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EVALUATION
OF
FLAME SPREAD AND VAPOR PERMEABILITY
PROPERTIES OF INTERIOR FINISHES

by

J. V. Ryan, E. W. Bender,
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U. S. DEPARTMENT OF COMMERCE
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Building Technology Division

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

EVALUATION OF FLAME SPREAD AND VAPOR PERMEABILITY PROPERTIES OF INTERIOR FINISHES

ABSTRACT

Results are presented of an investigation of the flame spread and vapor barrier characteristics of interior surface finish materials for the protection of plywood. The results are presented in tabular form.

1. INTRODUCTION

In each of two fire endurance tests of 10 by 16 ft walls, a pronounced flash and dense fumes were observed to develop from the fire exposed surface during the first minute of exposure. Each fire exposed surface was finished with a vinyl plastic and glass fabric material. Since such surface flash fires appeared to represent a hazard to the occupants of buildings, the National Bureau of Standards, at the request of the U. S. Air Force Installations Representative-North Atlantic Region, undertook a research program to evaluate the flame spread, decomposition products, and vapor permeability characteristics of several surface finish materials. Flame spread characteristics were determined by two methods; the flammability of one material was investigated; and the decomposition products of several materials were analyzed to determine the amounts of certain toxic gases present. For the applications considered, it was desirable that the interior surface finish provide a barrier to the transmission of water vapor. Therefore, the water vapor permeabilities of many specimens were determined.

2. MATERIALS

The specimens subjected to the various methods of evaluation were made up of one or more of the following materials. Following the name of each is an abbreviation that appears in the tables:

2.1 1/4 in. exterior grade Douglas fir plywood (X-ply)

The surface to which any subsequent coatings were applied was class A ply. The plywood was obtained from the stock of a local supply house and was given no special conditioning.

2.2 Harborite (Har).

A material consisting of 1/4 in. exterior grade plywood with phenolic resin impregnated paper bonded to each face.

This material was manufactured by the Harbor Plywood Corporation of Aberdeen, Washington. Samples of this material were received from both the manufacturer and a sub-contractor on a construction project for USAFIR-NAR and received no special conditioning.

2.3 "All Purpose Fire and Weather Resist" paint (SK)

This is a product of the SK Laboratories, Baltimore, Md. The paint was received from the supplies of a sub-contractor on a construction project for USAFIR-NAR. The paint weighed 9.8 lb/gal and was sprayed with heavy duty equipment. The manufacturer recommended two coats, the first at 175-200 ft^2/gal and the second at a greater coverage. He recommended 48 hours drying at 125°F between coats and before any subsequent coatings were applied.

2.4 "Albi 99" (Albi 99)

This is a product of Albi Mfg. Co., Rockville, Conn. This paint was claimed to provide fire protection and good paintability. The material, in white color, was obtained from the stock of a local distributor. The paint weighed 10.2 lb/gal as received and 10.0 lb/gal when thinned with 1/2 pt of recommended thinner/gal. The paint was sprayed with heavy duty equipment. The manufacturer recommended one coat at 250 ft^2/gal., with 48 hours drying at room temperature before application of subsequent coatings or before test.

2.5 "Bar-Fire 1-48 Fire and Heat Retardant Paint" (Bar F)

This is a product of the Barnard Chemical Co., Los Angeles, California. The paint, in white color, was received from the manufacturer directly. He recommended two spray coats, each at 200 ft^2/gal. It weighed 10.8 lb/gal and was sprayed with conventional equipment.

2.6 "Fire-ban" (F ban)

This is a product of the E. H. O'Neill Floors Co., Cicero, Illinois. The material comes as a powder to be mixed with water. It was received from the manufacturer and mixed and sprayed, under the supervision of his representatives, to produce a mineral coating.

2.7 Kerloid 1197 (Kerl 7)

This is a product of the Kerloid Corp., Baltimore, Md., and is represented as having a mineral filler of slate. The material was received directly from the manufacturer, along with a "vehicle" to be used as a combined surface cleaner and primer. The vehicle was brushed on and the Kerloid 1197 applied in two coats by heavy duty spray equipment.

2.8 Kerloid 1198 (Kerl 8)

This product is similar to Kerloid 1197 but represented as having a mica filler rather than slate. Used in same manner.

2.9 Flintkote Aluminum Paint (Flkt)

This is a product of the Flintkote Co., New York, N.Y. The paint consists of fine aluminum flakes in an asphalt base. This paint was intended to provide a light reflecting surface and a vapor barrier. It was sprayed with conventional equipment. The manufacturer recommended coverage of 300-500 ft^2/gal. The material was received from the manufacturer.

2.10 Flintkote Asphalt Primer (Flpr)

This is an asphaltic solution to serve as a primer for Flintkote Aluminum Paint. The material was received from the manufacturer, who recommended coverage of 200-500 ft^2/gal.

2.11 Permalume (Prlu)

This is a product of the Grems Manufacturing Co., Klamath Falls, Oregon. A paint consisting of fine aluminum flakes in an asphalt resin base. This paint was intended to provide a light-reflecting surface and a vapor barrier. It was sprayed with heavy duty equipment after having been thinned. The manufacturer, from whom the material was received, recommended coverage of 200 to 500 ft^2/gal.

2.12 Permaphane (Prph)

This is a product of the Grems Manufacturing Co., Klamath Falls, Oregon. Represented by the manufacturer, from whom the material was received, as being essentially the same as Permalume with the omission of the aluminum flakes. It was thinned with an equal volume of methyl ethyl ketone and applied by brush.

2.13 DuPont Sealer Coater (PVA)

This is a primer and sealer of the polyvinyl acetate type, produced by the E.I.Dupont Corporation. The material was obtained from a local paint supply house and was applied with conventional spray equipment.

2.14 Dexolium (Dex)

This is a product of the Dexolium Corp., South Norwalk, Connecticut, consisting of a vinyl plastic sheet on a woven glass fabric backing. It was obtained from the manufacturer both with and without a precoated adhesive on the glass fabric face, in rolls 37 in. wide. The material was gray and smooth on the vinyl face,

and was about 0.019 in. thick including the glass fabric. The material was intended for application with the vinyl surface exposed, but was reversed for some of the specimens. In that case, the abbreviation Dex R is used. Various adhesives or activators were used in the application of Dexolium. They were identified on the containers' labels as follows: L-7-AB-1 Activator; 148x40 Fire Retardant Adhesive.

2.15 Dexolium Fire Retardant Primer 148x43 (Dxpr)

This is a product of the Dexolium Corp., South Norwalk, Connecticut. A primer for use with Dexolium, it was brushed or sprayed.

2.16 Aluminum foil (Al)

This is a product of the Aluminum Company of America. The foil came in a continuous roll 4 ft wide and 0.003 in. thick, and was shiny on both surfaces. The alloy and temper identifications were 1145-0. The foil was applied by means of an adhesive produced by and recommended for this purpose by the Minnesota Mining and Manufacturing Co., St. Paul, Minnesota. It was labeled EC 1368 and was applied by heavy duty spray equipment.

2.17 Corrulux (Crlx)

This is a product of the Corrulux Division of L-O-F Glass Fibers Company. Samples with three different code identification numbers were obtained from the manufacturer. Each was a green translucent sheet about as flexible as heavy cardboard. The sheets ranged in thickness from about 0.050 in. to about 0.095 in.; variations being observed from sheet to sheet and over individual sheets to a lesser degree. The samples were identified as follows: Sample no. 39-108-1, glass fiber mat 2 oz/ft^2, fire retardant polyester, and antimony oxide filler; sample no. 39-108-2, same glass mat and filler as no. 1 but general purpose light stable polyester; sample no. 39-108-3, same glass mat and polyester as no. 1 but calcium carbonate filler. These sheets were applied with an adhesive produced by the Minnesota Mining and Manufacturing Co., labeled EC 1383.

2.18 Aluma-life 4061 Heat Resisting Primer (Al Life-P)

This is a product of the Aluma-life Co., Memphis, Tennessee. The material, weighing about 6.7 lb/gal, was applied by brush. It was intended for interior use only.

2.19 Aluma-life 4061A Interior Hurricane Tite Finish (Al Life-V)

The material, weighing about 6.7 lb/gal., was applied by brush and was intended to provide a vapor barrier when used with the Primer.

2.20 Aluma-life Armor Plate (Al Life-F)

This is a coating intended to provide fire resistance. The material, weighing about 9.2 lb/gal. was applied by screeding. It was of about the same consistency as mayonnaise. The manufacturer stated that for large areas it would be applied by very heavy duty spray equipment.

3. SPECIMENS

Each specimen was made of one or more of the materials described in section 2. Each material was applied and aged under the conditions recommended by the manufacturer whenever practical. Twenty-nine specimens consisted of a sheet of 1/4 in. exterior grade plywood or a sheet of 1/4 in. Harborite, 4 ft long by 8 ft, and any other coatings. After the applications and aging of materials, the finished specimens were cut up to produce three pieces each 32 by 36 in., two pieces each 12 in. square, and eight pieces each 6 by 18 in. The pieces were marked and placed in a room maintained at 75°F and 50 percent relative humidity for 48 or more hours conditioning prior to testing. There were a few exceptions to this. Specimen 7 was tested after 24 hours at room temperature in order to determine the effect, if any, of short drying time. Specimen 34, having aged at least six weeks at room temperature, was conditioned about 24 hours. Specimen 33 was aged by placing the samples in sunlight whenever possible and was in the conditioning room overnight before test. The pieces for vapor permeability and decomposition products determinations were not conditioned because conditioning would not influence the results. The various materials assembled into each specimen are indicated in table 1, with the average coverage obtained and the tests performed on the specimen. All the specimens were prepared at the National Bureau of Standards and by Bureau personnel except specimen no. 33.

Aging was by air drying in the work room or by accelerated drying in an enclosure heated to 100 to 125°F, and ranged from 24 hours of air drying at room temperature to over 48 hours at elevated temperatures. Specimens of Harborite with SK paint on both sides had been on hand about six weeks at room temperatures when specimen preparation began.

4. TEST PROCEDURES

Samples cut from each specimen were subjected to one or more tests to determine the flame spread, flammability vapor permeability, or the combustion products.

4.1 Flame spread by SS-A-118b

Tests of 29 specimens were carried out under the procedures of Federal Specification SS-A-118b. However, the data obtained and the evaluations based thereon were more discriminating than called for in that specification. In this test method a conditioned specimen sample 32 by 36 in. was laid to cover the 30 in. square opening in a horizontal frame of 2 in. steel angles. An incombustible backing and two weights were laid on top, the latter to flatten out any warped samples and insure continuous contact between frame and specimen. Thermocouples were located to permit the measurement of temperatures 1 in. below the center of the sample and between the sample and the incombustible backing. Premixed air and natural gas were forced through a vertical pipe to an open burner tip located 28-3/4 in. below the center of the specimen. The apparatus, with specimen in place, is shown in figure 1. The flame thus produced was controlled, by regulation of the gas flow, to produce temperatures at the thermocouple 1 in. below the specimen that corresponded closely to those defined in the specification, which include: 1000°F at 5 min, 1300°F at 10 min., 1399°F at 15 min., and 1462°F at 20 min. The regulation of the gas flow was accomplished automatically. Three samples of each specimen were tested. Tests were of 20 min. duration except in a few cases in which it appeared the sample might be fully consumed by that time. Observations were made of the times at which the first flame from the specimen was observed, the time at which flame touched the angle supporting frame, amount of flame, smoke, duration of continued burning of specimen after the end of the test exposure, and of the condition of the sample during and after test.

4.2 Flame spread by radiant panel

The apparatus used for the tests is shown in Figure 17. It consisted of a radiant panel, a frame for support of the test specimen and associated measuring equipment.

The radiant panel consisted of a cast iron frame enclosing a 12"x18" porous refractory material. The panel was mounted in a vertical plane and a pre-mixed gas-air mixture supplied from the rear burned in intimate contact with the refractory surface providing a radiant heat source. The panel approached its equilibrium temperature of approximately 800°C in about one-half hour after ignition and its energy output was maintained by regulation of the gas flow according to the indication of a radiation pyrometer.

A small metal stack was placed under the hood above the test specimen to receive the hot products of combustion and smoke. Thermocouples placed within the stack were used to measure the maximum rise in temperature of these exhaust gases. The temperature was automatically recorded on a potentiometer recorder. A sampling tube was also placed within the stack to collect a deposit of smoke on a glass fiber filter paper. An aspirator was used to draw the stack gases through the paper at a rate maintained constant throughout the test and the weight of the resultant deposit was determined after completion of the test.

The test specimen measuring 6"x18" was placed in a formed sheet metal holder and was backed up with a sheet of asbestos board. The loaded specimen holder was then placed in position on the supporting frame (inclined 30° to the vertical) at time zero and observations were then made of the progress of the flame front, the occurrence of flashes, etc. A pilot igniter fed by an air-acetylene mixture served both to initiate flaming at the upper edge of the test specimen and to ignite combustible gases rising from the specimen. An electrical elapsed time meter was used during observations of the progress of flaming along the length of the test specimen and other significant times.

With one exception (specimen No. 7), all test specimens were conditioned by placement in a room maintained at 75°F and 50 percent relative humidity for at least 48 hours prior to test. They were removed individually and tested almost immediately after transfer to the test room.

The test duration was 15 minutes or until sustained flaming had traversed the entire 18 inch length of specimen, whichever time was less.

Except for the three greatest smoke-producing test assemblies the flow rate through the smoke-collecting filter paper was kept constant at 5000 cc/minute.

4.3 Flammability tests

These tests were made on samples of Dexolium only. They were brought into this investigation because of the behavior of the Dexolium in the large wall tests. These tests were conducted in accordance with the procedures given in an American Society for Testing Materials test method ASTM D568-43. Strips of material cut 1 in. wide by 12-1/2 in. long were suspended in the center of a 1 ft square by 2-1/2 ft high enclosure. The strips were ignited at the bottom and observations made of the time during which the strip continued to burn and of the area burned.

4.4 Water Vapor Permeability

Water vapor permeability determinations were made in general accordance with ASTM Method E96-53T, Procedure E, on specimens approximately 11.46 sq. in. in area. Anhydrous calcium chloride was used as the desiccant.

Assemblies with and without desiccant were used, those without desiccant being regarded as "blanks" to determine the amount of moisture absorbed by the sample (plywood and coating). The data are reported in perms, i.e.

$$\frac{\text{grains}}{\text{hr. sq. ft. in. Hg}}$$

4.5 Decomposition products

Determinations of the products of decomposition as to identity, amount, and hazard each represents are being conducted. However, considerable time will be required. Therefore, the method and results will be presented in a later separate report.

5. Results and Evaluation of Data

Whenever possible, the results are presented as tables and photographs.

5.1 Flame Spread by SS-A-118b

The data obtained in the tests made by the method given in Federal Specification SS-A-118b are given in Table 2. The ranges or spreads of the data among the three samples of each specimen are given with the averages. The classifications that would be given under the criteria in SS-A-118b are listed. In those instances wherein the samples of a specimen did not all fall into the same classification, the classifications of the individual samples are indicated, although such materials would be rated in the lower classification (D) by strict interpretation of SS-A-118b. Visual estimates of the smoke accumulations in the test room are given.

In order to analyze the data in a more quantitative manner than provided for in SS-A-118b, the various specimens have been evaluated on three types of observations made during the tests: (1) the time from the start of test until flaming appeared from the specimen; (2) the time from the start of test until flames touched an angle-iron side of the 30 in. square frame; (3) the damage to the plywood or Harborite base of the specimen as indicated by the diameter of char on the reverse of the specimen samples. These characteristics were chosen for this arbitrary evaluation as representing respectively: (1) an indication of

the ease of ignition; (2) an indication of the flame spread characteristics; and (3) an indication of the heat contributed by and damage resulting to the specimen. The 20 min. period of test was divided into intervals and each interval assigned a numerical rank position, small rank corresponding to later time and better performance. The diameter of char was related to the same scale of rank positions. The specimens were tabulated according to these three observed features and the sum of rank positions taken for each specimen. The relative rank of each specimen, as indicated by the sum of rank positions, was determined. This evaluation is given in Table 3.

The test apparatus is shown in Figure 1 and the specimens in Figures 2 through 16. Both the exposed surfaces and the unexposed surfaces are shown.

5.2 Flame Spread By Radiant Panel Method.

Tests were made on at least four duplicate samples from each specimen. The results are given in Table 4. The listed values are those for the duplicate sample exhibiting the most rapid flame spread and for the sample exhibiting the earliest flash among the samples of the particular specimen. The intensity of the combustion process was indicated by the maximum increase of the temperature in the stack over its steady-state value. Correction has been made for a slight stack temperature increase observed when an incombustible material was placed in the test position.

The weight of the smoke deposit reported is the average of all duplicate samples for each specimen and is based upon at least three tests.

Fire index has been computed as the product of the peak stack temperature rise and a flame spread factor. The flame spread factor is

$$F_s = 0.1 + \frac{1}{60}\left(\frac{10}{t_3} + \frac{100}{t_{12}}\right)$$

where t_3 and t_{12} are the times, in minutes, for sustained flames to pass the 3" and 12" marks, respectively, on the test specimen. The flash index is $F_f = \frac{1}{60} \cdot \frac{40}{t_6}$ where t_6 is the time, in minutes, for a pilot-initiated flash to pass the 6" mark on the test specimen. The factor $\frac{1}{60}$ drops out of each formula if times are expressed in seconds.

The fire index and flash index values have been tabulated in Table 4. Test assemblies have been given relative rank according to fire index performance only. The test apparatus is shown in Figure 17 and the exposed surfaces of representative samples in Figures 18, 19 and 20.

5.3 Flammability

The evaluation described in section 4.3 was carried out on Dexolium, the only material involved in this study to which the method, ASTM D568-43, titled "Flammability of plastics 0.050 in. and under in thickness", was applicable. The Dexolium with precoated adhesive was tested as received, after treatment with the solvent activator, and with the glass fabric stripped off. The results are given in Table 5. No comparisons are possible since the other materials were not tested for flammability. Although not defined in the test method, the term "self-extinguishing" has been used frequently to describe materials for which results have been obtained approximately equal to those for Dexolium, when tested by this method.

5.4 Water Vapor Permeabilities

Water vapor permeability determinations were carried out as described in Section 4.4. Previous experience with aluminum foil in thicknesses of about 0.003 in. had indicated that its water vapor permeability was essentially zero. Therefore, specimens in which aluminum foil was included were not tested but were assumed to have zero permeability. The test results are given in Table 6. The column headed Moisture Absorbed (A) gives the data obtained for samples without desiccant in the cups and the column headed Moisture Absorbed and Transmitted (A+T) gives the data obtained for samples with desiccant in the cups. The permeabilities, or rates of water vapor transmission, were computed by the following formula:

$$R = 0.1 \left\{ \frac{(A+T) - A}{h} \right\}$$

R = permeability in perms
A = absorbed water vapor in milligrams
T = transmitted water vapor in milligrams
h = time in hours

The coefficient 0.1 is a function of the test conditions.

5.5 Supplementary Observations

The following comments are presented as a result of observations made during use of the various coating materials. It should however be emphasized that these comments are not the results of specific tests for such properties but are included only to indicate a need for careful consideration of other behavior characteristics than those evaluated in this report.

SK paint - appreciable difficulty was encountered in spraying this paint, even with heavy duty equipment, because the paint formed a "skin" that clogged the spray gun.

Albi 99 - the samples of this paint on plywood, for water vapor permeability tests, checked and cracked, apparently due to the high humidity; required heavy duty spray equipment.

Bar Fire 1-48 - this paint showed a slight tendency to powder when dry.

Fireban - this material exhibited hygroscopic properties under high humidity conditions; it powdered and was brittle.

Kerloid 1197 - this material showed hygroscopic properties under high humidity conditions; it cracked and flaked from a few spots during aging.

Kerloid 1198 - specimens coated with this material showed hygroscopic properties under high humidity conditions.

Kerloid vehicle (primer) - Under high humidity exposure conditions this material appeared to bleed through Kerloid 1197 and 1198, staining them brown and forming small drops on the surface.

Flintkote - stained through Albi 99, even with polyvinyl acetate primer; Flintkote surface remained soft.

Flintkote primer - ran and dripped at coverage used.

Permalume - surface remained soft.

Permaphane - was brushed on because it was found very difficult to spray; made cobwebs when sprayed.

DuPont Sealer Coater - did not prevent severe "bleeding" of Flintkote through to subsequent Albi 99 coat.

Aluminum - considerable care was required to get it on smoothly.

Aluma-life Armor Plate - would require very heavy duty equipment if sprayed.

The aforementioned items may be of interest and may warrent further consideration in any choice of materials. No attempt was made to include these items in the evaluations of the materials. Neither were any procedures carried out to evaluate any of the materials as to permanence, abrasion resistance, ease of cleaning, resistance to cleaning solutions, staining, light, or atmospheric conditions such as warmth, cold, high or low humidity (aside from vapor permeability) or chemical composition of the atmosphere to which exposed. No evaluation was made of the fire and health hazards that might be associated with the application of the various materials.

6. Summary and Discussion

A summary of the original data obtained for flame spread and water vapor permeability together with the relative ranks of the specimens derived from the data are given in Tables 2, 3, 4 and 6. The derivation of rankings from the flame spread data did not include the consideration of smoke production. Neither was the flash index included in the radiant panel method of ranking.

Consideration of the smoke data was omitted from the derivation of the rankings so that the latter would be based on data related to the development of a fire on a surface. Smoke is of importance in that it may interfere with evacuation of a building or with fire-fighting therein but is not a direct indication of the fire intensity. All data utilized in the rankings were measurements of the ignition or flame spread characteristics of the specimens.

In order to present a more simple tabulation of the results and to facilitate comparisons among the results obtained by the different methods, the specimens have been grouped according to the data. Each group covers a range of data. The ranges for the first three groups were kept approximately equal, and the fourth group included all specimens not in one of the first three. The choice of the ranges, and of the number of groups, was arbitrary. The smoke measurement data from the radiant panel method tests has been used as the basis for a separate grouping. The groups, and the corresponding ranges of data, are given in Table 7.

The degree of agreement between the relative ranking of any specimen by the SS-A-118b method and by the radiant panel fire index was affected by the differences in the test methods and by the nature of the materials in the specimen. In general, specimens with a bright highly reflective surface were significantly higher in the relative ranking by the radiant panel fire index than in that by the SS-A-118b method. This is as would be expected since such surfaces act as reflectors of radiant energy. However, the burner flame in the SS-A-118b method tests was in contact with the specimen surface for all but the first $3\frac{1}{2}$ to $4\frac{1}{2}$ minutes. Therefore, the ranking of the reflector of radiant

energy is lower by that method than the ranking of the insulator against heat transfer by conduction.

The fire exposure to which an interior surface finish is subjected in the event of a fire may be characterized by one or more types of heat transfer. As a result, the use of both of these methods for evaluation of flame spread characteristics appears desirable.

Table 1. Schedule of specimen assemblies for tests.

Under the specimen number the letters of the alphabet are placed on fire or high humidity, b the next material, etc. The average coverage of 2.1 through 2.20 for descriptions of materials.

Material \ Specimen No.	1	2	3	4	5	6	7*	8	9	10	11	12	13
SK (2 cts,330 ft^2/gal ea)			a							a			
Albi 99 (1 ct 200 ft^2/gal)				a					a			a	a
Dex					a	a	a						
Dex R								a	b				
Dxpr						b		b	c				
Al										b	a	b	b
Crlx No. 1													
Crlx No. 2													
Crlx No. 3													
PVA													
Flkt (1 ct,250 ft^2/gal)													
Flpr (1 ct,250 ft^2/gal)													
Prlu (1 ct,460 ft^2/gal)													
Prph (1 ct,440 ft^2/gal)													
Al Life-F (1 ct,650-700 ft^2/gal)													
Al Life-V (1 ct,440 ft^2/gal)													
Al Life-P (1 ct,35 ft^2/gal)													
SK (as SK above)					b		b	c		c		c	c
Ker 7 (2 cts,125 ft^2/gal ea)													
Ker 8 (2 cts,125 ft^2/gal ea)													
BdrF (2 cts, 125 ft^2/gal ea)													
Fban (1 ct, 32 ft^2/gal)													
Xply		a	b	b	c	c	c	d	d	d	b	d	
Har	a												d
SK (as SK above)													e
TESTS													
Flame spread	x	x	x	x	x	x	x	x	x	x	x	x	x
Vapor permeability	x	x	x	x	x	x							
Decomposition products	x	x	x	x	x				x				
Flammability													

*Tested with 24 hours air-dry curing; no accelerated curing.

.ine with the materials used; the letter a being the material exposed to
aterial is given in parentheses after the name abbreviation. See Sections

4	15	16	17	18	19	20	21	22	24	25	26	31	32	33	34	35	36	37	38	39	40	41
				a	a											a	a	a				a
				.		a	a															
a b		a b		b c d				a											a b			
	a b		a b		b c									a						a b		
						b	b	b		a				b c d	a						a	b
									a		a	a	a									
c	c	c	c	e	d	c	c	c	b	b	b	b	b	e f	b c						b c	c d
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
x	x	x	x	x	x		x		x					x	x	x					x	x
		x	x	x	x	x	x	x	x							x	x	x	x	x		
																x						

Table 2. Data from flame spread

All averages are those of three samples. All durations 20 min because it was doubtful that any of the samples would have remained by individual samples fell into different classifications under SS-A-118b into the same classification.

Specimen	Materials	SS-A-118b Classification	Time to Flame		Time Flame First Touched Angle	
			Av m:s	Range m:s	Av m:s	Range m:s
1	Har	D	4:46	4:27-5:00	7:43	5:05-9:45
2	Xply	D	4:37	4:16-4:50	5:35	4:45-7:00
3	Xply;SK	D	4:49	4:30-5:10	4:55	4:32-5:15
4	Xply;Albi 99	D	6:02	4:55-7:10	10:38	7:40-12:1
5	Xply;SK;Dex	D-D-C*	6:24	4:28-8:20	11:47+	4:30-20:0
6	Xply;Dxpr;Dex	C	12:46	9:05-19:00	20:00+	> 20
7	Xply;SK;Dex[a]	C-C-D*	4:57	4:22-6:00	14:51+	4:33-20:+
8	Xply;SK;Dxpr;Dex R	C	6:47	6:40-7:02	20:00+	> 20
9	Xply;Dxpr;Dex R;Albi 99	C	10:07	9:00-11:00	20:00+	> 20
10	Xply;SK;Al;SK	C-C-D*	4:38[c]	4:32-4:45[c]	18:45+	16:15-20:
11	Xply;Al	D	7:52	7:20-8:40	11:30	10:40-12:
12	Xply;SK;Al;Albi 99	C-C-D*	15:29	12:01-17:20	18:08+	14:25-20:
13	SK;Har;SK;Al;Albi 99	C	15:00	11:17-18:30	20:00+	> 20
14	Xply;Flpr;Flkt	D	4:43	4:25-4:55	4:49	4:32-5:0
15	Xply;Prph;Prlu	D	4:38	4:24-4:45	4:51	4:48-4:5
16	Har;Flpr;Flkt	D	4:38	4:30-4:40	4:48	4:33-5:0
17	Har;Prph;Prlu	D	4:27	4:20-4:35	4:52	4:45-4:5
18	Xply;Flpr;Flkt;Pva;Albi99	D	5:48	3:20-8:05	9:07	6:42-10:5
19	Xply;Prph;Prlu;Albi 99	D-D-C*	6:42	6:15-7:05	13:42+	9:20-20:
20	Xply;SK;Crlx No. 1	C	4:36	4:20-4:50	20:00+	>20
21	Xply;SK;Crlx No. 2	D	4:24	4:20-4:30	4:42	4:38-4:4
22	Xply;SK;Crlx No. 3	C-C-D*	4:11	4:00-4:17	18:00+	6:00-20:
24	Xply;Fban	D	6:05	5:55-6:20	8:12	7:10-9:5
25	Har;SK	D	4:44	4:35-4:50	7:03	6:23-8:0
26	Har;Bar-F	C	7:51	7:00-8:30	20:00+	>20
31	Har;Kerl 7	D-D-C*	5:01	4:37-5:42	11:47+	7:02-20:
32	Har;Kerl 8	D-D-C*	12:44[c]	8:57-16:30[c]	15:29+	9:14-20:
33	SK;Har;SK;Al Life-P; Al Life-V;Al Life-F	D	4:03	3:50-4:20	9:01	8:07-10:
34	SK;Har;SK	D	5:23	4:38-6:05	6:25	6:03-6:4

+Time given includes use of 20 min 0 sec time for specimens that did not flame to angle during test.

[a]Tested 24 hours after preparation, no accelerated aging.

[b]Lightly scorched over indicated diameter; no char.

[c]One of three samples did not flame during test, average based on other two samples.

*Note: According to SS-A-118b, when samples of the same specimen fall in different classifications, the lower shall apply to the specimen; therefore, D classification would apply.

tests by SS-A-118b method

except specimens 14, 15, and 17 which were stopped in 10 to 14 min 20 min. In tests of specimens 5, 7, 10, 12, 19, 22, 31 and 32 the as indicated. For the remaining specimens, all three samples fell

Elapsed Time For Flame Advance to Angle m:s	Hole Through Diameter		Diam of Char, Av		Continued Flaming		Smoke
	Av in.	Max in.	Exp in.	Rev in.	Av m:s	Max m:s	
2:57	6	6	16	11	0:15	0:20	M
0:58	12		28	22		0:12	
0:06	11	12	24	14	0:23	0:30	H
4:36	7	10	17	12	0:43	0:50	
5:23+	None	None	26	11	0:00	0:00	VH
7:14+	None	None	23	10	0:00	0:00	H
9:54+	None	None	25	13	0:04	0:12	VH
13:13+	None	None	22	12	0:00	0:00	VH
9:53+	None	None	12	6[b]	0:00	0:00	H
14:07+	1	3	30	11	0:43	1:20	L
3:38	14	18	19	22	1:03	1:15	L
2:39+	Crack	1	22	12	0:38	1:02	M
5:00+	Crack	½	23	12[b]	0:47	0:54	M
0:06	10	14	30	16	0:56	1:20	M-H
0:13	12	18	30	24	0:59	1:05	M
0:10	12	14	30	21	0:57	1:30	
0:25	11	14	29	20	1:20	1:52	
3:19	9	11	25	14	0:42	0:53	M
7:00+	7	8	21	11	0:24	0:30	L-H
15:24+	None	None	11	11	0:00	0:00	VH-Ac
0:18	None	None	30	9	0:00	0:00	VVH
13:49+	None	None	20	11	0:00	0:00	H-Ac
2:07	13	16	26	19	1:55	4:25	
2:19	5	7	23	12	0:23	0:27	L-M
12:09+	None	None	16	6[b]	1:00	1:33	M
6:46+	4	7	19	13	0:23	0:32	L
2:45+	None	None	Blister	11	0:11	0:29	L-M
4:58	8	12	28	20	0:36	1:10	H-VH
1:02	7	8	25	11	0:16	0:21	L-M

Table 3. Evaluation of data derived from horizontal panel tests (SS-A-118b)

This table gives rank positions, the criteria by which rank positions are determined, and the specimens, by number, having the rank positions. The rank positions under the three headings are totaled for each specimen. The relative rank of each specimen is given, as indicated by the total of rank positions, and indicates apparent relative merit, a low total representing better performance than a higher total.

Rank Position	Time to Flame		Time for Flame to Reach Angle		Damage to Reverse Side		Specimen Number	Total of Rank Positions	Relative Rank
	Criterion min	Specimen Number	Time min	Specimen Number	Criterion Dia of Char	Specimen Number			
1	20+(None)		20+	6,8,9,13, 20,26	None		1	41	18
							2	48	26
2	19-20		19-20				3	45	24
3	18-19		18-19	10,12,22	Scorch	9,13,26	4	36	14
4	17-18		17-18				5	35	12
5	16-17		16-17		3 in.		6	19	4
6	15-16	12,13	15-16	32			7	35	12
7	14-15		14-15	7	5		8	26	7
8	13-14		13-14	19	7		9	15	2
9	12-13	6,32	12-13		9	6,21	10	30	9
10	11-12		11-12	5,11,31	11	1,4,5,8,10,	11	39	16
						12,19,20,22,	12	19	4
						25,32,34	13	10	1
11	10-11	9	10-11	4	13	3,7,18,31	14	46	25
12	9-10		9-10	18,33	15	14	15	50	29
13	8-9		8-9	24	17		16	49	28
14	7-8	11,26	7-8	1,25	19	17,24,33	17	48	26
15	6-7	4,5,8,19,24	6-7	34	21	11,16,2	18	39	16
16	5-6	18,31,34	5-6	2	23	15	19	33	11
17	4-5	1,2,3,7,10,14,	4-5	3,14,15,	25		20	28	8
		15,16,17,20,		16,17,21			21	43	22
		21,22,25,33					22	30	9
18	3-4		3-4		27		24	42	21
19	2-3		2-3		29		25	41	18
20	1-2		1-2		30x30		26	18	3
							31	37	15
							32	25	6
							33	43	22
							34	41	18

TABLE 4. Summary of data obtained by radiant panel method, and computed indexes. Blank spaces indicate the feature corresponding to the column heading was not observed in the 15 min. test durati

SPECIMEN	MATERIALS	FLAME SPREAD		FLASH
		Time Flames to 3"	Time Flames to 12"	Time Flash to 6"
		min.	min.	min.
1	Har	2.35	5.16	1.10
2	Xply	0.73	2.55	-
3	Xply;SK	0.70	8.25	-
4	Xply;Albi 99	1.30	11.10	2.40
5	Xply;SK;Dex	1.50	2.10	0.30
6	Xply;Dxpr;Dex	4.00	-	0.48
7	Xply;SK;Dex	5.90	5.90	0.25
8	Xply;SK;Dxpr;Dex R	-	-	3.40
9	Xply;Dxpr;Dex R;Albi 99	0.60	-	0.47
10	Xply;SK;Al;SK	0.16	-	-
11	Xply;Al	-	-	-
12	Xply;SK;Al;Albi 99	-	-	-
13	SK;Har;SK;Al;Albi 99	-	-	0.91
14	Xply;Flpr;Flkt	2.80	11.25	-
15	Xply;Prph;Prlu	1.65	9.80	-
16	Har;Flpr;Flkt	4.25	-	0.41
17	Har;Prph;Prlu	5.42	14.20	-
18	Xply;Flpr;Flkt;Pva;Albi 99	1.65	-	0.20
19	Xply;Prph;Prlu;Albi 99	2.15	-	2.60
20	Xply;SK;Crlx No. 1	-	-	4.25
21	Xply;SK;Crlx No. 2	0.96	4.11	-
22	Xply;SK;Crlx No. 3	0.80	5.15	-
24	Xply;Fban	2.00	-	2.55
25	Har;SK	0.39	-	-
26	Har;Bar F	9.50	-	0.57
31	Har;Kerl 7	-	-	-
32	Har;Kerl 8	-	-	-
33	SK;Har;SK;Al Life-P; Al Life-V;Al Life-F	2.80	2.90	-
34	SK;Har;SK	0.88	-	-

*Based on Fire Index

REACTION INTENSITY Net Peak Stack Temp. Rise	SMOKE Avg Weight of Deposit	FIRE Index	FLASH Index	RELATIVE RANK*
Deg. C	mg			
70	0.9	35	.61	21
108	0.3	106	-	29
83	1.0	45	-	25
70	1.2	26	.28	20
58	2.7	58	2.2	26
57	3.6	8.8	1.4	10
41	3.2	17	2.7	17
56	3.0	5.6	.20	7
24	1.7	9.1	1.4	12
36	1.2	41	-	24
9	0.1	0.9	-	1
56	1.0	5.6	-	6
23	1.1	2.3	.73	2
76	0.8	23	-	18
67	1.1	25	-	19
65	2.0	9.0	1.6	11
38	1.7	9.4		13
33	1.5	6.6	3.3	9
78	1.2	14	.26	15
56	6.8	5.6	.16	8
94	25.8	64	-	27
57	15.5	36	-	23
65	1.0	12	.26	14
68	1.2	36	-	22
23	1.2	2.7	1.2	3
44	0.4	4.4	-	5
31	0.6	3.1	-	4
117	1.8	86	-	28
59	0.7	17	-	16

Table 5. Flammability of Dexolium

Ignition was by the benzene drop method, given in ASTM D568-43. All Dexolium used had precoated adhesive on glass fabric.

Condition of Sample	Thickness in	Number of Specimens	Time of Flaming		Char Area	
			Av	Range	Av in^2	Range in^2
Glass Fabric On; No Activator	0.019-0.023	8	5.7	4.5-7.2	0.8	0.5-1.0
Glass Fabric Off, No Activator	0.015-0.017	8	6.8	5.0-8.6	1.1	0.9-1.25
Glass Fabric On, Activator applied	*					
½ hr drying		5	12.6	6.2-17.4	3.4	0.6-6.0
2 hr drying		5	11.4	4.7-28.0	3.8	1.25-12.0
Activator, Glass Fabric Off	*					
½ hr drying		4	8.5	4.8-13.5	2.5	0.7-7.0
2 hr drying		3	7.1	6.0-8.3	3.2	1.0-5.0

*Too soft to be "miked" after activator applied, probably within 0.002 in. of above.

Table 6. Water Vapor Permeabilities

The data obtained and the computed permeabilities are given, the latter in perms = grains/ft^2, hr, in. Hg. The values of moisture absorbed and transmitted represent the averages of three samples. The permeabilities of specimens 10, 11, 12 and 13 were assumed 0.0 perms from known characteristics of aluminum foil. Specimens 7, 8, 9, 20 and 22 were not tested because the vapor barrier materials in those specimens were in other tested specimens.

Specimen No.	Materials	Moisture absorbed (A)	Moisture absorbed and transmitted (A+T)	Permeability
		mg	mg	perms
1	Har	3404	5356	0.7
2	Xply	2936	8515	1.9
3	Xply;SK	900	1731	0.3
4	Xply;Albi 99	4212	6310	0.7
5	Xply;SK;Dex	78[a]	126	<0.1
6	Xply;Dxpr;Dex	460	607	<0.1
7	Xply;SK;Dex			[b]
8	Xply;SK;Dxpr;Dex R			[b]
9	Xply;Dxpr;Dex R;Albi 99			[b]
10	Xply;SK;Al;SK			0.0
11	Xply;Al			0.0
12	Xply;SK;Al;Albi 99			0.0
13	SK;Har;SK;Al;Albi 99			0.0
14	Xply;Flpr;Flkt	363	303	<0.1[c]
15	Xply;Prph;Prlu	3906	3850	<0.1[c]
16	Har;Flpr;Flkt	2648	2520	<0.1[c]
17	Har;Prph:Prlu	3946	7548	1.3
18	Xply;Flpr;Flkt;Pva; Albi 99	130[a]	223	<0.1
19	Xply;Prph;Prlu;Albi 99	218[a]	397	0.2
20	Xply;SK;Crlx No. 1			[d]
21	Xply;SK;Crlx No. 2	136	146	<0.1
22	Xply;SK;Crlx No. 3			[d]
24	Xply;Fban	266[a]	789	0.5
33	SK;Har;SK;AlLife-P; AlLife-V;AlLife-F	13[a]	103	<0.1
34	SK;Har;SK	667	803	<0.1
35	Dex(with adhesive)	22	1489	0.5
35	Dex(no adhesive)	33	1745	0.6
40	SK;Xply;SK	1261	1716	0.1
41	SK;Xply;SK;Dex	629	948	0.1

[a] These samples exposed to test conditions for about 120 hours, others about 300 hours.

[b] Not tested, see similar specimens 5 and 6.

[c] A greater than A+T, therefore permeability could not be computed but is indicated as low.

[d] Not tested, see similar specimen 21.

Table 7. Groupings by specimen number and evaluation method

The groups represent a simplification of the relative ranks; Group I indicates better performance than Group II, etc. The specimen numbers are given in numerical order within the groups. For relative rank see tables 3, 4, and 6. The groups are based on arbitrarily chosen ranges of data or computed numbers, as follows:

	SS-A-118b Sum of rank Positions	Radiant Panel		Water Vapor Permeability
		Fire Index	Smoke Weight	
			mg	perms
Group I	10-20	0-6.0	0-2.0	<0.1
II	21-30	6.1-12.0	2.1-4.0	0.1-0.5
III	31-40	12-18	4.1-6.0	0.6-1.0
IV	>40	>18	>6.0	>1.0

Groups by specimen numbers

	SS-A-118b	Radiant Panel		Water Vapor Permeability
		Fire	Smoke	
Group I	6,9,12,13, 26	8,11,12, 13,20,26, 31,32	1,2,3,4, 9,10,11, 12,13,14, 15,16,17, 18,19,24, 25,26,31, 32,33,34	5,6,7,8,9,10,11, 12,13,14,15,16, 18,20,21,22,33, 34
II	8,10,20, 22,32	6,9,16, 17,18,24	5,6,7,8	3,19,24,40,41
III	4,5,7,11, 18,19,31	7,19,34	---	1,4,35
IV	1,2,3,14, 15,16,17, 21,24,25, 33,34	1,2,3,4, 5,10,14, 15,21,22, 25,33	20,21,22	2,17

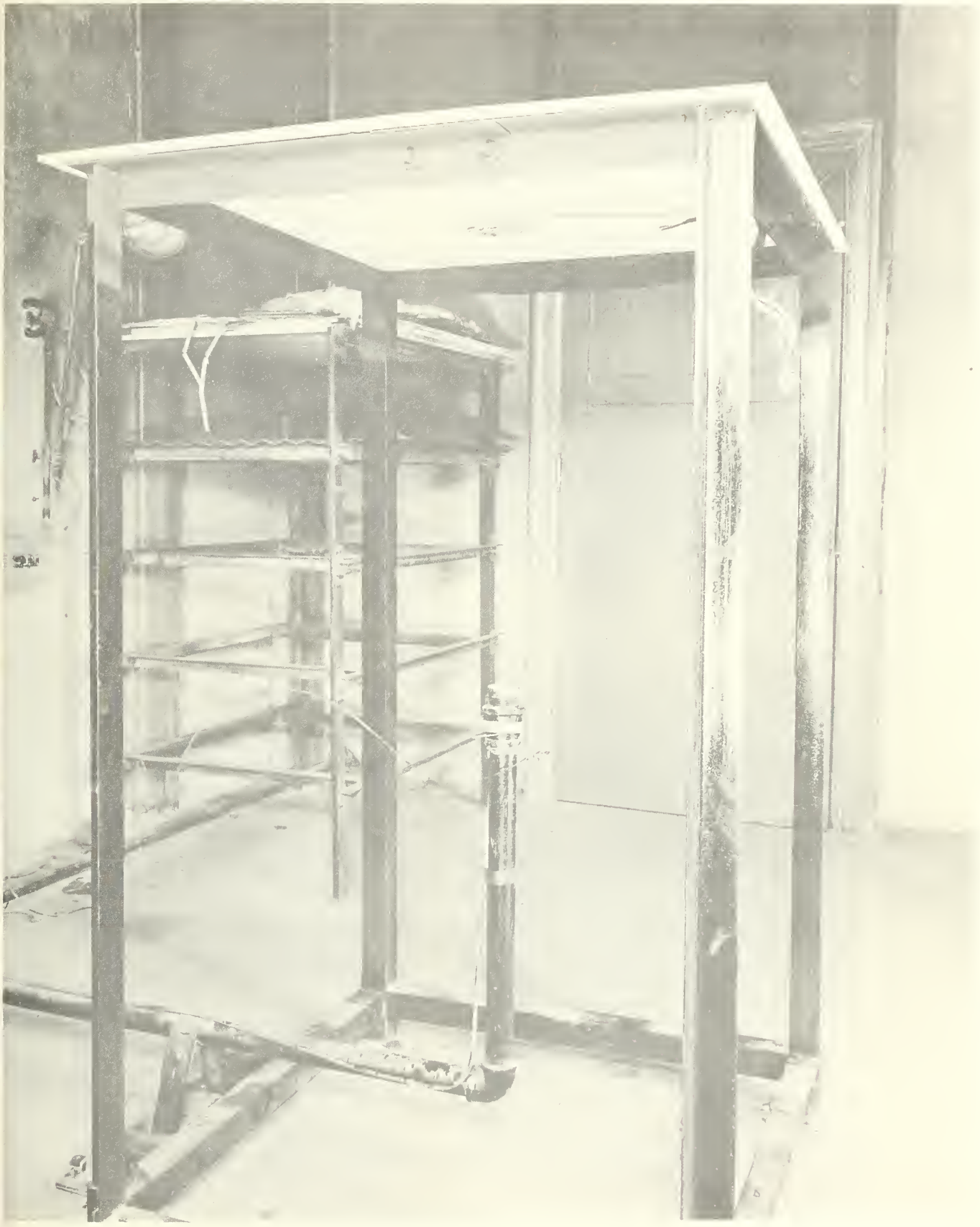
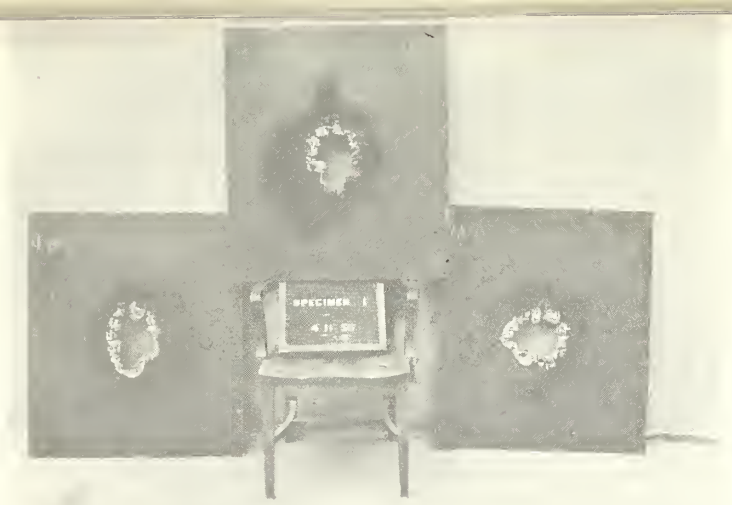
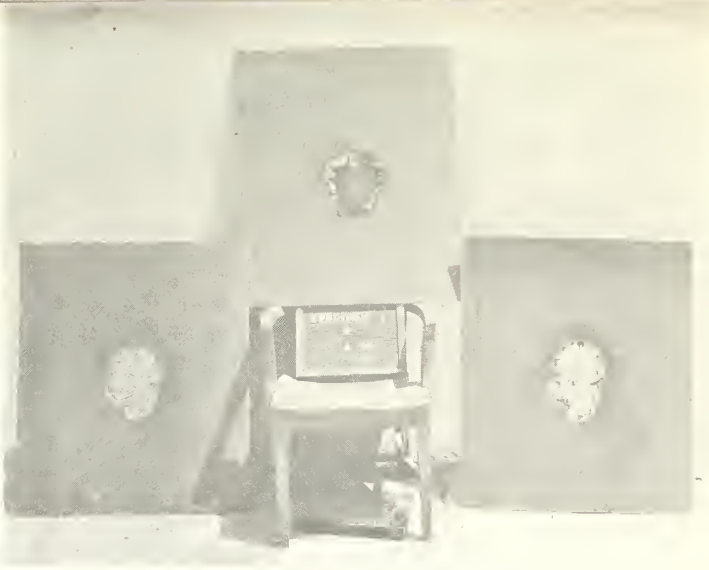


Fig. 1 Frame, burner, and thermocouple for SS-A-118b tests, with specimen in place.





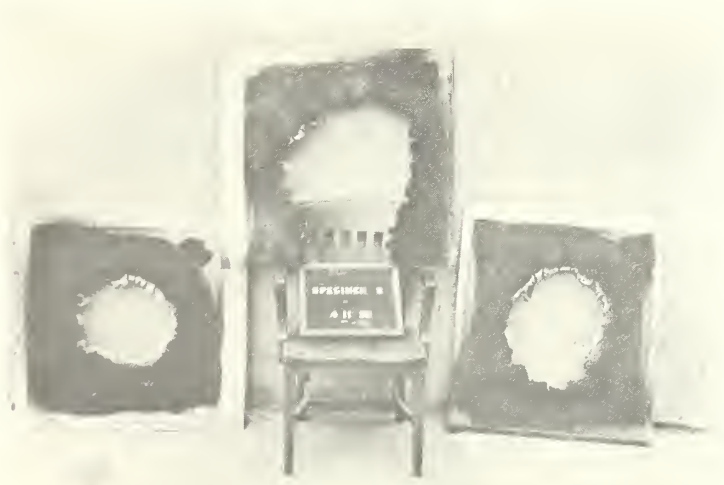
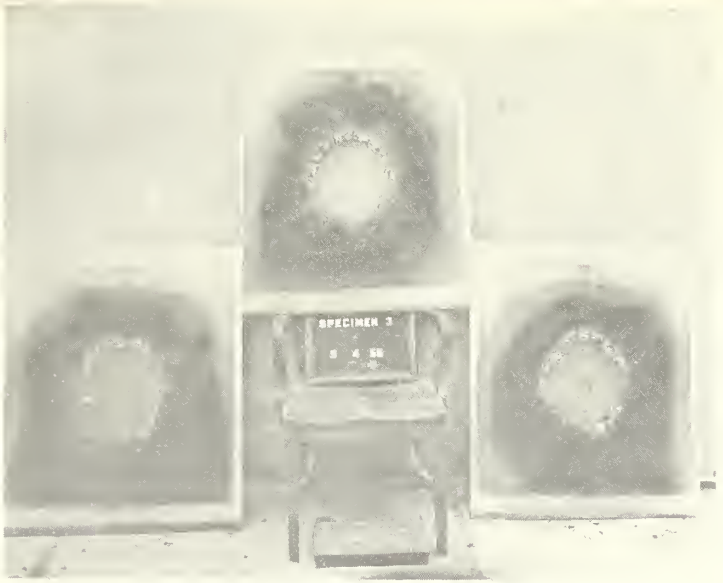
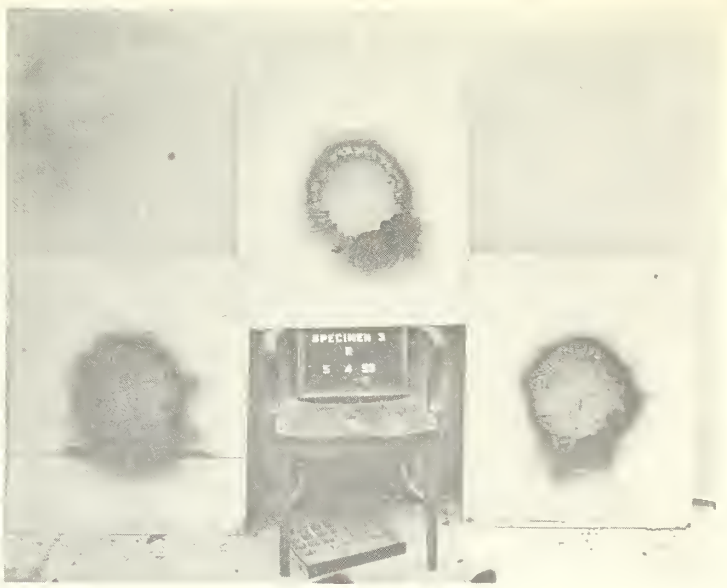


Fig. 2

Exposed Surface

Unexposed Surface





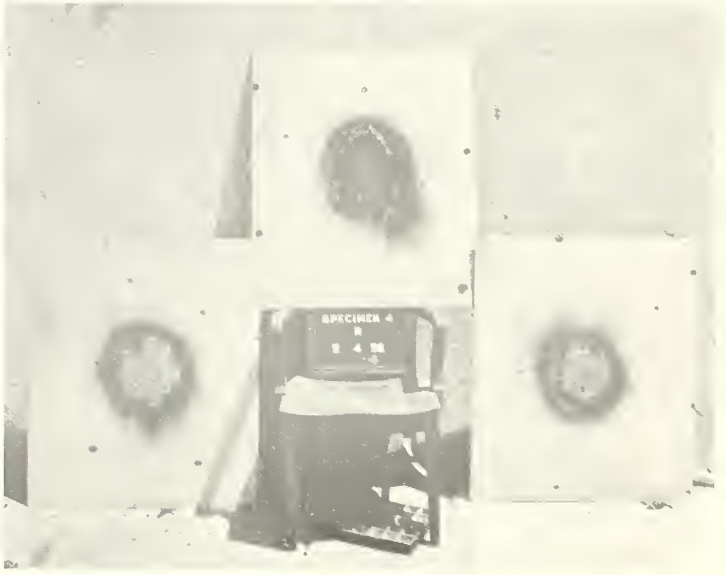
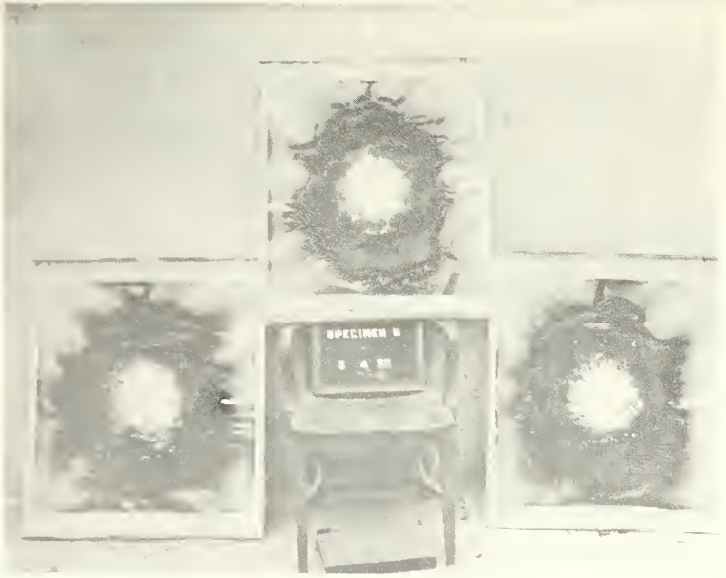
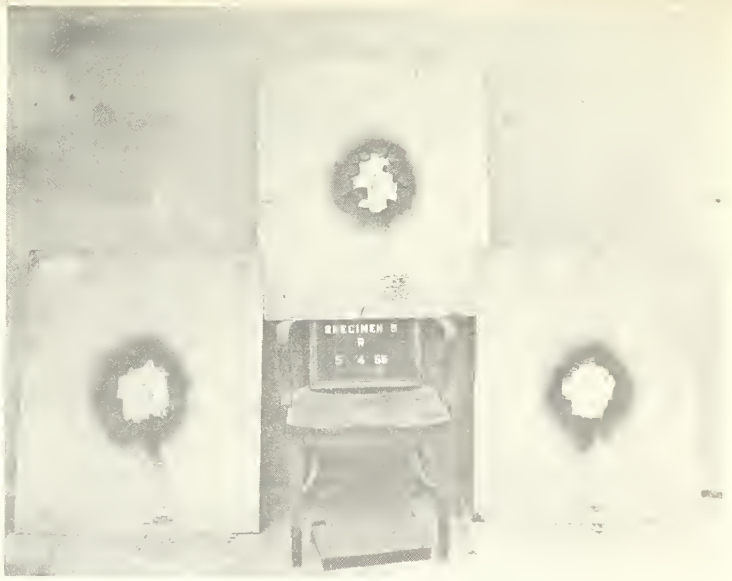


Fig. 3

Exposed Surface

Unexposed Surface





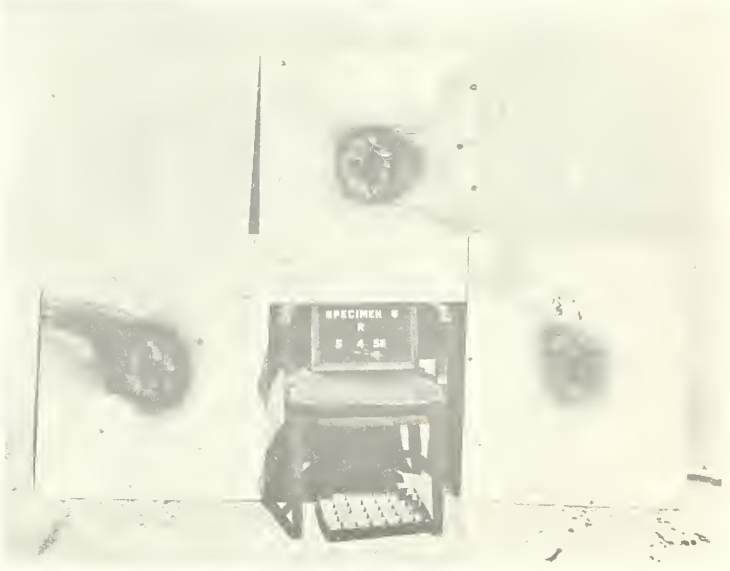


Fig. 4

Exposed Surface

Unexposed Surface

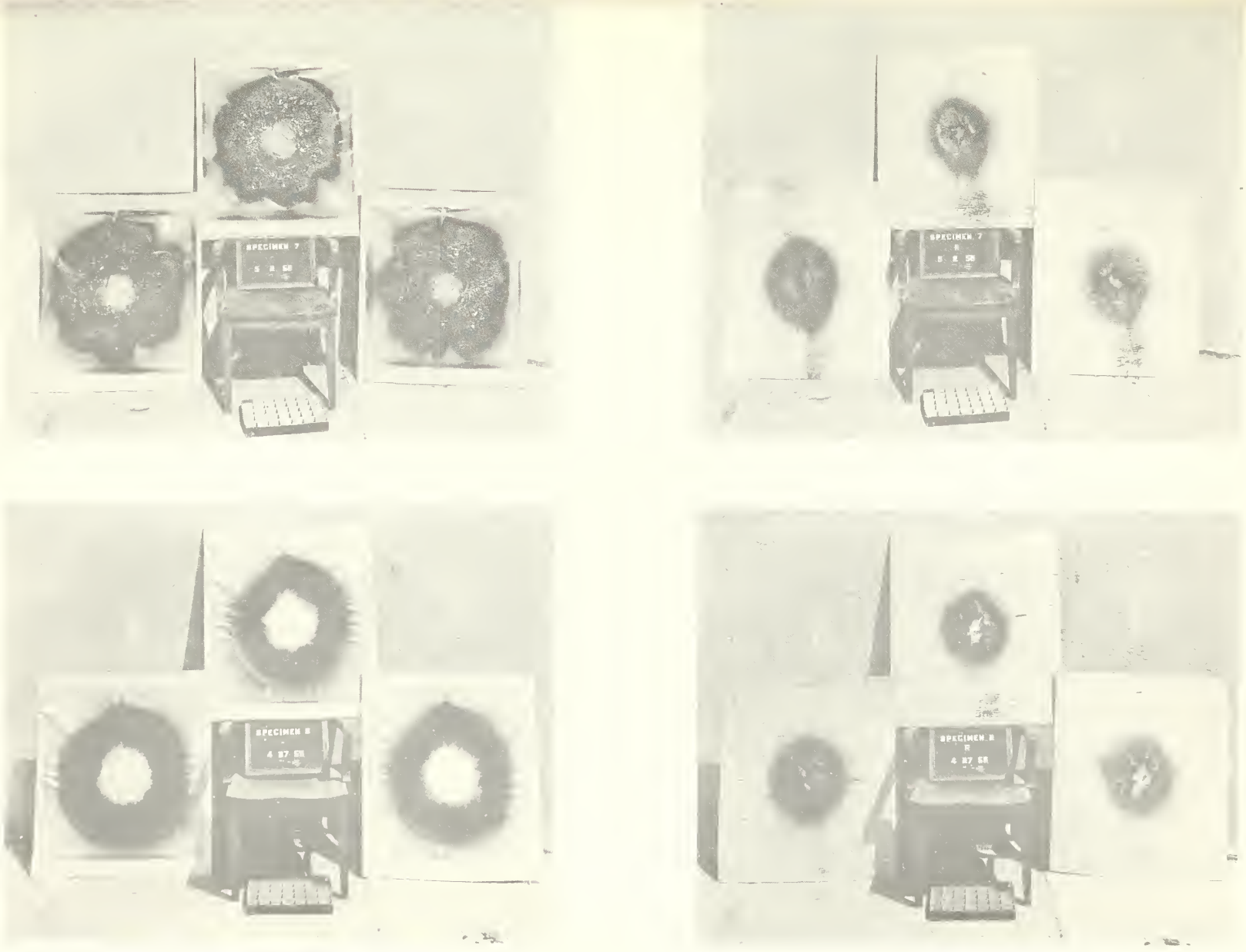
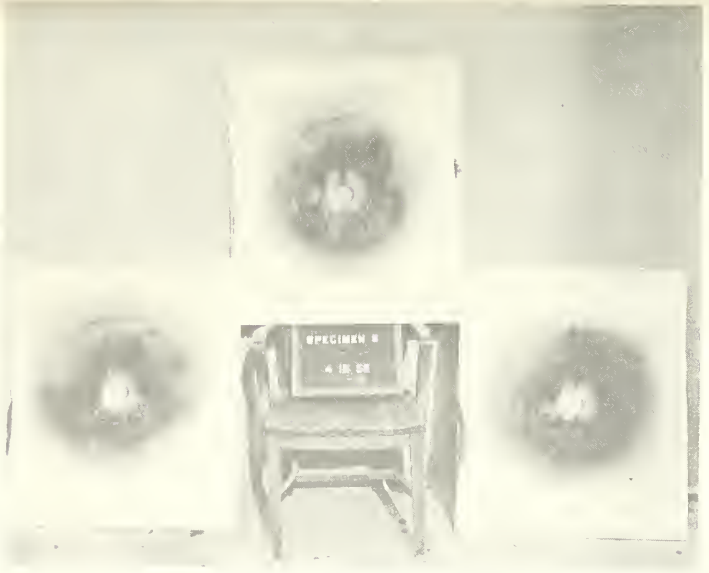


Fig. 5

Exposed Surface

Unexposed Surface



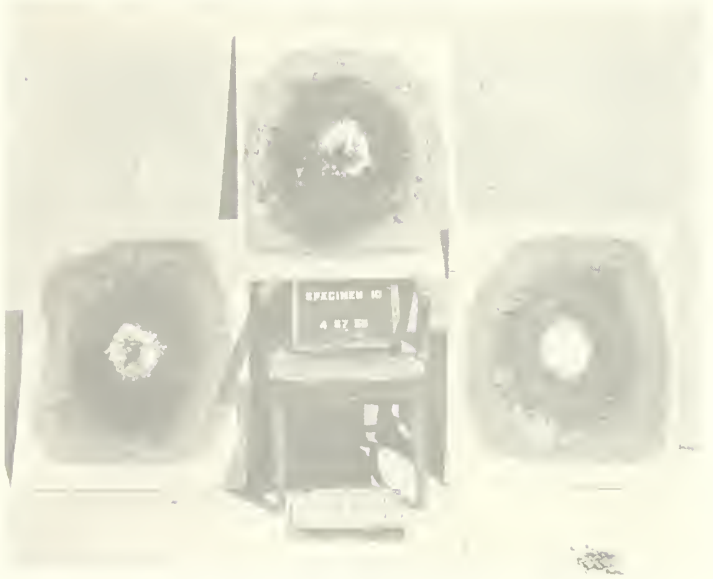


Fig. 6

Exposed Surface

Unexposed Surface

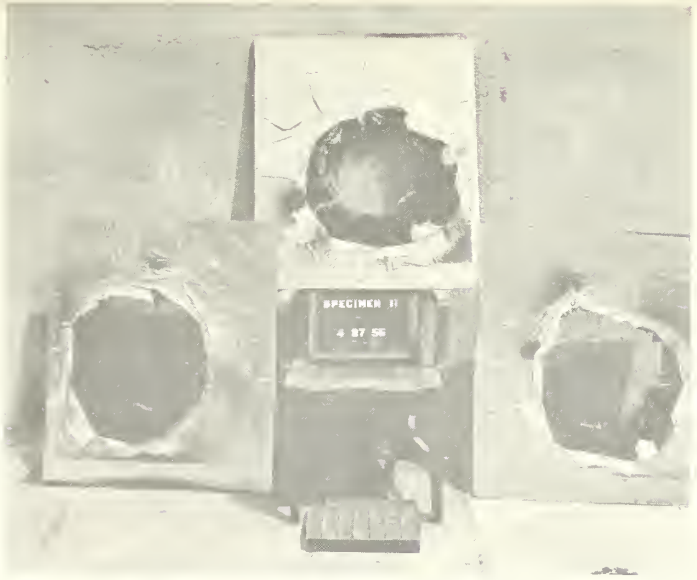
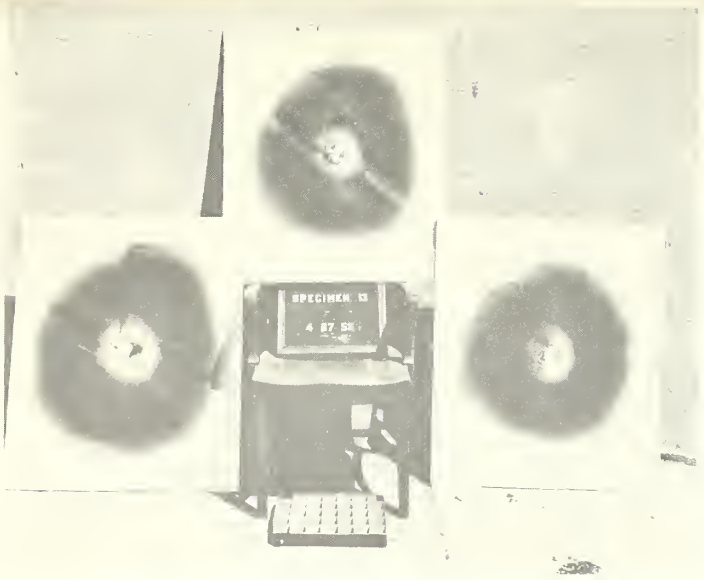
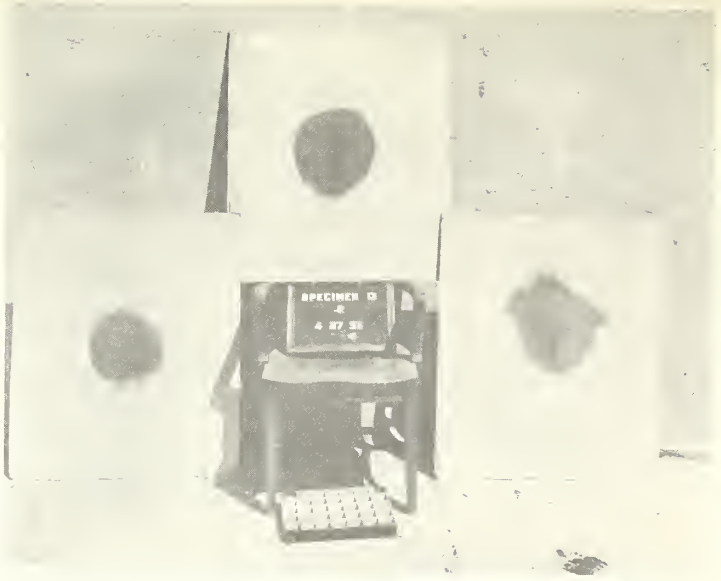


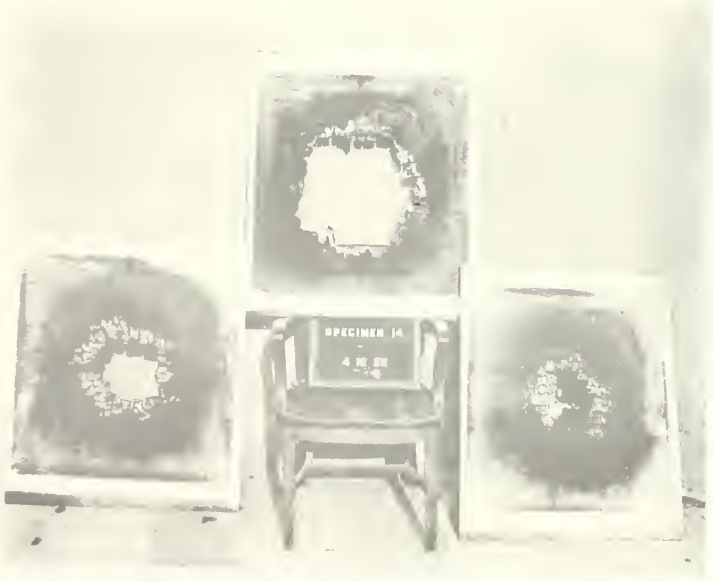
Fig. 7

Exposed Surface

Unexposed Surface







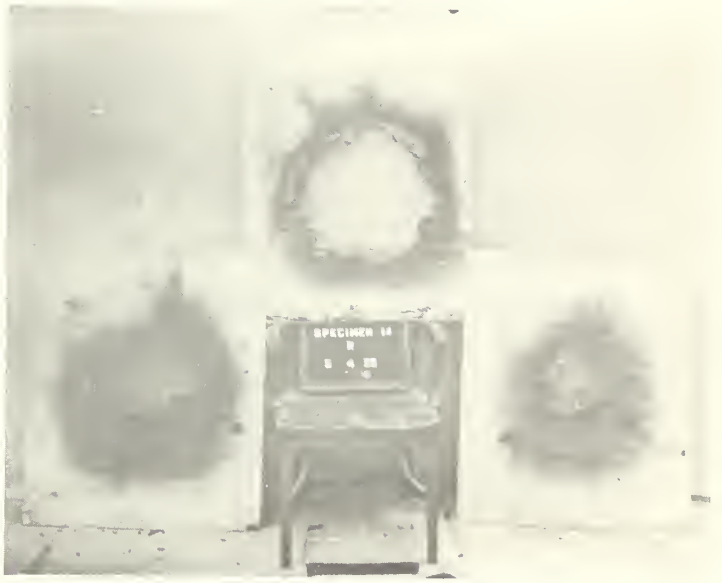
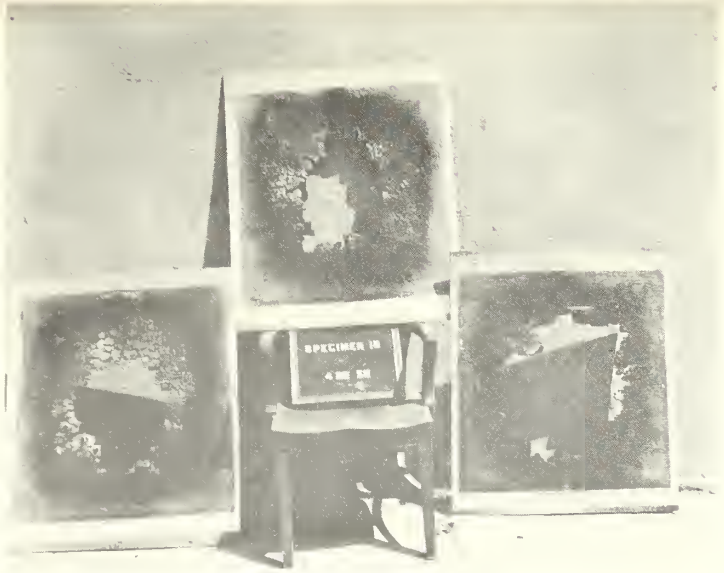


Fig. 8

Exposed Surface

Unexposed Surface



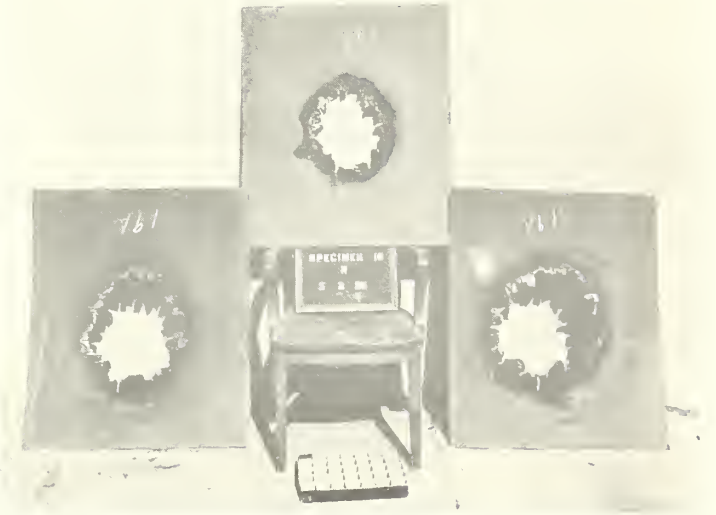
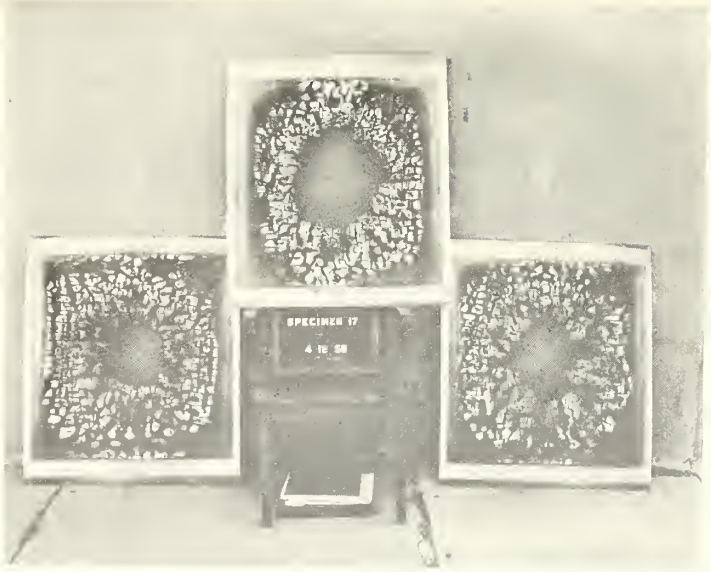


Fig. 9

Exposed Surface

Unexposed Surface



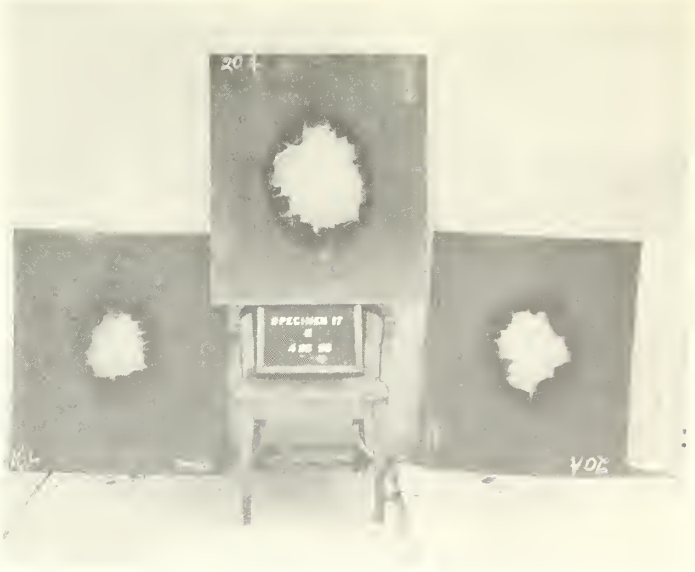
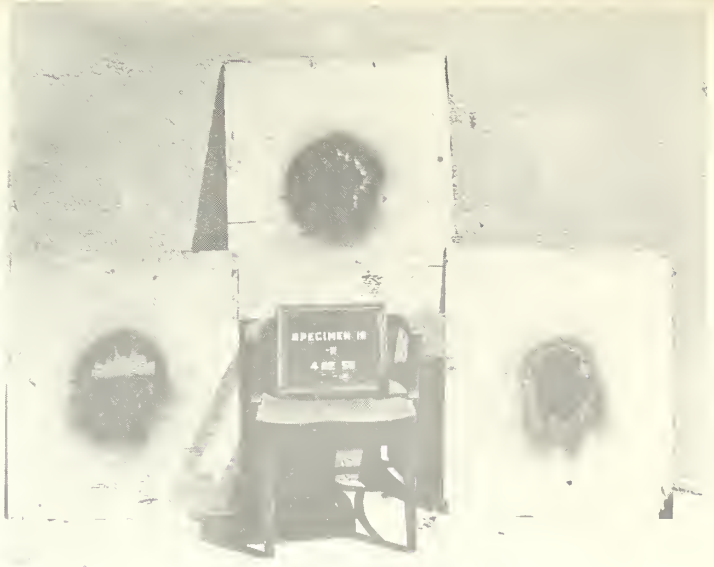


Fig. 10

Exposed Surface

Unexposed Surface



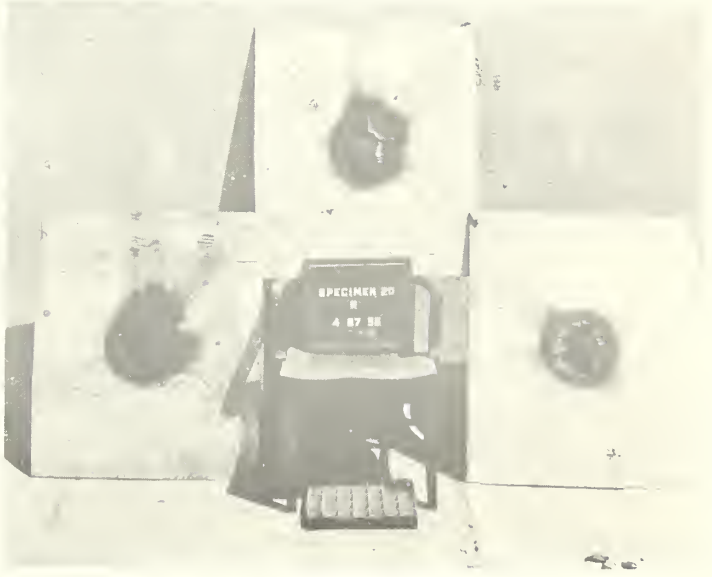
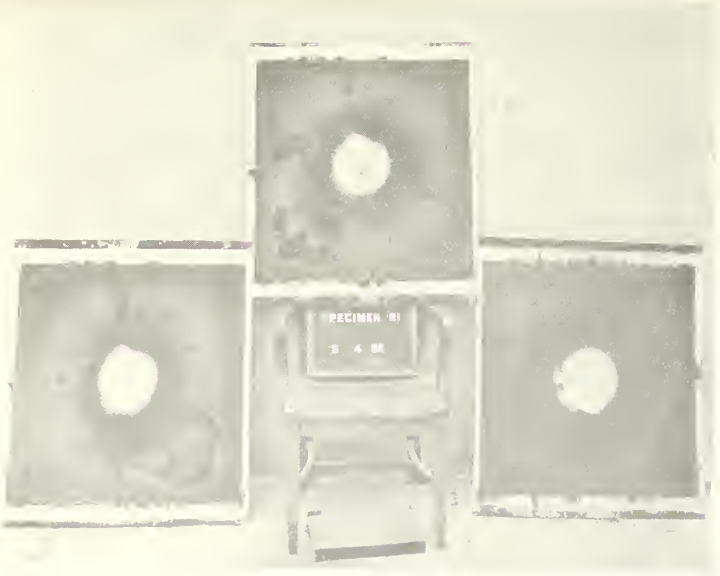
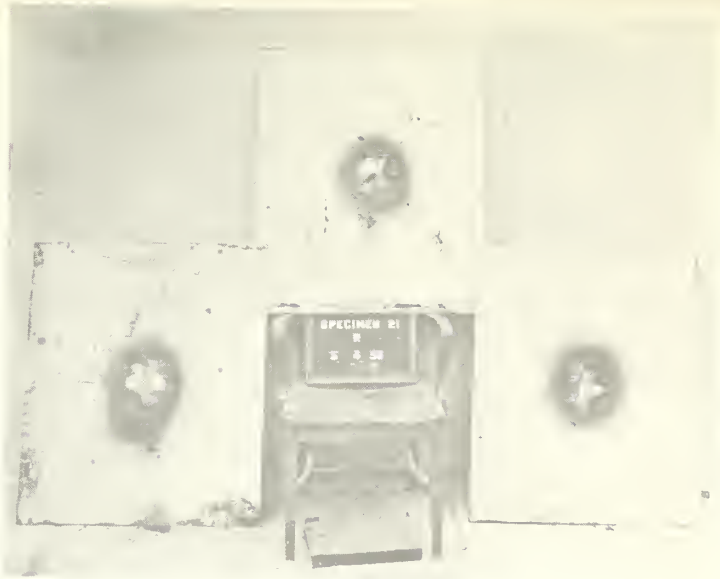


Fig. 11

Exposed Surface

Unexposed Surface





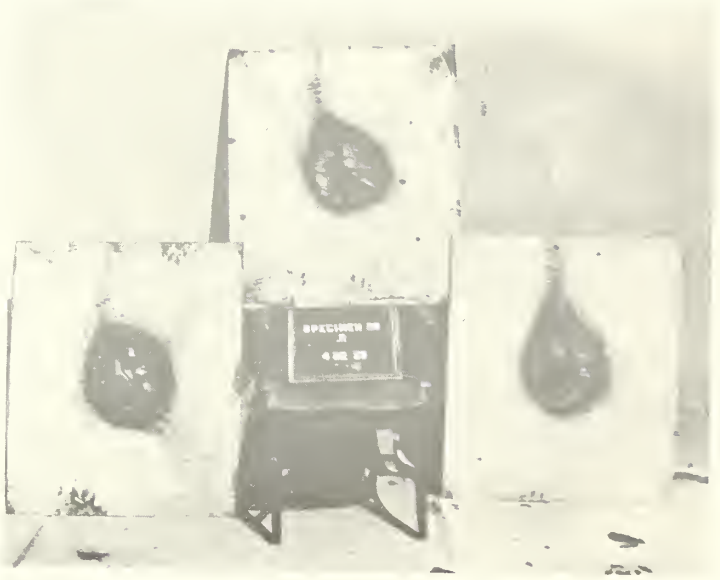


Fig. 12

Exposed Surface

Unexposed Surface

Fig. 13

Exposed Surface

Unexposed Surface

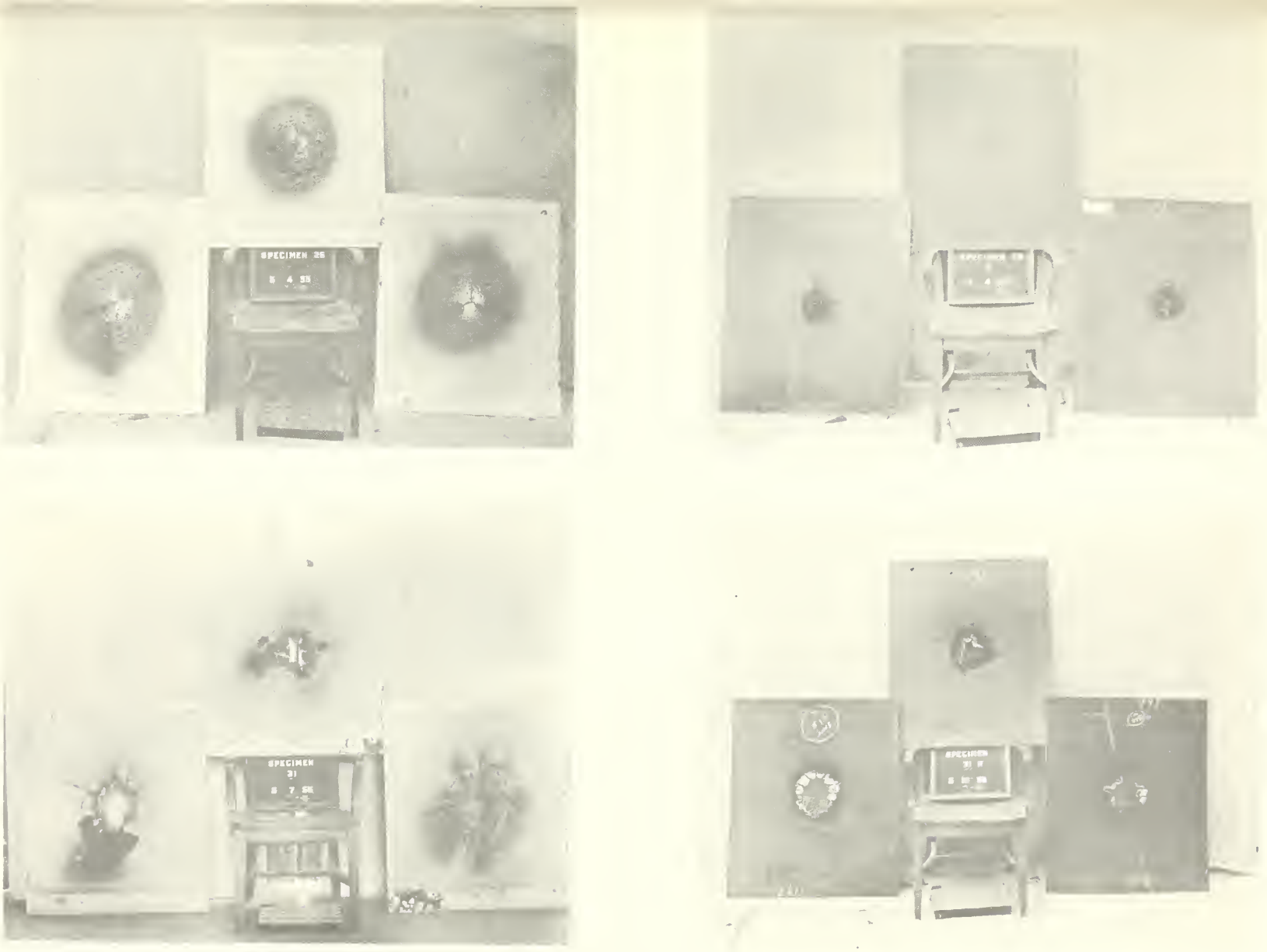


Fig. 14

Exposed Surface

Unexposed Surface

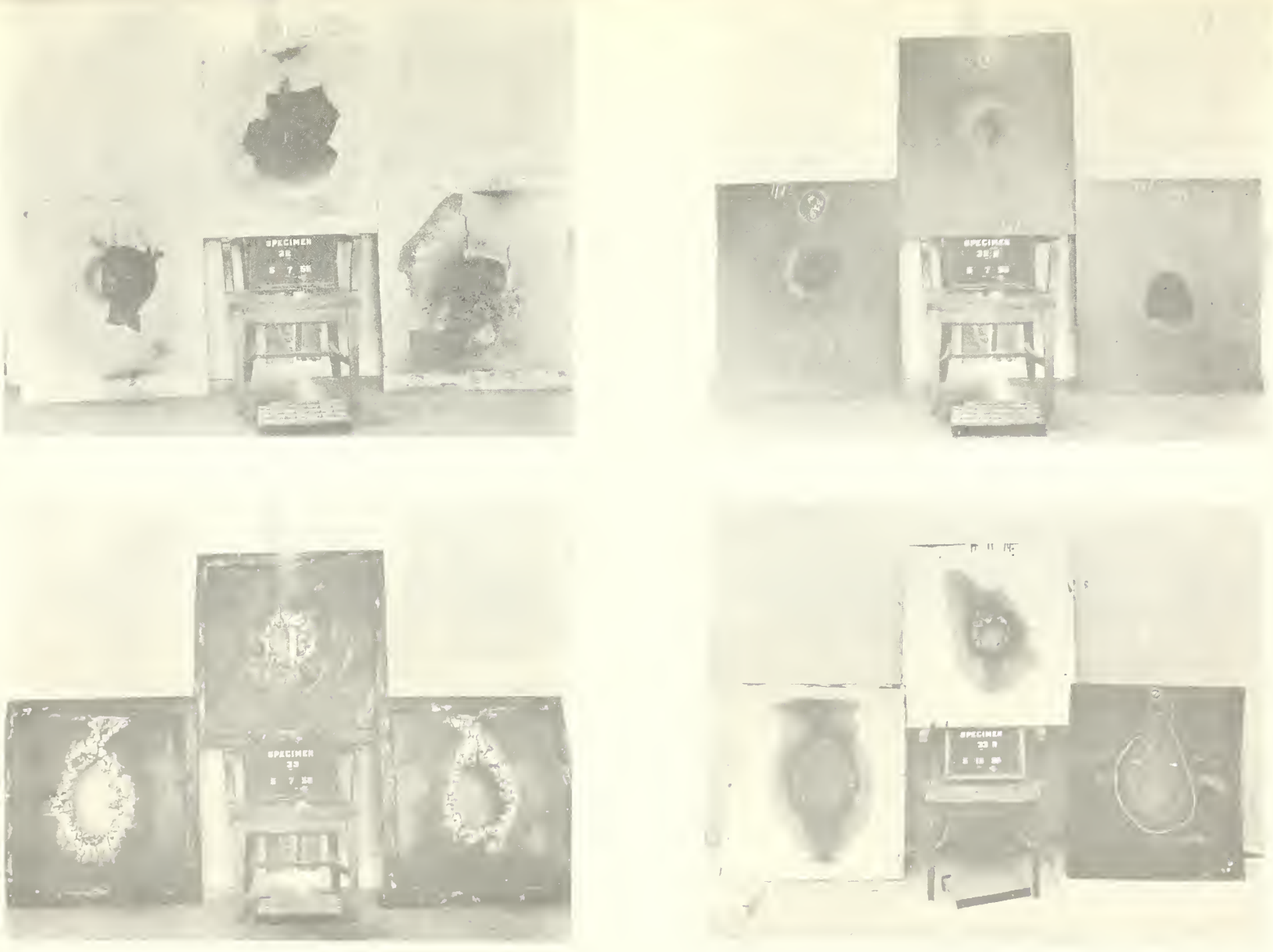


Fig. 15

Exposed Surface

Unexposed Surface

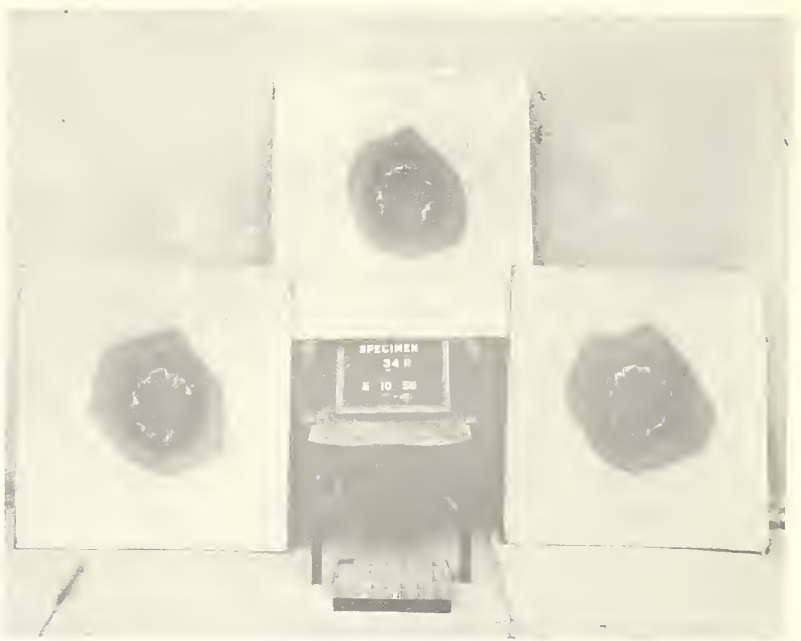


Fig. 16

Exposed Surface

Unexposed Surface

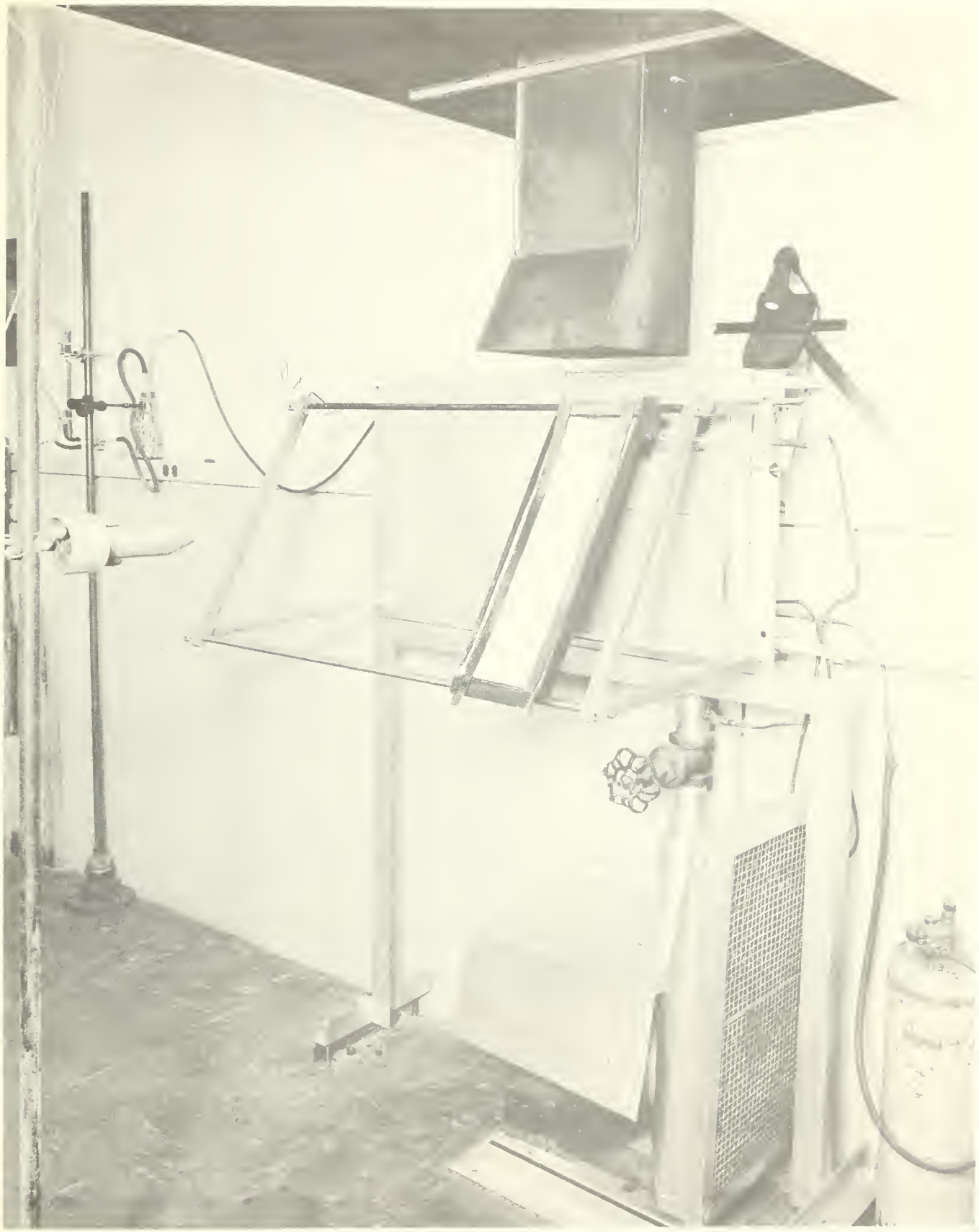


Fig. 17. Apparatus for radiant panel tests, with specimen in inclined frame.

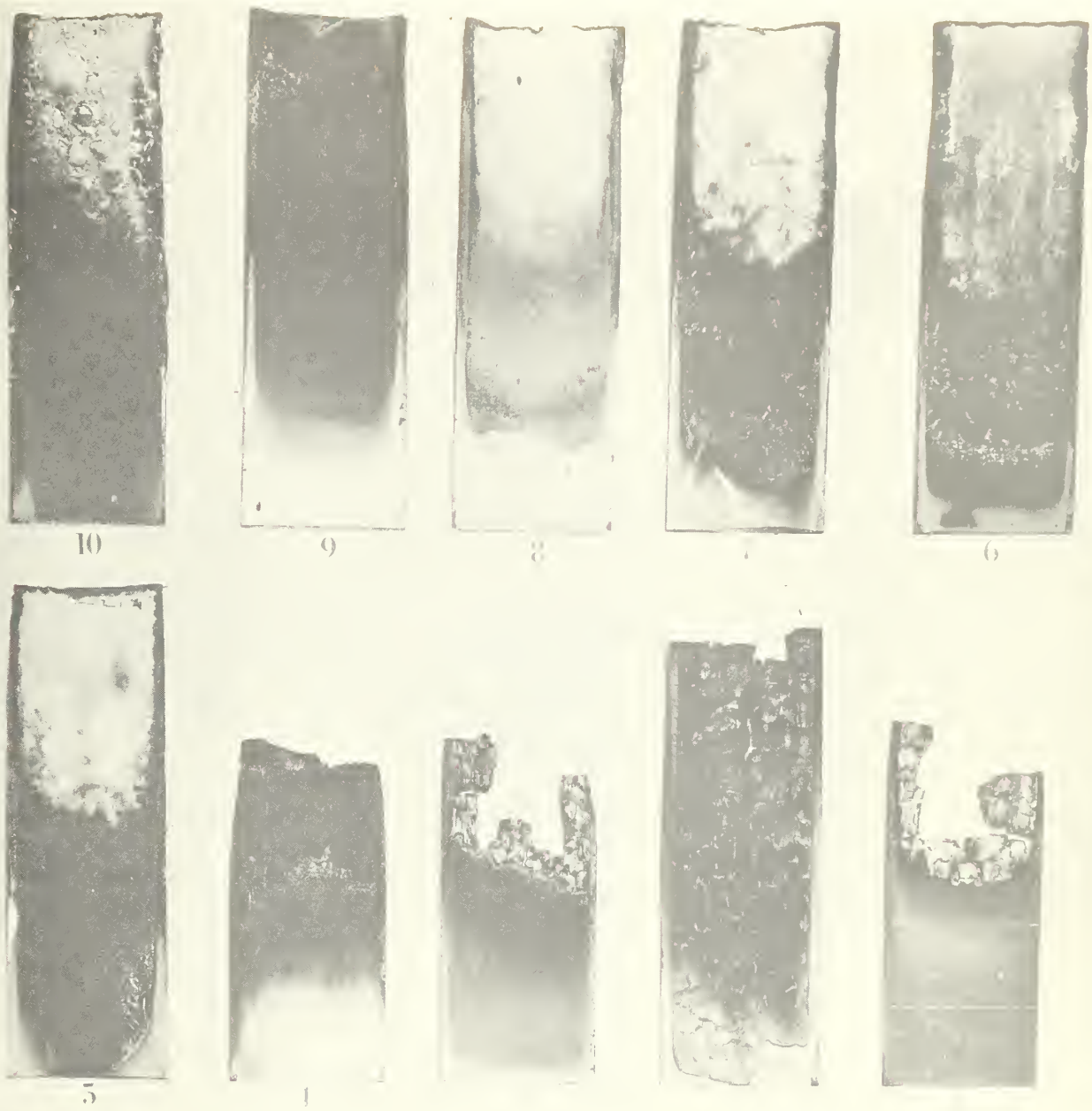


Fig. 18. Samples from radiant panel tests, with specimen numbers.

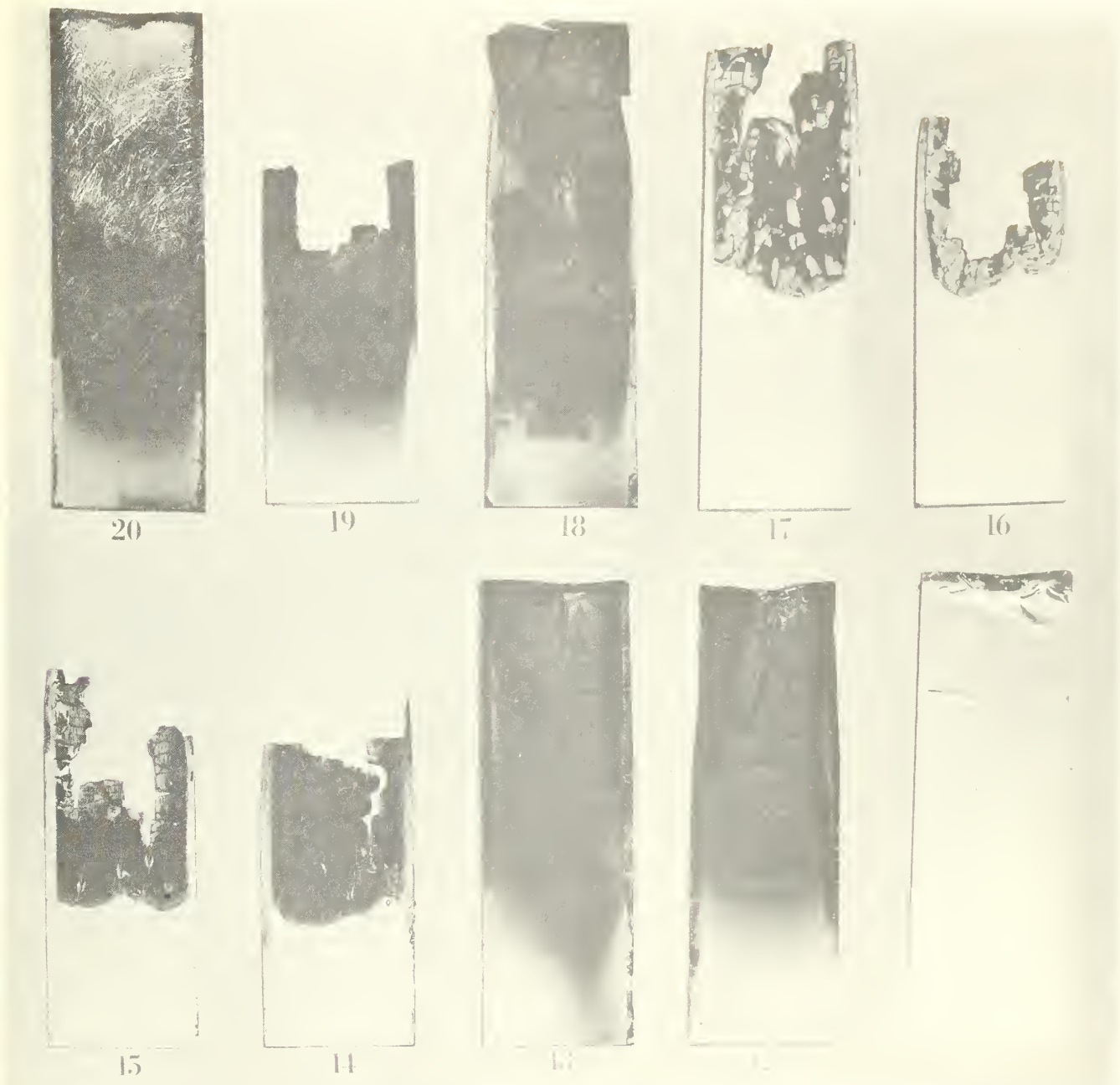


Fig. 19. Samples from radiant panel tests, with specimen numbers.

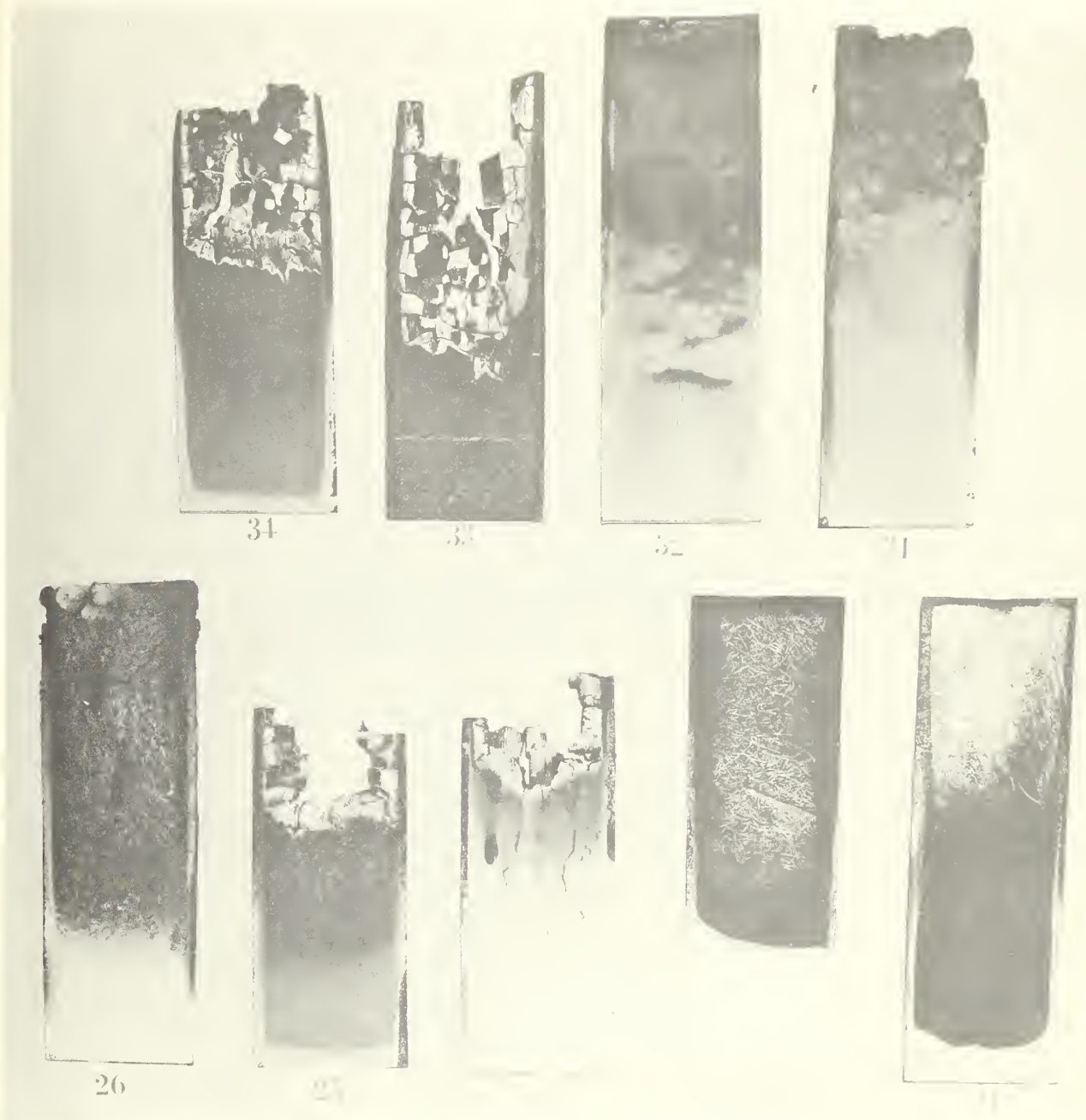


Fig. 20. Samples from radiant panel tests, with specimen numbers.

THE NATIONAL BUREAU OF STANDARDS

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