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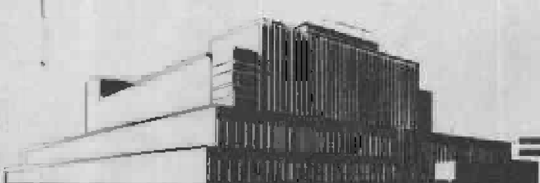

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

EXPERIMENTS WITH PRESERVATIVES FOR SOYBEAN GLUE AND SOYBEAN-GLUED PLYWOOD[1]

Forest Products Laboratory,[2] Forest Service
U.S. Department of Agriculture

A number of experiments with preservatives for soybean glue and soybean-glued plywood have been made at the Forest Products Laboratory. These experiments were begun following the receipt of unfavorable reports on the performance of soybean-glued plywood shipping containers in outdoor storage and exposure to high moisture conditions, which appeared to be due mainly to molds. The development of mold growth on the surface obliterated stencil and other markings, which was objectionable but probably not so serious as the delamination of the plywood and the consequent weakening of the containers. Most of this delamination was attributed to molds and other micro-organisms, but it is probable that part of it may have been due to the direct effect of moisture on the glue lines. Soybean glue joints do, however, possess considerable moisture resistance, particularly when used on softwoods, whereas they have little or no mold resistance unless protected with preservatives. Under continuous exposure to high moisture conditions, therefore, unprotected soybean glue joints would be expected to deteriorate much more rapidly from molds and possible other micro-organisms than from the direct action of water on the glue proteins.

All the experiments described in this report were made under laboratory conditions favorable to the development of molds and do not include observations under service conditions such as may exist when plywood export shipping containers are left exposed to the weather. The improvement in mold resistance and resistance to delamination obtained under laboratory

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[1] Original report dated April 7, 1944, written jointly by J. Oscar Blew and F. H. Kaufert, technologists.

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

conditions through the use of preservatives cannot, therefore, be translated directly in terms of percentage improvement under service conditions.

The primary objectives of these experiments were:

a. To determine the effectiveness of various oil-soluble preservatives in preventing surface mold growth and protecting the glue lines from fungus deterioration, when applied by short dip treatments to plywood glued with unpreserved soybean glue.

b. To determine the effectiveness of various chemicals as preservatives for soybean glue.

c. To measure the improvement in resistance to molds and delamination that could be obtained by incorporating effective preservatives in the glue and by treating the plywood with oil solutions of several preservatives.

These experiments were not extended to include protection against decay or insects, which may be factors in the deterioration of shipping containers during long storage under very unfavorable conditions. If the exposure conditions are such that there is a serious hazard from decay and insects, more thorough preservation than dip treatment is needed, and the use of soybean-glued plywood is questionable. The protection against decay or insects that might be provided by the preservative treatments used in these studies would probably be of limited value and would be incidental to the primary function of protecting the plywood surfaces and glue joints from early mold attack.

The Effectiveness Against Molds of Oil-Soluble Preservatives When Used as Short Dip Treatments For Plywood Glued With Unpreserved Soybean Glues

The first tests to determine the effectiveness of oil-soluble preservatives when used as short dip treatments for plywood glued with an unpreserved soybean glue were made with 5-ply, 5/16-inch thick hardwood plywood (cottonwood, sweetgum, and sycamore), furnished by a commercial producer. Cleated and uncleated plywood panels 12 inches square were dipped for 15 seconds in oil solutions of several proprietory water-repellent preservatives and then dried until the solvents had evaporated. The panels were soaked for 2 hours in water to which a heavy suspension of mold spores had been added and then stacked on stickers in a room maintained at 80° F. and 97 percent relative humidity. The panels were inspected for evidence of surface mold growth and delamination after 4, 11, 18, 25, and 39 days in this high humidity room.

The tests were not extensive enough to permit more than general observations. Some of the water-repellent preservative solutions reduced surface mold growth, and those reported to contain a chlorophenol appeared to be somewhat more effective in this respect than others. There was little correlation, however, between the appearance of panels or amount of surface mold growth and extent of delamination or glue joint deterioration at the end of 39 days, when all the panels showed considerable delamination. When the face plies and cross bands of a part of each panel were cut away to show the condition of the glue joints, panels that showed the least surface mold growth often showed the heaviest mold growth in the glue joints and complete deterioration of the glue.

It was concluded from these preliminary studies that, although such short dip treatment might provide satisfactory surface protection for a time, it did not penetrate sufficiently to protect the glue joints. The fact that some of the plywood was heartwood, which is usually very resistant to penetration of liquids, and some was sapwood, which absorbs preservatives more readily, further complicated the evaluation of results.

In order to obtain a better measure of the protection that these surface treatments might afford the glue joints, a second test was made. In this case, however, plywood shear specimens were cut from representative panels and the quality of the glue joints was determined in standard plywood shear testing equipment. The hardwood plywood was of the same species and from the same source as that used in the preliminary tests. In addition to a number of treating solutions of known composition, several of the proprietory treating solutions tried in the first tests were used. The plywood panels were dipped for 15 seconds in the treating solutions, stickered to permit the solvent to evaporate, soaked for 2 hours in water heavily inoculated with mold spores, and then continuously exposed in a room maintained at 80° F. and 97 percent relative humidity. At intervals of 1, 2, 3, 5, 7, and 10 weeks one representative panel for each species and treatment was cut into plywood shear specimens and tested to determine the quality of the glue joints. The amount of surface mold growth was recorded for each panel.

The results of the plywood shear tests and observations on amount of mold growth on the surfaces of panels are given in table 1.

Although the conditions for mold growth did not appear to be so severe as in the preliminary tests, the glue joints of the untreated panels were completely deteriorated by molds at the end of 7 weeks or earlier. The panels treated with a 1.5 percent oil solution of pentachlorophenol were no better than the controls but the panels treated with higher concentrations of pentachlorophenol, copper naphthenate, and several of the proprietory preservatives still retained a part of their shear strength after 10 weeks. Most of these treatments were very effective in preventing or reducing surface mold growth to a point where it was not considered objectionable.

The results of these tests with short immersion dip treatments for hardwood plywood glued with unpreserved soybean glue indicated that the primary effect of such treatments was the prevention of surface mold growth. Some protection against mold deterioration of the glue joints was afforded by several of these treatments but the results were not consistent nor was the amount of protection great enough in most cases to increase the useful life of the plywood more than a few weeks beyond that of the untreated controls.

It was evident from these results that the glue joints of the plywood would have to be more effectively protected against mold if the durability of soybean-glued plywood was to be greatly increased under high moisture and mold hazard conditions.

The Effectiveness of Various Chemicals As Soybean Glue Preservatives

In the studies described in this part of the report, preservatives were incorporated in the glues and the surfaces of the plywood were left untreated, thus providing suitable conditions for heavy surface mold growth. Although effectiveness against molds and other micro-organisms is the most important characteristic that chemicals for this use must possess, there are other important considerations. The physical form of the preservative, its effect on viscosity of the glue and water resistance of the glue joints, its toxicity to workers, and its cost which are also important from the practical standpoint, will be considered separately.

The problems associated with the preservation of soybean glues are similar to those that have been described for casein glues.[3]

Mold Exposure Tests on Plywood Shear Specimens

Yellow birch, cottonwood, and Douglas-fir veneers 1/16 inch thick were glued into 3-ply panels with a soybean glue prepared according to the manufacturers' directions. The moisture content of the birch and Douglas-fir veneer was about 6 percent and that of the cottonwood was 12 percent at the time of gluing. Glue spreads were between 70 and 75 pounds of wet glue per 1,000 square feet of single glue line. Assembly periods were held to less than 12 minutes and pressures of 150 pounds per square inch were applied to the panels.

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[3] U.S. Forest Products Laboratory Report No. 1332. Increasing the Durability of Casein Glue Joints With Preservatives. 1943. Information reviewed and reaffirmed 1961.

Pressure was maintained for at least 8 hours and the panels were then conditioned on stickers at 80° F. and 65 percent relative humidity for at least a week before they were cut into plywood shear specimens.

All preservatives that were water soluble or which could be ground to fine powders were added to the soybean meal before mixing with the water and other ingredients. Preservatives in the form of oils were added to the liquid glues after mixing had been completed. Waxy preservatives were dissolved in a small quantity of alcohol or acetone and added in solution to the liquid glues after the completion of mixing. All preservative concentrations were expressed as a percentage of the soybean meal.

Since most of these preservatives caused some thickening or increase in viscosity of this glue, it was usually necessary to add some water beyond the amount specified by the formula. To assure approximately equal dry glue spreads, wet glue spreads were increased when it was necessary to add more than 3.0 percent additional water to obtain glues of satisfactory viscosities.

The question of viscosity changes produced by preservatives, and the necessity for and effects of adding water beyond the amount called for by formulas, are discussed more fully later in this report.

The plywood glued with these soybean-glue preservative mixtures was cut into standard plywood shear specimens which were then used in measuring the mold resistance of the glue joints. The mold exposure tests were made according to the procedures outlined in Forest Products Laboratory Report No. 1344, "Procedures for Measuring the Mold Resistance of Protein Glues." That these mold exposures are extremely severe is shown by the fact that shear specimens glued with unpreserved soybean glue and exposed to the conditions described have little or no shear strength after a week or 10 days. The results obtained in tests of this type cannot be readily translated into terms of durability of plywood in the form of larger panels because not only are the exposure conditions in these tests severe but the small plywood shear specimens provide almost optimum conditions for the rapid penetration of molds from the edges, glue lines, and saw cuts. The results of such tests are thus purely relative and the only valid comparisons that can be made are those between unpreserved and preserved glues.

The results of these tests are summarized in tables 2 and 3. In all these tests the shear specimens were tested immediately upon removal from the high humidity exposure chambers. The moisture content of specimens when taken from the humidity chambers usually varied from about 28 to 35 percent. The specimens were thus neither dry nor soaked, so that comparisons of shear strength after exposure to mold cannot be made with either the original wet or dry strengths. The original wet and dry strengths serve mainly as indications of how well the panels were glued and whether the preservatives affected the water resistance of the glue. This moisture content variable should not affect the interpretation of results if this point is kept in mind and comparisons are limited to the shear strength of specimens glued with preserved and unpreserved glues and subjected to mold tests.

The results given in table 2 indicate that most of the preservatives tested effected some increase in mold resistance of the glue joints. With the chlorophenols, chlorophenates, and orthophenylphenol 2.0 and 3.0 percent concentrations gave some increase in mold resistance but consistently large improvements were not obtained unless at least 5.0 percent concentrations were used. The results with sodium orthophenylphenate were usually not so good as those with orthophenylphenol because no allowance was made for water of crystallization, which made up about one-third of the weight of the sodium orthophenylphenate used. Although fairly effective, copper naphthenate cannot be considered a promising preservative for soybean glue because it causes the glues to gel shortly after mixing. Phenyl mercury oleate at 0.5 percent proved fairly effective. The mixtures of chlorophenols or chlorophenates with orthophenylphenol or sodium orthophenylphenate gave consistently good results in this test.

The results reported for cottonwood and Douglas-fir plywood in table 3 are, with a few exceptions, in reasonably close agreement with those of table 2 for birch plywood. The rather poor results obtained with sodium pentachlorophenate on cottonwood plywood were at first considered to be due to some gluing variable, but the results of other tests (table 4) with this combination of wood and chemical are likewise poor.

Mold Exposure Tests on Plywood Panels

These tests were made to determine whether the relative effectiveness of preservatives indicated by the exposures on plywood shear specimens would hold for somewhat larger pieces of plywood that did not have as much glue joint area exposed to mold attack.

Sweetgum, heartwood and sapwood, and cottonwood veneers 1/16 inch thick were glued into 5-ply panels with the same soybean glue and soybean-glue preservative mixtures as used in the plywood for the exposure tests on shear specimens (tables 2 and 3). After conditioning for 1 week, these panels were trimmed to 5 by 12 inches, soaked for 2 hours in water heavily inoculated with mold spores, and stacked on stickers in a room maintained at 80° F. and 97 percent relative humidity. Although these exposure conditions were not so severe as those for the plywood shear specimens, (tables 2 and 3), a heavy growth of mold developed on the faces and edges of the cottonwood and sweetgum sapwood panels within a week or 10 days after they were stacked in the high humidity room. Molds developed more slowly on the sweetgum heartwood panels but the faces and edges were rather uniformly covered with a light mold growth within a month after exposures were started. Because no surface treatment was used and the faces and edges of the panels were thus left unprotected, there was little difference in the amount of mold growth on the surface of panels glued with preserved glues and those glued with unpreserved glues.

The results of these tests are given in tables 4 and 5. Several panels for each species and glue-preservative combination were removed at the intervals shown in tables 4 and 5 and cut into plywood shear specimens. The shear strength of these specimens was determined soon after the panels were removed from the high humidity room, and their moisture content was between 25 and 30 percent.

The results given in tables 4 and 5 indicate that it is more difficult to protect soybean glue joints in cottonwood plywood than it is for sweetgum sapwood or heartwood plywood. Also, there appears to be some difference in the effectiveness of soybean glue preservatives with these species. The highly chlorinated phenols, tetrachlorophenol, pentachlorophenol, and their sodium salts were much less effective soybean glue preservatives on cottonwood than on sweetgum plywood. Orthophenylphenol and sodium orthophenylphenate, which are generally less effective soybean glue preservatives than the highly chlorinated phenols on birch, gum, and Douglas-fir, were more effective on cottonwood. No logical explanation for this difference in effectiveness has been found. Because of the greater mold resistance of sweetgum heartwood plywood, the unpreserved glue joints had somewhat greater strength or resisted mold attack longer than did similar joints for cottonwood and sweetgum sapwood plywood. Regardless of the species, however, the addition to the glues of sufficient quantities of effective preservatives greatly increased the mold resistance and durability of the glue joints under these exposure conditions.

These results are in fairly close agreement with those obtained on plywood shear specimens, tables 2 and 3, and they indicate that consistently large improvements in mold resistance of soybean glue joints are not obtained unless at least 5.0 percent of effective preservatives, based on weight of soybean meal, is used. With the exception of the results obtained on cottonwood, the highly chlorinated phenols gave consistently good results. Orthophenylphenol also gave good results, usually better than sodium orthophenylphenate, probably because no allowance was made for the water of crystallization in the latter compound. A mixture of sodium tetrachlorophenate and sodium orthophenylphenate gave rather good results on cottonwood, where the highly chlorinated phenols alone did not perform so well. Phenyl mercury oleate at 0.5 percent, creosote at 10.0 percent, copper naphthenate at 8.0 percent, and several mixtures of chlorophenols or chlorophenates with orthophenylphenol or sodium orthophenylphenate effected considerable improvement in mold resistance. A special glue-grade of 2-chlororthophenylphenol gave good results in the test on sweetgum sapwood plywood.

Experiments With Combinations of Glue Preservatives and Panel Surface Treatments

The preliminary tests with short dip or surface treatments for plywood glued with unpreserved soybean glue showed that some of these treatments would effectively control surface molds but that none of them satisfactorily protected the glue joints. This failure of surface treatments to prevent delamination of the plywood can probably be directly attributed to the relatively shallow penetration obtained with the short dip treatments employed.

The tests with preservatives for soybean glue showed that the mold resistance of glue joints could be greatly increased by the addition to the glue of sufficient quantities of effective preservatives. The preservation of the glue lines did not, however, prevent the growth of molds on the surface of the panels, which is considered objectionable in case of shipping containers and other uses.

Experiments to determine the effectiveness of treating both the glue and the panel surfaces were the logical outgrowth of the earlier studies.

These experiments were made with Douglas-fir (heartwood) and sweetgum (sapwood) veneers. The sweetgum veneer (1/16 inch) and Douglas-fir (1/16 and 1/8 inch) were glued into 12-inch by 12-inch 5-ply panels with soybean glue and soybean glue-preservative mixtures. All glue mixtures were prepared according to the manufacturers' directions. After a period of drying and conditioning, these 12- by 12-inch panels were cut in two and the 6- by 12-inch panels were used throughout the remainder of the study.

Surface treatments were applied by immersing the panels for 15 seconds in oil solutions of several preservatives or combinations of a preservative and a water repellent. The panels were then loosely stickered to allow the solvent to evaporate.

All the 5/16-inch Douglas-fir and sweetgum panels were then soaked for 4 hours and 2 hours respectively in a heavy suspension of mold spores in tap water and then stacked on 1/2-inch stickers in a room maintained at 80° F. and 97 percent relative humidity. Soaking the panels before placing them in this high humidity room produces conditions that are almost optimum for mold growth and this exposure can be considered to be very severe. At intervals of 1, 2, 3, 5, and 8 months at this exposure, 4 of the 6- by 12-inch panels for each glue-preservative mixture and combination of glue-preservative mixture and panel treatment were removed and 5 plywood shear specimens cut from the center of each panel. The shear specimens were cut so that the inner glue lines were tested. This manner of sampling undoubtedly favored the plywood because when delamination begins it is usually at the edges and develops last at the center of the panel. Since the tests were made to compare treatments, however, the procedure followed should be satisfactory and should afford as good a comparison as though all shear specimens had been cut from the edges of the panels.

The 5-ply, 5/8-inch Douglas-fir panels were exposed to a cyclic exposure involving 4 hours of soaking in tap water heavily inoculated with mold spores, 12 days in a room maintained at 97 percent relative humidity and 80° F., and 3 days in a room maintained at 30 percent relative humidity and 80° F. This cycle was repeated for the duration of the study although tap water without added molds was used during the subsequent 4-hour soaking periods. The panels in this cyclic exposure were thus subjected not only to severe mold conditions but to mechanical stresses introduced by the wetting and drying and also to a certain amount of water hydrolysis. At intervals of 1, 2, 3, 5, and 8 months under these cyclic exposures 4 of the 6- by 12-inch panels for each test condition were removed and 5 plywood shear specimens were cut from the center of each. These shear specimens, as was the case for those cut from the thinner panels, were prepared to test the center glue lines. In this case, as was true for the thinner panels, some delamination was often present in the face plies and at the edges of panels that still gave good shear strengths, indicating again that the method of testing favored the material. The comparisons between treatments and between treatments and controls are still valid, however, and probably just as significant as though sampling had been done in some other manner.

The results of this study, which was concluded after 8 months of the high humidity or cyclic exposures, are given in table 6.

In case of the 5/16-inch Douglas-fir plywood continuously exposed to high humidity conditions, the panels glued with unpreserved glue and not given a surface treatment were delaminated or had no measurable shear strength at the end of 2 months. Most of the panels glued with soybean glue to which effective preservatives had been added, on the other hand, still retained a high percentage of their original shear strength after 8 months. The rather poor results obtained with 2-chlororthophenylphenol in this test, as contrasted to those obtained in earlier tests, may be attributable to the fact that a product of low purity was used and this increased the viscosity of the glue to such an extent that the joints were not of high quality at the start of the exposures. The glue joints of plywood glued with unpreserved soybean glue and treated with oil solutions of preservatives or mixtures of preservatives and water repellents had slightly more mold resistance than the controls but the difference was not large. The panels treated with preservative solutions that were effective against surface molds had a better appearance after exposure to the high humidity conditions than did panels without such treatment. Under the conditions of these exposures, however, there appeared to be only a slight advantage in the use of water repellents with the preservative solutions.

The results on the thicker Douglas-fir panels subjected to cyclic exposures do not indicate so large a difference between controls and treated panels as the results on material continuously exposed to high humidities. This indicates that mechanical action, shrinking and swelling, and possibly water hydrolysis contributed considerably to the failures. Even though the differences between controls and panels glued with preserved glues are less striking than in the continuous high humidity exposures, the improvement obtained by adding preservatives to the glues and treating the panels with oil solutions of preservatives is still evident and significant.

The results on the sweetgum sapwood panels indicate that this material is harder to protect against molds than is Douglas-fir heartwood. The necessity of adding effective preservatives to the glue is evident from the results obtained. Surface treatments with oil solutions of preservatives appeared to have more protective action on the glue joints of sweetgum sapwood panels than they did in case of Douglas-fir. This is probably attributable to the larger retentions and deeper penetration obtained with the oil soluble preservatives on sweetgum sapwood plywood. The inclusion of water repellents in the treating solutions appeared to have some beneficial effects and slightly improved the appearance of the panels. Less bloom or surface deposits of pentachlorophenol were evident with treatments containing water repellents than for the oil solution of pentachlorophenol alone. Oil solutions of pentachlorophenol and copper naphthenate were more effective in reducing surface mold growth than were oil solutions of phenyl mercury oleate.

Problems Associated With the Use and Addition of Preservatives to Soybean Glues

The addition of preservatives to soybean glue involves several problems. These must be considered because they have a direct bearing on the selection of chemicals and their practical application.

The Effect of Preservatives on Viscosity

One of the most important considerations associated with the application of soybean glue preservatives is their effect on viscosity. With the possible exception of phenyl mercury oleate, creosote, and beta naphthol, all of the preservatives tried in soybean glue increase the viscosity of the glue mixture. This increase may be unimportant in some cases but great enough in others to eliminate some of the chemicals from consideration. Copper naphthenate and the other copper compounds tested are examples of preservatives that increase the viscosity of the soybean glue so greatly that they would be impractical even though they were highly effective. Viscosity measurements and observations on the working characteristics of a soybean glue to which 5.0 percent of several preservatives had been added indicate that the most promising of the preservatives extensively tested may be roughly grouped into the following classes with respect to their effect on viscosity:

a. Extreme increases in viscosity: copper naphthenate and other copper compounds.

b. Large increases in viscosity: pentachlorophenol, sodium pentachlorophenate, and an impure form of 2-chlororthophenylphenol.

c. Medium to large increases in viscosity: tetrachlorophenol, sodium tetrachlorophenate, a pure form of 2-chlororthophenylphenol, and mixtures of equal parts of the chlorophenols or chlorophenates and orthophenylphenol or sodium orthophenylphenate.

d. Small increases in viscosity: orthophenylphenol, sodium orthophenylphenate, trichlorophenol, and sodium trichlorophenate.

e. Little or no increase in viscosity: creosote, beta naphthol, and phenyl mercury oleate.

Observations made during plant runs and in the laboratory indicate that the viscosity of all soybean glues is not affected to the same extent by these preservatives but that their relative effects on the viscosity of a given glue are approximately as given above. Whether the viscosity changes produced by a given preservative are important under plant conditions will depend considerably on the nature of the glue distributing system and other operating conditions. With certain soybean glues it may be necessary to add some water beyond the amount called for by the formula, when preservatives are added.

The amount of additional water that may be required to correct or bring the viscosity of a glue to a point where it is best suited to operating conditions will, therefore, vary somewhat with every glue and plant. Laboratory tests with one soybean glue and several preservatives indicate that glues of approximately the same viscosity as the unpreserved glue can be obtained by the addition of the amounts of water shown below:

Preservative	Concentration (in percent of weight of soybean meal)	Amount of additional water required to correct viscosity (expressed in percent of total water called for by the formula)
Pentachlorophenol	3	4-6
Pentachlorophenol	5	5-8
Sodium pentachlorophenate	3	4-6
Sodium pentachlorophenate	5	5-8
Sodium tetrachlorophenate	3	2-4
Sodium tetrachlorophenate	5	3-5
Orthophenylphenol	3	None
Orthophenylphenol	5	1-3
Sodium orthophenylphenate	3	None
Sodium orthophenylphenate	5	1-3
Mixture of equal parts sodium tetrachlorophenate and sodium orthophenylphenate	3	2-4
Mixture of equal parts sodium tetrachlorophenate and sodium orthophenylphenate	5	3-5
Phenyl mercury oleate	0.5	None

Because it is usually desirable to limit the amount of water required to produce a workable glue, the effect of preservatives on viscosity requires consideration and when there is a choice between materials of approximately equal effectiveness, as, for example, between sodium pentachlorophenate and sodium tetrachlorophenate, the latter compound would appear to have some advantage.

The Effect of Preservatives on the Dry Strength and Water Resistance of Soybean Glue Joints

With the possible exception of the results reported in table 6 for impure 2-chlororthophenylphenol, there is no evidence that any of the chemicals tested injured the adhesive properties of the glues. The original dry and wet joint strength of the plywood glued with preserved glues was usually about equal to that of the controls. The results given in table 3, for cottonwood and Douglas-fir plywood shear specimens soaked for 1 month, indicate that the preservatives did not decrease the water resistance of the glue joints, and in some cases there is indication of increased water resistance.

Under plant conditions, however, it is possible that the preservatives could indirectly affect the quality of glue joints by so increasing viscosity and shortening the permissible assembly time that the equivalent of dried-joint conditions might result. For this reason, it seems desirable to correct the viscosity of preserved soybean glues by adding enough water to bring the glues to satisfactory working conditions. This practice was followed in all of the studies reported here.

That the addition of up to 8.0 percent water, beyond the amount specified in the formula used, did not affect the quality of the glue joints is evident from all of the tests made. Whenever more than 3.0 percent of added water was required to correct the viscosity, however, wet spreads were increased sufficiently to insure dry spreads approximately equal to those for unpreserved glues. A similar practice would appear advisable under plant conditions.

The Process of Adding Preservatives to Soybean Glues

It is possible to add most of the preservatives that can be ground to fine powders to the soybean meals, a process followed with some of the preservatives used in this study. When this procedure is followed with preservatives that seriously thicken the glues, however, it is necessary to make adjustments in the mixing procedure, to increase the amount of water used in the first mixing operation. Unless such an adjustment is made the glue will be too viscous to mix well with the lime, caustic, and other ingredients added later. With the exception of their effect on viscosity, there was no evidence in any of the laboratory tests that the preservatives interfered with the reactions required to make a satisfactory adhesive from soybean meal.

Because of the necessity of some reformulation when preservatives are added to the soybean meal, it may be more practical to add the preservatives to the liquid glues after they have been prepared according to formula. The latter procedure was followed in the laboratory tests when adding liquid preservatives and those that were of a waxy nature. This procedure is also practical with other preservatives, such as the water soluble chlorophenates, and compounds such as orthophenylphenol and tetrachlorophenol, which are highly soluble in alcohol or other solvents. The dry, powdered preservatives could probably also be added to the finished liquid glues but there is some question regarding the thoroughness of mixing that would be accomplished.

Toxicity to Humans and Hazards Associated With the Use of Preservatives

Although the preservatives included in these studies differ considerably in their toxicity to humans, all of them should be carefully handled and every precaution should be taken to reduce to a minimum contact with the pure chemicals or concentrated solutions. The chemicals especially the chlorophenates should be furnished in such form or so handled that irritating dusts are not present and concentrated solutions should be handled with the same precautions now practiced with concentrated caustic solutions. Furnishing these chemicals to the mixing rooms as concentrated solutions or in heavily sized cloth bags from which the chemicals can be dissolved without opening appear to be the most practical and safest procedures to follow.

Summary

When continuously exposed to high moisture and favorable temperature conditions in laboratory tests, the glue joints of soybean-glued plywood are rapidly deteriorated by molds and the surfaces of the panels may become covered with mold growth.

Under laboratory exposure conditions involving severe mold hazards, it has been possible to improve greatly the mold resistance of soybean glue joints through the addition of sufficient quantities of effective preservatives to the glues and to reduce markedly mold growth on the surfaces of panels by short dip treatments in oil solutions of preservatives.

Surface treatments, applied by dipping soybean-glued plywood panels for 15 seconds in oil solutions of preservatives effective against molds, were found to decrease or eliminate troublesome surface mold growths but these treatments did not afford a great deal of protection to the glue joints.

A 5.0 percent oil solution of pentachlorophenol and a copper naphthenate solution containing the equivalent of 2.0 percent copper were found almost equally effective in reducing surface mold growth. Several proprietory preservatives reported to contain 5.0 percent of pentachlorophenol or other chlorophenols gave similar results.

The inclusion of a water repellent in the treating solution reduced the amount of "bloom," or deposit of pentachlorophenol on the surface of panels, and in some cases improved the general appearance of the plywood. There was slight evidence of added protection to glue joints or improvement in control of surface molds when water repellents were added to oil solutions of effective preservatives.

With few exceptions the addition to soybean glue of 5.0 percent of effective preservatives, based on weight of soybean meal, gave consistently large increases in durability or mold resistance of the glue joints. The addition of smaller quantities of effective preservatives usually gave some improvement in mold resistance but the results were not always consistent.

With the exceptions noted in the text, the chlorophenols, sodium chlorophenates, orthophenylphenol, sodium orthophenylphenate, and a special glue-grade of 2-chlororthophenylphenol were the most effective of the soybean glue preservatives extensively tested. In the tests in which it was included, phenyl mercury oleate at 0.5 percent likewise gave fairly good results.

The results with sodium orthophenylphenate are complicated by the fact that no allowance was made for water of crystallization in the product used.

The surfaces and glue joints of cottonwood plywood appear to be particularly difficult to protect from mold attack. Higher concentrations of glue preservatives and mixtures of preservatives appear to be more desirable with this species than with sweetgum or Douglas-fir.

The surfaces of sweetgum heartwood and Douglas-fir heartwood plywood are less subject to mold growth than are those of cottonwood, sweetgum sapwood, and birch plywood. The greater mold resistance of sweetgum and Douglas-fir heartwoods affords some natural protection to soybean glue joints, but the increases in mold resistance obtained through the addition of effective preservatives to the soybean glues used in gluing these heartwoods were proportionately as great as they were for the less mold resistant species.

Plywood glued with preserved soybean glue and given a short dip treatment in preservative delaminated more rapidly under wet and dry cyclic exposures than when continuously exposed to high moisture conditions. The improvement effected through the use of preservatives was still considerable, however, even in the cyclic exposures.

Most of the glue preservatives tested increased the viscosity of the soybean glue used. The greatest increases in viscosity were observed with such compounds as pentachlorophenol and copper naphthenate whereas phenyl mercury oleate and sodium orthophenylphenate had very little effect on viscosity.

The addition of preservatives to the glues did not affect the original dry or wet strength or the water resistance of the glue joints. No noticeable effect on joint strength was observed when up to 8.0 percent of added water was used to correct viscosities and the wet spreads were proportionately increased.

Table 1.--Summary of periodic inspection and shear test results on surface treated 5-ply, 5/16- by 12- by 12-inch plywood panels bonded with unpreserved soybean glue. Panels soaked for 2 hours in water and then exposed at 80° F. and 97 percent relative humidity for the periods indicated.

Panel set number	Preservative	Species	Absorption of solution	Exposure period[1]																	
				1 week			15 days			3 weeks			5 weeks			7 weeks			10 weeks		
				Mold growth		Shear[2]	Mold growth		Shear[2]	Mold growth		Shear[2]	Mold growth		Shear[2]	Mold growth		Shear[2]	Mold growth		Shear[2]
				Surface	Edges		Surface	Edges		Surface	Edges		Surface	Edges		Surface	Edges		Surface	Edges	
			Lb. per sq. ft.																		
1	A[3], chlorophenols	Mixed[4]	4.7	None	None		No change		356-96	Moderate	None	118-58	No change		232-24	Moderate	Moderate	223-60	No change		79-12
		Cottonwood	2.9	None	None		No change		205-18	No change		135-0	No change		124-4	Moderate	Slight	16-0	No change		0-0
2	B[3],	Mixed[4]	4.0	None	None		No change		307-68	No change		189-57	No change		184-8	No change		118-48	Moderate	Slight	0-0
		Cottonwood	3.2	None	None		No change		255-0	No change		188-12	No change		112-6	No change		16-0	Moderate	Slight	14-0
3	C[3], phenyl mercury oleate	Mixed[4]	4.9	None	None		Slight	Complete	191-89	No change		164-86	Complete	Complete	263-16	No change		174-32	No change		96-1
		Cottonwood	3.4	None	Slight		Moderate	Complete	249-26	Complete	Complete	129-6	No change		129-2	No change		84-5	No change		0-0
4	D[3], chlorophenols	Mixed[4]	4.3	None	None		Slight	None	252-88	No change		201-94	Moderate	None	215-30	No change		100-5	Moderate	Slight	56-0
		Cottonwood	3.0	None	None		Slight	None	238-22	No change		198-44	Moderate	None	144-4	No change		80-0	Moderate	Slight	0-0
5	E[3], chlorophenols	Mixed[4]	4.1	None	None		Slight	None	341-78	No change		109-78	Moderate	None	108-4	No change		210-45	Moderate	Slight	0-0
		Cottonwood	3.0	None	None		Slight	None	290-29	No change		182-40	Moderate	Slight	126-5	No change		102-3	No change		0-0
6	5% pentachlorophenol, 5% estergum	Mixed[4]	4.4	None	None		Slight	None	230-69	Moderate	Moderate	182-90	No change		133-10	No change		15-0	No change		0-0
		Cottonwood	2.9	None	None		Slight	None	189-3	Slight	Moderate	128-0	Moderate	Moderate	170-4	No change		60-0	No change		0-0
7	5% pentachlorophenol, 20% paraffin	Mixed[4]	4.5	Slight	Complete		No change		189-63	No change		182-71	Moderate	Complete	210-30	No change		84-4	Complete	Complete	38-0
		Cottonwood	3.0	Slight	Complete		No change		296-71	Moderate	Complete	128-6	No change		174-2	No change		48-2	Complete	Complete	16-0
8	Copper naphthenate (2% Cu metal)	Mixed[4]	4.6	None	None		Slight	None	279-43	Moderate	None	157-16	No change		145-14	Moderate	Moderate	108-6	No change		106-12
		Cottonwood	3.4	None	None		Slight	None	248-60	No change		176-40	No change		114-2	Moderate	Moderate	50-0	No change		0-0
9	1.5% sodium pentachlorophenate	Mixed[4]	3.0	Moderate	Complete		No change		251-62	Complete	Complete	148-7	No change		88-0	No change		0-0	No change		0-0
		Cottonwood	2.6	Bad	Complete		No change		176-11	Complete	Complete	94-2	No change		105-1	No change		0-0	No change		0-0
10	Untreated	Mixed[4]	---	Moderate	Complete	127-21[5]	Complete	Complete	222-74	No change		204-27	No change		146-5	No change		0-0	--	--	---
		Cottonwood	---	Light	Complete	92-0[5]	Complete	Complete	184-12	No change		123-0	No change		112-0	No change		0-0	--	--	---

[1] The results shown for each period of exposure were obtained from one 12- by 12-inch panel of each species and treatment.

[2] The first value represents the average shear strength in pounds per square inch, and the second value represents the average percentage of wood failure for approximately 10 shear specimens. One-half of the shear specimens represented in these averages were conditioned at a 97-percent relative humidity and one-half at 65-percent relative humidity before testing.

[3] Proprietary water-repellent preservatives.

[4] Mostly sycamore, but some sweetgum.

[5] Half of the shear specimens tested were held in the exposure chamber for an additional period of 10 days due to a shortage in testing facilities.

Z M 53215 F

Table 2.--Results of mold exposure tests on yellow birch plywood shear specimens glued with soybean glue and soybean glue-preservative mixtures

Preservative	Concentration[1] of preservative in glue	Joint strength and percentage of wood failure[2]: Original dry	Wet after 48 hours soaking	After exposure in mold test for 7 days	14 days	28 days
	Percent					
			Series I			
None	---	340-11	195-0	65-0	12-0	0-0
Pentachlorophenol	2.0	345-2	151-0	78-0	25-0	73-0
Pentachlorophenol	5.0	319-3	176-0	160-0	183-1	161-2
Pentachlorophenol	8.0	345-1	197-0	176-1	199-0	220-8
Sodium pentachlorophenate	2.0	363-7	208-0	86-0	7-0	9-0
Sodium pentachlorophenate	5.0	379-9	197-0	197-0	147-0	115-0
Sodium pentachlorophenate	8.0	331-4	187-0	156-0	160-0	260-63
Orthophenylphenol	2.0	332-3	188-0	111-0	26-0	0-0
Orthophenylphenol	5.0	330-3	184-0	183-0	184-0	196-27
Orthophenylphenol	8.0	315-2	174-0	176-1	153-18	153-19
Sodium orthophenylphenate	2.0	303-2	184-0	177-3	105-0	117-0
Sodium orthophenylphenate	5.0	331-2	167-0	172-0	108-0	111-9
Sodium orthophenylphenate	8.0	280-3	174-1	183-3	215-29	166-35
Tetrachlorophenol	5.0	345-2	143-0	145-1	153-0	142-7
Sodium tetrachlorophenate	5.0	351-3	170-0	213-1	157-0	151-2
Beta naphthol	8.0	298-2	170-0	97-5	90-1	29-0
Creosote[3]	10.0	323-3	154-0	98-0	72-0	75-6
Copper naphthenate[3]	8.0	300-2	174-0	157-2	127-2	148-5
Pentachlorophenol 2.5 percent + orthophenylphenol 2.5 percent	5.0	322-3	178-0	141-0	158-0	150-0
Sodium tetrachlorophenate 2.5 percent + sodium orthophenylphenate 2.5 percent	5.0	335-3	176-0	181-1	174-2	184-7
Sodium pentachlorophenate 2.5 percent + sodium orthophenylphenate 2.5 percent	5.0	337-2	143-0	113-0	105-0	144-0
			Series II			
None	---	266-77	158-2	10-0	0-0	0-0
Pentachlorophenol	3.0	244-9	133-0	238-12	154-4	147-9
Pentachlorophenol	4.0	263-7	169-0	265-10	245-10	124-1
Pentachlorophenol	5.0	261-13	193-0	323-8	237-16	215-4
Pentachlorophenol	6.0	266-6	194-0	297-4	276-10	248-7
Sodium pentachlorophenate	3.0	262-19	175-0	260-8	104-1	128-4
Sodium pentachlorophenate	4.0	272-13	157-0	256-5	214-5	110-2
Sodium pentachlorophenate	5.0	245-5	147-0	220-6	154-4	210-8
Sodium pentachlorophenate	6.0	256-2	181-0	284-6	277-14	256-0
Orthophenylphenol	3.0	276-9	163-0	177-1	39-0	28-0
Orthophenylphenol	4.0	272-13	171-0	173-0	48-0	35-0
Orthophenylphenol	5.0	267-34	159-0	238-7	183-4	214-5
Orthophenylphenol	6.0	280-7	151-0	268-3	214-2	208-4
Sodium orthophenylphenate	3.0	266-8	147-0	148-6	39-0	35-0
Sodium orthophenylphenate	4.0	295-1	168-0	172-2	53-0	10-0
Sodium orthophenylphenate	5.0	214-2	151-0	174-6	123-8	107-3
Sodium orthophenylphenate	6.0	234-3	157-0	275-5	226-3	114-0
Tetrachlorophenol	5.0	276-12	180-0	291-22	288-14	261-0
Sodium tetrachlorophenate	5.0	266-16	152-0	284-6	306-8	277-4
2-Chlororthophenylphenol[3]	5.0	258-30	174-2	282-13	294-7	309-7
Zinc tetrachlorophenate	5.0	214-4	131-0	167-0	149-0	145-0
Copper pentachlorophenate	5.0	151-3	129-2	225-5	191-3	81-0
Copper naphthenate[3]	8.0	275-21	176-3	206-4	201-2	163-1
Copper resinate	8.0	265-31	167-2	222-7	179-4	110-0
Phenyl mercury oleate[4] [3]	.3	268-12	193-0	137-1	94-0	0-0
Phenyl mercury oleate[4] [3]	.5	269-56	191-0	201-4	194-0	154-0
Orthophenylphenol 2.5 percent + pentachlorophenol 2.5 percent	5.0	243-29	175-3	264-35	219-3	191-1
Sodium orthophenylphenate 2.5 percent + sodium pentachlorophenate 2.5 percent	5.0	237-25	174-3	222-17	203-2	225-0

[1] Based on weight of soybean meal.

[2] The first value represents the joint strength in pounds per square inch; the second value represents the percentage of wood failure. Each value is an average of 8 yellow birch sapwood plywood shear specimens.

[3] Added to the glue at the time of mixing.

[4] Furnished as a 10 percent oil solution of phenyl mercury oleate.

Table 3. —Results of shear tests on cottonwood and Douglas-fir plywood glued with soybean glue and soybean-glue preservative mixtures and the shear specimens exposed in soaking and mold tests

Panels	Preservative	Concentration of preservative in glue[1]	Joint strength and percentage of wood failure[2]					
			Original dry	After soaking in water for:		After exposure in mold tests for		
				48 hours	1 month	2 weeks	4 weeks	8 weeks
			Cottonwood					
1-10	1. Control	-	291-59	143-3	57-0	0-0	0-0	0-0
11-20	2. Sodium orthophenylphenate	5.0	295-48	139-3	71-2	107-25	0-0	0-0
21-30	3. Sodium pentachlorophenate	5.0	294-70	152-5	147-4	37-4	43-0	0-0
31-40	4. Sodium trichlorophenate	5.0	274-51	133-4	114-3	191-31	223-71	229-46
41-50	5. 2-chlororthophenylphenol	5.0	257-37	146-1	110-1	198-70	223-66	52-14
51-60	6. Sodium tetrachlorophenate	5.0	309-56	142-1	138-1	155-65	146-0	0-0
61-70	7. Orthophenylphenol	5.0	273-47	140-3	120-1	184-57	175-27	0-0
71-80	8. Organic mercury formula[3]	1.25	254-56	110-2	84-0	145-55	58-3	0-0
81-90	9. Organic mercury formula[3]	2.5	249-38	130-4	106-3	178-75	133-14	0-0
	10. Mixture (50-50) sodium tetrachlorophenate and sodium 2-chlororthophenylphenate	5.0	284-80	139-8	141-6	183-61	158-16	48-0
			Douglas-fir					
1-10	1. Control	-	262-59	132-5	112-2	49-2	0-0	0-0
11-20	2. Sodium orthophenylphenate	5.0	253-64	135-6	74-1	154-54	108-18	0-0
21-30	3. Sodium pentachlorophenate	5.0	263-61	128-7	128-18	165-48	173-54	44-3
31-40	4. Sodium trichlorophenate	5.0	263-52	133-8	135-5	156-53	179-67	126-19
41-50	5. 2-chlororthophenylphenol	5.0	254-58	119-4	104-2	179-67	164-36	50-0
51-60	6. Sodium tetrachlorophenate	5.0	270-69	116-4	104-5	173-67	178-53	37-2
61-70	7. Orthophenylphenol	5.0	234-63	131-4	115-3	185-63	150-37	33-1
71-80	8. Organic mercury formula[3]	1.25	227-62	106-4	101-2	106-20	21-7	0-0
81-90	9. Organic mercury formula[3]	2.5	260-58	105-3	105-3	124-30	16-1	0-0
	10. Mixture (50-50) sodium tetrachlorophenate and sodium 2-chlororthophenylphenate	5.0	248-71	128-6	118-8	168-45	141-10	63-1

[1]Based on weight of soybean meal.

[2]The first value represents the joint strength in pounds per square inch; the second value represents the percentage of wood failure. Each value is an average for 10 plywood shear specimens.

[3]Contains 6.25 percent ethyl mercury phosphate as the active ingredient.

Z M 51958 F

Table 4.--Results of mold exposure tests on cottonwood and sweetgum heartwood plywood glued with soybean glue and soybean glue-preservative mixtures

Preservative	Concentration[1] of preservative in glue	Cottonwood[2] — Joint strength[4] and percentage of wood failure after soaking panels 4 hours and continuous exposure in a 97 percent relative humidity room for					Sweetgum heartwood[3] — Joint strength[4] and percentage of wood failure after soaking panels 4 hours and continuous exposure in a 97 percent relative humidity room for				
		1 week	3 weeks	5 weeks	8 weeks	10 weeks	1 week	3 weeks	5 weeks	10 weeks	14 weeks
	Percent										
None	---	26-1	51-1	0-0	0-0	0-0	266-66	237-20	155-7	0-0	13-0
Pentachlorophenol	2.0	89-3	44-1	5-0	45-0	0-0	186-20	239-13	205-3	149-1	120-1
Pentachlorophenol	5.0	36-1	60-3	42-1	46-0	0-0	253-1	275-13	246-55	147-4	161-5
Pentachlorophenol	8.0	139-2	47-1	67-1	64-0	68-0	245-4	239-1	237-20	228-8	176-3
Sodium pentachlorophenate	2.0	55-0	60-1	48-5	0-0	0-0	276-17	249-15	192-22	186-14	70-1
Sodium pentachlorophenate	5.0	80-1	52-5	15-0	28-0	0-0	200-22	208-30	213-13	193-9	187-12
Sodium pentachlorophenate	8.0	163-20	127-11	78-3	0-0	0-0	284-23	261-16	179-13	230-15	164-9
Orthophenylphenol	2.0	181-16	132-3	84-2	73-0	0-0	285-18	216-10	182-10	121-0	124-0
Orthophenylphenol	5.0	240-30	186-9	124-0	93-0	24-0	248-26	224-10	264-41	79-0	89-1
Orthophenylphenol	8.0	156-3	191-6	141-4	176-7	155-6	271-10	264-7	239-12	245-7	176-6
Sodium orthophenylphenate	2.0	123-2	152-10	70-1	0-0	0-0	312-27	260-23	237-8	33-0	5-0
Sodium orthophenylphenate	5.0	156-7	170-12	166-10	78-0	43-3	263-13	277-24	218-12	140-1	61-1
Sodium orthophenylphenate	8.0	210-23	146-17	195-6	143-5	104-2	265-10	286-14	264-16	145-1	113-2
Tetrachlorophenol	5.0	24-0	165-2	83-0	0-0	0-0	246-30	209-8	263-8	159-2	189-6
Sodium tetrachlorophenate	5.0	101-9	147-16	40-1	23-0	0-0	323-24	264-24	276-47	236-47	157-3
Beta naphthol	8.0	150-2	143-3	72-0	0-0	0-0	231-7	279-10	184-2	64-0	47-0
Creosote[5]	10.0	108-1	181-3	164-1	123-0	0-0	264-46	238-23	201-8	196-10	194-1
Copper naphthenate[5]	8.0	150-4	144-3	22-1	17-0	0-0	188-6	240-4	166-4	120-4	125-1
Pentachlorophenol 2.5 percent + orthophenylphenol 2.5 percent	5.0	168-2	235-10	131-1	71-0	70-0	264-7	233-12	182-12	181-11	138-0
Tetrachlorophenol 2.5 percent + orthophenylphenol 2.5 percent	5.0	136-4	144-8	102-0	70-0	40-0	237-11	216-24	226-4	186-17	127-3
Sodium pentachlorophenate 2.5 percent + sodium orthophenylphenate 2.5 percent	5.0	190-11	140-6	70-1	91-0	66-0	236-9	307-29	123-10	96-0	121-1
Sodium tetrachlorophenate 2.5 percent + sodium orthophenylphenate 2.5 percent	5.0	189-6	161-18	187-4	150-0	118-6	---	---	---	---	---

[1]Based on weight of soybean meal.
[2]Average original dry strength of cottonwood panels glued with unpreserved soybean glue 188 pounds per square inch with 84 percent wood failure.
[3]Average original dry strength of sweetgum heartwood panels glued with unpreserved soybean glue 291 pounds per square inch with 68 percent wood failure.
[4]The first value represents the joint strength in pounds per square inch: the second value represents the percentage of wood failure. Each value based on 20 plywood shear specimens, 10 from each of 2 (5" x 12") five-ply panels.
[5]Added to the glue at the time of mixing.

Z M 51956 F

Table 5.--Results of mold exposure tests on sweetgum sapwood plywood glued with soybean glue and soybean glue-preservative mixtures

Preservative	Concentration[1] of preservative in glue	Joint strength[2] and percentage of wood failure after soaking panels 4 hours and continuous exposure in 97 percent relative humidity room for[3]				
		1 week	3 weeks	5 weeks	9 weeks	18 weeks
	Percent					
None	---	45-2	0-0	0-0	0-0	0-0
Pentachlorophenol	3.0	277-11	250-5	171-0	91-0	0-0
Pentachlorophenol	4.0	194-2	206-1	240-1	209-4	140-0
Pentachlorophenol	5.0	303-13	337-2	245-1	167-0	154-0
Pentachlorophenol	6.0	232-5	256-1	261-0	223-0	153-0
Sodium pentachlorophenate	3.0	249-2	267-5	236-1	172-0	0-0
Sodium pentachlorophenate	4.0	259-1	291-1	246-0	153-0	54-0
Sodium pentachlorophenate	5.0	289-4	174-0	138-0	145-0	120-0
Sodium pentachlorophenate	6.0	295-5	233-8	232-0	248-0	133-0
Orthophenylphenol	3.0	319-5	249-3	263-8	0-0	0-0
Orthophenylphenol	4.0	275-11	240-1	232-1	0-0	0-0
Orthophenylphenol	5.0	318-9	267-3	301-5	192-0	154-2
Orthophenylphenol	6.0	281-12	279-13	226-0	256-0	186-0
Sodium orthophenylphenate	3.0	242-19	308-41	242-3	35-0	18-0
Sodium orthophenylphenate	4.0	239-2	260-8	137-1	0-0	40-0
Sodium orthophenylphenate	5.0	302-9	272-19	216-1	124-1	81-0
Sodium orthophenylphenate	6.0	240-3	260-4	220-0	142-0	133-0
Tetrachlorophenol	5.0	272-8	291-8	220-0	141-0	177-0
Sodium tetrachlorophenate	5.0	293-2	265-2	256-2	171-1	145-0
2-Chlororthophenylphenol[4]	5.0	309-11	241-12	267-2	260-3	138-0
Zinc tetrachlorophenate	5.0	---	263-5	241-3	83-1	0-0
Copper pentachlorophenate	5.0	213-4	123-1	186-3	0-0	0-0
Copper naphthenate[4]	8.0	312-27	170-5	170-1	135-1	128-0
Copper resinate	8.0	192-0	189-0	131-0	0-0	0-0
Phenyl mercury oleate[5] [4]	.3	232-3	205-3	210-2	0-0	50-0
Phenyl mercury oleate[5] [4]	.5	292-17	203-3	232-8	120-0	123-0
Orthophenylphenol 2.5 percent + pentachlorophenol 2.5 percent	5.0	233-2	272-0	188-0	168-0	123-0
Sodium orthophenylphenate 2.5 percent + sodium pentachlorophenate 2.5 percent	5.0	295-1	231-0	212-0	170-0	138-0
Sodium orthophenylphenate 2.5 percent + sodium tetrachlorophenate 2.5 percent	5.0	278-19	242-0	261-9	181-0	160-0

[1]Based on weight of soybean meal.

[2]The first value represents the joint strength in pounds per square inch; the second value represents the percentage of wood failure. Each value based on 16 plywood shear specimens, 8 from each of 2 (5" x 12") five-ply panels.

[3]Average dry shear strength of sweetgum sapwood plywood shear specimens glued with unpreserved soybean glue was 316 pounds with 71 percent wood failure.

[4]Added to the glue at the time of mixing.

[5]Furnished as a 10 percent oil solution of phenyl mercury oleate.

Z M 51957 F

Table 6.--Results of mold exposure tests on Douglas-fir heartwood and sweetgum sapwood plywood panels glued with soybean glue with and without preservatives and treated with oil solutions of several preservatives

Glue preservative: Name	Glue preservative: Concentration[1]	Panel treatment - 15-second dip in oil solution of: Preservative	Panel treatment: Concentration of preservative in oil solution	Panel treatment: Absorption of preservative solution	Joint strength and percentage of wood failure[2]: Original dry	Wet -- after 48 hours cold soaking	After exposure for -- months: 1	2	3	5	8	Amount of mold growth on panels after (months): 1	8
	Percent			Pounds per cubic foot									
Results on 5-ply 5/16-inch Douglas-fir heartwood plywood panels (6" x 12") -- soaked 4 hours in water suspension of mold spores and then continuously exposed at 97 percent relative humidity at 80° F.													
None		None			188-69	107-0	196-74	0-0	0-0	0-0	0-0	None	Heavy
Sodium orthophenylphenate	5.0	None			215-57	99-1	218-82	221-45	231-55	27-0	47-1	None	Heavy
Sodium pentachlorophenate	5.0	None			211-38	104-1	230-35	190-22	165-18	134-28	108-18	None	Heavy
Sodium tetrachlorophenate	5.0	None			207-45	109-2	222-67	220-57	173-40	180-36	131-14	None	Light
Orthophenylphenol	5.0	None			211-51	109-2	212-47	195-22	187-60	169-26	145-32	Light	Light
Pentachlorophenol	5.0	None			213-29	120-0	228-32	190-34	166-19	131-3	96-9	None	Heavy
2-Chlor-4-phenylphenol	5.0	None			202-18	118-0	195-63	213-28	224-48	208-38	198-59	None	Light
2-Chlororthophenylphenol	5.0	None			180-22	89-1	160-36	110-36	0-0	0-0	0-0	None	Light
None		Pentachlorophenol	5.0	1.9			208-78	67-3	0-0	0-0	0-0	None	Trace
Sodium orthophenylphenate	5.0	Pentachlorophenol	5.0	1.6			220-83	230-47	192-44	248-38	25-8	None	Trace
Sodium pentachlorophenate	5.0	Pentachlorophenol	5.0	2.0			178-69	164-18	176-43	154-19	76-7	None	Trace
None		Pentachlorophenol + 16.5 percent water repellent	5.0	1.7			236-80	110-10	0-0	0-0	0-0	None	Light
Sodium orthophenylphenate	5.0	Pentachlorophenol + 16.5 percent water repellent	5.0	1.8			217-67	193-43	200-46	212-60	210-81	None	Light
None		Phenyl mercury oleate[3]	.5	1.8			186-76	42-0	0-0	0-0	0-0	Light	Heavy
Sodium orthophenylphenate	5.0	Phenyl mercury oleate	.5	1.7			199-81	211-40	217-28	208-42	0-0	Light	Heavy
None		Copper naphthenate[4]	17.5	1.9			197-77	14-0	0-0	0-0	0-0	None	Light
Sodium orthophenylphenate	5.0	Copper naphthenate	17.5	1.8			239-98	212-44	218-61	221-48	105-18	None	Trace
None		Pentachlorophenol	2.5	1.8			215-82	16-1	0-0	0-0	0-0	None	Medium
Sodium orthophenylphenate	5.0	Pentachlorophenol	2.5	1.7			207-89	210-24	218-36	131-9	54-9	None	Medium
Results on 5-ply 5/16-inch sweetgum sapwood plywood panels (6" x 12") -- soaked 4 hours in water suspension of mold spores and then continuously exposed at 97 percent relative humidity and 80° F.													
None		None			245-43	115-5	103-1	0-0	0-0	0-0	0-0	Light	Heavy
Sodium orthophenylphenate	5.0	None			273-48	122-2	178-14	174-2	0-0	0-0	0-0	Medium	Heavy
Sodium pentachlorophenate	5.0	None			237-29	99-2	194-25	205-2	144-8	63-0	0-0	Light	Heavy
None		Pentachlorophenol	5.0	2.5			245-34	189-5	142-1	42-2	0-0	Light	Light
Sodium orthophenylphenate	5.0	Pentachlorophenol	5.0	2.7			189-34	242-18	217-3	75-0	40-0	Light	Light
Sodium pentachlorophenate	5.0	Pentachlorophenol	5.0	1.8			264-13	227-19	172-0	138-0	90-0	Light	Light
None		Pentachlorophenol + 16.5 percent water repellent	5.0	2.8			249-33	178-8	173-8	0-0	0-0	Light	Light
Sodium orthophenylphenate	5.0	Pentachlorophenol + 16.5 percent water repellent	5.0	2.7			227-26	222-14	199-5	164-7	54-0	None	Light
None		Phenyl mercury oleate[3]	.5	3.2			152-15	115-3	129-2	0-0	0-0	Heavy	Heavy
Sodium orthophenylphenate	5.0	Phenyl mercury oleate	.5	3.4			204-12	233-25	186-3	147-9	0-0	Heavy	Heavy
None		Copper naphthenate[4]	17.5	3.0			184-19	118-4	152-1	0-0	0-0	Light	Light
Sodium orthophenylphenate	5.0	Copper naphthenate	17.5	3.0			200-18	100-0	160-4	164-16	62-0	Light	Light
None		Pentachlorophenol	2.5	3.7			180-28	129-7	191-1	47-5	0-0	Medium	Light
Sodium orthophenylphenate	5.0	Pentachlorophenol	2.5	2.4			250-19	244-24	222-10	209-8	52-0	Light	Light
Results on 5-ply 5/8-inch Douglas-fir heartwood plywood panels (6" x 12") -- exposed in cycle tests[5]													
None		None			218-51	115-4	193-44	168-36	47-6	0-0	0-0	Trace	Trace
Sodium orthophenylphenate	5.0	None			202-47	110-7	166-49	228-21	208-28	0-0	0-0	Trace	Medium
Sodium pentachlorophenate	5.0	None			208-48	120-4	219-51	177-54	248-40	230-19	0-0	Trace	Trace
None		Pentachlorophenol	5.0	1.1			215-66	217-68	197-34	0-0	0-0	None	Trace
Sodium orthophenylphenate	5.0	Pentachlorophenol	5.0	1.1			212-46	155-47	189-23	208-21	0-0	Trace	Light

[1]Based on weight of soybean meal.

[2]The first value represents the joint strength in pounds per square inch; the second value represents the percentage of wood failure. Each value is an average for 20 plywood shear specimens, 5 cut from the center of each of 4 (6" x 12") panels.

[3]Furnished as a 10 percent oil solution of phenyl mercury oleate.

[4]Treating solution contained 17.5 percent copper naphthenate, equivalent to 2.0 percent metallic copper.

[5]Cycle consisted of 4 hours soaking in cold water, 12 days in a room maintained at 97 percent relative humidity and 80° F., 3 days in a room maintained at 30 percent relative humidity and 80° F., and repeat.

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