DETERIORATION OF FIBERBOARD BY MOLDS

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DETERIORATION OF FIBERBOARD BY MOLDS

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The mold resistance of fiberboard has been studied to provide a basis for recommendations on the relative merits of various types of commercial and of experimental fiberboards. The experimental fiberboards were prepared by the Division of Pulp and Paper of the Forest Products Laboratory.

The scope of these investigations includes:

(1) The relative amount of deterioration of various types of commercial fiberboards.

(2) The resistance to molding of various types of laminating adhesives used in commercial fiberboard samples.

(3) The protective value of adding a preservative to the adhesive only, to the furnish only, or to both.

(4) The ability of molds to penetrate the unbroken surfaces of fiberboards.

(5) The effect of molding and delamination on the tensile and bursting strength of the boards.

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[2]In cooperation with the Forest Products Laboratory, maintained by the Forest Service, United States Department of Agriculture, at Madison 5, Wisconsin, in cooperation with the University of Wisconsin.

MATERIALS

Forty samples of commercial fiberboard were tested. These included samples of V1s, V2s, V3s, V3c, W5c, W5s, and W6c, the designations "s" and "c" referring to solid and corrugated types, respectively. "V" fiberboard, grades 1, 2, and 3, was developed primarily for exterior containers for overseas shipment, often requiring high weather resistance. "W" board, grades 5 and 6, also designed to withstand moist conditions, is of lower strength and was developed primarily for use as interior boxes that are overpacked in wood or "V" board for overseas shipment. Table 1 shows the requirements for these different grades as given by joint Army-Navy Specification JAN-P-108 dated June 1944. In most cases the fillers of these boards were laminated with a urea-formaldehyde-starch or a urea-formaldehyde-starch-emulsified asphalt adhesive. The liners were bonded either with these adhesives or with asphalt. Five samples were laminated with a proprietary polyvinyl resin adhesive and one was asphalt impregnated. Two of the boards were laminated with urea-formaldehyde starch containing 0.08 percent sodium pentachlorophenate. Where known, the resin content of the urea-formaldehyde-starch adhesive was about 6 to 8 percent based on the dry weight of the starch.

In addition to the commercial boards, the Division of Pulp and Paper of the Forest Products Laboratory provided experimental solid fiberboards with and without preservative, and with the furnish composed entirely of reclaimed fiber. Sodium pentachlorophenate was added to the furnish in half of the boards prior to the addition of 3 percent rosin and 3 percent alum as sizing. Two concentrations of the preservative were tried, 1.7 and 2.0 percent. Chemical analysis of the board treated with 1.7 percent sodium pentachlorophenate showed that 0.6 percent of the preservative was retained.

The liners of these boards were laminated with asphalt and the filler with a urea-formaldehyde-starch adhesive containing 20 percent resin based on the weight of the dry starch. Twelve and one-half percent ammonium chloride based on the weight of the resin was added as a catalyzer.

METHODS

All of the test samples were soaked in distilled water at room temperature in order to raise the moisture of the boards to a content favorable for mold development. The soaking period was varied for the different types of fiberboards, depending on preliminary trials and the type of board. The corrugated boards were immersed for 1/4 hour, the solid commercial tensile-tested boards for 1/2 hour, the commercial and experimental Mullen-tested fiberboards for 4 hours, and the experimental tensile-tested boards for 16 hours. The Mullen test is a common bursting test. Half of the samples were inoculated by dipping them in a water suspension of mold spores and bacteria which had previously been isolated

from moldy fiberboard and other cellulose material. No attempt was made to work with pure cultures or specific organisms, but similar inoculum was used throughout the tests. The inoculated samples were incubated for periods up to 12 weeks in a closed container stored in a room maintained at 97 percent relative humidity and 80° F. Water was put in the bottom of the container, but it did not come in direct contact with the specimens. The uninoculated samples or controls were incubated in separate containers under the same conditions except that volatile fungicides were placed in the containers to prevent mold growth. The fungicides used were pyridine, paradichlorobenzene, and Insl-X Volatile Fungicide.

Some of the V-boards were edge-coated with beeswax containing 5 percent pentachlorophenol and 5 percent rosin after the initial soaking and prior to inoculation. The treatment was designed to prevent molding through the edges of the board, and thereby determine the ability of the molds to penetrate the unbroken surface of the board.

Both the wet and dry tensile and bursting strengths of the original boards were determined. At regular intervals, samples of the inoculated and uninoculated boards were removed, data on their condition recorded, and either the bursting strength or the tensile strength determined. One specimen of each treatment was tested as removed from the incubation chamber, and one after being conditioned to equilibrium at 50 percent relative humidity and 80° F. The moisture content of the conditioned boards was between 6 and 8 percent. Boards tested for bursting strength by the Mullen test were punctured in 5 different places and the average for the 5 punctures considered as the bursting strength of the sample. Boards tested for tensile strength were cut into four 1-by 6-inch strips after approximately 1/2 to 1 inch was removed from each side of the board in order to avoid excessive effect from edge molding or delamination. The long dimension of the strips was cut parallel with the machine direction of the board for solid boards or parallel with the corrugations for the corrugated boards.

RESULTS ON COMMERCIAL V-BOARD

All the commercial V-boards molded. The amount of molding, tensile and bursting strength values, and moisture contents are shown in table 2. In general, the deterioration and delamination as a result of action by organisms was not reflected in significant decreases in bursting strength. In some cases the sample was heavily molded and completely delaminated after 12 weeks' exposure, but its bursting strength was still as high or higher than the original strength, or the corresponding uninoculated control. Apparently little actual injury to the fibers took place during the period of the tests. Tensile strength tests reflected loss due to molding and resultant delamination somewhat better than did the Mullen tests.

It was not possible to separate the possible action of bacteria from that of molds in the deterioration and delamination of the fiberboards. As a consequence, when referring to strength loss and delamination by molds in this report the possible effects by bacteria are included with those by molds. It has been shown that a moisture content of at least 55 percent is required for bacteria acting alone to weaken casein-glued plywood joints.[3]

Some of the inconsistencies in results may lie in the lack of uniformity in the fiberboard. Also, differences in moisture content of those specimens tested wet may account for some of the variations in strength values. However, moisture content is not a cause of variation in those samples tested after being conditioned at 50 percent relative humidity and 80° F.

To bring out more clearly the relationship of molding to strength values, table 3 shows the decrease in strength for each test period as compared with the original strength values. For those boards in which tensile tests were made, the decrease in strength is presented in graphic form in figure 1.

The amount of molding on all V-board specimens is summarized in table 2, and the amount of delamination in table 4. Mold development on representative samples after 12 weeks' exposure is shown in figure 2.

Boards laminated with the proprietary polyvinyl resin adhesive were only lightly molded even after 12 weeks' exposure, and showed no delamination. The asphalt-impregnated boards were moderately molded but not delaminated.

All of the solid V-board samples laminated with urea-formaldehyde-starch or with urea-formaldehyde-starch-asphalt emulsion molded readily and began to delaminate after 5 weeks' exposure. Some had completely delaminated after 12 weeks. The addition of 0.08 percent sodium pentachlorophenate in the urea-formaldehyde-starch adhesive did not inhibit mold growth, and the boards so treated molded and delaminated almost as readily as untreated ones.

The corrugated V3 boards molded and delaminated quite readily. The rapid delamination may be explained by the presence of the corrugations, which allowed the inoculation spore suspension to run into the inside of the board.

None of the uninoculated control samples showed any delamination except for the corrugated samples, which were partially delaminated after 12 weeks. The presence of the volatile fungicides in the containers in which these specimens were incubated held molding to a minimum. Since the

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[3] Duncan, Catherine G. The effect of moisture on bacterial delamination of casein-bonded plywood. Office Report, 10 pp. April 1946.

control specimens were incubated under the same conditions with moisture contents approximately the same as the molded specimens, there is little question that the delamination of the solid boards and most of it in the corrugated boards was due to mold attack on the inoculated specimens.

Penetration of Molds

One of the purposes of the study was to determine whether molds are able to penetrate the unbroken surfaces of the fiberboard or whether penetration is dependent upon breaks in the board. In order to obtain information on this question the edges of one set of the boards were sealed with a fungicidal wax before inoculation. In that way the attack by molds was restricted to the surface plies. Detailed notes on the delamination after 7 and 12 weeks' exposure of the inoculated specimens with edges exposed and with the edges sealed are given in table 4. The samples with sealed edges generally were somewhat less delaminated after 7 weeks' exposure than the unsealed samples. After 12 weeks, however, delamination in the sealed specimens was practically as great as in the specimens having their edges exposed. Delamination of the samples with exposed edges generally progressed from the outside toward the center. In many cases these samples had begun to separate along the edges after 5 weeks' exposure.

These observations indicate that the delamination of fiberboard having no other means of entrance for micro-organisms than penetration through the surface plies may be almost as rapid as in fiberboard having open edges. It seems unlikely that organisms may have penetrated the wax seal since no delamination was noted around the waxed edges when the plies were separated for observation.

Small-scale penetration tests with decay fungi on fiberboard with wax-sealed edges showed that two fungi causing brown rots grew through V2s boards in 7 days' time. Certain molds came through V3s board in 15 days.

From these tests it is readily seen that some of the adhesives regularly used in laminating fiberboard are not resistant to attack by micro-organisms when such fiberboard is exposed for extended periods of time to conditions that favor mold growth.

RESULTS ON COMMERCIAL W-BOARD

The results of tensile tests and notes on molding and delamination of W-board are given in table 5. After about 1 week, molding was observed on all of the corrugated boards, and after 3 weeks they were heavily molded. Mold was about as heavy within the corrugations as on the faces. The solid W5 board laminated with a proprietary polyvinyl resin adhesive

was only lightly molded with no delamination at the end of 12 weeks, while the same type of board laminated with urea-formaldehyde-starch was heavily molded and 90 percent delaminated after 3 weeks.

To illustrate more clearly the decrease in tensile strength of these boards due to molding, the data in table 5 are presented graphically in figure 1.

The tensile strength of all inoculated W-boards was reduced. Since some further loss in the inoculated boards occurred after delamination, it appears that the organisms present decreased the fiber strength. However, a greater part of the decrease in tensile value was apparently due to delamination. No delamination was noted in the uninoculated samples incubated under similar conditions. In evaluating the results, however, differences in moisture content as well as differences in the strength values of individual boards should be recognized.

RESULTS ON EXPERIMENTAL FIBERBOARD

Three sets of experimental fiberboards were prepared and tested against molding. One set had 1.7 percent sodium pentachlorophenate added to the fiber furnish with varying amounts of this preservative added to the urea-formaldehyde-starch adhesive. Chemical analysis showed, however, that only 0.6 percent of the preservative was retained in the fiber. Another set had 2.0 percent sodium pentachlorophenate added to the furnish and varying amounts of the chemical added to the adhesive, while still another was made of untreated furnish.

The results of the Mullen tests made on the boards treated with 1.7 percent sodium pentachlorophenate are recorded in table 6, and those of tensile tests on boards treated with 2.0 percent preservative are recorded in table 7. Notes on molding and delamination and the moisture contents of those specimens that were tested wet are included in the same tables in order to facilitate correlation of the strengths with amount of molding and moisture content.

All the boards without sodium pentachlorophenate added to the furnish molded heavily, and likewise showed a greater reduction in both bursting and tensile strength than did boards with the furnish treated. The loss in tensile strength of the experimental boards tested is illustrated graphically in figure 3. The addition of 2 percent or less of sodium pentachlorophenate in the adhesive gave little or no evidence of preventing deterioration and consequent loss in tensile strength. The incorporation of the preservative in the adhesive as well as in the furnish adds little to the cost and should aid in preventing molding; additional tests with 2 percent and higher concentrations in the adhesive are needed before concluding against it.

The asphalt liners tended to loosen after preliminary soaking and subsequent incubation. The asphalt supported surface mold growth, which indicates that treatment of the asphalt might also be advantageous.

Figure 4 shows the amount of molding of the reclaimed treated and untreated fiberboards after 12 weeks' incubation at 97 percent relative humidity and 80° F.

SUMMARY AND CONCLUSIONS

Mold tests made on various V- and W-fiberboards and experimental fiberboards gave the following results:

(1) Urea-formaldehyde-starch and urea-formaldehyde-starch-asphalt-emulsion resins in solid V- and W-boards were not mold resistant.

(2) V- and W-boards laminated with a proprietary polyvinyl resin adhesive were more mold resistant than those boards laminated with other adhesives. Only light molding with no delamination was noted on these boards after 12 weeks.

(3) Both V and W corrugated boards laminated with urea-formaldehyde-starch molded heavily and were badly delaminated after 3 weeks.

(4) Uninoculated corrugated and solid boards did not delaminate as readily as inoculated boards.

(5) Molds penetrated through the surface of the solid fiberboard and caused delamination.

(6) The addition of 1.7 and 2.0 percent sodium pentachlorophenate to the furnish reduced molding and strength loss appreciably with the higher concentration giving the best results.

(7) The addition of 2 percent sodium pentachlorophenate to the adhesive gave no evidence of value when the furnish was untreated, or of improving the protection when the furnish was treated. However, until additional evidence is available it would be safest to treat the adhesive, probably using a higher concentration than the 2 percent used in these experiments.

(8) Asphalt is not mold-inhibiting and should probably be treated along with the other constituents in making a mold-resistant board.

Table 1.--Requirements for V-board and W-board exterior and interior grades

Type	Grade	Compliance symbol	Corrugated fiberboard; nominal caliper of paperboard[1]			Solid fiberboard nominal caliper[1]	Minimum average bursting strength		Maximum permissible ply separation (wet)
			Outer liners	Inner liners	Corrugated material[2]		Dry	After 24 hours immersion	
			In.	In.	In.	In.	Lb.	Lb.	In.
Exterior grades									
SF	1	V1s				0.100	750	500	1/4
SF	2	V2s				.090	550	500	1/4
SF	3	V3s				.090	400	150	1/4
CF	3	V3c	0.023	0.023	0.010		400	150	1/4
Interior grades									
SF	5	W5s				.075	275	100	1/4
CF	5	W5c	.016	.016	.010		275	100	1/4
SF	6	W6s				.060	175	50	1/4
CF	6	W6c	.010	.010	.010		175	50	1/4

[1] A 5 percent minus and unlimited plus tolerance is permitted.

[2] Corrugations shall be "B" or "C" flute having approximately 50 or 42 flutes per foot, respectively.

Table 2.--Tensile strength, bursting strength, molding, and moisture content of commercial V-boards subjected to molding at 97 percent relative humidity and 80° F.

Type of board	Test period	Tensile strength[1]				Bursting strength[2]				Amount of molding	Moisture content of wet boards			
		Tested wet		Tested dry		Tested wet		Tested dry			Tensile tests		Bursting tests	
		Inoculated	Control[3]	Inoculated	Control	Inoculated	Control	Inoculated	Control		Inoculated	Control	Inoculated	Control
	Weeks	Lb. per in.	Lb. per in.	Lb. per in.	Lb. per in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.		Percent	Percent	Percent	Percent
A. Laminated with urea-formaldehyde-starch														
V1s	Original	--	582	--	651	--	840	--	882	--	--	16	--	31
	3	214	182	292	303	815	795	843	808	Light	21	24	23	32
	6	242	340	640	609	740	775	794	784	Medium	25	28	31	40
	9	303	238	527	276	648	750	766	774	Medium	62	28	34	42
	12	131	160	588	602	601	708	731	761	Heavy	27	33	34	40
V2s	Original	--	--	--	--	--	601	--	675	--	--	--	--	28
	3	--	--	--	--	651	631	631	671	Light	--	--	26	26
	6	--	--	--	--	520	530	600	640	Medium	--	--	33	34
	9	--	--	--	--	480	556	558	670	Heavy	--	--	32	32
	12	--	--	--	--	441	531	503	711	Heavy	--	--	33	32
V3s	Original	--	347	--	505	--	262	--	452	--	--	19	--	36
	3	228	291	471	482	266	130	376	367	Light	33	28	38	57
	6	245	210	404	518	180	160	314	299	Medium	32	32	40	47
	9	214	247	389	335	162	150	259	215	Heavy	32	29	41	43
	12	213	223	431	487	135	130	214	266	Heavy	35	34	41	39
V3c	Original	--	121	--	264	--	207	--	358	--	--	25	--	80
	3	34	43	164	238	186	180	352	356	Medium	56	58	72	66
	6	18	43	111	249	200	140	314	334	Heavy	49	61	60	60
	9	19	46	87	234	170	164	319	323	Heavy	47	48	52	50
	12	14	21	33	237	153	187	--	307	Heavy	46	110	48	39
B. Laminated with urea-formaldehyde-starch treated with 0.08 percent sodium pentachlorophenate														
V3s	Original	--	--	--	--	--	442	--	584	--	--	--	--	32
	3	--	--	--	--	480	439	532	549	Light	--	--	28	37
	6	--	--	--	--	420	360	526	558	Medium	--	--	34	38
	9	--	--	--	--	408	334	516	543	Heavy	--	--	32	37
	12	--	--	--	--	370	334	519	536	Heavy	--	--	33	38
C. Laminated with urea-formaldehyde-starch-emulsified-asphalt adhesive														
V1s	Original	--	--	--	--	--	900	--	764	--	--	--	--	33
	3	--	--	--	--	762	860	819	887	Heavy	--	--	36	36
	6	--	--	--	--	734	906	794	834	Heavy	--	--	32	36
	9	--	--	--	--	636	894	724	803	Heavy	--	--	33	32
	12	--	--	--	--	613	892	712	798	Heavy	--	--	34	31
V2s	Original	--	--	--	--	--	604	--	601	--	--	--	--	27
	3	--	--	--	--	618	666	578	581	Light	--	--	22	21
	6	--	--	--	--	611	600	575	568	Medium	--	--	26	24
	9	--	--	--	--	604	597	561	557	Heavy	--	--	27	26
	12	--	--	--	--	565	623	566	550	Heavy	--	--	30	27
V3s	Original	--	527	--	811	--	426	--	428	--	--	18	--	12
	3	360	360	686	642	404	364	460	454	Light	29	26	29	35
	6	303	293	637	754	389	288	420	458	Medium	32	45	34	37
	9	280	370	540	715	418	303	433	444	Heavy	35	28	31	38
	12	400	339	568	726	486	326	468	454	Heavy	30	31	32	38
D. Asphalt impregnated														
V2s	Original	--	--	--	--	--	488	--	530	--	--	--	--	23
	3	--	--	--	--	414	326	504	506	Light	--	--	25	36
	6	--	--	--	--	408	418	530	530	Medium	--	--	28	34
	9	--	--	--	--	421	388	520	478	Medium	--	--	27	34
	12	--	--	--	--	480	418	482	432	Medium	--	--	26	33
E. Laminated with a proprietary polyvinyl resin adhesive														
V2s	Original	--	415	--	589	--	602	--	628	--	--	17	--	23
	3	315	265	482	501	654	686	624	594	Light	25	28	18	27
	6	254	175	532	513	565	518	606	614	Light	28	33	27	28
	9	116	196	194	567	544	478	602	608	Light	29	29	24	24
	12	270	179	580	503	506	479	592	618	Light	28	35	25	33
V3s	Original	--	--	--	--	--	237	--	518	--	--	--	--	58
	3	--	--	--	--	299	234	476	507	Light	--	--	44	69
	6	--	--	--	--	276	238	448	492	Light	--	--	57	68
	9	--	--	--	--	268	258	440	475	Light	--	--	46	71
	12	--	--	--	--	265	276	452	444	Light	--	--	45	49

[1] An average of 4 tests for each board.

[2] An average of 5 punctures for each of 1 or 2 boards.

[3] The uninoculated control samples were incubated under similar conditions as the inoculated ones except for the addition of volatile fungicides. The original strength figures apply to both.

Table 3.--Decrease in tensile and bursting strength of V-boards subjected to molding at 97 percent relative humidity and 80° F. Based upon strength loss in comparison to original boards.

Type of board	Test period	Loss in tensile strength				Loss in bursting strength				Moisture content of wet boards			
		Tested wet		Tested dry		Tested wet		Tested dry		Tensile tests		Bursting tests	
		Inoculated	Control	Inoculated	Control	Inoculated	Control	Inoculated	Control	Inoculated	Control	Inoculated	Control
	Weeks	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
A. Laminated with urea-formaldehyde-starch													
V1s	3	63	69	55	53	3	5	4	8	21	24	23	32
	6	58	42	2	6	9	8	10	11	25	28	31	40
	9	48	59	19	58	23	11	13	12	62	28	34	42
	12	77	73	10	8	28	16	17	14	27	33	34	40
V2s	3	--	--	--	--	+8	+5	7	1	--	--	26	26
	6	--	--	--	--	13	12	11	5	--	--	33	34
	9	--	--	--	--	20	7	17	1	--	--	32	32
	12	--	--	--	--	27	12	25	+5	--	--	33	32
V3s	3	34	16	7	5	+2	50	17	19	33	28	38	57
	6	29	39	20	+3	31	39	31	34	32	32	40	47
	9	38	29	23	34	38	43	43	52	32	29	41	43
	12	39	36	15	4	48	50	53	41	35	34	41	39
V3c	3	72	65	38	10	10	13	2	1	56	58	72	66
	6	85	65	58	6	3	32	12	7	49	61	60	60
	9	84	62	67	11	18	21	11	10	47	48	52	50
	12	88	83	88	11	26	10	--	14	46	110	48	39
B. Laminated with urea-formaldehyde-starch treated with 0.08 percent sodium pentachlorophenate													
V3s	3	--	--	--	--	+9	1	9	6	--	--	28	37
	6	--	--	--	--	5	19	10	4	--	--	34	38
	9	--	--	--	--	8	24	12	7	--	--	32	37
	12	--	--	--	--	16	24	11	8	--	--	33	38
C. Laminated with urea-formaldehyde-starch-emulsified-asphalt adhesive													
V1s	3	--	--	--	--	15	4	+7	+16	--	--	36	36
	6	--	--	--	--	18	+1	+4	+9	--	--	32	36
	9	--	--	--	--	29	1	5	+5	--	--	33	32
	12	--	--	--	--	32	1	7	+4	--	--	34	31
V2s	3	--	--	--	--	+2	+10	4	3	--	--	22	21
	6	--	--	--	--	+1	1	4	5	--	--	26	24
	9	--	--	--	--	0	1	7	7	--	--	27	26
	12	--	--	--	--	6	+3	6	8	--	--	30	27
V3s	3	32	32	15	21	5	15	+7	+6	29	26	29	35
	6	43	44	21	7	9	32	2	+7	32	45	34	37
	9	47	30	33	12	2	29	+1	+4	35	28	31	38
	12	24	36	30	10	+14	23	+9	+6	30	31	32	38
D. Asphalt impregnated													
V2s	3	--	--	--	--	15	33	5	5	--	--	25	36
	6	--	--	--	--	16	14	0	0	--	--	28	34
	9	--	--	--	--	14	20	2	10	--	--	27	34
	12	--	--	--	--	2	14	9	18	--	--	26	33
E. Laminated with a proprietary polyvinyl resin adhesive													
V2s	3	24	36	18	15	+9	+14	1	5	25	28	18	27
	6	39	58	10	13	6	14	4	2	28	33	27	28
	9	72	53	62	4	10	21	4	3	29	29	24	24
	12	35	57	2	15	16	20	6	2	28	35	25	33
V3s	3	--	--	--	--	+26	1	8	2	--	--	44	69
	6	--	--	--	--	+16	0	14	5	--	--	57	68
	9	--	--	--	--	+13	+9	15	9	--	--	46	71
	12	--	--	--	--	+12	+16	13	14	--	--	45	49

Table 4.--The delamination of commercial fiberboard samples after 7 and 12 weeks' exposure to molding at 97 percent relative humidity and 80° F.

Type of board	Delamination after 7 weeks		Delamination after 12 weeks	
	Edges exposed	Edges sealed	Edges exposed	Edges sealed
A. Laminated with urea-formaldehyde-starch				
V1s	Delaminated to depth of 1/2 to 1-1/2 inches from edges	10% delamination	All plies delaminated except for small area at center of each ply	90% delamination
V2s	Delaminated except for small area at center	90% delamination	Completely delaminated	Completely delaminated
V3s	85% delamination	50% delamination	Completely delaminated	Completely delaminated
V3c	Completely delaminated	45% delamination	Completely delaminated	80% delamination
B. Laminated with urea-formaldehyde-starch treated with 0.08% sodium pentachlorophenate				
V3s	Outer plies 50% delaminated Inner plies delaminated along edges	60% delamination	Outer plies completely delaminated Inner plies 70% delaminated	80% delamination
C. Laminated with urea-formaldehyde-starch-emulsified-asphalt adhesive				
V1s	60% delamination of outer plies only	30% delamination of outer plies only	Outer plies completely delaminated No delamination of inner plies	50% delamination of outer plies
V2s	Delaminated except for small area at center	No delamination	Completely delaminated	Completely delaminated
V3s	90% delamination	15% delamination	Outer plies completely delaminated Inner plies delaminated around edges	Outer plies completely delaminated Inner plies 50% delaminated
D. Asphalt impregnated				
V2s	No delamination	No delamination	No delamination	No delamination
E. Laminated with a proprietary polyvinyl resin adhesive				
V2s	No delamination	No delamination	No delamination	No delamination
V3s	No delamination	No delamination	No delamination	No delamination

Table 5.--Tensile strength, molding, delamination, and moisture content of commercial W-boards subjected to molding at 97 percent relative humidity and 80° F.

Type of board	Test period	Tensile strength[1]				Moisture content of wet boards		Amount of molding	Delamination	
		Tested wet		Tested dry						
		Inoculated	Control[2]	Inoculated	Control	Inoculated	Control		Inoculated	Control
	Weeks	Lb. per in.	Lb. per in.	Lb. per in.	Lb. per in.	Percent	Percent		Percent	Percent
A. Laminated with urea-formaldehyde-starch										
W5c	Original	--	54	--	184	--	31	--	--	--
	3	28	36	127	170	55	60	Heavy	90	0
	6	22	40	103	180	49	55	Heavy	95	5
	9	23	39	96	176	43	56	Heavy	100	10
	12	21	32	83	168	45	79	Very heavy	100	25
W5s	Original	--	207	--	452	--	29	--	--	--
	3	37	41	210	373	59	68	Heavy	90	0
	6	29	89	177	339	48	46	Very heavy	90	0
	9	33	96	137	393	39	41	Very heavy	100	10
	12	17	113	139	400	39	49	Very heavy	100	10
W6c	Original	--	40	--	135	--	33	--	--	--
	3	23	29	93	126	52	62	Heavy	75	0
	6	17	31	73	141	48	57	Heavy	95	5
	9	15	33	58	130	41	49	Very heavy	100	10
	12	13	16	42	127	37	92	Very heavy	100	20
B. Laminated with a proprietary polyvinyl resin adhesive										
W5s	Original	--	291	--	348	--	16	--	--	--
	3	208	191	331	344	21	27	Light	0	0
	6	192	135	326	345	24	32	Light	0	0
	9	193	158	305	314	25	27	Light	0	0
	12	186	196	354	351	--	30	Light	0	0

[1] Average of 4 tests for each board.

[2] The uninoculated control samples were incubated under similar conditions as the inoculated ones except for the addition of volatile fungicides. The original strength figures apply to both.

Table 6.--Bursting strength, molding, delamination, and moisture content of experimental fiberboards treated with varying amounts of sodium pentachlorophenate and subjected to molding at 97 percent relative humidity and 80° F.

Sample number	Preservative added	Test period	Bursting strength[1]				Amount of molding	Amount of delamination	Moisture content of wet specimens	
			Tested wet		Tested dry					
			Inoculated	Control[2]	Inoculated	Control			Inoculated	Control
	Percent	Weeks	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.			Percent	Percent
86	Furnish 0.0	Original	346	--	504	--	--	--	21	--
	Adhesive 0.0	3	545	--	511	--	Light	0	24	--
		7	344	--	412	--	Very heavy	Slight	35	--
		12	206	--	432	--	Very heavy	Heavy	38	--
88	Furnish 0.0	Original	--	498	--	530	--	--	--	37
	Adhesive 0.5	3	577	536	550	511	Light	0	23	23
		7	468	520	560	536	Heavy	0	37	22
		12	313	507	440	530	Heavy	Slight	33	26
87	Furnish 0.0	Original	--	450	--	480	--	--	--	24
	Adhesive 1.0	3	600	540	511	461	Light	0	23	23
		7	328	524	402	532	Heavy	Slight	34	23
		12	141	513	--	--	Very heavy	Heavy	35	23
90	Furnish 0.0	Original	--	516	--	562	--	--	--	19
	Adhesive 2.0	3	563	534	546	515	Light	0	29	19
		7	379	518	432	550	Heavy	0	38	26
		12	393	507	392	548	Heavy	Medium	35	25
84	Furnish 1.7	Original	--	492	--	472	--	--	--	21
	Adhesive 0.0	3	526	472	465	535	None	0	27	23
		7	412	427	458	502	Light	0	31	24
		12	371	420	480	--	Medium	Slight	30	27
89	Furnish 1.7	Original	--	472	--	482	--	--	--	27
	Adhesive 0.5	3	515	482	553	495	Very light	0	31	30
		7	437	452	514	512	Very light	0	38	24
		12	513	463	--	454	Light	0	29	27
85	Furnish 1.7	Original	--	464	--	462	--	--	--	30
	Adhesive 1.0	3	495	502	525	484	None	0	37	22
		7	441	482	472	502	Light	0	37	25
		12	433	496	486	516	Medium	0	33	46
91	Furnish 1.7	Original	--	480	--	530	--	--	--	29
	Adhesive 2.0	3	560	562	527	531	None	0	27	23
		7	516	495	534	486	Very light	0	29	22
		12	441	493	--	496	Light	0	33	24

[1] Each figure is an average of 5 punctures.

[2] The uninoculated control samples were incubated under similar conditions as the inoculated ones except for the addition of volatile fungicides. The original strength figures apply to both.

Table 7.--Tensile strength, molding, delamination, and moisture content of experimental fiberboards treated with varying amounts of sodium pentachlorophenate and subjected to molding at 97 percent relative humidity and 80° F.

Sample number	Preservative added	Test period	Tensile strength[1]				Amount of molding	Amount of delamination	Moisture content of wet specimens	
			Tested wet		Tested dry					
			Inoculated	Control[2]	Inoculated	Control			Inoculated	Control
		Weeks	Lb. per in.	Lb. per in.	Lb. per in.	Lb. per in.			Percent	Percent
99	Furnish 0.0	Original	--	161	--	229	--	--	--	17
	Adhesive 0.0	3	119	140	229	217	Very light	0	24	18
		6	127	140	195	207	Heavy	0	26	23
		9	93	98	181	193	Heavy	Light	30	32
		12	95	132	164	229	Heavy	Heavy	31	26
101	Furnish 0.0	Original	--	129	--	237	--	--	--	20
	Adhesive 0.5	3	114	--	173	--	Light	0[3]	21	--
		6	93	114	140	176	Heavy	Light[3]	28	21
		9	95	95	142	152	Heavy	Light	32	27
		12	107	112	139	176	Heavy	Medium	26	27
103	Furnish 0.0	Original	--	146	--	242	--	--	--	18
	Adhesive 1.0	3	168	147	232	224	Light	0	17	16
		6	135	140	220	217	Heavy	0	24	22
		9	91	122	183	196	Heavy	Slight	36	28
		12	100	139	146	217	Heavy	Heavy	32	26
105	Furnish 0.0	Original	--	149	--	241	--	--	--	17
	Adhesive 2.0	3	147	114	229	208	Light	0[3]	21	19
		6	152	129	196	201	Heavy	Slight[3]	23	21
		9	90	125	146	193	Heavy	Slight	28	30
		12	85	124	129	190	Heavy	Medium	34	28
98	Furnish 2.0	Original	--	115	--	224	--	--	--	18
	Adhesive 0.0	3	137	122	224	229	Trace	0	19	20
		6	134	140	218	222	Trace	0[3]	24	24
		9	130	132	215	210	Trace	Slight[4]	30	26
		12	132	137	180	222	Very light	Slight[4]	28	27
100	Furnish 2.0	Original	140	--	--	234	--	--	20	--
	Adhesive 0.5	3	135	--	239	--	None	0	19	--
		6	142	--	181	225	Very light	0	26	--
		9	132	--	225	--	Very light	0[4]	28	--
		12	--	--	--	--	Very light	Slight[4]	--	--
102	Furnish 2.0	Original	--	173	--	241	--	--	--	17
	Adhesive 1.0	3	152	146	232	232	Very light	0[3]	17	17
		6	127	139	200	220	Very light	Slight[3]	24	23
		9	144	139	208	227	Very light	Slight[3]	27	26
		12	144	--	210	--	Light	Slight[4]	27	--
104	Furnish 2.0	Original	--	159	--	239	--	--	--	19
	Adhesive 2.0	3	164	146	242	227	Very light	0	17	16
		6	178	151	220	217	Very light	0	22	20
		9	140	127	207	224	Very light	0[4]	28	29
		12	140	124	232	213	Very light	Slight[4]	28	28

[1] Each figure is an average of 4 tests.

[2] The uninoculated control samples were incubated under similar conditions as the inoculated ones except for the addition of volatile fungicides. The original strength figures apply to both.

[3] Outer plies only.

[4] At corners only.

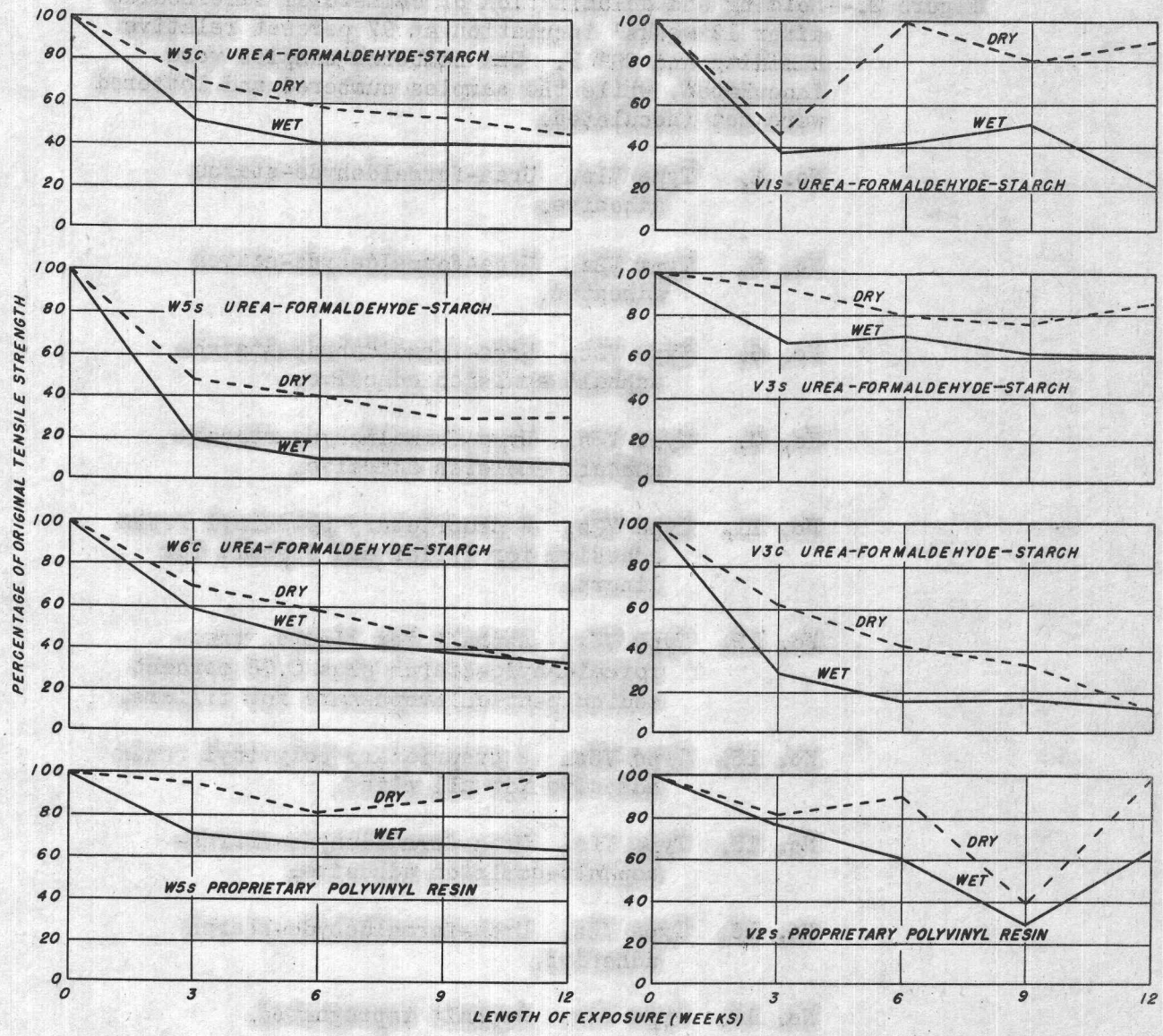


FIGURE 1.--WET AND DRY TENSILE STRENGTH OF V- AND W- BOARDS EXPOSED TO MOLDING AT 97 PERCENT RELATIVE HUMIDITY AND 80° F.

Z M 67475 F

Figure 2.--Molding and delamination of commercial fiberboards after 12 weeks' incubation at 97 percent relative humidity and 80° F. The numbered samples were inoculated, while the samples numbered and lettered were not inoculated.

No. 1. Type V1s. Urea-formaldehyde-starch adhesive.

No. 5. Type V2s. Urea-formaldehyde-starch adhesive.

No. 6. Type V2s. Urea-formaldehyde-starch-asphalt emulsion adhesive.

No. 7. Type V3s. Urea-formaldehyde-starch-asphalt emulsion adhesive.

No. 11. Type V2s. A proprietary polyvinyl resin adhesive for filler and asphalt for liners.

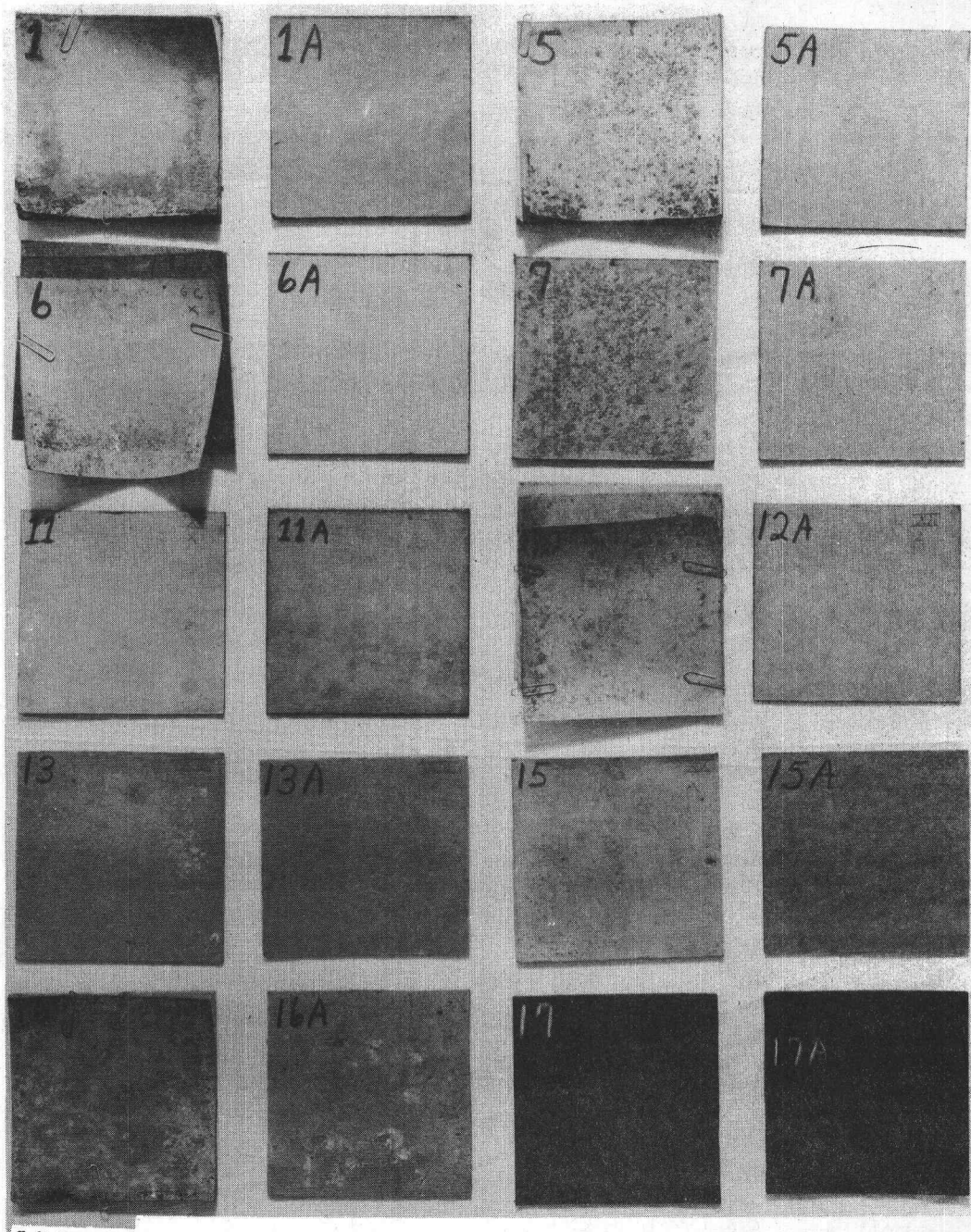
No. 12. Type V3s. Asphalt for liners, urea-formaldehyde-starch plus 0.08 percent sodium pentachlorophenate for fillers.

No. 13. Type V3s. A proprietary polyvinyl resin adhesive for all plies.

No. 15. Type V1s. Urea-formaldehyde-starch-asphalt-emulsion adhesive.

No. 16. Type V3s. Urea-formaldehyde-starch adhesive.

No. 17. Type V2s. Asphalt impregnated.



Z M 70356 F

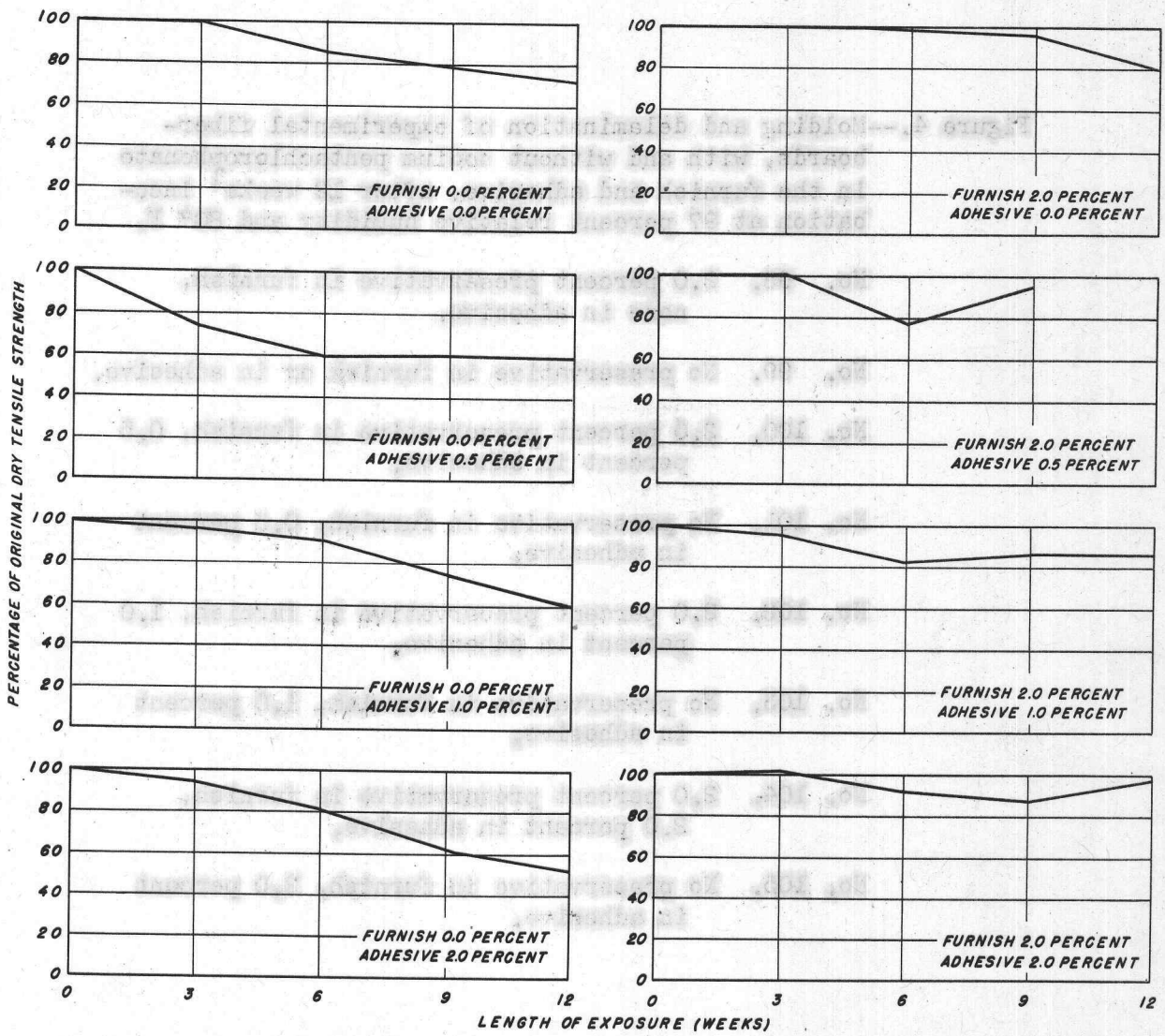


Figure 3.--Tensile strength of reclaimed fiberboard treated with sodium pentachlorophenate and subjected to molding at 97 percent relative humidity and 80° F.

Z M 87476 F

Figure 4.--Molding and delamination of experimental fiberboards, with and without sodium pentachlorophenate in the furnish and adhesive, after 12 weeks' incubation at 97 percent relative humidity and 80° F.

No. 98. 2.0 percent preservative in furnish, none in adhesive.

No. 99. No preservative in furnish or in adhesive.

No. 100. 2.0 percent preservative in furnish, 0.5 percent in adhesive.

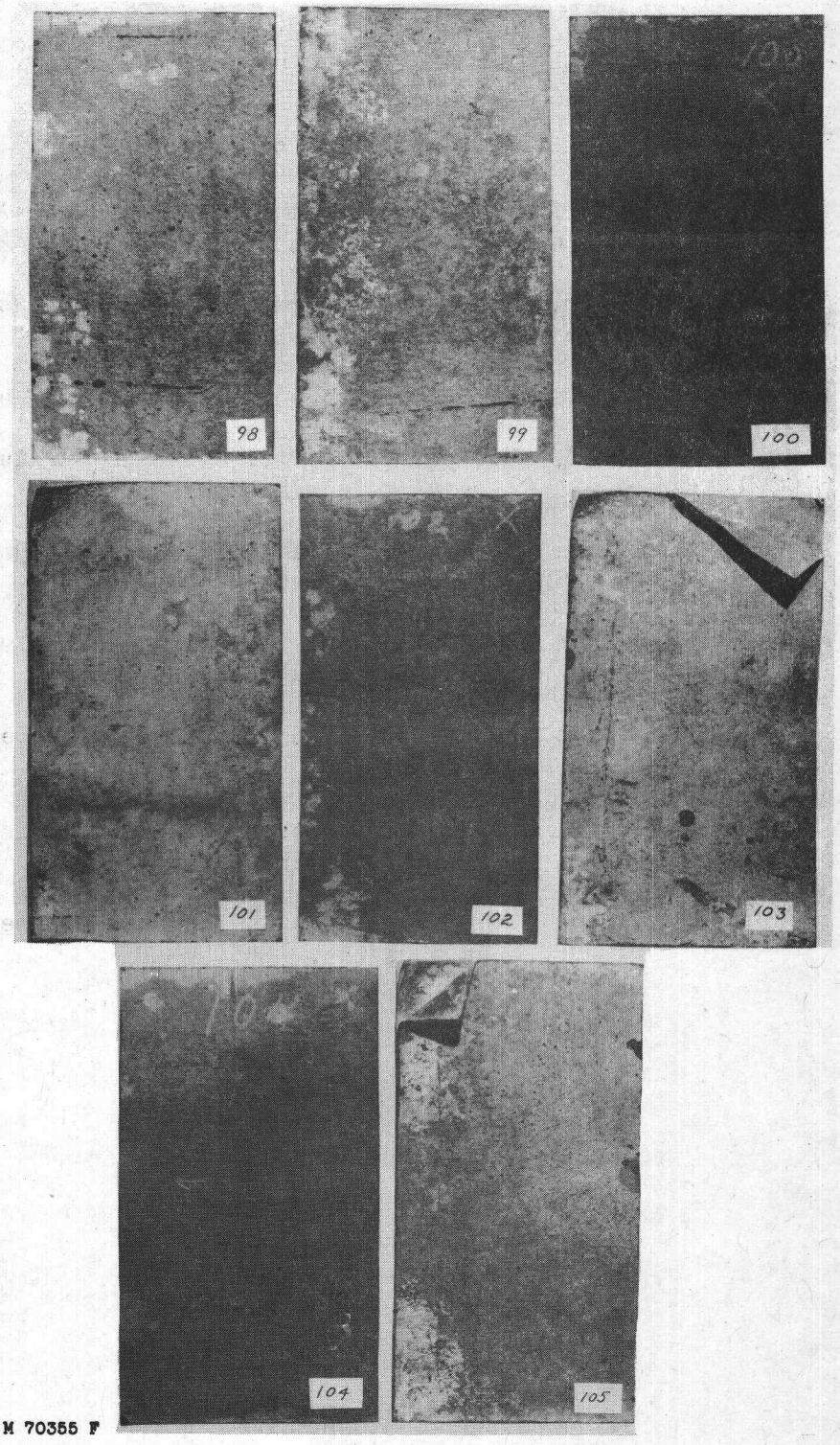
No. 101. No preservative in furnish, 0.5 percent in adhesive.

No. 102. 2.0 percent preservative in furnish, 1.0 percent in adhesive.

No. 103. No preservative in furnish, 1.0 percent in adhesive.

No. 104. 2.0 percent preservative in furnish, 2.0 percent in adhesive.

No. 105. No preservative in furnish, 2.0 percent in adhesive.



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