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PAINT PERFORMANCE ON FOREST PRODUCTS

Modification of wood and plywood to improve paintability

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PAINT PERFORMANCE ON FOREST PRODUCTS[1]

MODIFICATION OF WOOD AND PLYWOOD TO IMPROVE PAINTABILITY

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The performance of paint on ordinary lumber and plywood has been studied in detail at the Forest Products Laboratory since 1924. Most of the studies concerned house paints because they usually wear out in 4 or 5 years. Interior coatings may last for many years unless, like floors, they are subject to severe mechanical wear. Interior and exterior coatings are affected by wood characteristics in much the same way except that more concern may be expressed about surface imperfections, such as raised grain and wood checks, in connection with interior than with exterior finishes.

Results of the studies of house paints on ordinary lumber of all of the commercially important native woods have been published repeatedly (9, 11, 13, 14, 15).[3] Plywood has essentially the same painting properties as lumber of the kind of wood with which the plywood is faced. Some plywood is reputed to be more seriously given to face checking than is lumber of the same kind of wood, but, in part, that reputation may be due to the fact that wood checks are more displeasing on the large surfaces presented by plywood than they are on relatively narrow boards.

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[2]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3]Numbers in parentheses refer to literature cited at end of article.

Although all commercially important softwoods can be kept well painted economically, some of them are much more exacting than others in their requirements of priming procedures, paints, and maintenance programs to that end. Only 10 percent of the annual cut of softwoods is of the lightweight species easiest to keep well painted, and nearly 70 percent is of the heavy species that require greatest care. Moreover, only a fraction of the production of softwoods is of the clear grades suitable for fully satisfactory painting.

Many studies have been made to find better ways of painting the more exacting woods. Special priming paints were discovered that go a long way toward making the heavier softwoods hold paint as well as the lightweight woods do (3, 6, 7, 12, 17).

As far back as 1929, at a wood-painting conference at the Forest Products Laboratory, representatives of the paint industry suggested that modification of the wood should be considered in an effort to improve paint performance on the more exacting woods; they considered it unfair to hold paint responsible for making all of the modifications needed. Efforts to alter wood surfaces were started soon after, but progress with them was slow. Wood surfaces are much less amenable than paint to practicable modifications. As it turned out, some of the most fruitful alterations of wood surfaces had to await the development of new auxiliary materials.

Treatment of Wood Surfaces with Chemicals

The studies of paint performance on different woods gave evidence that extractives in some of the woods that are easiest to keep painted, particularly in redwood and southern cypress, exert a favorable effect on the durability of paint (14). Accordingly, tests were started in 1930 in which the aqueous extract of redwood heartwood and the alcoholic extract of cypress heartwood were transferred to the surfaces of boards of eastern hemlock, which were then tested for painting properties. The treated boards gave better paint performance than matched but untreated boards (9). The extent of the improvement, however, was relatively small. The beneficial ingredients in the cypress and redwood extracts are probably antioxidants for linseed oil; in moderate proportions they may retard the embrittlement of paint as it ages. But antioxidants cannot be used in larger proportions for fear of preventing the initial drying of paint. Even the proportions normally present in redwood and cypress seriously retard the drying of many paints under the unfavorable conditions of high humidity, low temperature, and absence of sunlight (2).

In 1932 tests were started in which lumber was treated superficially with reactive gases or with aqueous solutions of inorganic chemicals that alter the pH and might alter the surface reactivity of cellulose and lignin. It was admittedly "shot-gun" research without much clear scientific guidance. The hope was that one or more of the treatments might improve the adhesion and durability of paint. None of the treatments, however, improved paint performance; most of them had little or no effect and some impaired paint durability. Perhaps the outcome should have been expected from an understanding of the nature of adhesion of paint to wood (5), for any effect of chemically altering the cellulose and lignin in wood surfaces would have to do primarily with specific adhesion of paint to wood, which is believed to be very good as long as the paint is young but to be gradually lost as the paint becomes embrittled with age (8). Adherence of old paint is thought to be strictly mechanical. If so, the modifications of wood surfaces necessary to improve mechanical adhesion would have to be on a macroscopic or a microscopic scale rather than on a molecular scale. Later in this paper it will be shown that mechanical adhesion of aged paint to the heavier softwoods can be improved by suitable coarse roughening of the surfaces.

Dimensionally Stabilized Wood

Since old, brittle paint adheres to wood mechanically, it is reasonable to suppose that actual breaking away of the coating is hastened by alternate swelling and shrinking of the wood fibers at the interface in response to changes in moisture content. Paint durability, then, should be improved by treating the wood in such a way as to render it more nearly stable, dimensionally; that is, by antishrink treatment, provided that the treatment is not harmful to paint in some other respect. Several methods of stabilizing wood have been developed (19), though none of them is as yet inexpensive and convenient enough to have attained widespread use.

Acetylated Wood

Acetylated wood (20), in which hydroxyl groups of the lignin and cellulose have been esterified with acetic anhydride to the extent of approximately 20 percent by weight, has only 30 percent of the shrinkage of normal wood. Accordingly, preliminary tests were started in 1947 to determine the effect of acetylation on paint performance.

Test panels were 12 by 16 inches in size, made of five-ply, resin-bonded plywood with core and crossbands of Douglas-fir and 1/32-inch face veneers of sweetgum veneers. Panels were made in pairs in which the face veneers of one panel were acetylated and those of the other panel were left untreated for comparison. Twelve pairs of panels were faced with sapwood of sweetgum and four pairs with heartwood of sweetgum. The treated sapwood contained 20 percent of acetyl groups, and the treated heartwood 18 percent. One pair of panels with sapwood faces was exposed without any coating.

Table 1 records the paint, enamel, or lacquer coatings tested and the extent to which the performance of each coating proved better on acetylated than on untreated wood. The meaning of the symbols for concisely indicating the composition of the coatings is explained in the appendix to this report. All coatings of paint or enamel consisted of one application of priming paint or of enamel undercoater followed by two applications of finish paint or enamel. Lacquers were applied by spraying until satisfactory hiding was obtained. The test panels were exposed to the weather in the vertical position, facing south, at Madison, Wis., in March 1947 and were last inspected in September 1951, about 4-1/2 years later.

On 2 pairs of panels out of the 15 pairs no difference in performance of the coatings had appeared up to the last inspection, and the coatings remained in good condition on both treated and untreated wood. On the other 13 pairs of coated panels the performance of the coating proved better on the acetylated than on the untreated wood. Sometimes, as with paint L and with enamel T_{139}(pre), the improvement from acetylation was slight, though it may become more marked as the exposures continue to ultimate coating failure. But with other coatings, such as enamel $(TZ_{15})_{325}$(ar) and with the lacquers performance was very much superior on the acetylated than on the untreated wood. First evidence of such superiority sometimes appeared as early as November 1948, after 1-1/2 years of exposure. Figure 1 shows some of the results.

Acetylation affected the performance of coatings only in matters of coating integrity, such as cracking, curling, flaking, and scaling. Matters of coating appearance, such as gloss, color, collection of dirt, and susceptibility to mildew, were not affected by acetylation, nor were chalking and erosion as far as could be determined. The pair of panels exposed without any coating proved that acetylation markedly delayed and reduced wood checking and greatly retarded the graying of the wood from weathering. Acetylation, therefore, offers great promise of improving paint performance and minimizing wood checking. A need for further experiments with such woods as Douglas-fir and southern yellow pine, both as plywood and as lumber, is clearly indicated.

Impreg

Another method of improving the dimensional stability of wood is that of impregnation with resin-forming materials followed by curing of the resins in place in the wood structure. The product is known as impreg (18). Preliminary exposure tests of the painting of impreg were started in 1937 and were continued until December 1944.

The test panels were 3/8 by 18 by 18 inches in size, made of three plies of 1/8-inch Douglas-fir veneer. Six panels were made with untreated face plies and six with face plies of impreg produced from the Douglas-fir veneer. All of the panels were bonded with hot-pressed phenolic-resin glue. Before painting, the bottom half (9 by 18 inches) of each impreg-faced panel was thoroughly sandpapered to remove any continuous layer of resin and to permit contact of the paint with impregnated wood fibers. One plain- and one impreg-faced panel were coated on all surfaces and edges with one of each of the following finishes:

1. Three coats of paint L p/nv 0.27.
2. One coat of aluminum house paint plus 2 coats of paint L p/nv 0.27.
3. Three coats of paint $(TL_{28}Z_{28})_{116}$ p/nv 0.29.
4. One coat of aluminum house paint plus 2 coats of paint $(TL_{28}Z_{28})_{116}$ p/nv 0.29.
5. One coat of paint L, plus 1 coat of a mixture of equal parts of paint L and enamel $(TZ_{66})_{207}$(e) p/nv 0.19, plus 1 coat of enamel $(TZ_{66})_{207}$(e) p/nv 0.19.
6. One coat of aluminum house paint, plus 1 coat of the mixture of paint L and enamel $(TZ_{66})_{206}$(e), plus 1 coat of enamel $(TZ_{66})_{207}$(e) p/nv 0.19.

The painted panels were exposed to the weather in the vertical position facing south.

There were both favorable and unfavorable developments in paint performance on the impreg as compared with plain Douglas-fir. There was little or no crumbling or flaking of paint from the bands of summerwood in impreg even after 7-1/2 years of exposure. On untreated Douglas-fir, paint L, when self-primed, began to crumble from summerwood after 3-1/2 years and left the summerwood almost entirely bare within 7-1/2 years. Paint $(TL_{28}Z_{28})_{116}$, when self-primed, and enamel $(TZ_{66})_{207}$(e), when primed with paint L, began to flake from the summerwood of untreated Douglas-fir during the fourth and fifth years. But on impreg, paint L showed little crumbling and paint $(TL_{28}Z_{28})_{116}$ and enamel $(TZ_{66})_{207}$(e) showed no flaking over summerwood after 7-1/2 years. Use of aluminum primer on plain Douglas-fir also succeeded in preventing crumbling or flaking from summerwood, though no more effectively than the impreg did.

Both of the paints and the enamel, however, developed their normal checking or cracking patterns just as early over impreg as they did on plain Douglas-fir. But on impreg the checking or cracking led to alligatoring during the fourth year with the enamel or the fifth year with the two paints. With paint L the alligatoring was confined to the summerwood bands in the impreg. Alligatoring occurred earlier and became much more pronounced when paint $(TL_{28}Z_{28})_{116}$ or the enamel were applied over aluminum primer on impreg than when they were applied over white primer. Thus the beneficial effect of impreg in preventing crumbling and flaking was partly offset by a tendency to cause alligatoring. It is possible, however, that the finishing systems were more than usually prone to alligatoring in consequence of their application indoors without exposure to sunshine b tween coats, for paint $(TL_{28}Z_{28})_{116}$ eventually became distinctly alligatored over aluminum primer on untreated Douglas-fir. Nevertheless, the alligatoring in the 1937 tests on impreg should be kept in mind in connection with the alligatoring reported later on in the 1941 tests on plywood covered with resin-impregnated paper pulp.

Sandpapering the surfaces before painting exerted little or no effect on the performance of the coatings. On two or three of the panels there was slightly less alligatoring over the sandpapered than over the unroughened part of the surface, but the difference was too slight to be considered significant.

No wood checking ever appeared in the impreg-faced panels. The plain Douglas-fir faces, however, developed a moderate degree of wood checking during the course of the tests.

Figure 2 shows how the impreg prevented crumbling and flaking from summerwood. It also shows alligatoring over the impreg not found on the comparison panels of plain Douglas-fir.

Paper Covering

In 1932, following a proposal by M. E. Dunlap of the Forest Products Laboratory, tests were started in which 6-inch bevel siding of southern yellow pine was covered on all six sides with paper. To make the test panels, 6-foot boards were cut in half (to 3-foot lengths) and paper glued to one half but not to the other half. Thus panels of covered and of ordinary siding were assembled in which the wood was carefully matched. Two weights of paper were tested, one a thin, unsized tissue paper and the other a fairly heavy kraft wrapping paper. The paper was glued in place with water-resistant animal glue of the paraformaldehyde formula (1), inasmuch as resin glues had not yet been developed.

A covered and an uncovered test panel were painted with three coats of paint L p/nv 0.27, and another pair of panels was painted with paint $(TZ_{23})_{92}$ p/nv 0.29. During the painting the panels were exposed to sunshine for 8 hours between coats of paint. After painting the panels were exposed at 45 degrees from the vertical facing south on the test fences at Madison, Wis. The exposures lasted from August 29, 1932 to July 8, 1935.

The results are summarized in table 2. Paint was applied slightly more generously over paper of each kind, making slightly thicker coatings, than over uncovered wood. The coatings were somewhat thicker than 0.005 inch,generally considered optimum for initial paint jobs on previously unpainted wood. As a result the coatings were distinctly more durable than is normally expected on southern yellow pine exposed at 45 degrees facing south, but when flaking or scaling began the stresses operating at the paint-paper interfaces may have been abnormally high.

Figure 3 shows the panels painted with pure white lead paint at the conclusion of the tests. The covering of kraft paper succeeded in preventing early crumbling from the summerwood, which can be plainly seen on the uncovered panel, and thereby materially prolonged the durability of the coating. Similar results were obtained with paint $(TZ_{23})_{92}$. The tissue paper, however, proved too weak to withstand the shrinking of crumbling or scaling paint after it has checked or cracked and started to break away. The kraft paper, moreover, kept the exposed surfaces free from observable wood checking and reduced the amount of cupping of the boards under the severe weathering conditions of the test.

The test panels were removed from the fence in 1935 and stored in a laboratory, kept warm but not humidified in winter, until April 1937. Drying of the wood led to shrinkage, which partly loosened the glue bond between kraft paper and wood and left the paper slightly rumpled. The panels covered with kraft paper and their matched but uncovered panels were then repainted with two coats of fresh paint of the kinds used originally and were restored to the test fences, but this time in the vertical position facing south. The new exposures continued until the summer of 1944. Reabsorption of moisture out of doors soon swelled the wood sufficiently to draw the kraft paper taut again, but contraction of the paint coating as it aged cracked the paper over the areas where the glue bond had broken. Paper and coating then began to curl and scale from the wood. On the other hand, where the paper remained firmly glued to the wood, it continued to improve paint durability by preventing crumbling or flaking from the summerwood bands.

The 1932 tests showed clearly that a covering of paper of sufficient strength would greatly improve the performance of paint on the heavy softwoods provided that the paper could be held firmly in place by more weather-resistant glue than animal glue treated with paraformaldehyde.

Tests in 1949

In 1949 further studies were made with paper coverings on southern yellow pine. Paper was glued to both faces of boards 25/32 inch thick and 6-1/4 inches wide.[4] The boards were then resawed and edge-jointed to make nominal 6-inch bevel siding with paper glued on the exposed face only. Preliminary tests showed that ordinary paper gave trouble in jointing or crosscutting because the paper became badly frayed at the cut edges. Kraft paper impregnated with 5 percent by weight of water-soluble phenolic resin and cured without pressure at 325° F. for 15 minutes, when glued to the boards permitted cutting to smooth edges without any fraying.

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[4] Bruce G. Heebink designed and prepared all of the paper-covered boards for these tests.

For the tests two thicknesses of treated kraft paper were used on different panels, namely, 2 mils and 6 mils. For each thickness of paper, test panels were made with each of three different glues to bond the paper to the wood, namely, casein glue, urea-resin glue, and a phenolic-resin glue of the type curing at room temperature. For each combination of thickness of paper and kind of glue, one test panel was exposed on the test fences without painting and one panel was painted on the exposed face. There were also two panels of southern yellow pine without covering of paper, one painted and one allowed to weather without painting. All painting consisted of a priming coat of paint $(TL_{25})_{79}$ p/nv 0.35 and one finish coat of paint $(TZ_{20}Z_{20})_{114}$ p/nv 0.30, which made coatings approximately 3.4 mils thick. The panels were exposed vertically, facing south, from July 27, 1949 to October 31, 1950.

Within 2 or 3 weeks after starting the exposures, some of the panels covered with casein-glued paper, both painted and unpainted, began to show blisters where there was separation at the wood-paper interface. There was also some separation of paper from wood along the bottom edges of boards. Such early failures are attributed to inadequate gluing; probably to unduly long assembly time in the gluing operation. By October 1950, after 14-1/2 months, all unpainted panels with paper covering blistered and loosened at bottom edges; those with casein glue were most seriously and those with phenolic-resin glue least seriously damaged. The painted panels with paper covering glued with either urea-resin or phenolic-resin glue were still in excellent condition.

The painted panels with paper glued with urea-resin or phenolic-resin glue and the painted panel without paper were reassembled and restored to the test fence in the spring of 1951. By May 1952, after a little more than 2 years of total exposure, there was blistering on all of the paper-covered panels. On the control panel without paper the paint was beginning to flake from summerwood. On paper coverings there was no paint flaking. The 2-mil paper did not succeed in hiding raised grain, but the 6-mil paper allowed no raised grain to show.

Paper covering for the exposed faces of siding, if about 6 mils thick, shows promise of improving paint performance on the heavier softwoods, but more work is needed to develop the technique of gluing the paper in place reliably.

Coverings of Resin-Impregnated Pulp or Paper

In 1941 tests were started with a commercial product consisting of exterior-grade plywood of Douglas-fir faced on both sides with a covering said to be pulpboard impregnated and glued to the plywood with phenolic resin. The pulpboard may have been somewhat compressed in the hot-press gluing, but it was by no means saturated with resin and remained somewhat porous, though not so absorptive of liquids as wood is. The covering was 1/32 inch thick.

Test panels were 2 feet by 6 feet in size but were marked off into test areas 2 feet by 1-1/2 feet in size. Panels were mounted in the vertical position on both the north side and the south side of the test fence so that the backs, which remained unpainted, were not exposed to the weather. The upper half of the exposed face of each panel was sandpapered enough to roughen the surface slightly and to remove any continuous film of resin that might have been at the surface. On any one panel each test area received a different priming coat or combination of priming coat and undercoat, but all four test areas of any one panel received the same finishing paint or enamel. During painting the panels were exposed to sunshine for at least 8 hours between coats. The panels were exposed on the test fence at Madison, Wis., on June 3, 1941, and the final inspection was made on August 25, 1944.

It was found that priming paints spread about 15 to 20 percent farther on the surfaces of resin-impregnated pulpboard than they did on wood. The difference arose from less absorption of paint liquids by the impregnated surfaces. The thickness of dried coating formed was probably about the same as on wood.

Sandpapering the surfaces before painting usually exerted no effect on the performance of the coating, but with 8 of the 24 coating systems tested the durability was impaired, sometimes seriously, by sandpapering.

Table 3 lists the coating systems tested and the important observations of their performance. Unpigmented primers such as wood sealer and spar varnish had markedly adverse effect on the durability of the paints and enamels. Aluminum house paint as a primer gave the best performance with the two house paints and one of the enamels, and one of the best with the second enamel. The presence of any zinc oxide in a primer proved distinctly harmful to the durability of any of the paints or enamels applied over it. Figures 4 and 5 show some of the results. The most significant development in the tests, however, was the tendency for many of the coatings to become alligatored, sometimes seriously so. With all of the coatings tested, alligatoring must be considered an abnormality of performance. Yet only three of the systems (both of the enamels when applied over aluminum primer and enamel T_{420}(ar) when self-primed) remained entirely free from alligatoring. Presence of zinc oxide in a primer under either of the house paints made alligatoring especially conspicuous. Sandpapering before painting either failed to alter or increased the tendency toward alligatoring.

Since the abnormality of alligatoring had appeared previously in resin-impregnated surfaces in the 1937 tests of impreg, there seemed to be a strong presumption that the impregnating resin was responsible for it. Incompatibility between the resin and paint coatings seemed to be indicated. The findings that the antagonism was worse toward house paints, with oil vehicles, than toward enamels, with resinous vehicles, and that presence of zinc oxide in a primer was an aggravation, were consistent with that view. Nevertheless, judgment should be reserved in the light of tests described farther on.

Although no further tests have been made at the Forest Products Laboratory with the resin-impregnated pulpboard surfacing, one of the authors (F. L. Browne) has seen adequate tests made by a paint manufacturer's laboratory in the Chicago area with the same brand of covered plywood as manufactured since the close of the war. Paint and enamel systems reasonably similar to those of the Forest Products Laboratory tests were used. No difficulty with alligatoring was experienced in the more recent tests. It is not known whether the covered plywood had been changed in any way, such as by the amount or kind of resin used, by the curing conditions, or by any lubricants used on the press cauls.

Papreg Tests

A wartime study of problems in aircraft finishing, started in 1943, involved comparative tests of 44 different finishing systems on birch plywood, poplar plywood, and on papreg, which is a resin-impregnated paper laminate containing about 35 percent of phenolic resin (16) and compressed to a smooth surface that is practically nonabsorptive of paint liquids. Before applying finishes, half the area of each test panel of papreg was sandpapered enough to destroy the glossiness and to make the surface slightly rough.

The finishes applied were all commercial products, most of which presumably conformed to currently applicable military specifications of the performance type, but the composition of the finishes was only partly disclosed. They included oleoresinous enamel systems, nitrocellulose lacquer systems, and nitrocellulose dope systems with and without fabric. In each class there were sealers, surfacers, and pigmented finish coats that were tested in several combinations. Both glossy and lusterless (camouflage) finish coats in yellow, dark-blue, aluminum, and olive-drab colors were included. There were no house paints.

The outcome of the tests failed to indicate any incompatibility between papreg and the finishes of aircraft type. Abnormal forms of failure such as alligatoring or coarse scaling were almost entirely absent. In general, the ultimate form of failure of each coating was essentially the same on papreg and on plywood, though the rate at which failure took place varied among the substrates.

As a rule, the finishes lasted longer on papreg than on yellow-poplar plywood and longer on yellow-poplar than on birch plywood. According to a scoring system adopted for the purpose in which the highest number represented the longest life of the coating, the average score for all finishes on papreg was 4.7, on yellow-poplar 3.6, and on birch 3.0. Oleoresinous finishes outlasted lacquer finishes, but the difference between them was much less on papreg than on plywood. Thus the scores for oleoresinous finishes on papreg and on yellow-poplar were 4.8 and 4.3, respectively, whereas for lacquer finishes the corresponding scores were 4.0 and 2.5. Sandpapering the surface of papreg had little effect on the performance of finishes. For 34 finishing systems there was no observable effect of sandpapering, for 5 systems durability was slightly impaired, and for 5 it was slightly improved by sandpapering.

Resin-Impregnated Paper Covering (1944)

A comprehensive series of tests was started in 1944 on Douglas-fir plywood with and without covering on both faces with resin-impregnated paper. The covering consisted of three plies of paper containing 40 to 50 percent of water-soluble phenolic resin, subsequently cured and compressed to a thickness of 0.009 inch, and having a weight of 80 pounds per thousand square feet of single surface. The press cauls used produced a surface of very low gloss and a slight degree of roughness. The covering material used was a commercial product, the manufacturer of which supplied both the covered and uncovered plywood for the tests.

The size and arrangement of test panels on the test fence at Madison, Wis., were essentially the same as has already been described for the 1941 tests of resin-impregnated pulpboard covering, except for a much greater number of panels and for repetition of all tests on plain plywood as well as on the covered plywood. There were 320 test areas, 160 of which were plain plywood and 160 were plywood covered with resin-impregnated paper. Eighty test areas of each kind were exposed facing south and 80 facing north. A total of 77 finishing systems were tested, of which 33 were house-paint primers and house paints, 36 were oleo resinous enamels with various primers and undercoaters, and 8 were nitrocellulose lacquer systems. For the present purpose it is sufficient to report results with 18 of the house-paint systems and 10 of the enamel systems in table 4. With respect to the nature of the differences in performance on plain and covered plywood, the unreported finishing systems behaved like those reported.

The upper halves of all test areas of plywood covered with resin-impregnated paper were sandpapered before any finishing material was applied. As a rule, such roughening of the surface produced no noticeable difference in the performance of the coatings on exposure. On 6 of the 80 test areas of covered plywood facing south the coating failed slightly more rapidly on the sandpapered portion than it did on the unroughened portion. All of the tests of resin-impregnated surfaces, whether wood, pulpboard, or paper, indicate that sandpapering seldom proves helpful, usually has little effect, and when it does is more often harmful than beneficial.

The upper halves of all test areas of plain plywood in the 1944 tests were treated with a water repellent before painting. The water repellent was a solvent naphtha solution of 1.5 percent of paraffin wax and 13.5 percent of resin by weight. The treatment failed to improve the performance of any of the finishing systems tested. It likewise failed to effect any noticeable reduction in the amount of face checking of the plywood during the course of the tests.

During the painting it was found that the first coat of finishing material applied, whatever its nature, usually was spread farther on the nonabsorptive surface of the covered plywood than it was on plain plywood. The average spreading rate for all first coats was 600 square feet per gallon on covered and 900 square feet per gallon on plain plywood. Thus the covered plywood requires only two-thirds the material needed for plain plywood. When the thicknesses of dried coating were calculated, assuming no absorption of primer liquids by the resin-impregnated paper, the average for all first coats was 1.1 mils for both the plain and covered plywood. The difference in consumption of priming material, then, seems to be wholly the quantity absorbed by plain wood.

The average spreading rates for all second coats were 611 and 653 square feet per gallon on plain and on covered plywood, respectively. The corresponding averages for all third coats were 722 and 713. Thus in applying coatings about 4.5 mils thick, there was a saving of a little less than 15 percent of finishing material for the covered plywood as compared with plain plywood.

The covering of resin-impregnated paper presented a smooth, uniform surface on which enamel finishes appeared to best advantage; on plain plywood the appearance of the enamels was often impaired by slightly raised grain in the wood, which formed noticeable ridges in the enamel surface over some of the bands of summerwood. With paint finishes such effects of slightly raised grain were usually made inconspicuous by the pattern of brush marks left in the surface of the coating.

Table 4 shows that nearly all coatings proved more durable on the covered than on the plain plywood. Only the southern exposures are reported because in 6 years the coatings facing north did not deteriorate sufficiently to estimate their relative durabilities. The advantage for the covered plywood was usually greatest for the least durable coatings. Thus the systems consisting of sealer followed by two coats of house paint lasted about 20 months longer on covered than on plain plywood. Where coatings were durable for 70 months or longer on plain plywood, the durability on covered plywood could hardly be more than a few months longer. The average durability of 33 house-paint systems was 58 months on plain plywood and 74 months on covered plywood. For 36 enamel systems the average durability was 63 months on plain and 77 months on covered plywood. For 8 lacquer systems the average durability was 51 months on plain and 71 months on covered plywood.

Particularly significant is the fact that the difference between the most durable and the least durable coating on covered plywood was much less than the corresponding difference on plain plywood. In other words, the covered plywood proved materially less sensitive to variation in the quality of the coating than was plain plywood. A few of the most durable finishing systems on plain plywood, particularly those in which aluminum priming paint was used, compared favorably in durability with the best systems on covered plywood.

The optimum pigment volume for priming coats in house-paint systems turned out to be somewhat higher for covered plywood than for plain plywood. On covered plywood pigment volume 0.4 generally gave best results, but on plain plywood 0.3 or sometimes even 0.2 proved better. Such difference was to be expected because wood absorbs much of the liquid from priming coats and thereby raises the pigment volume in the dried coating, whereas on resin-impregnated paper there is no such absorption. For enamel systems special primers or undercoaters usually proved advantageous for plain plywood, but on the covered plywood the simpler practice of priming with the same enamel used for the finish coat often proved better.

Figure 6 shows how coating on plain plywood eventually wore out by crumbling or flaking from summerwood until the grain pattern of the wood was clearly revealed. On covered plywood, shown in figure 7, crumbling or flaking set in irregularly, following no pattern related to the grain of the wood or the structure of the covering. In general, each paint or enamel followed its own characteristic course of disintegration by checking and crumbling or by cracking, curling, and flaking, whether it was on plain plywood or on covered plywood. The covering, however, succeeded in preventing the unduly early onset of crumbling or of flaking from summerwood that is so troublesome on the heavier softwoods.

In the 1944 tests on resin-impregnated paper coverings none of the paints, enamels, or lacquers tested developed abnormal alligatoring such as was observed in the 1937 tests on impreg and the 1941 tests on resin-impregnated pulpboard coverings. This was true even though a number of the priming paints or enamel undercoaters contained zinc oxide. The alligatoring of coatings in the 1937 and 1941 tests, therefore, cannot be attributed to the mere presence of resin in the surface or of zinc oxide in the priming coat. The alligatoring that has been observed in certain tests remains for the present unexplained. Until more is learned about it, resin-impregnated surfaces must be tested for paint performance on them to see whether difficulties with alligatoring may be experienced. The Forest Products Laboratory has more recent tests underway on paper coverings impregnated with varying proportions of different resins, but the work has not yet advanced sufficiently to warrant detailed description.

Resin-Bonded Sawdust Covering

Tests were started in 1951 on a commercial product that consists of Douglas-fir plywood covered on one face only with a finely granular material said to be finely ground wood waste bonded together and to the plywood with resin. The surface presented is light in color, lusterless, and slightly rough to feel. It was found to be much more absorptive of paint liquids than plain plywood.

When oil-rich house paints were thinned with extra linseed oil or paint thinner for application on the covered plywood, the granular covering absorbed liquid so rapidly and extensively that the paint became dry under the brush and was exceedingly difficult to spread evenly. Brushing had to be done very quickly. Excessive quantities of priming paint were consumed, up to half again as much as was needed for plain plywood. Moreover, such primers failed to seal the surface adquately to permit one subsequent coat of finish paint to dry with uniform gloss. A second finish coat, the third coat in all, dried with uniform gloss.

Special house-paint primers made with a substantial proportion of bodied oil, which provides the property commonly called controlled penetration, proved reasonably satisfactory on the granular covering, though it was still necessary to spread the paint rapidly. The extra consumption of special priming paint was only 3 to 15 percent of that needed on plain plywood. One coat of house-paint primer sealed the surface well enough for one coat of finish paint to dry with uniform gloss.

Covering the plywood on one face only produced an unbalanced construction that led to marked cupping of the test panels while they were in process in the carpenter shop and painting laboratory. The covered face became concave. When the panels were straightened by nailing them in place on the test fence, a number of conspicuous cracks developed in the granular covering and the coating of paint over it. It would be advisable to balance the construction of the product to avoid such difficulties, because precise control of moisture content at all times during building construction cannot be expected.

The tests have not yet been exposed long enough to give significant indication of the performance of the coatings.

Mechanical Treatment of Wood Surfaces

The chief shortcoming of the heavier softwoods comes from the wide bands of summerwood presented for contact with the paint coating. Edge-grain boards, in which the bands of summerwood are of minimum width, hold paint materially longer than otherwise similar flat-grain boards. Better paintability of flat-grain boards should be expected if a mechanical processing of the surfaces can be devised to subdivide the wide bands of summerwood.

Douglas-fir plywood with striated surfaces, such as are shown in figure 8, has been on the market for some time. From observations of practical experience like that shown in figure 8, it is evident that the striations succeed in improving paint performance by narrowing the bands of summerwood in contact with the paint. In addition, the process very significantly reduces face checking in Douglas-fir plywood.

In 1951 the Forest Products Laboratory began tests of striations on lumber siding of Douglas-fir and of southern yellow pine. The tests are not yet old enough to tell whether an improvement in paint performance has been effected. They have shown, however, that when siding is erected with the striations horizontal, the paints often become more seriously soiled with dirt than they do on smooth lumber or on striated lumber erected vertically. Further tests would be highly desirable in which other patterns of striations would be tried, particularly if some mechanical method of narrowing the bands of summerwood without so greatly altering the appearance of the painted wood could be found.

Conclusion

The heavier softwoods, which are the most abundantly available woods for building construction, are less desirable for durable painting than the lightweight but less abundant softwoods. Paint performance on the heavier softwoods can be improved by careful selection, application, and maintenance of the most suitable paints, but it can also be improved with a wider tolerance for different kinds of paints by any one of several methods of specially processing lumber or plywood.

The beneficial processing methods discovered thus far depend on more than one principle, stabilizing the wood against swelling and shrinking, covering the wood with thin layers of uniformly textured material, and mechanically treating the surface to subdivide the troublesome wide bands of summerwood.

Moisture stability can be imparted by acetylating the wood, or at least the parts of the wood nearest the painted surface. The method involves problems of chemical engineering that have not yet been completely solved, but if offers promise of better paint performance without appreciable change in any of the desirable properties of wood. Stabilization by suitable impregnation with resins is also effective in improving paint performance, but it alters the weight, appearance, and toughness of wood and adds seriously to cost.

Coverings to improve paintability have so far been developed more extensively for plywood than for lumber, though in principle they are applicable to both. Successful coverings usually involve resin impregnation, which under some circumstances not yet fully understood may tend to cause abnormal alligatoring of coatings, though it is evident that such troubles can be controlled when more is known about them. Coverings can be made of pulpboard, paper, ground wood, and doubtless of other materials not yet tried. Coverings materially alter the appearance of wood for use without finishes or with transparent finishes.

Mechanically striating the surfaces of Douglas-fir plywood greatly improves paint performance and minimizes face checking. The process should be applicable to other woods, including lumber. The striations now used greatly alter the appearance of wood, though the novel appearance is an advantage for many purposes. Other methods of mechanical treatment that produce less alteration of appearance might well be sought.

How far the burden of changing customary practices in the interest of better paint performance should fall on lumber producers and how far on paint makers is a matter for the give and take of industry to determine. It has now become evident that, from at least the technical point of view, progress can be made on both sides of the paint-wood interface.

<u>Appendix</u>

The method used to express the approximate composition of house paints concisely by suitable symbols was published in 1937 (10). Capital letters with their subscripts stand for the opaque white pigments and their proportions in percentages of the total pigment by volume. The letter L stands for white lead, Z for zinc oxide, T for titanium dioxide, and S for zinc sulfide. Thus paint L was pure white-lead paint. It might be written L_{100}, but the subscript is omitted when it is obvious. Paint LZ_{55} would have a pigment composed of 55 percent zinc oxide and 45 percent (100 minus 55) by volume of white lead. In a paint $(LZ_{30})_{80}$, the parentheses indicate that the opaque pigments, white lead and zinc oxide, together amounted to 80 percent of the total pigment (30 percent of zinc oxide plus 50 percent white lead). The remaining 20 percent of pigment in this paint would be extending pigments. When titanium dioxide is present, it is assumed that, unless otherwise indicated, there are 3.2 volumes of extending pigment for each volume of titanium dioxide. Thus, paint $TL_{28}Z_{28}$ was paint with a pigment composed of 28 percent zinc oxide, 28 percent of white lead, and 44 percent of titanium pigment (100 less 28 for the zinc oxide, less 28 for the white lead), or 10.5 percent of titanium dioxide (44 divided by the quantity (3.2 plus 1)) and 33.5 percent of extending pigment. But in paint $(TL_{28}Z_{28})_{116}$ the equivalent opaque pigment was 116 percent, signifying less than the standard dilution of titanium dioxide with extending pigment; hence, the content of titanium dioxide was 14.3 percent (116 minus 28 minus 28 divided by the quantity (3.2 plus 1)) and that of extending pigment was 29.7 percent (100 minus 28 minus 28 minus 14.3).

Unless otherwise indicated, the nonvolatile vehicle in house paints is understood to be a drying oil, such as linseed oil, chiefly in unbodied (not thickened in viscosity) form. In priming paint TL_{29}(e) or in enamel $(TL_{10}Z_{20})_{133}$(e) much or all of the drying oil was bodied. In an enamel $(TZ_{25})_{138}$(re) the vehicle would contain resin of unspecified kind and bodied oil, that is, an oleoresinous varnish. In enamel $(TZ_{25})_{138}$(pre) the varnish was one made with phenolic resin. In enamel T_{246}(ar) the vehicle was an alkyd resin with no bodied drying oil other than that contained in the resin itself. If bodied drying were added together with the alkyd resin, the symbol would be (are).

The ratio by volume of total pigment to total nonvolatile material in a paint, which is also the fraction of the dried coating occupied by pigment, is indicated by the symbol p/nv and the appropriate decimal fraction. Thus p/nv 0.29 means that the paint, as used for the finish coat, contained 0.29 gallon of total pigment to a gallon of total nonvolatile material.

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Table 1.--The 1947 tests on acetylated wood -- relative performance of coatings on acetylated as compared with untreated wood after 4-1/2 years' exposure to the weather facing south at Madison, Wis.

Priming paint or enamel undercoating: Chief ingredients and their proportions[1]	Priming paint or enamel undercoating: Pigment volume, p/nv	Finish paint or enamel: Chief ingredients and their proportions[1]	Finish paint or enamel: Pigment volume, p/nv	Relative performance of coating on acetylated sweetgum as compared with untreated sweetgum
		On panels faced with sweetgum sapwood		
L	0.30	L	0.30	Slightly[2] more durable
$TL_{30}(e)$	.40	$(TL_{29}Z_{30})_{168}$	.29	Distinctly more durable
$(TL_{30}Z_{30})_{168}$	.19	$(TL_{29}Z_{30})_{168}$	.29	Distinctly more durable
$T_{133}(e)$	.60	$(TL_{10}Z_{20})_{133}(e)$	.40	Distinctly more durable
$T_{133}(e)$	.60	$T_{133}(e)$	.40	No difference up to 4-1/2 years
$T_{133}(e)$	.60	$T_{139}(pre)$	.31	Very slightly more durable
$T_{133}(e)$	.60	$T_{244}(ar)$	.22	Markedly more durable
Low-viscosity nitrocellulose lacquer enamel, white				Very markedly more durable
High-viscosity nitrocellulose lacquer enamel, white				Markedly more durable
Aluminum[3]	--	$(TL_{29}Z_{30})_{168}$	.29	No difference up to 4-1/2 years
$T_{133}(e)$	.60	$(TZ_{15})_{325}(ar)$	.36	Very markedly more durable
		On panels faced with sweetgum heartwood		
L	.30	L	.30	Slightly more durable
$(TL_{30}Z_{30})_{168}$	.19	$(TL_{29}Z_{30})_{168}$	.29	No difference up to 4-1/2 years
$T_{133}(e)$	.60	$T_{244}(ar)$	.22	Distinctly more durable
Low-viscosity nitrocellulose lacquer enamel, white				Very markedly more durable

[1]For the meaning of the symbols for compositions of paints see the appendix to this paper.

[2]The adverbs indicate increasingly significant differences in the following order: very slightly, slightly, distinctly, markedly, very markedly.

[3]Aluminum house paint made with aluminum powder in bodied linseed oil, resin-free vehicle.

Table 2.--The 1932 tests on paper coverings glued on southern yellow pine bevel siding

Covering on siding	Paint coating (Three coats were applied)		Relative performance	
	Kind of paint[1]	Thickness[2]	Durability[3]	Integrity[3] after 35 months
		Mils	Months	
Kraft paper	L p/nv 0.28	6.1	35	Poor[4]
None	do	5.2	29	Bad
Tissue paper	do	6.6	22	Bad[5]
None	do	5.8	30	Bad+
Kraft paper	$(TZ_{23})_{92}$p/nv 0.28	6.6	35	Poor[4]
None	do	6.0	30	Bad
Tissue paper	do	6.1	25	Bad[5]
None	do	5.9	25	Bad

[1] For the meanings of the symbols for composition of the paints see the appendix to this paper.

[2] Thickness of the dried coating was calculated from the spreading rates by methods previously described (12). One mil is 0.001 inch.

[3] Successive stages in the deterioration in integrity of coatings are rated good, fair, poor, and bad with the added subdivisions of high (+), medium, and low (-) in each stage. The time elapsed until the coating reaches medium poor, when it is considered ready for repainting, is called the durability (4).

[4] Crumbs or flakes of paint became detached from the surface of the kraft paper, leaving the paper firmly attached to the wood.

[5] Crumbs or scales of paint that became detached took with them part or all of the tissue paper, that is, the line of separation was chiefly within the paper.

Table 3.--The 1941 tests on Douglas-fir plywood covered with resin-impregnated pulp board.

Painting system[1]: First coat- (p/nv)	Painting system[1]: Second coat- (p/nv)	Painting system[1]: Third coat- (p/nv)	Thickness of coating[2]	Facing south: Alligatoring[3]	Facing south: Rating for coating integrity[4] after 39 months	Facing south: Durability[5]	Facing north: Alligatoring[3]	Facing north: Rating for coating integrity[4] after 39 months	Facing north: Durability[5]
			Mils						
Wood sealer	L (0.37)	L (0.27)	4.0	T	[6]Bad+	18	T	Poor+	42
Spar varnish	do	do	4.2	S	[6]Bad+	18	M	Poor+	42
L (0.37)	do	do	5.1	T	Poor	39	T	Fair-	45
Aluminum[7]	do	do	4.3	S	Poor+	42	O	Fair+	51
$(TL_{58})_{208}$(e)(0.20)	L (0.27)	None	3.9	M	[6]Poor	39	M	Poor	39
TL_{28}(e)(0.40)	do	do	4.4	S	Poor+	42	M	Poor+	42
L (0.37)	do	do	4.3	T	Poor	39	T	Fair	48
L (0.23)	do	do	3.9	M	Bad	22	O	Fair	48
Wood sealer	$(TL_{28}Z_{28})_{116}$(0.29)	$(TL_{28}Z_{28})_{116}$(0.29)	4.2	T	[6]Bad+	28	M	Poor	39
Spar varnish	do	do	4.4	V	[6]Bad+	28	M	Poor+	42
$(TL_{28}Z_{28})_{116}$(0.40)	do	do	5.0	VM	[6]Bad	24	VM	Bad	27
Aluminum[7]	do	do	4.5	M	[6]Poor	39	S	Poor+	42
$(TL_{58})_{208}$(e)(0.20)	$(TL_{28}Z_{28})_{116}$(0.29)	None	3.6	T	Poor+	42	S	Fair-	45
TL_{28}(e)(0.40)	do	do	4.0	S	Poor+	42	T	Fair-	45
$(TL_{28}Z_{28})_{116}$(0.40)	do	do	3.7	VM	[6]Bad-	15	VM	Bad	27
$(TL_{28}Z_{28})_{116}$(0.23)	do	do	4.5	VM	Bad+	22	VM	Bad+	30
$(TL_{20}Z_{30})_{126}$(e)(0.29)	$(TL_{20}Z_{30})_{126}$(e)(0.29)	$(TL_{20}Z_{30})_{126}$(e)(0.29)	5.6	T	[6]Bad+	28	O	[6]Poor	39
$(TL_{20}Z_{10})_{78}$(e)(0.60)	$(TL_{20}Z_{10})_{78}$(e)(0.60)	do	4.3	T	[6]Bad	25	O	[6]Fair-	45
TL_{28}(e)(0.40)	do	do	4.4	T	Poor+	42	O	Good	57
Aluminum[7]	do	do	3.7	O	Fair	48	O	Good	57
T_{144}(e) (0.30)	T_{144}(e)(0.30)	T_{420}(ar)(0.18)	2.6	S	Poor-	29	T	Fair-	45
T_{420}(ar) (0.18)	T_{420}(ar) (0.18)	do	2.5	O	Fair+	51	O	Good	57
TL_{28}(e) (0.40)	T_{144}(e) (0.30)	do	2.9	VM	Poor-	31	S	Fair-	45
Aluminum[7]	do	do	2.2	O	Fair+	51	O	Good-	54

[1]For meanings of the symbols for composition of paints see the appendix to this paper.

[2]Coating thickness was calculated by the Forest Products Laboratory method (12) except that the resin-impregnated pulpboard is assumed to absorb only one-fourth of the nonvolatile vehicle from priming coats. One mil is 0.001 inch.

[3]Degree of alligatoring indicated by O for none, T for trace, S for slight, M for marked, VM for very marked. Degrees M and VM were conspicuous enough to bring the rating for integrity of coating into poor or bad stage even though there may have been no crumbling or flaking.

[4]Successive stages in the deterioration in integrity of coatings are rated good, fair, poor, and bad with the added subdivision of high (+), medium, and low(-) in each stage (4).

[5]The durability is the age of the coating when it was first rated medium poor in integrity.

[6]Sandpapering the surfaces before painting proved harmful to the durability of the coating. The rating recorded is for the part that was not sandpapered.

[7]Aluminum house paint made with aluminum powder in bodied linseed oil, resin-free vehicle.

Z M 90652 F

Table 4.--The 1944 tests on Douglas-fir plywood covered with resin-impregnated paper.

Painting system[1]: First coat (p/nv)	Second coat (p/nv)	Third coat (p/nv)	Thickness of coating[2] on - Plain wood (Mils)	Covered wood (Mils)	Performance of coating during exposure facing south[3]: On plain plywood: Rating for coating in-tegrity[4] after 71 months	Dura-bility[5]	On covered plywood: Rating for coating in-tegrity[4] after 71 months	Dura-bility[5]
Sealer (pre)	L (0.30)	L (0.30)	4.6	4.3	Bad	49	Bad	65
Aluminum[6]	do.	do.	4.9	4.5	Fair-	77	Poor+	74
L (0.40)	do.	do.	5.0	4.6	Bad-	52	Fair-	77
L (0.30)	do.	do.	5.3	5.0	Bad-	63	Poor+	74
TL_{29}(e) (0.40)	do.	None	3.0	3.2	Poor-	68	Poor	71
TL_{29}(e) (0.30)	do.	do.	3.2	3.5	Poor	71	Poor+	74
Sealer (pre)	$TL_{28}Z_{28}$ (0.30)	$TL_{28}Z_{28}$ (0.30)	6.0	5.8	Bad	49	Poor-	70
Aluminum[6]	do.	do.	6.4	6.1	Poor	71	Poor	71
$TL_{28}Z_{28}$ (0.40)	do.	do.	6.1	6.0	Bad-	46	Fair+	83
$TL_{28}Z_{28}$ (0.30)	do.	do.	5.9	6.0	Bad-	49	Fair-	77
TL_{29}(e) (0.40)	do.	None	3.6	3.3	Bad+	53	Poor	71
TL_{29}(e) (0.30)	do.	do.	3.7	3.8	Poor-	57	Poor	71
Sealer (pre)	$(TL_{10}Z_{20})_{97}$ (0.30)	$(TL_{10}Z_{20})_{97}$ (0.30)	5.0	5.2	Bad-	46	Bad	66
Aluminum[6]	do.	do.	5.4	5.7	Poor	71	Poor	71
$(TL_{10}Z_{20})_{97}$ (0.40)	do.	do.	5.4	5.2	Bad-	47	Fair+	83
$(TL_{10}Z_{20})_{97}$ (0.20)	do.	do.	5.7	6.0	Poor-	58	Poor	71
TL_{29}(e) (0.40)	do.	None	3.6	3.5	Poor	71	Fair+	83
TL_{29}(e) (0.30)	do.	do.	3.8	4.1	Poor+	74	Fair-	77
Aluminum[6]	$(TL_{10}Z_{20})_{133}$(e)(0.40)	$(TL_{10}Z_{20})_{133}$(e)(0.40)	3.7	3.8	Fair-	77	Fair	80
TL_{29}(e) (0.40)	do.	do.[7]	3.9	2.8	Poor-	57	Poor+	74
$(TL_{10}Z_{20})_{133}$(e)(0.40)	do.	do.[7]	4.0	2.6	Bad	49	Fair+	83
Aluminum[6]	$(TZ_{25})_{138}$(pre)(0.31)	$(TZ_{25})_{138}$(pre)(0.31)	3.5	3.6	Fair-	77	Good-	86
TL_{29}(e) (0.40)	do.	do.[7]	4.1	3.0	Fair-	77	Fair+	83
$(TZ_{25})_{138}$(pre)(0.40)	do.	do.[7]	3.9	2.8	Poor+	74	Fair+	83
TL_{29}(e) (0.40)	$(TZ_{25})_{243}$(ar)(0.22)	$(TZ_{25})_{243}$(ar)(0.22)	3.6	2.9	Poor-	65	Fair	80
$(TZ_{25})_{243}$(ar)(0.22)	do.	do.	3.1	2.0	Bad+	57	Bad+	69
TL_{29}(e) (0.40)	T_{246}(ar) (0.22)	T_{246}(ar) (0.22)	3.5	2.9	Poor-	64	Poor	71
T_{246}(ar)(0.22)	do.	do.[7]	3.1	2.1	Poor	71	Fair-	77

[1] For meanings of the symbols for composition of paints see the appendix to this paper.

[2] Coating thickness was calculated by the Forest Products Laboratory method (12) but the resin-impregnated paper covering was considered nonabsorptive. One mil is 0.001 inch.

[3] Northern exposures are not recorded because the coatings did not deteriorate enough in 71 months to permit significant rating.

[4] Successive stages in the deterioration in integrity of coatings are rated good, fair, poor, and bad with the added subdivisions of high (+), medium and low(-) in each stage (4).

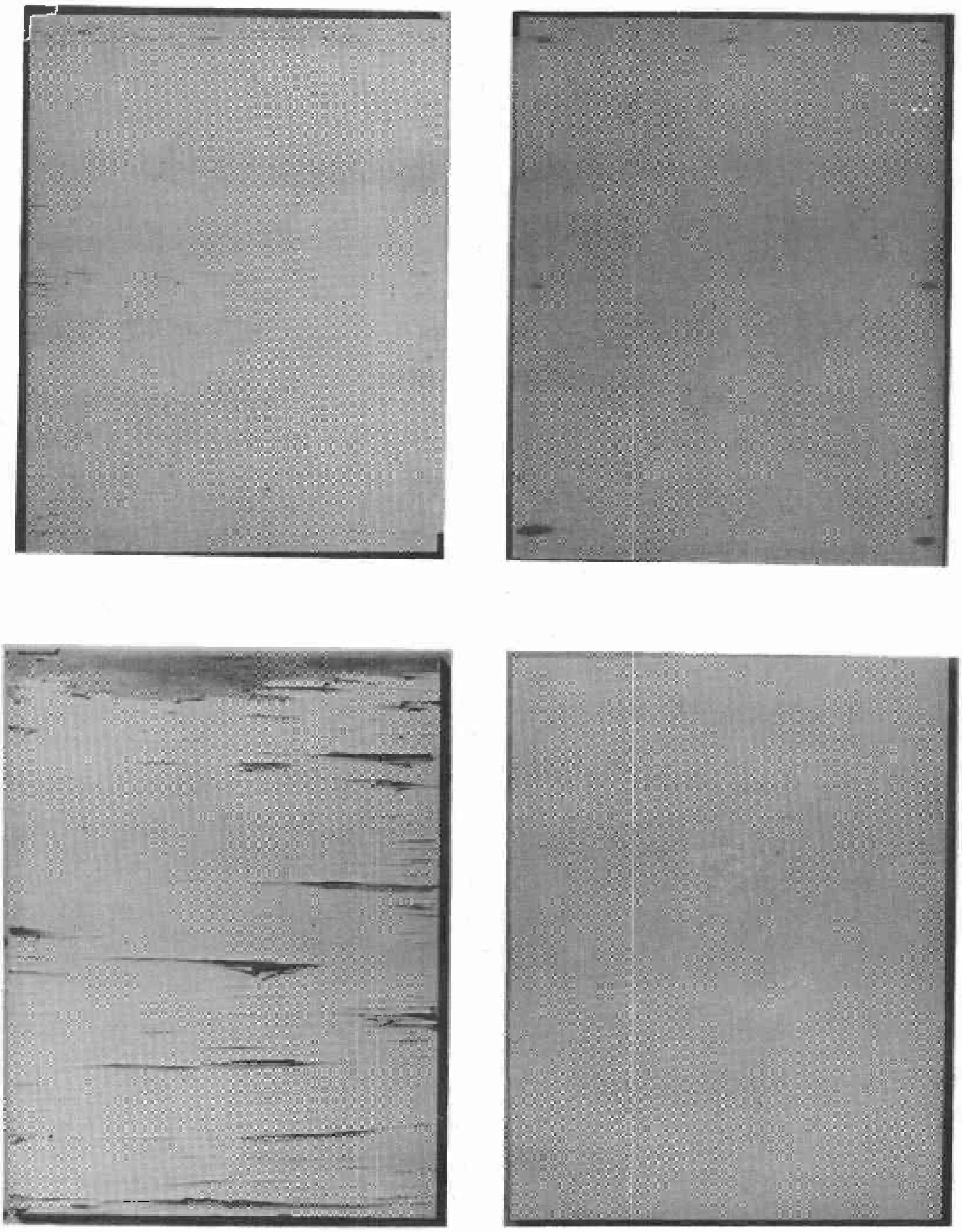
[5] The durability is the age of the coating when it was first rated medium poor in integrity.

[6] Aluminum house paint made with aluminum powder in bodied-oil, resin-free vehicle.

[7] The third coat was applied on plain plywood but was omitted on covered plywood.

Z M 90653 F

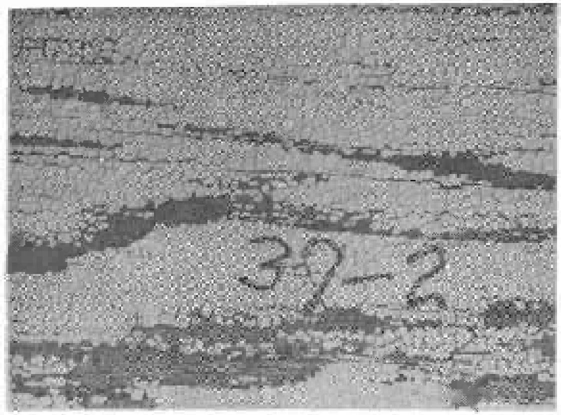
Figure 1.--Better performance of paint and enamel on acetylated than on untreated wood after 4-1/2 years' exposure to the weather vertically facing south at Madison, Wis. The two plywood panels at the left were faced with ordinary sweetgum, and the two at the right with acetylated sweetgum. The two upper panels were painted with house-paint primer TL_{30}(e) and house paint $(TL_{29}Z_{30})_{168}$. The two lower panels were painted with enamel undercoater T_{33}(e) and enamel $(TZ_{15})_{325}$(ar).

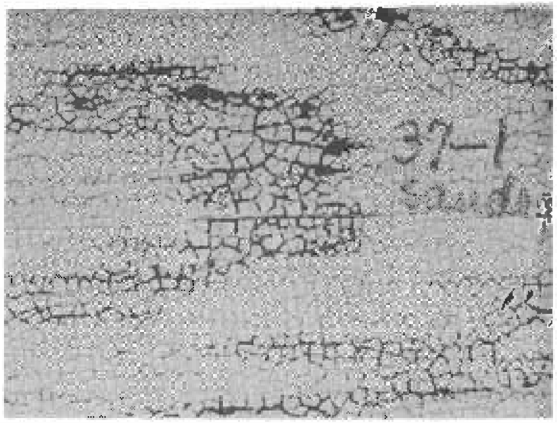


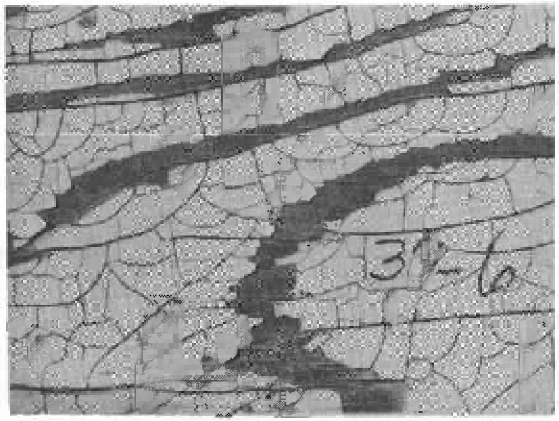
Z M 90113 F

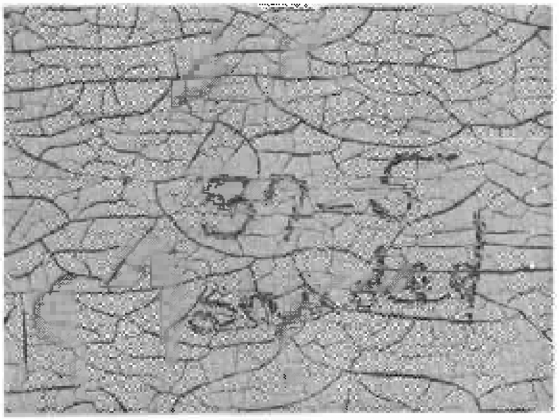
Figure 2.--Condition of house paints on impreg-faced and on plain Douglas-fir plywood after 7-1/2 years' exposure vertically facing south at Madison, Wis. The two panels at the left were plain plywood and the two at the right were plywood faced with impreg. The two upper panels were painted with paint L and the two lower panels with paint $(TL_{28}Z_{28})_{116}$.

Impreg prevented crumbling or flaking from summerwood but alligatoring developed on the impreg.









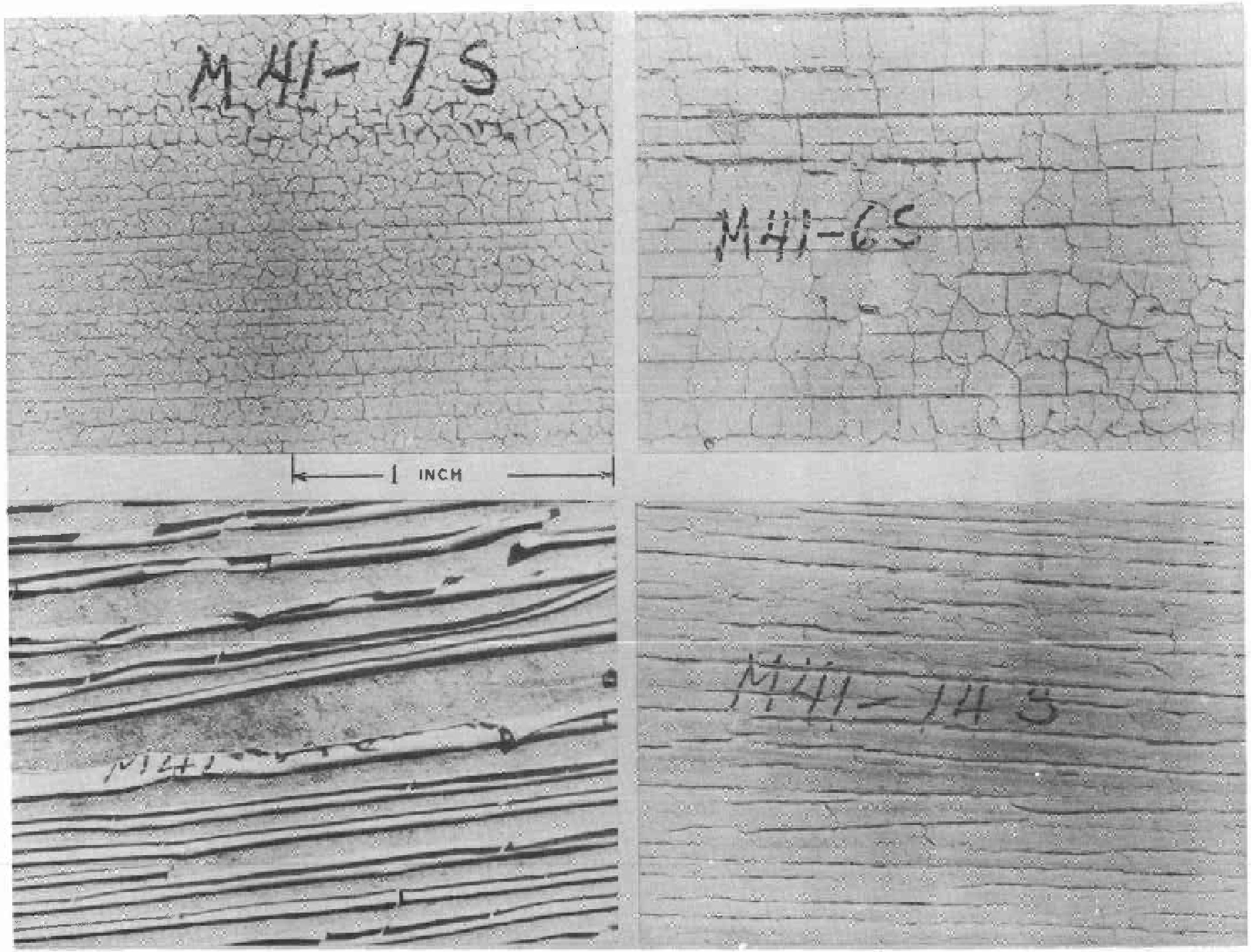
Z N 90112 F

Figure 3.--Performance of paint L on southern yellow pine (the two panels at the right) and on southern yellow pine covered with kraft paper (upper panel at left) or with tissue paper (lower panel at left) after 35 months' exposure at 45° facing south at Madison, Wis. (1932 tests).

ZM 67355 F

Figure 4.--Condition of some of the coatings of house paint on plywood covered with resin-impregnated pulpboard (tests of 1941) after 28 months' exposure vertically facing south at Madison, Wis. The two upper test areas were coated with paint L, the two lower test areas with paint $(TL_{28}Z_{28})_{116}$. The two test areas at the left were primed with the same paint used for the finish coat; the two test areas at the right were primed with house-paint primer $TL_{28}(e)$.

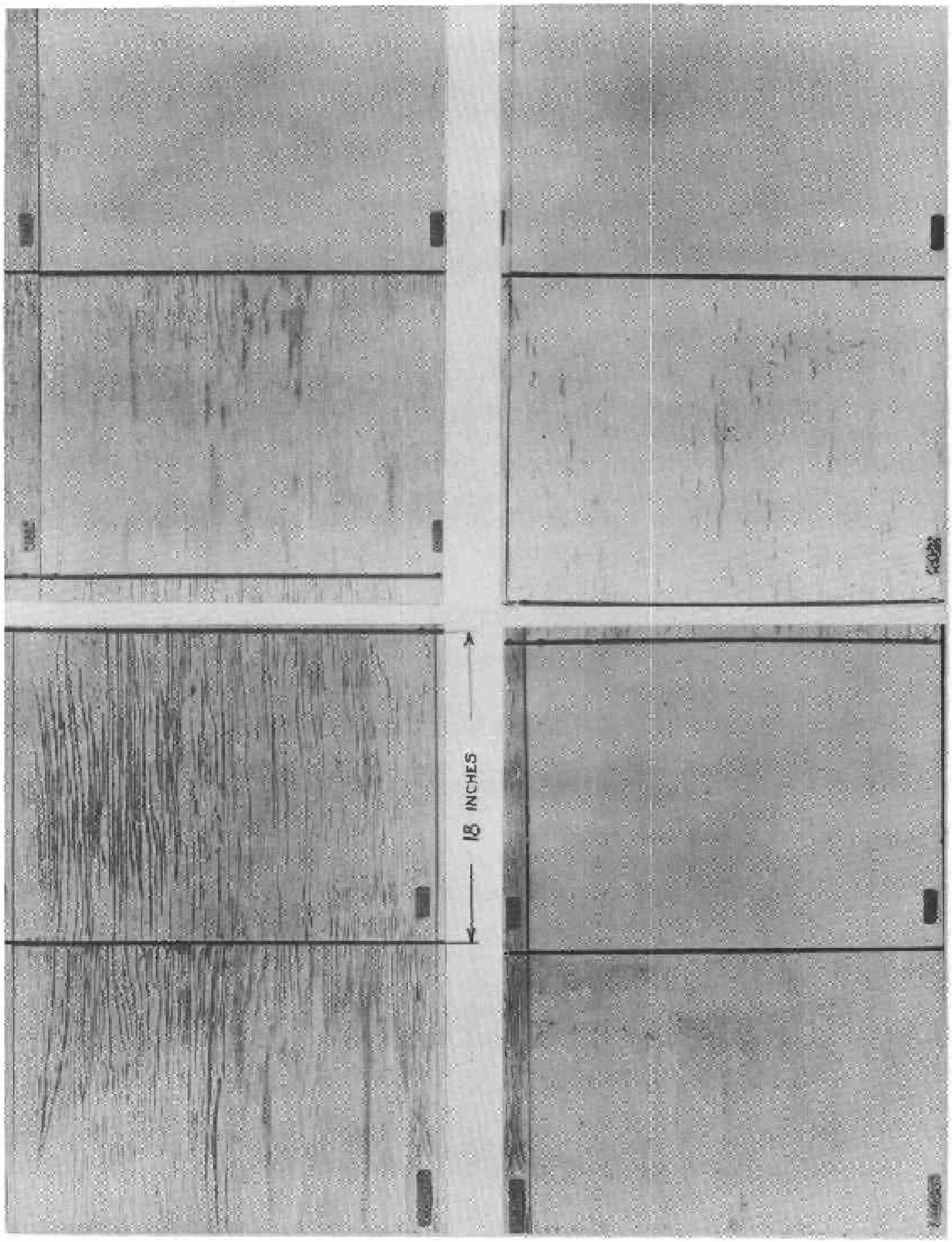
ZM 67357 F



Z M 67357 F

Figure 5.--Condition of some of the coatings of enamel on plywood covered with resin-impregnated pulpboard (tests of 1941) after 40 months' exposure vertically facing south at Madison, Wis. The upper test areas were coated with enamel $(TL_{20}Z_{30})_{126}$(e), the lower test areas with enamel T_{420}(ar). From left to right the four upper test areas were primed with the finish enamel, undercoater $(TL_{20}Z_{10})_{78}$(e), house-paint primer TL_{28}(e), and aluminum primer, respectively; the four lower test areas were primed with undercoater T_{144}(e), the finish enamel, house-paint primer TL_{28}(e), and aluminum primer, respectively.

ZM 67354 F



M 87304 F

Figure 6.--Condition of paint on plain Douglas-fir plywood in the 1944 tests of plywood covered with resin-impregnated paper (see fig. 7) after exposure vertically facing south for 71 months at Madison, Wis. The top and middle rows of four test areas each received a priming coat followed by two finish coats of paint L; the bottom row of four test areas received a priming coat followed by one finish coat of paint L. From left to right the priming coats on the top row of test areas were wood sealer (pre), wood sealer (ar), aluminum in bodied linseed oil, aluminum in phenolic-resin varnish; on the middle row paint L with p/nv 0.50, p/nv 0.40, p/nv 0.30, p/nv 0.20; and on the bottom row house-paint primer TL_{29}(e) p/nv 0.50, paint L p/nv 0.40, primer TL_{29}(e) p/nv 0.40, and primer TL_{29}(e) p/nv 0.30.

ZM 88954 F

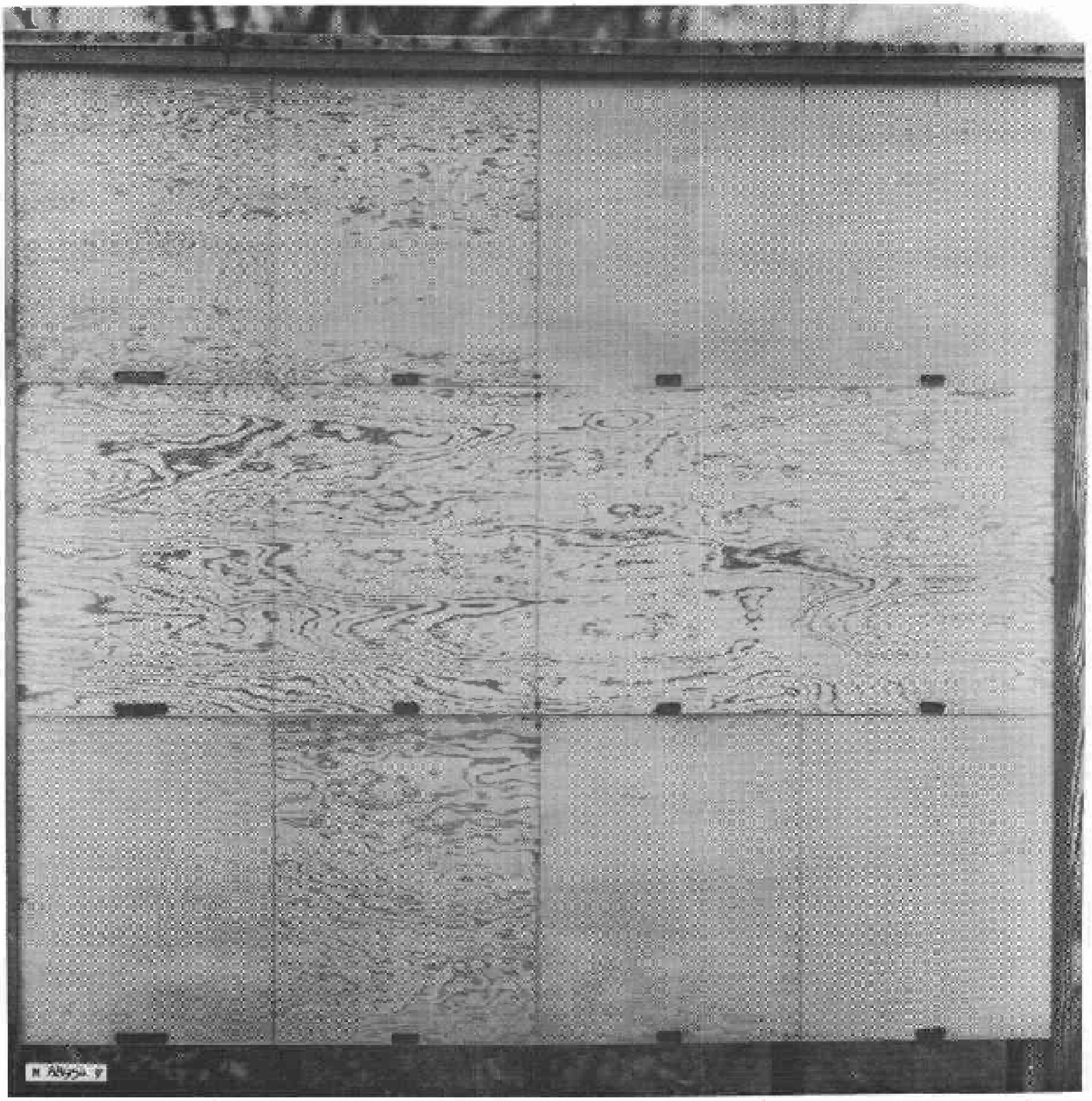


Figure 7.--Condition of paint on plywood covered with resin-impregnated paper in the 1944 tests after exposure vertically facing south for 71 months at Madison, Wis. The primers and paints and their arrangement on the test areas were the same as they were on the plain plywood shown in figure 6.

ZM 88951 F

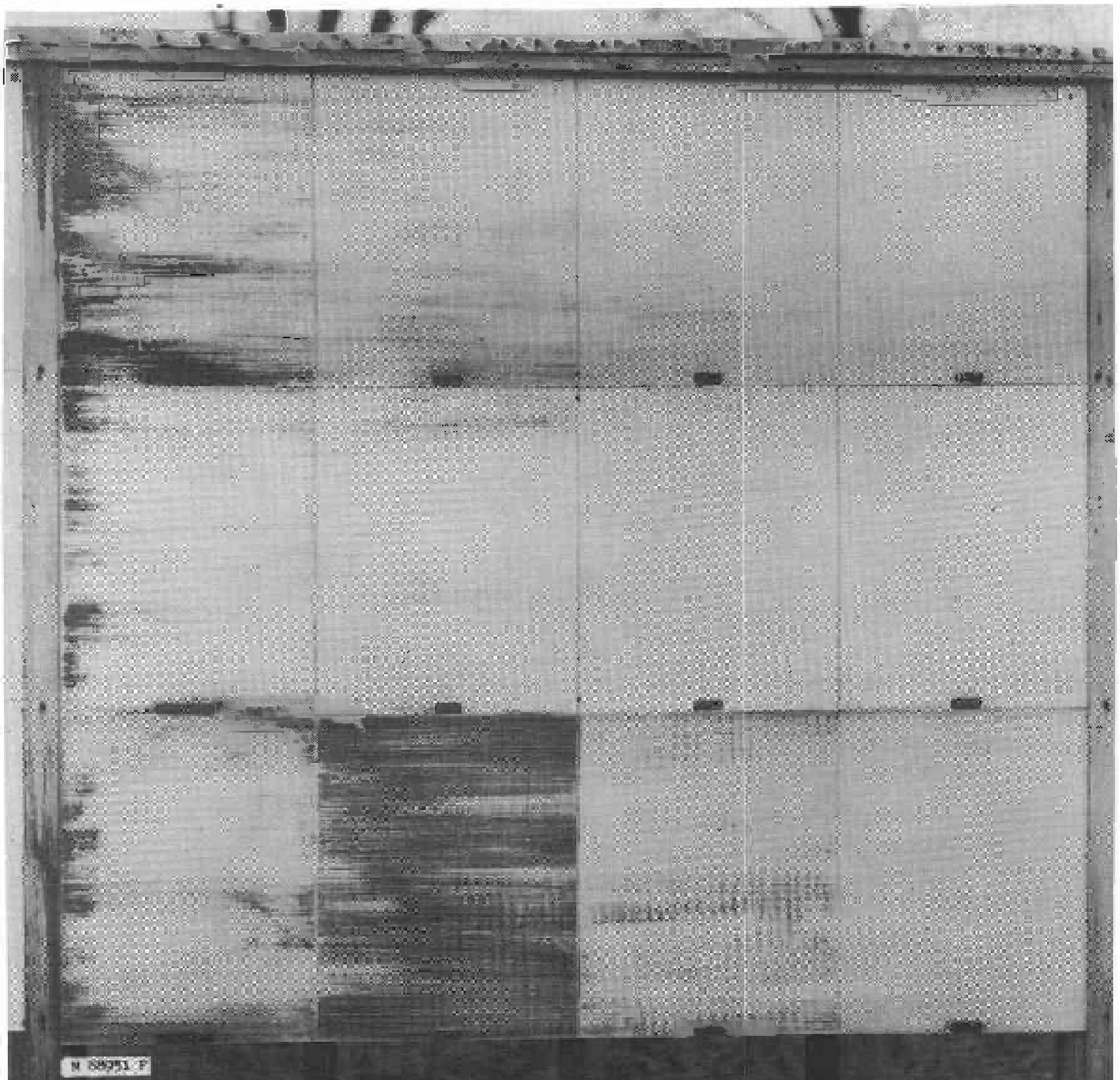


Figure 8.--Superior performance of paint on striated Douglas-fir plywood as compared with plain plywood. Both views were taken on parts of the same building in southern Arizona that were last painted about 2 years previously with the same kind of paint. Note that the striated plywood shows no face checking as well as superior coating integrity, whereas the plain plywood checked very badly.

ZM 90110 F

ZM 90111 F