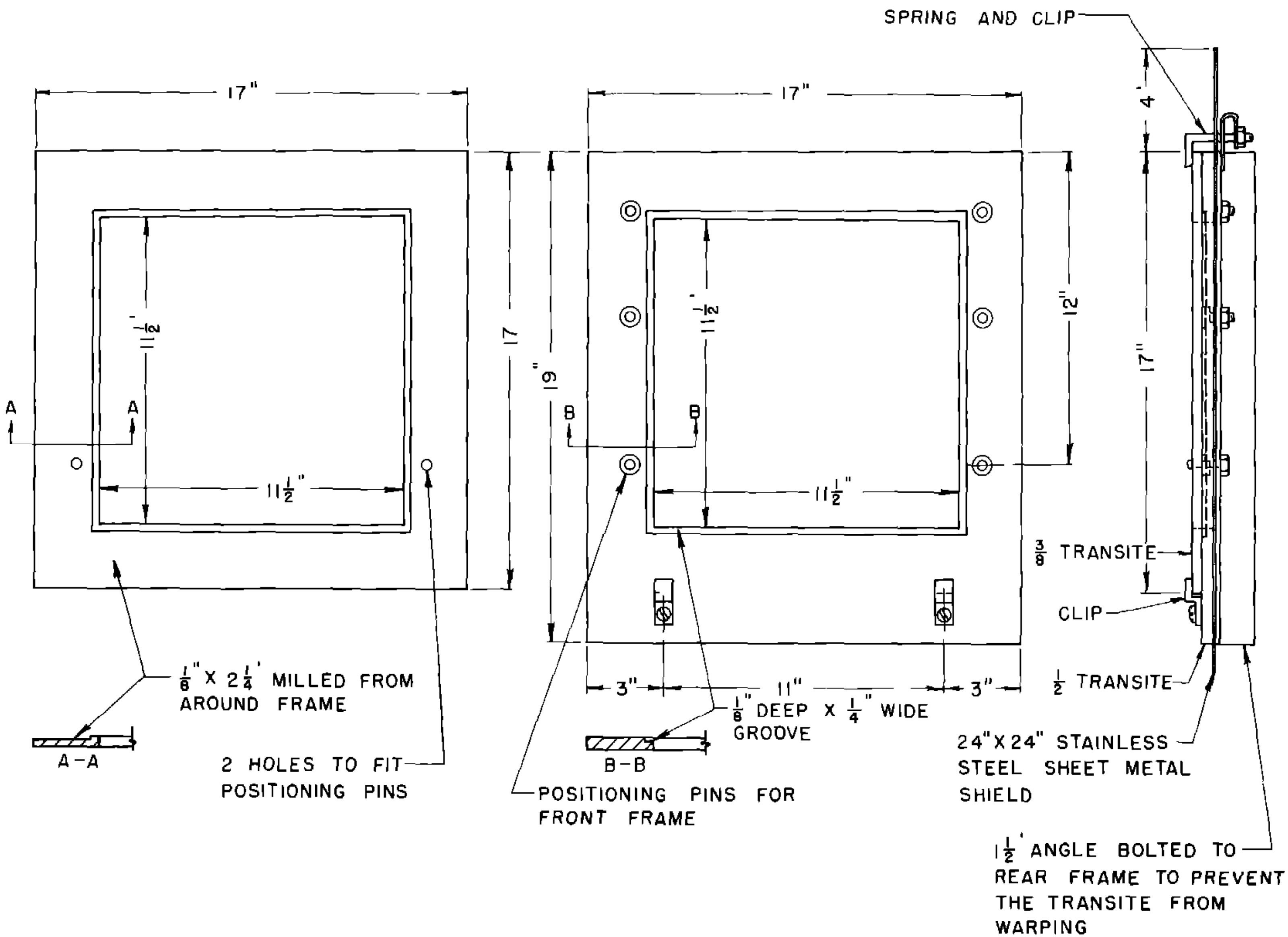


FIG. 4 DETAILS OF TRANSITE FRAME TEST PANEL SUPPORT

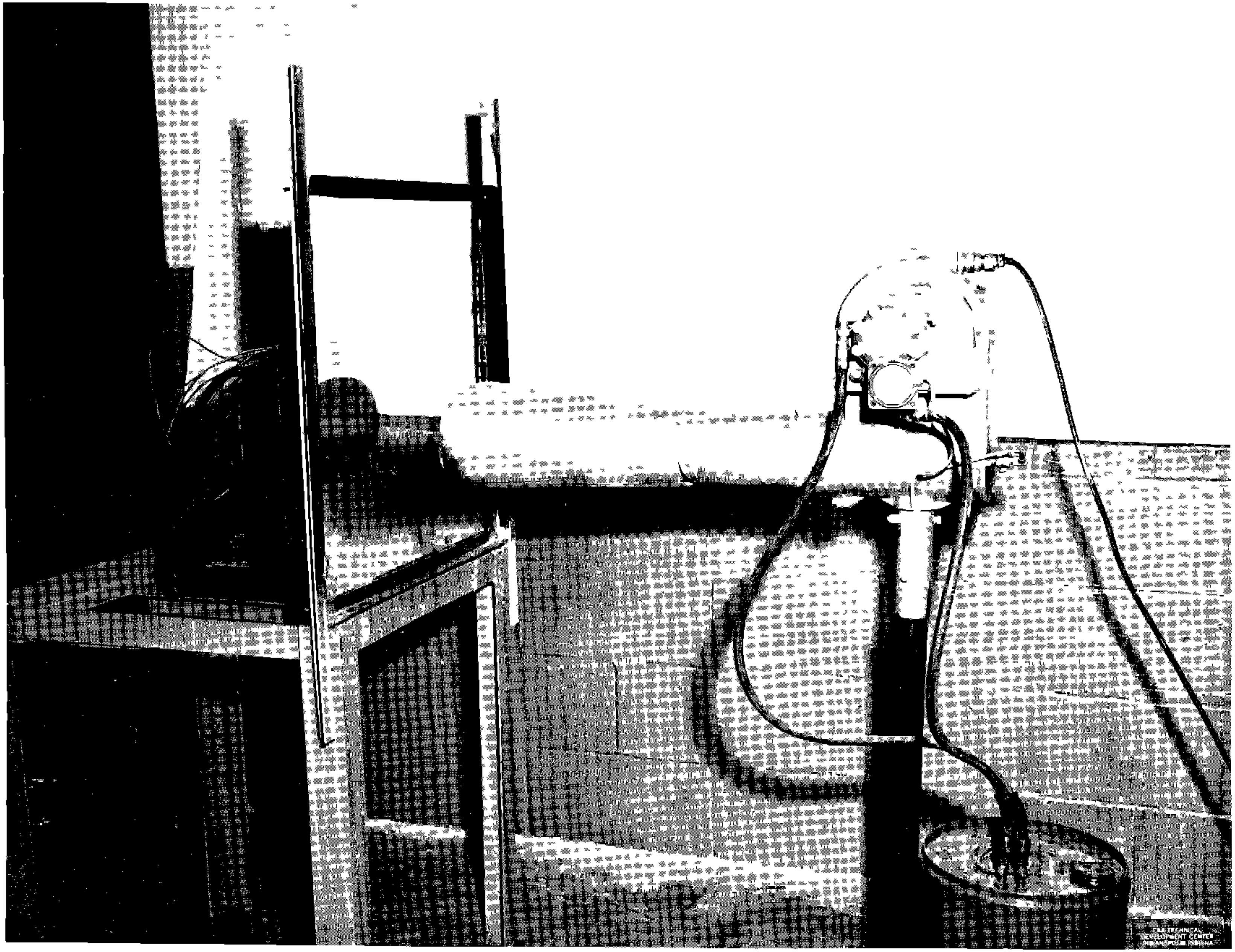


FIG. 5 FRAME FOR SUPPORTING 24- BY 24-INCH-SQUARE TEST PANELS

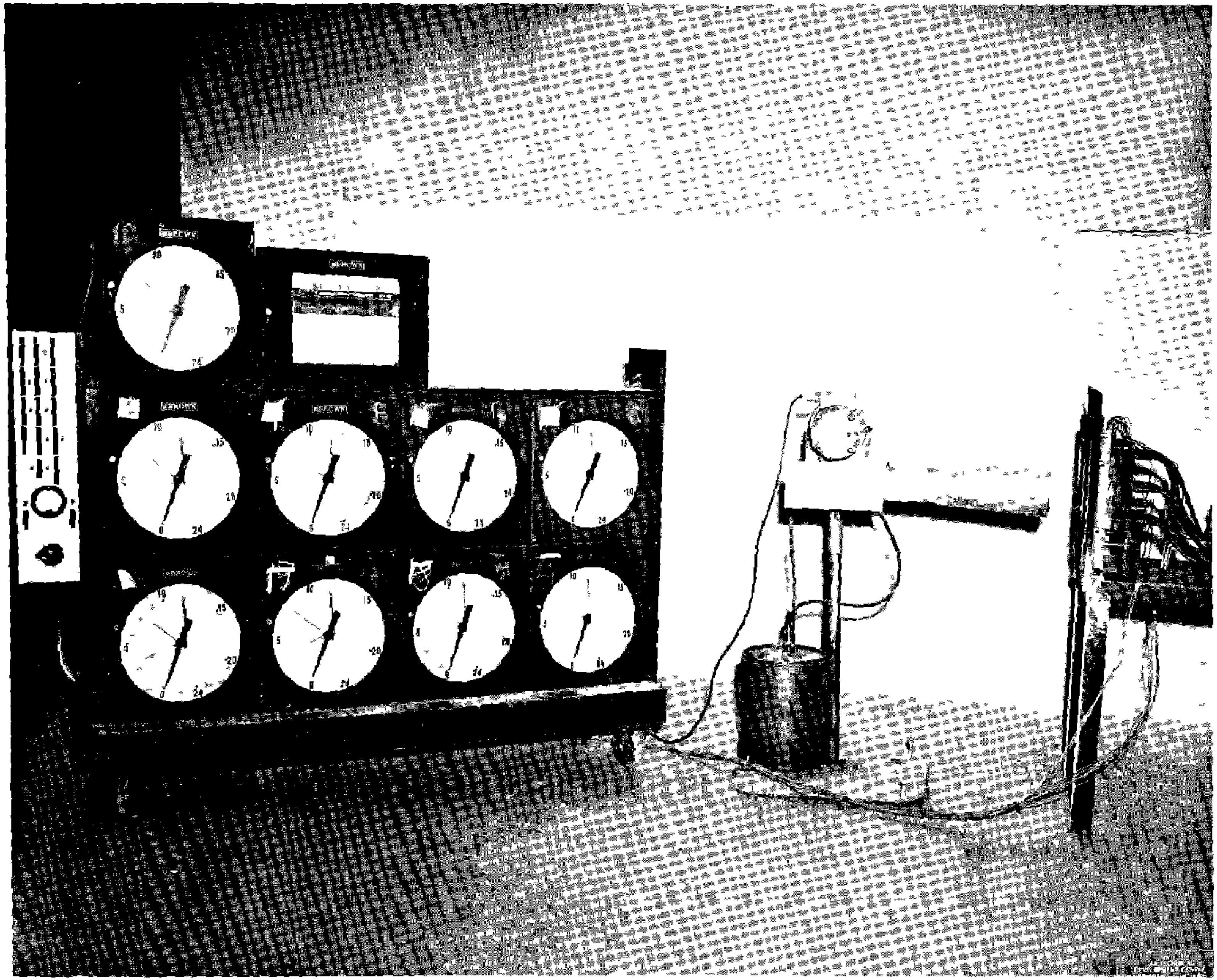


FIG. 6 POTENTIOMETER TEMPERATURE RECORDER BANK

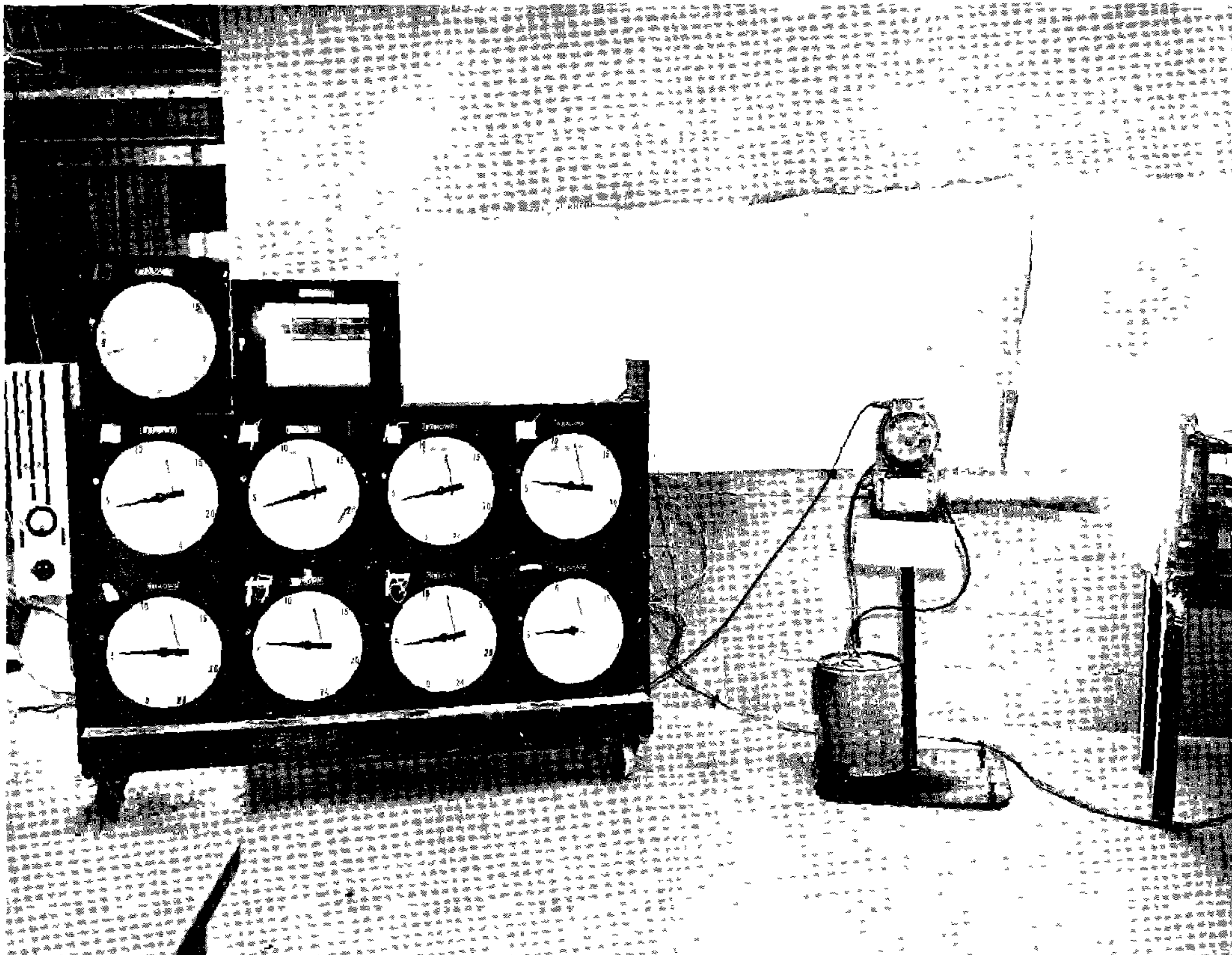


FIG. 7 TYPICAL FIRE TEST ON COATED ALUMINUM PANEL

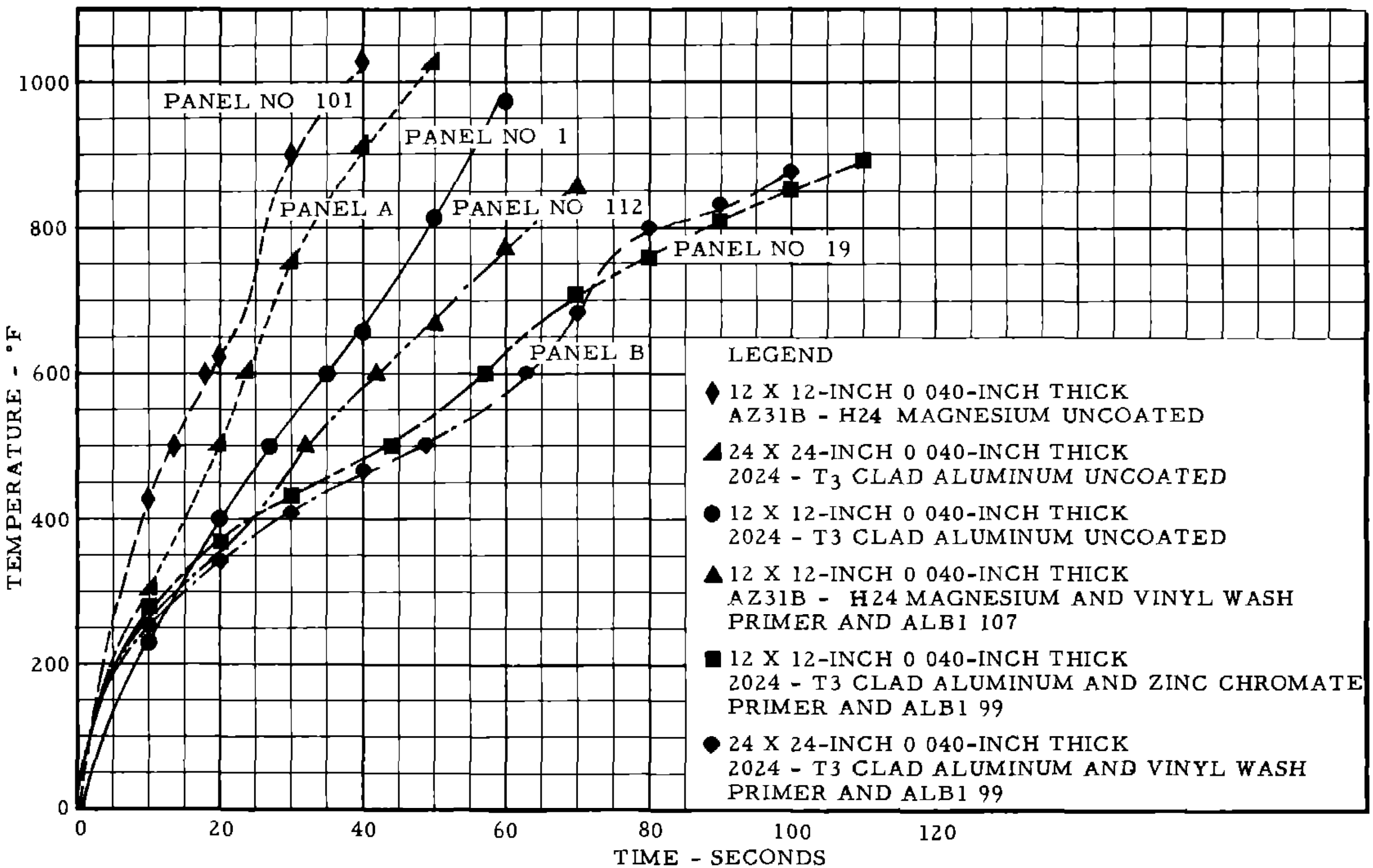


FIG. 8 FIRE PROTECTION PROVIDED BY DIFFERENT COATINGS WHEN APPLIED TO ALUMINUM AND MAGNESIUM TEST PANELS

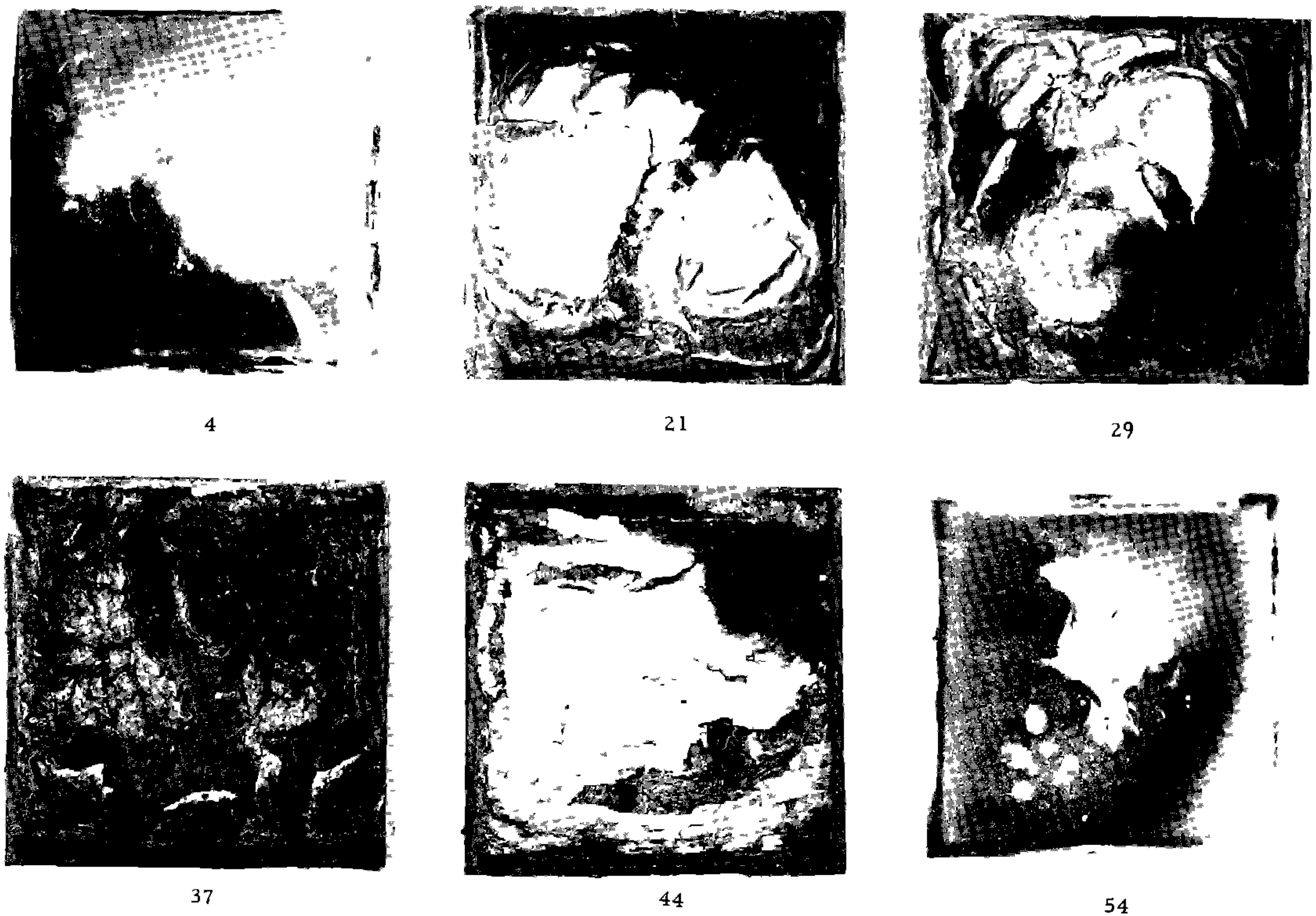
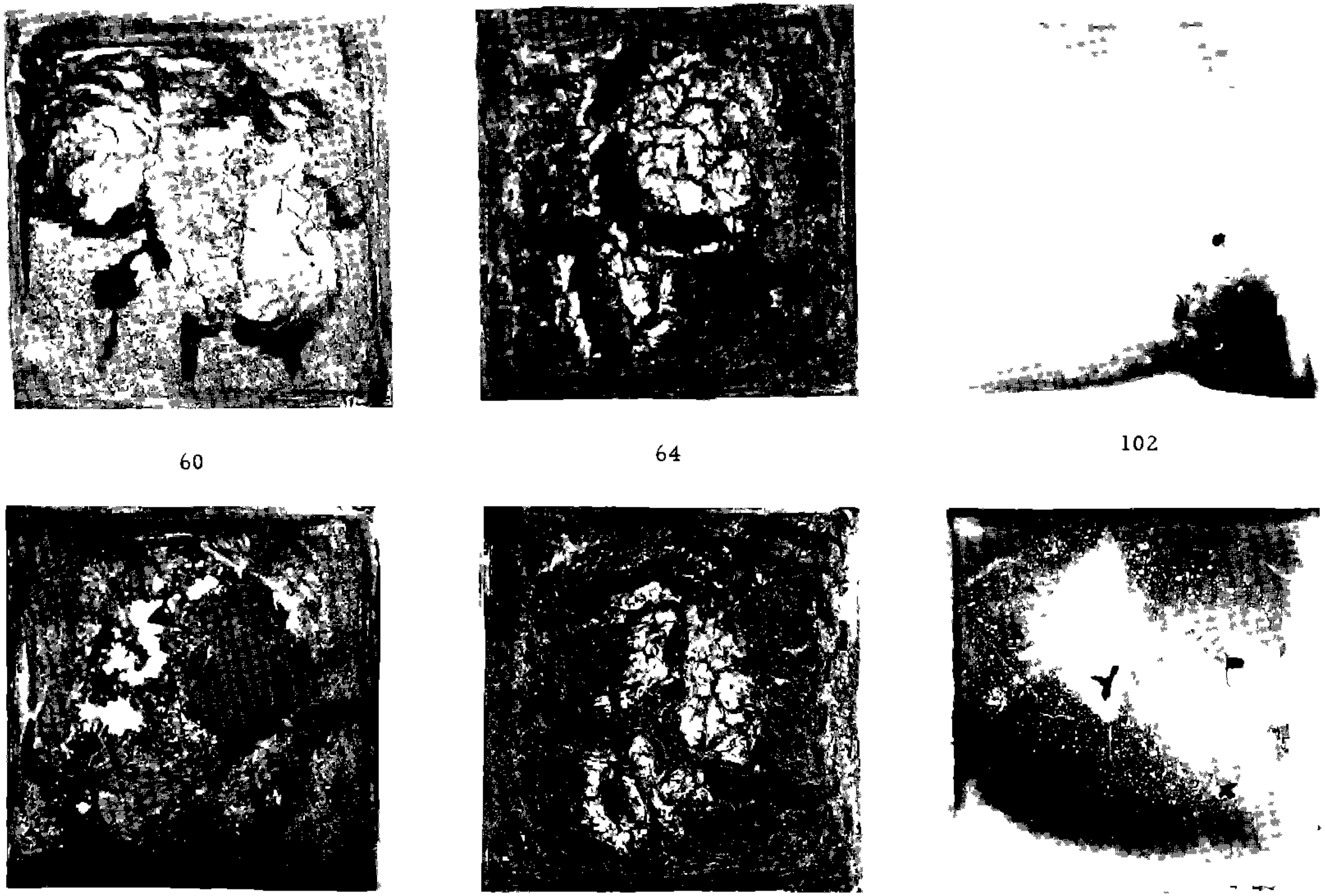


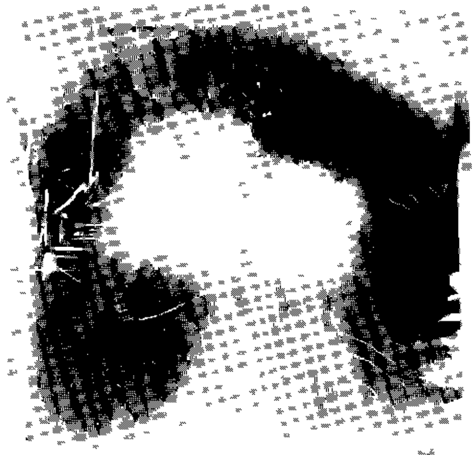
FIG 9 APPEARANCE OF ALUMINUM TEST PANELS AFTER FIRE TEST TO DESTRUCTION



60 64 102

107 110 119

FIG 10 APPEARANCE OF ALUMINUM AND MAGNESIUM TEST PANELS AFTER FIRE TEST TO DESTRUCTION



A

B

C

D

FIG 11 APPEARANCE OF 24-BY-24-INCH-SQUARE ALUMINUM TEST PANELS AFTER FIRE TEST TO DESTRUCTION